NUCLEAR DATA AND MEASUREMENTS SERIES

ANL/NDM-144

A Compilation of Information on the $^{31}P(p,\alpha)^{28}Si$ Reaction and Properties of Excited Levels in the Compound Nucleus ^{32}S

by

Roy E. Miller and Donald L. Smith

November 1997

ARGONNE NATIONAL LABORATORY,
ARGONNE, ILLINOIS 60439, U.S.A.

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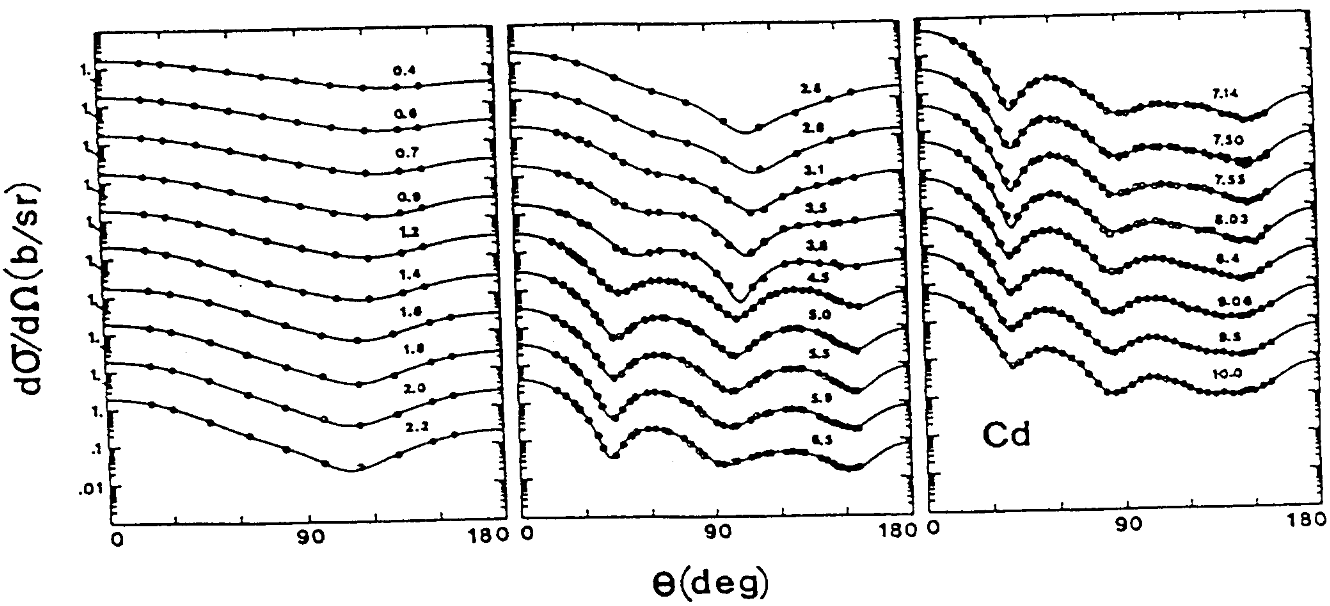

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ANL/NDM-144

A Compilation of Information on the $^{31}P(p,\alpha)^{28}Si$ Reaction and Properties of Excited Levels in the Compound Nucleus ^{32}S [a]

by

Roy E. Miller and Donald L. Smith[b]

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November 1997

DATA COMPILATION. Nuclear reaction $^{31}P(p,\alpha)^{28}Si$. Compound nucleus ^{32}S. Level spins/parities. Resonance interactions $p + {}^{31}P$. Cross sections. Particle-decay widths. Astrophysics. Reaction rates.

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[a] This work was supported by the U.S. Department of Energy, Energy Research Programs, under Contract W-31-109-Eng-38.

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ANL/NDM-143

Roy E. Miller and Donald L. Smith, *A Compilation of Information on the* $^{32}S(p,\gamma)^{33}Cl$ *Reaction and Properties of Excited Levels in* ^{33}Cl, July 1997.

A Compilation of Information on the $^{31}P(p,\alpha)^{28}Si$ Reaction and Properties of Excited Levels in the Compound Nucleus ^{32}S [a]

by

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Abstract

This report documents a survey of the literature, and provides a compilation of data contained therein, for the $^{31}P(p,\alpha)^{28}Si$ reaction. Attention is paid here to resonance states in the compound-nuclear system ^{32}S formed by $^{31}P + p$, with emphasis on the alpha-particle decay channels, $^{28}Si + \alpha$ which populate specific levels in ^{28}Si. The energy region near the proton separation energy for ^{32}S is especially important in this context for applications in nuclear astrophysics. Properties of the excited states in ^{28}Si are also considered. Summaries of all the located references are provided and numerical data contained in them are compiled in EXFOR format where applicable.

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[a] This work was supported by the U.S. Department of Energy, Energy Research Programs, under Contract W-31-109-Eng-38.

[b] Participant in the Argonne National Laboratory Summer and Autumn 1997 Student Research Participation Program administered by the Division of Educational Programs.

1. Introduction

The (p,γ) and (p,α) hydrogen-burning reactions for nuclei in the mass range A = 30 - 50 are important for understanding energy generation and nucleosynthesis in hot and explosive stellar environments such as those found in novas and supernovas [A96, C83, RR88]. Reactions of the type (p,γ) contribute to the production of progressively heavier nuclei while (p,α) reactions are responsible in part for their destruction. Detailed knowledge of the competition between these reaction processes is of considerable importance in gaining an understanding of the relative abundances of various nuclear species that are generated in hot stellar environments and ultimately ejected into the interstellar medium as a consequence of violent nova and supernova processes.

Due to Coulomb barrier effects, the cross sections for these reactions tend to be quite small and difficult if not impossible to measure directly for energies of astrophysical interest. Furthermore, they tend to vary rapidly with interaction energy. The corresponding reaction rates for a Maxwellian distribution of reactant energies are also very sensitive to the temperature of stellar environment in question. Consequently, it is often necessary to calculate the reaction cross sections using nuclear models and then derive reaction rates from these results. In the mass range A = 30 - 50, the cross sections can be influenced by prominent discrete resonances in the compound-nuclear systems as well as by continuum-compound and direct interaction processes. The relative importance of these mechanisms depends on structural details for the target nuclei involved. Extensive information on nuclear potentials, nuclear level densities, spins and parities of specific nuclear levels, and properties of discrete resonances and their decay modes by particle emission and electromagnetic transitions must be considered in performing these calculations.

A long-term program of compiling some of the important information needed for determining (p,γ) and (p,α) reaction rates involving targets in the mass range A = 30-50 has been undertaken at Argonne National Laboratory. The scope of this program is as follows: i) collect pertinent references from the literature; ii) prepare summaries of these references; iii) extract numerical values from these works and compile them in computerized data files for convenient access. Nuclear Science References (NSR) is used as the principal reference source for this activity [NSR97]. The emphasis, with some exceptions, is on work reported during the last 30 years. A report on the $^{32}S(p,\gamma)^{33}Cl$ reaction has already been issued [MS97].

The present report focuses on the $^{31}P(p,\alpha)^{28}Si$ reaction. This reaction has a Q-value of 1.916 MeV [T95]. The first excited state of ^{28}Si is at 1.779 MeV and the second excited state is at 4.618 MeV [FS96]. Consequently, only those α-decay transitions which de-excite the compound nucleus ^{32}S and involve populating the ground state (α_0), and possibly the first-excited state (α_1), of ^{28}Si are of any practical relevance for astrophysical applications. However, the proton separation energy for

^{32}S is 8.864 MeV [T95], *i.e.*, Q = + 8.864 MeV, so the compound nucleus ^{32}S is formed at a relatively high excitation energy (> 8.9 MeV) even for the relatively low proton energies encountered in a stellar environment. Using non-relativistic kinematics, and neglecting the small difference in mass between the ^{32}S compound nucleus in its ground state and at 8.864-MeV excitation for purposes of momentum conservation, it can be shown that the relationship between the incident proton energy E_p and the corresponding compound-nucleus excitation energy E_x for a resonance in ^{32}S formed by p + ^{31}P is given adequately by the expression

$$E_x \approx 0.96848E_p + Q, \qquad (1)$$

where Q = + 8.864 MeV, as indicated above. Thus, the pertinent level density in the compound nucleus, ^{32}S, is substantial under these conditions [FS96].

A total of 42 reference citations pertaining to the $^{31}P(p,\alpha)^{28}Si$ reaction were extracted from NSR. It was possible to locate 36 of these contributions through the available resources of the Argonne National Laboratory Information and Publishing Services. Of these, 35 were used and one was discarded as useless. Some other references were located through citations in the reviewed references from NSR. Summaries of the useful contributions appear in Section 2 while data files in EXFOR format [CINDA97], corresponding to references containing numerical as well as descriptive information, appear in Appendix A. The references to works included here are identified by codes for convenience in accessing the compiled information, *e.g.*, the contribution of Fang *et al.* (1988) is identified by the code F+88. In some cases two or more references are collected under the same code because of similarity or duplication. Absolute values of resonance strength, $S_\alpha = (2J+1)\Gamma_p\Gamma_\alpha/\Gamma$ (where J = resonance spin, Γ_p = proton partial width, Γ_α = gamma partial width and Γ = total width), for $^{31}P(p,\alpha)^{28}Si$ which were reported in some of these references are collected into a single table (Table 2) in Section 3 of the present report to facilitate their comparison. Note that some authors denote the expression $(\omega\gamma)_\alpha = S_\alpha/[(2J_p+1)(J_t+1)]$ as the resonance strength, where J_p is the incident projectile spin (J_p = ½ for a proton) and J_t is the target spin (J_t = ½ for ^{31}P). Thus, in the present situation, $(\omega\gamma)_\alpha = S_\alpha/4$. For consistency, all resonance strengths listed in Table 2 are expressed as values of S, not $\omega\gamma$. These resonance strengths can be used directly in calculating reaction rates according to the formalism given in Rolfs and Rodney [RR88] and elsewhere.

Appendix B lists those seven references appearing in NSR which we were unable to locate in the present compilation effort or which proved useless. These references are given in the exact form in which they appear in the NSR citation. The list is included in this report for the convenience of those readers who might wish to try and locate some of these references and examine their content.

Table 1: References, Summaries, and EXFOR Data Files Included in this Compilation

Ref. Code	Author(s)	Summary	EXFOR File	Comment(s)
A+67	Acerbi *et al.*	X		
BN80	Behkami and Najafi	X	X	
CAP59	Clarke *et al.*	X	X	
DA68	Dallimore and Allardyce	X	X	
D+65	Dearnaley *et al.*	X(A)[a]		Related to LFG72
D+94	Drake *et al.*	X	X	
E90	Endt	X(A)	X	
EL78	Endt and Van der Leun	X(A)	X	
F87	Fang	X(A)	X	Related to F+88
FL80	Forster and Lehmann	X(A)		
F+85	Fauber *et al.*	X(A)		
F+86	Fang *et al.*	X(A)		Related to F+88
F+88	Fang *et al.*	X	X	
HG81	Hsu and Gonsior	X	X	
I+90	Iliadis *et al.*	X(A)		
I+91	Iliadis *et al.*	X	X	
I+93	Iliadis *et al.*	X	X	
K67	Katsanos	X	X	Related to VKH68
KH73a	Kildir and Huizenga	X	X	
KH73b	Kildir and Huizenga	X(A)		Related to KH73a
KMC68	Karadzhev *et al.*	X	X	
KMC69a	Karadzhev *et al.*	X		Related to KMC68
KMC69b	Karadzhev *et al.*	X	X	Related to KMC68
KS74	Kurup and Sharma	X(A)	X	Related to SAN73
K+85	Kiss *et al.*	X	X	
LFG72	Leachman *et al.*	X	X	
MS95	Mitchell and Shriner	X(A)		Related to D+94
MS96	Mitchell and Shriner	X(A)		Related to D+94
M+93	Mitchell *et al.*	X(A)		Related to D+94
P+71	Philipp *et al.*	X	X	
RWK87	Raisanen *et al.*	X	X	
R+67	Riley *et al.*	X	X	

R+95	Ross *et al.*	X	X	
S67	Staub	X	X	
S83	Sargood	X	X	
SAN73	Sharma *et al.*	X	X	
SKP75	Sharma *et al.*	X(A)	X	Related to SAN73
SLD67	Seaman and Leachman	X(A)		Related to LFG72
SSB74	Shapira *et al.*	X(A)		Related to BN80
VKH68	Vonach *et al.*	X	X	
VLT67	Vernotte *et al.*	X	X	
V+73a	Vernotte *et al.*	X		
V+73b	Vernotte *et al.*	X	X	
W+88	Westerfeldt *et al.*	X(A)		Related to F+88
W+92	Wilkerson *et al.*	X	X	

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[a] (A): Summary consists of the given abstract only.

2. Summaries of Work Reported in the Literature

Written summaries were generated for those collected references where the content merited such an effort. Some of these references contain rather extensive information that is potentially useful for nuclear astrophysics applications while others are either abstracts or short communications that are basically extended abstracts. Repetition is avoided when identical material appears in more than one location. The lengths of the summaries presented here tend to reflect the relative content of pertinent information in the corresponding references. Those summaries with considerable information are organized according to a more or less standard format for the convenience of the reader. All the numerical information that was compiled in EXFOR format is printed in Appendix A but is not duplicated in the summaries.

A+67

TITLE

Reazoni (p,α) con Protoni di 38 MeV su Nuclei Leggeri

REFERENCE

E. Acerbi, M. Castiglioni, G. Dutto, I. Iori, A. Luccio, S. Micheletti, N. Molho, M. Pignanelli, R. Resmini, G. Strini, G. Succi, and G. Tagliaferri, Supplemento al Nuovo Cimento V, No. 4, 1252 (1967). [In Italian].

ABSTRACT

There is no abstract. The following text in Italian is the Introduction section of this paper:

In questa relazione ei proponiamo di descrivere sommariamente l'inizio dell'attivita sperimentale con il ciclotrone AVF di Milano. La macchina, che accelera protoni all'energia massima di 45 MeV, e per ora disponibile solo parzialmente per esperienze, e l'apparecchiatura di trasporto del fascio e largamente incompleta . Tuttavia, pur con le limitazioni derivanti da questa situazione - del resto in via di miglioramento - e stato possibile avviare una linea di ricerca i eui primi risultati sembrano giustificare una piu sistematica raccolta di dati sperimentali.

Le ragioni della nostra scelta di cominciare l'attivita al ciclotrone con misure sulle reazioni (p,α) sono in breve le seguenti. E noto che, se si esamina lo stato delle conoscenze sulle reazioni nucleari indotte da protoni di bassa energia, si trova che, ad eccezione del caso dello scattering elastico, i dati sperimentali ad energie del protone incidente superiori a circa 20 MeV sono piuttosto scarsi. Questa situazione e principalmente dovuta al fatto che solo di recente sono entrati in funzione ciclotroni per protoni di energia dell'ordine di 50 MeV; gli acceleratori lineari esistenti, per energie dello stesso ordine, sono meno adatti allo studio di reazioni nucleari aventi sezione d'urto piccola, a causa della loro bassa intensita di corrente media e dello sfavorevole valore del "duty cycle".

Nel caso specifico di reazioni (p,α) le sezioni d'urto, anche per nuclei leggeri, vanno da qualche μb/sr a pochi mb/sr. Questo e quindi un campo di indagine in cui un ciclotrone come quello di Milano puo essere utilmente impiegato. Data la presente situazione del laboratorio, ed in considerazione della semplicita del dispositive sperimentale necessario, abbiamo quindi ritenuto conveniente iniziare come prima attivita sperimentale lo studio di reazioni (p,α) su nuclei leggeri e medio-leggeri.

REACTION

$^{31}P(p,\alpha)^{28}Si$

FACILITY

45-MV AVF Cyclotron, Istituto Nazionale di Fisica Nucleare - Sezione di Milano, Milan, Italy.

EXPERIMENT

Measured α-particle angular distributions over the range 20-95 degrees (center of mass) at an incident proton energy of about 38 MeV for the $^{31}P(p,\alpha)^{28}Si$ reaction. Transitions leading to the ground state and first-excited state (1.77 MeV excitation) of ^{28}Si were observed.

MEASUREMENT PROCEDURES

H^- ions were accelerated in the Milano AVF cyclotron. These were extracted and converted to H^+ ions using a 2 mg/cm^2 Al foil. The beam was then analyzed with a dipole magnet and focused using a quadrupole doublet. The focused beam was directed onto the target located in a scattering chamber. The beam current was monitored with a current integrator. The target used in the $^{31}P(p,\alpha)^{28}Si$ measurements was fabricated by evaporating 2.64 mg/cm^2 of red phosphorus on a Moplefan backing. The α-particles were detected with a Si detector mounted on a goniometer inside the scattering chamber. Data were acquired with a 512-channel analyzer.

DATA ACQUIRED

Obtained α-particle yields corresponding to the ground-state and first-excited state transitions for the $^{31}P(p,\alpha)^{28}Si$ reaction which result from proton bombardment of a phosphorus target. Measurements were made at various angles in the range indicated above. The experimenters also recorded current integrator readings to normalize these angular distribution data.

DATA ANALYSIS

A particle-identification procedure was used to distinguish the α-particles from other charged particles that were incident on the Si detectors. Alpha-particle yields and current-integrator data were used to generate the angular distributions.

RESULTS AND DISCUSSION

No numerical data are given. The results are presented in graphical form in Fig. 11 of the paper [A+67]. The authors concluded that the outcome of their experiment showed that studies of (p,α) reactions in this energy range could provide useful data for an investigation of direct-reaction models.

BN80

TITLE

Statistical Analysis of the Energy Level Widths in Charged-particle-induced Reactions

REFERENCE

A.N. Behkami and S.I. Najafi, Journal of Physics G: Nuclear Physics **6**, 685 (1980).

ABSTRACT

Characteristic nuclear level widths determined from various nuclear reactions for nuclei 24 ≤ A ≤

108 are compared with a microscopic theory which includes the nuclear pairing interaction. The single-particle levels of Nilsson *et al.* and Seeger and Perisho are used in the calculations. The gross features of the experimental data due to nuclear shells are reproduced with the microscopic theory. The agreement between experiment and calculated level widths obtained from this statistical analysis is good considering the uncertainties in the experimental data, the theoretical single-particle levels and the pairing energy.

REACTION

$^{31}P(p,\alpha_0)^{28}Si$

FACILITY

None. This work is an analytical study.

EXPERIMENT

None. This is an attempt to improve upon previous work aimed at determining nuclear energy-level widths for charged particle reactions which lead to formation of a compound nucleus and subsequent particle emission. These improvements are made through the use of a microscopic theory that utilizes realistic single-particle levels and the pairing interaction. The level widths are calculated and compared to experimental widths for various nuclei with $24 \leq A \leq 108$.

MEASUREMENT PROCEDURES

None. Theoretical models are used to calculate level widths for comparison with compiled experimental results.

DATA ACQUIRED

None. Experimental data on nuclear level widths are compiled from the literature for comparison with the results of model calculations performed in this investigation. The only information pertinent to the present interest is the width for forming the compound nucleus, ^{32}S, followed by emission of an alpha particle to the ground state of ^{28}Si.

DATA ANALYSIS

Computer programs were used to calculate the various partial widths and the total width of the compound nucleus, using formulas given in the article [BN80]. Input values for the main code consisted of single-particle levels, level density and transmission coefficients. A Nilsson-model program generated the single-particle levels. The spin-dependent nuclear level density was calculated using formulae given in the paper. The GENOA computer program was employed to calculate the requisite transmission coefficients. Transmission coefficients, level density and spin cut-off factors referring to the emission of various kinds of particles and residual nuclei were calculated with energy bins of 0.1 MeV. The results of these calculations were then fitted to a polynomial over various ranges of energy. The results of this fitting procedure were then used to calculate the partial widths of the different particles by numerical integration using the formulas in the paper. The total width was then determined from an equation given in the article. The theoretical formalism and the numerical procedures are well documented in this work.

RESULTS AND DISCUSSION

The results of the statistical analysis are shown in Table 1 of the paper [BN80]. This table shows both the experimental results and calculated ones. The experimental value for $^{31}P(p,\alpha_0)^{28}Si$ was obtained from an Argonne National Laboratory report [K67]. The calculations were repeated for the two sets of pairing energies given in Fig. 2 of the paper. It was found that the total width depended considerably on the pairing gap parameter used. An examination of the results in Table 1 (and also shown in Fig. 7) shows that the energy widths obtained from the statistical model of nuclei and nuclear reactions generally agree reasonably well with experiment. In addition, the general trend of the natural log of the total widths plotted versus $(A/E^*)^{1/2}$, where A is mass number and E* is excitation energy, agrees with semi-empirical results from previous papers.

CAP59

TITLE

Properties of Levels Excited in (p,α) Reactions on ^{18}O, ^{31}P, ^{35}Cl, ^{37}Cl ^{39}K and ^{41}K

REFERENCE

R.L. Clarke, E. Almqvist, and E.B. Paul, Nuclear Physics **14**, 472 (1959/60).

ABSTRACT

Excitation functions and differential cross sections at 90° to the beam have been measured for the (p,α) ground state reactions in ^{18}O, ^{31}P, ^{35}Cl, ^{37}Cl, ^{39}K and ^{41}K from 1 to 3 MeV proton energy using a magnetic spectrometer to detect the alpha particles. Reduced widths and strength functions for protons and alpha particles are derived; the alpha-particle strength functions are a factor of five smaller than the proton values which agree with published results of (p,n) studies in the mass 40 region. The reduced widths of protons and alpha particles in units of $(h/2\pi)^2/(\mu R^2)$ are both 3 x 10^{-2} for ^{31}P and decrease to 0.4 x 10^{-2} near mass 40. The equality of the proton and alpha-particle reduced widths suggests that these particles appear on the nuclear surface with equal probability. The measured mean level spacing runs from 78 keV for ^{31}P to < 15 keV in the mass 40 region. These are larger than is predicted by the semi-empirical level spacing equation of Cameron. The measured Q-values of the (p,α) reaction on the isotopes shown are: ^{35}Cl = 1.865 ± 0.015 MeV; ^{37}Cl = 3.015 ± 0.015 MeV; ^{39}K = 1.267 ± 0.020 MeV; ^{41}K = 4.002 ± 0.020 MeV.

REACTION

$^{31}P(p,\alpha)^{28}Si$

FACILITY

3-MeV electrostatic accelerator, A.E.C.L. Chalk River Nuclear Laboratories, Chalk River, Ontario, Canada.

EXPERIMENT

The objective of this investigation was to obtain information on partial widths for proton and α-particle emission through the measurement of absolute yields of α-particles. An additional goal was to make an accurate determination of reaction Q-values to contribute to the knowledge of mass differences of the target and residual nuclei. In the case of $^{31}P(p,\alpha)^{28}Si$, it is possible to study individual levels and thus obtain values of $\sigma\Gamma$ where σ is the cross section at the resonance and Γ is the total width. In some cases Γ could be measured directly. As a result of these measurements it was possible to obtain limits for the average reduced proton and α-particle widths of the compound states by making some approximations.

MEASUREMENT PROCEDURES

The 3-MeV electrostatic accelerator at Chalk River Nuclear Laboratories was used in the present study of (p,α) reactions. The beam energy was stabilized to within ± 3 keV. It was measured indirectly by determining the magnetic field of the beam deflecting magnet. The magnetic field was measured with a nuclear magnetic resonance system that had been calibrated via the threshold of the $^{7}Li(p,n)^{7}Be$ reaction at 1.881 MeV. The calibration was repeated several times during the experiment to insure stability.

The target chamber was located ten and a half feet from the beam-deflecting magnet. The spot size on target was about 1/8 inch and the beam current was about 1 μA. It was measured by a current integrator. A beam suppressor operating at -300 VDC was used to minimize distortion of the recorded current due to secondary electron emission. The target was mounted at 45° to the incident beam and the emitted α-particles were measured at 90° to the incident beam. These α-particles were pre-analyzed by a magnetic spectrometer and were counted with a scintillation detector. The spectrometer was of the 180° double-focusing type and had a radius of curvature of 16 inches. The distance from the target to the detector face was also 16 inches. A KI(Tl) or CsI scintillation crystal attached to an RCA 5819 photomultiplier tube served as the detector. The signals were processed to generate a 30-channel pulse-height spectrum from which the α-particles of interest could be identified.

The target itself consisted of Zn_3P_2 evaporated onto either Ta or polished graphite backings. The measured target thicknesses varied from 0.3 to 10 keV for 1.9-MeV protons. In some cases both α-particle and γ-ray spectra were recorded simultaneously. The targets with Ta backings were used in these instances to avoid γ-rays from $^{12}C(p,\gamma)$ reactions. However, in cases where precise knowledge of the target thickness was required, the graphite backing was preferred because it was possible to clearly resolve the protons elastically scattered from the heavier elements from those scattered by C. Then, it was possible to determine the heavier-element thickness by assuming Rutherford scattering of the low-energy protons. Deviations from Rutherford scattering appeared to be < 10% in the case of both P and Zn.

DATA ACQUIRED

The data acquired were in the form of an excitation function from 1 to 3 MeV proton energy. This is shown in Fig. 5 of the article [CAP59]. The energies of the observed resonances are defined to an accuracy of 10 keV while the uncertainty in small differences in these energies is about 2 to 3 keV. The absolute yield of α-particles from $^{31}P(p,\alpha)^{28}Si$ was determined by comparing the measured yield to the yield of protons scattered elastically from ^{31}P, again under the assumption of Rutherford scattering for the protons.

DATA ANALYSIS

The analysis involved the $^{31}P(p,\alpha_0)^{28}Si$ reaction, *i.e.*, the ground-state α-particle group. There are very few details given concerning the data analysis in the present article [CAP59]. The angle-integrated cross section, σ, was obtained from the 90° differential cross section by assuming isotropic α-particle emission. The relative errors in the differential cross sections were estimated to be 20% while the absolute errors were assumed to be about 25%. A direct estimate of the total width, Γ, could be made in those cases where the width was considerably greater than the experimental resolution. Otherwise, only the product $\sigma\Gamma$, which is related to the resonance strength, could be deduced from the integrated peak yield for isolated resonances. In cases where a fairly accurate determination of resonance width was possible, it was estimated that the uncertainties in these widths were about 2 keV. The analysis was hampered considerably by the fact that many of the spin (J) values for the resonances were not known and no angular distributions were measured in the present experiment. Because of this, the uncertainties in the reduced widths deduced from the present experiment are quite high.

RESULTS AND DISCUSSION

The results of interest in the present context are contained in Table 3 of the article [CAP59]. A general conclusion from this work was that the (p,α) reaction proceeds through relatively few levels which have large average proton widths. No evidence was found for any large decrease in the (p,α) yield for the first MeV above the neutron threshold owing to competition with the (p,n) reaction, perhaps because the emission of low-energy neutrons is inhibited by the angular momentum barrier.

DA68

TITLE

A Fluctuation Analysis of the Reaction $^{31}P(p,\alpha)^{28}Si$

REFERENCE

P.J. Dallimore and B.W. Allardyce, Nuclear Physics **A108**, 150 (1968)

ABSTRACT

The reaction $^{31}P(p,\alpha)^{28}Si$ has been investigated for alpha particles detected at 13 angles in the proton energy range 8.50-12.30 MeV, corresponding to excitations in the compound nucleus, ^{32}S, of between 17.36 and 21.16 MeV. The excitation functions were measured in ten-keV steps. The two α-particle groups α_0 and α_1 were recorded. All of the data, *i.e.*, 26 excitation functions each of 380 points are quantitatively in agreement with the Hauser-Feshbach statistical assumptions including statistical fluctuations. No evidence is found for direct interaction or for doorway states. The mean level widths of the compound nucleus for decay to the ground and first excited states of ^{28}Si have been found to be 47 ± 7 keV and 42 ± 5 keV, respectively. The statistical dependencies of these values on the range of data *n* and on the experimental values of the autocorrelation are discussed and found to be important considerations.

REACTION

$^{31}P(p,\alpha)^{28}Si$

FACILITY

Tandem Van de Graaff accelerator, Oxford University Nuclear Physics Laboratory, Oxford, England, United Kingdom.

EXPERIMENT

This experiment involves measuring excitation functions for the reaction $^{31}P(p,\alpha)^{28}Si$. The principal objective was to test predictions of the theory of fluctuations. Another objective was to investigate the effects of a finite range of data (FRD) on the statistical analysis. The excitation functions were measured in the proton-energy range 8.5-12.3 MeV, which corresponds to excitation energies in the compound nucleus, ^{32}S, of between 17.36 and 21.16 MeV. Earlier work performed elsewhere had shown that the condition $\Gamma > D$, *i.e.*, that the level widths encountered exceed the average level spacing, as required for validity of the theory of fluctuations, appears to be valid under these circumstances. Another required condition is that the mean cross section remain constant with energy. Since this requirement was not satisfied here, corrections were required to the experimental excitation functions in order to proceed with the statistical analysis. This paper [DA68] describes the experiment, outlines the data analysis procedure, and derives mean level widths for the ground-state and first-excited-state α-particle transitions that de-excite the compound nucleus, ^{32}S. Several methods for obtaining mean level widths were explored and the most satisfactory results were obtained from the autocorrelation functions of the Hauser-Feshbach corrected excitation functions.

This approach is described in some detail in the article [DA68].

MEASUREMENT PROCEDURES

The proton beam from the tandem accelerator entered the scattering chamber through a series of tantalum collimators and an annular counter. After passing through the target, the beam was collected in a Faraday cup and the integrated current was measured. The beam currents were from 0.1 to 1.0 μC, and the charge accumulated was usually 150 μC. Surface barrier detectors (Au/Si) detected α-particles up to 13.5 MeV. Data were taken in two runs as follows: The first of these was in the proton energy range of 8.5 to 11.6 MeV and included the detector angles 90°, 120°, 135°, 150° and 177°. The second run was in the energy range of 8.5 to 12.3 MeV with the detector angles 44°, 59°, 74°, 90°, 105°, 143°, 157° and 169°. Repetition of the 90° angle enabled reproducibility to be checked and, as different targets were used in each run, it allowed the target thickness to be normalized. The angle settings were reproducible to within ± 0.5°, and the angular resolution was less than 2°. In the forward angles, only the ground-state and first-excited state α-particle groups could be resolved from the background. At back angles, distinct peaks were seen for the first three excited states as well as the ground state. The targets were made by vacuum evaporation of natural phosphorous onto carbon backings (≈ 10 μg thick). These targets were 1.1 cm in diameter and their thicknesses were measured by weighing a glass slide before and after evaporation. Two sets of targets were made. They had phosphorus thicknesses of about 90 $\mu g/cm^2$ and 150 $\mu g/cm^2$, respectively. Actual measurement experience with these targets indicated a mass ratio of about 1.0 to 1.9, which implied a thickness closer to 180 $\mu g/cm^2$ for the thicker targets. This corresponded to an energy loss of about 7 keV for 8.5 MeV protons with the target oriented at 60°. Since the energy resolution of the proton beam from the tandem accelerator was about 5 keV at these proton energies, this suggested an overall energy resolution of < 10 keV, which is considerably smaller than the mean level width of 45 keV. Consequently, it was assured that all the fine structure could be observed with both the thin and the thick targets. The experimental resolution was therefore adequate to enable a fluctuation analysis to be performed on the acquired data.

DATA ACQUIRED

Twenty-six excitation functions, each of 380 points, were determined. Except for a few representative plots, no direct experimental results are given in the article [DA68]. Determination of the absolute magnitude of the differential cross section is difficult. Experimentally this is due to the large errors in the target thickness together with smaller errors from the solid angle determination and from counting statistics. Nevertheless absolute values of the experimental cross sections were obtained and compared with theoretical calculations, as demonstrated in Fig. 5 of the paper.

DATA ANALYSIS

The experimental excitation functions were found to exhibit a marked energy dependence of the mean cross section due to Hauser-Feshbach decay of the compound nucleus. Since the objective of the present investigation was to perform an autocorrelation analysis on these data, it was necessary to provide a correction to the actual data before performing such an analysis. The procedure is discussed in considerable detail in the article [DA68]. Basically, it involved dividing the experimental excitation functions by the calculated local mean cross sections. These mean cross sections were computed using Hauser-Feshbach theory, as discussed in the paper. Calculated level densities in ^{31}P and ^{28}Si were used in determining the dependence of the mean cross section on the incident proton energy and in obtaining an approximate result for the absolute value of the mean differential compound nucleus cross section. Use was made of a computer program by Wilmore in this analysis (see the reference list given in the article [DA68]).

RESULTS AND DISCUSSION

There are a number of figures provided in the paper. These contain sample graphs related to the different aspects of the data analysis. However, very few numerical results are actually given. Four tables of numerical information are provided. These involve derived results for the α_0 and α_1 groups. Tables 1 and 2 present results from the autocorrelation analysis that are not of particular interest in the present context. Tables 3 and 4 give mean levels widths resulting from the present investigation. This information has been included in the EXFOR file prepared for this reference.

The reaction process for ^{31}P(p,α)^{28}Si is explained satisfactorily in the present range of excitation in the compound nucleus, ^{32}S, through a combination of the Hauser-Feshbach decay of the compound nucleus and the pure fluctuation theory. No evidence for a direct-reaction component or for the existence of any doorway states is seen. The reaction process is purely statistical. The experimental data and theoretical productions appear to agree within the data errors. Several different ways for generating the mean level widths were examined. Of all these methods, a Hauser-Feshbach analysis of the experimental excitation functions gave the most reasonable derived level widths.

COMMENTS

It is unfortunate that no numerical experimental results were provided. The information which we have included in the EXFOR file entry is very indirect and thus very dependent upon the method used in analysis of the original experimental excitation functions.

D+65

TITLE

Investigation of the $^{27}Al(\alpha,p)$ Reaction by Cross-section Fluctuation Studies

REFERENCE

G. Dearnaley, W.R. Gibbs, R.B. Leachman and P.C. Rogers, Physical Review **139**, No. 5B, B1170 (1965).

ABSTRACT

Cross sections for the reaction $^{27}Al(\alpha,p)^{30}Si$ have been measured with energy resolutions which, in the incoming alpha-particle channel, are finer than the energy width of the overlapping levels of the compound system, ^{31}P. Fluctuations in these cross sections were analyzed for the coherence widths of this compound nucleus and for details of the reaction mechanism, such as the behavior of reaction amplitudes as shown by the form of the frequency distribution of the cross section, the independence of the reactions leading to the different magnetic sub-states, and the amounts of compound-nucleus and direct-interaction processes. Cross sections were measured at 11 angles between 0° and 175° and at 5-keV energy steps for energies between 5.8 and 8.6 MeV. Lack of a cross correlation between the yields of protons to the ground (0^+) and first excited (2^+) states of ^{30}Si confirmed the expected overlapping of levels of the compound nucleus, which is a basic requirement of fluctuation analysis. The coherence width of the compound-nucleus ^{31}P was found to increase from 8 to 18 keV over the range of excitation energy 14.7 to 17.1 MeV. At the back angles of 175° and 170° the frequency distributions of cross sections for protons to the ground state of ^{30}Si agree with χ^2 distributions with only slightly more than two effective degrees of freedom. This number corresponds to the slightly more than one effective magnetic sub-state allowed by angular-momentum properties near 180°. This agreement substantiates cross-section fluctuation theory and indicates negligible direct interaction at these back angles. At 140° and 160° direct interactions were assumed still to be negligible, and then from the frequency distributions of cross sections the number of independent magnetic quantum states at these angles was found to be less than expected from an analysis based on angular-momentum properties and a Hauser-Feshbach calculation. This difference is a consequence of the small orbital angular momenta involved in the (α,p) reaction at these energies. These effective numbers of magnetic sub-states were used at the corresponding forward angles to determine the amounts of compound-nucleus and direct-interaction processes from fluctuations in cross sections. At the lowest energies of incident alpha particles the amount of direct interaction was too low to be determined with accuracy, but at the highest energies the maximum

direct-interaction cross section was roughly equal to the compound-nucleus cross section. The direct-interaction cross section was found to vary with angle roughly as expected from distorted-wave Born-approximation calculations.

COMMENTS

This work is included here because it provides a description of the experimental setup and measurement procedure which is relevant to Ref. LFG72. No detailed summary has been prepared because most of the material in this communication is irrelevant for the present purposes.

D+94

TITLE

Detailed-balance Tests of Time-reversal Invariance with Interfering Charged-particle Resonances

REFERENCE

J.M. Drake, E.G. Bilpuch, G.E. Mitchell and J.F. Shriner, Jr., Physical Review **C49**, No. 1, 411 (1994).

ABSTRACT

Detailed-balance tests of time-reversal invariance (TRI) with charged-particle resonance reactions are reexamined from the view that there may be large enhancement of TRI violation near two interfering resonances. In our proton resonance data on ^{23}Na, ^{27}Al, ^{31}P, ^{35}Cl, and ^{39}K targets, there are 41 pairs of adjacent resonances with the same angular momentum and parity. Using experimental resonance parameters, the difference in the differential cross sections for the (p,α_0) and (α,p_0) reactions was calculated for each of these resonance pairs. An appropriate figure of merit involving both the difference of the two cross sections and the magnitudes of the cross sections was determined for each resonance pair. Both the differences and the figures of merit show very strong dependence on energy, angle, and the particular pair of resonances; the relative sensitivity varies by many orders of magnitude. These results suggest that suitably chosen charged-particle resonance tests of TRI violation would be much more sensitive than previous detailed-balance tests.

REACTIONS

$^{31}P(p,\alpha_0)^{28}Si$ and $^{28}Si(\alpha,p_0)^{31}P$ (inverse reactions)

FACILITY

This paper reports on an analysis which utilizes data acquired in earlier experiments at the Triangle Universities Nuclear Laboratory (TUNL). References to these experimental studies are given in the present paper [D+94] but no specific information on these experiments is provided here.

EXPERIMENT

No experimental work is reported here. However, reference is made to earlier experiments in which resonance data were acquired. These results proved useful for the present investigation of detailed balance in inverse reactions. There is a direct relationship between time reversal invariance (TRI) and the principle of detailed balance, *i.e.*, comparing the rate of a nuclear reaction and its inverse. So, any confirmed violation of detail balance observed in experimental data would be strong evidence for TRI. The present paper [D+94] reports on an analytical study which utilized accumulated experimental data from earlier investigations. It involves examining the possibility of observing enhancements in angle-integrated cross sections, based on an approach suggested by Bunakov and Weidenmuller (see reference in the present article [D+94]). Experimental resonance parameters were used in the present study to calculate the relative enhancement of detailed-balance violation. Reactions of the type (p,α_0) and (α,p_0) on the five targets listed in the abstract are considered. However, for present purposes we are concerned only with results obtained from considering $^{31}P + p \rightleftharpoons {}^{28}Si + \alpha$.

MEASUREMENT PROCEDURES

No details are given on the measurement procedures used in the earlier experiments at TUNL.

DATA ACQUIRED

The present investigation limits the discussion to consideration of situations involving just two adjacent interfering resonances "a" and "b" of the same angular momentum J and parity π. The resonance energies and total widths are (E_a, Γ_a) and (E_b, Γ_b), respectively. Any violation of TRI is assumed to occur only in the compound states (internal mixing) and not in the entrance or exit channels. A parameter, Δ, is introduced as a convenient measure of detailed-balance violation. This parameter is defined in the article [D+94] in terms of relative wave numbers, differential cross sections and statistical weighting factors for the inverse reactions. A non-zero value of Δ is evidence of TRI violation. As discussed in the article, $\Delta \propto W$, where W is the matrix element of the portion of the Hamiltonian which violates TRI. The proportionality constant is a complicated function of energy, angle, target, compound-state spins, and resonance parameters. The formulas are exceedingly complex when the target and/or compound states have high spin. For the inverse reaction process $^{31}P + p \rightleftharpoons {}^{28}Si + \alpha$, the formalism is relatively manageable. Criteria were established for selecting resonance pairs for consideration. In addition to those mentioned above, it was required that a measured width for the (p,α_0) channel exist for at least one member of each pair considered. The factor Δ/W was defined as a measure of relative enhancement of TRI violation. This factor was calculated for each of the considered resonance pairs. Various effects were observed: The magnitude of Δ/W was noted to depend strongly on energy and angle, and frequently is the largest in those situations where the differential cross section is smallest. In assessing the best conditions for observing enhancement of TRI, an appropriate figure of merit which compromised between large values of the magnitude of Δ/W and small $d\sigma/d\Omega$ values was required. The approach taken is discussed in the paper.

DATA ANALYSIS

For present purposes, we are not interested so much in the issue of TRI, but rather in compiling values of resonance parameters and cross sections which are useful in calculating reaction rates in a stellar environment. The reader who is interested in TRI can refer to the extensive discussion of this topic found in the article.

RESULTS AND DISCUSSION

The information which is useful for present purposes consists of those entries in Tables I and II which correspond to compound nucleus, ^{32}S.

E90

TITLE

Energy Levels of A = 21 - 44 Nuclei (VII)

REFERENCE

P.M. Endt, Nuclear Physics **A521**, 1 (1990).

ABSTRACT

The experimentally determined properties of A = 21 - 44 nuclides are compiled and evaluated with special emphasis on nuclear spectroscopy. Separate tables for each of the nuclides reviewed present the available information about the following properties (in this order):
- excitation energies E_x,
- γ-ray branching ratios b(γ),
- γ-ray mixing ratios δ,
- lifetimes τ_m or width Γ,
- neutron, proton, or α-particle resonances,
- partial widths,
- single-nucleon transfer reactions,
- beta decay,
- arguments for spin and parity (J^π) and isospin (T) assignments.

For each nuclide a master table summarizing the "best" or adopted values for E_x, J^π; T and τ_m or Γ precedes the auxiliary tables listed above. The review of each A-chain concludes with a discussion of isospin multiplets. Figures are presented of the level schemes of all nuclei and, for each A-chain, an overview of the relative energies of the ground states and lowest analogue states of all nuclei in the chain.

COMMENTS

This is one of the best known and most comprehensive compilations available on nuclear data for light nuclei; it occupies an entire volume of the journal Nuclear Physics. Data for the $^{31}P(p,\alpha)^{28}Si$ reaction that appear to be pertinent to determining reaction rates for astrophysical applications are included in the EXFOR file prepared from this source. The origins of these data are documented in the compilation [E90] so they are not repeated in the EXFOR file entry. It should be noted that this data compilation supersedes Ref. EL78.

EL78

TITLE

Energy Levels of A = 21 - 44 Nuclei (VI).

REFERENCE

P.M. Endt and C. Van der Leun, Nuclear Physics **A310**, 1 (1978).

ABSTRACT

The experimentally determined properties of the A = 21 - 44 nuclei are compiled and evaluated, special emphasis being given to nuclear structure. Separate tables for each of the nuclides reviewed give all available information about the following properties in this order:
- excitation energies (E_x),
- γ-ray branching ratios,
- γ-ray mixing ratios (δ),
- lifetimes (τ_m) or widths (Γ),
- spin and parity (J^π) and isospin (T) assignments, and
- any other data on single-particle transfer, resonance levels, etc.

The "best"(or adopted) values for E_x, τ_m or Γ, J^π and T are summarized in a master table. The review of each A-chain concludes with
- a discussion of isospin multiplets,
- a few remarks about the experimental situation, and
- a compilation of references to relevant theoretical papers.

COMMENTS

This is one of the best known and most comprehensive compilations available on nuclear data for light nuclei; it occupies an entire volume of the journal Nuclear Physics. Data for the $^{31}P(p,\alpha)^{28}Si$ reaction that appear to be pertinent to determining reaction rates for astrophysical applications are included in the EXFOR file prepared from this source. The origins of these data are documented in the compilation [EL78] so they are not repeated in the EXFOR file entry. However, it should be noted that this data compilation has been superseded by E90.

TITLE

Proton Resonance Spectroscopy in ^{32}S

REFERENCE

Dufei Fang, Thesis, Triangle Universities Nuclear Laboratory, Duke Station, Durham, North Carolina 27706. Dissertation submitted in partial fulfillment of the requirements for degree of Doctor of Philosophy in the Department of Nuclear Science in the Graduate School of Fudan University, Shanghai, China (1987).

ABSTRACT

Excitation functions for proton elastic scattering and for proton-induced reactions on ^{31}P were measured with the KN Van de Graaff accelerator and associated high resolution system at TUNL. Differential cross sections for $^{31}P(p, p_0)$, (p,p_1), (p,α_0) and (p,α_1) were measured in the range E_p = 1.00 to 4.01 MeV. The data were measured at five angles with an overall resolution of about 350 eV.

The measured excitation functions were analyzed with a multi-level, multi-channel R-matrix formalism. A total of 143 resonances were analyzed and the resonance parameters extracted. Resonance parameters include resonance energy, total angular momentum, parity, partial elastic and reaction widths, channel spin or orbital angular momentum mixing ratios, and for some resonances the relative signs of width amplitudes. A number of resonances have strong level-level interference effects.

Seven isobaric analog resonances were identified in ^{32}S. The proton spectroscopic factors for these resonances obtained from the present experiment are in a good agreement with spectroscopic factors from the (d, p) measurement. The resonance strengths were compared with shell model predictions. Good agreement was found when strengths for the two isospin values were summed. The elastic scattering strength functions were obtained to investigate the nucleon-nucleus dependence on isospin, spin-spin and spin-orbit interactions. The measured s-wave strength function ratio $S_{J=1}/S_{J=0}$ = 1.4. Several resonances have strong α_0 decay; for one resonance relatively strong isospin forbidden α_0 decay was observed. The thermonuclear reaction rates for the $^{28}S(\alpha,p_0)^{31}P$ reaction were evaluated from the $^{31}P(p,\alpha_0)^{28}Si$ resonance parameters obtained in the present experiment, by using the principle of detailed balance. The reaction rates in the region T_9 = 2 - 5 are in good agreement with predictions.

COMMENTS

This reference is to an unpublished thesis [F87]. The experimental details associated with this work are adequately described in the summary which is provided for a later journal publication by Fang *et al.* [F+88] so these details are omitted here. However, a separate EXFOR entry has been prepared for relevant numerical results contained in this thesis, and this material appears in Appendix A.

FL80

TITLE

Winkelverteilung der α-Teilchen in den Resonanzen der Reaktion $^{32}P(p,\alpha_0)^{28}Si$ Zwischen E_p = 640 keV und 1530 keV

REFERENCE

J. Forster and D. Lehmann, Report ZFK-408, Zentralinstitut fuer Kernforschung, Rossendorf, Democratic Republic of Germany, 8 (1980). [In German].

ABSTRACT

The following is the text of this short progress report contribution:

In den 9 bekannten Resonanzen der Reaktion $^{32}P(p,\alpha_0)^{28}Si$ fuer Inzidenzenergien der Protonen zwischen 640 keV und 1530 keV wurden die Winkelverteilungen der α-Teilchen aus dieser Reacktion zum Grundzustand des Kerns ^{28}Si mit Festkorperspurdetektoren (Celluloseazetat-Folie vom VEB ORWO Wolfen) im Winkelbereich zwischen 25° und 160° simultan aufgenommen. Als phosphorhaltige Targets verwendeten wir Zn_3P_2-Schichten (energetische Dicke etwa 4.5 keV, bezogen auf Protonen mit E_p = 1 MeV) auf einer freitragenden Kohlenstoff-Unterlage von ca. 30 μg/cm² Staerke. Die Energiemonitorierung aller Resonanzen ueber E_p = 1 MeV erfolgte ueber die direkte Registrierung der α-Telchen mit einem Halbleiterdetektor, waehrend bei den restlichen Resonanzen die Energiebestimmung und - kontrolle ueber die Aufnahme der γ-Ausbeute aus der Reaktion $^{31}P(p,\gamma)^{32}Cl$ zur gleichen Resonanz mit einem im Faraday-Becher der Reaktionskammer angebrachten zweiten Zn_3P_2-Target (energetische Dicke ca. 2 keV fuer Protonen von einem MeV) auf Tantal-Unterlage durchgefuehrt wurde.

Die experimentallen Winkelverteilungen wurden mit Hilfe des Programme LEGFIT nach Legendre-Polynomen entwickelt und anschliessend aus den so gewonnenen Entwicklungs-koeffizienten fuer jede Resonanz die aus der R-Matrix-Theorie abzuleitenden Mischungsparameter fuer den Kanalspin (τ) berechnet. Die Bildung des Compoundkerns ^{32}S ueber die Reaktion ^{31}P + p verbietet dabei aus Gruenden der Drehimpuls- und Paritaetserhaltung eine zusaetzlich moegliche Mischung mehrerer Bahndrehimpulse im Eingangskanal. Abb. 1 zeit die experimentallen Worte, die mit dem Programm PALFA gewonnanen theoretischen Kurven fuer die untersuchten Winkelverteilungen sowie die Kanalspinmischungsparameter fuer die Bildung des jeweiligen hochangeregten Compound-kern-Zustands im ^{32}S. Die bei der Mehrzahl der Resonanzen auftretenden τ-Werte ueber 0.5 weisen auf eine Bevorzugung der Zwischenkornbildung ueber den Eingangskanalspin s = 1 hin.

COMMENTS

This short communication reports on angular distribution measurements for α-particles emitted in the $^{32}P(p,\alpha_0)^{28}Si$ reaction. These measurements were performed at 9 known resonance energies for the incident protons and several α-particle emission angles in the range 25° und 160°. No numerical data are given but the experimental angular distributions along with theoretical curves are presented in a figure.

F+85

TITLE

Isospin-forbidden T = 2 Resonance in $^{31}P(p,\alpha_0)^{28}Si$

REFERENCE

R.E. Fauber, E.J. Ludwig, T.B. Clegg, H.J. Karwowski, T.M. Mooney and W.J. Thompson, Bulletin of the American Physical Society **30**, 1256, Paper BC 1 (1985).

ABSTRACT

Isospin-forbidden alpha particle decay from T = 2 states to T = 0 final states are especially interesting by virtue of their pure isotensor character. The lowest-lying T = 2 state in ^{32}S was observed as a resonance at E_p = 3.290 MeV using the $^{31}P(p,\alpha_0)^{28}Si$ reaction. Excitation-function data

were obtained at lab angles of 88.2°, 108.1°, 123.7°, 139.3°, 142.4°, and 163.0° using a proton beam with total beam energy spread less than 400 eV. The (p,α_0) data, combined with data from proton elastic scattering are being analyzed to extract alpha and proton partial widths, total widths, and the extent of iso-tensor mixing.

COMMENTS

This reference is only an abstract of a paper presented at an American Physical Society meeting.

F+86

TITLE

Levels of ^{32}S from High Resolution Proton Scattering

REFERENCE

D.F. Fang, C.R. Westerfeldt, E.G. Bilpuch and G.E. Mitchell, Bulletin of the American Physical Society **31**, 1764, Paper DC 4 (1986).

ABSTRACT

Differential cross sections for $^{31}P(p,p_0)$, (p,p_1), (p,α_0), and (p,α_1) have been measured at 7 angles for the energy range E_p = 1.00 to 4.00 MeV. Data were obtained with the TUNL KN Van de Graaff accelerator and high resolution system, with an overall resolution of about 400 eV. The targets consisted of 1 - 3 μg/cm^2 Zn_3P_2 on carbon backings with a thin nickel coating. Incident proton energy steps varied from 100 eV to 400 eV. Excitation functions are being fit with a multi-level, multi-channel R-matrix based computer program to obtain resonance parameters, including spins, parities, partial widths and channel spin and orbital angular momentum mixing ratios. Examples to illustrate the analysis will be presented. Preliminary results indicate about 100 resonances, several of which show strong interference effects.

COMMENTS

This reference is only an abstract of a paper presented at an American Physical Society meeting.

F+88

TITLE

Proton Resonances in ^{32}S from $E_x = 9.83$ to 12.74 MeV

REFERENCE

D.F. Fang, E.G. Bilpuch, C.R. Westerfeldt, and G.E. Mitchell, Physical Review **C37**, No. 1, 28 (1988).

ABSTRACT

Differential cross sections for the $^{31}P(p,p_0)$, (p,p_1), (p,α_0) and (p,α_1) reactions were measured in the range of $E_p = 1.00$ to 4.01 MeV with an overall resolution of about 400 eV. The resonance parameters were extracted for 143 levels with a multilevel, multichannel R-matrix code. These parameters include resonance energy, total angular momentum, parity, partial widths, channel spin or orbital angular momentum mixing ratios, and, for some resonances, the relative signs of width amplitudes. Eight isobaric analog resonances were identified in ^{32}S. Proton resonance strengths were compared with shell model predictions. The $^{31}P(p,\alpha_0)$ data were used to obtain the reaction rates for the inverse reaction $^{28}Si(\alpha,p_0)$.

REACTIONS

$^{31}P(p,p_0)$, (p,p_1), (p,α_0) and (p,α_1)

FACILITY

KN Van de Graaff accelerator, Triangle Universities Nuclear Laboratory, Duke Station, Durham, North Carolina.

EXPERIMENT

^{32}S was studied by proton scattering from ^{31}P. This work was undertaken as part of a larger program of investigating odd-mass target nuclei in the 2s-1d shell. The present experiment covers an important energy gap wherein there was a lack of information on excited states of ^{32}S. The $^{31}P(p,\alpha_0)$ channel is open throughout the entire energy range of the present experiment.

MEASUREMENT PROCEDURES

This experiment was performed with the KN Van de Graaff accelerator and associated high resolution system at TUNL. The authors refer to a paper in Nuclear Instruments and Methods describing this facility [W+88]. The system used was able to provide an energy resolution of 300 - 400 eV for thin solid targets over the proton beam range 1 - 4 MeV. Proton-induced reactions were measured from 1.00 - 4.01 MeV at intervals of 100 - 400 eV. Surface-barrier detectors were used to detect the emitted charged particles. They were placed at laboratory angles 90°, 127°, 145°, and 165°. Detector solid angles were adjusted so that the Rutherford scattering yield was approximately equal at all angles. In order to measure the $^{31}P(p,\alpha_1)$ reaction above E_p = 2.98 MeV, transmission detectors were place at 108°,135°, and 165° to detect the α_1 particles. This was necessary because these particles generated the same pulse height as protons elastically scattered from ^{16}O. The targets were prepared by evaporating Zn_3P_2 onto ultra-pure Ni-coated (~ 0.5 $\mu g/cm^2$) carbon foils (4 - 5 $\mu g/cm^2$). The targets contained 1-3 $\mu g/cm^2$ ^{31}P. Ni was added because it enhances both target stability and uniformity. These targets were able to withstand beam currents of 2 - 3 μA. The data were acquired with a VAX 11/750 computer and general data processing software system which is described in Ref. W+88 which is referred to in the present paper [F+88]. Absolute energy calibration for the system was performed with the secondary-standard reactions $^{44}Ca(p,p)$ and $^{56}Fe(p,p)$ which were in turn calibrated with respect to the primary neutron threshold standards $^{7}Li(p,n)$ at E_p = 1.8804 and $^{13}C(p,n)$ at E_p = 3.2357 MeV. The uncertainty in the absolute resonance energies is about 3 keV.

DATA ACQUIRED

The yield curves for $^{31}P(p,p_0)$, (p,p_1), (p,α_0) and (p,α_1) were obtained from charged-particle spectra recorded with the solid state detectors. These spectra were monitored on-line and stored for detailed off-line analysis. Data were measured in 100 - 400 eV steps, depending on the resonance structure, and the counting statistics were better than 2%. Excitation functions were determined for the proton energy range 1 - 4 MeV; most of these were measured twice to ensure reproducibility. These excitation functions are shown in figures given in the paper. An examination of these excitation functions provided evidence for 143 resonances. Excitation functions for the reactions are shown in three figures corresponding to three different energy ranges.

DATA ANALYSIS

A resonance analysis was carried out using the multi-level, multi-channel R-matrix program MULTI6. Resonance parameters for the various reaction channels were extracted from these data. Typical uncertainties in the resonance parameters were about 10% for small resonances. For large resonances ($\Gamma \geq 15$ keV) the laboratory widths have larger uncertainties (~ 20%), especially for resonances whose inelastic widths are larger than their elastic widths.

RESULTS AND DISCUSSION

The authors state that there is generally good agreement between the present results and previous data compiled by Endt and Van der Leun [EL78]. However, there were three major points of disagreement with previous results which are explained in detail in the article [F+88]. The actual values for the resonance energies, widths and corresponding uncertainties generated from this work are not given in the paper. The reader is encouraged to contact the authors privately to acquire this information. Instead, the authors provide an extensive discussion of the physical implications of this work, including identification of analog states, determination of information on the $\alpha + {}^{28}Si$ reaction by detailed balance, and discussion of astrophysical reaction rates for both the (p,α) and (α,p) processes, both of which involve the compound nucleus, ${}^{32}S$. The examination of strong α-decay resonances was very fruitful due to the fact that resonances with large α-parentage provide a test for the cluster model. Results for (α,p) were deduced from those for (p,α) by exploiting the principle of detailed balance.

COMMENTS

It is unfortunate that the detailed resonance-parameter information is not given in tabular form in the paper. Numerical information which appears to be relevant to present interests is found in Tables I, II, and IV. These values are included in the EXFOR file for this reference.

HG81

TITLE

Comment on the Compound-nucleus Cross Section from Nuclear Charge-density Distributions

REFERENCE

C.C. Hsu and B. Gonsior, Journal of Physics G: Nuclear Physics 7, 1099 (1981).

ABSTRACT

Two equations for calculating the average cross section of statistical compound nuclear reactions are recommended in order to determine the maximum value of angular momentum which contributes to the cross section. The equations are applied to several reactions. The results are in good agreement with the experimental measurements.

REACTION

$^{31}P(p,\alpha_0)^{28}Si$

FACILITY

None. This work is an analytical study.

EXPERIMENT

None. This paper deals with statistical-model calculations based on Hauser-Feshbach theory. Use is made of certain assumptions which enable simplifications to be made in the Hauser-Feshbach formulas for calculating cross sections associated with formation of the compound nucleus and various reaction cross sections associated with decay of the compound nucleus. Although these assumptions originally were developed to apply to heavy-ion reactions, this work shows that there is also considerable validity to the notion of applying this methodology in the case of light-ion reactions. The assumptions also lead to a simple formula for determining the maximum value of orbital angular momentum which contributes to a particular reaction cross section.

MEASUREMENT PROCEDURES

None. This work is an analytical study.

DATA ACQUIRED

No data were measured but some important parameters were calculated for the following reactions: $^{26}Mg(p,\alpha_0)^{23}Na$, $^{37}Cl(p,\alpha_{1+2})^{34}S$, $^{24}Mg(d,\alpha_0)^{22}Na$, $^{28}Si(d,p_0)^{29}Si$ and $^{31}P(p,\alpha_0)^{28}Si$. These parameters are given in Table 1 of the article [HG81]. In the case of $^{31}P(p,\alpha_0)^{28}Si$, reference is made to another paper included in the present compilation, namely, the work of Dallimore and Allardyce [DA68].

DATA ANALYSIS

The analysis is based on an equation suggested by Horn and Ferguson (Phys. Rev. Lett. **41**, 1529, 1978). The current paper discusses this formalism in considerable detail and refers to other relevant articles in the literature.

RESULTS AND DISCUSSION

A prediction is made of the level overlapping parameter $<\Gamma>/D_0$ and the maximum orbital angular momentum, l_m, for the $^{31}P(p,\alpha)^{28}Si$ reaction. The authors indicate that the values $<\Gamma>/D_0 = 17.2$ and $l_m = 3$ which they obtained are reasonable when compared to those observed experimentally for other reactions with similar compound nuclear masses and excitations. It is therefore concluded that the equation suggested by Horn and Ferguson is useful not only for the calculation of heavy-particle compound nuclear cross-sections, but also for the calculation of cross-sections for compound nuclei formed by light incident particles.

I+90

TITLE

The Influence of Low Energy Resonances in $^{31}P(p,\gamma)^{32}S$

REFERENCE

C. Iliadis, U. Giesen, J. Gorres, L. Van Wormer, M. Wiescher, R.E. Azuma, J. King, M. Buckby, C. A. Barnes and T.R. Wang, Bulletin of the American Physical Society **35**, No.8, 1673, Paper DD 3 (1990).

ABSTRACT

The understanding of the rp-process nucleosynthesis in the Si-P-S region is of particular interest for the interpretation of the recently observed high Si and S abundances in nova ejecta (M. Wiescher *et al.*, Astron. Astrophys. **160**, 56, 1986). The reaction branch between $^{31}P(p,\gamma)$ and $^{31}P(p,\alpha)$ determines whether the material is processed further towards the Fe-Ni region, or whether it is stored in a SiPS-cycle(M.Weischer and J. Gorres, *Radioactive Nuclear Beams*, eds. W.D. Myers, J.M. Nitschke, E.B. Norman, World Scientific, Singapore, 229, 1990) which would lead to an enrichment in the abundances of these isotopes. We therefore measured the $^{31}P(p,\gamma)^{32}S$ and the $^{31}P(p,\alpha)^{28}Si$ reactions in the proton energy range of $280 \leq E \leq 830$ keV in search for resonances in the two reaction channels. The experiments were performed at the JN Van de Graaff at the University of Toronto and at the 3MV Pelletron at CalTech. Six resonances were observed in the (p,γ)-channel. Resonance strengths were obtained for all observed levels. The influence of these resonances on the $^{31}P(p,\gamma)$ and $^{31}P(p,\alpha)$ reaction rates as well as the possibility of a SiPS-cycle at nova conditions will be discussed.

COMMENTS

No data were provided in this American Physical Society meeting contribution for the reactions mentioned, including the (p,α) reaction. The comment about the importance of the $^{31}P(p,\gamma)$ and $^{31}P(p,\alpha)$ reaction processes in determining the extent to which nucleosynthesis progresses toward heavier-mass isotopes versus remaining in the Si-P-S region is of general importance; it serves as justification for a very careful examination of these data.

I+91

TITLE

The Reaction Branching $^{31}P(p,\gamma)/^{31}P(p,\alpha)$ in the rp-Process

REFERENCE

C. Iliadis, U. Giesen, J. Gorres, S. Graff, M. Wiescher, R.E. Azuma, J. King, M. Buckby, C.A. Barnes and T.R. Wang, Nuclear Physics **A533**, 153 (1991).

ABSTRACT

The reactions $^{31}P(p,\gamma)^{32}S$ and $^{31}P(p,\alpha)^{28}Si$ have been studied in the energy range 280 - 620 keV to investigate the influence of low-energy resonances on the stellar reaction rates. Several new resonances have been observed and the resonance strengths for both reaction channels have been determined. The reaction rates have been calculated from the present results and are compared with the results of Hauser-Feshbach calculations.

REACTION

$^{31}P(p,\alpha)^{28}Si$ and $^{31}P(p,\gamma)^{32}S$

FACILITIES

3-MV Pelletron tandem accelerator, Kellogg Radiation Laboratory, California Institute of Technology, Pasadena, California; 1-MV Van de Graaff accelerator, University of Toronto, Toronto, Canada; and 350-kV Cockcroft-Walton accelerator, University of Toledo, Toledo, Ohio.

EXPERIMENT

The rp-process is thought to be one of the major mechanisms in explosive hydrogen burning environments for the processing of CNO material into the Fe-Ni mass region. Nucleosynthesis proceeds by a sequence of proton (or α-particle) capture and β-decay processes. Reactions of the type (p,γ) lead toward the heavier elements while (p,α) reactions transfer material back toward lower masses. In this work, an experimental investigation is performed for the (p,γ) and (p,α) reactions on ^{31}P in an energy range that is significant for novae and supernovae. Measurements were performed at two separate facilities, one set for the range E_p = 0.35 - 0.62 MeV for $^{31}P(p,\gamma)^{32}S$ and the other set for E_p = 0.28 - 0.45 MeV for both $^{31}P(p,\alpha)^{28}Si$ and $^{31}P(p,\gamma)^{32}S$. Since the reaction strengths for both of these processes are dominated by resonances under the conditions of interest for astrophysics, the main objective of this experiment was to search for resonances and to determine their strengths so that the reaction-rate branching ratio (p,γ)/(p,α) could be ascertained for explosive stellar environments.

MEASUREMENT PROCEDURES

Three accelerator facilities at three different laboratories were used in this study. A 350-kV Cockcroft-Walton generator at University of Toledo was used to prepare phosphorus targets by ion implantation in 0.5-mm-thick Ta backings. The accelerator energy was 200 keV. This gave a well-defined target thickness of about 15 keV at 355-keV bombarding energy. The phosphorus-ion beam was scanned across the tantalum target surface to ensure homogeneous implantation of target atoms over an area of 1.5 cm^2. The target thickness and stoichiometry, Ta_2P_3, were determined by measuring the thick-target yield curve of the well-known $^{31}P(p,\gamma)^{32}S$ resonance at E_p = 811 keV. These targets were water cooled during the proton-reaction measurements at the other two facilities, and they proved to be very stable under proton bombardment. The $^{31}P(p,\gamma)^{32}S$ measurements for E_p = 0.35 - 0.62 MeV were carried out at the 3-MV Pelletron tandem accelerator at California Institute of Technology. Beams up to 100 μA were obtained using an RF source installed at the terminal. An energy resolution of about 1 keV was verified by measuring the narrow $^{27}Al(p,\gamma)^{28}Si$ resonance at 991.88 ± 0.04 keV. The proton energy was calibrated using this resonance and the above-mentioned 811-keV resonance in $^{31}P(p,\gamma)^{32}S$. The second set of measurements in the range 0.28 - 0.45 MeV for $^{31}P(p,\alpha)^{28}Si$ and $^{31}P(p,\gamma)^{32}S$ were carried out using the 1-MV Van de Graaff accelerator at University of Toronto. This machine produced beam currents up to 50 μA with a resolution of about 1 keV and an energy calibration that was known to within ± 2 keV. The experimental setups at these two facilities were quite similar. The proton beam passed through a Ta collimator and was directed onto the target which was mounted at 45° with respect to the beam direction. A liquid-nitrogen-cooled copper tube placed between the target and collimator inhibited carbon deposition on the target. A negative bias of 300 V was applied to the target to suppress secondary electron emission. Gamma-radiation was measured with a 35%-efficient, Pb-shielded Ge detector placed in close geometry at 55°. Two surface-barrier detectors with 450-mm^2 area were placed about 5.5 cm from the target at 90° and 135° to measure the α-particles. The intense yield of scattered protons was suppressed by 2.2-μm Havar foils placed between the collimators and the surface-barrier detectors. Even so, at beam energies higher than 450 keV the proton background interfered substantially with the α-particles from $^{31}P(p,\alpha_0)^{28}Si$. The resolution and spectrum peak shapes for the α-particle detectors were measured by observing the spectrum resulting from the strong resonance at 340 keV in $^{19}F(p,\alpha_2)$.

DATA ACQUIRED

An excitation function for $^{31}P(p,\gamma)^{32}S$ was measured in steps smaller than the target thickness over the range E_p = 280 - 620 keV. Six resonance were observed. Two of these were seen for the first time in this experiment. An excitation function for $^{31}P(p,\alpha)^{28}Si$ was determined over the range E_p = 280 - 450 keV in steps of less than 5 keV. The recorded α-particle spectra were plagued with background from several sources mentioned in the article [I+91], and various techniques were used to identify and subtract these background events. The background-corrected yield curve for $^{31}P(p,\alpha_0)^{28}Si$ increases smoothly with beam energy, but indicates clear structure corresponding to a resonance at 383 keV. There is evidence of this same resonance in the excitation function for $^{31}P(p,\gamma)^{32}S$.

DATA ANALYSIS

Excitation energies for the compound levels formed by $^{31}P(p,\gamma)^{32}S$ were deduced from the energies of the observed γ-ray transitions to the ground state and to known excited states in ^{32}S. The known Q-value for this reaction was also employed in determining the (p,γ) resonance energies. Resonance strengths were calculated from the observed γ-ray and α-particle yields according to the procedure described in the paper. These results are provided in tables in the article [I+91]. Since they were deemed to be small, no corrections were applied for angular distribution effects in the analysis of the $^{31}P(p,\gamma)^{32}S$ data; however, corrections for angular effects were applied to the $^{31}P(p,\alpha)^{28}Si$ data.

RESULTS AND DISCUSSION

A table of resonance energies is provided in the article [I+91]. Information is also given on gamma-ray branching for $^{31}P(p,\gamma)^{32}S$ but this is of limited interest in the present context. Values are also given in tables for the resonance widths and strengths deduced from this work. One single resonance was observed for the $^{31}P(p,\alpha)^{28}Si$ reaction in the investigated energy range. The α-decay of ^{32}S is only possible for a natural-parity state. No evidence was found for a suggested resonance at 342 keV in either $^{31}P(p,\alpha)^{28}Si$ or $^{31}P(p,\gamma)^{32}S$. In the case of $^{31}P(p,\alpha)^{28}Si$, such a resonance would be isospin-forbidden. The final section of the paper is dedicated to the astrophysical implications. A discussion of the Si-P-S cycle can also be found there.

I+93

TITLE

Explosive Hydrogen Burning of ^{31}P

REFERENCE

C. Iliadis, J. Gorres, J.G. Ross, K.W. Scheller, M. Wiescher, C. Grama, Th. Schange, H.P. Trautvetter and H.C. Evans, Nuclear Physics **A559**, 83 (1993).

ABSTRACT

Proton threshold states in ^{32}S have been studied via the reactions $^{31}P(p,\gamma)^{32}S$, $^{31}P(p,\alpha)^{28}Si$ and $^{28}Si(\alpha,\gamma)^{32}S$ to investigate their influence on a possible SiP cycle in explosive hydrogen burning. One new resonance at $E_p = 200 \pm 2$ keV has been found in the (p,γ) reaction channel, but only upper limits could be deduced for the corresponding (p,α) and (α,γ) resonance strengths. The stellar reaction rates for $^{31}P(p,\gamma)^{32}S$ are now experimentally determined for stellar temperatures $T_9 \geq 0.05$, whereas the stellar rates for $^{31}P(p,\alpha)^{28}Si$ still carry large uncertainties for $T_9 < 0.4$. The results of the present work suggest only weak cycling in the SiP mass range at all stellar temperatures of interest.

REACTION

$^{31}P(p,\alpha)^{28}Si$

FACILITY

400-kV accelerator, Ruhr-Universitat Bochum, Bochum, Germany.

EXPERIMENT

The present investigation was an extension of earlier work reported in Ref. I+91. For present purposes we consider only that portion of the discussion which pertains to the $^{31}P(p,\alpha)^{28}Si$ reaction. The objective of the investigation was to determine the relative reaction rates for $^{31}P(p,\gamma)^{32}S$ and $^{31}P(p,\alpha)^{28}Si$ in order to determine whether at ^{31}P there is a greater likelihood for progression to higher masses through the (p,γ) reaction or whether there is a tendency to store material in the SiP cycle which would be the case if the (p,α) reaction were dominant. The main uncertainty in determining these relative reaction rates arises from the possible influence of a state at $E_x = 9060$ keV in ^{32}S, corresponding to a proton resonance at $E_R = 200$ keV. The focus of the present experiment was to examine this particular state in ^{32}S by the three reactions indicated in the abstract of this paper.

MEASUREMENT PROCEDURES

The 400-kV Bochum accelerator provided proton beams of 80 - 180 μA in the energy range $E_p = 160$ - 370 keV. The proton beam passed through a collimator and was focused into a profile of 1.5 cm diameter onto the target. The target was produced by bombarding a 0.25-mm-thick tantalum backing with ^{31}P ions using the SNICS source at the University of Notre Dame. The implantation dose was 200 μA-h at an ion energy of 80 keV. This resulted in a target thickness of 15 keV at a bombarding energy E_p = 355 keV. The target stoichiometry was determined by means of the well-known resonance at E_R = 811 keV in $^{31}P(p,\gamma)^{32}S$. Using the stopping power tables of Andersen and Ziegler (H.H. Andersen and J.F. Ziegler, *Stopping Powers and Ranges of All Elements*, Pergamon Press, New York, 1977) yielded a tantalum-to-phosphorus ratio of 0.8 ± 0.2. A liquid-nitrogen-cooled copper tube was placed between the beam collimator and the target. In spite of this, it was impossible to avoid some contamination of the target with carbon so a correction for proton energy loss in the carbon was estimated by monitoring the intensity and width of the primary gamma-ray peak resulting from the $^{12}C(p,\gamma)^{13}N$ reaction. The target was water cooled directly and it was placed at 45° relative to the incident-proton-beam direction. The target and chamber formed a Faraday cup which was biased at a negative 300 volts to suppress secondary electron emission. The α–particles and γ–rays were detected simultaneously. These γ-rays were measured using a Ge detector with 100% efficiency; however, this aspect of the experiment is not of primary concern in the present context. The detectors for the α-particles were two Si surface barrier detectors with an active area of 600 mm^2. These detectors were placed at the laboratory angles 90° and 135° relative to the incident-proton-beam direction, at a distance of 6.1 cm from the target. The detectors were covered with Ni foils to stop scattered protons. Their absolute efficiencies were determined geometrically and by observing the α-particle yield from a calibrated ^{241}Am source. The energy resolution with the Ni foils in front of the detectors was about 100 keV for 2-MeV α-particles.

In order to search for a (p,α) resonance corresponding to the observed E_R = 200 keV resonance in the (p,γ) channel, α-particle spectra were recorded simultaneously with γ-rays. The expected energetic positions of the α-particle peaks in the spectra from the two α-detectors were determined from kinematics and the α-energy calibrations. No α-particles from the $^{31}P(p,\alpha_0)^{28}Si$ reaction were observed in any of these runs. Based on the observed sensitivity of the detection system, an upper limit could be placed on resonance strength for α-decay based on this investigation.

DATA ACQUIRED

Several particle spectra were recorded with the two Si surface-barrier detectors in the vicinity of E_p = 200 keV, with negative results. The α-particles that were observed could be attributed to the ^{18}O(p,α) and ^{11}B(p,3α) reactions.

DATA ANALYSIS

From the number of counts N_c observed in the region of the expected resonance, it was possible to set an upper limit to the number of α_0 particles by applying the formula $N_\alpha \leq (2N_c)^{1/2}$ to counts observed in the expected α–region. From this assumption it was possible to determine an upper limit for the strength of α-particle decay of the E_R = 200 keV resonance. This limit was used to estimate the contribution to the stellar reaction rate from this process. Details of the data analysis procedure for the α-particle spectra are rather limited in this paper, but the reader can refer to earlier work from this group [I+91] for further information.

RESULTS AND DISCUSSION

The authors devote a considerable portion of their article [I+93] to a consideration of the astrophysical implications of nuclear data for the ^{31}P(p,γ) and (p,α) reactions. Our concern here is with the (p,α) reaction. The reaction rate at stellar temperatures can have contributions from narrow resonances, low-energy wings of unbound resonances and the high-energy wing of the E_R = -3.5 keV sub-threshold resonance. These contributions were determined separately and added to provide estimates of the total reaction rate for various stellar temperatures T_9 from 0.03 to 2.0 in units of 10^9 °K. The reaction-rate contributions for discrete narrow resonances were calculated using the formula in Eq. (4) of the article. This approach was applied for all known resonances with observed α-particle decay in the range E_R = 383 - 2027 keV (observed resonances). The method was also used in determining upper-bound contributions from resonances at E_R = 164, 200, 207, and 342 keV from which no α-particle decay was observed (unobserved resonances). A different approach was used to determine contributions from the wings of broader resonances. Cross sections in these resonance wings were calculated from the known total widths and resonance strengths using a Breit-Wigner formulation. These cross sections were then converted to values of the astrophysical S-factor which were, in turn, fitted as a function of energy by a parameterized polynomial and integrated to obtain the reaction rate, using standard techniques referred to in the article. The results of this analysis appear in Table 3 of the article. It is seen that for $T_9 > 0.1$ the observed, narrow resonances dominate the stellar reaction rates. The contribution from unobserved resonances at E_R =164, 200, 207 and 342 keV can increase the calculated reaction rates by several orders of magnitude for the lower stellar temperatures, so they are very important. The contributions from these unobserved resonances are estimated and included in the analysis in an attempt to improve stellar-model calculations. However, it is clear that this is a source of great uncertainty in these calculations. Except at the very lowest temperatures, the contributions from the wings of the resonances indicated above appear to be quite small.

K67

TITLE

Studies of Low-energy Nuclear Reactions and Level Densities for Medium-mass Nuclei

REFERENCE

A.A. Katsanos, Report ANL-7289, Argonne National Laboratory (1967). This report constitutes the dissertation of Anastasios A. Katsanos which was prepared in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

ABSTRACT

This dissertation has no abstract. The following material duplicates the Introduction section of the document:

The atomic nucleus can exist in a series of quantum levels, each characterized by a specific energy, E, parity, π, and angular momentum, J. Each level is composed of $(2J + 1)$ degenerate states. A state is characterized by energy, E, parity, π, angular momentum, J, and the projection, M, of the angular momentum, J, on some arbitrary axis. Every level has an energy width, Γ, related to its mean lifetime, τ, by $\tau\Gamma = h/2\pi$. The spacing, D, between the levels decreases exponentially with increasing excitation energy, U, and the density of levels $\rho(U)$ increases. The behavior is typical of a system with many degrees of freedom, and statistical thermodynamics can be applied.

Four statistical models have been proposed for the nuclear level density; (1) the independent-particle Fermi-gas model, (2) the Fermi-gas model with pairing energy between nucleons in twofold degenerate levels, (3) the superconductor, and (4) the constant-temperature model. In the simple Fermi-gas case the nucleus is described as a gas of independent fermions which have a quasiadditive spectrum. The Fermi gas with pairing energy is an extension of the first method with a correction for the interaction among the nucleons. It has been fairly successful in explaining the odd-even difference in the level densities of odd and even nuclei. The superconductor model, by analogy to the superconducting metal state, has been proposed to explain the energy gap observed in low-lying nuclear levels. Finally, the constant-temperature model is a simplified thermodynamic representation, which is a good approximation for the extension of the density of energy levels in the neighborhood of an energy where the absolute value of the density is known.

Experimental information about level densities is obtained primarily from "compound nucleus" reactions. According to the independence hypothesis, the probability of decay of the compound nucleus is independent of the mode of formation. The decay probability depends on the level densities of the residual and compound nuclei, and the appropriate transmission coefficients. Compound-nucleus processes occur at low bombarding energies, for which a relatively stable intermediate system is formed, with a long lifetime in comparison with the time required for the incoming particle to pass through the nucleus. As the incoming energy increases, direct interaction also takes place.

The main source of information about nuclear level densities was at first the experiments on slow-neutron resonance capture. During the last few years extended information has been obtained by use of magnetic spectrographs. For a given incoming energy, the energy distribution of the emitted particles consists of a series of peaks corresponding to the energy levels of the residual nucleus. One can count the individual levels up to an excitation energy where the spacing, D, begins to approach the experimental resolution. The only errors in this method are those due to unresolved levels. By using a Tandem Van de Graaff accelerator in conjunction with a magnetic spectrograph for the analysis of the outgoing particles, total resolution of 5 to 10 keV can be obtained. The separation of more than 100 levels up to excitation energies 5 to 8 MeV for medium-mass nuclei has been achieved in this way, and numerous publications using this technique have appeared. A third method is based on the analysis of the yields of particles of the evaporation spectra. Although this is an indirect method and larger errors are involved, it has the advantage that it can be used up to higher excitation energies than in the previous method. Most of the reported measurements are at energies in the neighborhood of the neutron binding energy.

The experimental testing of the level-density models has been limited so far up to excitation energies of 12 to 13 MeV. Researchers analyze their data in terms of either the Fermi-gas or the constant-temperature model and report, respectively, the Fermi-gas constant or the nuclear temperature. There is not sufficient evidence to favor one model over the other. The differences in the level densities derived by the two models are within the limits of the experimental errors. Moreover, by either model, one can fit curves to the experimental data in this small energy region with various combinations of the level-density constants. These facts call for measurements in the region of high excitation energy.

The theory of statistical fluctuations, which has been widely tested experimentally in the recent years, enables one to calculate the level density of the compound nucleus in the continuum. At low bombarding energies, where $\Gamma/D < 1$, one observes resonances in the reaction cross section corresponding to individual levels of the compound nucleus. As the excitation energy increases, the level widths broaden because more exit channels become available and the transparency of the Coulomb barrier increases. Since D decreases exponentially, the ratio, Γ/D, grows rapidly with excitation energy. In the region where $\Gamma/D \gg 1$ there are many overlapping levels and one can no longer observe the individual resonances. This condition is fulfilled for medium-mass nuclei at an excitation energy of about 20 MeV. In experiments with a beam spread smaller than Γ, the excitation functions show strong fluctuations with energy. From the analysis of the excitation functions according to the statistical theory, developed by T. Ericson and by D. Brink and R. Stephen, the average width, Γ, can be obtained. From the width, Γ, the experimental differential cross section, and the optical-model transmission coefficients, the level density of the compound nucleus can be calculated. Only preliminary results have been published by this method.

The level densities of ^{32}S, ^{52}Cr and ^{56}Fe in an excitation energy range up to about 20 MeV were studied in the present work, with a combination of the above-described methods. The following considerations were taken into account in the choice of these nuclei. The mass number A should be low, so that the width, Γ, which decreases with increasing A, will be larger than the available experimental resolution. On the other hand, A should be high enough so that Γ/D is large such that statistical theory can be applied at a relatively low excitation energy, where the probability of direct interaction is fairly small. These conditions are fulfilled with A between 30 and 60. Moreover, if odd-mass targets with odd Z are used to study the statistical fluctuations, the products are spinless in the (p,α) reactions, for the ground state of the residual nuclei. Only one reaction channel is open at $0°$ and at $180°$ in this case. The mean square fluctuation of the excitation functions is then predicted from the statistical theory to be equal to unity for pure compound-nucleus reactions, and the amount of direct interaction can be checked this way. Finally, the resolution of the energy levels at low excitation energy of these nuclei should be experimentally possible with the magnetic spectrograph.

The energy levels of ^{52}Cr and ^{56}Fe up to excitation energies of 6.3 and 6.7 MeV, respectively, were resolved from the reactions $^{52}Cr(p,p')^{52}Cr$, $^{55}Mn(p,\alpha)^{52}Cr$, $^{56}Fe(p,p')^{56}Fe$, and $^{59}Co(p,\alpha.)^{56}Fe$ with thin targets. The proton beam from the ANL Tandem Van de Graaff (TVDG) accelerator was used, and the outgoing particles were analyzed with a single-gap broad-range magnetic spectrograph. By analyses of the spectra in the continuum according to the evaporation theory, the level densities of the residual nuclei, up to an excitation energy of 8 MeV, were calculated. In addition, the excitation functions for the reactions $^{31}P(p,\alpha)^{28}Si$, $^{51}V(p,\alpha)^{48}Ti$, and $^{55}Mn(p,\alpha)^{52}Cr$ were obtained from experiments with surface-barrier solid-state detectors, and the average widths, Γ, of the compound nuclei ^{32}S, ^{52}Cr and ^{56}Fe were calculated at excitation energies around 20 MeV. The absolute value of the cross sections for the last two reactions are also reported. The experimental widths are compared with theoretical values computed with optical-model transmission coefficients. Finally, the level density up to about 20 MeV of excitation energy was calculated for each of the three nuclides. The results obtained are compared with curves derived from the Fermi-gas and constant-temperature models. The data on the level density of ^{32}S at low excitation energy and the absolute values of the cross section for the reaction $^{31}P(p,p')^{31}P$ were taken from the literature.

REACTION

$^{31}P(p,\alpha)^{28}Si$

FACILITY

Tandem Van de Graaff Accelerator (TVDG), Argonne National Laboratory, Argonne, Illinois, U.S.A.

EXPERIMENT

The objective of this experiment was to investigate α-particle decay of compound nuclei (CN) formed by proton-induced reactions at CN excitations in the vicinity of 20 MeV. In this region, the ratio of average level width to average level spacing is $\Gamma/D >> 1$ for medium mass nuclei. Under these conditions individual levels cannot be resolved and the reaction-yield excitation functions can be expected to fluctuate strongly with incident proton energy (Ericson fluctuations). An analysis of such data yields information on the average level width, Γ, the experimental differential cross section, the optical-model transmission coefficients, and the level density in the CN. In the present study the reaction $^{31}P(p,\alpha)^{28}Si$ was studied along with $^{51}V(p,\alpha)^{48}Ti$ and $^{55}Mn(p,\alpha)^{52}Cr$.This summary is limited to consideration of the $^{31}P(p,\alpha_0)^{28}Si$ reaction.

MEASUREMENT PROCEDURES

The phosphorus targets were prepared using the ANL mass separator. Thin targets of about 10 $\mu g/cm^2$ were used for (p,α) measurements with the magnetic spectrograph, in order to obtain the best possible resolution. Targets of about 50 $\mu g/cm^2$ were used in studies of statistical fluctuations. Finally, thick targets in the range 0.5 to 1.0 mg/cm^2 were used for measurements of the angular and energy distributions of the absolute values of the cross sections, in order to dampen the statistical fluctuations. The proton-beam energy resolution was found to be better than 5 keV at $E_p = 10$ MeV.

The proton beam from the TVDG was collimated by two Ta apertures before impinging on the target. The maximum beam current was between 0.5 and 1.0 μA, with a maximum beam energy of approximately 13 MeV. The emitted α-particles were detected with several Si surface barrier detectors. One of these detectors was used as a monitor while the others were positioned in the same reaction plane on a movable plate that could be controlled remotely. The target was placed so that it bisected the angle between the two most-widely separated detectors at 90° and 175°. These detectors subtended an angle of 7°. The geometry was checked by observing α-particles from a ^{244}Cm source. Collimators were placed in front of the detectors and they were covered with Ni foils of 100 μg/cm^2 to exclude low-energy electrons and light. In order to discriminate against protons, these detectors were biased to just stop the ground-state α-particles.

DATA ACQUIRED

The basic data acquired were α-particle excitation functions for the $^{31}P(p,\alpha_0)^{28}Si$ and $^{31}P(p,\alpha_1)^{28}Si$ reactions. These were measured under the following conditions: 1) at 30°, 60°, 90°, 120°, 150°, 170°, and 175° for E_p = 8.37 - 9.00 MeV; 2) at 39°, 69°, 81°, 111°, 171° and 175° for E_p = 10.00 - 11.77 MeV, and 3) at both angle sets for E_p = 10.00 to 10.50 MeV.

DATA ANALYSIS

The procedures used in analyzing the data are discussed in the dissertation. Among the corrections considered were those for laboratory to center-of-mass coordinates and for the dead time of the detectors. The experimental results are compared with calculated curves derived from Fermi gas and constant-temperature models.

RESULTS AND DISCUSSION

The results from this extensive dissertation are given in tables and figures too numerous to consider here. There are also appendices included which deal with various experimental details, level-density calculations, level-width determinations, and cross section calculations.

KH73a

TITLE

Isospin Dependence of the Nuclear Level Width

REFERENCE

M. Kildir and J.R. Huizenga, Physical Review **C8**, No. 5, 1965 (1973).

ABSTRACT

Statistical fluctuation analyses of $^{31}P(p,\alpha)$ and $^{31}P(p,p')$ excitation functions are used to deduce level widths for the $T_<$ and $T_>$ isospin states in ^{32}S at 17.8 MeV of 38.7 ± 2.7 and 26.2 ± 3.5 keV, respectively. These two widths in ^{55}Mn at 17.6 MeV are reported also. Relative level densities of the two isospins are calculated for each nucleus.

REACTIONS

$^{31}P(p,\alpha)$ and $^{31}P(p,p')$

FACILITY

Nuclear Structure Research Laboratory and Department of Chemistry and Physics, University of Rochester, Rochester, New York. Measurements were made in the proton-energy interval 8.51 to 10.01 MeV. No mention is made in the article [KH73a] of the type of accelerator used. Presumably it was a Tandem Van de Graaff accelerator.

EXPERIMENT

The objective of this experiment was to determine widths for levels corresponding to each of the two isospins, $T_<$ and $T_>$, based on an analysis of fluctuations in the excitation functions for the reactions $^{31}P(p,p_0)$, $^{31}P(p,p_2)$, $^{31}P(p,\alpha_0)$, and $^{31}P(p,\alpha_1)$.

MEASUREMENT PROCEDURES

The description of experimental procedures is very limited. Excitation functions were measured simultaneously for the (p,p') and (p,α) reactions in the proton energy range of 8.51 to 10.01 MeV in 10-keV steps. The target was placed at 30° to the incident beam in a 51-cm scattering chamber. This target consisted of 40 μg/cm^2 of ^{31}P which was vacuum-evaporated onto a 20 μg/cm^2 carbon foil. Alpha particles and protons were detected with surface-barrier solid state detectors placed at several angles between 85° and 165° (laboratory angles). The detectors for the protons, except the one at 90°, were covered with sufficient thickness of aluminum to just stop the α-particles.

DATA ACQUIRED

The data acquired consisted of proton and α-particle yield excitation functions measured at various angles in 10-keV energy steps over the energy range 8.51 to 10.01 MeV.

DATA ANALYSIS

Each of the experimental excitation functions exhibited, on the average, a small decrease in cross section with increasing energy. This energy dependence was removed from these excitation functions before proceeding with the fluctuation analysis. Two different methods were used to estimate this energy dependence. One was based on Hauser-Feshbach calculations. The second involved a simple straight-line fit to the experimental data. Level widths were deduced from auto-correlation functions based on the experimental data. The widths deduced in this manner appeared to be insensitive to the method used to remove the energy dependence of the excitation functions.

Widths for both of the levels in two isospin categories of the compound nucleus, ^{32}S, were determined from the excitation functions for $^{31}P(p,p_0)$, $^{31}P(p,p_2)$, $^{31}P(p,\alpha_0)$ and $^{31}P(p,\alpha_1)$ reactions. Each of these was done at three different angles. Relative level densities from T = 0 and T =1 states of ^{32}S were also obtained.

RESULTS AND DISCUSSION

The results are reported in the text and tables of this paper [KH73a]. The average level widths in ^{32}S determined from the $^{31}P(p,p')$ and $^{31}P(p,\alpha)$ reactions are 30.0 ± 1.4 keV and 38.7 ± 2.7 keV, respectively. These values are similar to those determined for ^{32}S from several reactions discussed elsewhere in the literature. The most probable explanation for the experimental level width from the (p,α) reaction channels being different from that of the (p,p') reaction channels is the partial or complete conservation of isospin in the intermediate composite nucleus. If isospin is a good quantum number, the (p,α_0) and (p,α_1) reactions proceed through only $T_<$ isospin states in the composite nucleus. Hence, the level width extracted from the excitation functions for these reactions is the width of the $T_<$ isospin states. However, the $^{31}P(p,p')$ reactions can involve both $T_<$ and $T_>$ isospin states. From the measured excitation functions it was determined that the level widths for the $T_<$ =

0 and $T_>$ = 1 isospin states in the composite nucleus ^{32}S are 38.7 ± 2.7 keV and 26.2 ± 3.5 keV, respectively. It was also found that the ratio of level densities for $T_<$ to $T_>$ states at an excitation of 17.8 MeV in ^{32}S is about 1. This result is in a large part accounted for by nuclear pairing. The T = 0 states originate from an even-even nucleus with a large pairing energy while the T = 1 states of ^{32}S are analog states of ^{32}P which is an odd-odd nucleus.

KH73b

TITLE

Dependence of the Nuclear Width of ^{32}S on Isospin

REFERENCE

M. Kildir and J.R. Huizenga, Bulletin of the American Physical Society **18**, 668, Paper HE 10 (1973).

ABSTRACT

Excitation functions of the $^{31}P(p,p')$ and $^{31}P(p,\alpha)$ reactions were measured simultaneously in the proton energy interval 8.51 to 10.01 MeV in 10-keV steps. The average level widths extracted from analyses of six excitation functions for each of the above reactions at an excitation energy in ^{32}S of 17.6 MeV are 30.0 ± 1.4 and 38.7 ± 2.7 keV, respectively. If isospin is a good quantum number, the (p,α) reaction gives a width of the $T_<$ isospin states of 38.7 keV. The width determined from the (p,p') excitation functions is a weighted average of the widths of the $T_<$ and $T_>$ states. Analysis of these data gives a width for the $T_>$ states of 26.5 ± 3.5 keV. From these results the relative density of the $T_<$ = 0 and $T_>$ = 1 levels in the compound nucleus ^{32}S is determined. Similar analyses are performed for the compound nucleus ^{55}Mn from previous measurements.

COMMENTS

This reference is just an abstract, as it appears above.

KMC68

TITLE

Elastic Scattering of Protons by Phosphorus and the Reactions $^{31}P(p,\alpha_0)^{28}Si$ and $^{31}P(p,\alpha_1)^{28}Si$ in the Energy Interval 1.0 - 3.8 MeV

REFERENCE

K.V. Karadzhev, V.I. Man'ko and F.E. Chukreev, Soviet Journal of Nuclear Physics **7**, No. 2, 170 (1968).

ABSTRACT

We investigated the elastic scattering of protons by phosphorus, and also the reactions $^{31}P(p,\alpha_0)^{28}Si$ and $^{31}P(p,\alpha_1)^{28}Si$ in the proton energy interval 1.0 - 3.8 MeV. We obtained the energy dependence of the differential scattering cross section at the angles 150° and 90° in the laboratory, respectively. The presence of numerous and strong resonances in the elastic scattering of protons by phosphorus offers evidence that the partial proton and α-particle widths for the levels of the ^{32}S nucleus are of approximately the same order. We measured the angular distributions of the α particles in the vertices of most resonances of the foregoing reactions (altogether about 40 distributions), and expanded these distributions by least squares in terms of Legendre polynomials. An appreciable fraction of the distributions contains polynomials of order not higher than the second, thus evidencing that the spins of the corresponding states do not exceed unity.

REACTIONS

$^{31}P(p,\alpha_0)^{28}Si$, $^{31}P(p,\alpha_1)^{28}Si$ and $^{31}P(p,p)^{31}P$

FACILITY

There is no mention in the paper [KMC68] of the particular facility used for this work other than to say that the accelerator employed was an electrostatic generator. The reader is referred to two earlier references (K.V. Karadzhev, V.I. Man'ko, and F.E. Chukreev, Sov. Phys.-JETP **17**, 593, 1964; and K.V. Karadzhev, V.I. Man'ko, and F.E. Chukreev, Sov. J. Nuc. Phys. **4**, 648, 1967) for further details. A later paper included in the present compilation [KMC69b] implies that this work was carried out at the Kurchatov Institute, Moscow, Russia.

EXPERIMENT

The present experiment involved investigation of nuclear reactions in the proton-energy interval 1 - 3.8 MeV. In particular, the following reactions involving ^{31}P were studied: $^{31}P(p,\alpha_0)^{28}Si$, $^{31}P(p,\alpha_1)^{28}Si$, and proton elastic scattering, *i.e.*, $^{31}P(p,p)^{31}P$. Emitted α-particle and scattered proton excitation functions were measured. In addition, angular distributions of emitted α-particles corresponding to both reactions were obtained on the resonances. An analysis of these data provided such important characteristics of the excited states of ^{32}S as spins, parities and reduced widths, as well as yielding the relative contributions of the different input channels.

MEASUREMENT PROCEDURES

An electrostatic generator was used for these measurements. The details are discussed in the other papers mentioned above. The proton beam entered a reaction chamber whose upper lid could be rotated allowing for measurements at various scattering angles. The beam current was measured with a Faraday cylinder (cup?) mounted behind the chamber. The entrance chamber contained two diaphragms and the angle between the beam axis and the chamber axis was 0.3°. The target was a carbon film on which Zn_3P_2 was evaporated in a vacuum to a thickness of about 20 - 30 μg/cm². The carbon film had about the same thickness. These targets were sufficiently strong to withstand beam-current densities exceeding 1 μA/mm² for a long time. The α-particle spectra were measured with ordinary Si surface-barrier detectors. Since the protons had a longer range, their spectra were measured using a semiconductor counter with p-i-n structure, made of silicon compensated with lithium. With these detectors it was possible to distinguish the protons and α-particles.

DATA ACQUIRED

The energy-dependence of the yield of α-particles was measured at 90° in the laboratory system (l.s.) since the odd-order Legendre polynomial terms in the distributions vanish at this angle. The $^{31}P(p,\alpha_0)^{28}Si$ reaction was studied in the proton energy interval 1000 - 3500 keV while the $^{31}P(p,\alpha_1)^{28}Si$ reaction was examined in the proton energy interval 2850 - 3500 keV. In addition, the α-particle yield was measured at 120° l.s. in the energy interval 2100 - 2300 keV. This was done since there were two excited states seen here, at $E_p = 2114$ and 2255 keV, which scarcely appear in the excitation function at 90°. Finally, the energy dependence of the α-particle yield from both reactions was measured at 120° l.s. in the proton energy interval 3500 - 3800 keV. Concerning the yield of elastically-scattered protons from ^{31}P and the isotopes of Zn, measurements were made at 150° simultaneously with the α-particles in the proton energy interval 1000 - 3500 keV. It was assumed that far from resonances, the elastic proton scattering was entirely due to the Rutherford process. These measurements made it possible to derive absolute differential cross sections from the (p,α_0) and (p,α_1) data, as expressed below.

DATA ANALYSIS

Absolute differential cross sections at 90° for the $^{31}P(p,\alpha_0)^{28}Si$ and $^{31}P(p,\alpha_1)^{28}Si$ reactions could be derived directly from an examination of the elastic scattering of protons from ^{31}P at 150°, based on the assumption of Rutherford scattering, as mentioned above. The details of this analysis are described in the paper [KMC68]. Normalization was ultimately based on the absolute cross sections for proton scattering from the isotopes of Zn and ^{12}C. The errors in the normalization of the cross sections for ^{31}P were on the order of 25%. All of the α-particle angular distributions measured on the resonances were fitted by the method of least squares using a Legendre polynomial expansion. The fitting coefficients and their uncertainties are tabulated in the paper.

RESULTS AND DISCUSSION

Absolute cross section for the ^{31}P reactions are not given in this paper. Instead, a table is provided which indicates the energies of the resonances in ^{32}S, including a designation of which ones were observed in (p,p), (p,α_0) and (p,α_1). Furthermore, the even Legendre coefficients resulting from fits to the α-particle distributions are given along with upper bounds on the magnitude of the odd coefficients. One of the results from this investigation was to learn that the odd-Legendre terms resulting from fits to the distributions were indeed quite small. Furthermore, these α-particle angular distributions, particularly those for the proton energies lower than 3 MeV, contain Legendre polynomial terms of order no higher than second. The resonant energies that are given in this paper are not very accurately established due to the fact that their determination was not an objective of this study. The uncertainties in these energies are several keV. The authors conclude that the presence of numerous and strong resonances in the elastic scattering $^{31}P(p,p)^{31}P$ offers evidence that the partial proton and α-particle widths for the levels of ^{32}S are approximately of the same order.

KMC69a

TITLE

Spin Mixing in the Input Channels of the Reaction $^{31}P(p,\alpha_0)^{28}Si$

REFERENCE

K.V. Karadzhev, V.I. Man'ko and F.E. Chukreev, Soviet Journal of Nuclear Physics **8**, No. 2, 184 (1969).

ABSTRACT

The angular distributions of α particles from the reaction $^{31}P(p,\alpha_0)^{28}Si$ were used to determine the spin-mixing coefficient, which equals the ratio Γ_{p0}/Γ_{p1} of the partial proton widths, corresponding to two possible reaction channels - with spins 0 and 1. The distribution of these coefficients does not agree with the calculated one, based on the assumptions of statistical independence of the width Γ_{p0} and Γ_{p1} and on the assumption that each of them obeys the Porter-Thomas distribution (C.E. Porter and R.G. Thomas, Phys. Rev. **104**, 483, 1956). The form of the indicated distribution offers evidence of the presence of a correlation between the widths Γ_{p0} and Γ_{p1}. This correlation is close to that which should be realized in the case of jj coupling; this in turn can mean that even at such high excitation energies (10.0 - 12.5 MeV) one can speak of the occurrence of relatively simple shell configurations.

REACTION

$^{31}P(p,\alpha_0)^{28}Si$

FACILITY

No mention is made in the paper [KMC69a] of the institute where this work was carried out. However, in a later work included in the present compilation [KMC69b] it is implied that the work was done at the Kurchatov Institute, Moscow, Russia.

EXPERIMENT

This work consists of an analytical study which makes use of experimental data reported earlier (*e.g.*, Ref. KMC68). Spin mixing in the channel p + ^{31}P is investigated in this simple case of the reaction $^{31}P(p,\alpha_0)^{28}Si$, where the incident proton has spin/parity ½$^+$, the target ^{31}P has spin/parity ½$^+$, the α-particle has spin/parity 0^+ and the final nucleus ^{28}Si has spin/parity 0^+. Under these conditions, the input channel spin can assume one or other of two values, namely, s = 0 and s = 1, and the output channel spin can have only one value, namely, s' = 0. The contributions made to the cross-section of each of the input channel spins were determined from an analysis of angular distribution data for the $^{31}P(p,\alpha_0)^{28}Si$ reaction.

MEASUREMENT PROCEDURES

The measurement procedures which generated the data used in this study are described in an earlier paper [KMC68] and other references mentioned therein.

DATA ACQUIRED

Thirty experimental α-particle angular distributions were available for consideration in this investigation; they covered the proton energy range 1.0 to 3.8 MeV.

DATA ANALYSIS

The measured angular distributions were fitted with Legendre-polynomial expansions by the method of least squares. The coefficients resulting from this analysis are presented in a table contained in the earlier paper [KMC68]. The present analysis resorted to the formalism of Blatt and Biedenharn (Rev. Mod. Phys. **24**, 258, 1952). Comparison of the theoretical coefficients and those obtained from fitting the data enabled values for the spin mixing coefficient t_0 to be extracted. The analysis involved examining two extreme cases. The first considers the partial proton widths to be statistically independent while the second assumes that the partial proton widths to be rigidly correlated. The equations and a description of coefficients in these equations are described in the paper. There is also a description of the LS- and jj-coupling quantum numbers that were used.

RESULTS AND DISCUSSION

There are no numerical results provided in this paper [KMC69a]. A histogram of the distribution of spin mixing coefficients t_0 is provided in Fig. 2 of the paper. This can be compared with the form of this distribution which is derived from theory, based on various assumptions. It was pointed out that the errors in determining the spin mixing coefficients t_0 were approximately $\pm$ 0.03. This study provides evidence that jj-coupling is the most probable type of coupling in the present situation.

KMC69b

TITLE

Properties of the Excited States of the ^{32}S Nucleus

REFERENCE

K.V. Karadzhev, V.I. Man'ko and F.E. Chukreev, Soviet Journal of Nuclear Physics 9, No. 4, 431 (1969).

ABSTRACT

The characteristics of the excited states of the ^{32}S nucleus in the excitation-energy interval 10.0 - 12.5 MeV were determined from an analysis of the energy dependence of the elastic scattering $^{31}P(p,p)^{31}P$ and the reactions $^{31}P(p,\alpha_0)^{28}Si$ and $^{31}P(p,\alpha_1)^{28}Si$, and also of the angular distributions of the α particles from these reactions. The angular momenta and the parities of most states were determined, as well as the partial and reduced proton and α-particle widths of these states, *etc.* The reduced α-particle widths turned out to be, on the average, larger than the proton widths by two orders of magnitude, thus indicating strong clustering of the nucleons in the ^{32}S nucleus. For each of the two investigated reactions, a group of states was observed, with reduced widths close to the single-particle widths, the distance between these groups being approximately equal to the energy of the first excited level of ^{28}Si. This has made it possible to interpret the indicated states as excitations of the system $^{28}Si + \alpha$ particle, the ^{28}Si nucleus being respectively either in the ground state or in the first-excited state.

REACTIONS

$^{31}P(p,p)^{31}P$, $^{31}P(p,\alpha_0)^{28}Si$, and $^{31}P(p,\alpha_1)^{28}Si$

FACILITY

I.V. Kurchatov Institute of Atomic Energy, Moscow, Russia. Note that this work represents an analytical study. No experimental details are indicated here, but there is a reference to an earlier paper [KMC68] in which some experimental details are mentioned.

EXPERIMENT

The experiment examines the properties of the excited states of ^{32}S. This is accomplished by considering those levels that appear as resonances in the $^{31}P(p,\alpha_0)^{28}Si$ and $^{31}P(p,\alpha_1)^{28}Si$ reactions, as well as those observed through the proton elastic scattering process $^{31}P(p,p)^{31}P$ for protons in the energy range of 1.0 - 3.8 MeV. The excitation energy that corresponds to this interval is 10.0 - 12.5 MeV. Particularly useful are the α-particle angular-distribution data. The angular momenta and parities of the states in ^{32}S are deduced by comparing the experimental angular distributions with those calculated from basic theory under various assumptions of the quantum numbers of the states in the compound nucleus. The procedure is relatively simple in the case of the $^{31}P(p,\alpha_0)^{28}Si$ reaction, as discussed in another paper in this series [KMC69a]. However, for the $^{31}P(p,\alpha_1)^{28}Si$ reaction the situation is much more difficult because the first-excited state of ^{28}Si is spin/parity 2^+ rather than 0^+ as is the case for the ground state.

MEASUREMENT PROCEDURES

The measurement procedures are discussed in an earlier paper [KMC68] and other references mentioned therein.

DATA ACQUIRED

Data on the energy dependence of $^{31}P(p,\alpha_0)^{28}Si$, $^{31}P(p,\alpha_1)^{28}Si$ and $^{31}P(p,p)^{31}P$ from 1.0 to 3.8 MeV, along with angular distributions of emitted α-particles measured on the resonances, provide the basic experimental information used in the present analysis. Refer to an earlier paper for details [KMC68].

DATA ANALYSIS

To determine angular momenta and parities involved in the resonant-state excitations, the experimentally determined α-particle angular distributions were compared with those calculated from theory using various assumptions for the quantum numbers. This allowed the authors to determine which values for the angular momenta and parities were most likely to be the correct ones. The details are discussed in the present paper [KMC69b] as well as in earlier ones in the series from this laboratory [KMC68,KMC69a].

RESULTS AND DISCUSSION

The present results seem to indicate that the formation of an α-particle on the surface of the ^{32}S nucleus is more likely to happen in the investigated excitation-energy range than the formation of a proton. Numerical information is contained in Tables I and II of the present paper [KMC69b].

KS74

TITLE

An Upper Limit to the Life Time of 9.709 MeV State in ^{32}S by Blocking Technique

REFERENCE

M.B. Kurup and R.P. Sharma, Bombay Conference (Nuclear, Solid State Physics) **17B**, 131 (1974).

ABSTRACT

No abstract is available; however, this conference contribution is sufficiently short to include here in its entirety in the exact form originally provided by the authors:

The charged particle blocking effect in single crystals offers a unique method (W.M. Gibson and M. Maruyama, *Channeling: Theory, Observation and Applications*, D.V. Morgan, Editor, John Wiley, London, 1973) of determining nuclear lifetimes in the range 10^{-17} secs. The 9.709 MeV state in ^{32}S is a weak resonance (strength ~ 5.6 eV) excited in the reaction $^{31}P(p,\alpha)^{28}Si$ at 872 keV incident proton energy and is well suited for such a measurement. The direct measurement of the compound nuclear lifetime in the reaction reveals the width of the level.

Single crystal of GaP oriented in the <111> direction has been used in this measurement. The crystal was mounted on a double axis goniometer connected to the beam tube of a 5.5 MeV Van de Graaff machine. A well collimated (0.5 x 0.5 mm^2) beam of protons (molecular beam energy 1755 keV) was incident on the crystal. At first the crystal was oriented in the usual way by the channeling technique using back scattered protons. The orientation was so adjusted that the two <111> axes which are at 71° apart in the crystal, were at 10° and 81° respectively relative to the incident beam.

The blocking patterns of the α-particles emitted in the reaction $^{31}P(p,\alpha)^{28}Si$ were detected in these two directions on the plastic films (cellulose nitrate) placed at a distance of 15 cms from the crystal. The use of plastic films is very essential as by proper etching (G. Somogyi, M. Varnagy and G. Peto, Nucl. Instr. **59**, 299, 1968), the large proton back-ground (for every 10^6 protons scattered there is only one α-particle emitted) can be completely eliminated. The effect due to radiation damage was minimized by shifting the beam spot on the crystal after every 40 μC by moving the goniometer in two perpendicular directions parallel to the crystal surface. The details are described elsewhere [SAN73]. A total dose of 7000 μC has been accumulated.

The blocking patterns obtained on the plastic films kept at the 10° and 81° directions respectively were scanned around the <111> minima and the counts from the 0.25 x 25 mm^2 squares in successive circular rings were added to get the axial dips. These are shown in Fig. 1(a) and (b) [Note: these figures are not included here]. As the total dose is less, the statistics are not good and though the minimum yield appears to be higher in the 81° direction, we are able to put only an upper limit to the lifetime of this excited state.

From the minimum yields χ_1 and χ_2 measured along the two <111> directions the mean lifetime, τ, has been obtained using the expression

$$\chi_1 - \chi_2 = 2CNd\pi v_T \tau^2.$$

Here N is the atomic density, d is the lattice spacing and v_T is the transverse velocity of the recoiling compound nucleus which is 2.8 x 10^7 cms/sec as obtained from reaction kinematics. The constant C has been introduced by Barrett (Phys. Rev. **B3**, 1527, 1971) and in the present case its value is taken as 2.5. Using the observed value of $\Delta\chi$ from fig. 1 [Note: This figure is not included here] an upper limit of 4 x 10^{-17} secs. for the mean lifetime of the 9.709 MeV state in ^{32}S has been found. The total width of this state is thus Γ = 16 eV.

The present measurement is an attempt to show the feasibility of carrying out such experiments at the 5.5 MeV Van de Graaff machine at Trombay. A longer exposure (~ one week, *i.e.*, a total dose of 15000μC) of the plastic films will considerably improve the statistics and the value of lifetime can be determined with certainty.

The technique is now getting well set and it appears possible to study directly the decay widths and level density parameters and the enhancement of compound nucleus fine structure near analogue resonances.

COMMENTS

This investigation was carried out at the Tata Institute of Fundamental Research, Trombay, Bombay, India. The work reported here is similar to that discussed in Refs. SAN73 and SKP75.

TITLE

Measurements of Relative Thick Target Yields for PIGE Analysis on Light Elements in the Proton Energy Interval 2.4 - 4.2 MeV

REFERENCE

A.Z. Kiss, E. Koltay, B. Nyako, E. Somorjai, A. Anttila and J. Raisanen, Journal of Radioanalytical and Nuclear Chemistry **89**, No. 1, 123 (1985).

ABSTRACT

In order to extend the energy range of the systematic investigation on relative thick target yields performed by Anttila *et al.* (J. Radioanal. Chem. **62**, 441, 1981) for $1 \leq E_p \leq 2.4$ MeV bombarding energies, gamma spectra and yield data are presented for elements Z = 3 - 9, 11 - 17, 19 and 21 in the energy range $2.4 \leq E_p \leq 4.2$ MeV, and the results are discussed from the point of view of the PIGE analysis.

REACTION

$^{31}P(p,\alpha_1\gamma)^{28}Si$

FACILITY

5-MV Van de Graaff accelerator, Institute of Nuclear Research, Hungarian Academy of Sciences, Debrecen, Hungary.

EXPERIMENT

Relative thick target yields are compiled to enable an optimal selection of experimental parameters on a given sample matrix to be made as the basis for practical applications of the PIGE (proton-induced gamma emission) method for determination of the constituents of samples. A consistent set of yield data is presented in the article [K+85] for nearly all $3 \leq Z \leq 21$ elements in the proton energy interval $1 \leq E_p \leq 4.2$ MeV. The yield data for $1 \leq E_p \leq 2.4$ MeV are taken from earlier research. Similar data were generated from measurements performed in the present experiment over the energy range $2.4 \leq E_p \leq 4.2$ MeV. These newer data were normalized to results from the earlier, lower-energy work. The intent of this work was clearly applied rather than basic. Furthermore, the results provided, while of general interest, are of little practical use for astrophysical purposes.

MEASUREMENT PROCEDURES

The proton beam was supplied by the 5-MV Van de Graaff accelerator of the Institute of Nuclear Research, Debrecen. This beam was well collimated and, furthermore, passed through a 50-cm-long liquid nitrogen cold trap before hitting the target (presumably in order to reduce buildup of contaminants on the targets). The angle between the beam and the targets was 45°. Elemental targets (Be, Mg, C, Al and Si) were prepared in the form of thick plates. All the other targets were made by pressing appropriate chemical compounds into pellets. A 25-cm^3 Ge(Li) detector with 2.6-keV resolution for E_γ = 1.33 MeV gammas was used to detect the gamma radiation in the present experiment. For the case of the reaction $^{31}P(p,\alpha_1\gamma)^{28}Si$, this amounted to observation of the single gamma ray of energy 1.779 MeV which de-excites the first-excited state of ^{28}Si. This detector was situated at 55° relative to the beam direction at a detector-to-target distance of 10 cm. Since a larger Ge(Li) detector (100 cm^3) had been used earlier for the work at energies $E_p \leq 2.4$ MeV, it was necessary to generate a relative efficiency calibration for these two detectors in the range $0.11 \leq E_\gamma \leq 3.56$ MeV so that the present results could be properly normalized to values from the earlier investigation. Beam currents in the range 1 nA to 1 μA were used. The beam intensity was adjusted to keep the dead time for the detection system nearly constant for measurements with various samples. Gamma-ray spectral data were acquired with a 4K-channel analyzer and PDP-8 computer.

DATA ACQUIRED

Gamma-ray spectra from proton bombardment of thick samples at energies E_p = 3.1, 3.8, and 4.2 MeV were recorded for all elements in the range $3 \leq Z \leq 21$, except neon and argon. Typical spectra from this work are shown as figures in the article [K+85], including one for phosphorus at E_p = 3.8 MeV.

DATA ANALYSIS

Individual full-energy-peak lines in these gamma spectra were identified as belonging either to the element under consideration or to other components of the sample compound or to background sources. Reference was made to known level and decay schemes in this identification process. Yields of peaks attributed to the elements in question were determined and corrected for dead-time losses. In many cases several lines corresponding to the same element were available, which offered some redundancy and hence a check against possible elemental assay errors. In the case of phosphorus, the principal lines observed were due to $^{31}P(p,p'\gamma)$, $(p,\alpha_1\gamma)$, and (p,γ). The present gamma-ray yields were generally normalized to earlier work at lower proton energies using the relative sensitivities of the 25 cm^3 and the 100 cm^3 detectors. Due to the strong decrease in the sensitivity of the smaller detector, no normalization was made for the gamma-ray peaks seen in the fluorine target spectra with $E_\gamma > 3.56$ MeV. The yields of these higher-energy gamma lines are presented only on the intensity scale of the 25-cm^3 Ge(Li) detector.

RESULTS AND DISCUSSION

The results of this work appear in Figs. 1 - 17 and in Table 1 of the article [K+85]. This body of information represents a consistent set of thick target gamma-ray yields for $3 \le Z \le 21$ elements (except for neon and argon) in the bombarding proton energy interval $1 \le E_p \le 4.2$ MeV. When increasing the proton energy from 2.5 to 4.2 MeV, the number of isotopes with open (p,n) neutron channels increased from 7 to 15 in the present Z range. These reactions contribute gammas in addition to those resulting from the proton capture and charged-particle emission reactions. This complicates the gamma-ray spectra at higher proton energies. Of course this complexity has a positive side in that it broadens the applications for PIGE analysis at higher proton bombarding energies because the opening reaction channels provide additional signature reactions.

LFG72

TITLE

Variation of the ^{32}S Compound-nucleus Width with Energy and Spin

REFERENCE

R.B. Leachman, P. Fessenden, and W.R. Gibbs, Physical Review **C6**, No. 4, 1240 (1972).

ABSTRACT

Coherence widths of the compound nucleus, ^{32}S, were determined from excitation functions of the differential cross section for the reactions $^{31}P(p,\alpha)^{28}Si$ and $^{16}O(^{16}O,\alpha)^{28}Si$. The proton-induced reaction provided a lower average spin of the compound nucleus. Excitation functions were measured for $^{31}P(p,\alpha)^{28}Si$ from 13.90- to 14.24-MeV and from 26.62- to 30.56-MeV compound nucleus energy. The average coherence widths were 11 ± 1.2 and 95 ± 15 keV, respectively. For the

oxygen-induced reaction, excitation functions were measured from 28.99 to 34.42 MeV with a resulting 73 ± 7 keV coherence width, which is nearly the same as for the lower-spin proton-induced case.

These coherence widths were used to test the Gilbert and Cameron level-density formulation. Good agreement with the above data was obtained if the compound nucleus ^{32}S is considered to be spherical in this formulation. The increase in the calculated width for the ^{16}O induced reaction with increasing excitation energy is greater than indicated by combining our data with another measurement at higher excitation.

REACTION

$^{31}P(p,\alpha)^{28}Si$

FACILITIES

Single-stage Van de Graaff accelerator and three-stage Van de Graaff accelerator, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, U.S.A.

EXPERIMENT

Information on level densities of nuclei as a function of excitation energy and spin is sought. The measurement of level widths offers the main opportunity for determining level densities at compound-nucleus excitation energies above 6 MeV. At lower energies, where the level widths are frequently smaller than the mean spacing, other techniques such as direct counting are quite useful. The present experiment undertook to measure excitation functions in sufficiently small steps of incident energy, with good resolution, in order to permit fluctuation analyses of the data to be carried out. Two reactions were studied, namely, $^{31}P(p,\alpha)^{28}Si$ and $^{16}O(^{16}O,\alpha)^{28}Si$. The proton-induced reaction, due to the ½ spin of both the proton and target nucleus ^{31}P, is a convenient vehicle for studying the low-spin case. This is the only reaction that is discussed here.

The general approach of this study is as follows. Values of widths Γ deduced from fluctuation analysis of the excitation function data can be compared with those calculated from nuclear theory. The theoretical models have as input assumed information on the level density and transmission coefficients. It is difficult to choose between various approaches to representing level density because the free choices allowed in level-density parameterization in the calculation of level widths often exceeds the number of available datum points of width. In addition, it turns out that the formalism relating width to level density is expressed qualitatively as a function of the ratio between level densities of the compound nucleus and residual nucleus. In this range of nuclei, the residual and compound entities have similar masses and thus relatively similar level density parameterizations. This obviously limits the sensitivity of calculated widths to these parameters. To avoid this problem, the decision was made to focus in the present investigation on the formalism of Gilbert and Cameron (Canadian Journal of Physics **43**, 1446, 1965) in which essentially all of the parameters are fixed by comparison with lower-energy data.

MEASUREMENT PROCEDURES

Two different measurement procedures were used for the $^{31}P(p,\alpha)^{28}Si$ reaction studies in this investigation.

The measurements at low energies utilized protons from a single-stage Van de Graaff accelerator. The procedures are described in earlier communications from this group [D+65, SLD67]. Briefly, the approach was as follows. The beam current was approximately 0.1 μA. The proton-energy region spanned was between 5.20 and 5.55 MeV. Energy increments of 2.5 keV were used throughout this interval. The protons were incident on a 13.8 ± 1.1 μg/cm^2 ^{31}P target deposited by an isotope separator on a 0.1mg/cm^2 carbon foil. Thin semiconductor detectors of 45 to 77 μm thickness were used to detect the α-particles leading to the 0^+ (ground) and 2^+ (first-excited) states of ^{28}Si. The arrangement involved three detectors, at laboratory angles 130°, 150° and 170°, respectively. These α-counters subtended 4° to 6° angular spans.

To provide compound-nucleus excitation energies comparable to the lowest-energy oxygen-induced reactions, it was necessary to use protons with energies around 20 MeV for the second set of measurements. These protons were obtained from a three-stage Van de Graaff accelerator. The measurements were performed with energy increments of 20 keV over the range 18.4 to 22.4 MeV. The beam current was typically 0.35μA. The experiment employed a 50-cm scattering chamber with the target positioned perpendicular to the beam. The beam was collimated to 0.4 cm diameter and it impinged upon a target of ^{31}P which was 37 ± 2μg/cm^2 thick. The phosphorus was deposited from the vapor phase on a cooled carbon foil of 30 μg/cm^2. Owing to the large number of competing exit channels in the reaction at these higher energies, the $^{31}P(p,\alpha)^{28}Si$ cross sections were observed to be two or three orders of magnitude lower than for the low-energy domain. Consequently, special effort was required to increase the detection solid angle so that reasonably short observation times could be had for the individual fluctuation-data runs. Six surface-barrier detectors were covered with aluminum absorber foils and mounted in a collimator assembly that formed a 7.9°-wide spherical zone in the vicinity of 133°. This assembly was used for detection of the α-particles during the excitation-function measurements. Angular distributions were measured separately by a conventional detector setup in a horizontal plane. These detectors subtended 6.5° angles seen from the target.

DATA ACQUIRED

The first set of measurements at lower proton energies yielded excitation functions for the proton-energy range 5.20 - 5.55 MeV (13.90- to 14.24-MeV compound-nucleus excitation energies) at laboratory angles 130°, 150° and 170°. The second set of measurements at higher proton energies yielded excitation functions for the proton-energy range 18.4 to 22.4 MeV (26.62- to 30.56-MeV compound-nucleus excitation energies) at a laboratory angle of 133°. Furthermore, α-particle angular distributions were obtained at E_p = 18.40, 18.80, 20.40, 20.80, 22.00 and 22.40 MeV.

DATA ANALYSIS

Both the low- and high-energy excitation function data sets were corrected for the effects of resolution resulting from target thickness and beam-energy spread. The reader of the present paper [LFG72] is referred to an earlier work [D+65] for a description of the low-energy fluctuation analysis. In the case of the high-energy data, it is noted that since the protons approach the target well above the Coulomb barrier, the repulsive electrostatic effect no longer causes the cross section to increase with energy. In fact, the cross section is expected to decrease with increasing energy due to an increasing number of open exit channels. Consequently, to prepare the raw excitation-function data for a fluctuation analysis, the cross section at each energy was normalized to a smooth variation of cross section with energy which is basically an exponential function (shown in Fig. 2 of the paper [LFG72]). Further details on the analysis procedure are given in the paper [LFG72].

RESULTS AND DISCUSSION

Many of the results presented in this paper are not directly useful for present purposes and, frequently, they are presented in graphs. The numerical information of greatest potential interest is presented in Table II. In particular, the widths Γ extracted from the fluctuation analyses are included in the EXFOR file prepared for this contribution. Cross-correlation data for the high-energy reaction confirm that fluctuation analysis is a valid approach to processing these data. Determinations of the fractions of reaction yield due to direct processes appear to be inconclusive, but the values obtained are consistent with an observed small fraction of direct-reaction yield for $^{31}P(p,\alpha)^{28}Si$ at low energies. The low-energy densities are extracted from good fits of the Gilbert and Cameron level-density expression to experimental data. There is also evidence that there is a greater increase of width with increasing energy for high spin reactions than for low-spin reactions. The authors of this work [LFG72] conclude that the magnitude, variation with energy, and variation with angular momentum of the total width can be understood with a simple statistical model for the reaction process.

MS95

TITLE

Parity Violation in Charged Particle Resonances

REFERENCE

G.E. Mitchell and J.F. Shriner, Jr., Nuclear Instruments and Methods in Physics Research **B99**, 305 (1995).

ABSTRACT

Recent parity nonconservation (PNC) measurements in nuclei use the compound nucleus as a laboratory for the study of symmetry breaking, with the symmetry breaking matrix elements treated as random variables. This approach is made appealing by the observation of very large parity violation in neutron resonances. One key issue is the mass dependence of the effective nucleon-nucleus weak interaction. The neutron measurements do not appear feasible for light nuclei. We have calculated PNC observables for charged-particle resonance reactions for over 100 states in five s-d shell nuclides using experimental values of the resonance parameters. Analyzing powers show strong dependence on energy and angle, and vary greatly from resonance to resonance. Proposed PNC experiments are discussed.

COMMENTS

No data pertinent to the $^{31}P(p,\alpha)^{28}Si$ reaction are given in this paper. It focuses on a discussion of the methodology used for observing parity non-conservation in nuclear interactions involving resonances. This work is related to earlier work from the same group [D+94].

MS96

TITLE

Parity Violation in Charged-particle Resonance Reactions

REFERENCE

G.E. Mitchell and J.F. Shriner, Jr., Physical Review **C54**, No. 1, 371 (1996).

ABSTRACT

Parity nonconservation (PNC) measurements utilizing charged-particle resonance reactions are proposed. PNC observables have been calculated for over 300 resonance pairs (with the same angular momentum and opposite parity) in five s-d shell nuclei. Detailed numerical results are presented for the longitudinal analyzing powers in the $^{31}P(\mathbf{p},\alpha_0)$ reaction [Note: **p** indicates a polarized proton beam]. There is strong dependence on energy, angle, and resonance parameters. A figure of merit that includes both the relative enhancement of the parity violation and the cross section is used to identify the most promising resonances for study. A proposed detector design and experimental procedure are described. These measurements should provide information on the weak spreading width (the effective nucleon-nucleus weak interaction) in light nuclei.

COMMENTS

This is not an experimental paper. Theory is used to calculate values for total widths, analyzing power, figures of merit, angle for maximum figures of merit, and parameters related to parity-violation enhancement. This work is related to earlier studies in this laboratory [D+94].

M+93

TITLE

Detailed Balance Test of Time Reversal Invariance with Interfering Resonances

REFERENCES

G.E. Mitchell, E.G. Bilpuch, C.R. Bybee, J.M. Drake, and J.F. Shriner, Jr., Nuclear Physics **A560**, 483 (1993). See also: Nuclear Instruments and Methods in Physics Research **B79**, 290 (1993). Note that these two papers are very similar.

ABSTRACT

The following abstract is taken from the Nuclear Physics paper:

Bunakov and Weidenmuller recently proposed that there may be large enhancement of time-reversal invariance violation in a test of detailed balance near two interfering resonances. In our (p,α) resonance data on ^{23}Na, ^{27}Al, ^{31}P, ^{35}Cl, and ^{39}K, there are 33 pairs of adjacent resonances which have the same spin and parity. The difference in the differential cross sections for the (p,α) and (α,p) reactions was calculated for these resonance pairs using experimental values for the partial widths. The collision matrix elements were obtained for a hamiltonian $H = H_0 + iH_{TRIV}$ by following the approach of Moldauer. The differences show striking dependence on energy, angle, and the particular pair of resonances; the relative sensitivity varies by many orders of magnitude. These preliminary results suggest that this class of experiments may be much more sensitive than previous detailed balance tests.

COMMENTS

These two references precede and support a more comprehensive later document from this group [D+94]. Neither of the papers included under reference code M+93 contain data appropriate for an EXFOR entry.

P+71

TITLE

The Collective Nature of the Low-lying States in ^{27}Al and ^{23}Na Investigated with (p,α) Reactions

REFERENCE

G. Philipp, W.-D. Emmerich, A. Hofmann, G. Kroner, and K. Thomas, Nuclear Physics **A160**, 654 (1971).

ABSTRACT

With a tandem Van de Graaff accelerator, (p,α) reactions have been performed on the target nuclei ^{31}P, ^{30}Si, ^{27}Al and ^{26}Mg. At bombarding energies between 5.8 and 8.2 MeV and between 10 and 11.5 MeV differential cross sections for the excitation of the low-lying states of the residual nuclei have been measured. The spin dependence of the integrated cross sections and angular distributions are discussed using collective models.

REACTION

$^{31}P(p,\alpha)^{28}Si$

FACILITY

Tandem Van de Graaff accelerator, University of Erlangen-Nuernberg, Nuernberg, Germany.

EXPERIMENT

The basic objective of this experiment was to examine the residual nuclei ^{27}Al and ^{23}Na in order to explore the relative influence of weak and strong coupling in this mass region. These particular nuclei can be excited by the reactions $^{30}Si(p,\alpha)^{27}Al$ and $^{26}Mg(p,\alpha)^{23}Na$, respectively. With the reactions $^{31}P(p,\alpha)^{28}Si$ and $^{27}Al(p,\alpha)^{24}Mg$ it is possible to examine the ^{28}Si and ^{24}Mg nuclei which serve as the "core nuclei" for ^{27}Al and ^{23}Na in the excited core model. So, the present investigation actually seeks indirectly to obtain additional information about the model description of ^{27}Al and ^{23}Na by comparison of cross section data for these nuclei with those of the corresponding "core nuclei".

MEASUREMENT PROCEDURES

The experimental details given in the paper are sparse, but there are references to earlier papers. The tandem Van de Graaff accelerator at the University of Erlangen-Nuernberg was used as a proton source in measurements of differential cross sections for the (p,α) reactions. This was accomplished in 100-keV steps for proton bombarding energies in the ranges 5.8 - 8.2 MeV and 10 - 11.5 MeV. The α-particles were detected with 16 surface-barrier detectors. Alpha-particle energy spectra were measured between 20° and 170° in 5° increments. The (p,α) cross sections were measured absolutely. Special care was taken to determine the integrated beam current and to measure the target thickness, but the specific details are not given in this paper [P+71].

DATA ACQUIRED

Differential cross-section excitation functions for the $^{31}P(p,\alpha)^{28}Si$ reaction were obtained over the indicated energy and angular ranges.

DATA ANALYSIS

The measured excitation-function data were used to determine differential cross sections in the c.m. system, to derive an "isotropic" contribution (based on the minimum of the angular distribution), and to find the difference between the total cross section σ_{tot} and the isotropic contribution σ_{isotr}. The procedure is discussed in a 1970 thesis by Philipp which is mentioned in the reference list. The integrated cross sections were analyzed in terms of the (2I+1) rule described by McDonald (Nuclear Physics **33**, 110, 1962). Assuming its validity, the direct-reaction contribution to the cross section can be obtained from the experimentally measured cross section. However, misleading influences coming from the (p,α) Q-values and from Ericson fluctuations which appeared in the data had to be considered first. The α-particles have considerably lower energies than the Coulomb barrier. Therefore, the cross sections were corrected with penetrability coefficients.

RESULTS AND DISCUSSION

A careful comparison was made of the cross sections for the $^{31}P(p,\alpha)^{28}Si$ reaction and $^{30}Si(p,\alpha)^{27}Al$ reaction. The sum of the excitation cross sections of the ^{27}Al quintet of levels was found to equal the cross section of the 2^+ state of ^{28}Si. This result supports the idea of an excited-core model description of the ^{27}Al nucleus. One figure in the paper pertains to the $^{31}P(p,\alpha)^{28}Si$ reaction. One table presents results related to the $^{31}P(p,\alpha)^{28}Si$ reaction.

RWK87

TITLE

Absolute Thick-target γ-Ray Yields for Elemental Analysis by 7 and 9 MeV Protons

REFERENCE

J. Raisanen, T. Witting and J. Keinonen, Nuclear Instruments and Methods in Physics Research **B28**, 199 (1987).

ABSTRACT

A systematic study of absolute thick-target γ-ray yields, produced in the bombardment of elements with Z = 3-9, 11-17, 19, 20, 22-30, 32, 39-42, 44, 46-51, 53, 62, 64, 70, 72-74, 78, 79, and 82 by 7 and 9 MeV protons, has been carried out. The most suitable γ-ray energies and absolute yields for elemental analysis are listed. Relative neutron yields are also given.

REACTIONS

^{31}P(p,p'γ),(p,n'γ),(p,γ),(p,α'γ)

FACILITY

The 5-MV tandem accelerator EGP-10-11, Accelerator Laboratory, University of Helsinki, Hameentie 100, SF-00550 Helsinki, Finland.

EXPERIMENT

Proton-induced γ-ray emission (PIGE) has been applied extensively in the analysis of light elements. Several references to earlier discussions of the technique are given in this paper. Prior to the present work, such investigations were carried out at relatively low proton energies, *i.e.*, for $E_p < 4.5$ MeV. The aims of the present work were to use higher bombarding energies than had previously been considered to examine γ-ray yields for particle channels, to extend the γ-ray yield data for the analysis of elements with Z > 20, and to determine the most suitable γ-ray energies for elemental analysis. Neutrons can be produced at these higher incident-proton energies. This could be a drawback, so it was considered important to measure the relative neutron yields also.

MEASUREMENT PROCEDURES

An incident beam of protons was supplied by the tandem accelerator EGP-10-11 at the University of Helsinki. A shielded 80-cm^3 Canberra Ge(Li) detector having an energy resolution of 1.9 keV and efficiency of 18% at E_γ = 1.33 MeV was used to detect the γ-ray radiation. In order to minimize possible angular-distribution effects, and thereby increase the accuracy of the yield measurements, this detector was placed at 55° relative to the beam, and was situated at a target-to-detector distance of 27 cm so that target-related geometric differences would be negligible. A BF_3 detector located 30 cm from the target detected the neutrons. The collected proton charge was determined accurately using a calibrated current integrator and a suppressor against secondary electrons. The proton beam current was adjusted to keep the γ-count rate constant and the dead-time correction below 1%. Most of the targets that were used in this experiment were metallic plates 1 mm thick and 1 cm x 1 cm square in shape. Powdered chemical compounds were used along with the metallic plate targets. These chemical targets were in the form of pellets 1 mm thick and 6 mm in diameter.

DATA ACQUIRED

The data acquired were in the form of Ge(Li) γ-ray spectra. Typical spectra are shown in Figs. 1-3 of the paper. The relevant γ-ray peak yields were derived from these spectra, and from these the thick-target absolute γ-ray yields per μC-sr were determined. Also the relative neutron yields from the various targets were deduced from measurements with the BF_3 proportional counter.

DATA ANALYSIS

The gamma-ray yields per unit charge were determined and these were further corrected for detector absolute efficiency, for γ-ray absorption, and for Ge(Li) detector dead time. The γ-yields from the compound targets were corrected for the stopping power so that these yields would correspond to pure-elemental targets. All γ-rays with energies < 511 keV were excluded from consideration in this investigation for several reasons: i) The absorption was significant in the target holder and Ge(Li) detector neutron shield so it would have been difficult to obtain a good efficiency calibration. ii) The peak density is high in the low-energy region. iii) The spectrum in this energy region is strongly contaminated by the Compton distribution from 511-keV annihilation γ-rays. Although equivalent neutron-yield data are given for these targets, no mention is made in the article as to how these data were analyzed.

The experimental uncertainties in the absolute γ-ray yield values are stated to be < 10%. They include the uncertainties in the stopping power (2%), γ-ray intensities (2 - 5%), and absolute γ-ray detector efficiency (5%). No uncertainties are given in this paper for the neutron yields. However, it is stated that they agree well with those reported by Elwyn *et al.* (Phys. Rev. **146**, 957, 1966). In order to investigate the possibility of systematic errors, measurements were made with various compound targets. Generally, the agreement between the values obtained with different targets were within 20%. The deviations can be explained by changes in the target stoichiometry leading to errors in stopping power.

RESULTS AND DISCUSSION

The principal results of this paper appear in Table 1 (normalized γ-ray yields) and Table 2 (normalized neutron yields). These results correspond to many different elements. However, here we are only concerned only with data corresponding to the $^{31}P(p,p'\gamma),(p,n'\gamma),(p,\gamma),(p,\alpha'\gamma)$ reactions. There is evidence that with increasing proton energy the (p,p') and (p,n) reactions become increasingly dominant over the (p,γ) reaction. This is found by comparing the present yield values with those reported earlier by this group at $E_p = 4.2$ MeV. Though it is not mentioned in this paper [RWK87], it is likely that the (p,α) reaction also will tend to dominate over the (p,γ) process at higher energies.

R+67

TITLE

Levels of ^{32}S Studied by the $^{31}P(p,\alpha_0)^{28}Si$ Reaction

REFERENCE

P.J. Riley, G.A. Lock, J.A. Rawlins and Y.M. Shin, Nuclear Physics **A96**, 641 (1967).

ABSTRACT

Differential cross sections have been measured for the $^{31}P(p,\alpha_0)^{28}Si$ reaction between $E_p = 1$ and 5.5 MeV. Seventy eight resonances were observed. Analysis of the angular distributions, measured at 36 of the lower-energy resonances, has allowed unique spin and parity assignments to be given in 18 cases. Limits have been evaluated for the reduced proton and alpha particle widths for the above 36 resonances. The observed level densities are shown to be in good agreement with those predicted from theory.

REACTION

$^{31}P(p,\alpha_0)^{28}Si$

FACILITIES

University of Texas KN Van de Graaff 4-MeV accelerator and the University of Texas EN tandem Van de Graaff accelerator, University of Texas, Austin, Texas.

EXPERIMENT

The differential cross section for the $^{31}P(p,\alpha_0)^{28}Si$ reaction has been measured between 1 and 5.5 MeV, corresponding to excitation energies in the compound nucleus ^{32}S between 9.8 and 14.2 MeV. Angular distributions of the ground-state transition α-particles have been measured at the observed resonances in order to obtain information both on the spin and parity of the resonances and on the channel-spin mixing parameters in the proton channel. Limits on the partial widths for proton and α-particle emission have been calculated from the absolute yield of α-particles. These widths, in turn, have been used to determine values for the strengths of the observed resonances. Finally, information concerning level densities and level widths for the compound states through which the (p,α) reaction can proceed have been deduced from this experiment.

MEASUREMENT PROCEDURES

Natural red phosphorus was evaporated onto thin carbon backings to create the targets used in this investigation. The target thicknesses were determined by Rutherford scattering. A 6 $\mu g/cm^2$ target was used for measurements between 1 and 3 MeV, whereas the measurements over 3 MeV proton energy employed targets that were 17 $\mu g/cm^2$ thick. Effective target thicknesses were in the range 1 to 1.5 keV. Frequent checks were made for target deterioration during the course of this experiment.

The proton-energy range from 1 to 2.8 MeV was studied using the KN 4-MeV Van de Graaff accelerator. Energy calibration was carried out using the $^{7}Li(p,n)$ neutron threshold at 1880.6 keV. The proton-beam energy spread was approximately 1 keV. The detection-equipment setup in these lower-energy measurements involved four surface barrier detectors, each with 25-mm^2 active area and 300-μm depletion depth. They were situated in a 20.3-cm-dia scattering chamber. The solid angle subtended is indicated in the article [R+67] to be approximately ± 0.0025 sr. [Note: It is not certain what the authors mean by "±" in this specification, but probably it should read ≈ 0.0025 sr instead.] Yield-curve measurements were carried out only between 1.98 and 2.10 MeV where several closely spaced resonances occur, as shown in Fig. 1 of the article. It is apparent from this figure (not the text) that these measurements were made at 90°, 110°, 130°, and 150° with the four above-mentioned detectors. Energy steps of approximately 1 keV were taken. Angular distributions were then performed at all of the known resonances between 1 and 2.8 MeV, except for those reported earlier by Clarke *et al.* [CAP59] at 1.161, 2.029, and 2.041 MeV. It should be noted that a new resonance not reported earlier by Clarke *et al.* was observed at 2.011 MeV in the present experiment. There were no differential cross sections measured in this energy region. Instead, for analysis purposes, the 90° differential cross sections of Clarke *et al.* were employed.

The EN tandem Van de Graaff accelerator was used for studies in the proton-energy range 2.8 to 5.5 MeV. The energy calibration was based on the $^{27}Al(p,n)^{27}Si$ threshold at 5797 keV. The proton-beam energy spread was approximately 2 keV. The same 20.3-cm-dia scattering chamber mentioned above was used in this work. However, there were only two detectors used in the yield-curve measurements, at 90° and 155°. Data were taken at 5-keV steps except near the resonances where steps of 2.5 keV or less were used. Angular-distribution measurements were taken at 10° intervals between 30° and 160° in the laboratory at the proton energies of the resonances, as indicated in Figs. 3 and 4 of the article [R+67].

Conventional electronics were utilized in the measurements at both accelerator facilities. Alpha-particle spectra were recorded with a TMC 400-channel analyzer. The proton-beam charge was integrated with an Eldorado Model A309A current integrator. Generally, a total of approximately 60 μC of charge was collected for each run with beam currents on the order of 0.1 μA being the norm.

DATA ACQUIRED

The recorded data consisted of α-particle spectra measured with the surface-barrier detectors at all the above-mentioned proton energies and scattering angles. Yields of the α_0 group were determined from each spectrum. These raw data were normalized to recorded incident-proton charge and converted to excitation functions and angular distributions. It should be noted that at forward angles pile-up events from proton elastic scattering introduced considerable uncertainty into the measurements. Because of this, angular distribution measurements at some resonances were not obtained at laboratory angles less than 60°.

DATA ANALYSIS

Angular distribution data were analyzed using the method described by Kuperus *et al.* (Physica **29**, 1281, 1963) using an ALGOL computer program provided by these authors and later modified for use on the University of Texas CDC-1604 computer. This program yielded the best values and an associated error matrix for the angular-distribution coefficients. It also gave corresponding values of the goodness-of-fit parameter χ^2 and of the channel-spin mixing parameters. Since both the outgoing α-particles and the final ground state of the product nucleus ^{28}Si have spin zero, the angular momentum of the compound nucleus, ^{32}S, must be carried off as orbital angular momentum of the outgoing particle. Orbital angular momentum mixing of the outgoing α-particles therefore cannot occur and, because of parity conservation, only the natural-parity compound states (0^+, 1^-, 2^+, 3^-, *etc.*) are possible. The prohibitively low probability for formation of high orbital angular momentum compound states, due to proton and α-particle barrier penetration considerations, led to the elimination of resonance spin states above 3 from consideration in the present analysis.

The resonance energies and widths were extracted directly from the yield-curve measurements. Corrections to these resonance widths were made to account for target thickness and beam spreading. The narrowest uncorrected widths were 1.6 keV, as measured with the 4-MeV accelerator at E_p = 1.014 MeV, and 3.9 keV, as measured with the tandem accelerator at E_p = 3.853 MeV. At each resonance, the observed angular distribution was used to evaluate the cross section by integration. An analysis in terms of reduced widths was performed in a manner similar to that used by Clarke *et al.* [CAP59]. The area under the resonance peak was taken to be proportional to the product, $\sigma\Gamma$, of the resonance cross section, σ, and the width, Γ. A formula for resonance strength in terms of the total, proton and α-particle widths is given in the text of this article [R+67]. Some simplifying assumptions could be made concerning these widths that enabled proton and α-particle reduced widths, γ^2, to be calculated from the individual widths. Finally, dimensionless widths, θ^2, were determined for both protons and α-particles.

RESULTS AND DISCUSSION

Of the 36 angular distributions measured, 30 were found to be symmetric about 90°. From these 30, it was possible to assign unique spin values in 18 cases with confidence. For 7 additional cases, the choice could be limited to two possibilities. For 5 other cases, spin assignments were not possible. Finally, for the 6 remaining cases the angular distributions were clearly asymmetric about 90° which indicated that the assumption of an isolated resonance was not applicable. The resonance parameters resulting from this analysis appear in Table 1 of the article [R+67]. The authors state that the absolute energies should be accurate to 10 keV, while small differences in resonance energies are correct to within 2 keV. This table also gives resonance spins and parities, widths, differential cross sections at 90°, resonance strengths, reduced widths and dimensionless widths, as defined in the text of the article. The widths are corrected for target thickness. Except for the narrowest resonances, these corrections are negligible. The errors in these widths are estimated to be about 1 keV. Between 1.014 and 3.119 MeV the 90° differential cross sections by Clarke *et al.* [CAP59] are used. For these, the relative error is assumed to be 20% and the absolute error 25%. Above 3.119 MeV proton energy, the cross sections were calculated from the measured target thickness and the absolute error is again estimated to be 25%. The authors have provided a discussion on the derivation of the total cross section, calculation of resonance strengths, and indications as to the density of levels with various spins based on counting the individual levels and comparing this information to predictions of the Ericson formula. The reader is referred to the article for further details [R+67]. The conclusion concerning level densities is that they are in reasonable agreement with what might be expected from theory except for the excessive number of 1^- levels. This large number is attributed to the fact that some of the small reduced width 2^+ and 3^- levels were not observed.

R+95

TITLE

Indirect Study of Low-energy Resonances in $^{31}P(p,\alpha)^{28}Si$ and $^{35}Cl(p,\alpha)^{32}S$

REFERENCE

J.G. Ross, J. Gorres, C. Iliadis, S. Vouzoukas, M. Wiescher, R.B. Vogelaar, S. Utku, N.P.T. Bateman, and P.D. Parker, Physical Review **C52**, No. 3, 1681 (1995).

ABSTRACT

The reaction sequences governing the reaction flow in the rp-process are important for the understanding of the energy generation and nucleosynthesis of heavy elements in hot and explosive stellar hydrogen burning. Of considerable interest are (p,α) reactions along the process path which lead to the formation of reaction cycles rather than to chains of proton capture processes and β decays. Previous direct attempts to measure the low-energy reaction cross sections for $^{31}P(p,\alpha)^{28}Si$ and $^{35}Cl(p,\alpha)^{32}S$ resulted only in upper limits for the strengths of possible low-energy resonances which may dominate the reaction rates. In this paper an indirect experimental approach is presented to study the structure of the low-energy unbound states in the compound nuclei ^{32}S and ^{36}Ar. The results allow a more accurate determination of the contributions of these low-energy levels in the (p,α) reaction channel.

REACTION

$^{31}P(^{3}He,d)^{32}S$
[This proton transfer reaction was used to study the $^{31}P(p,\gamma)$ and $^{31}P(p,\alpha)$ reactions indirectly]

FACILITY

Princeton AVF Cyclotron, Princeton University, Princeton, New Jersey.

EXPERIMENT

Proton unbound states in ^{32}S were populated in the present experiment using the (^3He,d) single-particle transfer reaction on a ^{31}P target. Previous investigations, *e.g.*, Iliadis *et al.* (Nuclear Physics **A571**, 132, 1994) showed that many proton-unbound levels of ^{32}S in the excitation range of interest are strongly populated by this process. This suggests that most of these levels have a pronounced single-particle configuration and, therefore, also should be strongly populated in resonant proton-capture reactions. The objective of the present experiment was to investigate the excitation of these proton-unbound states at relatively low excitation energy, indirectly, via the (^3He,d) reaction. This would, in principle, enable the proton, α-particle and γ-ray widths, and (p,γ) and (p,α) resonance-strength factors, to be determined, as needed to estimate the otherwise unmeasurable reaction rates for resonant-proton excitation of ^{32}S from ^{31}P targets, followed by the decay of these compound states via γ or α-particle emission.

MEASUREMENT PROCEDURES

^3He beams of 25 MeV incident energy, with an average beam intensity of 50 nA, were obtained from the Princeton AVF cyclotron. Targets of ^{31}P for the $^{31}P(^3He,d)^{32}S$ reaction measurements were prepared by vacuum evaporation of a Co_2P layer of 30 - 50 μg/cm^2 thickness onto a 40 μg/cm^2 carbon foil. An elemental Co target was also prepared by a similar method for use in background measurements.

The reaction deuterons were detected at a laboratory angle of 0° in the focal plane of the Princeton QDDD magnetic spectrometer. The energy resolution was typically about 20 keV, which was sufficient to resolve most of the levels of interest in this experiment. Protons and α-particles from the decay of the populated states were measured in coincidence with the corresponding deuteron groups using three 450 mm^2 Si surface-barrier detectors placed at the back laboratory angles of 90°, 110°, and 145° with-respect-to the incident ^3He beam direction. These detectors were positioned about 9.5 cm from the ^{31}P target. The charged-particle detectors were energy-calibrated using a source of ^{241}Am α-particles ($E_\alpha = 5.48$ MeV). The energy resolution for this experiment was typically $\approx$ 100 keV. The detector solid angles were calculated from a knowledge of the geometrical parameters. They were also determined independently through measurements of α-particle emission from the well-known reaction $^{19}F(^3He,d)^{20}Ne$. Since three charged-particle detectors were available, it was possible to make a direct measurement of the angular distributions of emitted protons and α-

particles. The experimental α-particle angular distributions were fitted using even-order Legendre polynomial expansions up to 4th order.

A 12.7 x 10.2 cm^2 NaI detector was placed at 90° in the laboratory relative to the incident ^{3}He beam, and 5.4 cm away from the ^{31}P target, in order to measure the γ-ray decay of the resonant states, *i.e.*, to measure the γ-rays in coincidence with the observed deuteron groups from the $^{31}P(^3He,d)^{32}S$ reaction. A 3-mm-thick Pb plate was position between this detector and the target to reduce the count rate of low-energy γ-rays from the target that interfered with measurement of the desired higher-energy γ-rays. The detector efficiency and absorption corrections were calculated. These calculations values were validated by comparing them with the results of a measurements using a calibrated ^{137}Cs source of 661-keV γ-rays and γ-rays from the decay of the well-known state at 9.059-MeV excitation in ^{32}S.

A typical deuteron spectrum from the $^{31}P(^3He,d)^{32}S$ reaction is shown in Fig. 4 of the article [R+95]. There were two well-resolved deuteron groups corresponding levels at 9.023- and 9.059- MeV excitation in ^{32}S that had not been observed directly in previous resonance proton-capture measurements. The corresponding particle-decay (protons and α-particles) spectra in coincidence with specific deuteron groups are shown in Fig. 5 of the article. The yield was low, but the evidence was relatively firm for proton decay from the higher excited states at 9.255 and 9.389 MeV. Also, decay into the α-particle channel was observed for the 3^- level at 9.023 MeV and the 1^- level at 9.236 MeV. Relative partial widths, Γ_p/Γ_{total} and $\Gamma_\alpha/\Gamma_{total}$, were deduced from these data.

Similar measurements were performed for γ-ray emission. That is, γ-ray spectra in coincidence with specific deuteron groups were observed. Since the γ-energy and spatial resolution capabilities of the NaI detector were limited, and the statistics were quite poor, these measurements were not very accurate. Nevertheless, it was possible to make some estimates of the relative partial widths, $\Gamma_\gamma/\Gamma_{total}$, from the data.

DATA ACQUIRED

The experimental data consisted of the following: deuteron spectra from the $^{31}P(^3He,d)^{32}S$ reaction; proton and α-particle spectra at the three laboratory angles mentioned above in coincidence with individual deuteron groups; and γ-ray spectra in the vicinity of 90° laboratory angle, also in coincidence with individual deuteron groups.

DATA ANALYSIS

The measured yields of coincident α-particles and γ-rays were used to derive relative values for the widths of the proton resonance decays, namely, Γ_α and Γ_γ. Values for the proton widths, Γ_p, which were also needed to calculate, indirectly, the desired values of resonance strength, (ωγ), for the $^{31}P(p,\gamma)$ and $^{31}P(p,\alpha)$ reactions, were obtained to an accuracy of about 40% from a DWBA analysis of single-particle transfer reactions, *e.g.*, as discussed by Kalifa *et al.* (Physical Review **C17**, 1961, 1978).

RESULTS AND DISCUSSION

The pertinent numerical results from this work are reported in Tables I and III of this paper [R+95].

S67

TITLE

Q Values Determined from Resonance Reactions and the Effects of the Atomic Electrons

REFERENCE

H.H. Staub, Proceedings of the Third International Conference on Atomic Masses, Winnipeg, Manitoba, Canada, R.C. Barber, Ed., University of Manitoba Press, 495 (1967).

ABSTRACT

The author did not provide an abstract for this paper.

REACTION

$^{31}P(p,\alpha)^{28}Si$

FACILITY

5.5-MV Van de Graaff generator, University of Zurich, Zurich, Switzerland.

EXPERIMENT

The objective of this experiment was to obtained improved Q-values from resonance reactions induced by protons and α-particles. This was accomplished by maintaining better control over the accelerator calibration and its stability, and by recognizing the influence of atomic electrons and electron excited states in the analysis of the resonance data. The experimental resolution is ascertained by measuring the narrow resonance in $^{40}A(p,\gamma)^{41}K$ at $E_p = 1101.65 \pm 0.04$ keV. The energy of the resonance at $E_p \approx 642$ keV in $^{31}P(p,\alpha)^{28}Si$ is measured in this work along with that for the $^{27}Al(p,\alpha)^{24}Mg$ resonance at $E_p \approx 1600$ keV. A distinction is made between the Q-value based only on nuclear mass considerations (Q_n) and that based on atomic masses (Q_a). Since the fundamental electron mass term cancels, the only difference in these two quantities lies in the excitation energies of the electrons in the atomic species.

MEASUREMENT PROCEDURES

A proton beam was provided by the University of Zurich 5.5-MV Van de Graaff generator. The proton beam passed through a 90° magnetic analyzer stabilized by a nuclear magnetic resonance probe. The beam was then focussed on a target. A slit system 50 cm from the magnet exit received a small portion of the beam which provided a feedback signal for controlling the voltage of the accelerator. There was both slow and fast regulation of the beam energy. Slow regulation was provided in the conventional way by a corona gap whose grid was modulated by the error signal from the slits. Fast regulation was provided by an error signal which was transmitted optically to the terminal by a glow modulator or gallium-arsenide diode and photocell system in the pressure tank of the Van de Graaff generator. This signal controlled a variable voltage source situated between the high-voltage terminal and the accelerating tube. The power supply could provide a variable voltage between +1 and -1 kV. With this arrangement the energy spread of the beam (FWHM) should be less than 100 eV at 1 MeV. To verify this, a direct observation of the excitation curve for the narrow resonance in $^{40}A(p,\gamma)$ at 1.10 MeV was performed with a 17-eV thick gaseous target. This resonance is known to have a total width of 21 eV and the full Doppler broadening for the target at STP (300°K) is 87 keV. A direct determination of the proton beam energy resolution was measured by a 180° magnet and found to be 49 eV. Combining these sources of broadening for the observed resonance in quadrature suggested a FWHM of about 100 eV. As seen from Fig. 2 in the paper [S67], the measured width was about 130 keV. This difference can be explained only in terms of an additional source of broadening due to electron excitations in the target atoms.

DATA ACQUIRED

It is relevant to the present concern that an excitation function was measured for the $^{31}P(p,\alpha)^{28}Si$ reaction in the vicinity of the 642-keV resonance (9.487-keV excitation in the compound nucleus ^{32}S).

DATA ANALYSIS

What is given in this paper [S67] is a mathematical description of the determination of the Q value. If the Q value is determined from a resonance, what is being measured is more nearly equivalent to Q_a then it is to Q_n. The total electronic binding energy needs to be known in order to derive Q_n.

RESULTS AND DISCUSSION

The analysis of data for $^{31}P(p,\alpha)^{28}Si$ yielded the following results for the resonance in question: $E_p = 642.1 \pm 0.1$ keV, $E_x = 9.487$ MeV, $E_\alpha = 2901.1 \pm 0.2$ keV, and $Q_a = 1915.8 \pm 0.2$ keV.

S83

TITLE

Effect of Excited States on Thermonuclear Reaction Rates

REFERENCE

D.G. Sargood, Australian Journal of Physics **36**, 583 (1983).

ABSTRACT

Values of the ratio of the thermonuclear reaction rate of a reaction, with target nuclei in a thermal distribution of energy states, to the reaction rate with all target nuclei in their ground states are tabulated for neutron, proton and α-particle induced reactions on the naturally occurring nuclei from ^{20}Ne to ^{70}Zn, at temperatures of 1, 2, 3.5, and 5 (x 10^9) °K. The ratios are determined from reaction rates based on statistical model cross sections.

REACTION

$^{31}P(p,\alpha)^{28}Si$

FACILITY

None. This work is an analytical study.

EXPERIMENT

None. This paper deals only with theoretical calculations of the thermonuclear reaction rates $<\sigma v>^*$ corresponding to target nuclei in a thermal distribution of energy states and corresponding reaction rates $<\sigma v>^0$ obtained with all target nuclei in their ground states. Ratios of these two rates are derived and compiled in this work.

MEASUREMENT PROCEDURES

None. In this study the cross sections are generated using statistical-model calculations.

DATA ACQUIRED

None. No experimental data were produced in this investigation, but ratios of calculated reaction rates were generated for $T_9 = 1, 2, 3.5$ and 5 (*i.e.*, stellar temperatures in units of 10^9 °K) for a large number of target isotopes and nine different reaction types, namely, (n,γ), (n,p), (n,α), (p,γ), (p,n), (p,α), (α,γ), (α,n) and (α,p).

RESULTS AND DISCUSSION

The calculated values that are obtained for these ratios are listed in Tables 1 - 4 in the article [S83]. The author states that his work demonstrates that the excited states in target nuclei play a very important role in determining thermonuclear reaction rates under stellar conditions. The most dramatic effects occur very largely for reactions such as (n,p) and (n,α) on neutron-rich isotopes and (p,n) reactions on α-particle nucleus targets for which the stellar reaction rates are very small, *i.e.*, at least two, and sometimes as many as eight, orders of magnitude smaller than other strongly competing or even dominant open reaction channels. The statistical model appears to be the only means available to calculate the ratios $<\sigma v>^*/<\sigma v>^0$ in a systematic way for a large number of target nuclei and reactions. However, the statistical model is not reliable when the level density in the compound system (target + projectile) is relatively low. Under these conditions, the reaction rates calculated using experimental data and Maxwellian temperature distributions will lead to values which differ considerably from those obtained using the statistical model. Then, application of a correction factor obtained from the present compilation may lead to misleading results and should be viewed with some skepticism. However, if the level densities are relatively high and the statistical model can be expected to yield reasonably reliable values of $<\sigma v>^0$, then the present correction factors, which are relatively insensitive to fine details of the model, can be used with reasonable confidence when applied to reaction rates based largely on experimental information.

SAN73

TITLE

Application of the Blocking Technique to Measure Lifetimes of Nuclear Levels Excited in (p,α) Resonance Reactions in P and Al

REFERENCE

R.P. Sharma, J.U. Andersen and K.O. Nielsen, Nuclear Physics **A204**, 371 (1973).

ABSTRACT

The mean lifetimes of the 9.486 and 12.19 MeV levels in ^{32}S and ^{28}Si excited in the $^{31}P(p,\alpha)^{28}Si$ and $^{27}Al(p,\alpha)^{24}Mg$ reactions, respectively, have been measured by observing the axial blocking dips (shadows) of emitted α-particles with single crystals of GaP and Al as targets. The respective lifetimes are 80 and 100 as [Note: 1 as = 1 attosecond = 10^{-18} second]. These results are in good agreement with the values deduced from the resonance yields of (p,α), (p,γ), and (α,γ) reactions, and thus provide a test of the blocking technique.

REACTION

$^{31}P(p,\alpha)^{28}Si$

FACILITY

2-MV Van de Graaff accelerator, Institute of Physics, University of Aarhus, Aarhus, Denmark.

EXPERIMENT

The blocking method has been applied to measure the lifetimes of the compound nuclei ^{32}S and ^{28}Al formed by the ^{31}P(p,α)^{28}Si and ^{27}Al(p,α)^{24}Mg, respectively. In particular, we are concerned here with a measurement on the 642-keV resonance for ^{31}P(p,α)^{28}Si, corresponding to a level at 9.486-MeV excitation in ^{32}Si. The blocking technique is basically a time-of-flight approach, and it works only if the compound nucleus formed decays by the emission of a charged particle. It is also a solid-state phenomenon which relies on the regular atomic structure found in single crystals. When the decay occurs within a distance of 10^{-9} cm from a lattice site in a crystal, the emitted particles are blocked in axial and planar directions. With increasing displacement from the lattice site, the blocking effect becomes less effective. the velocity of the compound nucleus depends on the momentum of the captured particle and will normally be in the range of 10^7 - 10^9 cm/sec. Consequently, the blocking approach offers the possibility to measure lifetimes in the range 1 - 100 as [Note: 1 as = 1 attosecond = 10^{-18} second]. Shorter and longer lifetimes are not amenable to this technique. In the case of ^{31}P(p,α)^{28}Si, at the 642-keV resonance, the level has spin/parity of 1^- and it decays by emission of a 2.1-MeV α-particle. This case of an isolated resonance with convenient particle energies offered a good example to test the method.

MEASUREMENT PROCEDURES

The article [SAN73] discusses the procedures in considerable detail. Much of the discussion centers around the manner in which the crystal structure of GaP was exploited in the experiment. A thick crystal was used. In this case, the beam energy was set slightly above the resonance energy so that the reaction would be mainly confined to a shallow depth in the crystal. A well-collimated beam of protons (0.5 mm x 0.5 mm) was provided by a 2-MV Van de Graaff accelerator. Since a relatively large proton dose was required to perform the measurement ($\approx$ 2.5 α-particles are produced for 10^{10} incident protons), and the experiment was moderately sensitive to radiation damage effects in the GaP, pains were taken to distribute the dose over the total crystal area (6 mm x 8 mm). The crystal was mounted on a goniometer so that its orientation could be changed in small increments. The two <111> axes (A and B) were oriented at 10° and 81°, respectively relative to the incident proton beam. The precise orientation of the crystal was determined in the usual way by the channeling technique, using back-scattered protons. By observing a difference in the minimum yield along the A and B directions, it was possible to estimate the lifetime of the resonance in ^{32}S. The α-particle yields were measured with plastic films (cellulose nitrate) located 15 cm from the target. They were developed in such a way as to discriminate against the overwhelming background of scattered protons (approximately 10^6 protons for each α-particle). A position-sensitive detector was used to monitor for radiation damage of the GaP crystal during this experiment. Since the path lengths along directions A and B are significantly different, any de-channeling effects that might be present could affect interpretation of the data. To check for this effect, measurements were performed at an incident proton energy of 1.53 MeV, just above the 1.51-MeV resonance. This resonance is much stronger than the 642-keV resonance and it has a much shorter lifetime ($\approx$ 0.1 as), *i.e.*, one that is too short to influence the blocking pattern.

DATA ACQUIRED

The data acquired were α-particle yields as measured with the plastic-film detectors. The difference in the blocking dips were measured and plotted. The article [SAN73] discusses the procedure in considerable detail.

DATA ANALYSIS

The formalism for analyzing the data is discussed in the article [SAN73]. The main source of error was a determination of the constant "C" which appears in Eq. (1) of the paper. The authors believe that the uncertainty is no more than 30% for the lifetime measured by this method.

RESULTS AND DISCUSSION

The present experiment yielded the result $\tau = 80 \pm 24$ as for the mean lifetime of the 9.486-MeV excited state in ^{32}S. This corresponds to a total width $\Gamma = 8.2 \pm 2.5$ eV. This result agrees quite well with the value 8 eV obtained elsewhere by a measurement of the resonance strength.

COMMENTS

This paper is related to two other references in the present collection, namely Kurup and Sharma [KS74] and Sharma *et al.* [SKP75].

SKP75

TITLE

Use of Blocking Technique for the Measurement of Ultra Short Compound Nuclear Lifetimes

REFERENCE

R.P. Sharma, M.B. Kurup and K.G. Prasad, Report BARC-799, Bhabba Atomic Research Centre, Bombay, India, 30 (1975).

ABSTRACT

Experiments have been carried out to measure the lifetime of the 9.709 MeV state in ^{32}S. This level is excited at 872.4 keV incident proton energy in the resonance reaction $^{31}P(p,\alpha)^{28}Si$. The measurements are made by using a molecular hydrogen beam in the Van de Graaff machine. As the resonance is very weak (strength ~ 6) a long exposure of 84 hours was necessary. To avoid deterioration of blocking pattern by crystal damage the beam spot has been shifted by moving the crystal after a dose of every 40 C. An analysis of the blocking pattern has enabled to put an upper limit to the life time of the 9.709 MeV state at 5 x 10^{-17} secs.

COMMENTS

This communication consists only of a short abstract. There is a relationship between this paper and an earlier communication from this group [SAN73]. It is assumed that the "strength" indicated in the abstract is in units of eV. The beam "dose" of 40 C has to be a misprint. It should be 40 μC.

SLD67

TITLE

Fluctuation Studies of the (α,p) Reaction on ^{19}F, ^{23}Na, and ^{31}P

REFERENCE

G.G. Seaman and R.B. Leachman, Physical Review **153**, No. 4, 1194 (1967).

ABSTRACT

The (α,p) reaction for many angles between 0° and 175° has been used for fluctuation studies with target nuclei ^{19}F, ^{23}Na, and ^{31}P. Incident energies were 5.2 to 8.0 MeV, 5.9 to 7.9 MeV, and 13.0 to

15.7 MeV, and the measured coherence widths were 50, 35, and 33 keV, respectively. Cross-section peaks were unusually correlated between yields at different angles and between yields to different final states for 5.2- to 5.6-MeV alpha-particle energy on ^{19}F, and so only data above 5.6 MeV were analyzed for fluctuations for this target. The resulting sample sizes in the analyses were then 17, 20, and 27, respectively. Calculations of the effective number of sets of angular-momentum projections damping the fluctuations in the cross sections were used at all angles to determine the additional damping that results from the fraction of direct reactions. For the most forward angles, 0° and 30°, the fraction of direct reactions was generally found to be less than ½ for the ground-state reactions and about 0.6 for the first-excited-state reactions. Even though the data were analyzed for the whole span of energies measured, the modest sample sizes available in these studies resulted in large uncertainties in determining these fractions of direct reactions. Nevertheless, the measured cross sections were in qualitative agreement with both distorted-wave Born-approximation calculations of the direct-reaction cross sections and Hauser-Feshbach calculations of the compound-nucleus cross sections.

COMMENTS

This reference is not directly relevant to present concerns. However, it does give information on the experimental apparatus and procedures that were used in later studies of the $^{31}P(p,\alpha)^{28}Si$ reaction. This may be of interest to some readers.

SSB74

TITLE

Statistical Analysis of the Energy Dependence of the $^{12}C + {}^{12}C$ Cross Sections

REFERENCE

D. Shapira, R.G. Stokstad, and D.A. Bromley, Physical Review **C10**, No. 3, 1063 (1974).

ABSTRACT

A statistical analysis has been made of the narrow structure appearing in the excitation functions for $^{12}C + {}^{12}C$ induced interactions for elastic scattering ($13.5 \leq E_{c.m.} \leq 37.5$ MeV), inelastic scattering

($20 \le E_{c.m.} \le 30$ MeV), and α-particle production ($16 \le E_{c.m.} \le 21$ MeV). Average fluctuation widths, strengths and cross correlations predicted by the statistical models of nuclei and of nuclear reactions are compared with those obtained from the analysis of suitably reduced experimental data. Good agreement is found. The effects of gross structure, possible structure of intermediate width, and a small ratio of level width to spacing (Γ/D) on the analysis of the narrow structure were studied using synthetic excitation functions. Appropriate correction factors were obtained in this way for application to parameters extracted directly from the reduced data. The results of the studies with synthetic excitation functions support the validity of the present statistical analysis. Compound processes are found to contribute up to ~ 20% of the measured elastic scattering cross section at 90° c.m. New experimental results reported herein for $^{12}C(^{12}C,\alpha)^{20}Ne^*$ reactions also suggest a large direct component, in contrast to earlier measurements on this reaction at lower energies. Hauser-Feshbach predictions of absolute compound cross sections show over-all good agreement with the average fluctuating cross sections deduced from the experimental data. It is concluded that the structure with widths ~ 0.3 MeV observed in the experimental excitation functions studied here is of statistical origin, and that the statistical model can also explain the occasional structural features with individual widths up to ~ 0.8 MeV. Apart from the gross structure associated with potential scattering, no evidence is found in the elastic scattering data for structure requiring nonstatistical mechanisms for its explanation.

COMMENTS

This paper is of no direct interest in the present context. However, the methodology discussed therein is referred to in Ref. BN80 (see above) and, with some extensions, it has been applied there in the analysis of data for the $^{31}P(p,\alpha)^{28}Si$ reaction. Consequently, the present reference [SSB74] may be of some interest to the reader.

VKH68

TITLE

Determination of the Level Width and Density of ^{32}S Between 17 and 21 MeV Excitation Energy

REFERENCE

H.K. Vonach, A.A. Katsanos and J.R. Huizenga, Nuclear Physics **A122**, 465 (1968).

ABSTRACT

Excitation functions of the reactions $^{31}P(p,\alpha_0)^{28}Si$ and $^{31}P(p,\alpha_1)^{28}Si$ were measured with high resolution (< 5 keV) at 7 angles in 10-keV steps for bombarding energies of 8.37 to 9.00 and 10.00 to 11.77 MeV. Auto-correlation functions were calculated from the excitation functions. From these auto-correlation functions, average widths of the compound states of ^{32}S were determined to be 38 ± 5, 47 ± 4 and 45 ± 5 keV for excitation energies of 18.1, 19.8 and 20.7 MeV, respectively. These widths are compared with statistical model calculations in which level densities of the Fermi-gas type are used. Good agreement between experiment and theory is obtained for level-density parameters which give a fair description of the known low-energy level densities of the nuclei which enter the calculations.

REACTIONS

$^{31}P(p,\alpha_0)^{28}Si$ and $^{31}P(p,\alpha_1)^{28}Si$

FACILITY

Tandem Van de Graaff accelerator, Argonne National Laboratory, Argonne, Illinois, U.S.A.

EXPERIMENT

High-resolution excitation functions of nuclear reactions to isolated final states show strong, irregular fluctuations when the excitation energy is sufficiently high (Ericson fluctuations). This is indicative that a compound nucleus is formed in a region of strongly overlapping energy levels. According to the statistical theory of nuclear reactions, it is possible to determine the average level widths Γ from statistical analyses of these excitation functions, and to calculate level densities from experimentally determined widths. The present investigation for $^{31}P(p,\alpha_0)^{28}Si$ and $^{31}P(p,\alpha_1)^{28}Si$ was undertaken as a contribution to the study of mass and energy dependence of the level width Γ.

MEASUREMENT PROCEDURES

The Argonne Tandem Van de Graaff accelerator supplied proton beams in the energy intervals 8.37 to 9.00 MeV and 10.00 to 11.77 MeV in 10 keV steps. The protons impinged on a phosphorus target of approximately 25μg/cm² thickness prepared on 100μg/cm² carbon backing. Targets were prepared using the ANL mass separator. The entrance and exit slits of the beam analyzing magnet were set at 0.9 mm for the experiment. The radius of curvature of this magnet was 86 cm. The energy resolution of the proton beam was estimated from experiments with the ANL broad-range, single-gap magnetic spectrograph. Based on an analysis of the aberration of the spectrograph, and observed widths of peaks for inelastic proton scattering in the 6 to 8 MeV range, it was determined that the resolution of the beam was on the order of or better than 5 keV for proton bombarding energies of approximately 10 MeV.

The emitted α-particles were detected by surface-barrier solid-state detectors in a 45-cm scattering chamber. Silicon N-type detectors were used, with specific resistivities of 600 to 2000 ohm-cm and active areas of about 50 mm^2. In order to discriminate against protons, these detectors were biased to just stop the ground-state transition α-particles (α_0). Deuterons and tritons were energetically prohibited due to large negative Q-values of the producing reactions. Collimators of 0.63-cm dia were placed in front of the detectors, and they were covered with 100 $\mu g/cm^2$ Ni foil to stop low-energy electrons. These detectors were placed in the reaction plane; each detector subtended an angle of 7°.

DATA ACQUIRED

Excitation functions for decay of the compound nucleus ^{32}S by α-particle emission to the ground (0^+) and first-excited (2^+) levels in the residual nucleus ^{28}Si were measured in 10 keV steps for two proton energy regions. Measurements were made in the region 8.37 to 9.00 MeV at laboratory angles 30°, 60°, 90°, 120°, 150°, 170° and 175°, and in the region 10.00 to 11.77 MeV at 39°, 69°, 81°, 111°, 141°, 161° and 175°. In a third experiment, measurements of the excitation functions were repeated in the energy region 10.00 to 10.50 MeV. The average level widths were determined from these excitation function data; since more than one energy region was considered, the energy dependence of the level width was also examined.

DATA ANALYSIS

The data analysis procedures are described in Ref. DA68 so the discussion in the present article [VKH68] is minimal. For purposes of analysis, the measured excitation functions were subdivided into the following three regions: 8.37 - 9.00 MeV, 10.0 - 10.90 MeV, and 10.90 - 11.77 MeV. This led to the generation of 42 different autocorrelation functions. The autocorrelation function is derived from the excitation-function data for a particular energy interval according to Eq. (1) in the paper. The average cross sections were determined by averaging the measured high-resolution cross sections over energy intervals, which were broad compared to the average resonance width Γ. The theoretical formalism of Ericson (Annals of Physics **23**, 390, 1963) predicts that the autocorrelation function should be a Lorentzian function with half width Γ. This value Γ is exactly equal to the average resonance width under certain simplifying conditions which are reasonably well fulfilled by the present data, *i.e.*, if the finite-range effects are neglected. The relationship between the average level width of highly excited nuclei and the level density can be derived from statistical theory. This is the subject of Section 4.2 of the present article [VKH68]. Reference is made in this discussion to four models of level density: constant temperature, shifted Fermi-gas, back-shifted Fermi gas, and Gilbert-Cameron.

RESULTS AND DISCUSSION

The average resonance widths as a function of angle and energy interval are given in Fig. 1 of the article [VKH68]. A comparison between the experimental average resonance widths and values calculated from statistical model theory for several level-density representations is presented in Fig. 6 of the article. Use was made in the calculations of the shifted and back-shifted Fermi-gas models as well as the Gilbert-Cameron representation. Two important conclusions were drawn from this analysis: The first was that the J-dependence of the level width in the range J = 1 to 4 is rather weak. This result shows that the exact averaging procedure is not critical for the calculation of the average width Γ. The second conclusion, which is apparent from Figure 7 of the paper, is that the proton width Γ_p is the largest contributor to the total level width and therefore Γ is essentially determined by the level densities of the target nucleus ^{31}P and the compound nucleus ^{32}S. The Gilbert-Cameron model appears to give an adequate description of the nuclear level density up to at least 20 MeV for the nucleus ^{32}S. It also predicts values of Γ which are in reasonable agreement with the experiment except at high energies. The back-shifted Fermi-gas model also does a good job of describing Γ at low energies but is poor at high energies. These two models give, simultaneously, an adequate description of the level density in the 0 - 10 MeV range, whereas such agreement cannot be obtained for the conventional shifted Fermi-gas model. All models predict a large, unexplained increase of width Γ in the 20 - 30 MeV range.

COMMENTS

This paper contains many useful figures and graphs as well as numerical data. There is also a detailed description of the mathematical formalism used to relate the level densities and level widths.

VLT67

TITLE

Niveaux de ^{32}S Observes dans les Reactions $^{31}P(p,\alpha_0)^{28}Si$ et $^{28}Si(\alpha,\gamma)^{32}S$

REFERENCE

J. Vernotte, M. Langevin and F. Takeutchi, Nuclear Physics **A102**, 449 (1967). [In French].

ABSTRACT

Eight resonance levels of ^{32}S were observed through the reactions $^{31}P(p,\alpha_0)^{28}Si$ (E_p = 1.4 - 1.9 MeV) and $^{28}Si(\alpha,\gamma)^{32}S$ (E_α = 3.7 - 4.3 MeV). The spins and parities of these levels were determined by angular correlation measurements. The resonance strengths are reported.

REACTION

$^{31}P(p,\alpha_0)^{28}Si$

FACILITY

4-MeV Van de Graaff accelerator, Laboratoire Joliot-Curie, Institut de Physique Nucleaire, Orsay, France.

EXPERIMENT

The reaction $^{31}P(p,\alpha_0)^{28}Si$ has been studied in the proton-energy range 1.4 to 1.9 MeV. Only natural parity states, *i.e.*, those with parity $\pi = (-1)^J$ are observed in this reaction because of parity conservation. The same states can be excited in the inverse reaction $^{28}Si(\alpha,\gamma)^{32}S$. For this reason, both reactions have been investigated in order to obtain unambiguous information on the spins and parities of the observed levels in the compound nucleus ^{32}S. The present summary focuses only on those aspects of the work dealing with the (p,α) reaction. In the energy region studied, all the observed levels had been reported previously by Clarke *et al.* [CAP59]. However, angular distributions for the α-particle groups were not measured in the earlier work. The present investigation aimed to make up for this deficiency. Thus, the present experiment measured excitation functions and angular distributions (presumably on the resonances) for the ground-state α-particle transition over the indicated energy range of incident protons. This work provided resonance energies, total widths, possible spins and parities, resonance strengths and proton widths corresponding to the two possible entrance channel spins, namely, s = 0 and 1.

MEASUREMENT PROCEDURES

This paper [VLT67] contains relatively few details on the experimental procedure. The authors refer to an earlier paper by Vernotte *et al.* (J. de Physique **27**, 773, 1966) for more complete descriptions of the apparatus and procedures. Proton beams in the energy range 1.4 to 1.9 MeV were provided by a 4-MeV Van de Graaff accelerator. The beam was analyzed with a 90° magnet. The slits were set so that an energy resolution $\Delta E/E \approx 5 \times 10^{-4}$ was obtained. The energy calibration was checked by observing the 1346.6 ± 1.1 and 1373.5 ± 0.6 keV resonances in the $^{19}F(p,\alpha\gamma)^{16}O$ reaction and the threshold of the reaction $^{7}Li(p,n)^{7}Be$ at 1880.36 ± 0.22 MeV. Targets of Zn_3P_2 were prepared by evaporation onto 10 to 20 μg/cm² carbon backings. Three target thickness were used of approximately 190, 25 and 6 μg/cm², respectively. The target stoichiometry was monitored by observing the Rutherford scattering of protons by the target. The scattering chamber contained four surface-barrier detectors which were used to measure the emitted α-particles. Three of these detectors were assembled in a group spaced 25° apart. This array could be positioned at diverse angles. The fourth detector was located at 150°, and it served as a fixed monitor. The solid angle of these detectors was 6×10^{-4} sr. From kinematics, it was determined that the α-particle energies were roughly twice those of the elastically scattered protons. In order to avoid swamping the detectors with pile-up pulses from protons, it was necessary to limit the beam current to 0.05 to 0.1 μA. For the same reason, the angular distribution measurements were confined to the range 85° to 170°. This was considered to be adequate since the angular distributions are symmetric about 90°.

DATA ACQUIRED

The paper [VLT67] is not very clear regarding the specific data acquired. It is presumed that it consisted of excitation functions for emission of ground-state transition α-particles measured in the range E_p = 1.4 to 1.9 MeV. An earlier study had been performed with proton-energy steps of about 5 keV and a 70 μg/cm² target . As a result, this work had failed to observe that the resonance identified at 1468 ± 7 keV was actually a doublet. In the present study, 6 μg/cm² (thin) and 190 μg/cm² (thick) targets, as well as 0.5-keV proton-energy increments, were used to reveal the doublet; it consisted of resonances at 1470 and 1476 keV. Clarke *et al.* [CAP59] had failed to see the higher-energy member of the doublet because of an unfortunate choice of emission angle (90°) where the lower-energy member is five times stronger than its companion resonance.

DATA ANALYSIS

There is a very little discussion of the data analysis procedures in this paper [VLT67]. Presumably more details can be found in the earlier paper mentioned above.

RESULTS AND DISCUSSION

The results pertinent to the present compilation appear in Tables 1 and 2, and in Fig. 2 of Ref. VLT67. The resonance incident-proton and compound-nucleus excitation energies are specified to an accuracy of ± 6 keV. Values for the resonance total widths Γ were obtained directly from the excitation functions measured with thin targets. In some cases these were presented as upper-bound values. Resonance strengths, expressed as $S_{\alpha 0} = (2J+1)\Gamma_p\Gamma_{\alpha 0}/\Gamma$, were also derived from the data. Uncertainties in these resonance strengths were estimated to be on the order of 20%. Analysis of the angular-distribution data indicated the possible spin and parity assignments for the observed resonances. In particular, estimates could be made of the proton widths Γ_{ps} corresponding to the two possible assignments for the entrance channel spin s, namely s = 0 or 1.

V+73a

TITLE

Investigation of the Lowest T = 2 State of ^{32}S in the ^{31}P + p Reactions

REFERENCE

J. Vernotte, S. Gales, M. Langevin, and J.M. Maison, Physical Review **C8**, No. 1, 178 (1973).

ABSTRACT

Two resonances have been observed at 3.283 ± 0.003 and 3.289 ± 0.003 MeV in the $^{31}P(p,\gamma)^{32}S$ reaction. The corresponding excitation energies are 12.044 ± 0.004 and 12.050 ± 0.004 MeV. The γ-decay schemes and resonance strengths have been measured. On the basis of γ-ray angular-distribution and proton elastic scattering measurements the 12.044-MeV level has been assigned J^π,T = 4^-,1. The 12.050-MeV level has been assigned J = 0 from γ-ray angular-distribution and correlation measurements. A proton elastic scattering experiment has yielded an upper limit of 230 eV for the total width of the 12.050 MeV level. This state is shown to be the lowest J^π,T = 0^+,2 state in ^{32}S.

REACTION

$^{31}P(p,\alpha_0)^{28}Si$ and $^{31}P(p,\alpha_1\gamma)^{28}Si$

FACILITY

4-MV Van de Graaff accelerator, Institut de Physique Nucleaire, Orsay, France.

EXPERIMENT

It is interesting to look for the possibility of observing T = 2 states as sharp resonances in isospin-forbidden reactions even though it is experimentally difficult to do so among a high density of isospin-allowed resonances. Such an approach is capable of providing a precise determination of the excitation energy in the compound nucleus. The purpose of the present work was to study the properties of the 12.050-MeV state in ^{32}S by measurements on reactions associated with $^{31}P + p$, namely, $^{31}P(p,\gamma)^{32}S$, $^{31}P(p,p_0)^{31}P$, $^{31}P(p,p'\gamma)^{31}P$, and $^{31}P(p,\alpha_1\gamma)^{28}Si$. The major portion of this work, and the associated article describing it [V+73a], concerns proton capture, proton elastic scattering, and proton inelastic scattering. This summary focuses mainly on those aspects of the experiment involving the decay of ^{32}S by emission of α-particles.

MEASUREMENT PROCEDURES

Proton beams were obtained from the 4-MV Van de Graaff accelerator of the Institut de Physique Nucleaire. They were momentum analyzed by a 90° magnet which was calibrated using the $^{13}C(p,n)^{13}N$ threshold at 3.2357 ± 0.0007 MeV. The beam-energy resolution was measured at the 1.7476 ± 0.0009-MeV sharp resonance of the $^{13}C(p,\gamma)^{14}N$ reaction; it was found to be in the range $(2.5 - 3.0) \times 10^{-4}$. The proton beam was stopped 150 cm beyond the target in a graphite-lined Faraday cup. The targets were produced by evaporation of red phosphorus onto a 10 - 20-μg/cm² self-supporting carbon foil. The target thicknesses were 9.0 ± 0.3 μg/cm² for the charged-particle measurements and 11 ± 2 μg/cm² for the yield-curve measurements of γ-rays from the reactions $^{31}P(p,\gamma)^{32}S$, $^{31}P(p,p_1\gamma)^{31}P$, $^{31}P(p,p_2\gamma)^{31}P$, and $^{31}P(p,\alpha_1\gamma)^{28}Si$. The target thicknesses were determined by low-energy Rutherford scattering of protons. The beam current was limited to 300 nA to insure that these targets would sustain no damage.

The charged particles were detected by three surface-barrier detectors subtending solid angles of 0.55×10^{-3} sr and mounted in a 50-cm-dia scattering chamber. All the events from the detector at the farthest back angle were analyzed in order to observe every particle-decay channel for ^{32}S. To minimize dead time, only the proton-elastic-scattering events were selected for the other detectors. All the charged-particle spectra were recorded with a 4096-channel analyzer.

The γ-ray yield curves were measured in the range E_p = 3.27 to 3.30 MeV. These γ-rays were detected with a NaI(Tl) spectrometer located at 55° with respect to the incident proton beam and 6 cm away from the target. Single-channel analyzers were utilized to set windows on the photopeaks of the 1.27-, 1.78- and 2.23-MeV γ-rays associated with the $(p,p_1\gamma)$, $(p,\alpha_1\gamma)$, and $(p,p_2\gamma)$ reactions, respectively. A fourth single-channel analyzer was set to measure all γ-ray events between 3.5 and 12.5 MeV in order to obtain the yield curve for the (p,γ) reaction. Detailed studies of the γ-rays from the (p,γ) reaction were performed with a Ge(Li) detector. This aspect does not concern us here.

DATA ACQUIRED

The only data relevant to the present interest were α-particle spectra recorded with a solid-state detector at 160° and a yield curve for the 1.78-MeV γ-ray from the reaction $^{31}P(p,\alpha_1\gamma)^{28}Si$.

DATA ANALYSIS

Few details on the analysis of these data appear in the paper [V+73a]. The yield of 1.78-MeV γ-rays from $^{31}P(p,\alpha_1\gamma)$ was not corrected for Compton events due to the 2.23 MeV γ-ray from $^{31}P(p,p_2\gamma)$.

RESULTS AND DISCUSSION

There is very limited information about $^{31}P(p,\alpha_1\gamma)^{28}Si$ and $^{31}P(p,\alpha_0)^{28}Si$ reactions given in the article [V+73a], and what is provided in Table III for the properties of the particle decay of the 12.044- and 12.050-MeV levels in ^{32}S is attributed to other sources. It is stated in the paper that the yield curve was measured for the (p,α_0) reaction at 160° but not for the (p,α_1) reaction because in the latter case the α_1 group was about the same energy as the protons from $^{16}O(p,p)^{16}O$. The decreasing α_0 yield is due to a broad resonance of the $^{31}P(p,\alpha_0)^{28}Si$ reaction at 3.254 MeV. No resonance was observed in the (p,α_0) and $(p,\alpha_1\gamma)$ reactions in the present work; this contradicted the results reported earlier by McGrath *et al.* (Physical Review **C1**, 184, 1970). There is a discussion in the paper concerning possible reasons why the resonance in question was missed in the α-particle emission data from the present experiment. The most likely explanation is that it was too narrow to be distinguished from the background of events due to the stronger, lower-energy resonance at 12.050-MeV excitation in ^{32}S. No EXFOR file has been prepared for this reference since it provided no original data pertinent to the decay of ^{32}S by α-particle emission.

V+73b

TITLE

Recherche de Resonances Isobariques Analogues dans ^{32}S au Moyen des Reactions $^{31}P(p,\gamma)^{32}S$, $^{31}P(p,p)^{31}P$ et $^{31}P(p,\alpha_0)^{28}Si$

REFERENCE

J. Vernotte, S. Gales, M. Langevin and J.M. Maison, Nuclear Physics **A212**, 493 (1973). [In French].

ABSTRACT

Fourteen resonance levels have been observed in a study of the $^{31}P(p,\gamma)^{32}S$, $^{31}P(p,p)^{31}P$ and $^{31}P(p,\alpha_0)^{28}Si$ reactions in the proton energy range E_p = 1240 - 1600 keV. Resonance strengths have been determined for thirteen resonances of the $^{31}P(p,\gamma)^{32}S$ reaction. The γ-ray decay schemes of ten resonances have been studied by means of a Ge(Li) detector. Spin values of resonance levels and of some bound levels have been obtained or confirmed by γ-ray angular distribution measurements done at seven resonances. For the thirteen resonances of the $^{31}P(p,p)^{31}P$ reaction the proton orbital angular momenta have been determined. By combining the information from the three reactions, spins, parities, total and partial widths have been obtained for twelve resonance levels. Strong M1 transitions have been observed at the E_p = 1247, 1402, 1437, 1555 and 1581 keV resonances. Two T-mixed doublets are identified at E_p = 1247 and 1472 keV, $J^\pi = 2^-$, and at E_p = 1402 and 1469 keV, $J^\pi = 3^-$. The resonance levels at E_p = 1437 and 1581 keV may be components of a third almost completely mixed doublet. The E_p = 1555 keV resonance level has been assigned T = 1. The E_p = 1411 keV, $J^\pi = 1^+$, resonance level has been identified with a level previously observed in β^+ decay of ^{32}Cl. Strong E2 transitions similar to those observed in some other doubly even s-d shell nuclei have been observed between odd-parity levels of ^{32}S.

REACTIONS

$^{31}P(p,\gamma)^{32}S$, $^{31}P(p,p)^{31}P$, and $^{31}P(p,\alpha_0)^{28}Si$

FACILITY

4-MV Van de Graaff accelerator, Institut de Physique Nucleaire, Orsay, France.

EXPERIMENT

The present experiment was undertaken with the objective of performing a careful study of the resonances in $^{31}P + p$ in the range E_p = 1.24 - 1.60 MeV, corresponding to excited levels in the compound nucleus ^{32}S, by observing the open decay channels via the $^{31}P(p,\gamma)^{32}S$, $^{31}P(p,p)^{31}P$ and $^{31}P(p,\alpha_0)^{28}Si$ reactions. Spectra of emitted protons and α-particles were measured simultaneously and these data were used to obtain information on partial widths for resonances where decay by α-particle emission was allowed by energetics, parity conservation, and isospin conservation. Values of the resonance strength for proton capture and particle-emission were deduced from the data.

MEASUREMENT PROCEDURES

Proton beams from the 4-MV Van de Graaff at Orsay were focused to a spot 2 mm in diameter on targets of red phosphorus which had been prepared by evaporation onto foils of carbon 15 $\mu g/cm^2$ thick. These targets were oriented at 90° relative to the incident proton beam at the center of a 50-cm-dia scattering chamber. The proton beam was stopped in a Faraday cage lined with graphite at a distance of 150 cm from the target. The beam resolution was determined to be in the range (2.5 - 3.0) x 10^{-4} from measurements near the sharp resonance at E_p = 1747.6 ± 0.9 keV in the reaction $^{13}C(p,\gamma)^{14}N$. This resolution was obtained by adjusting the optics at the entrance to the analyzing magnet. Two target thicknesses were employed, namely, 2.1 ± 0.1 and 9.0 ± 0.3 $\mu g/cm^2$. The target thickness was measured by Rutherford scattering of protons at low energy in a region devoid of resonances. These targets were found to sustain beam currents of $\leq$ 0.3 μA for several days of operation without damage.

The charged particles (protons and α-particles) were measured with three surface-barrier detectors. Each of them subtended a solid angle of 0.55 x 10^{-3} sr. They were placed in the laboratory angle range 124° to 160° relative to the incident-beam direction. Conventional electronics were used with these detectors, and the spectra were recorded with an appropriately multiplexed 4096-channel analyzer.

DATA ACQUIRED

Spectra of protons and α-particles emitted by the (p,p) and (p,α_0) reactions were recorded in unspecified proton-energy increments over the range 1240 - 1600 keV. Four of the fourteen observed resonances exhibited observable α-particle emission strength. These were at E_p = 1402, 1469, 1474 and 1515 keV.

DATA ANALYSIS

Virtually no details are given in this paper [V+73b] on the data analysis procedures associated with the α-particle measurements.

RESULTS AND DISCUSSION

Values of α-particle width and resonance strengths associated with decay by α-particle emission are given in Tables 6 and 7 of the article. Supporting evidence for the existence of these specific resonances was also obtained from the $^{31}P(p,\gamma)^{32}S$ and $^{31}P(p,p)^{31}P$ reactions as well as from the $^{28}Si(\alpha,\gamma)^{32}S$ inverse reaction. These combined data allowed a precise determination of the spins and parities of the compound-nucleus levels in ^{32}S, and calculation of the pertinent resonance strength $S_{\alpha 0} = (2J+1)\Gamma_p\Gamma_{\alpha 0}/\Gamma$ from the total width and proton and α-particle partial widths.

W+88

TITLE

A Microcomputer-based System for Measuring Excitation Functions with Good Energy Resolution

REFERENCE

C.R. Westerfeldt, R.O. Nelson, E.G. Bilpuch, and G.E. Mitchell, Nuclear Instruments and Methods in Physics Research **A270**, 467 (1988).

ABSTRACT

A system is described which removes time-dependent energy fluctuations from a proton beam incident on solid targets. Operating under microcomputer control, this system permits automatic measurement of extended (several MeV) excitation functions with very good energy resolution (~ 300 eV FWHM) for thin solid targets. The long-term energy stability of this system has been measured to be 0.0003% at $E_p = 2.0$ MeV, with a short-term energy spread of $\sigma = 5$ eV.

COMMENTS

This article is not directly relevant to the $^{31}P(p,\alpha)^{28}Si$ reaction. However, it describes part of the experimental apparatus used in relevant measurements described in Refs. F87 and F+88 (see above).

W+92

TITLE

Isospin-nonconserving Particle Decays in Light Nuclei

REFERENCE

J.F. Wilkerson, T.M. Mooney, R.E. Fauber, T.B. Clegg, H.J. Karwowski, E.J. Ludwig, and W.J. Thompson, Nuclear Physics **A549**, 223 (1992).

ABSTRACT

Isospin-nonconserving (INC) proton decays of nineteen T = 3/2 states in light nuclei ($13 \leq A \leq 37$) and alpha decays of three T = 2 states in $24 \leq A \leq 32$ have been measured using high-energy-resolution beams (FWHM about 600 eV) to produce excitation functions near these states for (p,p), (p,α) and (α,α) reactions. Resonances were analyzed using a helicity-amplitude formalism. The widths agree qualitatively with recent shell-model calculations that include isospin dependencies in the hadronic part of the nucleon-nucleon force.

REACTION

$^{31}P(p,\alpha)^{28}Si$

FACILITY

FN Tandem Van de Graaff, Triangle Universities Nuclear Laboratory (TUNL), Durham, North Carolina, U.S.A.

EXPERIMENT

The objective of this experiment was to investigate isospin-nonconserving (INC) nuclear reactions by searching for very narrow resonances in the proton and α-particle decay channels of the compound nucleus ^{32}S. Reactions on other targets were investigated, but this is not of any concern in the present context. Excitation functions for the yield of charged particles were measured with very high resolution (≤ 1 keV) in the vicinity of suspected INC resonances. These measurements of excitation functions proceeded in the ordinary manner by incrementing the proton energy in modest steps (≤ a few keV) controlled by an analyzing magnet. When a resonance was located, much finer steps (typically ≈ 200 eV) were taken over a 10 - 20 keV range by fixing the magnetic field of the beam momentum analyzer and ramping the target voltage in small increments. Both polarized and unpolarized proton beams were used. The data of concern here were acquired with unpolarized beams. Values for resonance total width, α-particle width, proton width, and INC amplitudes were acquired from an analysis of the data.

MEASUREMENT PROCEDURES

Locating very narrow, weak INC resonances in a sea of broader isospin-conserving resonances presented challenging experimental problems. However, the facility at TUNL was designed to perform such experiments. Unpolarized proton beams of typical intensity 1 μA and FWHM 500 eV were obtained from a direct-extraction ion source at the TUNL Tandem Van de Graaff accelerator. Electron stripping in the tandem terminal was performed in gas, thus improving the energy resolution over what could be obtained with a foil stripper. Precise control over the beam energy and resolution was obtained by a combination of momentum analysis with a conventional magnet, steering magnets, narrow slits, and a target-voltage ramp system. The latter system consisted of an isolated target attached to a very stable, adjustable voltage supply with a range of 10 - 20 kV. Adjustment in target voltage, for a fixed magnetic field, could be made in steps as small as 200 eV. The precise energy of the beam seen through the above-mentioned slit system was determined by means of a nuclear resonance. For very narrow resonances, this also provided a measure of the effective beam-energy resolution. An energy reproducibility of the accelerator plus analyzing-magnet system of ± 2 keV was achieved by systematically recycling the analyzing magnets through their hysteresis cycles, and by measuring the excitation functions with unidirectional steps (increases) of the magnet current. Lastly, the beam current was collected and measured in an electron-suppressed Faraday cup downstream from the target assembly.

Targets of ^{31}P were prepared by vacuum evaporation of red phosphorus onto thin (3 - 10 μg/cm^2) carbon backings. These targets were placed at the center of a 61-cm dia. scattering chamber. Various processes which contributed to the effective resolution in measuring very narrow resonance widths had to be considered. Among these were proton and α-particle straggling in the targets, thermal broadening, lattice vibrations, and atomic-excitation effects. These diverse effects were modeled with computer programs, and the results of such analyses were used to estimate the effective overall resolution of the measurement procedure. Their combination led to an overall resolution of the order of 1 keV, which is comparable to the total widths typical of INC levels. Considerable care was therefore required in the acquisition, storage and analysis of data on these resonances in order to be able to obtain reliable results. It was estimated that the overall uncertainty in normalization of absolute cross sections was less than 10% due to target-thickness and current-integration errors.

Outgoing protons and α-particles were detected in silicon surface-barrier detectors which subtended angles of ± 1° in the scattering plane. From four to eight angles were measured simultaneously. Standard electronic components were used to shape the signals acquired from these detectors; data were recorded using a VAX 11/780 computer.

DATA ACQUIRED

The acquired data consisted of excitation functions for protons and α-particles emitted in the decay of the compound nucleus ^{32}S. Measurements were performed at several laboratory angles.

DATA ANALYSIS

The analysis of the excitation-function data required special care for the very narrow INC resonance decays, for two main reasons: First, the excitation energies in the compound nucleus ^{32}S were low enough so that no simple and reliable description of the off-resonance scattering could be found; furthermore, INC-resonance decays into the proton and α-particle channels are often small, and these resonances are usually revealed by interference patterns. Consequently, it was necessary to treat non-resonance amplitudes, as well as the cross sections off-resonance, simultaneously. A helicity formalism was used for describing these parameters. Second, the shapes in the excitation functions which revealed existence of these resonances were significantly broadened and distorted from their natural shapes by the various effects which influence the resolution, as mentioned above. The data analysis procedures actually used were rather complicated. They are discussed extensively in the article [W+92] so the interested reader is referred to that source for all details.

RESULTS AND DISCUSSION

The numerical results from this investigation appear in Tables 1 and 2 of the article [W+92]. The use of a model-independent helicity-amplitude analysis technique, proper accounting for energy-resolution effects, and the development of sophisticated parameter-search methods, resulted in relatively accurate determinations of total, proton and α-particle widths for INC levels in several nuclear reactions, including $^{31}P(p,\alpha)^{28}Si$.

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3. Resonance Properties and Concluding Remarks

Most of the relevant numerical information provided in the references assembled for the present compilation can be categorized as follows: i) resonance energies and strengths for the $^{31}P(p,\alpha)^{28}Si$ reaction; ii) properties of levels in the compound nucleus ^{32}S; iii) features of α-particle transitions associated with the decay of excited levels in ^{32}S (in most instances only those transitions involving α-particle transitions to the ^{28}Si ground state, α_0, or first-excited state, α_1, are considered); iv) data of an engineering nature which can be used in applications of the $^{31}P(p,\alpha)^{28}Si$ reaction for the assay of phosphorus in materials, *e.g.*, the excitation function for relative thick-target production of the 1.779-MeV gamma ray associated with decay of the first-excited state of ^{28}Si.

In astrophysics, the main concern is the determination of reaction rates for typical stellar environments in which there exist Maxwellian distributions of reactant energies. The present investigation deals mainly with reaction processes that proceed through resonances in the compound nucleus ^{32}S. At lower excitation energies, these resonances are mainly isolated ones, although the density of levels remains relatively large. At higher excitation energies the resonances are largely unresolved and the average width exceeds the average level spacing. Under these conditions, the reaction processes exhibit strong statistical fluctuations (Ericson fluctuations) and, therefore, analysis of these data must proceed differently from the case of discrete resonances. Since the density of discrete levels in ^{32}S is reasonably high in the domain of interest for astrophysics, the contribution from direct processes to the total reaction rate is expected to be fairly small throughout. Even in the case of the $^{32}S(p,\gamma)^{33}Cl$ reaction, where the level density for ^{33}Cl is smaller than for ^{32}S at excitation energies encountered in astrophysical environments, it has been found that direct processes are essentially negligible except in the narrow stellar temperature window $T_9 = 0.12$ to 0.16 [MS97]. This is the case since the reaction yields in most stellar environments, even the very hot ones encountered in novas and supernovas, tend to be affected by the cross sections for proton energies below a few MeV, corresponding to a region of excitation in ^{32}S dominated by the isolated resonances.

Because knowledge of the discrete-resonance energies and strengths is so important for astrophysical applications, values of these parameters acquired from the present review of the literature are collected in Table 2. The emphasis is on those resonances that correspond to formation of the compound nucleus ^{32}S by p + ^{31}P and possess observable α-decay strength. However, the tabulation of resonances in ^{32}S is not limited exclusively to those cases. This table lists discrete resonance energies (E_p and E_x), widths (Γ, Γ_p, and Γ_α) and strength S_α (see definition in Section 1), where available. Here, Γ_α and S_α correspond to total α-particle emission associated with the $^{31}P(p,\alpha)^{28}Si$ reaction, unless indicated otherwise. In the literature, widths and strengths for α_0 and α_1 emission (when the latter channel is open) are sometimes given separately and have to be added to obtain the total α-particle decay width and strength. Uncertainties in the resonance energies and the resonance strengths are provided whenever possible because these uncertainties propagate directly to the computed reaction rates through the standard formula used for analyses of resonance phenomena in stellar environments (*e.g.*, see Rolfs and Rodney [RR88]).

Table 2: Discrete Resonance Energies, Spin/Parity, Widths and Strength from the Literature

Ref. Code	E_p[a] (keV)	E_x[b] (keV)	$J\pi$[c]	Γ[d] (eV)	Γ_p[e] (eV)	Γ_α[f] (eV)	S_α[g] (eV)
CAP59	1024±10	9856[i]		≤ 3000		35[j]	104[j]
CAP59	1161±10	9988[i]		4000±2000		3.1[j]	24.4[j]
CAP59	1404±10	10224[i]		6000±2000		44[j]	132[j]
CAP59	1474±10	10292[i]		≤ 2400		11.3[j]	34[j]
CAP59	1514±10	10330[i]		7000±2000		1030[j]	3080[j]
CAP59	1640±10	10452[i]		4200±2000		77[j]	232[j]
CAP59	1710±10	10520[i]		≤ 5500		12[j]	36[j]
CAP59	1811±10	10618[i]		4700±2000		35[j]	104[j]
CAP59	1892±10	10696[i]		27000±2000		970[j]	2920[j]
CAP59	1976±10	10778[i]		≤ 2800		23[j]	68[j]
CAP59	1990±10	10791[i]		≤ 3600		40[j]	120[j]
CAP59	2018±10	10818[i]		≤ 3000		31[j]	92[j]
CAP59	2029±10	10829[i]		18000±2000		600[j]	1800[j]
CAP59	2031±10	10831[i]		6000±2000		160[j]	480[j]
CAP59	2041±10	10841[i]		6000±2000		27[j]	80[j]
CAP59	2109±10	10907[i]		≤ 4000		1.7[j]	5.2[j]
CAP59	2434±10	11221[i]		17000±2000		540[j]	1628[j]
CAP59	2644±10	11425[i]		5000±2000		31[j]	92[j]
CAP59	2779±10	11555[i]		8000±2000		160[j]	480[j]
CAP59	2805±10	11581[i]		17000±2000		180[j]	544[j]
CAP59	2874±10	11647[i]		5000±2000		29[j]	88[j]
CAP59	2922±10	11694[i]		10000±2000		360[j]	1092[j]
CAP59	3008±10	11777[i]		75000±2000		1830[j]	5480[j]
CAP59	3119±10	11885[i]		20000±2000		208[j]	624[j]

Note that the values in E90 supersede those found in EL78.

Ref. Code	E_p[a] (keV)	E_x[b] (keV)	$J\pi$[c]	Γ[d] (eV)	Γ_p[e] (eV)	Γ_α[f] (eV)	S_α[g] (eV)
E90	354.8±0.4	9208.1±0.7	(1,2)+	0.36±0.11			< 0.013[j]
E90	618.9±1.0	9463.9±1.2	2+				0.10[j]
E90	642.4±0.7	9486.7±0.9	1-	8.2±2.5			5.4[j]
E90	821.0±1.0	9659.6±1.2	(1,2)+	2.4±0.7			
E90	874.3±0.5	9711.3±0.8	1-,2+	3.6			5.6[j]
E90	983.8±1.0	9817.3±1.2	2+,3-				2.2[j]
E90	1016±3	9849±3	1-	100±10			56±6[j]
E90	1056.5±0.6	9887.7±0.8	(1,2)+	10±5			
E90	1089.6±0.6	9919.8±0.8	(2,3)+	10±5			
E90	1120.7±0.6	9949.9±0.8	1-	150±15			
E90	1155.1±0.6	9983.2±0.8	0+	100±10			19±2[j]
E90	1251.4±0.6	10076.5±0.8	2-	1500±150			
E90	1400.1±0.6	10220.5±0.8	3+	10±5			
E90	1402.9±0.8	10223.2±1.0	3-	56±10			80±8[j]

Ref. Code	E_p[a] (keV)	E_x[b] (keV)	Jπ[c]	Γ[d] (eV)	Γ_p[e] (eV)	Γ_α[f] (eV)	S_α[g] (eV)
E90	1406.0±1.5	10226.2±1.6	1-	180±20			
E90	1411.4±0.6	10231.5±0.8	1+	25±3			
E90	1438.3±0.7	10257.5±0.9	4-	35±4			
E90	1470.0±1.5	10288.2±1.6	3-	160±20			34±4[j]
E90	1473.1±0.6	10291.2±0.8	2-	125±13			
E90	1475.3±1.5	10293.3±1.6	2+	70±10			53±6[j]
E90	1515.8±1.5	10332.5±1.6	1-	6100±700			4300±500[j]
E90	1556.6±0.6	10372.1±0.8	2+	25±3			
E90	1582.9±0.6	10397.6±0.8	4-	12±2			
E90	1587.0±1.5	10401.6±1.6	0-	7000±700			
E90	1643±3	10456±3	0+	1700±200			350±40[j]
E90	1698.9±1.0	10509.9±1.2	2+	10±5			
E90	1717±3	10527±3	2+	80±10			93±10[j]
E90	1740±4	10550±4		8000			
E90	1764.2±1.0	10573.1±1.2	(2,3,4)+	15±2			
E90	1796.1±1.0	10604.0±1.2	1-	150±20			
E90	1818±3	10626±3	3-	660±70			90±35
E90	1891.5±1.0	10696.4±1.2	2+	180±20			
E90	1896.0±1.0	10700.8±1.2	1-	21000±4000			8800±900[j]
E90	1954.0±1.0	10757.0±1.2	2+	50±10			
E90	1967±3	10769±3	2-	5100±500			
E90	1977.1±1.0	10779.3±1.2	2+	620±70			400±40[j]
E90	1983.6±1.0	10785.6±1.2	1+	750±80			
E90	1985.2±1.0	10787.2±1.2	0+	600±60			46±5[j]
E90	1990.9±1.0	10792.7±1.2	2+	170±20			210±20[j]
E90	2025.3±1.0	10826.0±1.2	1-	22000±4000			6600±700[j]
E90	2026.6±1.0	10827.3±1.2	2+	320±30			390±40[j]

Note that portions of the ENSDF97 file for ^{32}S were derived from E90.

ENSDF97	164.2[h]	9023±2	3-				
ENSDF97	202.4[h]	9060±3	(0,1,2)-				
ENSDF97	207.5[h]	9065±2	4+				
ENSDF97	282.9[h]	9138±5					
ENSDF97	316.0[h]	9170±4					
ENSDF97	342.8[h]	9196±8	2+				
ENSDF97	355.3[h]	9208.1±0.7	1+	0.36±0.11			
ENSDF97	384.1[h]	9236±2	1-				
ENSDF97	403.7[h]	9255±10	(1,2,3)+				
ENSDF97	440.0[h]	9290.1±0.8	1+				
ENSDF97	542.0[h]	9388.9±0.8	2-				
ENSDF97	619.3[h]	9463.8±1.5	(3 to 7)-				
ENSDF97	619.4[h]	9463.9±1.2	2+				
ENSDF97	643.0[h]	9486.7±0.9	1-	8.2±2.5			
ENSDF97	715.6[h]	9557±10					
ENSDF97	797.5[h]	9636.4±1.5	(2 to 6)-				
ENSDF97	811.9[h]	9650.3±0.8	2+				
ENSDF97	821.5[h]	9659.6±1.2	1+	2.4±0.7			
ENSDF97	875.1[h]	9711.5±0.7	2+	3.6			
ENSDF97	888.3[h]	9724.3±0.8	(3,4)-				
ENSDF97	895.0[h]	9730.8±0.8	1-				
ENSDF97	951.0[h]	9785±5					
ENSDF97	984.3[h]	9817.3±1.2	3-				

Ref. Code	E_p[a] (keV)	E_x[b] (keV)	$J\pi$[c]	Γ[d] (eV)	Γ_p[e] (eV)	Γ_α[f] (eV)	S_α[g] (eV)
ENSDF97	994.3[h]	9827±3					
ENSDF97	1017.1[h]	9849±3	1-	100±10			
ENSDF97	1057.0[h]	9887.7±0.8	1+	10±5			
ENSDF97	1090.2[h]	9919.8±0.8	2+	10±5			
ENSDF97	1121.2[h]	9949.9±0.8	1-	150±15			
ENSDF97	1150.6[h]	9978.3±0.9	4-				
ENSDF97	1151.1[h]	9978.8±0.9	3+				
ENSDF97	1155.6[h]	9983.2±0.8	0+	100±10			
ENSDF97	1194.7[h]	10021±10	(2,3,4)-				
ENSDF97	1252.0[h]	10076.5±0.8	2-	1500±150			
ENSDF97	1280.5[h]	10104.1±1.0	2+,3-,4+				
ENSDF97	1400.7[h]	10220.5±0.8	3+	10±5			
ENSDF97	1403.4[h]	10223.2±1.0	3-	56±10			
ENSDF97	1406.5[h]	10226.2±1.6	1-	180±20			
ENSDF97	1412.0[h]	10231.5±0.8	1+	25±3			
ENSDF97	1438.9[h]	10257.5±0.9	4-	35±4			
ENSDF97	1458.0[h]	10276±8	4+				
ENSDF97	1470.6[h]	10288.2±1.6	3-	160±20			
ENSDF97	1473.7[h]	10291.2±0.8	2-	125±13			
ENSDF97	1475.8[h]	10293.3±1.6	2+	70±10			
ENSDF97	1516.3[h]	10332.5±1.6	1-	6100±700			
ENSDF97	1557.2[h]	10372.1±0.8	2+	25±3			
ENSDF97	1583.5[h]	10397.6±0.8	4-	12±2			
ENSDF97	1587.6[h]	10401.6±1.6	0-	7000±700			
ENSDF97	1614.9[h]	10428±10					
ENSDF97	1644.8[h]	10457±3	0+	1700±200			
ENSDF97	1699.5[h]	10509.9±1.2	2+	10±5			
ENSDF97	1718.2[h]	10528±3	2+	80±10			
ENSDF97	1740.9[h]	10550±4		8			
ENSDF97	1764.7[h]	10573.1±1.2	(2,3,4)+	15±2			
ENSDF97	1796.6[h]	10604.0±1.2	1-	150±20			
ENSDF97	1819.4[h]	10626±3	3-	660±70			
ENSDF97	1892.0[h]	10696.4±1.2	2+	180±20			
ENSDF97	1896.6[h]	10700.8±1.2	1-	21000±4000			
ENSDF97	1954.6[h]	10757.0±1.2	2+	50±10			
ENSDF97	1967.0[h]	10769±3	2-	5100±500			
ENSDF97	1977.6[h]	10779.3±1.2	2+	620±70			
ENSDF97	1984.1[h]	10785.6±1.2	1+	750±80			
ENSDF97	1985.8[h]	10787.2±1.2	0+	600±60			
ENSDF97	1991.5[h]	10792.7±1.2	2+	170±20			
ENSDF97	2025.9[h]	10826.0±1.2	1-	22000±4000			
ENSDF97	2027.2[h]	10827.3±1.2	2+	320±30			
ENSDF97	2118.8[h]	10916±3	1-	1600±200			
ENSDF97	2271.6[h]	11064±5	(0,2)+				
ENSDF97	2300.5[h]	11092±3	3-	70±7			
ENSDF97	2350.1[h]	11140±3	1+	2600±300			
ENSDF97	2408.9[h]	11197±3	3-	80±8			
ENSDF97	2848.8[h]	11623±3	1+	5500±600			
ENSDF97	3172.0[h]	11936±3	3-	1450±150			
ENSDF97	3276.3[h]	12037±3	4-	400±40			
ENSDF97	3289.7[h]	12050±3	0+	< 230			
F87	1017.0	9848.9[i]	1-			25	

Ref. Code	E_p[a] (keV)	E_x[b] (keV)	Jπ[c]	Γ[d] (eV)	$Γ_p$[e] (eV)	$Γ_α$[f] (eV)	$S_α$[g] (eV)
F87	1157.6	9985.1[i]	0+			75	
F87	1403.0	10222.8[i]	3-			40	
F87	1469.8	10287.5[i]	3-			150	
F87	1475.4	10292.9[i]	2+			60	
F87	1516.3	10332.5[i]	1-			3800	
F87	1643.3	10455.5[i]	0+			1200	
F87	1717.3	10527.2[i]	1-,2+			40	
F87	1818.4	10625.1[i]	3-			650	
F87	1893.8	10698.1[i]	1-			3500	
F87	1975.6	10777.3[i]	2+			520	
F87	1982.6	10784.1[i]	0+			50	
F87	1989.0	10790.3[i]	2+			85	
F87	2022.0	10822.3[i]	1-			2500	
F87	2023.3	10823.5[i]	2+			150	
F87	2118.3	10915.5[i]	1-			550	
F87	2257.5	11050.3[i]	2+			4000	
F87	2437.0	11224.2[i]	1-			150	
F87	2447.4	11234.3[i]	1-			800	
F87	2665.8	11445.8[i]	1-			400	
F87	2706.7	11485.4[i]	2+			45	
F87	2808.0	11583.5[i]	0+			2200	
F87	2811.0	11586.4[i]	1-			1500	
F87	2828.9	11603.7[i]	2+			30	
F87	2831.7	11606.4[i]	0+			300	
F87	2834.0	11608.7[i]	1-			1300	
F87	2854.5	11628.5[i]	1-			25000	
F87	2906.4	11678.8[i]	2+			2500	
F87	2949.7	11720.7[i]	2+			2200	
F87	2964.0	11734.6[i]	1-			1500	
F87	3034.1	11802.5[i]	3+			2	
F87	3035.6	11803.9[i]	3-			2000	
F87	3038.0	11806.2[i]	1-			4000	
F87	3050.0	11817.9[i]	2-			180	
F87	3063.6	11831.0[i]	2+			120	
F87	3097.5	11863.9[i]	2-			800	
F87	3101.5	11867.7[i]	0+			100	
F87	3135.7	11900.9[i]	3-			250	
F87	3145.2	11910.1[i]	1-			5000	
F87	3165.1	11929.3[i]	0+			60	
F87	3171.3	11935.3[i]	3-			800	
F87	3190.6	11954.0	3-			10	
F87	3217.4	11980.0[i]	(2,3)+			20	
F87	3237.6	11999.5[i]	2+			120	
F87	3251.5	12013.0[i]	2+			7300	
F87	3259.7	12021.0[i]	2+			2500	
F87	3276.2	12036.9[i]	4-			25	
F87	3384.5	12141.8[i]	3-			1200	
F87	3389.0	12146.2[i]	2+			12000	
F87	3394.1	12151.1[i]	3+			80	
F87	3396.3	12153.2[i]	3-			2300	
F87	3426.0	12182.0[i]	1+			500	
F87	3428.0	12183.9[i]	1-			1500	
F87	3439.0	12194.6[i]	1-			1000	

Ref. Code	E_p[a] (keV)	E_x[b] (keV)	$J\pi$[c]	Γ[d] (eV)	Γ_p[e] (eV)	Γ_α[f] (eV)	S_α[g] (eV)
F87	3471.0	12225.6[i]	3+			80	
F87	3487.5	12241.6[i]	1-			60	
F87	3518.2	12271.3[i]	3-			280	
F87	3543.0	12295.3[i]	1-			1000	
F87	3544.5	12296.8[i]	2+			220	
F87	3584.1	12335.1[i]	1-			50	
F87	3620.2	12370.1[i]	3-			150	
F87	3631.9	12381.4[i]	2+			250	
F87	3639.2	12388.5[i]	2+			1400	
F87	3640.4	12389.7[i]	1-			350	
F87	3649.4	12398.4[i]	(0,2)+			250	
F87	3672.0	12420.3[i]	3-			2600	
F87	3708.5	12455.6[i]	3-			500	
F87	3716.0	12462.9[i]	1-			100	
F87	3726.3	12472.8[i]	2+			240	
F87	3734.8	12481.1[i]	3-			150	
F87	3740.8	12486.9[i]	1-,2+			200	
F87	3767.0	12512.3[i]	2+			1000	
F87	3794.5	12538.9[i]	2+			3500	
F87	3823.0	12566.5[i]	2-			100	
F87	3847.3	12590.0[i]	2+			900	
F87	3852.9	12595.5[i]	2+			230	
F87	3889.5	12630.9[i]	3-			1300	
F87	3900.6	12641.7[i]	1-			50	
F87	3920.4	12660.8[i]	3-			1000	
F87	3932.9	12672.9[i]	2+			120	
F87	3945.4	12685.0[i]	3-			100	
F87	3967.8	12706.7[i]	2+			100	
I+91	163	9023	3-		5.5×10^{-11}	0.014	1.96×10^{-10}
I+91	206	9065	4+		7.0×10^{-11}	0.003	2.32×10^{-10}
I+91	342	9195[i]	2+				≤ 0.00168
I+91	383	9235[i]	1-				0.0108±0.0028
I+91	403	9254[i]	2+				≤ 0.00104

Note that some of the values for I+93 are reproduced from I+91.

I+93	164	9023	3-				4×10^{-10}
I+93	200±2	9059±2	(1,2)-				1.72×10^{-6}
I+93	207	9065	4+				1.32×10^{-8}
I+93	342	9196	2+				≤ 0.00168
I+93	383	9236	1-				0.0108±0.0028
I+93	403	9255	2+				≤ 0.00104
I+93	619	9464	2+				0.1

Note that the entries for KMC69b corresponding to the α_0 and α_1 transitions are shown separately. Thus, a particular resonance may appear more than once in this table.

KMC69b	1016	9848[i]	1-	3000			
KMC69b	1156	9984[i]		4000			
KMC69b	1401	10221[i]		2400			
KMC69b	1472	10290[i]		3400			
KMC69b	1512	10328[i]	1-	6400	4600	1800[j]	3881[i,j]

Ref. Code	E_p[a] (keV)	E_x[b] (keV)	Jπ[c]	Γ[d] (eV)	Γ_p[e] (eV)	Γ_α[f] (eV)	S_α[g] (eV)
KMC69b	1641	10453[i]	0+	4800	340	4460[j]	316[j,l]
KMC69b	1815	10622[i]		5200			
KMC69b	1890	10694[i]	1-	18000	13500	4500[j]	10125[j,l]
KMC69b	1972	10774[i]	1-	2500	730	20[j]	17.5[j,l]
KMC69b	1986	10787[i]	2+	3800	1580	50[j]	104[j,l]
KMC69b	2020	10820[i]	1-	10000	8800	1200[j]	3168[j,l]
KMC69b	2114	10911[i]	1-	3200	300	2900[j]	816[j,l]
KMC69b	2255	11048[i]	2+	6000	80	5920[j]	395[j,l]
KMC69b	2443	11230[i]	1-	10000			
KMC69b	2661	11441[i]	1-	4500	100	4400[j]	293[j,l]
KMC69b	2800	11576[i]	1-	7500	500	7000[j]	1400[j,l]
KMC69b	2833	11608[i]	1-	6600	6300	300[j]	859[j,l]
KMC69b	2905	11677[i]	1-	8200	160	8040[j]	471[j,l]
KMC69b	2944	11715[i]	2+	4100	200	3900[j]	951[j,l]
KMC69b	2970	11740[i]	1-	≈ 35000			
KMC69b	3024	11793[i]	2+	≈ 40000			
KMC69b	3045	11813[i]	0+	≈ 30000			
KMC69b	3140	11905[i]	1-	7000	930	6070[j]	2419[j,l]
KMC69b	3250	12012[i]	2+	14000	2200	10100[j]	7936[j,l]
KMC69b	3412	12168[i]		9000			
KMC69b	3442	12198[i]		8000			
KMC69b	3552	12304[i]	1-	17000			
KMC69b	3644	12393[i]	1-	8000			
KMC69b	3684	12432[i]		16000			
KMC69b	3802	12546[i]		10500			

KMC69b	2854	11628[i]		4600			
KMC69b	2984	11754[i]		4000			
KMC69b	3056	11824[i]	1+	32000	31000	640[k]	1860[k,l]
KMC69b	3095	11861[i]	2-	12000	11500	500[k]	2396[k,l]
KMC69b	3250	12012[i]	2+	14000	2200	1700[k]	1336[k,l]
KMC69b	3410	12167[i]		4000			
KMC69b	3438	12194[i]	2-	5500	5400	100[k]	491[k,l]
KMC69b	3481	12235[i]		6600			
KMC69b	3552	12304[i]		6500			
KMC69b	3592	12343[i]		7200			
KMC69b	3636	12385[i]		12000			
KMC69b	3684	12432[i]		13000			
KMC69b	3744	12490[i]		13000			
KMC69b	3776	12521[i]		13000			
KMC69b	3800	12544[i]		10500			

Note that data for a resonance at E_p = 2808 keV could not be read in the article for R+67 because of interference from the journal binding.

R+67	1014	9846[i]	1-	800			20[j]
R+67	1400	10220[i]	2+,3-	1800			44[j]
R+67	1466	10284[i]	3-	1300			64[j]
R+67	1513	10329[i]	1-	8300			2760[j]
R+67	1639	10451[i]	0+,1-	2900			160[j]
R+67	1715	10525[i]	2+	1800			106[j]
R+67	1815	10622[i]	3-?	3100			64[j]
R+67	1891	10695[i]	1-,2+	20000			4400[j]
R+67	1971	10773[i]	1-?,2+	4400			260[j]

Ref. Code	E_p[a] (keV)	E_x[b] (keV)	Jπ[c]	Γ[d] (eV)	Γ_p[e] (eV)	Γ_α[f] (eV)	S_α[g] (eV)
R+67	1985	10786[i]	1-	≤ 3000			152[j]
R+67	2004	10805[i]	1-	≈ 6000			272[j]
R+67	2011	10812[i]	1-	≈ 4000			204[j]
R+67	2015	10815[i]		≈ 4000			
R+67	2019	10819[i]	2+,3-?	≈ 2500			216[j]
R+67	2027	10827[i]					
R+67	2115	10912[i]	1-	2100			84[j]
R+67	2448	11235[i]	1-	9000			880[j]
R+67	2662	11425[i]	1-	≈ 4000			116[j]
R+67	2831	11606[i]	1-	10700			848[j]
R+67	2907	11679[i]	1-	6600			520[j]
R+67	2950	11721[i]	2+	8000			1000[j]
R+67	3040	11808[i]	1-,2+	30000			4000[j]
R+67	3148	11913[i]	1-	7600			1000[j]
R+67	3173	11937[i]	2+,3-	7300			236[j]
R+67	3254	12015[i]	2+?	11800			2480[j]
R+67	3394	12151[i]	2+,3-	6900			2200[j]
R+67	3434	12190[i]	0+	22000			1200[j]
R+67	3545	12297[i]	1-,2+	21000			2400[j]
R+67	3640	12389[i]	2+?,3-	4800			680[j]
R+67	3674	12422[i]	3-	7700			440[j]
R+67	3710	12457[i]	2+,3-	13900			800[j]
R+67	3768	12513[i]	2+	7800			344[j]
R+67	3796	12540[i]	1-,2+	18600			1160[j]
R+67	3837	12580[i]	2+	8400			180[j]
R+67	3853	12596[i]	2+	3000			360[j]
R+67	3886	12628[i]	2+,3-	7900			372[j]
R+67	4678	13395[i]	3-	10500			2680[j]
R+95	159	9023	3-		1.3×10^{-11}		$(3.4\pm2.0)\times10^{-11}$
R+95	194	9059	1-,2-				$\leq7.6\times10^{-8}$
R+95	201	9065	4+				$\leq1.3\times10^{-8}$
R+95	331	9196	2+				$\leq1.7\times10^{-3}$
R+95	344	9208	1+		8.0×10^{-3}		$\leq1.2\times10^{-3}$
R+95	371	9236	1-		6.7×10^{-3}		$(1.1\pm0.3)\times10^{-2}$
R+95	390	9255	2+		5.2×10^{-4}		$\leq1.7\times10^{-4}$
R+95	425	9290	1+		9.3×10^{-2}		$\leq3.6\times10^{-2}$
R+95	524	9389	2-		1.55		≤0.155
R+95	600	9464	2+				0.100±0.016
VLT67	1403±6	10223±6	2+,3-	≤ 700			95±17[j]
VLT67	1470±6	10288±6	3-	≤ 550			47±9[j]
VLT67	1476±6	10294±6	2+	≤ 450			62±15[j]
VLT67	1514±6	10331±6	1-	7000±1000			3000±300[j]
VLT67	1643±6	10456±6	0+,1-	≤ 2300			300±35[j]
VLT67	1715±6	10525±6	2+	≤ 1200			24±5[j]
VLT67	1817±6	10624±6	3-	≤ 1600			110±20[j]
VLT67	1896±6	10701±6	1-	24000±3000			7000±1000[j]
V+73b	1402	10222[i]	3-				85±17[j]
V+73b	1469	10287[i]	3-				49±10[j]
V+73b	1474	10292[i]	2+				66±13[j]
V+73b	1515	10331[i]	1-				4500±900[j]

Ref. Code	E_p[a] (keV)	E_x[b] (keV)	$J\pi$[c]	Γ[d] (eV)	Γ_p[e] (eV)	Γ_α[f] (eV)	S_α[g] (eV)
W+92	3288	12049		40±15	36±16	6.5±2.7	

[a] Incident proton energy (laboratory system) for the p + ^{31}P resonance.
[b] Excitation energy for the resonance state in the compound nucleus ^{32}S.
[c] Spin/parity of the resonance in ^{32}S. When more than one possibility is allowed by the available information, this is indicated.
[d] Total width of the compound-nuclear state in ^{32}S.
[e] Proton width of the compound-nuclear state in ^{32}S.
[f] Width for decay of the compound-nuclear state in ^{32}S by α-particle emission. Unless indicated otherwise, this is assumed to be the total width for this process and includes both α_0 and α_1 transitions.
[g] Strength of decay of the compound-nuclear state in ^{32}S by α-particle emission. Unless indicated otherwise, this is assumed to be the total strength for this process and includes both α_0 and α_1 transitions. As indicated in Section 1 of the text, the strength is defined here as $S_\alpha = (2J+1)\Gamma_p\Gamma_\alpha/\Gamma$.
[h] E_p is calculated from given E_x using Eq. (1) in the text.
[i] E_x is calculated from given E_p using Eq. (1) in the text.
[j] Value given is based only on observation of the α_0 transition.
[k] Value given is based only on observation of the α_1 transition.
[l] Calculated with formula from Section 1 using given values of J, Γ, Γ_p, and Γ_α.

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References

A96

D. Arnett, *Supernovae and Nucleosynthesis*, Princeton University Press, Princeton, New Jersey (1996).

A+67

E. Acerbi, M. Castiglioni, G. Dutto, I. Iori, A. Luccio, S. Micheletti, N. Molho, M. Pignanelli, F. Resmini, G. Strini, C. Succi and G. Tagliaferri, *Reazoni (p,α) con Protoni di 38 MeV su Nuclei Leggeri*, Supplemento al Nuovo Cimento **V**, No. 4, 1252 (1967). [In Italian].

BN80

A.N. Behkami and S.I. Najafi, *Statistical Analysis of the Energy Level Widths in Charged-particle -induced Reactions*, Journal of Physics G: Nuclear Physics **6**, 685 (1980).

C83

D.D. Clayton, *Principles of Stellar Evolution and Nucleosynthesis*, University of Chicago Press, Chicago, Illinois (1983).

CAP59

R.L. Clarke, E. Almqvist and E.B. Paul, *Properties of Levels Excited in (p,α) Reactions on ^{18}O, ^{31}P, ^{35}Cl, ^{37}Cl, ^{39}K and ^{41}K*, Nuclear Physics **14**, 472 (1959/1960).

CINDA97

CINDA (1935-1997), *The Index to Literature and Computer Files on Microscopic Neutron Data*, International Atomic Energy Agency (IAEA), Vienna, Austria. CINDA includes an index to all available EXFOR files containing neutron reaction data available from the IAEA Nuclear Data Center.

DA68

P.J. Dallimore and B.W. Allardyce, *A Fluctuation Analysis of the Reaction $^{31}P(p,\alpha)^{28}Si$*, Nuclear Physics **A108**, 150 (1968).

D+65

G. Dearnaley, W.R. Gibbs, R.B. Leachman and P.C. Rogers, *Investigation of $^{27}Al(\alpha,p)$ Reaction by Cross-section Fluctuation Studies*, Physical Review **139**, No. 5B, B1170 (1965).

D+94

J.M. Drake, E.G. Bilpuch, G.E. Mitchell and J.F. Shriner, Jr., *Detailed-balance Tests of Time-reversal Invariance with Interfering Charged-particle Resonances*, Physical Review **C49**, No. 1, 411 (1994).

E90

P.M. Endt, *Energy Levels of A = 21 - 44 Nuclei (VII)*, Nuclear Physics **A521**, 1 (1990).

EL78

P.M. Endt and C. Van der Leun, *Energy Levels of A = 21 - 44 Nuclei (VI)*, Nuclear Physics **A310**, 1 (1978).

ENSDF97

ENSDF (1997), *Evaluated Nuclear Structure Data File*, On-Line Data Retrieval Service, National Nuclear Data Center, Brookhaven National Laboratory, Upton, New York, U.S.A. (1997).

F87

Dufei Fang, *Proton Resonance Spectroscopy in ^{32}S*, Thesis, Triangle Universities Nuclear Laboratory, Duke Station, Durham, North Carolina 27706. Dissertation submitted in partial fulfillment of the requirements for degree of Doctor of Philosophy in the Department of Nuclear Science in the Graduate School of Fudan University, Shanghai, China (1987).

FL80

J. Forster and D. Lehmann, *Winkelverteilung der α-Teilchen in den Resonanzen der Reaktion* $^{31}P(p,\alpha_0)^{28}Si$ *Zwischen* E_p = *640 keV und 1530 keV*, Report ZFK-408, Zentralinstitut fuer Kernforschung, Rossendorf, Democratic Republic of Germany, 8 (1980). [In German].

FS96

R.B. Firestone and V.S. Shirley, *Table of Isotopes, 8th Edition*, John Wiley and Sons, Inc., New York (1996).

F+85

R.E. Fauber, E.J. Ludwig, T.B. Clegg, H.J. Karwowski, T.M. Mooney and W.J. Thompson, *Isospin-forbidden T = 2 Resonance in* $^{31}P(p,\alpha_0)^{28}Si$, Bulletin of the American Physical Society **30**, 1256, Paper BC 1 (1985).

F+86

D.F. Fang, C.R. Westerfeldt, E.G. Bilpuch, and G.E. Mitchell, *Levels of* ^{32}S *from High Resolution Proton Scattering*, Bulletin of the American Physical Society **31**, 1764, Paper DC 4 (1986).

F+88

D.F. Fang, E.G. Bilpuch, C.R. Westerfeldt and G.E. Mitchell, *Proton Resonances in* ^{32}S *from* E_x = *9.83 to 12.74 MeV*, Physical Review **C37**, No. 1, 28 (1988).

HG81

C.C. Hsu and B. Gonsior, *Comment on the Compound-nucleus Cross Section from Nuclear Charge-density Distributions*, Journal of Physics G: Nuclear Physics **7**, 1099 (1981).

I+90

C. Iliadis, U. Giesen, J. Gorres, L. Van Wormer, M. Wiescher, R.E. Azuma, J. King, M. Buckby, C.A. Barnes and T.R. Wang, *The Influence of Low Energy Resonances in* $^{31}P(p,\gamma)^{32}S$, Bulletin of the American Physical Society **35**, No. 8, Paper DD 3, 1673 (1990).

I+91

C. Iliadis, U. Giesen, J. Gorres, S. Graff, M. Wiescher, R.E. Azuma, J. King, M. Buckby, C.A. Barnes, and T.R. Wang, *The Reaction Branching* $^{31}P(p,\gamma)/^{31}P(p,\alpha)$ *in the rp-Process*, Nuclear Physics **A533**, 153 (1991).

I+93

C. Iliadis, J. Gorres, J.G. Ross, K.W. Scheller, M. Wiescher, C. Grama, Th. Schange, H.P. Trautvetter and H.C. Evans, *Explosive Hydrogen Burning of* ^{31}P, Nuclear Physics **A559**, 83 (1993).

K67

A.A. Katsanos, *Studies of Low-energy Nuclear Reactions and Level Densities for Medium-mass Nuclei*, Report ANL-7289, Argonne National Laboratory (1967).

KH73a

M. Kildir and J.R. Huizenga, *Isospin Dependence of the Nuclear Level Width*, Physical Review **C8**, No. 5, 1965 (1973).

KH73b

M. Kilder and J.R. Huizenga, *Dependence of the Nuclear Level Width of* ^{32}S *on Isospin*, Bulletin of the American Physical Society **18**, 668, Paper HE 10 (1973).

KMC68

K.V. Karadzhev, V.I. Man'ko and F.E. Chukreev, *Elastic Scattering of Protons by Phosphorus and the Reactions* $^{31}P(p,\alpha_0)^{28}Si$ *and* $^{31}P(p,\alpha_1)^{28}Si$ *in the Energy Interval 1.0 - 3.8 MeV*, Soviet Journal of Nuclear Physics **7**, No. 2, 170 (1968).

KMC69a

K.V. Karadzhev, V.I. Man'ko and F.E. Chukreev, *Spin Mixing in the Input Channels of the Reaction* $^{31}P(p,\alpha_0)^{28}Si$, Soviet Journal of Nuclear Physics **8**, No. 2, 184 (1969).

KMC69b

K.V. Karadzhev, V.I. Man'ko and F.E. Chukreev, *Properties of the Excited States of the ^{32}S Nucleus*, Soviet Journal of Nuclear Physics **9**, No. 4, 431 (1969).

KS74

M.B. Kurup and R.P. Sharma, *Upper Limit to the Life Time of 9.709 MeV State in ^{32}S by Blocking Technique,* Bombay Conference (Nuclear, Solid State Physics), Volume **17B**, 131 (1974).

K+85

A.Z. Kiss, E. Koltay, B. Nyako, E. Somorjai, A. Anttila and J. Raisanen, *Measurements of Relative Thick Target Yields for PIGE Analysis on Light Elements in the Proton Energy Interval 2.4 - 4.2 MeV*, Journal of Radioanalytical and Nuclear Chemistry **89**, No. 1, 123 (1985).

LFG72

R.B. Leachman, P. Fessenden and W.R. Gibbs, *Variation of the ^{32}S Compound-nucleus Width with Energy and Spin*, Physical Review **C6**, No. 4, 1240 (1972).

MS95

G.E. Mitchell and J.F. Shriner, Jr., *Parity Violation in Charged Particle Resonances*, Nuclear Instruments and Methods in Physical Research **B99**, 305 (1995).

MS96

G.E. Mitchell and J.F. Shriner, Jr., *Parity Violation in Charged-particle Resonance Reactions*, Physical Review **C54**, No. 1, 371 (1996).

MS97

Roy E. Miller and Donald L. Smith, *A Compilation of Information on the $^{32}S(p, \gamma)^{33}Cl$ Reaction and Properties of Excited Levels in ^{33}Cl*, Report ANL/NDM-143, Argonne National Laboratory (1997).

M+93

G.E. Mitchell, E.G. Bilpuch, C.R. Bybee, J.M. Drake and J.F. Shriner, Jr., *Detailed Balance Test of Time Reversal Invariance with Interfering Resonances*, Nuclear Physics **A560**, 483 (1993). See also: Nuclear Instruments and Methods in Physics Research **B79**, 290 (1993). The Nuclear Instruments and Methods paper is very similar to the Physical Review article so it is included as one component of two articles collected as a single blanket reference under the code M+93.

NSR97

Nuclear Science References (NSR), National Nuclear Data Center (NNDC), Brookhaven National Laboratory, Upton, New York. Available from NNDC on-line services.

P+71

G. Philipp, W.-D. Emmerich, A. Hofmann, G. Kroner and K. Thomas, *The Collective Nature of the Low-lying States in* ^{27}Al *and* ^{23}Na *Investigated with* (p,α) *Reactions*, Nuclear Physics **A160**, 654 (1971).

RR88

C.E. Rolfs and W.S. Rodney, *Cauldrons in the Cosmos*, University of Chicago Press, Chicago, Illinois (1988).

RWK87

J. Raisanen, T. Witting and J. Keinonen, *Absolute Thick-target* γ*-ray Yields for Elemental Analysis by 7 and 9 MeV Protons*, Nuclear Instruments and Methods in Physics Research **B28**, 199 (1987).

R+67

P.J. Riley, G.A. Lock, J.A. Rawlins and Y.M. Shin, *Levels of* ^{32}S *Studied by the* $^{31}P(p,\alpha_0)^{28}Si$ *Reaction*, Nuclear Physics **A96**, 641 (1967).

R+95

J.G. Ross, J. Gorres, C. Iliadis, S. Vouzoukas, M. Wiescher, R.G. Vogelaar, S. Utku, N.P.T. Bateman, and P.D. Parker, *Indirect Study of Low-energy Resonances in* $^{31}P(p,\alpha)^{28}Si$ *and* $^{35}Cl(p,\alpha)^{32}S$, Physical Review **C52**, No. 3, 1681 (1995).

S67

Hans H. Staub, *Q Values Determined from Resonance Reactions and the Effects of the Atomic Electrons*, Proceedings of the Third International Conference on Atomic Masses, Winnipeg, Manitoba, Canada, R.C. Barber, Ed., University of Manitoba Press, 495 (1967).

S83

D.G. Sargood, *Effect of Excited States on Thermonuclear Reaction Rates*, Australian Journal of Physics **36**, 583 (1983).

SAN73

R.P. Sharma, J.U. Andersen and K.O. Nielsen, *Application of the Blocking Technique to Measure Lifetimes of Nuclear Levels Excited in* (p,α) *Resonance Reactions in P and Al*, Nuclear Physics **A204**, 371 (1973).

SKP75

R.P. Sharma, M.B. Kurup and K.G. Prasad, *Use of Blocking Technique for the Measurement of Ultra Short Compound Nuclear Lifetimes*, Report BARC-799, Bhabha Atomic Research Centre, Bombay, India, 30 (1975).

SLD67

G.G. Seaman, R.B. Leachman and G. Dearnaley, *Fluctuation Studies of the* (α,p) *Reaction on* ^{19}F, ^{23}Na *and* ^{31}P, Physical Review **153**, No. 4, 1194 (1967).

SSB74

D. Shapira, R.G. Stokstad and D.A. Bromley, *Statistical Analysis of the Energy Dependence of* $^{12}C + ^{12}C$ *Cross Sections*, Physical Review **C10**, No. 3, 1063 (1974).

T95

J.K. Tuli, *Nuclear Wallet Cards (5th Edition)*, National Nuclear Data Center, Brookhaven National Laboratory, Upton, New York (1995).

VKH68

H.K. Vonach, A.A. Katsanos and J.R. Huizenga, *Determination of the Level Width and Density of ^{32}S Between 17 and 21 MeV Excitation Energy*, Nuclear Physics **A122**, 465 (1968).

VLT67

J. Vernotte, M. Langevin and F. Takeutchi, *Niveaux de ^{32}S Observes dans les Reactions $^{31}P(p,\alpha_0)^{28}Si$ et $^{28}Si(\alpha,\gamma)^{32}S$*, Nuclear Physics **A102**, 449 (1967). [In French].

V+73a

J. Vernotte, S. Gales, M. Langevin and J.M. Maison, *Investigation of the Lowest $T = 2$ State of ^{32}S in the $^{31}P + p$ Reactions*, Physical Review **C8**, No. 1, 178 (1973).

V+73b

J. Vernotte, S. Gales, M. Langevin and J.M. Maison, *Recherche de Resonances Isobariques Analogues dans ^{32}S au Moyen des Reactions $^{31}P(p,\gamma)^{32}S$, $^{31}P(p,p')^{31}P$ et $^{31}P(p,\alpha)^{28}Si$*, Nuclear Physics **A212**, 493 (1973). [In French].

W+88

C.R. Westerfeldt, R.O. Nelson, E.G. Bilpuch, and G.E. Mitchell, *A Microcomputer-based System for Measuring Excitation Functions with Good Energy Resolution*, Nuclear Instruments and Methods in Physics Research **A270**, 467 (1988).

W+92

J.F. Wilkerson, T.M. Mooney, R.E. Fauber, T.B. Clegg, H.J. Karwowski, E.J. Ludwig and W.J. Thompson, *Isospin-nonconserving Particle Decays in Light Nuclei*, Nuclear Physics **A549**, 223 (1992).

Appendix A: Compiled Information in EXFOR Format

The EXFOR format, which is widely used for compiling neutron cross section data, was adapted for the present purpose [CINDA97]. This format provides for an easily deciphered, platform-independent ASCII representation of both textual material and numerical data. Furthermore, it is a format which is generally familiar to investigators in the nuclear data community. Since the EXFOR format has been used in the past almost exclusively for compiling data on neutron reactions, some creativity had to be exercised in producing the present files of data relevant to charged-particle reactions and properties of reaction-product nuclei while still preserving most of the historical characteristics of the file structure. These files have been sent to the National Nuclear Data Center, Brookhaven National Laboratory, Upton, New York, U.S.A., for inclusion in the library of data on charged-particle reactions which is being collected there.

BN80

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ENTRY            BN80           0                             BN80 0     1
SUBENT        BN80  1           0                             BN80 1     1
BIB                 6          12                             BN80 1     2
INSTITUTE  (IRNPAH)                                           BN80 1     3
REFERENCE  (J,JP/G,6,685,1980)                                BN80 1     4
AUTHORS    (A.N.BEHKAMI,S.I.NAJAFI)                           BN80 1     5
TITLE      STATISTICAL ANALYSIS OF THE ENERGY LEVEL WIDTHS IN BN80 1     6
           CHARGED-PARTICLE-INDUCED REACTIONS                 BN80 1     7
FACILITY   PHYSICS DEPARTMENT, PAHLAVI UNIVERSITY, DANESHGAH, BN80 1     8
           SHIRAZ, IRAN. ANALYTICAL STUDY. NO EXPERIMENT.     BN80 1     9
COMMENTS   LEVEL WIDTHS FOR DECAY OF COMPOUND NUCLEI BY PARTICLE BN80 1  10
           EMISSION ARE CALCULATED USING A MICROSCOPIC THEORY. BN80 1   11
           THEORY DESCRIBED IN THE ARTICLE IN CONSIDERABLE DETAIL. BN80 1 12
           CALCULATED VALUES COMPARED WITH COMPILED EXPERIMENTAL BN80 1  13
           ONES. AGREEMENT IS GENERALLY REASONABLY GOOD.      BN80 1    14
ENDBIB             12                                         BN80 1    15
ENDSUBENT           1                                         BN80 199999
SUBENT        BN80  2           0                             BN80 2     1
BIB                 2           7                             BN80 2     2
REACTION   31P(P,ALPHA)28SI                                   BN80 2     3
COMMENTS   CALCULATED VALUES ARE TAKEN FROM TABLE 1 OF PAPER. BN80 2     4
           COMPOUND NUCLEUS IS 32S. EXCITATION ENERGY IS 19.0 MEV. BN80 2 5
           GAMMA1 = ENERGY WIDTH CALCULATED USING PAIRING GAPS FROM BN80 2 6
           BOHR AND MOTTLESON. GAMMA2 = ENERGY WIDTH CALCULATED BN80 2   7
           USING PAIRING GAPS FROM NEMIROWSKY AND ADAMCHUK.   BN80 2     8
           NO ERRORS ARE GIVEN FOR THESE CALCULATED VALUES.   BN80 2     9
ENDBIB              7                                         BN80 2    10
DATA                2           1                             BN80 2    11
GAMMA1     GAMMA2                                             BN80 2    12
KEV        KEV                                                BN80 2    13
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43.8	29.7		BN80 2 14
ENDDATA		3	BN80 2 15
ENDSUBENT		2	BN80 299999
ENDENTRY		2	BN809999999

CAP59

ENTRY	CAP59	0	CAP59 0 1
SUBENTRY	CAP59 1	0	CAP59 1 1
BIB	12	56	CAP59 1 2
INSTITUTE	(CANCRC)		CAP59 1 3
REFERENCE	(J,NP,14,472,1959/60)		CAP59 1 4
AUTHORS	(R.L.CLARKE,E.ALMQVIST,E.B.PAUL)		CAP59 1 5
TITLE	PROPERTIES OF LEVELS EXCITED IN (P,ALPHA) REACTIONS ON		CAP59 1 6
	18O, 31P, 35CL, 37CL, 39K AND 41K		CAP59 1 7
FACILITY	(VDG) 3-MEV ELECTROSTATIC ACCELERATOR, A.E.C.L. CHALK		CAP59 1 8
	RIVER NUCLEAR LABORATORIES, CHALK RIVER, ONTARIO,		CAP59 1 9
	CANADA.		CAP59 1 10
INC-PART	(P) PROTONS.		CAP59 1 11
TARGETS	ZN3P2 EVAPORATED ON TA OR GRAPHITE (CARBON) BACKINGS.		CAP59 1 12
	THICKNESS VARIED FROM 0.3-10 KEV FOR 1.9-MEV PROTONS.		CAP59 1 13
METHOD	PROTON-BEAM ENERGY STABILIZED TO WITHIN 3 KEV OF		CAP59 1 14
	SELECTED VALUE. ENERGY SCALE WAS CALIBRATED USING THE		CAP59 1 15
	7LI(P,N) THRESHOLD AT 1.881 MEV. CALIBRATION REPEATED		CAP59 1 16
	FREQUENTLY TO INSURE FIDELITY OF BEAM ENERGY. BEAM		CAP59 1 17
	ENERGY WAS SELECTED USING A MAGNETIC SPECTROMETER.		CAP59 1 18
	MAGNETIC FIELD WAS MONITORED WITH A NUCLEAR MAGNETIC		CAP59 1 19
	RESONANCE DEVICE. THE EMITTED PROTONS AND ALPHA-		CAP59 1 20
	PARTICLES WERE DETECTED WITH A SCINTILLATION DETECTOR		CAP59 1 21
	FOLLOWING ANALYSIS BY A MAGNETIC SPECTROMETER. THE		CAP59 1 22
	TARGET WAS PLACED AT 45 DEG. TO THE INCIDENT PROTON		CAP59 1 23
	BEAM. EMITTED PROTONS AND ALPHA PARTICLES WERE		CAP59 1 24
	MEASURED AT 90 DEG. TO THE INCIDENT BEAM. EXPERIMENT		CAP59 1 25
	MEASURED EXCITATION FUNCTION FOR ALPHA-PARTICLES		CAP59 1 26
	CORRESPONDING TO THE GROUND-STATE TRANSITION OF		CAP59 1 27
	THE 31P(P,ALPHA)28SI REACTION. ALSO DETECTED PROTONS		CAP59 1 28
	ELASTICALLY SCATTERED FROM 31P. TARGETS WITH TA		CAP59 1 29
	BACKING WERE USED WHEN GAMMA-RAYS AND ALPHA-PARTICLE		CAP59 1 30
	WERE MEASURED SIMULTANEOUSLY. CARBON BACKING TARGETS		CAP59 1 31
	WERE USED WHEN ABSOLUTE ALPHA-PARTICLE YIELDS WERE		CAP59 1 32
	SOUGHT. BASED YIELD CALIBRATION ON A COMPARISON WITH		CAP59 1 33
	THE YIELD OF ELASTICALLY SCATTERED PROTONS, ASSUMING		CAP59 1 34
	RUTHERFORD SCATTERING. DETERMINED DIFFERENTIAL CROSS		CAP59 1 35
	SECTION FOR ALPHA-PARTICLE EMISSION ON THE RESONANCES.		CAP59 1 36
	DEDUCED TOTAL WIDTHS FOR ISOLATED RESONANCES IN THOSE		CAP59 1 37
	INSTANCES WHERE THIS WIDTH CONSIDERABLY EXCEEDED THE		CAP59 1 38
	EXPERIMENTAL RESOLUTION. IN OTHER CASES, DEDUCED THE		CAP59 1 39
	PRODUCT OF THE WIDTH AND CROSS SECTION FROM THE AREA		CAP59 1 40
	UNDER RESONANCE CURVE. ANGLE-INTEGRATED CROSS SECTION		CAP59 1 41
	WAS CALCULATED FROM DIFFERENTIAL CROSS SECTION BY		CAP59 1 42
	ASSUMING ISOTROPIC ALPHA-PARTICLE EMISSION. ESTIMATED		CAP59 1 43
	PROTON AND ALPHA-PARTICLE PARTIAL WIDTHS AND REDUCED		CAP59 1 44

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             WIDTHS BASED ON ASSUMPTIONS ABOUT THE INDIVIDUAL          CAP59 1     45
             RESONANCES, E.G., THE RESONANCE SPIN VALUES.              CAP59 1     46
DETECTOR     (SCINT) KI(TL) OR CSI SCINTILLATION CRYSTAL. EMITTED      CAP59 1     47
             PARTICLES WERE PRE-ANALYZED WITH A 180-DEG. DOUBLE-       CAP59 1     48
             FOCUSING MAGNETIC SPECTROMETER. RCA 5819 P.M. TUBE.       CAP59 1     49
MONITOR      (CI) CURRENT INTEGRATOR.                                  CAP59 1     50
ERR-ANALYS   RESONANCE ENERGY ABSOLUTE UNCERTAINTIES ABOUT 10 KEV.     CAP59 1     51
             UNCERTAINTIES IN DIFFERENCES OF RESONANCE ENERGIES ARE    CAP59 1     52
             ABOUT 2 TO 3 KEV. UNCERTAINTIES IN TOTAL WIDTHS FOR       CAP59 1     53
             RESONANCES WHERE WIDTHS COULD BE MEASURED DIRECTLY ARE    CAP59 1     54
             ABOUT 2 KEV. RELATIVE UNCERTAINTIES IN DIFFERENTIAL       CAP59 1     55
             CROSS SECTIONS ARE 20 PCT. ABSOLUTE UNCERTAINTIES ARE     CAP59 1     56
             25 PCT.                                                   CAP59 1     57
COMMENTS     PUBLISHED IN NUCLEAR PHYSICS. DATA COMES FROM TABLE 3.    CAP59 1     58
ENDBIB                56                                               CAP59 1     59
ENDSUBENT              1                                               CAP59 199999
SUBENTRY         CAP59 2          0                                    CAP59 2      1
BIB                    2         14                                    CAP59 2      2
REACTION     31P(P,ALPHA0)28SI                                         CAP59 2      3
COMMENTS     DATA OBTAINED FROM TABLE 3 OF THE ARTICLE. EP = PROTON    CAP59 2      4
             ENERGY OF THE RESONANCE. DSIG90 = DIFFERENTIAL CROSS      CAP59 2      5
             SECTION MEASURED AT 90 DEG. GAMMA = TOTAL WIDTH OF        CAP59 2      6
             THE RESONANCE. SIGGAMMA = PRODUCT OF THE RESONANCE        CAP59 2      7
             ANGLE-INTEGRATED CROSS SECTION AND ITS TOTAL WIDTH.       CAP59 2      8
             STRENG = RESONANCE STRENGTH AS DEFINED IN THE ARTICLE.    CAP59 2      9
             GAMALPHA = CALCULATED ALPHA-PARTICLE WIDTH BASED ON       CAP59 2     10
             THE ASSUMPTIONS DISCUSSED IN THE ARTICLE. SEVERAL OF      CAP59 2     11
             THE VALUES FOR DSIG90 GIVEN IN TABLE 3 ARE INDICATED      CAP59 2     12
             TO BE LOWER BOUNDS WHILE CORRESPONDING VALUES FOR         CAP59 2     13
             GAMMA ARE INDICATED TO BE UPPER BOUNDS. REFER TO THE      CAP59 2     14
             ARTICLE FOR DETAILS. NO ERRORS ARE GIVEN EXPLICITLY       CAP59 2     15
             FOR THE VALUES IN THIS TABLE.                             CAP59 2     16
ENDBIB                14                                               CAP59 2     17
DATA                   6         24                                    CAP59 2     18
```

EP	DSIG90	GAMMA	SIGGAMMA	STRENG	GAMALPHA	
KEV	MB/SR	KEV	MB*KEV	EV	EV	
1024.0	1.8	3.0	70.0	26.0	35.0	CAP59 2 21
1161.0	0.29	4.0	15.0	6.1	3.1	CAP59 2 22
1404.0	0.87	6.0	65.0	33.0	44.0	CAP59 2 23
1474.0	0.53	2.4	16.0	8.5	11.3	CAP59 2 24
1514.0	16.1	7.0	1410.0	770.0	1030.0	CAP59 2 25
1640.0	1.9	4.2	98.0	58.0	77.0	CAP59 2 26
1710.0	0.21	5.5	15.0	9.0	12.0	CAP59 2 27
1811.0	0.68	4.7	40.0	26.0	35.0	CAP59 2 28
1892.0	3.2	27.0	1070.0	730.0	970.0	CAP59 2 29
1976.0	0.68	2.8	24.0	17.0	23.0	CAP59 2 30
1990.0	0.94	3.6	43.0	30.0	40.0	CAP59 2 31
2018.0	0.85	3.0	32.0	23.0	31.0	CAP59 2 32
2029.0	2.74	18.0	620.0	450.0	600.0	CAP59 2 33
2031.0	2.2	6.0	160.0	120.0	160.0	CAP59 2 34
2041.0	0.36	6.0	27.0	20.0	27.0	CAP59 2 35
2109.0	0.07	4.0	2.0	1.3	1.7	CAP59 2 36
2434.0	2.5	17.0	540.0	407.0	540.0	CAP59 2 37
2644.0	0.39	5.0	25.0	23.0	31.0	CAP59 2 38
2779.0	1.2	8.0	120.0	120.0	160.0	CAP59 2 39
2805.0	0.63	17.0	130.0	136.0	180.0	CAP59 2 40
2874.0	0.34	5.0	21.0	22.0	29.0	CAP59 2 41
2922.0	2.1	10.0	260.0	273.0	360.0	CAP59 2 42

(Header rows: EP … GAMALPHA = CAP59 2 19; KEV … EV = CAP59 2 20)

```
 3008.0     1.3        75.0       1250.0     1370.0     1830.0     CAP59 2     43
 3119.0     0.55       20.0       140.0      156.0      208.0      CAP59 2     44
ENDDATA               26                                           CAP59 2     45
ENDSUBENT              2                                           CAP59 299999
SUBENTRY       CAP59   3           0                               CAP59 3      1
BIB                    2          14                               CAP59 3      2
REACTION   31P(P,ALPHA0)28SI                                       CAP59 3      3
COMMENTS   DATA OBTAINED FROM TABLE 3 OF THE ARTICLE. EP = PROTON  CAP59 3      4
           ENERGY OF THE RESONANCE. GAMALPHA2 = REDUCED ALPHA-     CAP59 3      5
           PARTICLE WIDTH. GAMP2 = REDUCED PROTON WIDTH.           CAP59 3      6
           THALPHA2 = DIMENSIONLESS REDUCED ALPHA-PARTICLE WIDTH   CAP59 3      7
           (X 10**-2). THP2 = DIMENSIONLESS REDUCED PROTON WIDTH   CAP59 3      8
           (X 10**2). REDUCED WIDTHS CALCULATED ON THE BASIS OF    CAP59 3      9
           SEVERAL ASSUMPTIONS MENTIONED IN THE ARTICLE. SINCE     CAP59 3     10
           MANY OF THE RESONANCE SPINS ARE UNKNOWN AND ANGULAR     CAP59 3     11
           DISTRIBUTIONS WERE NOT MEASURED IN THE PRESENT STUDY,   CAP59 3     12
           THERE ARE LARGE UNCERTAINTIES IN THESE DERIVED          CAP59 3     13
           WIDTHS. REFER TO THE ARTICLE FOR DETAILS. NO ERRORS     CAP59 3     14
           ARE GIVEN EXPLICITLY FOR THE VALUES IN THIS TABLE.      CAP59 3     15
           SOME VALUES OF GAMP2 AND THP2 ARE UPPER BOUNDS.         CAP59 3     16
ENDBIB                14                                           CAP59 3     17
DATA                   5          24                               CAP59 3     18
EP         GAMALPHA2  GAMP2      THALPHA2   THP2                   CAP59 3     19
KEV        KEV        KEV        NO-DIM     NO-DIM                 CAP59 3     20
 1024.0     11.2       3100.0     2.9        141.0                 CAP59 3     21
 1161.0     1.4        1800.0     0.35       83.0                  CAP59 3     22
 1404.0     3.3        930.0      0.82       42.0                  CAP59 3     23
 1474.0     0.7        288.0      0.18       13.0                  CAP59 3     24
 1514.0     56.6       483.0      1.41       22.0                  CAP59 3     25
 1640.0     2.9        252.0      0.72       11.0                  CAP59 3     26
 1710.0     0.37       258.0      0.09       12.0                  CAP59 3     27
 1811.0     0.84       164.0      0.21       7.0                   CAP59 3     28
 1892.0     19.4       741.0      4.8        34.0                  CAP59 3     29
 1976.0     0.37       60.0       0.09       3.0                   CAP59 3     30
 1990.0     0.64       75.0       0.17       3.5                   CAP59 3     31
 2018.0     0.47       60.0       0.12       3.0                   CAP59 3     32
 2029.0     8.6        350.0      2.1        17.0                  CAP59 3     33
 2031.0     2.3        114.0      0.6        5.0                   CAP59 3     34
 2041.0     0.39       115.0      0.98       5.0                   CAP59 3     35
 2109.0     0.02       76.0       0.004      3.5                   CAP59 3     36
 2434.0     3.5        149.0      0.87       6.8                   CAP59 3     37
 2644.0     0.14       29.0       0.03       1.3                   CAP59 3     38
 2779.0     0.58       38.0       0.146      1.7                   CAP59 3     39
 2805.0     0.63       78.0       0.16       3.6                   CAP59 3     40
 2874.0     0.09       20.0       0.023      0.9                   CAP59 3     41
 2922.0     1.04       38.0       0.26       1.6                   CAP59 3     42
 3008.0     4.75       255.0      1.18       11.6                  CAP59 3     43
 3119.0     0.47       58.0       0.12       2.7                   CAP59 3     44
ENDDATA               26                                           CAP59 3     45
ENDSUBENT              3                                           CAP59 399999
ENDENTRY               3                                           CAP599999999
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DA68

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ENTRY            DA68          0                              DA68 0      1
SUBENT        DA68  1          0                              DA68 1      1
BIB                13         37                              DA68 1      2
INSTITUTE  (UKOXF)                                            DA68 1      3
REFERENCE  (J,NP/A,108,150,1968)                              DA68 1      4
AUTHORS    (P.J.DALLIMORE,B.W.ALLARDYCE)                      DA68 1      5
TITLE      A FLUCTUATION ANALYSIS OF THE REACTION             DA68 1      6
           31P(P,ALPHA)28SI                                   DA68 1      7
FACILITY   (VDG) TANDEM VAN DE GRAAFF ACCELERATOR, THE UNIVERSITY DA68 1  8
           OF OXFORD NUCLEAR PHYSICS LABORATORY, OXFORD, ENGLAND. DA68 1  9
INC-PART   (P) PROTONS.                                       DA68 1     10
TARGET     NATURAL PHOSPOROUS EVAPORATED ONTO A CARBON BACKING. DA68 1   11
METHOD     INCIDENT PROTONS OF 8.50 - 12.30 MEV PASSED THROUGH A DA68 1  12
           SERIES OF TANTALUM COLLIMATORS AND AN ANNULAR COUNTER. DA68 1 13
           BEAM WAS COLLECTED IN A FARADAY CUP. BEAM CURRENTS DA68 1     14
           IN THE RANGE OF 0.1 TO 1.0 MICROAMPS WERE ENCOUNTERED. DA68 1 15
           ALPHA PARTICLES DETECTED UP TO AN ENERGY OF 13.5 MEV. DA68 1  16
           DETECTION ANGLES: SET 1 - 90, 120, 135, 150, 177 DEG.; DA68 1 17
           SET 2 - 44, 59, 74, 90, 105, 143, 157, 169 DEG.    DA68 1     18
           90-DEG. POSITION MEASURED TWICE FOR CHECKING PURPOSES. DA68 1 19
           VARIOUS TECHNIQUES USED IN DATA ANALYSIS, AS DESCRIBED DA68 1 20
           IN THE ARTICLE. LEVEL WIDTHS DEDUCED.              DA68 1     21
DETECTORS  (SOLST) AU/SI SURFACE-BARRIER DETECTORS.           DA68 1     22
CORRECTION CORRECTIONS MADE TO THE EXPERIMENTAL EXCITATION    DA68 1     23
           FUNCTIONS SO THAT THE EFFECTIVE MEAN CROSS SECTION DA68 1     24
           REMAINS CONSTANT WITH PROTON ENERGY CHANGES, AS NEEDED DA68 1 25
           IN ORDER TO PERFORM FLUCTUATION ANALYSIS. THE DERIVED DA68 1  26
           AUTOCORRELATION VALUES HAVE BEEN CORRECTED FOR THE DA68 1     27
           FINITE RANGE OF DATA. VARIOUS ANALYSIS METHODS TRIED DA68 1   28
           TO SEE WHICH GAVE THE BEST RESULTS. HAUSER-FESHBACH DA68 1    29
           CORRECTIONS ARE MADE TO AUTOCORRELATION VALUES.    DA68 1     30
ERR-ANALYS ERRORS ARE ESTIMATED FOR EXPERIMENTAL DIFFERENTIAL CROSS DA68 1 31
           SECTIONS. ERRORS ESTIMATED FOR AUTOCORRELATION ANALYSIS. DA68 1 32
STATUS     RESULTS PUBLISHED IN NUCLEAR PHYSICS. SOME EXCITATION DA68 1  33
           FUNCTIONS GIVEN IN GRAPHICAL FORM. NUMERICAL RESULTS IN DA68 1 34
           IN TABLES 1-4 OF THE ARTICLE. VALUES GIVEN ONLY FOR THE DA68 1 35
           ALPHA0 AND ALPHA1 GROUPS.                          DA68 1     36
COMMENTS   INFORMATION CONTAINED IN FIGURES PRESENTED IN THE  DA68 1     37
           ARTICLE MAY BE USEFUL BUT THESE RESULTS ARE NOT INCLUDED DA68 1 38
           IN THIS FILE BECAUSE NUMERICAL VALUES ARE NOT AVAILABLE. DA68 1 39
ENDBIB             37                                         DA68 1     40
ENDSUBENT           1                                         DA68 199999
SUBENT        DA68  2          0                              DA68 2      1
BIB                 2         10                              DA68 2      2
REACTION   31P(P,ALPHA)28SI                                   DA68 2      3
COMMENTS   MEAN LEVEL WIDTHS FROM TABLE 3 OF ARTICLE AS CALCULATED DA68 2 4
           FROM THE EXCITATION FUNCTIONS FOR THE ALPHA0 GROUP. DA68 2     5
           THETA-CM = CENTER-OF-MASS ANGLE FOR ALPHA PARTICLES. DA68 2    6
           GAMMA = MEAN LEVEL WIDTH. VARIOUS METHODS USED TO FIND. DA68 2 7
           GAMMA-EXP = VALUE FROM UNCORRECTED RESULTS. GAMMA-HF = DA68 2  8
           VALUE FROM HAUSER-FESHBACH CALCULATIONS. GAMMA-BL = DA68 2     9
           VALUE FROM BASE LINE SHIFT OF AUTOCORRELATION FUNCTION. DA68 2 10
           GAMMA-MAX = VALUE OBTAINED FROM COUNTING THE NUMBER OF DA68 2  11
           MAXIMA IN THE EXCITATION FUNCTIONS. NO ERRORS GIVEN. DA68 2    12
ENDBIB             10                                         DA68 2     13
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DATA                 5          13                                          DA68 2    14
THETA-CM   GAMMA-EXP  GAMMA-HF   GAMMA-BL   GAMMA-MAX                       DA68 2    15
DEG        KEV        KEV        KEV        KEV                             DA68 2    16
46.        66.        51.        42.        42.                             DA68 2    17
62.        90.        88.        59.        41.                             DA68 2    18
78.        74.        93.        52.        37.                             DA68 2    19
93.        63.        57.        49.        39.                             DA68 2    20
108.       58.        42.        52.        41.                             DA68 2    21
123.       64.        44.        53.        39.                             DA68 2    22
138.       42.        33.        28.        33.                             DA68 2    23
145.       43.        51.        31.        36.                             DA68 2    24
152.       45.        32.        33.        38.                             DA68 2    25
159.       73.        41.        48.        35.                             DA68 2    26
166.       50.        37.        45.        37.                             DA68 2    27
169.       56.        39.        46.        38.                             DA68 2    28
177.       42.        34.        42.        36.                             DA68 2    29
ENDDATA             15                                                      DA68 2    30
ENDSUBENT            2                                                      DA68 299999
SUBENT        DA68   3           0                                          DA68 3     1
BIB                  2          10                                          DA68 3     2
REACTION   31P(P,ALPHA)28SI                                                 DA68 3     3
COMMENTS   MEAN LEVEL WIDTHS FROM TABLE 4 OF ARTICLE AS CALCULATED          DA68 3     4
           FROM THE EXCITATION FUNCTIONS FOR THE ALPHA1 GROUP.              DA68 3     5
           THETA-CM = CENTER-OF-MASS ANGLE FOR ALPHA PARTICLES.             DA68 3     6
           GAMMA = MEAN LEVEL WIDTH. VARIOUS METHODS USED TO FIND.          DA68 3     7
           GAMMA-EXP = VALUE FROM UNCORRECTED RESULTS. GAMMA-HF =           DA68 3     8
           VALUE FROM HAUSER-FESHBACH CALCULATIONS. GAMMA-BL =              DA68 3     9
           VALUE FROM BASE LINE SHIFT OF AUTOCORRELATION FUNCTION.          DA68 3    10
           GAMMA-MAX = VALUE OBTAINED FROM COUNTING THE NUMBER OF           DA68 3    11
           MAXIMA IN THE EXCITATION FUNCTIONS. NO ERRORS GIVEN.             DA68 3    12
ENDBIB              10                                                      DA68 3    13
DATA                 5          13                                          DA68 3    14
THETA-CM   GAMMA-EXP  GAMMA-HF   GAMMA-BL   GAMMA-MAX                       DA68 3    15
DEG        KEV        KEV        KEV        KEV                             DA68 3    16
46.        570.       55.        39.        30.                             DA68 3    17
62.        300.       39.        42.        31.                             DA68 3    18
78.        280.       41.        50.        32.                             DA68 3    19
94.        410.       35.        44.        33.                             DA68 3    20
109.       390.       35.        44.        31.                             DA68 3    21
123.       295.       55.        35.        30.                             DA68 3    22
138.       275.       33.        28.        35.                             DA68 3    23
146.       235.       36.        48.        32.                             DA68 3    24
152.       100.       30.        31.        31.                             DA68 3    25
159.       92.        38.        52.        28.                             DA68 3    26
166.       44.        40.        33.        32.                             DA68 3    27
169.       51.        41.        41.        32.                             DA68 3    28
177.       36.        41.        33.        31.                             DA68 3    29
ENDDATA             15                                                      DA68 3    30
ENDSUBENT            3                                                      DA68 399999
SUBENT        DA68   4                                                      DA68 4     1
BIB                  2           9                                          DA68 4     2
REACTION   31P(P,ALPHA)28SI                                                 DA68 4     3
COMMENTS   AVERAGE LEVEL WIDTHS GIVEN IN PAPER AS SUMMARY RESULTS           DA68 4     4
           FROM PRESENT INVESTIGATION. GAMMA-0 = WIDTH FOR DECAY            DA68 4     5
           OF COMPOUND NUCLEUS 32S TO GROUND STATE OF 28SI BY               DA68 4     6
           ALPHA-PARTICLE EMISSION. ERR-GAMMA-0 = ERROR IN                  DA68 4     7
           GAMMA-0. GAMMA-1 = WIDTH FOR DECAY OF COMPOUND NUCLEUS           DA68 4     8
           32S TO FIRST-EXCITED STATE OF 28SI BY ALPHA-PARTICLE             DA68 4     9
```

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          EMISSION. ERR-GAMMA-1 = ERROR IN GAMMA-1. VALUES TAKEN   DA68 4    10
          FROM P. 175 OF THE ARTICLE.                               DA68 4    11
ENDBIB             9                                                DA68 4    12
DATA               4          1                                     DA68 4    13
GAMMA-0   ERR-GAMMA-0GAMMA-1   ERR-GAMMA-1                          DA68 4    14
KEV       KEV        KEV        KEV                                 DA68 4    15
47.       7.         42.        5.                                  DA68 4    16
ENDDATA            3                                                DA68 4    17
ENDSUBENT          4                                                DA68 499999
SUBENT        DA68 5                                                DA68 5     1
BIB                2          5                                     DA68 5     2
REACTION  31P(P,ALPHA)28SI                                          DA68 5     3
COMMENTS  HALF LIFE FOR DE-EXCITATION OF COMPOUND NUCLEUS 32S AT    DA68 5     4
          EXCITATION ENERGIES BETWEEN 17 AND 20 MEV IS ESTIMATED    DA68 5     5
          FROM THE LEVEL WIDTHS. THALF = HALF LIFE. NO ERROR IS     DA68 5     6
          GIVEN FOR THIS ESTIMATE.                                  DA68 5     7
ENDBIB             5                                                DA68 5     8
DATA               1          1                                     DA68 5     9
THALF                                                               DA68 5    10
SEC                                                                 DA68 5    11
 1.4000E-20                                                         DA68 5    12
ENDDATA            3                                                DA68 5    13
ENDSUBENT          5                                                DA68 599999
ENDENTRY           5                                                DA689999999
```

D+94

```
ENTRY            D+94         0                                     D+94 0     1
SUBENT        D+94 1          0                                     D+94 1     1
BIB                9         20                                     D+94 1     2
INSTITUTES (USANCS)                                                 D+94 1     3
           (USADKE)                                                 D+94 1     4
           (USATTU)                                                 D+94 1     5
REFERENCE  (J,PR/C,49,1,411,1994)                                   D+94 1     6
AUTHORS    (J.M.DRAKE,E.G.BILPUCH,G.E.MITCHELL,J.F.SHRINER,JR.)     D+94 1     7
TITLE      DETAILED-BALANCE TESTS OF TIME-REVERSAL INVARIANCE WITH  D+94 1     8
           INTERFERING CHARGED-PARTICLE RESONANCES                  D+94 1     9
FACILITY   WORK CARRIED OUT AT TRIANGLE UNIVERSITIES NUCLEAR        D+94 1    10
           LABORATORY (TUNL). EXPERIMENTS PERFORMED EARLIER.        D+94 1    11
TARGETS    31P AS WELL AS 23NA, 27AL, 35CL AND 39K.                 D+94 1    12
METHOD     NOT DISCUSSED. PAPER REPORTS ON A THEORETICAL ANALYSIS   D+94 1    13
           OF DATA OBTAINED IN EARLIER EXPERIMENTS AT TUNL.         D+94 1    14
STATUS     RESULTS PUBLISHED IN PHYSICAL REVIEW.                    D+94 1    15
COMMENTS   PAPER GIVES NO INFORMATION ABOUT TARGET FABRICATION,     D+94 1    16
           EXPERIMENTAL SETUP, DETECTORS, CORRECTIONS OR ERROR      D+94 1    17
           ANALYSIS. RESONANCE PARAMETERS OBTAINED EARLIER ARE      D+94 1    18
           USED FOR A STUDY OF DETAILED BALANCE AND TIME-REVERSAL   D+94 1    19
           INVARIANCE (TRI) IN INVERSE REACTIONS. TRI VIOLATION     D+94 1    20
           SOUGHT BY LOOKING FOR EQUIVALENT VIOLATIONS OF DETAILED  D+94 1    21
           BALANCE.                                                 D+94 1    22
ENDBIB            20                                                D+94 1    23
ENDSUBENT          1                                                D+94 199999
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SUBENT        D+94  2          0                              D+94 2     1
BIB                 2         12                              D+94 2     2
REACTION   31P(P,ALPHA0)28SI                                  D+94 2     3
COMMENTS   VALUES OBTAINED FROM TABLE I OF THE ARTICLE. ALL   D+94 2     4
           RESULTS CORRESPOND TO COMPOUND NUCLEUS 32S. PAIR-IDENT D+94 2 5
           = INDEX WHICH IDENTIFIES RESONANCE PAIR, AS INDICATED D+94 2  6
           IN THE TABLE. EA = C.M. ENERGY FOR MEMBER OF RESONANCE D+94 2 7
           PAIR IDENTIFIED BY "A". GAMMA-A = TOTAL WIDTH OF   D+94 2     8
           RESONANCE "A" OF THE PAIR. EB = C.M. ENERGY FOR MEMBER D+94 2 9
           OF RESONANCE PAIR IDENTIFIED BY "B". GAMMA-B = TOTAL D+94 2  10
           WIDTH OF RESONANCE "B" OF THE PAIR. NO ERRORS ARE GIVEN. D+94 2 11
           J-PI = SPIN AND PARITY OF THE RESONANCES. NOTE THAT BOTH D+94 2 12
           "A" AND "B" BY CHOICE HAVE THE SAME SPIN AND PARITY D+94 2   13
           (SEE DISCUSSION IN THE PAPER).                     D+94 2    14
ENDBIB             12                                         D+94 2    15
DATA                6         10                              D+94 2    16
PAIR-IDENT EA         GAMMA-A    EB         GAMMA-B    J-PI   D+94 2    17
NO-DIM     MEV        KEV        MEV        KEV        NO-DIM D+94 2    18
         8 2.1864     4.17       2.2191     0.085      2.0    D+94 2    19
         9 2.7231     0.16       2.7398     0.5        2.0    D+94 2    20
        10 2.7645     26.8       2.7716     1.9       -1.0    D+94 2    21
        11 2.8148     2.62       2.8567     2.75       2.0    D+94 2    22
        12 3.0151     3.6        3.0369     2.35      -3.0    D+94 2    23
        13 3.1356     1.97       3.1490     9.0        2.0    D+94 2    24
        14 3.1490     9.0        3.1570     2.6        2.0    D+94 2    25
        15 3.3200     10.5       3.3306     5.5       -1.0    D+94 2    26
        16 3.5174     0.70       3.5245     1.8        2.0    D+94 2    27
        17 3.7261     2.0        3.7315     0.4        2.0    D+94 2    28
ENDDATA            12                                         D+94 2    29
ENDSUBENT           2                                         D+94 299999
SUBENT        D+94  3          0                              D+94 3     1
BIB                 2          9                              D+94 3     2
REACTION   31P(P,ALPHA0)28SI                                  D+94 3     3
COMMENTS   VALUES OBTAINED FROM TABLE II OF THE ARTICLE. ALL  D+94 3     4
           RESULTS CORRESPOND TO COMPOUND NUCLEUS 32S. PAIR IDENT D+94 3 5
           = INDEX WHICH IDENTIFIES RESONANCE PAIR, AS INDICATED D+94 3  6
           IN THE TABLE. E-CM = C.M. ENERGY OF THE PARTICULAR D+94 3     7
           MEMBER OF THE RESONANCE PAIR FOR WHICH CROSS-SECTION D+94 3   8
           INFORMATION IS PROVIDED. THETA-CM = C.M. ANGLE FOR D+94 3     9
           ALPHA-PARTICLE EMISSION. DSIG-DOMEG = DIFFERENTIAL D+94 3    10
           CROSS SECTION FOR ALPHA-PARTICLE EMISSION.         D+94 3    11
ENDBIB              9                                         D+94 3    12
DATA                4         10                              D+94 3    13
PAIR-IDENT E-CM       THETA-CM   DSIG-DOMEG                   D+94 3    14
NO-DIM     MEV        DEG        MB/SR                        D+94 3    15
         8 2.2190     180.       0.011                        D+94 3    16
         9 2.7231     132.       0.0011                       D+94 3    17
        10 2.7716     180.       5.6                          D+94 3    18
        11 2.8566     126.       0.023                        D+94 3    19
        12 3.0152     180.       0.0019                       D+94 3    20
        13 3.1350     180.       2.0                          D+94 3    21
        14 3.1565     180.       2.3                          D+94 3    22
        15 3.3280     180.       0.49                         D+94 3    23
        16 3.5174     180.       0.20                         D+94 3    24
        17 3.7312     180.       2.0                          D+94 3    25
ENDDATA            12                                         D+94 3    26
ENDSUBENT           3                                         D+94 399999
ENDENTRY            3                                         D+949999999
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E90

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ENTRY              E90           0                                          E90 0      1
SUBENT         E90  1            0                                          E90 1      1
BIB                 6           10                                          E90 1      2
INSTITUTE  (NETUTR)                                                         E90 1      3
REFERENCE  (J,NP/A,521,1,1990)                                              E90 1      4
AUTHOR     (P.M.ENDT)                                                       E90 1      5
TITLE      ENERGY LEVELS OF A = 21-44 NUCLEI (VII)                          E90 1      6
COMMENTS   AN EXTENSIVE COMPILATION OF DATA ON LIGHT NUCLEI.                E90 1      7
           INCLUDED IN THIS FILE ARE THE RELEVANT DATA FOR THE              E90 1      8
           INDICATED REACTION. ORIGINAL DATA SOURCES ARE GIVEN IN           E90 1      9
           THE REFERENCE. EMPHASIS HERE IS ON DATA WHICH PERTAIN            E90 1     10
           TO THE DETERMINATION OF REACTION RATES FOR ASTROPHYSICS.         E90 1     11
STATUS     DATA COMPILATION PUBLISHED IN NUCLEAR PHYSICS.                   E90 1     12
ENDBIB             10                                                       E90 1     13
ENDSUBENT           1                                                       E90 199999
SUBENT         E90  2            0                                          E90 2      1
BIB                 2            8                                          E90 2      2
REACTION   31P(P,ALPHA0)28SI                                                E90 2      3
COMMENTS   VALUES FROM FROM TABLE 32.20A OF ARTICLE. EP = RESONANCE         E90 2      4
           PROTON ENERGY. ERR-EP = ERROR IN EP. GAMMA = TOTAL               E90 2      5
           WIDTH OF RESONANCE. ERR-GAMMA = ERROR IN GAMMA. STRENG =         E90 2      6
           RESONANCE STRENGTH FOR ALPHA-PARTICLE EMISSION TO THE            E90 2      7
           GROUND STATE OF 28SI. SEE TABLE FOR DEFINITION OF TERMS.         E90 2      8
           VALUE OF STRENG GIVEN FOR EP = 354.8-KEV RESONANCE IS            E90 2      9
           AN UPPER BOUND. ERR-STRENG = ERROR IN STRENG.                    E90 2     10
ENDBIB              8                                                       E90 2     11
DATA                6           20                                          E90 2     12
EP         ERR-EP     GAMMA      ERR-GAMMA  STRENG     ERR-STRENG           E90 2     13
KEV        KEV        EV         EV         EV         EV                   E90 2     14
 354.8      0.4        0.36       0.11       0.013                          E90 2     15
 618.9      1.0                              0.10                           E90 2     16
 642.4      0.7        8.2        2.5        5.4                            E90 2     17
 874.3      0.5        3.6                   5.6                            E90 2     18
 983.8      1.0                              2.2                            E90 2     19
 1016.0     3.0        100.0      10.0       56.0       6.0                 E90 2     20
 1155.1     0.6        100.0      10.0       19.0       2.0                 E90 2     21
 1402.9     0.8        56.0       10.0       80.0       8.0                 E90 2     22
 1470.0     1.5        160.0      20.0       34.0       4.0                 E90 2     23
 1475.3     1.5        70.0       10.0       53.0       6.0                 E90 2     24
 1515.8     1.5        6100.0     700.0      4300.0     500.0               E90 2     25
 1643.0     3.0        1700.0     200.0      350.0      40.0                E90 2     26
 1717.0     3.0        80.0       10.0       93.0       10.0                E90 2     27
 1818.0     3.0        660.0      70.0       90.0       35.0                E90 2     28
 1896.0     1.0        21000.0    4000.0     8800.0     900.0               E90 2     29
 1977.1     1.0        620.0      70.0       400.0      40.0                E90 2     30
 1985.2     1.0        600.0      60.0       46.0       5.0                 E90 2     31
 1990.9     1.0        170.0      20.0       210.0      20.0                E90 2     32
 2025.3     1.0        22000.0    4000.0     6600.0     700.0               E90 2     33
 2026.6     1.0        320.0      30.0       390.0      40.0                E90 2     34
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ENDDATA             22                                          E90 2    35
ENDSUBENT            2                                          E90 299999
ENDENTRY             2                                          E909999999
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EL78

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ENTRY            EL78            0                              EL78 0     1
SUBENT        EL78  1            0                              EL78 1     1
BIB                 6           10                              EL78 1     2
INSTITUTE  (NETUTR)                                             El78 1     3
REFERENCE  (J,NP/A,310,1,1978)                                  EL78 1     4
AUTHORS    (P.M.ENDT,C.VAN-DER-LEUN)                            EL78 1     5
TITLE      ENERGY LEVELS OF A = 21-44 NUCLEI (VI)               EL78 1     6
COMMENTS   AN EXTENSIVE COMPILATION OF DATA ON LIGHT NUCLEI.    EL78 1     7
           INCLUDED IN THIS FILE ARE THE RELEVANT DATA FOR THE  EL78 1     8
           INDICATED REACTION. ORIGINAL DATA SOURCES ARE GIVEN IN EL78 1   9
           THE REFERENCE. EMPHASIS HERE IS ON DATA WHICH PERTAIN EL78 1   10
           TO THE DETERMINATION OF REACTION RATES FOR ASTROPHYSICS. EL78 1 11
STATUS     DATA COMPILATION PUBLISHED IN NUCLEAR PHYSICS.       EL78 1    12
ENDBIB             10                                           EL78 1    13
ENDSUBENT           1                                           EL78 199999
SUBENT        EL78  2            0                              EL78 2     1
BIB                 2            9                              EL78 2     2
REACTION   31P(P,ALPHA0)28SI                                    EL78 2     3
COMMENTS   VALUES FROM FROM TABLE 32.19 OF ARTICLE. EP = RESONANCE EL78 2  4
           PROTON ENERGY. ERR-EP = ERROR IN EP. STRENG = RESONANCE EL78 2  5
           STRENGTH FOR ALPHA-PARTICLE EMISSION TO THE GROUND STATE EL78 2 6
           OF 28SI. GAMMA = RESONANCE TOTAL WIDTH. ERR-GAMMA =  EL78 2     7
           ERROR IN GAMMA. SEE TABLE FOR DEFINITIONS OF TERMS.  EL78 2     8
           GAMMA GIVEN FOR EP = 1475.3-KEV RESONANCE IS A LOWER EL78 2     9
           BOUND. GAMMA GIVEN FOR EP = 3289.0-KEV RESONANCE IS  EL78 2    10
           AN UPPER BOUND.                                      EL78 2    11
ENDBIB              9                                           EL78 2    12
DATA                5           23                              EL78 2    13
EP         ERR-EP     STRENG     GAMMA      ERR-GAMMA           EL78 2    14
KEV        KEV        EV         EV         EV                  EL78 2    15
 618.9     1.0         0.10                                     EL78 2    16
 642.4     0.7        5.4         8.2        2.5                EL78 2    17
 821.0     1.0                    2.9        0.7                EL78 2    18
 874.3     0.5        5.6         5.6                           EL78 2    19
 983.8     1.0        2.2                                       EL78 2    20
 1016.0    3.0        100.0                                     EL78 2    21
 1155.1    0.6        24.0                                      EL78 2    22
 1251.4    0.6                    1600.0     240.0              EL78 2    23
 1402.9    0.8        95.0        65.0       25.0               EL78 2    24
 1411.4    0.6                    25.0       10.0               EL78 2    25
 1438.3    0.7                    45.0       20.0               EL78 2    26
 1470.0    1.5        47.0        180.0      60.0               EL78 2    27
 1473.1    0.6                    125.0      20.0               EL78 2    28
 1475.3    1.5        62.0        100.0                         EL78 2    29
 1515.8    1.5        3000.0      7600.0     800.0              EL78 2    30
 1556.6    0.6                    30.0       10.0               EL78 2    31
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 1582.9    0.6                   25.0       15.0                 EL78 2   32
 1587.0    1.5                   8300.0     1300.0               EL78 2   33
 1643.0    6.0        300.0      6000.0                          EL78 2   34
 1740.0    4.0                   8000.0                          EL78 2   35
 1904.0    4.0        7000.0     20000.0    3000.0               EL78 2   36
 3283.0    3.0                   470.0      50.0                 EL78 2   37
 3289.0    3.0                   230.0                           EL78 2   38
ENDDATA            25                                            EL78 2   39
ENDSUBENT           2                                            EL78 299999
ENDENTRY            2                                            EL789999999
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F87

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ENTRY             F87          0                                    F87 0    1
SUBENT         F87  1          0                                    F87 1    1
BIB                13         43                                    F87 1    2
INSTITUTE  (USATNL)                                                 F87 1    3
REFERENCE  (T,TUNL,1987)                                            F87 1    4
AUTHOR     (DUFEI FANG)                                             F87 1    5
TITLE      PROTON RESONANCE SPECTROSCOPY IN 32S                     F87 1    6
FACILITY   (VDG) KN VAN DE GRAAFF ACCELERATOR AND ASSOCIATED HIGH   F87 1    7
           RESOLUTION TARGET SYSTEM, TRIANGLE UNIVERSITY NUCLEAR    F87 1    8
           LABORATORY, DURHAM, NORTH CAROLINA.                      F87 1    9
INC-PART   (P) PROTONS.                                             F87 1   10
TARGET     EVAPORATED ZN3P2 ONTO ULTRA-PURE NI-COATED CARBON FOILS. F87 1   11
           CARBON THICKNESS (4-5 MICROGRAM/CM**2). NI THICKNESS     F87 1   12
           (0.5 MICROGRAM/CM882). TARGETS CONTAINED 1-3 MICROGRAM/  F87 1   13
           CM**2 OF 31P. NI WAS ADDED TO BACKING FOR STABILITY AND  F87 1   14
           UNIFORMITY.                                              F87 1   15
METHOD     PROTON BEAMS WITH ENERGY BETWEEN 1.00 AND 4.01 MEV WERE  F87 1   16
           INCIDENT ON TARGETS. PROTON-INDUCED REACTION YIELDS WERE F87 1   17
           MEASURED USING SURFACE BARRIER DETECTORS PLACED AT 90,   F87 1   18
           127, 145 AND 165 DEGREES. TRANSMISSION DETECTORS WERE    F87 1   19
           USED TO IDENTIFY ALPHA PARTICLES AT 108, 135 AND 165     F87 1   20
           DEGREES. SOLID ANGLE ADJUSTED SO RUTHERFORD SCATTERING   F87 1   21
           YIELD WAS APPROXIMATELY EQUAL FOR ALL COUNTERS. STUDIED  F87 1   22
           REACTIONS 31P(P,P0), (P,P1), (P,ALPHA0) AND (P,ALPHA1).  F87 1   23
           MEASURED EXCITATION FUNCTIONS. 300-400 EV RESOLUTION.    F87 1   24
           ENERGY STEPS IN RANGE 100-400 EV. EXTRACTED RESONANCE    F87 1   25
           PARAMETERS WITH MULTI-LEVEL, MULTI-CHANNEL R-MATRIX      F87 1   26
           CODE. SEARCHED FOR ANALOG STATES. EXAMINED INVERSE       F87 1   27
           REACTIONS. MORE DETAILS ARE GIVEN IN THE THESIS.         F87 1   28
DETECTORS  (SOLST) SI SURFACE BARRIER AND TRANSMISSION DETECTORS.   F87 1   29
CORRECTION NO DISCUSSION OF DATA CORRECTIONS IS PROVIDED.           F87 1   30
ERR-ANALYS MOST EXCITATION FUNCTIONS WERE MEASURED TWICE TO INSURE  F87 1   31
           REPRODUCIBILITY. RESONANCE ENERGY UNCERTAINTY GENERALLY  F87 1   32
           WAS ABOUT 3 KEV. A 10% UNCERTAINTY WAS ESTIMATED FOR     F87 1   33
           THE WIDTHS OF SMALL RESONANCES AND 20% FOR THE LARGE     F87 1   34
           RESONANCES. THESIS PROVIDES EXTENSIVE DESCRIPTION OF THE F87 1   35
           BASIC THEORY AND EXPERIMENTAL PROCEDURES, INCLUDING      F87 1   36
           DATA ANALYSIS. EXPERIMENTAL RESULTS ARE INTERPRETED.     F87 1   37
STATUS     MATERIAL EXTRACTED FROM A THESIS SUBMITTED IN PARTIAL    F87 1   38
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FULFILLMENT OF REQUIREMENTS FOR PH.D. DEGREE AT FUDAN F87 1 39
UNIVERSITY, SHANGHAI, CHINA, IN COLLABORATION WITH TUNL, F87 1 40
DUKE UNIVERSITY, DURHAM, NORTH CAROLINA. F87 1 41
COMMENTS PORTIONS OF THIS THESIS WERE LATER PUBLISHED IN A F87 1 42
JOURNAL ARTICLE IN PHYSICAL REVIEW (REF. CODE F+88 IN F87 1 43
THIS COMPILATION). DESCRIPTIVE MATERIAL HERE IS QUITE F87 1 44
SIMILAR TO EXFOR ENTRIES FOR THAT PHYS. REV. ARTICLE. F87 1 45
ENDBIB 43 F87 1 46
ENDSUBENT 1 F87 199999
SUBENT F87 2 0 F87 2 1
BIB 2 13 F87 2 2
REACTION 31P(P,ALPHA0)28SI F87 2 3
COMMENTS DATA OBTAINED FROM TABLE 4.2 OF THE REFERENCE. ONLY THE F87 2 4
RESULTS FOR THE GROUND-STATE ALPHA-EMISSION CHANNEL ARE F87 2 5
REPRODUCED FROM THE TABLE. EP = RESONANCE PROTON ENERGY. F87 2 6
J-PI = RESONANCE SPIN/PARITY. L = ORBITAL ANGULAR MOMEN- F87 2 7
TUM. S = COUPLED SPIN OF ALPHA PARTICLE + 28SI. GAMMA F87 2 8
= RESONANCE WIDTH FOR ALPHA0 EMISSION. GAMMA2 = REDUCED F87 2 9
WIDTH. VALUES EXTRACTED FROM FITS TO EXCITATION FUNCTION. F87 2 10
NO ERRORS ARE GIVEN FOR THE WIDTHS DERIVED FROM THE DATA; F87 2 11
HOWEVER, QUALITATIVE VALUES FOR THE ERRORS IN THE WIDTHS F87 2 12
ARE GIVEN IN THE TEXT OF THE THESIS (P. 99). THE J-PI F87 2 13
ASSIGNMENTS ARE NOT ALWAYS UNIQUE. AMBIGUITIES FOR TWO F87 2 14
RESONANCES ARE: 1.7173 KEV (1-,2+), 3.6494 KEV (2+,0+). F87 2 15
ENDBIB 13 F87 2 16
DATA 6 62 F87 2 17

EP	J-PI	L	S	GAMMA	GAMMA2	
MEV	NO-DIM	NO-DIM	NO-DIM	KEV	KEV	F87 2 19
1.0170	-1.0	1.0	0.0	0.025	6.72	F87 2 20
1.1576	0.0	0.0	0.0	0.075	7.30	F87 2 21
1.4030	-3.0	3.0	0.0	0.04	16.94	F87 2 22
1.4698	-3.0	3.0	0.0	0.15	52.14	F87 2 23
1.4754	2.0	2.0	0.0	0.06	6.28	F87 2 24
1.5163	-1.0	2.0	0.0	3.80	155.88	F87 2 25
1.6433	0.0	0.0	0.0	1.20	22.36	F87 2 26
1.7173	-1.0	1.0	0.0	0.04	0.89	F87 2 27
1.8184	-3.0	3.0	0.0	0.650	70.02	F87 2 28
1.8938	-1.0	1.0	0.0	3.50	47.62	F87 2 29
1.9756	2.0	2.0	0.0	0.52	1.19	F87 2 30
1.9826	0.0	0.0	0.0	0.05	0.38	F87 2 31
1.9890	2.0	2.0	0.0	0.085	1.87	F87 2 32
2.0220	-1.0	1.0	0.0	2.50	24.58	F87 2 33
2.0233	2.0	2.0	0.0	0.15	3.02	F87 2 34
2.1183	-1.0	1.0	0.0	0.55	4.30	F87 2 35
2.2575	2.0	2.0	0.0	4.00	45.34	F87 2 36
2.4370	-1.0	1.0	0.0	0.15	0.60	F87 2 37
2.4474	-1.0	2.0	0.0	0.80	3.12	F87 2 38
2.6658	-1.0	1.0	0.0	0.40	1.05	F87 2 39
2.7067	2.0	2.0	0.0	0.045	0.20	F87 2 40
2.8080	0.0	0.0	0.0	2.20	3.45	F87 2 41
2.8110	-1.0	1.0	0.0	1.50	3.11	F87 2 42
2.8289	2.0	2.0	0.0	0.03	0.11	F87 2 43
2.8317	0.0	0.0	0.0	0.30	0.46	F87 2 44
2.8340	-1.0	1.0	0.0	1.3	2.60	F87 2 45
2.8545	-1.0	1.0	0.0	25.0	48.44	F87 2 46
2.9064	2.0	2.0	0.0	2.50	7.92	F87 2 47
2.9497	2.0	2.0	0.0	2.20	6.50	F87 2 48
2.9640	-1.0	1.0	0.0	1.50	2.47	F87 2 49

(Header row: F87 2 18)

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3.0356     -3.0       3.0       1.0       2.00      12.23      F87 2    50
3.0380     -1.0       1.0       0.0       4.00      5.94       F87 2    51
3.1357     -3.0       3.0       0.0       0.25      1.29       F87 2    52
3.1452     -1.0       1.0       0.0       5.00      6.44       F87 2    53
3.1651      0.0       0.0       0.0       0.06      0.06       F87 2    54
3.1713     -3.0       3.0       0.0       0.80      3.88       F87 2    55
3.2376      2.0       2.0       0.0       0.02      0.038      F87 2    56
3.2515      2.0       2.0       0.0       6.80      12.77      F87 2    57
3.2597      2.0       2.0       0.0       2.50      4.64       F87 2    58
3.3845     -3.0       3.0       0.0       1.20      4.14       F87 2    59
3.3890      2.0       2.0       0.0       12.0      18.74      F87 2    60
3.3963     -3.0       3.0       0.0       2.30      7.81       F87 2    61
3.4280     -1.0       1.0       0.0       1.50      1.38       F87 2    62
3.4390     -1.0       1.0       0.0       1.00      0.91       F87 2    63
3.5182     -3.0       3.0       0.0       0.28      0.80       F87 2    64
3.5430     -1.0       1.0       0.0       1.00      0.81       F87 2    65
3.5445      2.0       2.0       0.0       0.10      0.13       F87 2    66
3.5841     -1.0       2.0       0.0       0.10      0.13       F87 2    67
3.6392      2.0       2.0       0.0       1.40      1.62       F87 2    68
3.6404     -1.0       1.0       0.0       0.20      0.15       F87 2    69
3.6494      2.0       0.0       0.0       0.20      0.12       F87 2    70
3.6720     -3.0       3.0       0.0       1.80      4.14       F87 2    71
3.7085     -3.0       3.0       0.0       0.50      0.83       F87 2    72
3.7263      2.0       2.0       0.0       0.10      0.10       F87 2    73
3.7670      2.0       2.0       0.0       1.00      1.00       F87 2    74
3.7945      2.0       2.0       0.0       3.50      3.41       F87 2    75
3.8473      2.0       2.0       0.0       0.60      3.00       F87 2    76
3.8529      2.0       2.0       0.0       0.15      0.14       F87 2    77
3.8895     -3.0       3.0       0.0       1.30      2.27       F87 2    78
3.9006     -1.0       1.0       0.0       0.05      0.03       F87 2    79
3.9204     -3.0       3.0       0.0       1.00      1.68       F87 2    80
4.0000     -1.0       1.0       0.0       6.00      3.22       F87 2    81
ENDDATA              64                                        F87 2    82
ENDSUBENT             2                                        F87 299999
SUBENT          F87   3             0                          F87 3     1
BIB                   2            14                          F87 3     2
REACTION   31P(P,ALPHA1)28SI                                   F87 3     3
COMMENTS   DATA OBTAINED FROM TABLE 4.2 OF THE REFERENCE. ONLY THE  F87 3     4
           RESULTS FOR THE FIRST-STATE ALPHA-EMISSION CHANNEL ARE   F87 3     5
           REPRODUCED FROM THE TABLE. EP = RESONANCE PROTON ENERGY. F87 3     6
           J-PI = RESONANCE SPIN/PARITY. L = ORBITAL ANGULAR MOMEN- F87 3     7
           TUM. S = COUPLED SPIN OF ALPHA PARTICLE + 28SI. GAMMA    F87 3     8
           = RESONANCE WIDTH FOR ALPHA1 EMISSION. GAMMA2 = REDUCED  F87 3     9
           WIDTH. VALUES EXTRACTED FROM FITS TO EXCITATION FUNCTION. F87 3    10
           NO ERRORS ARE GIVEN FOR THE WIDTHS DERIVED FROM THE DATA; F87 3    11
           HOWEVER, QUALITATIVE VALUES FOR THE ERRORS IN THE WIDTHS F87 3    12
           ARE GIVEN IN THE TEXT OF THE THESIS (P. 99). THE J-PI    F87 3    13
           ASSIGNMENTS ARE NOT ALWAYS UNIQUE. AMBIGUITIES FOR       F87 3    14
           THREE RESONANCES ARE: 3.2174 KEV (3+,2+), 3.6494 KEV     F87 3    15
           (2+,0+), 3.7408 (1-,2+).                                 F87 3    16
ENDBIB               14                                        F87 3    17
DATA                  6            31                          F87 3    18
EP         J-PI       L         S         GAMMA     GAMMA2     F87 3    19
MEV        NO-DIM     NO-DIM    NO-DIM    KEV       KEV        F87 3    20
 3.0341     3.0       2.0       2.0       0.002     0.54       F87 3    21
 3.0500    -2.0       1.0       2.0       0.18      19.94      F87 3    22
 3.0636     2.0       1.0       2.0       0.12      8.97       F87 3    23
 3.0975    -2.0       1.0       2.0       0.80      80.35      F87 3    24
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 3.1015    0.0        2.0        2.0        0.10       22.71        F87 3    25
 3.1906   -3.0        1.0        2.0        0.01       0.66         F87 3    26
 3.2174    3.0        0.0        2.0        0.02       2.94         F87 3    27
 3.2376    2.0        0.0        2.0        0.10       3.27         F87 3    28
 3.2515    2.0        0.0        2.0        0.50       17.77        F87 3    29
 3.2762   -4.0        3.0        2.0        0.025      8.87         F87 3    30
 3.3941    3.0        2.0        2.0        0.08       5.84         F87 3    31
 3.4260    1.0        2.0        2.0        0.50       35.71        F87 3    32
 3.4710    3.0        2.0        2.0        0.08       4.56         F87 3    33
 3.4875   -1.0        1.0        2.0        0.06       1.50         F87 3    34
 3.5445    2.0        0.0        2.0        0.12       1.73         F87 3    35
 3.5841   -1.0        1.0        2.0        0.40       7.56         F87 3    36
 3.6202   -3.0        1.0        2.0        0.15       2.56         F87 3    37
 3.6319    2.0        0.0        2.0        0.25       2.84         F87 3    38
 3.6404   -1.0        1.0        2.0        0.15       2.42         F87 3    39
 3.6494    2.0        2.0        2.0        0.05       1.61         F87 3    40
 3.6720   -3.0        1.0        2.0        0.80       11.84        F87 3    41
 3.7160   -1.0        1.0        2.0        0.10       1.32         F87 3    42
 3.7263    2.0        0.0        2.0        0.14       1.24         F87 3    43
 3.7348   -3.0        1.0        2.0        0.15       1.88         F87 3    44
 3.7408   -1.0        1.0        2.0        0.20       2.65         F87 3    45
 3.8230   -2.0        1.0        2.0        0.10       1.00         F87 3    46
 3.8473    2.0        0.0        2.0        0.30       1.99         F87 3    47
 3.8529    2.0        0.0        2.0        0.08       0.52         F87 3    48
 3.9329    2.0        0.0        2.0        0.12       0.65         F87 3    49
 3.9454   -3.0        1.0        2.0        0.10       0.75         F87 3    50
 3.9678    2.0        0.0        2.0        0.10       0.54         F87 3    51
ENDDATA              33                                             F87 3    52
ENDSUBENT             3                                             F87 399999
SUBENT           F87  4          0                                  F87 4     1
BIB                   2          7                                  F87 4     2
REACTION   31P(P,ALPHA0)28SI                                        F87 4     3
COMMENTS   INFORMATION COMES FROM TABLE 4.3 OF REFERENCE. SOME OF   F87 4     4
           THE RESONANCE AMPLITUDES ARE NEGATIVE. PRESENT TABLE HAS F87 4     5
           ONLY DATA FOR THOSE RESONANCES WITH NEGATIVE AMPLITUDES. F87 4     6
           OTHERWISE, RESONANCE AMPLITUDES IN SUBENTRY F87 2 ABOVE  F87 4     7
           ARE ASSUMED TO HAVE POSITIVE SIGNS. THE QUANTITIES IN    F87 4     8
           PRESENT TABLE ARE DEFINED AS IN SUBENTRY F87 2 ABOVE.    F87 4     9
ENDBIB                7                                             F87 4    10
DATA                  5          3                                  F87 4    11
EP         J-PI       L          S          GAMMA                   F87 4    12
MEV        NO-DIM     NO-DIM     NO-DIM     KEV                     F87 4    13
 2.8545   -1.0        1.0        0.0        -25.0                   F87 4    14
 3.1357   -3.0        3.0        0.0        -0.25                   F87 4    15
 3.1713   -3.0        3.0        0.0        -0.80                   F87 4    16
ENDDATA               5                                             F87 4    17
ENDSUBENT             4                                             F87 499999
SUBENT           F87  5          0                                  F87 5     1
BIB                   2          7                                  F87 5     2
REACTION   31P(P,ALPHA1)28SI                                        F87 5     3
COMMENTS   INFORMATION COMES FROM TABLE 4.3 OF REFERENCE. SOME OF   F87 5     4
           THE RESONANCE AMPLITUDES ARE NEGATIVE. PRESENT TABLE HAS F87 5     5
           ONLY DATA FOR THE RESONANCE WITH A NEGATIVE AMPLITUDE.   F87 5     6
           OTHERWISE, RESONANCE AMPLITUDES IN SUBENTRY F87 3 ABOVE  F87 5     7
           ARE ASSUMED TO HAVE POSITIVE SIGNS. THE QUANTITIES IN    F87 5     8
           PRESENT TABLE ARE DEFINED AS IN SUBENTRY F87 3 ABOVE.    F87 5     9
ENDBIB                7                                             F87 5    10
DATA                  5          1                                  F87 5    11
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EP          J-PI        L           S           GAMMA                      F87 5    12
MEV         NO-DIM      NO-DIM      NO-DIM      KEV                        F87 5    13
 3.0975     -2.0         1.0         2.0        -0.80                      F87 5    14
ENDDATA              3                                                     F87 5    15
ENDSUBENT            5                                                     F87 599999
SUBENT          F87  6          0                                          F87 6     1
BIB                  2          6                                          F87 6     2
REACTION    31P(P,ALPHA0)28SI                                              F87 6     3
COMMENTS    GROUND-STATE THERMONUCLEAR REACTION RATES FROM TABLE 5.3 F87 6     4
            OF THE REFERENCE. T9 = STELLAR TEMPERATURE IN 10**9 DEG  F87 6     5
            KELVIN. REAC-RATE = REACTION RATE DEFINED IN THE TEXT.     F87 6     6
            NOTE THAT THIS TABLE IS ALSO REPRODUCED IN REF. F+88       F87 6     7
            AND IS INCLUDED IN THE EXFOR FILE FOR THAT DOCUMENT.       F87 6     8
ENDBIB               6                                                     F87 6     9
DATA                 2          10                                         F87 6    10
T9          REAC-RATE                                                      F87 6    11
10**9K      CM**3/MOL/S                                                    F87 6    12
 1.0         2.5400E+01                                                    F87 6    13
 1.5         1.5900E+03                                                    F87 6    14
 2.0         1.5700E+04                                                    F87 6    15
 2.5         6.4300E+04                                                    F87 6    16
 3.0         1.6400E+05                                                    F87 6    17
 3.5         3.2000E+05                                                    F87 6    18
 4.0         5.2600E+05                                                    F87 6    19
 4.5         7.6600E+05                                                    F87 6    20
 5.0         1.0300E+06                                                    F87 6    21
 5.5         1.3100E+06                                                    F87 6    22
ENDDATA             12                                                     F87 6    23
ENDSUBENT            6                                                     F87 699999
ENDENTRY             6                                                     F879999999
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F+88

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ENTRY            F+88           0                                          F+88 0    1
SUBENT       F+88  1            0                                          F+88 1    1
BIB                12          36                                          F+88 1    2
INSTITUTE   (USATNL)                                                       F+88 1    3
REFERENCE   (J,PR/C,37,1,28,1988)                                          F+88 1    4
AUTHORS     (D.F.FANG, E.G.BILPUCH,C.R.WESTERFELDT,G.E.MITCHELL)           F+88 1    5
TITLE       PROTON RESONANCES IN 32S FROM EX = 9.83 TO 12.74 MEV           F+88 1    6
FACILITY    (VDG) KN VAN DE GRAAFF ACCELERATOR AND ASSOCIATED HIGH         F+88 1    7
            RESOLUTION TARGET SYSTEM, TRIANGLE UNIVERSITY NUCLEAR          F+88 1    8
            LABORATORY, DURHAM, NORTH CAROLINA.                            F+88 1    9
INC-PART    (P) PROTONS                                                    F+88 1   10
TARGETS     EVAPORATED ZN3P2 ONTO ULTRA-PURE NI-COATED CARBON FOILS.       F+88 1   11
            CARBON THICKNESS (4-5 MICROGRAM/CM**2). NI THICKNESS           F+88 1   12
            (0.5 MICROGRAM/CM**2). TARGETS CONTAINED 1-3 MICROGRAM/        F+88 1   13
            CM**2 OF 31P. NI WAS ADDED TO BACKING FOR STABILITY AND        F+88 1   14
            UNIFORMITY.                                                    F+88 1   15
METHOD      PROTON BEAMS WITH ENERGY BETWEEN 1.00 AND 4.01 MEV WERE        F+88 1   16
            INCIDENT ON TARGETS. PROTON-INDUCED REACTION YIELDS WERE       F+88 1   17
            MEASURED USING SURFACE BARRIER DETECTORS PLACED AT 90,         F+88 1   18
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            127, 145 AND 165 DEGREES. TRANSMISSION DETECTORS WERE    F+88 1   19
            USED TO IDENTIFY ALPHA PARTICLES AT 108, 135 AND 165     F+88 1   20
            DEGREES. SOLID ANGLE ADJUSTED SO RUTHERFORD SCATTERING   F+88 1   21
            YIELD WAS APPROXIMATELY EQUAL FOR ALL COUNTERS.          F+88 1   22
            MEASURED EXCITATION FUNCTIONS. 300-400 EV RESOLUTION.    F+88 1   23
            ENERGY STEPS IN RANGE 100-400 EV. EXTRACTED RESONANCE    F+88 1   24
            PARAMETERS WITH MULTI-LEVEL, MULTI-CHANNEL R-MATRIX      F+88 1   25
            CODE. SEARCHED FOR ANALOG STATES. EXAMINED INVERSE       F+88 1   26
            REACTIONS. MORE DETAILS ARE GIVEN IN THE ARTICLE.        F+88 1   27
DETECTORS   (SOLST) SI SURFACE BARRIER AND TRANSMISSION DETECTORS.   F+88 1   28
CORRECTION  NO DISCUSSION OF DATA CORRECTIONS IS PROVIDED.           F+88 1   29
ERR-ANALYS  MOST EXCITATION FUNCTIONS WERE MEASURED TWICE TO INSURE  F+88 1   30
            REPRODUCIBILITY. RESONANCE ENERGY UNCERTAINTY GENERALLY  F+88 1   31
            WAS ABOUT 3 KEV. A 10% UNCERTAINTY WAS ESTIMATED FOR     F+88 1   32
            THE WIDTHS OF SMALL RESONANCES AND 20% FOR THE LARGE     F+88 1   33
            RESONANCES. ONLY LIMITED NUMERICAL RESULTS ARE PROVIDED  F+88 1   34
            IN THE ARTICLE. AUTHORS MUST BE CONTACTED TO OBTAIN      F+88 1   35
            EXPERIMENTAL RESULTS IN GREATER DETAIL.                  F+88 1   36
STATUS      PUBLISHED IN PHYSICAL REVIEW. RESULTS IN THE PAPER: 8    F+88 1   37
            FIGURES AND 4 TABLES. CONTACT AUTHORS FOR MORE DATA.     F+88 1   38
ENDBIB              36                                               F+88 1   39
ENDSUBENT            1                                               F+88 199999
SUBENT        F+88  2          0                                     F+88 2    1
BIB                 2          8                                     F+88 2    2
REACTION    31P(P,ALPHA0)28SI                                        F+88 2    3
COMMENTS    DATA OBTAINED FROM TEXT AND TABLE I FOUND IN ARTICLE.    F+88 2    4
            THIS TABLE IS CONCERNED WITH LEVEL INTERFERENCE EFFECTS. F+88 2    5
            NUM-RES = INTEGER WHICH IDENTIFIES RESONANCE IN 32S.     F+88 2    6
            EP = RESONANCE ENERGY. J-PI = RESONANCE SPIN/PARITY.     F+88 2    7
            GAMMA-ALPHA = WIDTH FOR ALPHA-DECAY OF RESONANCE.        F+88 2    8
            IT IS ASSUMED S = S' = 0, L = L' = 1 FOR RESONANCE 1 AND F+88 2    9
            S = S' = 0, L = L' = 2 FOR RESONANCE 2.                  F+88 2   10
ENDBIB               8                                               F+88 2   11
DATA                 4         2                                     F+88 2   12
NUM-RES     EP         J-PI       GAMMA-ALPHA                        F+88 2   13
NO-DIM      MEV        NO-DIM     KEV                                F+88 2   14
          1 2.0220     -1.0        3.00                              F+88 2   15
          2 2.0233      2.0        0.14                              F+88 2   16
ENDDATA              4                                               F+88 2   17
ENDSUBENT            2                                               F+88 299999
SUBENT        F+88  3          0                                     F+88 3    1
BIB                 2          7                                     F+88 3    2
REACTION    31P + P                                                  F+88 3    3
COMMENTS    DATA OBTAINED FROM TABLE II FOUND IN ARTICLE. THIS TABLE F+88 3    4
            IDENTIFIES RESONANCES WHICH CORRESPOND TO LEVELS IN 32S  F+88 3    5
            WHICH ARE ANALOGS TO THOSE IN 32P. EX = EXCITATION       F+88 3    6
            ENERGY IN 32S, EP = RESONANCE PROTON ENERGY. J-PI =      F=88 3    7
            RESONANCE SPIN/PARITY. L = ORBITAL ANGULAR MOMENTUM      F+88 3    8
            OF RESONANCE. GAMMA-P = PROTON WIDTH.                    F+88 3    9
ENDBIB              7                                                F+88 3   10
DATA                5         10                                     F+88 3   11
EX          EP         J-PI       L          GAMMA-P                 F+88 3   12
MEV         MEV        NO-DIM     NO-DIM     KEV                     F+88 3   13
 10.075      1.250     -2.0                   1.50                   F+88 3   14
 10.223      1.403     -3.0                   0.016                  F+88 3   15
 10.257      1.438     -4.0                   0.035                  F+88 3   16
 10.398      1.583     -4.0                   0.012                  F+88 3   17
 10.368      1.557      2.0                   0.025                  F+88 3   18
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  10.791     1.989       2.0                        0.08                   F+88 3   19
  10.824     2.023       2.0                        0.17                   F+88 3   20
  10.977     2.181      -2.0         1.0            6.60                   F+88 3   21
  10.977     2.181      -2.0         3.0            0.10                   F+88 3   22
  11.092     2.300      -3.0                        0.03                   F+88 3   23
ENDDATA             12                                                     F+88 3   24
ENDSUBENT            3                                                     F+88 399999
SUBENT          F+88  4          0                                         F+88 4    1
BIB                  2           4                                         F+88 4    2
REACTION    31P(P,ALPHA0)28SI                                              F+88 4    3
COMMENTS    GROUND-STATE THERMONUCLEAR REACTION RATES FROM TABLE IV        F+88 4    4
            OF THE ARTICLE. T9 = STELLAR TEMPERATURE IN 10**9 DEG          F+88 4    5
            KELVIN. REAC-RATE = REACTION RATE DEFINED IN THE TABLE.        F+88 4    6
ENDBIB               4                                                     F+88 4    7
DATA                 2          10                                         F+88 4    8
T9          REAC-RATE                                                      F+88 4    9
10**9K      CM**3/MOL/S                                                    F+88 4   10
 1.0         2.5400E+01                                                    F+88 4   11
 1.5         1.5900E+03                                                    F+88 4   12
 2.0         1.5700E+04                                                    F+88 4   13
 2.5         6.4300E+04                                                    F+88 4   14
 3.0         1.6400E+05                                                    F+88 4   15
 3.5         3.2000E+05                                                    F+88 4   16
 4.0         5.2600E+05                                                    F+88 4   17
 4.5         7.6600E+05                                                    F+88 4   18
 5.0         1.0300E+06                                                    F+88 4   19
 5.5         1.3100E+06                                                    F+88 4   20
ENDDATA             12                                                     F+88 4   21
ENDSUBENT            4                                                     F+88 499999
SUBENT          F+88  5          0                                         F+88 5    1
BIB                  2           5                                         F+88 5    2
REACTION    28SI(ALPHA,P0)31P                                              F+88 5    3
COMMENTS    GROUND-STATE THERMONUCLEAR REACTION RATES FROM TABLE IV        F+88 5    4
            OF THE ARTICLE. INVERSE OF 31P(P,ALPHA0)28SI REACTION.         F+88 5    5
            T9 = STELLAR TEMPERATURE IN 10**9 DEG KELVIN. REAC-RATE        F+88 5    6
            = REACTION RATE AS DEFINED IN THE TABLE.                       F+88 5    7
ENDBIB               5                                                     F+88 5    8
DATA                 2          10                                         F+88 5    9
T9          REAC-RATE                                                      F+88 5   10
10**9K      CM**3/MOL/S                                                    F+88 5   11
 1.0        3.9200E-09                                                     F+88 5   12
 1.5        4.1400E-04                                                     F+88 5   13
 2.0        1.7500E-01                                                     F+88 5   14
 2.5        6.9400E+00                                                     F+88 5   15
 3.0        8.1100E+01                                                     F+88 5   16
 3.5        4.2800E+02                                                     F+88 5   17
 4.0        1.7400E+03                                                     F+88 5   18
 4.5        4.7300E+03                                                     F+88 5   19
 5.0        1.0800E+04                                                     F+88 5   20
 5.5        2.0900E+04                                                     F+88 5   21
ENDDATA             12                                                     F+88 5   22
ENDSUBENT            5                                                     F+88 599999
ENDENTRY             5                                                     F+889999999
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HG81

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ENTRY            HG81           0                                            HG81 0      1
SUBENT         HG81   1         0                                            HG81 1      1
BIB                   5        12                                            HG81 1      2
INSTITUTE  (GERBOC)                                                          HG81 1      3
REFERENCE  (J,JP/G,7,1099,1981)                                              HG81 1      4
AUTHORS    (C.C.HSU ,B.GONSIOR)                                              HG81 1      5
TITLE      COMMENT ON THE COMPOUND-NUCLEUS CROSS SECTION FROM                HG81 1      6
           NUCLEAR CHARGE-DENSITY DISTRIBUTIONS                              HG81 1      7
COMMENTS   A SIMPLIFIED HAUSER-FESHBACH FORMALISM ORIGINALLY                 HG81 1      8
           DEVELOPED FOR HEAVY-ION STUDIES IS APPLIED TO LIGHT-              HG81 1      9
           ION REACTIONS. THIS FORMALISM IS USED TO CALCULATE THE            HG81 1     10
           COMPOUND-NUCLEUS FORMATION CROSS SECTION, THE STRENGTH            HG81 1     11
           FUNCTION (<GAMMA>/DO), THE REACTION CROSS SECTION FOR             HG81 1     12
           31P(P,ALPHAO)28SI, AND THE MAXIMUM ORBITAL ANGULAR                HG81 1     13
           MOMENTUM CONTRIBUTING TO THIS REACTION CROSS SECTION.             HG81 1     14
ENDBIB               12                                                      HG81 1     15
ENDSUBENT             1                                                      HG81 199999
SUBENT         HG81   2         0                                            HG81 2      1
BIB                   2         7                                            HG81 2      2
REACTION   31P(P,ALPHAO)28SI                                                 HG81 2      3
COMMENTS   THESE DATA ARE OBTAINED FROM TABLE I OF THE ARTICLE.              HG81 2      4
           EMIN = MINIMUM PROTON ENERGY OF RANGE. EMAX = MAXIMUM             HG81 2      5
           PROTON ENERGY OF RANGE. SIG = REACTION CROSS SECTION.             HG81 2      6
           STRENG = <GAMMA>/DO. LMI = MAXIMUM ORBITAL ANGULAR                HG81 2      7
           IN THE INCOMING CHANNEL. LMO = MAXIMUM ORBITAL ANGULAR            HG81 2      8
           MOMENTUM FOR THE OUTGOING CHANNEL.                                HG81 2      9
ENDBIB                7                                                      HG81 2     10
DATA                  6         1                                            HG81 2     11
EMAX       EMIN       SIG        STRENG     LMI        LMO                   HG81 2     12
MEV        MEV        MILLIBARN  NO-DIM     NO-DIM     NO-DIM                HG81 2     13
 8.5        11.6       2.0        17.2       3.0        3.0                  HG81 2     14
ENDDATA               3                                                      HG81 2     15
ENDSUBENT             2                                                      HG81 299999
ENDENTRY              2                                                      HG819999999
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I+91

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ENTRY            I+91           0                                            I+91 0      0
SUBENT         I+91   1         0                                            I+91 1      1
BIB                  12        62                                            I+91 1      2
INSTITUTES (USACAL)                                                          I+91 1      3
           (USATOL)                                                          I+91 1      4
           (USANOT)                                                          I+91 1      5
           (CANTOR)                                                          I+91 1      6
           (CANRPI)                                                          I+91 1      7
REFERENCE  (J,NP/A,533,153,1991)                                             I+91 1      8
AUTHORS    (C.ILIADIS,U.GIESEN,J.GORRES,S.GRAFF,M.WIESCHER,                  I+91 1      9
           R.E.AZUMA,J.KING,M.BUCKBY,C.A.BARNES,T.R.WANG)                    I+91 1     10
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TITLE      THE REACTION BRANCHING 31P(P,GAMMA)/31P(P,ALPHA) IN THE  I+91 1    11
           RP-PROCESS.                                              I+91 1    12
FACILITIES (PEL) 3-MV PELLETRON TANDEM ACCELERATOR, KELLOGG         I+91 1    13
           RADIATION LABORATORY, CALIFORNIA INSTITUTE OF            I+91 1    14
           TECHNOLOGY, PASADENA, CALIFORNIA.                        I+91 1    15
           (VDG) 1-MV VAN DE GRAAFF ACCELERATOR, UNIVERSITY         I+91 1    16
           OF TORONTO, TORONTO, CANADA.                             I+91 1    17
           (C-W) 350-KV COCKCROFT-WALTON ACCELERATOR, UNIVERSITY    I+91 1    18
           OF TOLEDO, TOLEDO, OHIO (FOR 31P ION IMPLANTATION).      I+91 1    19
INC-PART   (P) PROTONS.                                             I+91 1    20
TARGET     31P IONS IMPLANTED INTO A 0.5-MM-THICK TA BACKING WITH   I+91 1    21
           DOSAGE OF 133 MICROAMPERE-HOUR AT 200 KEV YIELDED A      I+91 1    22
           TARGET THICKNESS OF 15 KEV AT 355 KEV BOMBARDING ENERGY. I+91 1    23
           THESE TARGETS WERE FABRICATED AT UNIVERSITY OF TOLEDO    I+91 1    24
           COCKCROFT-WALTON ACCELERATOR FACILITY. FOR IMPLANTATION  I+91 1    25
           31P BEAM WAS SCANNED ACROSS A 1.5 CM**2 AREA TO INSURE   I+91 1    26
           PRODUCING A UNIFORM TARGET. TARGET BACKING WAS DIRECTLY  I+91 1    27
           WATER COOLED DURING EXPERIMENT TO INSURE STABILITY AND   I+91 1    28
           SURVIVAL OF TARGET. TARGET THICKNESS AND STOICHIOMETRY   I+91 1    29
           (TA2P3) WERE DETERMINED BY MEASURING THICK-TARGET YIELD  I+91 1    30
           OF WELL-KNOWN 32P(P,GAMMA)32S RESONANCE AT EP = 811 KEV. I+91 1    31
METHOD     MEASUREMENTS FOR 31P(P,GAMMA)32S WERE PERFORMED AT THE   I+91 1    32
           3-MV CAL TECH PELLETRON (EP = 0.35 - 0.62 MEV). BEAMS UP I+91 1    33
           TO 100 MICROAMPERES WITH 1-KEV RESOLUTION WERE USED.     I+91 1    34
           ENERGY RESOLUTION AND CALIBRATION WERE DETERMINED USING  I+91 1    35
           THE 27AL(P,GAMMA)28SI RESONANCE AT 991.88 KEV AND THE    I+91 1    36
           811-KEV RESONANCE IN 31P(P,GAMMA)32S. MEASUREMENTS FOR   I+91 1    37
           31P(P,GAMMA)32S AND 31P(P,ALPHA)28SI WERE CARRIED OUT    I+91 1    38
           AT THE UNIV. OF TORONTO 1-MV VAN DE GRAAFF (EP = 0.28 -  I+91 1    39
           0.45 MEV). ENERGY RESOLUTION WAS 1 KEV AND UNCERTAINTY   I+91 1    40
           IN ABSOLUTE BEAM ENERGY WAS 2 KEV. TA COLIMATORS WERE    I+91 1    41
           USED TO DEFINE PROTON BEAMS ON THE TARGETS. TARGETS      I+91 1    42
           WERE NEGATIVELY BIASED WITH 300 VOLTS TO SUPPRESS        I+91 1    43
           EMISSION OF SECONDARY ELECTRONS. GAMMA RAYS WERE         I+91 1    44
           MEASURED WITH A GE DETECTOR AT 55 DEG. ALPHA PARTICLES   I+91 1    45
           WERE MEASURED WITH SURFACE BARRIER DETECTORS AT 90 AND   I+91 1    46
           135 DEG. PROTONS WERE SUPPRESSED BY 2.2 MICROMETER       I+91 1    47
           HAVAR FOILS POSITIONED BEFORE THE ALPHA-PARTICLE         I+91 1    48
           DETECTORS. BACKGROUND WAS A TROUBLESOME PROBLEM IN       I+91 1    49
           ANALYSIS OF THE RECORDED ALPHA-PARTICLE SPECTRA.         I+91 1    50
           RESONANCE ENERGIES WERE CALCULATED FROM A KNOWLEDGE OF   I+91 1    51
           REACTION Q-VALUES AND GAMMA-RAY TRANSITIONS TO GROUND    I+91 1    52
           STATE AND KNOWN EXCITED STATES IN 32S. RESONANCE         I+91 1    53
           STRENGTHS WERE DETERMINED FROM GAMMA-RAY AND ALPHA-      I+91 1    54
           PARTICLE YIELDS ACCORDING TO PROCEDURES DESCRIBED IN     I+91 1    55
           THE PAPER.                                               I+91 1    56
DETECTORS  (GE) 35-PERCENT EFFICIENT GE PHOTON DETECTOR.            I+91 1    57
           (SOLST) TWO SURFACE BARRIER DETECTORS WITH 450 MM**2     I+91 1    58
           AREA (USED TO MEASURE ALPHA-PARTICLE SPECTRA).           I+91 1    59
MONITOR    (CI) CURRENT INTEGRATOR (USED TO NORMALIZE DATA).        I+91 1    60
CORRECTION A CORRECTION WAS APPLIED FOR ANGULAR DISTRIBUTION        I+91 1    61
           EFFECTS IN THE ANALYSIS OF 31P(P,ALPHA)28SI DATA.        I+91 1    62
STATUS     PUBLISHED IN NUCLEAR PHYSICS. EIGHT FIGURES AND FIVE     I+91 1    63
           DATA TABLES ARE AVAILABLE FROM THIS SOURCE.              I+91 1    64
ENDBIB             62                                               I+91 1    65
ENDSUBENT           1                                               I+91 199999
SUBENT        I+91  2          0                                    I+91 2     1
BIB                 2          6                                    I+91 2     2
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REACTION   31P(P,ALPHA)28SI                                               I+91 2     3
COMMENTS   SINGLE RESONANCE ENERGY IS GIVEN IN TABLE 1 OF ARTICLE.        I+91 2     4
           EX = RESONANCE EXCITATION ENERGY IN THE NUCLEUS 32S.           I+91 2     5
           J-PI = RESONANCE SPIN/PARITY. T = RESONANCE ISOSPIN.           I+91 2     6
           ER = RESONANCE ENERGY (ESSENTIALLY EQUIVALENT TO THE           I+92 2     7
           INCIDENT PROTON ENERGY). ERR-ER = UNCERTAINTY IN ER.           I+91 2     8
ENDBIB               6                                                    I+91 2     9
DATA                 5          1                                         I+91 2    10
EX         J-PI       T          ER         ERR-ER                        I+91 2    11
MEV        NO-DIM     NO-DIM     KEV        KEV                           I+91 2    12
 9.236     -1.0        0.0        383.0      2.0                          I+91 2    13
ENDDATA              3                                                    I+91 2    14
ENDSUBENT            2                                                    I+91 299999
SUBENT         I+91  3          0                                         I+91 3     1
BIB                  2          6                                         I+91 3     2
REACTION   31P(P,ALPHA)28SI                                               I+91 3     3
COMMENTS   DATA OBTAINED FROM TABLE 3 OF ARTICLE. ER = RESONANCE          I+91 3     4
           ENERGY. J-PI = RESONANCE SPIN/PARITY. STRENG = RESONANCE       I+91 3     5
           STRENGTH AS DEFINED IN EQ. (1) OF THE PAPER. ERR-STRENG        I+91 3     6
           = UNCERTAINTY IN STRENG. NOTE THAT THOSE VALUES GIVEN          I+91 3     7
           FOR THE 342- AND 403-KEV RESONANCES ARE UPPER LIMITS.          I+91 3     8
ENDBIB               6                                                    I+91 3     9
DATA                 4          3                                         I+91 3    10
ER         J-PI       STRENG     ERR-STRENG                               I+91 3    11
KEV        NO-DIM     EV         EV                                       I+91 3    12
 342.0      2.0        4.2000E-04                                         I+91 3    13
 383.0     -1.0        2.7000E-03 7.0000E-04                              I+91 3    14
 403.0      2.0        2.6000E-04                                         I+91 3    15
ENDDATA              5                                                    I+91 3    16
ENDSUBENT            3                                                    I+91 399999
SUBENT         I+91  4          0                                         I+91 4     1
BIB                  2          10                                        I+91 4     2
REACTION   31P(P,ALPHA)28SI                                               I+91 4     3
COMMENTS   TWO LOW-LYING RESONANCES IN THIS REACTION CHANNEL ARE          I+91 4     4
           TOO WEAK TO OBSERVE SO THEIR STRENGTHS WERE CALCULATED         I+91 4     5
           BY INDIRECT MEANS. EX = RESONANCE EXCITATION ENERGY IN         I+91 4     6
           32S. ER = RESONANCE ENERGY (ESSENTIALLY EQUIVALENT TO          I+91 4     7
           INCIDENT PROTON ENERGY IF MEASUREMENT COULD BE DONE).          I+91 4     8
           J-PI = RESONANCE SPIN/PARITY. GAM-P = RESONANCE PROTON         I+91 4     9
           WIDTH. GAM-A = RESONANCE ALPHA WIDTH. STRENG = RESONANCE       I+91 4    10
           STRENGTH AS DEFINED IN EQ. (1) OF THE ARTICLE. DATA ARE        I+91 4    11
           OBTAINED FROM TABLE 4 OF THE PAPER.                            I+91 4    12
ENDBIB               10                                                   I+91 4    13
DATA                 6          2                                         I+91 4    14
EX         ER         J-PI       GAM-P      GAM-A      STRENG             I+91 4    15
MEV        KEV        NO-DIM     EV         EV         EV                 I+91 4    16
 9.023      163.0     -3.0        5.5000E-11 0.014      4.9000E-11        I+91 4    17
 9.065      206.0      4.0        7.0000E-11 0.003      5.8000E-11        I+91 4    18
ENDDATA              4                                                    I+91 4    19
ENDSUBENT            4                                                    I+91 499999
SUBENT         I+91  5          0                                         I+91 5     1
BIB                  2          8                                         I+91 5     2
REACTION   31P(P,A)28SI                                                   I+91 5     3
COMMENTS   REACTION RATES (RR) ARE GIVEN IN TABLE 5. RR =                 I+95 5     4
           NA<SIG*V> IN UNITS OF CM**3/MOL/SEC (CM3/MOL/S).               I+91 5     5
           REACTION RATES ARE CALCULATED USING EQ. (4) IN PAPER.          I+91 5     6
           RR(UBOBS) = RR CONTRIBUTION FROM UNOBSERVED RESONANCES.        I+91 5     7
           RR(OBS) = RR CONTRIBUTION FROM OBSERVED RESONANCES.            I+91 5     8
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           RR(TOT) = RR(OBS) + RR(UOBS). T9 = STELLAR TEMPERATURE   I+91 5     9
           IN UNITS OF 10**9 DEG. KELVIN (10**9K).                  I+91 5    10
ENDBIB               8                                              I+91 5    11
DATA                 4          9                                   I+91 5    12
T9         RR(UNOBS)  RR(OBS)    RR(TOT)                            I+91 5    13
10**9K     CM3/MOL/S  CM3/MOL/S  CM3/MOL/S                          I+91 5    14
 0.05       8.3900E-20 1.2400E-33 8.3009E-20                        I+91 5    15
 0.08       3.9000E-14 7.0600E-20 3.9000E-14                        I+91 5    16
 0.1        2.7500E-12 2.4600E-15 2.7500E-12                        I+91 5    17
 0.2        1.0200E-08 2.0600E-06 2.0700E-06                        I+91 5    18
 0.3        1.3200E-07 1.5400E-03 1.5400E-03                        I+91 5    19
 0.5        8.2700E-07 5.6400E-01 5.6400E-01                        I+91 5    20
 0.8        1.8400E-06 4.5800E+01 4.5800E+01                        I+91 5    21
 1.0        2.1800E-06 2.3600E+02 2.3600E+02                        I+91 5    22
 2.0        2.1600E-06 2.0300E+04 2.0300E+04                        I+91 5    23
ENDDATA             11                                              I+91 5    24
ENDSUBENT            5                                              I+91 599999
ENDENTRY             5                                              I+919999999
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I+93

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ENTRY            I+93           0                                   I+93 0     1
SUBENT       I+93   1           0                                   I+93 1     1
BIB                 11         32                                   I+93 1     2
INSTITUTE  (USANOT)                                                 I+93 1     3
           (GERBOC)                                                 I+93 1     4
           (CANKQU)                                                 I+93 1     5
REFERENCE  (J,NP/A,559,83,1993)                                     I+93 1     6
AUTHORS    (C.ILIADIS,J.GORRES,J.G.ROSS,K.W.SCHELLER,M.WIESCHER,    I+93 1     7
           C.GRAMA,TH.SCHANGE,H.P.TRAUTVETTER,H.C.EVANS)            I+93 1     8
TITLE      EXPLOSIVE HYDROGEN BURNING OF 31P                        I+93 1     9
FACILITY   400-KV ACCELERATOR, RUHR UNIVERSITAET, BOCHUM, GERMANY.  I+93 1    10
           NOTE: MEASUREMENTS WERE ALSO PERFORMED ON THE 4-MV VAN   I+93 1    11
           DE GRAAFF AT QUEEN'S UNIVERSITY, KINGSTON, ONTARIO,      I+93 1    12
           CANADA, BUT ONLY FOR 31P(P,GAMMA) AND NOT FOR (P,ALPHA). I+93 1    13
INC-PART   (P) PROTONS.                                             I+93 1    14
TARGETS    31P TARGETS WERE PREPARED BY ION IMPLANTATION.           I+93 1    15
           A 0.25-MM-THICK TANTALUM BACKING WAS BOMBARDED WITH 31P  I+93 1    16
           IONS USING SNICS SOURCE AT NOTRE DAME. A TANTALUM TO     I+93 1    17
           PHOSPHORUS RATIO OF 0.8 +- 0.2 WAS OBTAINED WITH A DOSE  I+93 1    18
           OF 200 MICROAMP-H AT 80 KEV. TARGET WAS DIRECTLY WATER   I+93 1    19
           COOLED DURING THE (P,ALPHA) MEASUREMENTS AT BOCHUM.      I+93 1    20
METHOD     PROTON BEAM PASSED THROUGH A COLLIMATOR AND WAS FOCUSED  I+93 1    21
           ONTO THE TARGET WITH A PROFILE OF 1.5 CM. TARGET WAS     I+93 1    22
           PLACED AT 45 DEG. RELATIVE TO THE BEAM DIRECTION. ALPHA  I+93 1    23
           DETECTORS WERE SET AT 90 AND 135 DEG. LOOKED EXPLICITLY  I+93 1    24
           FOR ALPHA PARTICLES CORRESPONDING TO DECAY OF THE ER =   I+93 1    25
           200 KEV RESONANCE. NI FOILS IN FRONT OF THESE DETECTORS  I+93 1    26
           WERE USED TO STOP SCATTERED PROTONS.                     I+93 1    27
DETECTORS  (SOLST) TWO SI SURFACE BARRIER DETECTORS WERE USED.      I+93 1    28
           EACH HAD AN ACTIVE AREA OF 600 MM**2.                    I+93 1    29
CORRECTION INCIDENT PROTON ENERGIES WERE CORRECTED FOR ENERGY LOSS  I+93 1    30
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            DUE TO AN UNAVOIDABLE BUILDUP OF CARBON ON THE TARGET.   I+93 1    31
STATUS      PUBLISHED IN NUCLEAR PHYSICS. SEVEN FIGURES AND THREE    I+93 1    32
            DATA TABLES. RESULTS FROM TABLE 3 ARE INCLUDED IN THIS   I+93 1    33
            FILE.                                                    I+93 1    34
ENDBIB              32                                               I+93 1    35
ENDSUBENT            1                                               I+93 199999
SUBENT          I+93  2           0                                  I+93 2     1
BIB                  2           14                                  I+93 2     2
REACTION    31P(P,A)28SI                                             I+93 2     3
COMMENTS    STELLAR REACTION RATES BASED ON A MAXWELLIAN DISTRIB.    I+93 2     4
            ARE CALCULATED USING RESULTS FROM THE PRESENT EXPERIMENT I+93 2     5
            AND FROM THE LITERATURE. T9 = TEMPERATURE IN UNITS OF    I+93 2     6
            10**9 DEG. KELVIN (10**9K). RR = REACTION RATE IN UNITS  I+93 2     7
            OF CM**3/MOL/SEC (CM3/MOL/S). RR(OBS): OBSERVED NARROW   I+93 2     8
            RESONANCES. RR(UNOBS): UNOBSERVED NARROW RESONANCES.     I+93 2     9
            RR(WING): CONTRIBUTION FROM WINGS OF BROAD RESONANCES.   I+93 2    10
            RR(-3.5): CONTRIBUTION FROM SUBTHRESHOLD RESONANCE AT    I+93 2    11
            ER = -3.5 KEV. NOTE THAT THE VALUES GIVEN FOR RR(UNOBS)  I+93 2    12
            AND RR(-3.5) ARE UPPER LIMITS WHICH ARE CALCULATED AS    I+93 2    13
            DESCRIBED IN THE ARTICLE. THE PARTIAL CONTRIBUTIONS      I+93 2    14
            ARE USED TO DETERMINE TOTAL REACTION RATES GIVEN IN      I+93 2    15
            SUBENTRY I+93 3 BELOW.                                   I+93 2    16
ENDBIB              14                                               I+93 2    17
DATA                 5           14                                  I+93 2    18
T9          RR(OBS)    RR(UNOBS)  RR(WING)   RR(-3.5)                I+93 2    19
10**9K      CM3/MOL/S  CM3/MOL/S  CM3/MOL/S  CM3/MOL/S               I+93 2    20
 0.03        3.9400E-58 6.0600E-30 3.3200E-28 5.6500E-28             I+93 2    21
 0.05        1.5600E-33 2.7300E-19 1.6600E-22 1.1600E-22             I+93 2    22
 0.07        4.5700E-23 3.7400E-14 3.1900E-19 1.0900E-19             I+93 2    23
 0.09        2.7100E-17 3.1800E-11 5.3900E-17 1.0400E-17             I+93 2    24
 0.1         2.7600E-15 3.3300E-10 4.0800E-16 6.1300E-17             I+93 2    25
 0.15        2.5700E-09 3.4700E-07 5.1100E-13 3.2000E-14             I+93 2    26
 0.2         2.1800E-06 1.3100E-05 4.2900E-11 1.8400E-12             I+93 2    27
 0.3         1.6000E-03 1.4300E-03                                   I+93 2    28
 0.4         4.9500E-02 2.1100E-02                                   I+93 2    29
 0.5         5.7000E-01 1.0400E-01                                   I+93 2    30
 0.7         1.5000E+01 5.9600E-01                                   I+93 2    31
 1.0         2.1800E+02 1.92                                         I+93 2    32
 1.5         3.2900E+03 3.98                                         I+93 2    33
 2.0         2.3800E+04 5.07                                         I+93 2    34
ENDDATA             16                                               I+93 2    35
ENDSUBENT            2                                               I+93 299999
SUBENT          I+93  3           0                                  I+93 3     1
BIB                  2            8                                  I+93 3     2
REACTION    31P(P,A)28SI                                             I+93 3     3
COMMENTS    STELLAR REACTION RATES BASED ON A MAXWELLIAN DISTRIB.    I+93 3     4
            ARE CALCULATED USING RESULTS FROM THE PRESENT EXPERIMENT I+93 3     5
            AND FROM THE LITERATURE. T9 = TEMPERATURE IN UNITS OF    I+93 3     6
            10**9 DEG. KELVIN (10**9K). RR = REACTION RATE IN UNITS  I+93 3     7
            OF CM**3/MOL/SEC (CM3/MOL/S). COMPONENTS ARE DESCRIBED   I+93 3     8
            IN SUBENTRY I+93 2. RR(LOW) = RR(OBS) + RR(WING).        I+93 3     9
            RR(HIGH) = RR(OBS) + RR(UNOBS) + RR(WING) + RR(-3.5).    I+93 3    10
ENDBIB               8                                               I+93 3    11
DATA                 3           14                                  I+93 3    12
T9          RR(LOW)    RR(HIGH)                                      I+93 3    13
10**9K      CM3/MOL/S  CM3/MOL/S                                     I+93 3    14
 0.03        3.3200E-28 9.0300E-28                                   I+93 3    15
 0.05        1.6600E-22 2.7300E-19                                   I+93 3    16
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 0.07        3.1900E-19 3.7400E-14                                        I+93 3    17
 0.09        8.1000E-17 3.1800E-11                                        I+93 3    18
 0.1         3.1600E-15 3.3300E-10                                        I+93 3    19
 0.15        2.5700E-09 3.4900E-07                                        I+93 3    20
 0.2         2.1800E-06 1.5300E-05                                        I+93 3    21
 0.3         1.6000E-03 3.0300E-03                                        I+93 3    22
 0.4         4.9500E-02 7.0600E-02                                        I+93 3    23
 0.5         5.7000E-01 6.7400E-01                                        I+93 3    24
 0.7         1.5000E+01 1.5600E+01                                        I+93 3    25
 1.0         2.1800E+02 2.2000E+02                                        I+93 3    26
 1.5         3.2900E+03 3.2900E+03                                        I+93 3    27
 2.0         2.3800E+04 2.3800E+04                                        I+93 3    28
ENDDATA              16                                                   I+93 3    29
ENDSUBENT             3                                                   I+93 399999
ENDENTRY              3                                                   I+939999999
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K67

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ENTRY                K67          0                                       K67 0     1
SUBENT           K67  1           0                                       K67 1     1
BIB                  13          37                                       K67 1     2
INSTITUTE  (USAANL)                                                       K67 1     3
REFERENCE  (R,ANL-7289,6709)                                              K67 1     4
AUTHOR     (A.A.KATSANOS)                                                 K67 1     5
TITLE      STUDIES OF LOW-ENERGY NUCLEAR REACTIONS AND LEVEL              K67 1     6
           DENSITIES FOR MEDIUM-MASS NUCLEI                               K67 1     7
FACILITY   (VDG) TANDEM VAN DE GRAAFF ACCELERATOR, ARGONNE NATIONAL       K67 1     8
           LABORATORY, ARGONNE, ILLINOIS, U.S.A.                          K67 1     9
INC-PART   (P) PROTONS.                                                   K67 1    10
TARGETS    100 PERCENT PURE 31P TARGETS PREPARED USING ANL MASS           K67 1    11
           SEPARATOR: 10 MICROGRAM/CM**2 USED FOR MEASUREMENTS WITH       K67 1    12
           MAGNETIC SPECTROGRAPH. 20 MICROGRAM/CM**2 USED                 K67 1    13
           FOR (P,P) SCATTERING MEASUREMENTS. 50 MICROGRAM/CM**2          K67 1    14
           USED FOR STUDIES OF ERICSON FLUCTUATIONS. 0.5 - 1.0            K67 1    15
           MILLIGRAM/CM**2 USED TO MEASURE ENERGY AND ANGULAR             K67 1    16
           DISTRIBUTIONS OF ABSOLUTE CROSS SECTIONS. THESE                K67 1    17
           THICK TARGETS ALLOWED FOR AVERAGING OF THE ERICSON             K67 1    18
           FLUCTUATIONS.                                                  K67 1    19
METHOD     PROTON BEAM CURRENT WAS BETWEEN 0.5 AND 1.0 MICROAMP.          K67 1    20
           ENERGY RESOLUTION WAS 5 KEV AT 10 MEV. EP IN THE RANGE         K67 1    21
           8.37 - 11.77 MEV. THE TARGET BISECTED 90 AND 175 DEG.          K67 1    22
           LIMITING POSITIONS FOR THE ALPHA-PARTICLE DETECTORS.           K67 1    23
DETECTORS  (SOLST) SEVERAL SI SURFACE-BARRIER DETECTORS WERE USED.        K67 1    24
           DETECTORS HAD COLLIMATORS OF 0.63-CM DIA. AND NI FOILS         K67 1    25
           PLACED FRONT OF THEM TO ELIMINATE LIGHT AND LOW ENERGY         K67 1    26
           ELECTRONS. DETECTOR RANGE WAS 90 TO 175 DEG. THESE             K67 1    27
           DETECTORS SUBTENDED AN ANGLE OF 7 DEG. ALL DETECTORS           K67 1    28
           WERE SITUATED ON THE SAME REACTION PLANE.                      K67 1    29
MONITORS   (CI) BEAM-CURRENT INTEGRATOR.                                  K67 1    30
           (SOLST) ONE SI SURFACE-BARRIER DETECTOR WAS A MONITOR.         K67 1    31
CORRECTION CORRECTIONS WERE MADE FOR CENTER-OF-MASS TO LAB SYSTEM         K67 1    32
           CONVERSION AND FOR DETECTOR DEADTIME. DATA SUBJECTED TO        K67 1    33
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            A STATISTICAL CORRELATION ANALYSIS.                            K67 1     34
ERR-ANALYS  THE EXCITATION FUNCTION DATA HAVE AN ASSOCIATED ERROR OF       K67 1     35
            5 PCT. FOR THE GROUND-STATE TRANSITIONS AND 2 PCT. FOR         K67 1     36
            THE FIRST-EXCITED-STATE TRANSITIONS.                           K67 1     37
STATUS      RESULTS APPEAR IN A THESIS WHICH WAS PUBLISHED AS AN ANL       K67 1     38
            REPORT. DATA FOUND IN TABLES IN THIS EXTENSIVE REPORT.         K67 1     39
ENDBIB              37                                                     K67 1     40
ENDSUBENT            1                                                     K67 199999
SUBENT          K67  2          0                                          K67 2      1
BIB                  2         10                                          K67 2      2
REACTION    31P(P,ALPHA)28SI                                               K67 2      3
COMMENTS    INFORMATION ACQUIRED FROM TABLE 8 OF DOCUMENT. TABLE           K67 2      4
            GIVES APPROXIMATE VALUE OF ALPHA-DECAY WIDTH AND RATIO         K67 2      5
            OF WIDTH TO AVERAGE LEVEL SPACING D. FROM STATISTICAL          K67 2      6
            CALCULATIONS. EP = PROTON ENERGY. EX = EXCITATION              K67 2      7
            ENERGY IN COMPOUND NUCLEUS. GAMMA = AVERAGE WIDTH.             K67 2      8
            RATIO = RATIO OF GAMMA DIVIDED BY THE AVERAGE LEVEL            K67 2      9
            SPACING D. GAMMA(LO) = LOW VALUE OF GAMMA. GAMMA(HI)           K67 2     10
            = HIGH VALUE OF GAMMA. RATIO(LO) = LOW VALUE OF RATIO.         K67 2     11
            RATIO(HI) = HIGH VALUE OF RATIO.                               K67 2     12
ENDBIB              10                                                     K67 2     13
DATA                 6          2                                          K67 2     14
EP          EX         GAMMA(LO)  GAMMA(HI)  RATIO(LO)  RATIO(HI)          K67 2     15
MEV         MEV        KEV        KEV        NO-DIM     NO-DIM             K67 2     16
 8.0         16.9       20.0       50.0       4.0        10.0              K67 2     17
 12.0        20.9       50.0       90.0       60.0       120.0             K67 2     18
ENDDATA              4                                                     K67 2     19
ENDSUBENT            2                                                     K67 299999
SUBENT          K67  3          0                                          K67 3      1
BIB                  2         10                                          K67 3      2
REACTION    31P(P,ALPHA)28SI                                               K67 3      3
COMMENTS    DATA EXTRACTED FROM TABLE 9 OF THE DOCUMENT. GAMMA =           K67 3      4
            OBSERVED VALUE OF LEVEL WIDTH FOR ALPHA DECAY. DETERMINED      K67 3      5
            BY THREE DIFFERENT METHODS: GAMMA1 IS FWHM FROM THE AUTO-      K67 3      6
            CORRELATION FUNCTION. GAMMA2 IS THE WIDTH CALCULATED FROM      K67 3      7
            THE MEAN-SQUARE FLUCTUATION. GAMMA3 WAS CALCULATED FROM        K67 3      8
            THE NUMBER OF MAXIMA OBSERVED IN THE EXCITATION FUNCTION.      K67 3      9
            EX = AVERAGE EXCITATION ENERGY FOR THE RANGE OVER WHICH        K67 3     10
            THE EXCITATION FUNCTION WAS MEASURED. ERR-GAMMA1 IS THE        K67 3     11
            ESTIMATED UNCERTAINTY IN GAMMA1.                               K67 3     12
ENDBIB              10                                                     K67 3     13
DATA                 5          3                                          K67 3     14
EX          GAMMA1     ERR-GAMMA1 GAMMA2     GAMMA3                        K67 3     15
MEV         KEV        KEV        KEV        KEV                           K67 3     16
 17.3        32.        15.        20.        33.                          K67 3     17
 19.0        41.        11.        29.        46.                          K67 3     18
 19.9        38.        12.        32.        50.                          K67 3     19
ENDDATA              5                                                     K67 3     20
ENDSUBENT            3                                                     K67 399999
ENDENTRY             3                                                     K679999999
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KH73a

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ENTRY            KH73A           0                                KH73A 0     1
SUBENT        KH73A  1           0                                KH73A 1     1
BIB                 11          29                                KH73A 1     2
INSTITUTE  (USAROC)                                               KH73A 1     3
REFERENCE  (J,PR/C,8,5,1965,1973)                                 KH73A 1     4
AUTHORS    (M.KILDIR,J.R.HUIZENGA)                                KH73A 1     5
TITLE      ISOSPIN DEPENDENCE OF THE NUCLEAR LEVEL WIDTH          KH73A 1     6
FACILITY   NUCLEAR STRUCTURE RESEARCH LABORATORY, UNIVERSTIY OF   KH73A 1     7
           ROCHESTER, ROCHESTER, NEW YORK.                        KH73A 1     8
           NOTE: THIS EXPERIMENT WAS PRESUMABLY CONDUCTED USING A KH73A 1     9
           TANDEM VAN DE GRAAFF ACCELERATOR. HOWEVER, NO MENTION  KH73A 1    10
           IS MADE IN THE ARTICLE OF ANY OF THE DETAILS REGARDING KH73A 1    11
           THIS FACILITY.                                         KH73A 1    12
INC-PART   (P) PROTONS.                                           KH73A 1    13
TARGET     31P TARGET OF 40 OF MICROGRAM/CM**2 PREPARED BY VACUUM KH73A 1    14
           EVAPORATION ONTO A 20 MICROGRAM/CM**2 CARBON FOIL.     KH73A 1    15
METHOD     PROTON BEAMS IN THE ENERGY RANGE 8.51 TO 10.01 MEV WERE KH73A 1   16
           INCIDENT ON THE 31P TARGET SET AT 30 DEGREES IN A 51-  KH73A 1    17
           CM SCATTERING CHAMBER. PROTONS AND ALPHA PARTICLES     KH73A 1    18
           DETECTED SIMULTANEOUSLY. MEASURED SCATTERED-PROTON AND KH73A 1    19
           EMITTED ALPHA-PARTICLE EXCITATION FUNTIONS IN 10-KEV   KH73A 1    20
           STEPS OVER INDICATED ENERGY RANGE.                     KH73A 1    21
DETECTORS  (SOLST) SOLID-STATE SURFACE-BARRIER DETECTORS. PROTON  KH73A 1    22
           DETECTORS WERE COVERED WITH AL ABSORBERS JUST THICK    KH73A 1    23
           ENOUGH TO STOP THE ALPHA PARTICLES. SEVERAL DETECTORS  KH73A 1    24
           PLACED AT VARIOUS ANGLES WERE USED IN THE EXPERIMENT.  KH73A 1    25
CORRECTION ENERGY DEPENDENCE REMOVED FROM EXCITATION FUNCTIONS    KH73A 1    26
           BEFORE FLUCTUATION ANALYSIS. LEVEL WIDTHS ALSO         KH73A 1    27
           CORRECTED FOR FINITE ENERGY INTERVAL OF DATA.          KH73A 1    28
STATUS     PUBLISHED IN PHYSICAL REVIEW. DATA CONTAINED IN ONE    KH73A 1    29
           FIGURE (EXCITATION FUNCTIONS), TWO TABLES AND THE      KH73A 1    30
           TEXT OF THE ARTICLE.                                   KH73A 1    31
ENDBIB              29                                            KH73A 1    32
ENDSUBENT            1                                            KH73A 199999
SUBENT        KH73A  2           0                                KH73A 2     1
BIB                  2           5                                KH73A 2     2
REACTION   31P(P,P')                                              KH73A 2     3
COMMENTS   AVERAGE LEVEL WIDTH IN COMPOUND NUCLEUS 32S AT AN      KH73A 2     4
           EXCITATION ENERGY OF 17.8 MEV AS DETERMINED FROM PROTON KH73A 2    5
           SCATTERING. GAMMAPP = RESONANCE WIDTH. ERR-GAMMAPP =   KH73A 2     6
           ERROR IN GAMMAPP. DATA FROM TEXT OF ARTICLE.           KH73A 2     7
ENDBIB               5                                            KH73A 2     8
DATA                 2           1                                KH73A 2     9
GAMMAPP    ERR-GAMMAPP                                            KH73A 2    10
KEV        KEV                                                    KH73A 2    11
 30.0        1.4                                                  KH73A 2    12
ENDDATA              3                                            KH73A 2    13
ENDSUBENT            2                                            KH73A 299999
SUBENT        KH73A  3           0                                KH73A 3     1
BIB                  2           5                                KH73A 3     2
REACTION   31P(P,ALPHA)                                           KH73A 3     3
COMMENTS   AVERAGE LEVEL WIDTH IN COMPOUND NUCLEUS 32S AT AN      KH73A 3     4
           EXCITATION ENERGY OF 17.8 MEV AS DETERMINED FROM ALPHA- KH73A 3    5
           PARTICLE EMISSION. GAMMAA = AVG. RESONANCE WIDTH. ERR- KH73A 3     6
           GAMMAA = ERROR IN GAMMAA. DATA FROM TEXT OF ARTICLE.   KH73A 3     7
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ENDBIB              5                                      KH73A 3     8
DATA                2          1                           KH73A 3     9
GAMMAA     ERR-GAMMAA                                      KH73A 3    10
KEV        KEV                                             KH73A 3    11
 38.7       2.7                                            KH73A 3    12
ENDDATA             3                                      KH73A 3    13
ENDSUBENT           3                                      KH73A 399999
SUBENT         KH73A  4                                    KH73A 4     1
BIB                 2          6                           KH73A 4     2
REACTIONS  31P(P,P'),31(P,ALPHA)                           KH73A 4     3
COMMENTS   AVERAGE VALUE OF LEVEL WIDTH IN COMPOUND NUCLEUS 32S KH73A 4     4
           AT 17.8 MEV EXCITATION IS GIVEN BASED ON ISOSPIN. THE KH73A 4     5
           T = 0 LEVELS ARE THE T< LEVELS. THE T = 1 LEVELS ARE KH73A 4     6
           THE T> LEVELS. GAMMA = AVERAGE RESONANCE WIDTH.  KH73A 4     7
           ERR-GAMMA = ERROR IN GAMMA. T = ISOSPIN OF LEVELS. KH73A 4     8
ENDBIB              6                                      KH73A 4     9
DATA                3          2                           KH73A 4    10
T          GAMMA      ERR-GAMMA                            KH73A 4    11
NO-DIM     KEV        KEV                                  KH73A 4    12
 0.0        38.7        2.7                                KH73A 4    13
 1.0        26.2        3.5                                KH73A 4    14
ENDSUBENT           4                                      KH73A 499999
ENDENTRY            4                                      KH73A9999999
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KMC68

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ENTRY               KMC68          0                       KMC68 0     1
SUBENT         KMC68  1            0                       KMC68 1     1
BIB                14             49                       KMC68 1     2
INSTITUTE  (CCPKUR)                                        KMC68 1     3
REFERENCE  (J,SNP,7,2,170,1968)                            KMC68 1     4
AUTHORS    (K.V.KARADZHEV,V.I.MAN'KO,F.E.CHUKREEV)         KMC68 1     5
TITLE      ELASTIC SCATTERING OF PROTONS BY PHOSPHORUS AND THE KMC68 1     6
           REACTIONS 31P(P,ALPHA0)28SI AND 31P(P,ALPHA1)28SI KMC68 1     7
           IN THE ENERGY INTERVAL 1.0 - 3.8 MEV.           KMC68 1     8
FACILITY   ELECTROSTATIC GENERATOR WITH ELECTROSTATIC BEAM KMC68 1     9
           ANALYZER. SPECIFIC ACCELERATOR TYPE NOT MENTIONED. KMC68 1    10
           INSTITUTE DEDUCED FROM A LATER PAPER IN 1969.   KMC68 1    11
INC-PART   (P) PROTONS.                                    KMC68 1    12
TARGET     20 - 30 MICROGRAM/CM**2 ZN3P2 EVAPORATED ONTO CARBON KMC68 1    13
           FILM OF ABOUT THE SAME THICKNESS. TARGET WITHSTOOD KMC68 1    14
           1 MICROAMP/MM**2 BEAM POWER FOR A LONG TIME.    KMC68 1    15
METHOD     PROTON SOURCE WAS AN ELECTROSCATIC ACCELERATOR. EP = KMC68 1    16
           1.0 - 3.8 MEV. MEASURED PROTONS ELASTICALLY SCATTERED KMC68 1    17
           BY 31P AND ALPHA PARTICLES FROM 31P(P,ALPHA0)28SI AND KMC68 1    18
           31P(P,ALPHA1)28SI REACTIONS. EXCITATION FUNCTIONS WERE KMC68 1    19
           MEASURED AT 90 AND 120 DEG (LAB SYSTEM). ALPHA-PARTICLE KMC68 1    20
           ANGULAR DISTRIBUTIONS WERE MEASURED ON THE RESONANCES. KMC68 1    21
           PROTON ELASTIC SCATTERING FROM ZN AND 12C WAS ALSO KMC68 1    22
           MEASURED AND USED IN NORMALIZATION OF THE DATA. KMC68 1    23
           ABSOLUTE NORMALIZATION OF (P,ALPHA) CROSS SECTIONS KMC68 1    24
           WAS BASED ON PROTON ELASTIC SCATTERING WHICH WAS KMC68 1    25
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            ASSUMED TO BE RUTHERFORD SCATTERING. DETAILS GIVEN      KMC68 1    26
            IN THE PAPER. ANGULAR DISTRIBUTIONS FITTED WITH         KMC68 1    27
            LEGENDRE-POLYNOMIAL EXPANSIONS. MOST OF THESE ANGULAR   KMC68 1    28
            DISTRIBUTIONS INVOLVE LEGENDRE-EXPANSIONS WITH          KMC68 1    29
            ORDERS LESS THAN OR EQUAL TO TWO. THE ODD LEGENDRE      KMC68 1    30
            COEFFICIENTS WERE GENERALLY FOUND TO BE SMALL.          KMC68 1    31
DETECTORS   (SOLST) SILICON/GOLD SURFACE-BARRIER (FOR ALPHA         KMC68 1    32
            PARTICLES) AND SILICON P-I-N STRUCTURE COMPENSATED      KMC68 1    33
            WITH LITHIUM (FOR PROTONS).                             KMC68 1    34
MONITOR     (CI) CURRENT INTEGRATOR.                                KMC68 1    35
CORRECTION  DATA CORRECTIONS ARE NOT DISCUSSED IN THIS PAPER.       KMC68 1    36
ERR-ANALYS  ERRORS IN THE NORMALIZATION OF THE ABSOLUTE (P,ALPHA)   KMC68 1    37
            CROSS SECTIONS BASED ZN AND 12C PROTON ELASTIC          KMC68 1    38
            SCATTERING WERE ON THE ORDER OF 25 PCT. THE             KMC68 1    39
            UNCERTAINTIES IN RESONANCE ENERGIES ARE INDICATED TO    KMC68 1    40
            BE SEVERAL KEV SINCE NO SPECIAL EFFORT WAS MADE TO      KMC68 1    41
            MEASURE THESE ENERGIES CAREFULLY. ERRORS IN LEGENDRE    KMC68 1    42
            COEFFICIENTS FROM LEAST-SQUARES FITTING ALSO GIVEN.     KMC68 1    43
STATUS      PUBLISHED IN SOVIET JOURNAL OF NUCLEAR PHYSICS.         KMC68 1    44
COMMENTS    INFORMATION PROVIDED IN FOUR FIGURES AND ONE TABLE. THE KMC68 1    45
            TABLE INDICATES THE RESONANCE ENERGIES AND SHOWS WHICH  KMC68 1    46
            REACTIONS EXCITED THESE RESONANCES. VALUES OF THE       KMC68 1    47
            EVEN-ORDER LEGENDRE COEFFICIENTS UP TO SIXTH-ORDER ARE  KMC68 1    48
            GIVEN. UPPER LIMITS OF ODD-ORDER COEFFICIENTS ARE       KMC68 1    49
            PROVIDED IN SOME CASES. NO ABSOLUTE CROSS-SECTION       KMC68 1    50
            VALUES ARE REPORTED IN THIS PAPER.                      KMC68 1    51
ENDBIB               49                                             KMC68 1    52
ENDSUBENT             1                                             KMC68 199999
SUBENT          KMC68 2          0                                  KMC68 2     1
BIB                   2          7                                  KMC68 2     2
REACTION    31P(P,P)31P                                             KMC68 2     3
COMMENTS    RESONANCES SEEN IN ELASTIC PROTON SCATTERING FROM       KMC68 2     4
            31P. EP = INCIDENT PROTON ENERGY. EX = EXCITATION       KMC68 2     5
            ENERGY IN COMPOUND NUCLEUS 32S OF THE OBSERVED          KMC68 2     6
            RESONANCE. UNCERTAINTIES IN THESE ENERGIES ARE SAID     KMC68 2     7
            TO BE SEVERAL KEV. DETAILS ARE PROVIDED IN THE PAPER.   KMC68 2     8
            DATA TAKEN FROM THE SINGLE TABLE IN THE PAPER.          KMC68 2     9
ENDBIB                7                                             KMC68 2    10
DATA                  2         49                                  KMC68 2    11
EP          EX                                                      KMC68 2    12
KEV         KEV                                                     KMC68 2    13
 1156.       9983.                                                  KMC68 2    14
 1250.       10074.                                                 KMC68 2    15
 1401.       10221.                                                 KMC68 2    16
 1472.       10289.                                                 KMC68 2    17
 1512.       10328.                                                 KMC68 2    18
 1562.       10377.                                                 KMC68 2    19
 1592.       10406.                                                 KMC68 2    20
 1641.       10463.                                                 KMC68 2    21
 1720.       10530.                                                 KMC68 2    22
 1890.       10694.                                                 KMC68 2    23
 1972.       10774.                                                 KMC68 2    24
 1986.       10787.                                                 KMC68 2    25
 2020.       10820.                                                 KMC68 2    26
 2114.       10911.                                                 KMC68 2    27
 2177.       10972.                                                 KMC68 2    28
 2328.       11119.                                                 KMC68 2    29
 2350.       11140.                                                 KMC68 2    30
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 2443.      11230.                                              KMC68 2   31
 2448.      11235.                                              KMC68 2   32
 2661.      11441.                                              KMC68 2   33
 2690.      11470.                                              KMC68 2   34
 2721.      11500.                                              KMC68 2   35
 2754.      11532.                                              KMC68 2   36
 2785.      11562.                                              KMC68 2   37
 2800.      11576.                                              KMC68 2   38
 2833.      11608                                               KMC68 2   39
 2840.      11615.                                              KMC68 2   40
 2854.      11628.                                              KMC68 2   41
 2866.      11640.                                              KMC68 2   42
 2905.      11678.                                              KMC68 2   43
 2944.      11716.                                              KMC68 2   44
 2970.      11741.                                              KMC68 2   45
 2984.      11754.                                              KMC68 2   46
 3045.      11814.                                              KMC68 2   47
 3056.      11824.                                              KMC68 2   48
 3095.      11862.                                              KMC68 2   49
 3170.      11935.                                              KMC68 2   50
 3185.      11949.                                              KMC68 2   51
 3215.      11978.                                              KMC68 2   52
 3250.      12012.                                              KMC68 2   53
 3273.      12034.                                              KMC68 2   54
 3355.      12114.                                              KMC68 2   55
 3370.      12128.                                              KMC68 2   56
 3406.      12163.                                              KMC68 2   57
 3412.      12169.                                              KMC68 2   58
 3420.      12177.                                              KMC68 2   59
 3440.      12196.                                              KMC68 2   60
 3450.      12206.                                              KMC68 2   61
 3482.      12237.                                              KMC68 2   62
ENDDATA               51                                        KMC68 2   63
ENDSUBENT              2                                        KMC68 299999
SUBENT        KMC68  3          0                               KMC68 3    1
BIB                  2          7                               KMC68 3    2
REACTION   31P(P,ALPHA0)28SI                                    KMC68 3    3
COMMENTS   RESONANCES SEEN IN 31P(P,ALPHA0)28SI REACTION.       KMC68 3    4
           EP = INCIDENT PROTON ENERGY. EX = EXCITATION         KMC68 3    5
           ENERGY IN COMPOUND NUCLEUS 32S OF THE OBSERVED       KMC68 3    6
           RESONANCE. UNCERTAINTIES IN THESE ENERGIES ARE SAID  KMC68 3    7
           TO BE SEVERAL KEV. DETAILS ARE PROVIDED IN THE PAPER.KMC68 3    8
           DATA TAKEN FROM THE SINGLE TABLE IN THE PAPER.       KMC68 3    9
ENDBIB                7                                         KMC68 3   10
DATA                  2         45                              KMC68 3   11
EP         EX                                                   KMC68 3   12
KEV        KEV                                                  KMC68 3   13
 1016.      9947.                                               KMC68 3   14
 1156.      9983.                                               KMC68 3   15
 1401.      10221.                                              KMC68 3   16
 1472.      10289.                                              KMC68 3   17
 1512.      10328.                                              KMC68 3   18
 1562.      10377.                                              KMC68 3   19
 1592.      10406.                                              KMC68 3   20
 1641.      10463.                                              KMC68 3   21
 1720.      10530.                                              KMC68 3   22
 1815.      10622.                                              KMC68 3   23
 1890.      10694.                                              KMC68 3   24
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                                                         KMC68 3    25
1972.        10774.                                      KMC68 3    26
1986.        10787.                                      KMC68 3    27
2004.        10805.                                      KMC68 3    28
2010.        10811.                                      KMC68 3    29
2020.        10820.                                      KMC68 3    30
2114.        10911.                                      KMC68 3    31
2255.        11048.                                      KMC68 3    32
2443.        11230.                                      KMC68 3    33
2448.        11235.                                      KMC68 3    34
2661.        11441.                                      KMC68 3    35
2800.        11576.                                      KMC68 3    36
2833.        11608                                       KMC68 3    37
2905.        11678.                                      KMC68 3    38
2944.        11716.                                      KMC68 3    39
2970.        11741.                                      KMC68 3    40
3024.        11793.                                      KMC68 3    41
3045.        11814.                                      KMC68 3    42
3056.        11824.                                      KMC68 3    43
3140.        11906.                                      KMC68 3    44
3170.        11935.                                      KMC68 3    45
3250.        12012.                                      KMC68 3    46
3370.        12128.                                      KMC68 3    47
3412.        12169.                                      KMC68 3    48
3420.        12177.                                      KMC68 3    49
3440.        12196.                                      KMC68 3    50
3450.        12206.                                      KMC68 3    51
3482.        12237.                                      KMC68 3    52
3552.        12305.                                      KMC68 3    53
3592.        12344.                                      KMC68 3    54
3644.        12394.                                      KMC68 3    55
3684.        12433.                                      KMC68 3    56
3715.        12463.                                      KMC68 3    57
3724.        12472.                                      KMC68 3    58
3802.        12547.                                      KMC68 3    59
ENDDATA                 47                               KMC68 399999
ENDSUBENT                3                               KMC68 4     1
SUBENT          KMC68    4          0                    KMC68 4     2
BIB                      2          7                    KMC68 4     3
REACTION     31P(P,ALPHA1)28SI                           KMC68 4     4
COMMENTS     RESONANCES SEEN IN 31P(P,ALPHA1)28SI REACTION.   KMC68 4     5
             EP = INCIDENT PROTON ENERGY. EX = EXCITATION     KMC68 4     6
             ENERGY IN COMPOUND NUCLEUS 32S OF THE OBSERVED   KMC68 4     7
             RESONANCE. UNCERTAINTIES IN THESE ENERGIES ARE SAID   KMC68 4     8
             TO BE SEVERAL KEV. DETAILS ARE PROVIDED IN THE PAPER.   KMC68 4     9
             DATA TAKEN FROM THE SINGLE TABLE IN THE PAPER.   KMC68 4    10
ENDBIB                   7                               KMC68 4    11
DATA                     2          27                   KMC68 4    12
EP           EX                                          KMC68 4    13
KEV          KEV                                         KMC68 4    14
  2854.        11628.                                    KMC68 4    15
  2866.        11640.                                    KMC68 4    16
  2984.        11754.                                    KMC68 4    17
  3056.        11824.                                    KMC68 4    18
  3095.        11862.                                    KMC68 4    19
  3185.        11949.                                    KMC68 4    20
  3250.        12012.                                    KMC68 4    21
  3273.        12034.                                    KMC68 4    22
  3300.        12061.
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 3370.      12128.                                                      KMC68 4   23
 3406.      12163.                                                      KMC68 4   24
 3412.      12169.                                                      KMC68 4   25
 3420.      12177.                                                      KMC68 4   26
 3440.      12196.                                                      KMC68 4   27
 3450.      12206.                                                      KMC68 4   28
 3482.      12237.                                                      KMC68 4   29
 3505.      12259.                                                      KMC68 4   30
 3552.      12305.                                                      KMC68 4   31
 3592.      12344.                                                      KMC68 4   32
 3636.      12386.                                                      KMC68 4   33
 3660.      12409.                                                      KMC68 4   34
 3684.      12433.                                                      KMC68 4   35
 3715.      12463.                                                      KMC68 4   36
 3724.      12472.                                                      KMC68 4   37
 3744.      12491.                                                      KMC68 4   38
 3776.      12522.                                                      KMC68 4   39
 3802.      12547.                                                      KMC68 4   40
ENDDATA             29                                                  KMC68 4   41
ENDSUBENT            4                                                  KMC68 499999
SUBENT        KMC68  5          0                                       KMC68 5    1
BIB                  2         15                                       KMC68 5    2
REACTION   31P(P,ALPHA0)28SI                                            KMC68 5    3
COMMENTS   COEFFICIENTS OF LEGENDRE-POLYNOMIAL EXPANSION USED TO        KMC68 5    4
           FIT MEASURED ALPHA-PARTICLE ANGULAR DISTRIBUTIONS.           KMC68 5    5
           FITS CARRIED OUT USING THE LEAST-SQUARES METHOD.             KMC68 5    6
           EVEN-ORDER COEFFICIENTS A2 AND A4 ARE GIVEN. IT IS           KMC68 5    7
           ASSUMED THAT A0 = 1. IN SOME CASES AN UPPER BOUND IS         KMC68 5    8
           GIVEN FOR THE ODD COEFFICIENTS. FOR ONE RESONANCE,           KMC68 5    9
           NAMELY EP = 3412 MEV (EX = 12169 MEV), THERE IS A            KMC68 5   10
           NON-ZERO VALUE FOR THE SIXTH-ORDER COEFFICIENT.              KMC68 5   11
           IN THIS CASE, A6 = 1.35 +- 0.09. A2 = SECOND-ORDER           KMC68 5   12
           COEFFICIENT. ERR-A2 = ERROR IN A2. A4 = FOURTH-ORDER         KMC68 5   13
           COEFFICIENT. ERR-A4 = ERROR IN A4. A-ODD = UPPER             KMC68 5   14
           BOUND FOR ODD POLYNOMIALS. EX = EXCITATION ENERGY IN         KMC68 5   15
           COMPOUND NUCLEUS 32S OF THE OBSERVED RESONANCE.              KMC68 5   16
           DATA OBTAINED FROM THE SINGLE TABLE IN THE PAPER.            KMC68 5   17
ENDBIB              15                                                  KMC68 5   18
DATA                 6         45                                       KMC68 5   19
EX         A2         ERR-A2     A4         ERR-A4     A-ODD            KMC68 5   20
KEV        NO-DIM     NO-DIM     NO-DIM     NO-DIM     NO-DIM           KMC68 5   21
 9947.     -0.51       0.09       0.0        0.0        0.0             KMC68 5   22
 9983.      0.0        0.0        0.0        0.0        0.0             KMC68 5   23
 10221.     0.83       0.17       0.0        0.0        0.0             KMC68 5   24
 10289.     1.81       0.12       0.0        0.0        0.0             KMC68 5   25
 10328.    -0.70       0.03       0.0        0.0        0.0             KMC68 5   26
 10377.     0.0        0.0        0.0        0.0        0.0             KMC68 5   27
 10406.     0.0        0.0        0.0        0.0        0.0             KMC68 5   28
 10463.     0.0        0.0        0.0        0.0        0.0             KMC68 5   29
 10530.     0.0        0.0        0.0        0.0        0.0             KMC68 5   30
 10622.     0.87       0.12       0.0        0.0        0.0             KMC68 5   31
 10694.     1.26       0.05       0.0        0.0        0.0             KMC68 5   32
 10774.     0.80       0.06       0.0        0.0        0.0             KMC68 5   33
 10787.     1.30       0.70       0.49       0.07       0.15            KMC68 5   34
 10805.     0.0        0.0        0.0        0.0        0.0             KMC68 5   35
 10811.     0.47       0.08      -0.27       0.08       0.0             KMC68 5   36
 10820.     0.72       0.06       0.0        0.0        0.0             KMC68 5   37
 10911.     1.86       0.04       0.0        0.0        0.0             KMC68 5   38
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11048.	0.98	0.12	-1.22	0.11	0.15	KMC68 5	39
11230.	-0.40	0.04	0.0	0.0	0.0	KMC68 5	40
11235.	0.0	0.0	0.0	0.0	0.0	KMC68 5	41
11441.	0.61	0.06	0.0	0.0	0.0	KMC68 5	42
11576.	0.68	0.06	0.0	0.0	0.15	KMC68 5	43
11608	1.44	0.07	0.0	0.0	0.0	KMC68 5	44
11678.	1.67	0.08	0.0	0.0	0.15	KMC68 5	45
11716.	1.60	0.06	1.51	0.05	0.15	KMC68 5	46
11741.	1.15	0.07	0.21	0.07	0.15	KMC68 5	47
11793.	1.37	0.07	0.34	0.07	0.0	KMC68 5	48
11814.	0.83	0.05	0.0	0.0	0.0	KMC68 5	49
11824.	0.80	0.06	0.0	0.0	0.15	KMC68 5	50
11906.	1.55	0.05	0.0	0.0	0.0	KMC68 5	51
11935.	0.0	0.0	0.0	0.0	0.0	KMC68 5	52
12012.	1.42	0.06	2.37	0.06	0.15	KMC68 5	53
12128.	0.0	0.0	0.0	0.0	0.0	KMC68 5	54
12169.	1.66	0.09	1.50	0.12	0.15	KMC68 5	55
12177.	0.0	0.0	0.0	0.0	0.0	KMC68 5	56
12196.	-0.25	0.04	0.31	0.08	0.15	KMC68 5	57
12206.	0.0	0.0	0.0	0.0	0.0	KMC68 5	58
12237.	0.0	0.0	0.0	0.0	0.0	KMC68 5	59
12305.	1.11	0.05	0.08	0.05	0.15	KMC68 5	60
12344.	0.0	0.0	0.0	0.0	0.0	KMC68 5	61
12394.	1.10	0.05	0.0	0.0	0.0	KMC68 5	62
12433.	0.0	0.0	0.0	0.0	0.0	KMC68 5	63
12463.	0.0	0.0	0.0	0.0	0.0	KMC68 5	64
12472.	0.0	0.0	0.0	0.0	0.0	KMC68 5	65
12547.	0.52	0.06	-1.42	0.08	0.15	KMC68 5	66
ENDDATA		47				KMC68 5	67
ENDSUBENT		5				KMC68	599999
SUBENT	KMC68	6	0			KMC68 6	1
BIB		2	15			KMC68 6	2
REACTION	31P(P,ALPHA1)28SI					KMC68 6	3
COMMENTS	COEFFICIENTS OF LEGENDRE-POLYNOMIAL EXPANSION USED TO					KMC68 6	4
	FIT MEASURED ALPHA-PARTICLE ANGULAR DISTRIBUTIONS.					KMC68 6	5
	FITS CARRIED OUT USING THE LEAST-SQUARES METHOD.					KMC68 6	6
	EVEN-ORDER COEFFICIENTS A2 AND A4 ARE GIVEN. IT IS					KMC68 6	7
	ASSUMED THAT A0 = 1. IN SOME CASES AN UPPER BOUND IS					KMC68 6	8
	GIVEN FOR THE ODD COEFFICIENTS. FOR ONE RESONANCE,					KMC68 6	9
	NAMELY EP = 3412 MEV (EX = 12169 MEV), THERE IS A					KMC68 6	10
	NON-ZERO VALUE FOR THE SIXTH-ORDER COEFFICIENT.					KMC68 6	11
	IN THIS CASE, A6 = -1.13 +- 0.40. A2 = SECOND-ORDER					KMC68 6	12
	COEFFICIENT. ERR-A2 = ERROR IN A2. A4 = FOURTH-ORDER					KMC68 6	13
	COEFFICIENT. ERR-A4 = ERROR IN A4. A-ODD = UPPER					KMC68 6	14
	BOUND FOR ODD POLYNOMIALS. EX = EXCITATION ENERGY IN					KMC68 6	15
	COMPOUND NUCLEUS 32S OF THE OBSERVED RESONANCE.					KMC68 6	16
	DATA OBTAINED FROM TABLE.					KMC68 6	17
ENDBIB		15				KMC68 6	18
DATA		2	27			KMC68 6	19
EX	A2	ERR-A2	A4	ERR-A4	A-ODD	KMC68 6	20
KEV	NO-DIM	NO-DIM	NO-DIM	NO-DIM	NO-DIM	KMC68 6	21
11628.	0.0	0.0	0.0	0.0	0.0	KMC68 6	22
11640.	0.0	0.0	0.0	0.0	0.0	KMC68 6	23
11754.	0.0	0.0	0.0	0.0	0.0	KMC68 6	24
11824.	0.0	0.0	0.0	0.0	0.15	KMC68 6	25
11862.	-0.75	0.04	0.0	0.0	0.15	KMC68 6	26
11949.	0.0	0.0	0.0	0.0	0.0	KMC68 6	27
12012.	0.92	0.10	0.0	0.0	0.15	KMC68 6	28

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   12034.   0.0      0.0      0.0      0.0      0.0       KMC68 6   29
   12061.   0.0      0.0      0.0      0.0      0.0       KMC68 6   30
   12128.   0.0      0.0      0.0      0.0      0.0       KMC68 6   31
   12163.   0.0      0.0      0.0      0.0      0.0       KMC68 6   32
   12169.   0.28     0.59    -0.98     0.68     0.15      KMC68 6   33
   12177.   0.0      0.0      0.0      0.0      0.0       KMC68 6   34
   12196.  -0.80     0.06     0.0      0.0      0.15      KMC68 6   35
   12206.   0.0      0.0      0.0      0.0      0.0       KMC68 6   36
   12237.   0.0      0.0      0.0      0.0      0.0       KMC68 6   37
   12259.   0.0      0.0      0.0      0.0      0.0       KMC68 6   38
   12305.   1.05     0.09     0.52     0.10     0.15      KMC68 6   39
   12344.   0.0      0.0      0.0      0.0      0.0       KMC68 6   40
   12386.   0.12     0.30    -1.05     0.24     0.15      KMC68 6   41
   12409.   0.0      0.0      0.0      0.0      0.0       KMC68 6   42
   12433.   0.0      0.0      0.0      0.0      0.0       KMC68 6   43
   12463.   0.0      0.0      0.0      0.0      0.0       KMC68 6   44
   12472.   0.0      0.0      0.0      0.0      0.0       KMC68 6   45
   12491.   0.43     0.14    -0.45     0.11     0.15      KMC68 6   46
   12522.   0.0      0.0      0.0      0.0      0.0       KMC68 6   47
   12547.   0.0      0.0      0.0      0.0      0.15      KMC68 6   48
ENDDATA             29                                  KMC68 6   49
ENDSUBENT            6                                  KMC68 699999
ENDENTRY             6                                  KMC689999999
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KMC69b

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ENTRY            KMC69B          0                      KMC69B 0     1
SUBENT        KMC69B  1          0                      KMC69B 1     1
BIB                   7         26                      KMC69B 1     2
INSTITUTE  (CCPKUR)                                     KMC69B 1     3
REFERENCE  (J,SNP,9,4,431,1969)                         KMC69B 1     4
AUTHORS    (K.V.KARADZHEV,V.I.MAN'KO,F.E.CHUKREEV)      KMC69B 1     5
TITLE      PROPERTIES OF THE EXCITED STATES OF THE 32S NUCLEUS KMC69B 1  6
METHOD     THIS PAPER REPORTS THE RESULTS OF AN ANALYSIS OF DATA KMC69B 1 7
           ACQUIRED EARLIER AND REPORTED IN AN EARLIER PAPER. KMC69B 1   8
           THE DATA CONSISTED OF EXCITATION FUNCTIONS FOR KMC69B 1       9
           (P,P) ELASTIC SCATTERING, (N,ALPHA0) AND (N,ALPHA1) KMC69B 1 10
           REACTIONS ON THE TARGET 31P, AS WELL AS ANGULAR KMC69B 1     11
           DISTRIBUTIONS FOR THE (N,ALPHA0) AND (N,ALPHA1) KMC69B 1     12
           REACTIONS MEASURED ON THE RESONANCES. THE EXPERIMENTAL KMC69B 1 13
           ANGULAR DISTRIBUTIONS WERE COMPARED WITH THOSE KMC69B 1      14
           DERIVED FROM THEORY FOR VARIOUS VALUES OF SPIN AND KMC69B 1  15
           PARITY FOR THE LEVELS IN THE COMPOUND NUCLEUS 32S. KMC69B 1  16
           FROM THESE COMPARISONS IT WAS POSSIBLE TO DETERMINE KMC69B 1 17
           THE APPROPRIATE CHOICE FOR THE SPINS AND PARITIES OF KMC69B 1 18
           THE LEVELS IN 32S WHICH WERE EXCITED BY (N,ALPHA) KMC69B 1   19
           REACTIONS. NO CORRECTIONS OR ERROR ANALYSES WERE KMC69B 1    20
           DISCUSSED IN THE PAPER.                      KMC69B 1    21
COMMENTS   THE RESULTS OF THIS ANALYTIC STUDY SEEM TO INDICATE KMC69B 1 22
           THAT THE (N,ALPHA) REACTIONS ARE FAVORED OVER PROTON KMC69B 1 23
           EMISSION IN DECAY OF THE RESONANCES, I.E., THAT ALPHA KMC69B 1 24
           PARTICLES ARE MORE LIKELY TO BE FORMED ON THE SURFACE KMC69B 1 25
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            OF 32S THAN PROTONS                                      KMC69B 1    26
STATUS      PUBLISHED IN SOVIET JOURNAL OF NUCLEAR PHYSICS.           KMC69B 1    27
            RESULTS PRESENTED IN A TABLE.                            KMC69B 1    28
ENDBIB             26                                                KMC69B 1    29
ENDSUBENT           1                                                KMC69B 199999
SUBENT        KMC69B  2           0                                  KMC69B 2     1
BIB                 2          20                                    KMC69B 2     2
REACTION    31P(P,ALPHA0)28SI                                        KMC69B 2     3
COMMENTS    PROPERTIES OF RESONANCES IDENTIFIED IN THIS STUDY        KMC69B 2     4
            ARE GIVEN. PHYSICAL PARAMETERS APPEARING IN TABLE I      KMC69B 2     5
            ARE IDENTIFIED IN THE TEXT. FOR SOME OF THESE ITEMS      KMC69B 2     6
            THE DEFINITIONS ARE NOT VERY CLEARLY STATED. EP =        KMC69B 2     7
            PROTON ENERGY WHERE THE RESONANCE IS OBSERVED. JPI =     KMC69B 2     8
            SPIN/PARITY OF THE RESONANCE BASED ON THE PRESENT        KMC69B 2     9
            ANALYSIS. SIGMAX = TOTAL CROSS SECTION OF THE REACTION   KMC69B 2    10
            (P,ALPHA0) AT THE PEAK OF THE RESONANCE. GAMMAOBS =      KMC69B 2    11
            OBSERVED TOTAL WIDTH (NOT CLEARLY STATED SO THIS IS      KMC69B 2    12
            AN ASSUMPTION). GAMMAJPI = SUM OF PROTON AND ALPHA-      KMC69B 2    13
            PARTICLE WIDTH = GAMMAP + GAMMAALPHA. GAMMAP =           KMC69B 2    14
            PROTON WIDTH. GAMMAALPHA = ALPHA-PARTICLE WIDTH.         KMC69B 2    15
            NO INFORMATION IS GIVEN ON THE UNCERTAINTIES OF THESE    KMC69B 2    16
            PARAMETERS. THE VALUES OF SIGMAX AND GAMMAOBS GIVEN      KMC69B 2    17
            FOR THE RESONANCES AT EP = 2970, 3024 AND 3045 KEV       KMC69B 2    18
            ARE INDICATED IN TABLE I TO BE APPROXIMATE VALUES.       KMC69B 2    19
            NOTE THAT QUANTITIES APPEARING IN TABLE I WHICH CAN      KMC69B 2    20
            BE DERIVED FROM THE OTHERS ARE NOT REPRODUCED HERE       KMC69B 2    21
            IN ORDER TO AVOID REDUNDANCY.                            KMC69B 2    22
ENDBIB             20                                                KMC69B 2    23
DATA                5          30                                    KMC69B 2    24
EP          JPI        SIGMAX     GAMMAOBS   GAMMAJPI                KMC69B 2    25
KEV         NO-DIM     MILLIBARN  KEV        KEV                     KMC69B 2    26
  1016.     -1.0        43.4       3.0        1.14                   KMC69B 2    27
  1156.                 5.02       4.0        4.0                    KMC69B 2    28
  1401.                 17.6       2.4        0.31                   KMC69B 2    29
  1472.                 11.3       3.4        1.25                   KMC69B 2    30
  1512.     -1.0        264.0      6.4        6.4                    KMC69B 2    31
  1641.      0.0        26.5       4.8        4.8                    KMC69B 2    32
  1815.                 13.3       5.2        5.2                    KMC69B 2    33
  1890.     -1.0        196.5      18.0       18.0                   KMC69B 2    34
  1972.     -1.0        18.6       2.5        0.75                   KMC69B 2    35
  1986.      2.0        40.7       3.8        1.63                   KMC69B 2    36
  2020.     -1.0        102.0      10.0       10.0                   KMC69B 2    37
  2114.     -1.0        78.5       3.2        3.2                    KMC69B 2    38
  2255.      2.0        19.1       6.0        6.0                    KMC69B 2    39
  2443.     -1.0        42.4       10.0                              KMC69B 2    40
  2661.     -1.0        10.9       4.5        4.5                    KMC69B 2    41
  2800.     -1.0        45.5       7.5        7.5                    KMC69B 2    42
  2833.     -1.0        32.2       6.6        6.6                    KMC69B 2    43
  2905.     -1.0        12.8       8.2        8.2                    KMC69B 2    44
  2944.      2.0        51.6       4.1        4.1                    KMC69B 2    45
  2970.     -1.0        17.6       35.0                              KMC69B 2    46
  3024.      2.0        22.4       40.0                              KMC69B 2    47
  3045.      0.0        20.2       30.0                              KMC69B 2    48
  3140.     -1.0        74.0       7.0        7.0                    KMC69B 2    49
  3250.      2.0        122.3      14.0       14.0                   KMC69B 2    50
  3412.                 119.0      9.0                               KMC69B 2    51
  3442.                 31.3       8.0                               KMC69B 2    52
  3552.     -1.0        77.0       17.0       17.0                   KMC69B 2    53
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 3644.     -1.0         104.0      8.0        8.0                     KMC69B 2   54
 3684.                   45.8     16.0       16.0                     KMC69B 2   55
 3802.                   43.6     10.5       10.5                     KMC69B 2   56
ENDDATA            32                                                 KMC69B 2   57
ENDSUBENT           2                                                 KMC69B 299999
SUBENT       KMC69B 3          0                                      KMC69B 3    1
BIB                 2         15                                      KMC69B 3    2
REACTION   31P(P,ALPHA0)28SI                                          KMC69B 3    3
COMMENTS   PROPERTIES OF RESONANCES IDENTIFIED IN THIS STUDY          KMC69B 3    4
           ARE GIVEN. PHYSICAL PARAMETERS APPEARING IN TABLE I        KMC69B 3    5
           ARE IDENTIFIED IN THE TEXT. FOR SOME OF THESE THE          KMC69B 3    6
           DEFINITIONS ARE NOT VERY CLEARLY STATED. EP =              KMC69B 3    7
           PROTON ENERGY WHERE THE RESONANCE IS OBSERVED.             KMC69B 3    8
           GAMMAP = PROTON WIDTH. GAMMAALPHA = ALPHA-PARTICLE         KMC69B 3    9
           WIDTH. RWP = PROTON REDUCED WIDTH. RWALPHA = ALPHA-         KMC69B 3   10
           PARTICLE REDUCED WIDTH. DETAILS DISCUSSED IN PAPER.        KMC69B 3   11
           NOTE THAT QUANTITIES APPEARING IN TABLE I WHICH CAN        KMC69B 3   12
           BE DERIVED FROM THE OTHERS ARE NOT REPRODUCED HERE         KMC69B 3   13
           TO AVOID REDUNDANCY. REFER TO SUBENTRY KMC69B 2 FOR        KMC69B 3   14
           COMPLEMENTARY INFORMATION. NOTE THAT THE ABSENCE OF        KMC69B 3   15
           A PARTICULAR RESONANCE IN THE PRESENT SUBENTRY             KMC69B 3   16
           INDICATES THAT NO WIDTHS WERE OBTAINED.                    KMC69B 3   17
ENDBIB             15                                                 KMC69B 3   18
DATA                5         15                                      KMC69B 3   19
EP         GAMMAP     GAMMAALPHA RWP        RWALPHA                   KMC69B 3   20
KEV        KEV        KEV        NO-DIM     NO-DIM                    KMC69B 3   21
 1512.      4.6        1.8        5.2        20.0                     KMC69B 3   22
 1641.      0.34       4.46       0.10       22.2                     KMC69B 3   23
 1890.      13.5       4.5        5.0        15.4                     KMC69B 3   24
 1972.      0.73       0.02       0.22       0.06                     KMC69B 3   25
 1986.      1.58       0.05       2.5        0.28                     KMC69B 3   26
 2020.      8.8        1.2        2.4        2.9                      KMC69B 3   27
 2114.      0.3        2.9        0.07       5.5                      KMC69B 3   28
 2255.      0.08       5.92       0.07       15.2                     KMC69B 3   29
 2661.      0.1        4.4        0.01       2.62                     KMC69B 3   30
 2800.      0.5        7.0        0.04       3.3                      KMC69B 3   31
 2833.      6.3        0.3        0.5        0.13                     KMC69B 3   32
 2905.      0.16       8.04       0.01       3.2                      KMC69B 3   33
 2944.      0.2        3.9        0.05       2.4                      KMC69B 3   34
 3140.      0.93       6.07       0.05       1.7                      KMC69B 3   35
 3250.      2.2        10.1       0.36       3.9                      KMC69B 3   36
ENDDATA            17                                                 KMC69B 3   37
ENDSUBENT           3                                                 KMC69B 399999
SUBENT       KMC69B 4          0                                      KMC69B 4    1
BIB                 2         14                                      KMC69B 4    2
REACTION   31P(P,ALPHA1)28SI                                          KMC69B 4    3
COMMENTS   PROPERTIES OF RESONANCES IDENTIFIED IN THIS STUDY          KMC69B 4    4
           ARE GIVEN. PHYSICAL PARAMETERS APPEARING IN TABLE II       KMC69B 4    5
           ARE IDENTIFIED IN THE TEXT. FOR SOME OF THESE ITEMS        KMC69B 4    6
           THE DEFINITIONS ARE NOT VERY CLEARLY STATED. EP =          KMC69B 4    7
           PROTON ENERGY WHERE THE RESONANCE IS OBSERVED. JPI =       KMC69B 4    8
           SPIN/PARITY OF THE RESONANCE BASED ON THE PRESENT          KMC69B 4    9
           ANALYSIS. SIGMAX = TOTAL CROSS SECTION OF THE REACTION     KMC69B 4   10
           (P,ALPHA1) AT THE PEAK OF THE RESONANCE. LP = ORBITAL      KMC69B 4   11
           ANGULAR MOMENTUM OF THE PROTON. GAMMAP = PROTON WIDTH.     KMC69B 4   12
           RWP = PROTON REDUCED WIDTH. NOTE THAT QUANTITIES IN        KMC69B 4   13
           TABLE II WHICH CAN BE DERIVED FROM OTHER QUANTITIES        KMC69B 4   14
           APPEARING IN TABLE II ARE NOT REPRODUCED HERE IN ORDER     KMC69B 4   15
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             TO AVOID REDUNDANCY.                                          KMC69B 4   16
ENDBIB                 14                                                  KMC69B 4   17
DATA                    6          15                                      KMC69B 4   18
EP           JPI        SIGMAX     LP         GAMMAP     RWP               KMC69B 4   19
KEV          NO-DIM     MILLIBARN  NO-DIM     KEV        NO-DIM            KMC69B 4   20
 2854.                  9.4                                                KMC69B 4   21
 2984.                  0.88                                               KMC69B 4   22
 3056.        1.0       11.4       0.0        31.0       1.15              KMC69B 4   23
 3095.       -2.0       36.9       1.0        11.5       0.69              KMC69B 4   24
 3250.        2.0       18.8       2.0        2.2        0.36              KMC69B 4   25
 3410.                  21.8                                               KMC69B 4   26
 3438.       -2.0       22.9       1.0        5.4        0.25              KMC69B 4   27
 3481.                  8.8                                                KMC69B 4   28
 3552.        4.0       41.5       4.0                                     KMC69B 4   29
 3592.                  32.0                                               KMC69B 4   30
 3636.                  49.9                                               KMC69B 4   31
 3684.                  23.8                                               KMC69B 4   32
 3744.                  55.6                                               KMC69B 4   33
 3776.                  22.0                                               KMC69B 4   34
 3800.                  9.4                                                KMC69B 4   35
ENDDATA                17                                                  KMC69B 4   36
ENDSUBENT               4                                                  KMC69B 499999
SUBENT          KMC69B  5          0                                       KMC69B 5    1
BIB                     2          14                                      KMC69B 5    2
REACTION     31P(P,ALPHA1)28SI                                             KMC69B 5    3
COMMENTS     PROPERTIES OF RESONANCES IDENTIFIED IN THIS STUDY             KMC69B 5    4
             ARE GIVEN. PHYSICAL PARAMETERS APPEARING IN TABLE II          KMC69B 5    5
             ARE IDENTIFIED IN THE TEXT. FOR SOME OF THESE ITEMS           KMC69B 5    6
             THE DEFINITIONS ARE NOT VERY CLEARLY STATED. EP =             KMC69B 5    7
             PROTON ENERGY WHERE THE RESONANCE IS OBSERVED.                KMC69B 5    8
             GAMMAOBS = OBSERVED TOTAL WIDTH (NOT CLEARLY STATED           KMC69B 5    9
             SO THIS IS AN ASSUMPTION). LALPHA = ORBITAL ANGULAR           KMC69B 5   10
             MOMENTUM OF THE ALPHA PARTICLE. GAMMAALPHA = ALPHA-           KMC69B 5   11
             PARTICLE WIDTH. RWALPHA = ALPHA-PARTICLE REDUCED              KMC69B 5   12
             WIDTH. REFER TO SUBENTRY KMC69B 4 FOR COMPLEMENTARY           KMC69B 5   13
             INFORMATION. NOTE THAT QUANTITIES APPEARING IN TABLE          KMC69B 5   14
             II WHICH CAN BE DERIVED FROM THE OTHERS ARE NOT               KMC69B 5   15
             REPRODUCED HERE IN ORDER TO AVOID REDUNDANCY.                 KMC69B 5   16
ENDBIB                 14                                                  KMC69B 5   17
DATA                    5          15                                      KMC69B 5   18
EP           GAMMAOBS   LALPHA     GAMMAALPHA RWALPHA                      KMC69B 5   19
KEV          KEV        NO-DIM     KEV        NO-DIM                       KMC69B 5   20
 2854.       4.6                                                           KMC69B 5   21
 2984.       4.0                                                           KMC69B 5   22
 3056.       32.0       2.0        0.64       43.0                         KMC69B 5   23
 3095.       12.0       1.0        0.5        13.4                         KMC69B 5   24
 3250.       14.0       0.0        1.7        17.3                         KMC69B 5   25
 3410.       4.0                                                           KMC69B 5   26
 3438.       5.5        1.0        0.1        0.78                         KMC69B 5   27
 3481.       6.6                                                           KMC69B 5   28
 3552.       6.5        2.0                                                KMC69B 5   29
 3592.       7.2                                                           KMC69B 5   30
 3636.       12.0                                                          KMC69B 5   31
 3684.       13.0                                                          KMC69B 5   32
 3744.       13.0                                                          KMC69B 5   33
 3776.       13.0                                                          KMC69B 5   34
 3800.       10.5                                                          KMC69B 5   35
ENDDATA                17                                                  KMC69B 5   36
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ENDSUBENT             5                                            KMC69B 599999
ENDENTRY              5                                            KMC69B9999999
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KS74

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ENTRY            KS74         0                                    KS74 0     1
SUBENT        KS74  1         0                                    KS74 1     1
BIB                12        39                                    KS74 1     2
INSTITUTE  (INDTAT)                                                KS74 1     3
REFERENCE  (C,74BOMBAY,17B,131,1974)                               KS74 1     4
AUTHORS    (M.B.KURUP,R.P.SHARMA)                                  KS74 1     5
TITLE      AN UPPER LIMIT TO THE LIFE TIME OF 9.709 MEV STATE IN   KS74 1     6
           32S BY BLOCKING TECHNIQUE                               KS74 1     7
FACILITY   (VDG) 5.5 MEV VAN DE GRAAFF ACCELERATOR, TATA INSTITUTE KS74 1     8
           OF FUNDAMENTAL RESEARCH, TROMBAY, BOMBAY, INDIA.        KS74 1     9
INC-PART   (P) PROTONS.                                            KS74 1    10
TARGET     SINGLE GAP CRYSTAL.                                     KS74 1    11
METHOD     GAP CRYSTAL ALIGNED IN THE <111> DIRECTION. IT WAS      KS74 1    12
           MOUNTED ON A DOUBLE AXIS GONIOMETER ATTACHED TO THE BEAM KS74 1   13
           TUBE OF THE VAN DE GRAAFF ACCELERATOR. INCIDENT         KS74 1    14
           MOLECULAR BEAM ENERGY WAS 1755 KEV (ABOUT 782-KEV       KS74 1    15
           PROTONS). THE TWO <111> AXES OF THE CRYSTAL WERE        KS74 1    16
           SEPARATED BY 71 DEG. ORIENTATION OF APPARATUS WAS SUCH  KS74 1    17
           THAT THESE AXES CORRESPONDED TO 10 AND 81 DEG. WITH     KS74 1    18
           RESPECT TO INCIDENT BEAM. BLOCKING PATTERNS OF ALPHA    KS74 1    19
           PARTICLES FROM 31P(P,ALPHA)28SI REACTION WERE DETECTED  KS74 1    20
           IN THESE TWO DIRECTIONS. EFFECTS OF RADIATION DAMAGE    KS74 1    21
           WERE MINIMIZED BY SHIFTING THE BEAM SPOT ON THE CRYSTAL KS74 1    22
           AFTER EVERY 50 MICROCOULOMBS OF INTEGRATED CHARGE.      KS74 1    23
           BEAM SPOT WAS 0.5 X 0.5 MM**2 AS A RESULT OF CAREFUL    KS74 1    24
           COLLIMATION. A TOTAL DOSE OF 7000 MICROCOULOMBS OF      KS74 1    25
           CHARGE WERE ACCUMULATED IN THIS EXPERIMENT. THE FORMULA KS74 1    26
           USED TO ESTIMATE THE LIFETIME OF THE 9.709-MEV LEVEL    KS74 1    27
           IN 32S IS GIVEN IN THE PAPER. THIS PAPER IS A SHORT     KS74 1    28
           CONFERENCE CONTRIBUTION BUT THERE IS A REFERENCE TO     KS74 1    29
           EARLIER WORK REPORTED IN AN ARTICLE IN NUCLEAR INSTR.   KS74 1    30
           AND METHODS.                                            KS74 1    31
DETECTOR   CELLULOSE NITRATE PLASTIC FILMS AT 10 AND 81 DEGREES.   KS74 1    32
           NOTE THAT IT IS IMPORTANT THAT THESE PLASTIC FILMS BE   KS74 1    33
           USED BECAUSE THERE ARE ABOUT 10**6 PROTONS SCATTERED    KS74 1    34
           FOR EVERY ALPHA-PARTICLE EMITTED AND, THROUGH PROPER    KS74 1    35
           ETCHING TECHNIQUES, THE PROTON BACKGROUND CAN BE        KS74 1    36
           COMPLETELY ELIMINATED.                                  KS74 1    37
MONITOR    (CI) CURRENT INTEGRATOR.                                KS74 1    38
CORRECTION THE PLASTIC FILM ALLOWS FOR THE BACKGROUND TO BE        KS74 1    39
           ELIMINATED AND DOES NOT AFFECT THE BLOCKING PATTERN.    KS74 1    40
STATUS     THIS WORK IS REPORTED IN PROC. OF 74BOMBAY CONF.        KS74 1    41
ENDBIB             39                                              KS74 1    42
ENDSUBENT           1                                              KS74 199999
SUBENT        KS74  2         0                                    KS74 2     1
BIB                 2         7                                    KS74 2     2
REACTION 31P(P,ALPHA)28SI                                          KS74 2     3
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COMMENTS   CHANNELING MEASUREMENTS YIELD THE MEAN LIFE TIME AND     KS74 2     4
           LEVEL WIDTH FOR A STATE IN 32S. EX = LEVEL EXCITATION    KS74 2     5
           ENERGY. TAU = MEAN LIFETIME. GAMMA = LEVEL WIDTH.        KS74 2     6
           THE AUTHORS STATE THAT THE LIFE TIME VALUE OBTAINED WAS  KS74 2     7
           AN UPPER BOUND. THEREFORE, THE CORRESPONDING LEVEL WIDTH KS74 2     8
           IS A LOWER BOUND.                                        KS74 2     9
ENDBIB               7                                              KS74 2    10
DATA                 3          1                                   KS74 2    11
EX         TAU          GAMMA                                       KS74 2    12
MEV        SEC          EV                                          KS74 2    13
 9.709      4.0000E-17 16.0                                         KS74 2    14
ENDDATA              3                                              KS74 2    15
ENDSUBENT            2                                              KS74 299999
ENDENTRY             2                                              KS749999999
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K+85

Note: The entry for the EXFOR File below carries the label K+85A in order to avoid confusion with a similar file generated from the same reference for the $^{32}S(p,\gamma)^{33}Cl$ reaction (*e.g.*, see Ref. MS97).

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ENTRY            K+85A          0                                   K+85A 0     1
SUBENT        K+85A  1          0                                   K+85A 1     1
BIB                 12         32                                   K+85A 1     2
INSTITUTE  (HUNDEB)                                                 K+85A 1     3
REFERENCE  (J,JRN,89,1,123,1985)                                    K+85A 1     4
AUTHORS    (A.Z.KISS,E.KOLTAY,B.NYAKO,E.SOMORJAI,A.ANTTILA,         K+85A 1     5
           J.RAISANEN)                                              K+85A 1     6
TITLE      MEASUREMENTS OF RELATIVE THICK TARGET YIELDS FOR         K+85A 1     7
           PIGE ANALYSIS ON LIGHT ELEMENTS IN THE PROTON            K+85A 1     8
           ENERGY INTERVAL 2.4 - 4.2 MEV                            K+85A 1     9
FACILITY   (VDG) 5-MV VAN DE GRAAFF ACCELERATOR, INSTITUTE OF       K+85A 1    10
           NUCLEAR RESEARCH, HUNGARIAN ACADEMY OF SCIENCES,         K+85A 1    11
           DEBRECEN, HUNGARY.                                       K+85A 1    12
INC-PART   (P) PROTONS.                                             K+85A 1    13
TARGETS    VARIOUS CHEMICAL COMPOUNDS. FABRICATED BY PRESSING INTO  K+85A 1    14
           PELLETS. NO OTHER DETAILS ARE GIVEN.                     K+85A 1    15
METHOD     RELATIVE THICK TARGET YIELD DETERMINED. MEASURED WITH    K+85A 1    16
           AN INCIDENT PROTON BEAM FROM A 5-MV VAN DE GRAAFF        K+85A 1    17
           ACCELERATOR. INTENSITY OF THE BEAM WAS ADJUSTED SO       K+85A 1    18
           THAT THE DEAD TIME WOULD BE CONSTANT FOR THE DIFFERENT   K+85A 1    19
           TARGETS THAT WERE USED. THE BEAM PASSED THROUGH A 50-    K+85A 1    20
           CM-LONG LIQUID-NITROGEN TRAP BEFORE IMPINGING ON TARGET  K+85A 1    21
           PLACED AT ANGLE OF 45 DEG. GAMMA-RAY SPECTRA MEASURED    K+85A 1    22
           WITH A GE(LI) DETECTOR. SPECTRAL DATA WERE RECORDED      K+85A 1    23
           WITH A 4K CHANNEL ANALYZER AND THEN TRANSFERRED TO A     K+85A 1    24
           PDP/I-16K COMPUTER. DATA NORMALIZED TO RESULTS FROM      K+85A 1    25
           AN EARLIER EXPERIMENT IN THIS LABORATORY. USED           K+85A 1    26
           PUBLISHED STOPPING POWER VALUES IN THE ANALYSIS.         K+85A 1    27
DETECTOR   (GELI) 25 CM**3 GE(LI) DETECTOR SITUATED AT              K+85A 1    28
           AN ANGLE OF 55 DEG. AND A TARGET-TO-DETECTOR             K+85A 1    29
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           DISTANCE OF 10 CM.                                     K+85A 1    30
CORRECTION DATA CORRECTED FOR DETECTOR DEAD TIME.                 K+85A 1    31
ERR-ANALYS NO ERRORS ARE DISCUSSED IN THE PAPER.                  K+85A 1    32
STATUS     RESULTS PUBLISHED IN J. OF RADIOANALYTICAL AND NUCLEAR K+85A 1    33
           CHEMISTRY.                                             K+85A 1    34
ENDBIB             32                                             K+85A 1    35
ENDSUBENT           1                                             K+85A 199999
SUBENT        K+85A  2          0                                 K+85A 2     1
BIB                 2           6                                 K+85A 2     2
REACTION   31P(P,ALPHA1)28SI                                      K+85A 2     3
COMMENTS   GAMMA-RAY YIELDS ARE GIVEN IN TABLE 1 OF THE PAPER.    K+85A 2     4
           EGAMMA = OBSERVED GAMMA-RAY. EP = PROTON ENERGY.       K+85A 2     5
           NGMCSR = YIELD OF GAMMA RAYS PER MICROCOULOMB PER      K+85A 2     6
           STERADIAN (1/MC/SR). THIS IS A RELATIVE UNIT TO COMPARE K+85A 2    7
           THE YIELDS FOR VARIOUS ENERGIES, TARGETS AND REACTIONS. K+85A 2    8
ENDBIB              6                                             K+85A 2     9
DATA                3           4                                 K+85A 2    10
EGAMMA     EP         NGMCSR                                      K+85A 2    11
MEV        MEV        1/MC/SR                                     K+85A 2    12
 1.779      2.4        2.0000E+03                                 K+85A 2    13
 1.779      3.1        2.1000E+05                                 K+85A 2    14
 1.779      3.8        6.5000E+05                                 K+85A 2    15
 1.779      4.2        1.6000E+06                                 K+85A 2    16
ENDDATA             6                                             K+85A 2    17
ENDSUBENT           2                                             K+85A 299999
ENDENTRY            2                                             K+85A9999999
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LFG72

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ENTRY            LFG72          0                                 LFG72 0     1
SUBENT        LFG72  1          0                                 LFG72 1     1
BIB                13          59                                 LFG72 1     2
INSTITUTE  (USALAS)                                               LFG72 1     3
REFERENCE  (J,PR/C,6,4,1240,1972)                                 LFG72 1     4
AUTHORS    (R.B.LEACHMAN,P.FESSENDEN,W.R.GIBBS)                   LFG72 1     5
TITLE      VARIATIONS OF THE 32S COMPOUND-NUCLEUS WIDTH WITH      LFG72 1     6
           ENERGY AND SPIN                                        LFG72 1     7
FACILITIES (VDG) SINGLE-STAGE VAN DE GRAAFF ACCELERATOR, LOS      LFG72 1     8
           ALAMOS SCIENTIFIC LABORATORY, LOS ALAMOS, NEW MEXICO.  LFG72 1     9
           (VDG) THREE-STAGE VAN DE GRAAFF ACCELERATOR, LOS       LFG72 1    10
           ALAMOS SCIENTIFIC LABORATORY, LOS ALAMOS, NEW MEXICO.  LFG72 1    11
INC-PART   (P) PROTONS.                                           LFG72 1    12
TARGETS    LOW-ENERGY MEASUREMENTS: 13.8-MICROGRAM/CM**2 31P      LFG72 1    13
           DEPOSITED BY AN ISOTOPE SEPARATOR ON A 0.1-            LFG72 1    14
           MILLIGRAM/CM**2 CARBON FOIL.                           LFG72 1    15
           HIGH-ENERGY MEASUREMENTS: 37-MICROGRAM/CM**2 31P       LFG72 1    16
           DEPOSITED FROM VAPOR PHASE ON A COOLED CARBON FOIL OF  LFG72 1    17
           30 MICROGRAM/CM**2.                                    LFG72 1    18
METHODS    THE LOW-ENERGY MEASUREMENTS WERE DONE WITH A SINGLE-   LFG72 1    19
           STAGE VAN DE GRAAFF ACCELERATOR. PROTON-ENERGY RANGE   LFG72 1    20
           5.20-5.55 MEV. BEAM WAS 0.1 MICROAMPERE. ENERGY        LFG72 1    21
           INCREMENTS WERE 2.5 KEV. THREE SEMICONDUCTOR DETECTORS LFG72 1    22
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            47-77 MICRONS THICK LOCATED AT 130, 150 AND 170 DEGS.   LFG72 1    23
            IN THE LABORATORY. DETECTORS HAD 4-6 DEG. ANGULAR       LFG72 1    24
            SPANS. DETECTED ALPHA PARTICLES LEADING TO POPULATION   LFG72 1    25
            OF GROUND AND FIRST-EXCITED STATES OF 28SI.             LFG72 1    26
            THE HIGH-ENERGY MEASUREMENTS WERE DONE WITH A THREE-    LFG72 1    27
            STAGE VAN DE GRAAFF ACCELERATOR. INCIDENT PROTONS       LFG72 1    28
            WERE IN THE ENERGY RANGE 18.4-22.4 MEV. ENERGY          LFG72 1    29
            INCREMENTS 20 KEV. BEAM CURRENT 0.35 MICROAMPERES.      LFG72 1    30
            50-CM SCATTERING CHAMBER WITH TARGET PERPENDICULAR      LFG72 1    31
            TO THE BEAM. BEAM WAS COLLIMATED TO 0.4 CM DIA.         LFG72 1    32
            SIX SURFACE-BARRIER DETECTORS WITH ALUMINUM ABSORBERS   LFG72 1    33
            WERE ASSEMBLED INTO AN ARRAY NEAR 133 DEG. LABORATORY   LFG72 1    34
            ANGLE. THIS ASSEMBLY HAD AN ANGULAR SPREAD OF 7.9 DEG.  LFG72 1    35
            THESE DETECTORS WERE USED IN THE EXCITATION FUNCTION    LFG72 1    36
            MEASUREMENTS SINCE THE REACTION YIELD WAS LOW. ANGULAR  LFG72 1    37
            DISTRIBUTIONS OF ALPHA-PARTICLES WERE MEASURED AT       LFG72 1    38
            PROTON ENERGIES 18.40, 18.80, 20.40, 20.80, 22.00 AND   LFG72 1    39
            22.40 MEV. A CONVENTIONAL SOLID-STATE DETECTOR SETUP    LFG72 1    40
            IN A HORIZONTAL PLANE WAS USED.                         LFG72 1    41
DETECTORS   (SOLST) LOW-ENERGY DETECTORS WERE 45-77 MICRON THICK    LFG72 1    42
            SEMICONDUCTOR DETECTORS. THE MEASUREMENTS FOR HIGH-     LFG72 1    43
            ENERGY PROTONS USED SIX SURFACE BARRIER DETECTORS WITH  LFG72 1    44
            AL ABSORBER FOILS MOUNTED IN A COLLIMATOR SYSTEM THAT   LFG72 1    45
            WAS 7.9 DEGREES WIDE. ANGULAR DISTRIBUTIONS WERE MADE   LFG72 1    46
            WITH CONVENTIONAL DETECTORS - NO DETAILS ARE GIVEN.     LFG72 1    47
MONITORS    (SOLST) SOLID-STATE DETECTOR PLACED AT 15 DEG. TO       LFG72 1    48
            MONITOR TARGET DETERIORATION FOR HIGH-ENERGY EXPT.      LFG72 1    49
            (CI) CURRENT-INTEGRATORS.                               LFG72 1    50
CORRECTION  EXCITATION FUNCTIONS WERE CORRECTED FOR FINITE-         LFG72 1    51
            RESOLUTION EFFECTS CORRESPONDING TO TARGET THICKNESS    LFG72 1    52
            AND PROTON-BEAM ENERGY SPREAD.                          LFG72 1    53
            THE HIGH-ENERGY EXCITATION FUNCTION DATA WERE           LFG72 1    54
            NORMALIZED TO A SMOOTH VARIATION OF CROSS SECTION WITH  LFG72 1    55
            ENERGY BEFORE PERFORMING THE FLUCTUATION ANALYSIS.      LFG72 1    56
ERR-ANALYS  THE TOTAL UNCERTAINTY OF CALCULATED WIDTHS THAT ARE     LFG72 1    57
            ASSOCIATED WITH THE LEVEL-DENSITY EQUATION IS           LFG72 1    58
            ESTIMATED TO BE LESS THAN TEN PERCENT.                  LFG72 1    59
STATUS      RESULTS ARE PROVIDED IN TWO TABLES AND FOURTEEN         LFG72 1    60
            FIGURES IN A PHYSICAL REVIEW ARTICLE.                   LFG72 1    61
ENDBIB              59                                              LFG72 1    62
ENDSUBENT            1                                              LFG72 199999
SUBENT        LFG72  2          0                                   LFG72 2     1
BIB                  2         12                                   LFG72 2     2
REACTION    31P(P,ALPHA)28SI                                        LFG72 2     3
COMMENTS    CROSS-CORRELATION VALUES FROM TABLE I OF ARTICLE, BASED LFG72 2     4
            ON EQ. 3. CORRELATIONS BETWEEN CONDITIONS ARE GIVEN,    LFG72 2     5
            I.E., BETWEEN COND(I) AND COND(J); I,J=1,5. COND(1) =   LFG72 2     6
            130 DEG./G.S.; COND(2) = 150 DEG./G.S.; COND(3) =       LFG72 2     7
            170 DEG./G.S.; COND(4) = 130 DEG./E.S.; COND(5) =       LFG72 2     8
            170 DEG./E.S. REFER TO FIG. 1 OF ARTICLE. G.S. = ALPHA- LFG72 2     9
            PARTICLE TRANSITION TO 28SI GROUND STATE. E.S = ALPHA-  LFG72 2    10
            PARTICLE TRANSITION TO 28SI FIRST-EXCITED STATE.        LFG72 2    11
            CORREL(I,J) EQUALS CORRELATION BETWEEN COND(I) AND      LFG72 2    12
            COND(J,). DEDUCED FROM FLUCTUATION ANALYSIS OF          LFG72 2    13
            EXCITATION FUNCTION DATA.                               LFG72 2    14
ENDBIB              12                                              LFG72 2    15
DATA                 3          9                                   LFG72 2    16
INDEX-I     INDEX-J     CORREL(I,J)                                 LFG72 2    17
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NO-DIM      NO-DIM      NO-DIM                                      LFG72 2   18
           1           2 0.83                                       LFG72 2   19
           1           3 0.04                                       LFG72 2   20
           1           4-0.19                                       LFG72 2   21
           1           5-0.27                                       LFG72 2   22
           2           3 0.39                                       LFG72 2   23
           2           4-0.04                                       LFG72 2   24
           2           5-0.09                                       LFG72 2   25
           3           5 0.43                                       LFG72 2   26
           4           5 0.87                                       LFG72 2   27
ENDDATA               11                                            LFG72 2   28
ENDSUBENT              2                                            LFG72 299999
SUBENT         LFG72   3          0                                 LFG72 3    1
BIB                    2          8                                 LFG72 3    2
REACTION    31P(P,ALPHA0)28SI                                       LFG72 3    3
COMMENTS    DIRECT-REACTION FRACTIONS AND COHERENCE WIDTHS. DATA    LFG72 3    4
            FROM TABLE II. ANGLE = LAB. MEAS. ANGLE. YMIN, Y, AND   LFG72 3    5
            YMAX ARE DIRECT REACTION FRACTIONS BASED ON PRESENT     LFG72 3    6
            ANALYSIS, INCLUDING UNCERTAINTIES. GAMMA = CORRECTED    LFG72 3    7
            WIDTH (C.M.) FROM AUTOCORRELATION FUNCTION. ERR-GAMMA = LFG72 3    8
            ERROR IN GAMMA. RANGE OF EXCITATION ENERGY IN COMPOUND  LFG72 3    9
            NUCLEUS IS 13.90-14.24 MEV.                             LFG72 3   10
ENDBIB                 8                                            LFG72 3   11
DATA                   6          3                                 LFG72 3   12
ANGLE       YMIN       Y          YMAX       GAMMA      ERR-GAMMA   LFG72 3   13
DEG         NO-DIM     NO-DIM     NO-DIM     KEV        KEV         LFG72 3   14
 170.0         0.53       0.87       1.00       14.7        2.6     LFG72 3   15
 151.0         0.36       0.67       0.88       8.5         2.6     LFG72 3   16
 131.0         0.32       0.67       0.89       9.3         2.6     LFG72 3   17
ENDDATA                5                                            LFG72 3   18
ENDSUBENT              3                                            LFG72 399999
SUBENT         LFG72   4                                            LFG72 4    1
BIB                    2          8                                 LFG72 4    2
REACTION    31P(P,ALPHA1)28SI                                       LFG72 4    3
COMMENTS    DIRECT-REACTION FRACTIONS AND COHERENCE WIDTHS. DATA    LFG72 4    4
            FROM TABLE II. ANGLE = LAB. MEAS. ANGLE. YMIN, Y, AND   LFG72 4    5
            YMAX ARE DIRECT REACTION FRACTIONS BASED ON PRESENT     LFG72 4    6
            ANALYSIS, INCLUDING UNCERTAINTIES. GAMMA = CORRECTED    LFG72 4    7
            WIDTH (C.M.) FROM AUTOCORRELATION FUNCTION. ERR-GAMMA = LFG72 4    8
            ERROR IN GAMMA. RANGE OF EXCITATION ENERGY IN COMPOUND  LFG72 4    9
            NUCLEUS IS 13.90-14.24 MEV.                             LFG72 4   10
ENDBIB                 8                                            LFG72 4   11
DATA                   6          2                                 LFG72 4   12
ANGLE       YMIN       Y          YMAX       GAMMA      ERR-GAMMA   LFG72 4   13
DEG         NO-DIM     NO-DIM     NO-DIM     KEV        KEV         LFG72 4   14
 170.0         0.0        0.0        0.12       13.3        2.6     LFG72 4   15
 131.0         0.0        0.0        0.66       10.6        2.6     LFG72 4   16
ENDDATA                4                                            LFG72 4   17
ENDSUBENT              4                                            LFG72 499999
SUBENT         LFG72   5          0                                 LFG72 5    1
BIB                    2          9                                 LFG72 5    2
REACTION    31P(P,ALPHA0)28SI                                       LFG72 5    3
COMMENTS    COHERENCE WIDTHS FROM TABLE II. MEAS. AT 136 DEG. LAB.  LFG72 5    4
            ANGLE. GAMMA1 = CORRECTED WIDTH (C.M.) FROM PEAK        LFG72 5    5
            COUNTING (ONE STD. DEV.). ERR-GAMMA1 = ERROR IN GAMMA1. LFG72 5    6
            GAMMA2 = CORRECTED WIDTH (C.M.) FROM PEAK COUNTING      LFG72 5    7
            (TWO STD. DEVS.). ERR-GAMMA2 = ERROR IN GAMMA2.         LFG72 5    8
            GAMMA3 = CORRECTED WIDTH (C.M) FROM AUTOCORRELATION     LFG72 5    9
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           FUNCTION. ERR-GAMMA3 = ERROR IN GAMMA3. RANGE OF        LFG72 5    10
           EXCITATION IN COMPOUND NUCLEUS IS 26.62-30.56 MEV.      LFG72 5    11
ENDBIB               9                                             LFG72 5    12
DATA                 6          1                                  LFG72 5    13
GAMMA1     ERR-GAMMA1 GAMMA2     ERR-GAMMA2 GAMMA3     ERR-GAMMA3  LFG72 5    14
KEV        KEV        KEV        KEV        KEV        KEV         LFG72 5    15
 78.0       8.0        147.0      19.0       95.0       22.0       LFG72 5    16
ENDDATA              3                                             LFG72 5    17
ENDSUBENT            5                                             LFG72 599999
SUBENT        LFG72  6          0                                  LFG72 6     1
BIB                  2          9                                  LFG72 6     2
REACTION   31P(P,ALPHA1)28SI                                       LFG72 6     3
COMMENTS   COHERENCE WIDTHS FROM TABLE II. MEAS. AT 136 DEG. LAB.  LFG72 6     4
           ANGLE. GAMMA1 = CORRECTED WIDTH (C.M.) FROM PEAK        LFG72 6     5
           COUNTING (ONE STD. DEV.). ERR-GAMMA1 = ERROR IN GAMMA1. LFG72 6     6
           GAMMA2 = CORRECTED WIDTH (C.M.) FROM PEAK COUNTING      LFG72 6     7
           (TWO STD. DEVS.). ERR-GAMMA2 = ERROR IN GAMMA2.         LFG72 6     8
           GAMMA3 = CORRECTED WIDTH (C.M) FROM AUTOCORRELATION     LFG72 6     9
           FUNCTION. ERR-GAMMA3 = ERROR IN GAMMA3. RANGE OF        LFG72 6    10
           EXCITATION IN COMPOUND NUCLEUS IS 26.62-30.56 MEV.      LFG72 6    11
ENDBIB               9                                             LFG72 6    12
DATA                 6          1                                  LFG72 6    13
GAMMA1     ERR-GAMMA1 GAMMA2     ERR-GAMMA2 GAMMA3     ERR-GAMMA3  LFG72 6    14
KEV        KEV        KEV        KEV        KEV        KEV         LFG72 6    15
 98.0       11.0       157.0      20.0       86.0       22.0       LFG72 6    16
ENDDATA              3                                             LFG72 6    17
ENDSUBENT            6                                             LFG72 699999
ENDENTRY             6                                             LFG729999999
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P+71

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ENTRY            P+71           0                                  P+71 0      1
SUBENT        P+71   1          0                                  P+71 1      1
BIB                 13         25                                  P+71 1      2
INSTITUTE  (GERUEN)                                                P+71 1      3
REFERENCE  (J,NP/A,160,654,1971)                                   P+71 1      4
AUTHORS    (G.PHILIPP,W.-D.EMMERICH,A.HOFMANN,G.KRONER,K.THOMAS)   P+71 1      5
TITLE      THE COLLECTIVE NATURE OF THE LOW-LYING STATES IN 27AL   P+71 1      6
           AND 23NA INVESTIGATED WITH (P,ALPHA) REACTIONS          P+71 1      7
FACILITY   (VDG) TANDEM VAN DE GRAAFF ACCELERATOR, UNIVERSITY OF   P+71 1      8
           ERLANGEN-NUERNBERG, GERMANY.                            P+71 1      9
INC-PART   (P) PROTONS.                                            P+71 1     10
TARGETS    NO DESCRIPTION OF 31P TARGETS IS PROVIDED.              P+71 1     11
METHOD     DIFFERENTIAL CROSS SECTIONS FOR ALPHA-PARTICLE EMISSION P+71 1     12
           MEASURED IN 100-KEV STEPS FOR BOMBARDING ENERGIES IN    P+71 1     13
           RANGE 5.8-8.2 MEV AND 10-11.5 MEV. ENERGY SPECTRA       P+71 1     14
           MEASURED IN 5-DEG. INCREMENTS FROM 20 TO 170 DEG.       P+71 1     15
           SIXTEEN SURFACE-BARRIER DETECTORS WERE USED. TARGET     P+71 1     16
           THICKNESS AND INTEGRATED BEAM CURRENT WERE MEASURED.    P+71 1     17
           DIFFERENTIAL CROSS SECTIONS WERE DETERMINED ABSOLUTELY. P+71 1     18
DETECTORS  (SOLST) SURFACE-BARRIER DETECTORS.                      P+71 1     19
MONITOR    (CI) CURRENT INTEGRATOR.                                P+71 1     20
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CORRECTION CROSS SECTIONS CORRECTED FOR ALPHA-PARTICLE COULOMB-      P+71 1    21
           BARRIER PENETRABILITY AND FOR ERICSON FLUCTUATIONS.       P+71 1    22
ERR-ANALYS STATISTICAL ERRORS WERE CONSIDERED IN DETERMINATION       P+71 1    23
           OF THE ANGULAR DISTRIBUTIONS AS EXHIBITED IN              P+71 1    24
           FIGS. 3 AND 6 OF THE ARTICLE.                             P+71 1    25
STATUS     PUBLISHED IN NUCLEAR PHYSICS A. THERE ARE OF 6 FIGURES    P+71 1    26
           AND 3 DATA TABLES PROVIDED IN THIS COMMUNICATION.         P+71 1    27
ENDBIB             25                                                P+71 1    28
ENDSUBENT           1                                                P+71 199999
SUBENT         P+71 2          0                                     P+71 2     1
BIB                 2          9                                     P+71 2     2
REACTION   31P(P,ALPHA)28SI                                          P+71 2     3
COMMENTS   DATA PERTAINING TO THIS REACTION APPEAR IN TABLE 2.       P+71 2     4
           SIGTOT = CORRECTED TOTAL CROSS SECTION. SIGISO =          P+71 2     5
           CORRECTED ISOTROPIC CROSS SECTION. SIGD = SIGTOT -        P+71 2     6
           SIGISO. PROTON BOMBARDING ENERGY NOT GIVEN EXPLICITLY.    P+71 2     7
           INDEX "I" INDICATES A CONDITION WHERE THERE IS THE SAME   P+71 2     8
           ENERGY IN INTIAL CHANNEL AS 30SI(P,ALPHA)27AL REACTION.   P+71 2     9
           INDEX "F" INDICATES A CONDITION WHERE THERE IS THE SAME   P+71 2    10
           ENERGY IN FINAL CHANNEL AS 30SI(P,ALPHA)27AL REACTION.    P+71 2    11
ENDBIB              9                                                P+71 2    12
DATA                4          1                                     P+71 2    13
SIGTOTI    SIGDI      SIGTOTF    SIGDF                               P+71 2    14
MILLIBARN  MILLIBARN  MILLIBARN  MILLIBARN                           P+71 2    15
 2.48       0.83       8.16       2.56                               P+71 2    16
ENDDATA             3                                                P+71 2    17
ENDSUBENT           2                                                P+71 299999
ENDENTRY            2                                                P+719999999
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RWK87

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ENTRY           RWK87          0                                    RWK87 0     1
SUBENT        RWK87 1          0                                    RWK87 1     1
BIB                11         20                                    RWK87 1     2
INSTITUTE  (SFHLS)                                                  RWK87 1     3
REFERENCE  (J,NIMB,28,199,1987)                                     RWK87 1     4
AUTHORS    (J.RAISANEN,T.WITTING,J.KEINONEN)                        RWK87 1     5
TITLE      ABSOLUTE THICK-TARGET GAMMA RAY YIELDS FOR ELEMENTAL     RWK87 1     6
           ANALYSIS BY 7 AND 9 MEV PROTONS                          RWK87 1     7
FACILITY   (VDGT) 5-MV TANDEM ACCELERATOR, ACCELERATOR LAB.,        RWK87 1     8
           UNIVERSITY OF HELSINKI, HELSINKI, FINLAND.               RWK87 1     9
INC-PART   (P) PROTONS.                                             RWK87 1    10
TARGET     INP IN THE FORM OF 1-MM THICK BY 6-MM DIA. PELLETS.      RWK87 1    11
METHOD     PROTON BEAM DIRECTED ON TARGETS. GE(LI) DETECTOR WAS     RWK87 1    12
           LOCATED 27 CM DISTANT FROM TARGET AT 55 DEG. NEUTRONS    RWK87 1    13
           WERE MEASURED WITH A BF3 COUNTER LOCATED 30 CM FROM      RWK87 1    14
           THE TARGET. MEASURED ACCUMULATED PROTON CHARGE.          RWK87 1    15
           APPLICATION OF P.I.G.E. METHOD FOR ELEMENTAL ASSAY.      RWK87 1    16
DETECTORS  (GELI) 80 CM**3 GE(LI) GAMMA-RAY DETECTOR.               RWK87 1    17
           CALIBRATED USING 60CO, 56CO AND 152EU GAMMA-RAY          RWK87 1    18
           SOURCES. EFFICIENCY 18 PERCENT FOR 1.3-MEV GAMMA RAY.    RWK87 1    19
           (PROPC) BF3 PROPORTIONAL COUNTER NEUTRON DETECTOR.       RWK87 1    20
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MONITOR     (CI) PROTON CURRENT INTEGRATOR.                           RWK87 1    21
STATUS      PUBLISHED IN NUCLEAR INSTRUMENTS AND METHODS B.           RWK87 1    22
ENDBIB               20                                               RWK87 1    23
ENDSUBENT             1                                               RWK87 199999
SUBENT         RWK87  2          0                                    RWK87 2     1
BIB                   2          6                                    RWK87 2     2
REACTION    31P(P,P')31P                                              RWK87 2     3
COMMENTS    ABSOLUTE INELASTIC GAMMA-RAY YIELD IS GIVEN. UNITS ARE    RWK87 2     4
            GAMMA RAYS PER MICROCOULOMB PER STERADIAN (1/MC/SR).      RWK87 2     5
            EP = INCIDENT PROTON ENERGY. EGAMMA = ENERGY OF THE       RWK87 2     6
            OBSERVED GAMMA RAY. NGMCSR = NUMBER OF GAMMA RAYS PER     RWK87 2     7
            MICROCOULOMB PER STERADIAN.                               RWK87 2     8
ENDBIB                6                                               RWK87 2     9
DATA                  3          2                                    RWK87 2    10
EGAMMA      EP         NGMCSR                                         RWK87 2    11
KEV         KEV        1/MC/SR                                        RWK87 2    12
  1266.0     7.0         9.7400E+07                                   RWK87 2    13
  1266.0     9.0         1.7400E+08                                   RWK87 2    14
ENDDATA               4                                               RWK87 2    15
ENDSUBENT             2                                               RWK87 299999
SUBENT         RWK87  3          0                                    RWK87 3     1
BIB                   2          6                                    RWK87 3     2
REACTION    31P(P,ALPHA)28SI                                          RWK87 3     3
COMMENTS    ABSOLUTE (P,ALPHA) GAMMA-RAY YIELD IS GIVEN. UNITS ARE    RWK87 3     4
            GAMMA RAYS PER MICROCOULOMB PER STERADIAN (1/MC/SR).      RWK87 3     5
            EP = INCIDENT PROTON ENERGY. EGAMMA = ENERGY OF THE       RWK87 3     6
            OBSERVED GAMMA RAY. NGMCSR = NUMBER OF GAMMA RAYS PER     RWK87 3     7
            MICROCOULOMB PER STERADIAN.                               RWK87 3     8
ENDBIB                6                                               RWK87 3     9
DATA                  3          2                                    RWK87 3    10
EGAMMA      EP         NGMCSR                                         RWK87 3    11
KEV         KEV        1/MC/SR                                        RWK87 3    12
  1779.0     7.0         5.2200E+07                                   RWK87 3    13
  1779.0     9.0         8.1000E+07                                   RWK87 3    14
ENDDATA               4                                               RWK87 3    15
ENDSUBENT             3                                               RWK87 399999
SUBENT         RWK87  4          0                                    RWK87 4     1
BIB                   2          9                                    RWK87 4     2
REACTIONS    31P(P,P')31P, 31P(P,GAMMA)32S                            RWK87 4     3
COMMENTS    ABSOLUTE GAMMA-RAY YIELD IS GIVEN. UNITS ARE              RWK87 4     4
            GAMMA RAYS PER MICROCOULOMB PER STERADIAN (1/MC/SR).      RWK87 4     5
            EP = INCIDENT PROTON ENERGY. EGAMMA = ENERGY OF THE       RWK87 4     6
            OBSERVED GAMMA RAY. NGMCSR = NUMBER OF GAMMA RAYS PER     RWK87 4     7
            MICROCOULOMB PER STERADIAN. THE YIELD GIVEN HERE IS       RWK87 4     8
            THE SUM OF THE 2230.0-KEV GAMMA RAY FROM THE (P,P')       RWK87 4     9
            REACTION AND THE 2235.0-KEV GAMMA RAY FROM (P,GAMMA)      RWK87 4    10
            REACTION. NOMINAL GAMMA-RAY ENERGY IS 2232.5 KEV.         RWK87 4    11
ENDBIB                9                                               RWK87 4    12
DATA                  3          2                                    RWK87 4    13
EGAMMA      EP         NGMCSR                                         RWK87 4    14
KEV         KEV        1/MC/SR                                        RWK87 4    15
  2232.5     7.0         7.0100E+07                                   RWK87 4    16
  2232.5     9.0         1.3300E+08                                   RWK87 4    17
ENDDATA               4                                               RWK87 4    18
ENDSUBENT             4                                               RWK87 499999
ENDENTRY              4                                               RWK879999999
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R+67

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ENTRY            R+67           0                              R+67 0     1
SUBENT          R+67  1         0                              R+67 1     1
BIB                  13        63                              R+67 1     2
INSTITUTE  (USATEX)                                            R+67 1     3
REFERENCE  (J,NP/A,96,641,1967)                                R+67 1     4
AUTHORS    (P.J.RILEY,G.A.LOCK,J.A.RAWLINS,Y.M.SHIN)           R+67 1     5
TITLE      LEVELS OF 32S STUDIED BY THE 31P(P,ALPHA0)28SI REACTION R+67 1     6
FACILITIES (VDG) 4-MEV KN VAN DE GRAAFF ACCELERATOR AND EN TANDEM R+67 1  7
           VAN DE GRAAFF ACCELERATOR, UNIVERSITY OF TEXAS, AUSTIN, R+67 1  8
           TEXAS.                                              R+67 1     9
INC-PART   (P) PROTONS.                                        R+67 1    10
TARGETS    NATURAL RED PHOSPHORUS EVAPORATED ON THIN CARBON    R+67 1    11
           BACKINGS. THICKNESS CATEGORIES: 6 AND 17 MICROGRAM/CM**3 R+67 1 12
           FOR LOW- AND HIGH-ENERGY MEASUREMENTS, RESPECTIVELY. R+67 1   13
METHOD     YIELD-CURVE AND ANGULAR DISTRIBUTION MEASUREMENTS FOR R+67 1  14
           EMITTED ALPHA-PARTICLES. 4-MEV ACCELERATOR USED FOR R+67 1    15
           THE REGION FROM 1 TO 2.8 MEV. USED 7LI(P,N) REACTION R+67 1   16
           THRESHOLD AT 1880.6 KEV TO CALIBRATE PROTON ENERGY  R+67 1    17
           SCALE. PROTON-BEAM ENERGY SPREAD WAS ABOUT 1 KEV.   R+67 1    18
           YIELD CURVE MEASUREMENTS PERFORMED ONLY IN THE RANGE R+67 1   19
           1.98 TO 2.10 MEV IN STEPS OF 1 KEV. FOUR DETECTORS  R+67 1    20
           PLACED AT 90, 110, 130, AND 150 DEG. WERE USED. THESE R+67 1  21
           WERE PLACED INSIDE A 20.3-CM SCATTERING CHAMBER. ANGULAR R+67 1 22
           DISTRIBUTIONS WERE MEASURED AT THE KNOWN RESONANCES IN R+67 1 23
           RANGE 1 TO 2.8 MEV. TANDEM ACCELERATOR WAS USED FOR THE R+67 1 24
           MEASUREMENTS IN THE RANGE 2.8 TO 5.5 MEV. THE ENERGY R+67 1   25
           SCALE WAS BASED ON THE 27AL(P,N)27SI THRESHOLD AT 5797 R+67 1 26
           MEV. PROTON-BEAM ENERGY SPREAD WAS ABOUT 2 KEV. YIELD R+67 1  27
           CURVE MEASURED IN 5-KEV STEPS USING TWO DETECTORS, AT R+67 1  28
           90 AND 155 DEG. ANGULAR DISTRIBUTIONS MEASURED IN 10- R+67 1  29
           DEG. STEPS FROM 30 TO 160 DEG. LABORATORY ANGLE. THESE R+67 1 30
           MEASUREMENTS USED THE SAME 20.3-CM SCATTERING CHAMBER R+67 1  31
           EMPLOYED AT THE 4-MEV ACCELERATOR. RAW DATA WERE ALPHA- R+67 1 32
           PARTICLE SPECTRA RECORDED WITH A 400-CHANNEL ANALYZER. R+67 1 33
           PROTON BEAM CURRENTS WERE TYPICALLY 0.1 MICROAMPERE. R+67 1   34
           PROTON-BEAM CHARGE RECORDED WITH CURRENT INTEGRATOR. R+67 1   35
           EACH RUN CONSISTED OF ABOUT 60 MICROCOULOMB OF CHARGE. R+67 1 36
           DATA ANALYZED TO DETERMINE DIFFERENTIAL CROSS SECTIONS R+67 1 37
           AT 90 DEG. (ONLY FOR DATA FROM TANDEM EXPERIMENT),  R+67 1    38
           WIDTHS, SPINS AND PARITIES OF RESONANCES, REDUCED   R+67 1    39
           WIDTHS, AND DIMENSIONLESS WIDTHS. CROSS SECTIONS FOR R+67 1   40
           LOW-ENERGY REGION EXTRACTED FROM THE LITERATURE (CLARKE R+67 1 41
           ET AL., NUCLEAR PHYSICS 14, 472, 1959).             R+67 1    42
DETECTORS  (SOLST) FOUR SURFACE-BARRIER DETECTORS WITH 25-MM**2 R+67 1   43
           ACTIVE AREA AND 300-MICROMETER DEPLETION DEPTH WERE R+67 1    44
           USED. PLACED IN A 20.3 CM DIAMETER CHAMBER. EACH    R+67 1    45
           DETECTOR SUBTENDED A SOLID ANGLE OF APPROX. 0.0025 SR. R+67 1 46
MONITOR    (CI) CURRENT INTEGRATOR.                            R+67 1    47
CORRECTION CORRECTIONS WERE MADE FOR TARGET THICKNESS AND BEAM R+67 1    48
           ENERGY SPREAD. CORRECTIONS WERE GENERALLY NEGLIGIBLE R+67 1    49
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           EXCEPT FOR THE NARROWEST RESONANCES.                    R+67 1    50
ERR-ANALYS CROSS-SECTION ERROR ESTIMATED TO BE 20 PCT. RELATIVE    R+67 1    51
           AND 25 PCT. ABSOLUTE FOR CROSS SECTIONS FROM CLARKE ET  R+67 1    52
           AL. CROSS SECTIONS OBTAINED FROM PRESENT WORK IN THE    R+67 1    53
           HIGH-ENERGY REGION HAVE ERRORS WHICH ARE ASSUMED TO BE  R+67 1    54
           25 PCT. ABSOLUTE. ESTIMATED ERRORS FOR ABSOLUTE VALUES  R+67 1    55
           OF RESONANCE ENERGIES WERE CONSIDERED TO BE ABOUT 10    R+67 1    56
           KEV. ERRORS IN ENERGY DIFFERENCES FOR CLOSELY SPACED    R+67 1    57
           RESONANCES WERE PROBABLY ABOUT 2 KEV. MOST OF THE ERROR R+67 1    58
           IN THE RESONANCE STRENGTHS IS DUE TO UNCERTAINTIES IN   R+67 1    59
           THE CROSS-SECTION DETERMINATIONS.                       R+67 1    60
STATUS     PUBLISHED IN NUCLEAR PHYSICS. DATA FROM TABLE 1 AND     R+67 1    61
           PLOTS. THERE IS A PROBLEM WITH TABLE 1 IN THAT IT SPANS R+67 1    62
           TWO PAGES AND SOME OF THE PRINTED RESULTS ARE LOST IN   R+67 1    63
           THE VOLUME BINDING DUE TO A LACK OF FORESIGHT BY THE    R+67 1    64
           PUBLISHER IN SETTING THE PRINTING MARGINS.              R+67 1    65
ENDBIB            63                                               R+67 1    66
ENDSUBENT          1                                               R+67 199999
SUBENT        R+67  2          0                                   R+67 2     1
BIB                2          17                                   R+67 2     2
REACTION   31P(P,ALPHA0)28SI                                       R+67 2     3
COMMENTS   RESULTS ARE TAKEN FROM TABLE 1 OF THE ARTICLE. E =      R+67 2     4
           INCIDENT PROTON ENERGY FOR THE OBSERVED RESONANCE.      R+67 2     5
           GAMMA = TOTAL WIDTH OF THE RESONANCE. DSIG90 = REACTION R+67 2     6
           DIFFERENTIAL CROSS SECTION AT 90 DEG. SIG = ANGLE-      R+67 2     7
           INTEGRATED REACTION CROSS SECTION. STRENG = RESONANCE   R+67 2     8
           STRENGTH AS DEFINED IN THE ARTICLE. GAMMAP = PROTON     R+67 2     9
           WIDTH CALCULATED FROM THE RESONANCE STRENGTH, BASED ON  R+67 2    10
           THE ASSUMPTION THAT THE ALPHA-PARTICLE WIDTH IS         R+67 2    11
           APPROXIMATELY EQUAL TO THE TOTAL WIDTH. NO ERRORS ARE   R+67 2    12
           GIVEN EXPLICITLY FOR ANY OF THESE PARAMETERS IN TABLE 1. R+67 2   13
           SOME OF THE VALUES GIVEN FOR DSIG90 IN TABLE 1 ARE      R+67 2    14
           DESIGNATED AS APPROXIMATIONS OR LOWER BOUNDS. REFER TO  R+67 2    15
           THIS TABLE FOR DETAILS PERTAINING TO INDIVIDUAL CASES.  R+67 2    16
           NOTE THAT NO INFORMATION COULD BE DEDUCED FROM TABLE 1  R+67 2    17
           FOR THE RESONANCE AT 2.808 MEV BECAUSE THIS PORTION     R+67 2    18
           OF THE TABLE WAS HIDDEN BY THE VOLUME BINDING.          R+67 2    19
ENDBIB            17                                               R+67 2    20
DATA               6          37                                   R+67 2    21
E          GAMMA      DSIG90     SIG        STRENG     GAMMAP      R+67 2    22
MEV        KEV        MB/SR      MB         EV         EV          R+67 2    23
  1.014      0.8        1.8        16.0       5.0        6.7       R+67 2    24
  1.400      1.8        0.87       11.0       11.0       8.8       R+67 2    25
  1.466      1.3        0.53       22.0       16.0       9.2       R+67 2    26
  1.513      8.3        16.0       144.0      690.0      930.0     R+67 2    27
  1.639      2.9        1.9        22.0       40.0       160.0     R+67 2    28
  1.715      1.8        0.21       2.2        26.5       21.0      R+67 2    29
  1.815      3.1        0.7        7.4        16.0       9.1       R+67 2    30
  1.891      20.0       3.2        77.0       1100.0     900.0     R+67 2    31
  1.971      4.4        0.68       20.0       65.0       87.0      R+67 2    32
  1.985      3.0        0.94       16.0       38.0       50.0      R+67 2    33
  2.004      6.0        0.85       14.8       68.0       91.0      R+67 2    34
  2.011      4.0        1.0        16.0       51.0       68.0      R+67 2    35
  2.015      4.0        2.7                                        R+67 2    36
  2.019      2.5        2.2        28.0       54.0       31.0      R+67 2    37
  2.027                 0.4                                        R+67 2    38
  2.115      2.1        0.07       12.0       21.0       28.0      R+67 2    39
  2.448      9.0        2.5        27.0       220.0      303.0     R+67 2    40
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2.662      4.0        0.4        7.0        29.0       38.0            R+67 2    41
2.831      10.7       0.60       19.0       212.0      280.0           R+67 2    42
2.907      6.6        0.24       19.0       130.0      170.0           R+67 2    43
2.950      8.0        1.7        29.0       250.0      200.0           R+67 2    44
3.040      30.0       0.96       30.0       1000.0     1300.0          R+67 2    45
3.148      7.6        0.50       29.0       250.0      330.0           R+67 2    46
3.173      7.3        0.40       7.0        59.0       34.0            R+67 2    47
3.254      11.8       5.0        46.0       620.0      500.0           R+67 2    48
3.394      6.9        3.7        64.6       550.0      320.0           R+67 2    49
3.434      22.0       0.88       11.1       300.0      1200.0          R+67 2    50
3.545      21.0       0.90       22.0       600.0      790.0           R+67 2    51
3.640      4.8        1.4        27.0       170.0      140.0           R+67 2    52
3.674      7.7        0.64       11.0       110.0      64.0            R+67 2    53
3.710      13.9       0.31       10.0       200.0      110.0           R+67 2    54
3.768      7.8        0.78       8.1        86.0       69.0            R+67 2    55
3.796      18.6       0.52       11.0       290.0      390.0           R+67 2    56
3.837      8.4        0.19       3.9        45.0       37.0            R+67 2    57
3.853      3.0        1.4        21.0       90.0       73.0            R+67 2    58
3.886      7.9        0.62       8.3        93.0       53.0            R+67 2    59
4.678      10.5       2.4        34         670.0      370.0           R+67 2    60
ENDDATA              39                                              R+67 2    61
ENDSUBENT             2                                              R+67 299999
SUBENT          R+67  3          0                                   R+67 3     1
BIB                   2         16                                   R+67 3     2
REACTION   31P(P,ALPHA0)28SI                                         R+67 3     3
COMMENTS   RESULTS ARE TAKEN FROM TABLE 1 OF THE ARTICLE. E =        R+67 3     4
           THE INCIDENT PROTON ENERGY FOR THE OBSERVED RESONANCE.    R+67 3     5
           THP2A = DIMENSIONLESS REDUCED PROTON WIDTH CALCULATED     R+67 3     6
           UNDER ASSUMPTION THAT THE ALPHA-PARTICLE WIDTH IS         R+67 3     7
           APPROXIMATELY EQUAL TO THE TOTAL WIDTH. THA2A =           R+67 3     8
           DIMENSIONLESS REDUCED ALPHA-PARTICLE WIDTH BASED ON THE   R+67 3     9
           SAME ASSUMPTION. THP2P = DIMENSIONLESS REDUCED PROTON     R+67 3    10
           WIDTH CALCULATED UNDER THE ASSUMPTION THAT THE PROTON     R+67 3    11
           WIDTH IS APPROXIMATELY EQUAL TO THE TOTAL WIDTH.          R+67 3    12
           THA2P = DIMENSIONLESS REDUCED ALPHA-PARTICLE WIDTH        R+67 3    13
           BASED ON THE SAME ASSUMPTION. NOTE THAT THE DISCUSSION    R+67 3    14
           IN THE ARTICLE IS SOMEWHAT CONFUSING, AS ARE THE COLUMN   R+67 3    15
           LABELS IN TABLE 1. THE DATA ENTRY HERE IS BASED ON THE    R+67 3    16
           COMPILERS BEST ESTIMATE AS TO WHAT WAS INTENDED BY THE    R+67 3    17
           AUTHORS.                                                  R+67 3    18
ENDBIB               16                                              R+67 3    19
DATA                  5         35                                   R+67 3    20
E          THP2A      THA2A      THP2P      THA2P                    R+67 3    21
MEV        NO-DIM     NO-DIM     NO-DIM     NO-DIM                   R+67 3    22
 1.014      3.22       0.27       0.027      32.1                    R+67 3    23
 1.400      62.2       0.51       0.31       105.0                   R+67 3    24
 1.466      85.6       7.4        6.1        1043.0                  R+67 3    25
 1.513      20.9       3.05       2.33       27.3                    R+67 3    26
 1.639      2.07       0.10       0.12       1.81                    R+67 3    27
 1.715      42.8       0.32       0.50       27.9                    R+67 3    28
 1.815      121.0      1.62       3.57       552.0                   R+67 3    29
 1.891      39.5       7.75       17.8       171.5                   R+67 3    30
 1.971      7.6        0.08       0.15       3.74                    R+67 3    31
 1.985      5.07       0.041      0.085      2.47                    R+67 3    32
 2.004      10.0       0.071      0.152      4.65                    R+67 3    33
 2.011      6.62       0.051      0.112      3.00                    R+67 3    34
 2.019      777.0      2.82       9.6        227.0                   R+67 3    35
 2.115      3.25       0.02       0.044      1.23                    R+67 3    36
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2.448	10.9	0.09	0.367	2.97	R+67 3 37
2.662	4.19	0.009	0.040	0.89	R+67 3 38
2.831	9.3	0.054	0.25	2.09	R+67 3 39
2.907	5.50	0.030	0.113	1.13	R+67 3 40
2.950	51.4	0.21	1.16	8.37	R+67 3 41
3.040	23.9	0.191	1.06	4.31	R+67 3 42
3.148	5.64	0.041	0.25	0.94	R+67 3 43
3.173	628.0	0.224	2.89	48.6	R+67 3 44
3.254	59.6	0.334	2.52	7.75	R+67 3 45
3.394	459.0	0.142	21.0	31.0	R+67 3 46
3.434	5.75	0.059	0.318	1.07	R+67 3 47
3.545	12.8	0.068	0.377	1.80	R+67 3 48
3.640	10.8	0.089	0.50	3.12	R+67 3 49
3.674	388.0	0.18	3.18	21.7	R+67 3 50
3.710	661.0	0.27	5.3	36.2	R+67 3 51
3.768	25.3	0.023	0.23	2.53	R+67 3 52
3.796	47.9	0.12	0.21	120.0	R+67 3 53
3.837	25.4	0.010	0.11	2.48	R+67 3 54
3.853	9.0	0.021	0.21	0.88	R+67 3 55
3.886	319.0	0.105	2.15	16.2	R+67 3 56
4.678	205.0	0.315	7.33	14.0	R+67 3 57
ENDDATA		37			R+67 3 58
ENDSUBENT		3			R+67 399999
ENDENTRY		3			R+679999999

R+95

ENTRY	R95 0	R95 0 1
SUBENT	R95 1 0	R95 1 1
BIB	14 75	R95 1 2
INSTITUTE	(USAPTN)	R95 1 3
REFERENCE	(J,PR/C,52,3,1681,1995)	R95 1 4
AUTHORS	(J.G.ROSS,J.GORRES,C.ILIADIS,S.VOUZOUKAS,M.WIESCHER,	R95 1 5
	R.B.VOGELAAR, S.UTKU,N.P.T.BATEMAN,P.D.PARKER)	R95 1 6
TITLE	INDIRECT STUDY OF LOW-ENERGY RESONANCES IN	R95 1 7
	31P(P,ALPHA)28SI AND 35CL(P,ALPHA)32S	R95 1 8
FACILITY	(CYCLO) PRINCETON AVF CYCLOTRON, PRINCETON UNIVERSITY,	R95 1 9
	PRINCETON, NEW JERSEY.	R95 1 10
INC-PART	(3HE) 3HE PARTICLES.	R95 1 11
TARGETS	CO2P EVAPORATED ONTO CARBON FOIL. THICKNESSES: CO2P =	R95 1 12
	30-50 MICROGRAM/CM**2; CARBON = 40 MICROGRAM/CM**2.	R95 1 13
	ELEMENTAL CO TARGET ALSO PREPARED FOR BACKGROUND	R95 1 14
	MEASUREMENTS (NO THICKNESS GIVEN).	R95 1 15
METHOD	DIRECT MEASUREMENTS ON THE 31P(P,ALPHA)28SI REACTION FOR	R95 1 16
	LOW-ENERGY PROTONS ARE EXTREMELY DIFFICULT BECAUSE THE	R95 1 17
	REACTION YIELDS ARE VERY LOW. HOWEVER, THERE IS STRONG	R95 1 18
	EVIDENCE THAT PROTON UNBOUND LEVELS IN THE COMPOUND	R95 1 19
	SYSTEM 32S = 31P+P CAN BE EXCITED THROUGH SINGLE-PARTICLE	R95 1 20
	(PROTON) TRANSFER VIA THE (3HE,D) REACTION. THE GOAL OF	R95 1 21
	THE PRESENT EXPERIMENT, THEREFORE, WAS TO DETERMINE THE	R95 1 22
	RESONANCE ENERGIES AND WIDTHS (PROTON, ALPHA-PARTICLE	R95 1 23
	AND TOTAL) NEEDED TO CALCULATE THE RESONANCE STRENGTH BY	R95 1 24

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           INDIRECT MEANS. A BEAM OF 25-MEV 3HE PARTICLES WITH AN     R95 1    25
           INTENSITY TYPICALLY ABOUT 50 NANOAMPERES WAS DIRECTED      R95 1    26
           ONTO A TARGET OF CO2P WHICH HAD BEEN EVAPORATED ON         R95 1    27
           A CARBON BACKING. BACKGROUND MEASUREMENTS WERE PERFORMED   R95 1    28
           USING A FOIL OF PURE CO. THE DEUTERONS EMITTED AT ZERO     R95 1    29
           DEG. WERE MEASURED USING THE PRINCETON QDDD MAGNETIC       R95 1    30
           SPECTROMETER. THE RESOLUTION WAS TYPICALLY AROUND 20       R95 1    31
           KEV. EMITTED PROTONS AND ALPHA-PARTICLES WERE DETECTED     R95 1    32
           AT 90, 110, AND 145 DEG. IN THE LABORATORY SYSTEM. SI      R95 1    33
           SURFACE BARRIER DETECTORS WERE USED. THESE WERE PLACED     R95 1    34
           AROUND 9.5 CM AWAY FROM THE TARGET. THESE DETECTORS        R95 1    35
           WERE CALIBRATED USING A 241AM ALPHA-PARTICLE SOURCE.       R95 1    36
           THE DETECTOR SOLID ANGLES WERE CALCULATED FROM THE         R95 1    37
           GEOMETRY AND WERE ALSO MEASURED USING THE WELL-KNOWN       R95 1    38
           19F(3HE,D)20NE REACTION. SINCE THE AIM OF THIS WORK        R95 1    39
           WAS ALSO TO INVESTIGATE THE 31P(P,GAMMA) REACTION BY       R95 1    40
           INDIRECT MEANS, A 12.7 X 10.2 CM**2 NAI DETECTOR WAS       R95 1    41
           USED TO DETECT GAMMA RAYS FROM THE TARGET. THIS            R95 1    42
           DETECTOR WAS PLACED 5.4 CM FROM THE TARGET AT 90 DEG.      R95 1    43
           THE GAMMA DETECTOR CALIBRATION WAS ACCOMPLISHED USING      R95 1    44
           GAMMA RAYS FROM A 137CS SOURCE AND FROM THE DECAY OF       R95 1    45
           THE WELL-KNOWN STATE AT 9.059 MEV IN 32S. UNWANTED         R95 1    46
           LOW-ENERGY GAMMA RAYS WERE ATTENUATED USING A 3-MM         R95 1    47
           THICK PB PLATE. IN THE EXPERIMENT, EMITTED PROTONS,        R95 1    48
           ALPHA-PARTICLES AND GAMMA RAYS WERE MEASURED IN            R95 1    49
           COINCIDENCE WITH THE DEUTERONS. WINDOWS WERE SET ON        R95 1    50
           SPECIFIC DEUTERON GROUPS TO DEFINE THE RESONANCES.         R95 1    51
           THE EMITTED CHARGED PARTICLES WERE DETECTED WITH A         R95 1    52
           RESOLUTION OF AROUND 100 KEV. THIS WAS ADEQUATE TO         R95 1    53
           SEPARATE THE GROUPS. THE RESOLUTION FOR THE GAMMA-         R95 1    54
           RAY MEASUREMENTS WAS RELATIVELY POOR, NEVERTHELESS IT      R95 1    55
           WAS POSSIBLE TO MAKE SOME ESTIMATES OF THE RELATIVE        R95 1    56
           WIDTHS FOR RADIATIVE DECAY OF THE RESONANCES. THIS         R95 1    57
           EXPERIMENT YIELDED VALUES FOR THE RESONANCE EXCITATION     R95 1    58
           IN 32S AS WELL AS THE EQUIVALENT C.M. PROTON ENERGY, THE   R95 1    59
           SPIN, PARITY, AND ISOSPIN OF THE RESONANCES, RELATIVE      R95 1    60
           WIDTHS FOR DECAY OF THE RESONANCES BY GAMMA RAY AND        R95 1    61
           ALPHA-PARTICLE EMISSION, AND RESONANCE STRENGTHS. THE      R95 1    62
           PROTON WIDTHS WERE CALCULATED USING THE RESULTS OF A       R95 1    63
           DWBA ANALYSIS OF THE SINGLE-PARTICLE TRANSFER REACTION.    R95 1    64
DETECTORS  (SOLST) SILICON SURFACE BARRIER DETECTORS. SURFACE AREA    R95 1    65
           WAS ABOUT 450 MM**2.                                       R95 1    66
           (SCIN)  NAI SCINTILLATION DETECTOR, 12.7 X 10.2 CM**2.     R95 1    67
MONITOR    (CI) CURRENT INTEGRATOR.                                   R95 1    68
CORRECTION DATA WERE CORRECTED FOR BACKGROUND AS MEASURED USING A     R95 1    69
           PURE CO TARGET.                                            R95 1    70
ERR-ANALYS ESTIMATED ERRORS IN CALCULTING PROTON WIDTHS WERE 40 PCT.  R95 1    71
           STATISTICAL UNCERTAINTIES IN GAMMA-RAY AND ALPHA-PARTICLE  R95 1    72
           SPECTRA OBTAINED IN COINCIDENCE WITH DEUTERON GROUPS WERE  R95 1    73
           LARGE DUE TO THE LOW COUNT RATES.                          R95 1    74
STATUS     RESULTS ARE PUBLISHED IN PHYSICAL REVIEW C.                R95 1    75
COMMENTS   NUMERICAL DATA PERTINENT TO 31P REACTIONS ARE IN TABLES    R95 1    76
           I AND III OF THE ARTICLE.                                  R95 1    77
ENDBIB              75                                                R95 1    78
ENDSUBENT            1                                                R95 199999
SUBENT          R95  2           0                                    R95 2     1
BIB                  2          14                                    R95 2     2
REACTIONS  31P(3HE,D)32S                                              R95 2     3
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           31P(P,ALPHA)28S                                      R95 2     4
           31P(P,GAMMA)32S                                      R95 2     5
COMMENTS   THE FOLLOWING NUMERICAL DATA WERE OBTAINED FROM TABLES   R95 2     6
           I AND III OF THE REFERENCE. EX = EXCITATION ENERGY IN    R95 2     7
           THE COMPOUND SYSTEM 31P+P = 32S. EP = CORRESPONDING      R95 2     8
           PROTON ENERGY IN THE C.M. SYSTEM. J-PI = SPIN/PARITY OF  R95 2     9
           THE RESONANCE. A NEGATIVE SIGN INDICATES NEGATIVE        R95 2    10
           PARITY. MULTIPLE ENTRIES FOR THE SAME RESONANCE INDICATE R95 2    11
           THAT THE SPIN/PARITY ASSIGNMENT IS UNCERTAIN. T =        R95 2    12
           ISOSPIN OF THE RESONANT STATE. GAMMAP-J IS THE PROTON    R95 2    13
           WIDTH OF THE RESONANCE GIVEN IN THE FORM (2*J+1)*GAMMAP. R95 2    14
           AVG-NG = AVERAGE GAMMA-RAY MULTIPLICITY FOR RADIATIVE    R95 2    15
           DECAY OF THE RESONANCE.                                  R95 2    16
ENDBIB             14                                           R95 2    17
DATA                6          12                               R95 2    18
EX         EP         J-PI       T          GAMMAP-J   AVG-NG   R95 2    19
MEV        MEV        NO-DIM     NO-DIM     EV         NO-DIM   R95 2    20
 9.023      0.159     -3.0        0.0       9.1000E-11 2.2      R95 2    21
 9.059      0.194     -1.0                  4.9000E-06 2.0      R95 2    22
 9.059      0.194     -2.0                  4.9000E-06 2.0      R95 2    23
 9.065      0.201      4.0                                      R95 2    24
 9.170      0.305      3.0        1.0                  2.6      R95 2    25
 9.196      0.331      2.0                                      R95 2    26
 9.208      0.344      1.0        1.0       2.4000E-02 1.8      R95 2    27
 9.236      0.371     -1.0        0.0       2.0000E-02 2.6      R95 2    28
 9.255      0.390      2.0        1.0       2.6000E-03 2.6      R95 2    29
 9.290      0.425      1.0                  0.28       2.0      R95 2    30
 9.389      0.524     -2.0                  7.75       2.2      R95 2    31
 9.464      0.600      2.0                                      R95 2    32
ENDDATA             14                                          R95 2    33
ENDSUBENT            2                                          R95 299999
SUBENT          R95  3                                          R95 3     1
BIB                  2          16                              R95 3     2
REACTIONS  31P(3HE,D)32S                                        R95 3     3
           31P(P,ALPHA)28S                                      R95 3     4
           31P(P,GAMMA)32S                                      R95 3     5
COMMENTS   THE FOLLOWING NUMERICAL DATA WERE OBTAINED FROM TABLES   R95 3     6
           I AND III OF THE REFERENCE. EX = EXCITATION ENERGY IN    R95 3     7
           THE COMPOUND SYSTEM 31P+P = 32S. GAMREL = RELATIVE       R95 3     8
           WIDTH FOR ALPHA-PARTICLE EMISSION FROM THE RESONANCE,    R95 3     9
           I.E., THE ABSOLUTE ALPHA-PARTICLE WIDTH DIVIDED BY THE   R95 3    10
           TOTAL WIDTH OF THE RESONANCE. ERR-GAMREL = ERROR IN      R95 3    11
           GAMREL. NOTE: WHEN NO ERROR IS GIVEN, THE VALUE WHICH    R95 3    12
           APPEARS IN THE TABLE IS AN UPPER BOUND. STRENG =         R95 3    13
           RESONANCE STRENGTH FOR DECAY OF 32S BY ALPHA-PARTICLE    R95 3    14
           EMISSION. STRENG = 0.25*(2*J+1)*(PROTON WIDTH)*          R95 3    15
           (ALPHA-PARTICLE WIDTH)/(TOTAL WIDTH). ERR-STRENG = ERROR R95 3    16
           IN STRENG. NOTE: WHEN NO ERROR IS GIVEN, THE VALUE       R95 3    17
           WHICH APPEARS IN THE TABLE IS AN UPPER BOUND.            R95 3    18
ENDBIB             16                                           R95 3    19
DATA                5          11                               R95 3    20
EX         GAMREL     ERR-GAMREL STRENG     ERR-STRENG          R95 3    21
MEV        NO-DIM     NO-DIM     EV         EV                  R95 3    22
 9.023      0.37       0.13      8.4000E-12 4.9000E-12          R95 3    23
 9.059      0.03                 1.9000E-08                     R95 3    24
 9.065                           3.3000E-09                     R95 3    25
 9.170      0.08                                                R95 3    26
 9.196                           4.2000E-04                     R95 3    27
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9.208        0.05                                                       R95 3    28
9.236        1.00         0.08       2.7000E-03 0.7000E-03              R95 3    29
9.255        0.08                    4.2000E-05                         R95 3    30
9.290        0.13                                                       R95 3    31
9.389        0.02                                                       R95 3    32
9.464                                2.5000E-02 0.4000E-02              R95 3    33
ENDDATA              13                                                 R95 3    34
ENDSUBENT             3                                                 R95 399999
ENDENTRY              3                                                 R959999999
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S67

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ENTRY            S67           0                                        S67 0     0
SUBENT          S67   1        0                                        S67 1     1
BIB               13          28                                        S67 1     2
INSTITUTE  (SWTZUR) UNIVERSITY OF ZURICH.                               S67 1     3
REFERENCE  (C,67WINNIPEG,495,1967) PROC. 3RD INTL. CONF. ON ATOMIC      S67 1     4
           MASSES, WINNIPEG, MANITOBA, CANADA.                          S67 1     5
AUTHOR     (H.H.STAUB)                                                  S67 1     6
TITLE      Q VALUES DETERMINED FROM RESONANCE REACTIONS AND THE         S67 1     7
           EFFECTS OF THE ATOMIC ELECTRONS                              S67 1     8
FACILITY   (VDG) 5.5-MV VAN DE GRAAFF GENERATOR, UNIVERSITY OF          S67 1     9
           ZURICH, ZURICH, SWITZERLAND.                                 S67 1    10
INC-PART   (P) PROTONS.                                                 S67 1    11
TARGET     SOLID TARGET. NO FURTHER DETAILS PROVIDED.                   S67 1    12
METHOD     PROTON BEAM FROM 5.5-MV VAN DE GRAAFF ACCELERATOR WAS        S67 1    13
           ANALYZED WITH A 90 DEG. MAGNET CONTROLLED BY NUCLEAR         S67 1    14
           MAGNETIC RESONANCE PROBE. STRAY BEAM ON DEFINING SLITS       S67 1    15
           PROVIDED FEEDBACK TO CONTROL ACCELERATOR ENERGY BY           S67 1    16
           CORONA CURRENT AND BY A VOLTAGE AMPLIFIER THAT PROVIDED      S67 1    17
           A SUPPLEMENTARY VOLTAGE SOURCE BETWEEN THE ACCELERATOR       S67 1    18
           TERMINAL AND THE BEAM TUBE. A 180-DEG. MAGNET WAS USED       S67 1    19
           TO PROVIDE A DIRECT MEASUREMENT OF BEAM ENERGY AND           S67 1    20
           RESOLUTION WITHOUT TARGET PRESENT. EFFECTS OF ATOMIC         S67 1    21
           ELECTRON BINDING ENERGIES WERE EXAMINED.                     S67 1    22
DETECTOR   NO DETAILS.                                                  S67 1    23
MONITOR    (CI) NOT MENTIONED EXPLICITLY.                               S67 1    24
CORRECTION CORRECTIONS TO ACCOUNT FOR THE BINDING ENERGY OF THE         S67 1    25
           ELECTONS ARE DISCUSSED.                                      S67 1    26
ERR-ANALYS UNCERTAINTIES ARE ASSIGNED TO THE RESULTS BUT THERE IS       S67 1    27
           LITTLE DISCUSSION ABOUT HOW THESE UNCERTAINTIES WERE         S67 1    28
           DETERMINED.                                                  S67 1    29
STATUS     PUBLISHED IN THE PROCEEDINGS OF A CONFERENCE.                S67 1    30
ENDBIB            28                                                    S67 1    31
ENDSUBENT          1                                                    S67 199999
SUBENT          S67   2        0                                        S67 2     1
BIB                2           6                                        S67 2     2
REACTION   31P(P,ALPHA)28SI                                             S67 2     3
COMMENTS   RESONANCE ENERGY AND Q-VALUE DATA OBTAINED FROM THE TEXT.    S67 2     4
           EP = RESONANCE PROTON ENERGY. ERR-EPP = ERROR IN EP.         S67 2     5
           EALPHA = ALPHA-PARTICLE EMISSION ENERGY AT THE RESONANCE.    S67 2     6
           ERR-EALPHA = ERROR IN EALPHA. QA = REACTION ATOMIC Q-        S67 2     7
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               VALUE. ERR-QA = ERROR IN QA.                            S67 2     8
ENDBIB                   6                                             S67 2     9
DATA                     6          1                                  S67 2    10
EP          ERR-EP      EALPHA      ERR-EALPHA QA         ERR-QA       S67 2    11
KEV         KEV         KEV         KEV        KEV        KEV          S67 2    12
 642.1       0.1         2901.1      0.2        1915.8     0.2         S67 2    13
ENDDATA                  3                                             S67 2    14
ENDSUBENT                2                                             S67 299999
ENDENTRY                 2                                             S679999999
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S83

Note: The entry for the EXFOR File below carries the label S83A in order to avoid confusion with a similar file generated from the same reference for the $^{32}S(p,\gamma)^{33}Cl$ reaction (*e.g.*, see Ref. MS97).

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ENTRY            S83A          0                                   S83A 0     1
SUBENT        S83A  1          0                                   S83A 1     1
BIB                 7         16                                   S83A 1     2
INSTITUTE  (AULAML)                                                S83A 1     3
REFERENCE  (J,AUJ,36,583,1983)                                     S83A 1     4
AUTHOR     (D.G.SARGOOD)                                           S83A 1     5
TITLE      EFFECTS OF EXCITED STATES ON THERMONUCLEAR REACTION     S83A 1     6
           RATES                                                   S83A 1     7
METHOD     THIS PAPER IS A COMPILATION OF CALCULATED VALUES FOR    S83A 1     8
           THE RATIO OF THERMONUCLEAR REACTION RATES WITH TARGET   S83A 1     9
           NUCLEI IN A THERMAL DISTRIBUTION OF ENERGY STATES TO    S83A 1    10
           REACTION RATES WITH ALL TARGET NUCLEI IN THEIR GROUND   S83A 1    11
           STATES. USE IS MADE OF THE STATISTICAL MODEL IN THESE   S83A 1    12
           CALCULATIONS. NO EXPERIMENTAL DATA WERE ACQUIRED IN THIS S83A 1    13
           WORK. ONLY RESULTS FOR 31P(P,ALPHA)28SI ARE GIVEN HERE. S83A 1    14
COMMENTS   THE CALCULATIONS REPORTED IN THIS ARTICLE INVOLVE A     S83A 1    15
           NUMBER OF REACTIONS WITH NEUTRONS, PROTONS, AND ALPHA   S83A 1    16
           PARTICLES IN BOTH THE INCIDENT AND EXIT CHANNELS.       S83A 1    17
STATUS     PUBLISHED IN AUSTRALIAN JOURNAL OF PHYSICS.             S83A 1    18
ENDBIB             16                                              S83A 1    19
ENDSUBENT           1                                              S83A 199999
SUBENT        S83A  2          0                                   S83A 2     1
BIB                 2         10                                   S83A 2     2
REACTION   31P(P,ALPHA)28SI                                        S83A 2     3
COMMENTS   THE FOLLOWING VALUES ARE TAKEN FROM TABLES 1-4 OF THE   S83A 2     4
           PAPER. RATIOS OF THERMONUCLEAR REACTION RATES FOR FOUR  S83A 2     5
           DIFFERENT STELLAR TEMPERATURES ARE INCLUDED. T9 =       S83A 2     6
           STELLAR TEMPERATURE IN UNITS OF 10**9 DEG. KELVIN       S83A 2     7
           (10**9K). RATIO = RATIO OF REACTION RATE WITH TARGET    S83A 2     8
           NUCLEI OCCUPYING A STATISTICAL DISTRIBUTION OF EXCITED  S83A 2     9
           STATES AT THE GIVEN TEMPERATURE TO THE SAME REACTION    S83A 2    10
           RATE CALCULATED ASSUMING ALL TARGET NUCLEI ARE IN THE   S83A 2    11
           GROUND STATE.                                           S83A 2    12
ENDBIB             10                                              S83A 2    13
DATA                2          4                                   S83A 2    14
```

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T9          RATIO                                S83A 2    15
10**9K      NO-DIM                               S83A 2    16
 1.          1.00                                S83A 2    17
 2.          1.00                                S83A 2    18
 3.5         1.03                                S83A 2    19
 5.          1.11                                S83A 2    20
ENDDATA               6                          S83A 2    21
ENDSUBENT             2                          S83A 299999
ENDENTRY              2                          S83A9999999
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SAN73

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ENTRY            SAN73          0                               SAN73 0     1
SUBENTRY      SAN73  1          0                               SAN73 1     1
BIB                 12         40                               SAN73 1     2
INSTITUTE  (DENAAU)                                             SAN73 1     3
REFERENCE  (J,NP/A,204,371,1973)                                SAN73 1     4
AUTHORS    (R.P.SHARMA,J.U.ANDERSEN,K.O.NIELSEN)                SAN73 1     5
TITLE      APPLICATION OF THE BLOCKING TECHNIQUE TO MEASURE     SAN73 1     6
           LIFETIMES OF NUCLEAR LEVELS EXCITED IN (P,ALPHA)     SAN73 1     7
           RESONANCE REACTIONS IN P AND AL                      SAN73 1     8
FACILITY   (VDG) 2-MV VAN DE GRAAFF ACCELERATOR, INSTITUTE OF   SAN73 1     9
           PHYSICS, UNIVERSITY OF AARHUS, AARHUS, DENMARK.      SAN73 1    10
INC-PART   (P) PROTONS.                                         SAN73 1    11
TARGET     (CRYST) SINGLE THICK CRYSTAL OF GAP.                 SAN73 1    12
METHOD     ORIENTED CRYSTAL OF GAP ALONG TWO <111> DIRECTIONS,  SAN73 1    13
           THESE WERE AT 10 DEG. AND 81 DEG. RELATIVE TO BEAM   SAN73 1    14
           (DENOTED A AND B). USED GONIOMETER TO SET ORIENTATION SAN73 1   15
           PRECISELY. DETERMINED PROPER ORIENTATION BY CHANNELING SAN73 1  16
           MEASUREMENT BASED ON OBSERVATION OF BACK-SCATTERED   SAN73 1    17
           PROTONS. CHOSE INCIDENT PROTON ENERGY JUST ABOVE 642- SAN73 1   18
           KEV RESONANCE SO THAT MOST OF THE REACTION STRENGTH  SAN73 1    19
           WOULD BE CONFINED TO REGION JUST BELOW CRYSTAL SURFACE. SAN73 1 20
           COMPARED YIELD OF ALPHA-PARTICLES IN THE RESONANCE   SAN73 1    21
           DIP FOR THE TWO ORIENTATIONS (A AND B). DEDUCED      SAN73 1    22
           RESONANCE LIFETIME FROM THESE DATA ACCORDING TO A    SAN73 1    23
           FORMALISM DESCRIBED IN THE ARTICLE. CHECKED FOR THE  SAN73 1    24
           POSSIBILITY OF DE-CHANNELING EFFECTS BY MEASUREMENTS SAN73 1    25
           ON A RESONANCE AT 1.51 MEV WHICH WAS MUCH STRONGER   SAN73 1    26
           AND HAD A MUCH SHORTER LIFETIME THAN THE 642-KEV     SAN73 1    27
           RESONANCE. BLOCKING EFFECTS WERE NEGLIGIBLE THERE.   SAN73 1    28
DETECTOR   (NUC-EMUL) PLASTIC FILM (CELLULOSE NITRATE). FILMS   SAN73 1    29
           WERE DEVELOPED IN A MANNER TO SUPPRESS SCATTERED     SAN73 1    30
           PROTONS AND ALLOW ALPHA EVENTS TO BE COUNTED.        SAN73 1    31
MONITORS   (SOLST) POSITION SENSITIVE DETECTOR USED TO MONITOR  SAN73 1    32
           DETERIORATION OF GAP CRYSTAL.                        SAN73 1    33
           (CI) NOT MENTIONED, BUT PRESUMABLY A CURRENT          SAN73 1    34
           INTEGRATOR WAS USED TO MONITOR PROTON DOSE TO GAI    SAN73 1    35
           CRYSTAL AND THUS AVOID RADIATION DAMAGE EFFECTS.     SAN73 1    36
ERR-ANALYS PRINCIPAL SOURCE OF ERROR WAS UNCERTAINTY IN A       SAN73 1    37
           CONSTANT "C" WHICH APPEARS IN THE FORMULAS USED TO   SAN73 1    38
           DERIVE THE LIFETIME OF THE COMPOUND NUCLEUS. ERROR   SAN73 1    39
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         ESTIMATED TO BE LESS THAN 30 PCT.                    SAN73 1    40
STATUS   PUBLISHED IN NUCLEAR PHYSICS A. DATA TAKEN FROM TEXT SAN73 1    41
         OF THE ARTICLE.                                      SAN73 1    42
ENDBIB            40                                          SAN73 1    43
ENDSUBENT          1                                          SAN73 199999
SUBENT       SAN73 2            0                             SAN73 2     1
BIB                2            8                             SAN73 2     2
REACTION 31P(P,ALPHA)28SI                                     SAN73 2     3
COMMENTS LIFETIME OF THE EXCITED STATE AT 9.486-MEV EXCITATION SAN73 2    4
         IN THE COMPOUND NUCLEUS 32S WAS DETERMINED BY THE    SAN73 2     5
         BLOCKING TECHNIQUE. TAU = MEAN LIFETIME OF THIS      SAN73 2     6
         STATE. ERR-TAU = ERROR IN TAU. GAMMA = TOTAL WIDTH   SAN73 2     7
         OF THIS STATE. ERR-GAMMA = ERROR IN GAMMA. LIFETIME  SAN73 2     8
         IS GIVEN IN UNITS OF AS (1 AS = 1 ATTOSEC. =         SAN73 2     9
         10**-18 SEC.).                                       SAN73 2    10
ENDBIB             8                                          SAN73 2    11
DATA               4            1                             SAN73 2    12
TAU       ERR-TAU    GAMMA      ERR-GAMMA                     SAN73 2    13
AS        AS         EV         EV                            SAN73 2    14
 80.0      24.0       8.2        2.5                          SAN73 2    15
ENDDATA            3                                          SAN73 2    16
ENDSUBENT          2                                          SAN73 299999
ENDENTRY           2                                          SAN739999999
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SKP75

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ENTRY          SKP75            0                             SKP75 0     1
SUBENT       SKP75 1            0                             SKP75 1     1
BIB                7           12                             SKP75 1     2
INSTITUTE (INDTRM)                                            SKP75 1     3
REFERENCE (R,BARC,799,30,1975)                                SKP75 1     4
AUTHORS   (R.P.SHARMA,M.B.KURUP,K.G.PRASAD)                   SKP75 1     5
TITLE     USE OF BLOCKING TECHNIQUE FOR THE MEASUREMENT OF    SKP75 1     6
          ULTRA SHORT COMPOUND NUCLEAR LIFETIMES              SKP75 1     7
FACILITY  (VDG) 5-MEV VAN DE GRAAFF ACCELERATOR, BHABHA ATOMIC SKP75 1    8
          RESEARCH CENTRE, TROMBAY, BOMBAY, INDIA.            SKP75 1     9
COMMENTS  PROTONS INCIDENT AT 0.8724 MEV. EXPOSURE OF 84 HOURS. SKP75 1  10
          BEAM SPOT ON CRYSTAL SHIFTED PERIODICALLY TO AVOID  SKP75 1    11
          DETERIORATION OF BLOCKING PATTERN BY CRYSTAL DAMAGE. SKP75 1   12
          REFER TO EXFOR ENTRY KS74 FOR FURTHER DETAILS.      SKP75 1    13
STATUS    RESULTS REPORTED BRIEFLY IN A BARC PROGRESS REPORT. SKP75 1    14
ENDBIB            12                                          SKP75 1    15
ENDSUBENT          1                                          SKP75 199999
SUBENT       SKP75 2            0                             SKP75 2     1
BIB                2            4                             SKP75 2     2
REACTION  31P(P,ALPHA)28SI.                                   SKP75 2     3
COMMENTS  UPPER BOUND FOR HALF LIFE OF 9.709 MEV STATE IN 32S SKP75 2     4
          IS GIVEN. EP = INCIDENT PROTON ENERGY. EX = 32S     SKP75 2     5
          EXCITATION ENERGY. TAU = MEAN LIFE OF THIS LEVEL.   SKP75 2     6
ENDBIB             4                                          SKP75 2     7
DATA               3            1                             SKP75 2     8
EP        EX         TAU                                      SKP75 2     9
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MEV         MEV         SEC                                          SKP75 2    10
 0.8724      9.709       5.0000E-17                                  SKP75 2    11
ENDDATA               3                                              SKP75 2    12
ENDSUBENT             2                                              SKP75 299999
ENDENTRY              2                                              SKP759999999
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VKH68

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ENTRY            VKH68          0                                    VKH68 0     1
SUBENT        VKH68   1         0                                    VKH68 1     1
BIB                  13        51                                    VKH68 1     2
INSTITUTE  (USAANL)                                                  VKH68 1     3
REFERENCE  (J,NP/A,122,465,1968)                                     VKH68 1     4
AUTHORS    (H.K.VONACH,A.A.KATSANOS,J.R.HUIZENGA)                    VKH68 1     5
TITLE      DETERMINATION OF THE LEVEL WIDTH AND DENSITY OF 32S       VKH68 1     6
           BETWEEN 17 AND 21 MEV EXCITATION ENERGY                   VKH68 1     7
FACILITY   (VDGT) TANDEM VAN DE GRAAFF ACCELERATOR, ARGONNE          VKH68 1     8
           NATIONAL LABORATORY, ARGONNE, ILLINOIS, USA.              VKH68 1     9
INC-PART   (P) PROTONS.                                              VKH68 1    10
TARGET     PHOSPHORUS TARGET APPROXIMATELY 25 MICROGRAMS/CM**2       VKH68 1    11
           THICKNESS ON 100 MICROGRAM/CM**2 THICK CARBON BACKING.    VKH68 1    12
           PREPARED USING THE ARGONNE NATIONAL LABORATORY MASS       VKH68 1    13
           SEPARATOR.                                                VKH68 1    14
METHOD     THE ARGONNE TANDEM VAN DE GRAAFF ACCELERATOR SUPPLIED     VKH68 1    15
           PROTON BEAMS IN THE ENERGY INTERVALS 8.37 TO 9.00 MEV     VKH68 1    16
           AND 10.00 TO 11.77 IN 10-KEV STEPS. PROTON ENERGY         VKH68 1    17
           RESOLUTION WAS 5 KEV FOR PROTON ENERGIES AROUND 10 MEV.   VKH68 1    18
           THE ENTRANCE AND EXIT SLITS OF THE BEAM ANALYZING         VKH68 1    19
           MAGNET WERE SET AT 0.9 MM. THE ALPHA PARTICLES EMITTED    VKH68 1    20
           FROM THE PHOSPHORUS TARGET WERE DETECTED WITH SURFACE-    VKH68 1    21
           BARRIER SOLID-STATE DETECTORS. SILICON N-TYPE DETECTORS   VKH68 1    22
           WERE USED. COLLIMATORS OF 0.63-CM DIA. WERE USED          VKH68 1    23
           IN ORDER TO EXCLUDE LOW-ENERGY ELECTRONS. THE DETECTORS   VKH68 1    24
           WERE COVERED WITH 100 MICROGRAM/CM**2 NICKEL FOIL. EACH   VKH68 1    25
           DETECTOR SUBTENDED AN ANGLE OF 7 DEG. IN THE REACTION     VKH68 1    26
           PLANE. DETECTORS WERE BIASED TO JUST STOP THE GROUND-     VKH68 1    27
           STATE TRANSITION ALPHA PARTICLES. EXCITATION FUNCTIONS    VKH68 1    28
           WERE MEASURED FROM 8.37 TO 9.00 MEV AT 30, 60, 90, 120,   VKH68 1    29
           150, 170, AND 175 DEG. LABORATORY ANGLE. A SIMILAR        VKH68 1    30
           MEASUREMENT WAS PERFORMED IN THE RANGE 10.00 TO 11.77     VKH68 1    31
           MEV AT 39, 69, 81, 111, 141, 161, AND 175 DEG. IN A       VKH68 1    32
           THIRD EXPERIMENT THE MEASUREMENTS WERE REPEATED IN        VKH68 1    33
           THE RANGE 10.00 TO 10.50 MEV. THESE EXCITATION            VKH68 1    34
           FUNCTIONS WERE DIVIDED INTO THREE ENERGY INTERVALS:       VKH68 1    35
           8.37 TO 9.00 MEV, 10.00 TO 10.90 MEV, AND 10.90 TO        VKH68 1    36
           11.77 MEV. THE EXCITATION FUNCTIONS FOR THESE ENERGY      VKH68 1    37
           INTERVALS WERE SUBJECTED TO A FLUCTUATION ANALYSIS        VKH68 1    38
           ACCORDING TO THE METHOD OF ERICSON. THIS ANALYSIS         VKH68 1    39
           PROCEDURE PROVIDED AVERAGE RESONANCE WIDTHS AND           VKH68 1    40
           INFORMATION ON LEVEL DENSITIES FOR REGIONS STUDIED.       VKH68 1    41
DETECTORS  (SOLST) SURFACE-BARRIER SOLID-STATE DETECTORS OF          VKH68 1    42
           N-TYPE SILICON. RESISTIVITY 600 TO 200 OHM-CM.            VKH68 1    43
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MONITOR    (CI) CURRENT INTEGRATOR WAS MOST LIKELY USED ALTHOUGH    VKH68 1    44
           NO MENTION IS MADE IN THE PAPER.                         VKH68 1    45
CORRECTION NONE MENTIONED.                                          VKH68 1    46
ERR-ANALYS AN UNSPECIFIED UNCERTAINTY EXISTS IN THE AVERAGE         VKH68 1    47
           RESONANCE WIDTHS EXTRACTED FROM THE FLUCTUATION          VKH68 1    48
           ANALYSIS. THIS ERROR COMES ABOUT BECAUSE OF THE          VKH68 1    49
           FINITE RANGE OF THE ENERGY AVERAGING PROCESS. SEE        VKH68 1    50
           THE PAPER FOR DETAILS.                                   VKH68 1    51
STATUS     WORK PUBLISHED IN JOURNAL NUCLEAR PHYSICS A. RELEVANT    VKH68 1    52
           NUMERICAL RESULTS FOUND IN TABLES 1 AND 2.               VKH68 1    53
ENDBIB            51                                                VKH68 1    54
ENDSUBENT          1                                                VKH68 199999
SUBENT        VKH68  2          0                                   VKH68 2     1
BIB                2           12                                   VKH68 2     2
REACTION   31P(P,ALPHA0)28SI                                        VKH68 2     3
COMMENTS   DATA OBTAINED FROM TABLE 1 OF THE ARTICLE. VALUES OF     VKH68 2     4
           THE HALF WIDTHS OF THE LORENTZIAN AUTOCORRELATION        VKH68 2     5
           FUNCTION FOR VARIOUS PROTON ENERGY INTERVALS AND         VKH68 2     6
           ALPHA-PARTICLE EMISSION ANGLES ARE GIVEN. EPLOW =        VKH68 2     7
           LOWER LIMIT OF PROTON-ENERGY INTERVAL. EPHIGH = UPPER    VKH68 2     8
           LIMIT OF PROTON-ENERGY INTERVAL. ANGLE = ALPHA-PARTICLE  VKH68 2     9
           EMISSION ANGLE (LABORATORY). GAMHALF = HALF WIDTH OF     VKH68 2    10
           THE AUTOCORRELATION FUNCTION. NO ERRORS ARE GIVEN.       VKH68 2    11
           NOTE THAT ANGLE 172.5 DEG. IS THE AVERAGE OF 170 AND     VKH68 2    12
           175 DEG. ONLY ONE VALUE OF GAMHALF IS GIVEN FOR THESE    VKH68 2    13
           TWO ANGLES.                                              VKH68 2    14
ENDBIB            12                                                VKH68 2    15
DATA               4          20                                    VKH68 2    16
EPLOW      EPHIGH     ANGLE      GAMHALF                            VKH68 2    17
MEV        MEV        DEG        KEV                                VKH68 2    18
 8.37       9.00       30.0       53.0                              VKH68 2    19
 8.37       9.00       60.0       54.0                              VKH68 2    20
 8.37       9.00       90.0       16.0                              VKH68 2    21
 8.37       9.00       120.0      60.0                              VKH68 2    22
 8.37       9.00       150.0      16.0                              VKH68 2    23
 8.37       9.00       172.5      25.0                              VKH68 2    24
 10.00      10.90      39.0       39.0                              VKH68 2    25
 10.00      10.90      69.0       44.0                              VKH68 2    26
 10.00      10.90      81.0       57.0                              VKH68 2    27
 10.00      10.90      111.0      28.0                              VKH68 2    28
 10.00      10.90      141.0      28.0                              VKH68 2    29
 10.00      10.90      161.0      39.0                              VKH68 2    30
 10.00      10.90      175.0      38.0                              VKH68 2    31
 10.90      11.77      39.0       31.0                              VKH68 2    32
 10.90      11.77      69.0       59.0                              VKH68 2    33
 10.90      11.77      81.0       57.0                              VKH68 2    34
 10.90      11.77      111.0      36.0                              VKH68 2    35
 10.90      11.77      141.0      25.0                              VKH68 2    36
 10.90      11.77      161.0      21.0                              VKH68 2    37
 10.90      11.77      175.0      23.0                              VKH68 2    38
ENDDATA           22                                                VKH68 2    39
ENDSUBENT          2                                                VKH68 299999
SUBENT        VKH68  3          0                                   VKH68 3     1
BIB                2           12                                   VKH68 3     2
REACTION   31P(P,ALPHA1)28SI                                        VKH68 3     3
COMMENTS   DATA OBTAINED FROM TABLE 1 OF THE ARTICLE. VALUES OF     VKH68 3     4
           THE HALF WIDTHS OF THE LORENTZIAN AUTOCORRELATION        VKH68 3     5
           FUNCTION FOR VARIOUS PROTON ENERGY INTERVALS AND         VKH68 3     6
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           ALPHA-PARTICLE EMISSION ANGLES ARE GIVEN. EPLOW =        VKH68 3     7
           LOWER LIMIT OF PROTON-ENERGY INTERVAL. EPHIGH = UPPER    VKH68 3     8
           LIMIT OF PROTON-ENERGY INTERVAL. ANGLE = ALPHA-PARTICLE  VKH68 3     9
           EMISSION ANGLE (LABORATORY). GAMHALF = HALF WIDTH OF     VKH68 3    10
           THE AUTOCORRELATION FUNCTION. NO ERRORS ARE GIVEN.       VKH68 3    11
           NOTE THAT ANGLE 172.5 DEG. IS THE AVERAGE OF 170 AND     VKH68 3    12
           175 DEG. ONLY ONE VALUE OF GAMHALF IS GIVEN FOR THESE    VKH68 3    13
           TWO ANGLES.                                              VKH68 3    14
ENDBIB                12                                            VKH68 3    15
DATA                   4          20                                VKH68 3    16
EPLOW      EPHIGH      ANGLE      GAMHALF                           VKH68 3    17
MEV        MEV         DEG        KEV                               VKH68 3    18
  8.37       9.00       30.0       16.0                             VKH68 3    19
  8.37       9.00       60.0       27.0                             VKH68 3    20
  8.37       9.00       90.0       26.0                             VKH68 3    21
  8.37       9.00      120.0       34.0                             VKH68 3    22
  8.37       9.00      150.0       35.0                             VKH68 3    23
  8.37       9.00      172.5       28.0                             VKH68 3    24
 10.00      10.90       39.0       58.0                             VKH68 3    25
 10.00      10.90       69.0       47.0                             VKH68 3    26
 10.00      10.90       81.0       36.0                             VKH68 3    27
 10.00      10.90      111.0       26.0                             VKH68 3    28
 10.00      10.90      141.0       27.0                             VKH68 3    29
 10.00      10.90      161.0       31.0                             VKH68 3    30
 10.00      10.90      175.0       71.0                             VKH68 3    31
 10.90      11.77       39.0       46.0                             VKH68 3    32
 10.90      11.77       69.0       33.0                             VKH68 3    33
 10.90      11.77       81.0       32.0                             VKH68 3    34
 10.90      11.77      111.0       84.0                             VKH68 3    35
 10.90      11.77      141.0       28.0                             VKH68 3    36
 10.90      11.77      161.0       35.0                             VKH68 3    37
 10.90      11.77      175.0       33.0                             VKH68 3    38
ENDDATA                22                                           VKH68 3    39
ENDSUBENT               3                                           VKH68 399999
SUBENT          VKH68   4          0                                VKH68 4     1
BIB                     2         15                                VKH68 4     2
REACTION   31P(P,ALPHA)28SI                                         VKH68 4     3
COMMENTS   VALUES OF AVERAGE LEVEL WIDTH GAMMA FOR THE COMPOUND     VKH68 4     4
           NUCLEUS 32S ARE GIVEN. THESE VALUES ARE OBTAINED BY      VKH68 4     5
           AVERAGING THE LORENTZIAN AUTOCORRELATION FUNCTION        VKH68 4     6
           HALF WIDTHS, GAMHALF, GIVEN IN ENTRIES VKH68 2 AND       VKH68 4     7
           VKH68 3, OVER ANGLE AND FINAL STATES OF THE RESIDUAL     VKH68 4     8
           NUCLEUS. EPLOW = PROTON ENERGY LOWER LIMIT. EPHIGH =     VKH68 4     9
           PROTON ENERGY UPPER LIMIT. EXLOW = LOWER LIMIT OF        VKH68 4    10
           32S EXCITATION ENERGY. EXHIGH = UPPER LIMIT OF 32S       VKH68 4    11
           EXCITATION ENERGY. GAMMA = AVERAGE WIDTH OF 32S          VKH68 4    12
           RESONANCES IN THE INDICATED ENERGY RANGE. ERR-GAMMA =    VKH68 4    13
           UNCERTAINTY IN GAMMA. THIS UNCERTAINTY IS THE            VKH68 4    14
           STANDARD DEVIATION OF THE VALUES GAMHALF THAT WERE       VKH68 4    15
           AVERAGED TO OBTAIN THE RESULTS IN THE PRESENT TABLE.     VKH68 4    16
           NOTE THAT GAMHALF IS EQUIVALENT TO GAMMA.                VKH68 4    17
ENDBIB                15                                            VKH68 4    18
DATA                   6          3                                 VKH68 4    19
EPLOW      EPHIGH      EXLOW      EXHIGH     GAMMA      ERR-GAMMA   VKH68 4    20
MEV        MEV         MEV        MEV        KEV        KEV         VKH68 4    21
  8.37       9.00       17.8       18.40      38.0       5.0        VKH68 4    22
 10.00      10.90       19.4       20.25      47.0       4.0        VKH68 4    23
 10.90      11.77       20.25      21.10      45.0       5.0        VKH68 4    24
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ENDDATA              5                                         VKH68 4    25
ENDSUBENT            4                                         VKH68 499999
ENDENTRY             4                                         VKH689999999
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VLT67

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ENTRY          VLT67          0                                 VLT67 0     1
SUBENTRY       VLT67  1       0                                 VLT67 1     1
BIB               12         46                                 VLT67 1     2
INSTITUTE  (FRPAR)                                              VLT67 1     3
REFERENCE  (J,NP/A,102,449,1967) IN FRENCH.                     VLT67 1     4
AUTHORS    (J.VERNOTTE,M.LANGEVIN,F.TAKEUTCHI)                  VLT67 1     5
TITLE      NIVEAUX DE 32S OBSERVES DANS LES REACTIONS           VLT67 1     6
           31P(P,ALPHA0)28SI ET 28SI(ALPHA,GAMMA)32S            VLT67 1     7
FACILITY   (VDG) 4-MEV VAN DE GRAAFF ACCELERATOR, LABORATOIRE   VLT67 1     8
           JOLIOT-CURIE, INSTITUT DE PHYSIQUE NUCLEAIRE, ORSAY, VLT67 1     9
           FRANCE.                                              VLT67 1    10
INC-PART   (P) PROTONS.                                         VLT67 1    11
TARGETS    ZN3P2 EVAPORATED ONTO 10 AND 20 MICROGRAM/CM**2 CARBON VLT67 1  12
           BACKINGS. TARGET THICKNESSES USED WERE APPROXIMATELY VLT67 1    13
           190, 25, AND 6 MICROGRAM/CM**2, RESPECTIVELY.        VLT67 1    14
METHOD     EXCITATION FUNCTIONS OF EMITTED GROUND-STATE TRANSITION VLT67 1 15
           ALPHA PARTICLES WERE MEASURED OVER THE INCIDENT-PROTON VLT67 1  16
           ENERGY RANGE 1.4 TO 1.9 MEV. ANGULAR DISTRIBUTIONS WERE VLT67 1 17
           MEASURED (PRESUMABLY ON THE RESONANCES) FROM 85 TO 170 VLT67 1  18
           DEG. 4-MEV VAN DE GRAAFF ACCELERATOR PROVIDED PROTONS. VLT67 1  19
           THE PROTON BEAM WAS ANALYZED WITH A 90 DEG. MAGNET.  VLT67 1    20
           THE ENERGY RESOLUTION OF PROTON BEAM WAS 5*10**-4.   VLT67 1    21
           THE 1346.6- AND 1373.5-KEV RESONANCES IN 19F(P,ALPHA) VLT67 1   22
           AND 7LI(P,N) THRESHOLD AT 1880.36 KEV WERE USED FOR  VLT67 1    23
           ENERGY-SCALE CALIBRATION. THE BEAM CURRENT WAS LIMITED VLT67 1  24
           TO THE RANGE 0.05 TO 0.1 MICROAMP. TO AVOID PILEUP OF VLT67 1   25
           PULSES FROM ELASTICALLY SCATTERED PROTONS. RESONANCE VLT67 1    26
           TOTAL WIDTHS WERE DETERMINED DIRECTLY FROM EXCITATION- VLT67 1  27
           FUNCTION DATA. PROTON-ENERGY INCREMENTS OF 0.5 KEV   VLT67 1    28
           TAKEN IN THE VICINITY OF 1470 KEV REVEALED A RESONANCE VLT67 1  29
           DOUBLET THAT HAD NOT BEEN OBSERVED IN PREVIOUS WORK, VLT67 1    30
           NAMELY, AT 1470 AND 1476 KEV. THE DATA WERE ANALYZED VLT67 1    31
           TO PROVIDE RESONANCE TOTAL WIDTHS AND STRENGTHS,     VLT67 1    32
           POSSIBLE SPIN/PARITY ASSIGNMENTS, AND PROTON-WIDTH   VLT67 1    33
           RATIOS FOR TWO ENTRANCE CHANNEL SPINS (S = 0 AND 1). VLT67 1    34
DETECTORS  (SOLST) SURFACE-BARRIER DETECTORS. THREE DETECTORS,  VLT67 1    35
           SEPARATED BY 25 DEG., WERE GROUPED TOGETHER INTO AN  VLT67 1    36
           ARRAY. THE DETECTOR SOLID ANGLE WAS 6*10**-4 SR.     VLT67 1    37
MONITORS   (CI) CURRENT INTEGRATOR MONITORED BEAM CURRENT TO    VLT67 1    38
           PREVENT DETECTOR COUNT RATE FROM BECOMING TOO HIGH.  VLT67 1    39
           (SOLST) ONE SURFACE-BARRIER DETECTOR WAS PLACED AT   VLT67 1    40
           150 DEG. AND USED AS A FIXED MONITOR.                VLT67 1    41
ERR ANALYS ERRORS IN RESONANCE INCIDENT-PROTON AND COMPOUND-    VLT67 1    42
           NUCLEUS EXCITATION ENERGIES ARE +/- 6 KEV THROUGHOUT. VLT67 1   43
           UNCERTAINTIES IN THE RESONANCE STRENGTHS EXTRACTED   VLT67 1    44
           FROM THE DATA WERE ESTIMATED TO BE OF THE ORDER OF   VLT67 1    45
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           20 PCT.                                                VLT67 1   46
STATUS     PUBLISHED IN JOURNAL NUCLEAR PHYSICS A. PERTINENT      VLT67 1   47
           DATA ARE GIVEN IN TABLES AND FIGURES IN THIS ARTICLE.  VLT67 1   48
ENDBIB             46                                             VLT67 1   49
ENDSUBENT           1                                             VLT67 199999
SUBENT        VLT67  2          0                                 VLT67 2    1
BIB                 2          10                                 VLT67 2    2
REACTION   31P(P,ALPHA0)28SI                                      VLT67 2    3
COMMENTS   DATA TAKEN FROM TABLE 1 OF THE ARTICLE. EP = PROTON    VLT67 2    4
           ENERGY FOR THE RESONANCE. ERR-EP = ERROR IN EP. EX =   VLT67 2    5
           EXCITATION ENERGY OF RESONANCE IN COMPOUND NUCLEUS     VLT67 2    6
           32S. ERR-EX = ERROR IN EX. GAMMA = RESONANCE TOTAL     VLT67 2    7
           WIDTH. ERR-GAMMA = ERROR IN TOTAL WIDTH GAMMA.         VLT67 2    8
           NOTE THAT IN SOME CASES THE WIDTH IS AN UPPER-         VLT67 2    9
           BOUND VALUE AS INDICATED IN THE TABLE. STRENG =        VLT67 2   10
           RESONANCE STRENGTH AS DEFINED IN THE ARTICLE.          VLT67 2   11
           ERR-STRENG = ERROR IN STRENG.                          VLT67 2   12
ENDBIB             10                                             VLT67 2   13
COMMON              2          3                                  VLT67 2   14
ERR-EP     ERR-EX                                                 VLT67 2   15
KEV        KEV                                                    VLT67 2   16
 6.0        6.0                                                   VLT67 2   17
ENDCOMMON           2          3                                  VLT67 2   18
DATA                6          8                                  VLT67 2   19
EP         EX         GAMMA      ERR-GAMMA  STRENG     ERR-STRENG VLT67 2   20
KEV        KEV        KEV        KEV        EV         EV         VLT67 2   21
 1403.0     10223.0    0.70                  95.0       17.0      VLT67 2   22
 1470.0     10288.0    0.55                  47.0       9.0       VLT67 2   23
 1476.0     10294.0    0.45                  62.0       15.0      VLT67 2   24
 1514.0     10331.0    7.0        1.0        3000.0     300.0     VLT67 2   25
 1643.0     10456.0    2.3                   300.0      35.0      VLT67 2   26
 1715.0     10525.0    1.2                   24.0       5.0       VLT67 2   27
 1817.0     10624.0    1.6                   110.0      20.0      VLT67 2   28
 1896.0     10701.0    24.0       3.0        7000.0     1000.0    VLT67 2   29
ENDDATA            10                                             VLT67 2   30
ENDSUBENT           2                                             VLT67 299999
SUBENT        VLT67  3          0                                 VLT67 3    1
BIB                 2          12                                 VLT67 3    2
REACTION   31P(P,ALPHA0)28SI                                      VLT67 3    3
COMMENTS   RESULTS OF THE ANALYSIS OF ALPHA-PARTICLE ANGULAR      VLT67 3    4
           DISTRIBUTION MEASUREMENTS ARE PRESENTED IN TABLE 2.    VLT67 3    5
           EP = INCIDENT PROTON ENERGY FOR INDICATED RESONANCE.   VLT67 3    6
           JPI = SPIN/PARITY OF THE INDICATED RESONANCE. A        VLT67 3    7
           NEGATIVE VALUE OF JPI INDICATES NEGATIVE PARITY. IF    VLT67 3    8
           MORE THAN ONE SPIN/PARITY COMBINATION IS POSSIBLE,     VLT67 3    9
           BOTH OPTIONS ARE GIVEN. ASSOCIATED WITH EACH CHOICE    VLT67 3   10
           OF SPIN PARITY IS A PROTON WIDTH. T = RATIO OF THE     VLT67 3   11
           PROTON WIDTH FOR CHANNEL SPIN 1 DIVIDED BY THE         VLT67 3   12
           PROTON WIDTH FOR CHANNEL SPIN 0. ERR-T = UNCERTAINTY   VLT67 3   13
           IN T.                                                  VLT67 3   14
ENDBIB             12                                             VLT67 3   15
DATA                4          10                                 VLT67 3   16
EP         JPI        T          ERR-T                            VLT67 3   17
KEV        NO-DIM     NO-DIM     NO-DIM                           VLT67 3   18
 1403.0     2.0        0.76       0.02                            VLT67 3   19
 1403.0    -3.0        1.67       0.07                            VLT67 3   20
 1470.0    -3.0        0.20       0.01                            VLT67 3   21
 1476.0     2.0        0.49       0.02                            VLT67 3   22
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1514.0     -1.0        6.47       0.6                           VLT67 3   23
1643.0      0.0        0.0                                      VLT67 3   24
1643.0     -1.0        1.82       0.02                          VLT67 3   25
1715.0      2.0        0.05       0.01                          VLT67 3   26
1817.0     -3.0        2.94       0.20                          VLT67 3   27
1896.0     -1.0        0.45       0.01                          VLT67 3   28
ENDDATA               12                                        VLT67 3   29
ENDSUBENT              3                                        VLT67 399999
ENDENTRY               3                                        VLT679999999
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V+73b

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ENTRY            V73B                                             V73B 0    1
SUBENTRY       V73B  1           0                                V73B 1    1
BIB                  12          37                               V73B 1    2
INSTITUTE  (FRPAR)                                                V73B 1    3
REFERENCE  (J,NP/A,212,493,1973) IN FRENCH.                       V73B 1    4
AUTHORS    (J.VERNOTTE,S.GALES,M.LANGEVIN,J.M.MAISON)             V73B 1    5
TITLE      RECHERCHE DE RESONANCES ISOBARIQUES ANALOGUES DANS 32S V73B 1    6
           AU MOYEN DES REACTIONS 31P(P,GAMMA)32S, 31P(P,P )31P,  V73B 1    7
           ET 31P(P,ALPHA)28SI                                    V73b 1    8
FACILITY   (VDG) 4-MV VAN DE GRAAFF ACCELERATOR, INSTITUT DE      V73B 1    9
           PHYSIQUE NUCLEAIRE, ORSAY, FRANCE.                     V73B 1   10
INC-PART   (P) PROTONS.                                           V73B 1   11
TARGETS    RED PHOSPHORUS EVAPORATED ONTO 15 MICROGRAM/CM**2 THICK V73B 1  12
           CARBON FOILS. TWO TARGET THICKNESSES USED WERE 2.1 +/- V73B 1   13
           0.1 AND 9.0 +/- 0.3 MICROGRAM/CM**2. TARGET THICKNESSES V73B 1  14
           WERE DETERMINED BY RUTHERFORD SCATTERING OF LOW-ENERGY V73B 1   15
           PROTONS IN A REGION DEVOID OF RESONANCES.              V73B 1   16
METHOD     PROTON BEAMS WERE FOCUSED TO A SPOT 2 MM IN DIA ON THE V73B 1   17
           RED PHOSPHORUS TARGETS. PROTON ENERGY RESOLUTION WAS   V73B 1   18
           MEASURED BY OBSERVING THE 1747.6 +/- 0.9 KEV RESONANCE V73B 1   19
           IN 13C(P,GAMMA)14N. THIS RESOLUTION WAS ACHIEVED BY    V73B 1   20
           ADJUSTING THE OPTICS AT THE ENTRANCE TO THE ANALYZING  V73B 1   21
           MAGNET. BEAM CURRENTS WERE LIMITED TO 0.3 MICROAMP. TO V73B 1   22
           PRESERVE THE TARGETS DURING MEASUREMENT PERIODS OF     V73B 1   23
           SEVERAL DAYS. SPECTRA OF SCATTERED PROTONS AND EMITTED V73B 1   24
           ALPHA-PARTICLES WERE MEASURED AT ANGLES IN THE RANGE   V73B 1   25
           124 TO 160 DEG. IN THE LABORATORY. MEASUREMENTS WERE   V73B 1   26
           MADE IN THE PROTON ENERGY RANGE 1.24 TO 1.60 MEV. THE  V73B 1   27
           ENERGY INCREMENTS WERE NOT SPECIFIED. THIS EXPERIMENT  V73B 1   28
           YIELDED PARTIAL WIDTHS FOR GAMMA-RAY, PROTON AND ALPHA- V73B 1  29
           PARTICLE EMISSION AT THE RESONANCES. VALUES FOR THE    V73B 1   30
           RESONANCE STRENGTHS WERE CALCULATED.                   V73B 1   31
DETECTORS  (SOLST) THREE SURFACE-BARRIER DETECTORS. EACH DETECTOR V73B 1   32
           SUBTENDED A SOLID ANGLE OF 0.55*10**-3 SR.             V73B 1   33
MONITOR    (CI) CURRENT INTEGRATOR USED TO RECORD BEAM CURRENT.   V73B 1   34
ERR-ANALYS NO DISCUSSION OF ERRORS.                               V73B 1   35
STATUS     ARTICLE PUBLISHED IN JOURNAL NUCLEAR PHYSICS A. THE    V73B 1   36
           PERTINENT RESULTS FOR ALPHA-PARTICLE DECAY OF CERTAIN  V73B 1   37
           RESONANCES IN 32S ARE PRESENTED IN TABLES 6 AND 7 OF   V73B 1   38
           THE ARTICLE.                                           V73B 1   39
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ENDBIB              37                                            V73B 1    40
ENDSUBENT            1                                            V73B 199999
SUBENTRY        V73B 2          0                                 V73B 2     1
BIB                  2         11                                 V73B 2     2
REACTION    31P(P,ALPHA0)28SI                                     V73B 2     3
COMMENTS    DATA ARE ACQUIRED FROM TABLE 6 OF THE ARTICLE. ONLY THE V73B 2     4
            RESONANCES LISTED IN TABLE 6 WHICH SHOW MEASURABLE     V73B 2     5
            ALPHA EMISSION WIDTHS FOR DECAY OF THE COMPOUND NUCLEUS V73B 2     6
            32S ARE INCLUDED HERE. EP = INCIDENT PROTON ENERGY FOR V73B 2     7
            THE RESONANCE. LP = PROTON ANGULAR MOMENTUM. JPI =     V73B 2     8
            SPIN/PARITY OF COMPOUND NUCLEAR STATE. NEGATIVE VALUES V73B 2     9
            OF JPI INDICATE NEGATIVE PARITY. GAMMA = TOTAL WIDTH   V73B 2    10
            OF THE RESONANCE. ERR-GAMMA = UNCERTAINTY IN GAMMA.    V73B 2    11
            NOTE THAT FOR THE 1474-KEV RESONANCE THE VALUE GIVEN   V73B 2    12
            FOR GAMMA IS A LOWER BOUND.                            V73B 2    13
ENDBIB              11                                            V73B 2    14
DATA                 5          4                                 V73B 2    15
EP          LP         JPI        GAMMA      ERR-GAMMA            V73B 2    16
KEV         NO-DIM     NO-DIM     EV         EV                   V73B 2    17
  1401.9     3.0        -3.0        65.0       25.0               V73B 2    18
  1469.0     3.0        -3.0        180.0      60.0               V73B 2    19
  1474.3     2.0         2.0        105.0                         V73B 2    20
  1514.7     1.0        -1.0        7600.0     800.0              V73B 2    21
ENDDATA              6                                            V73B 2    22
ENDSUBENT            2                                            V73B 299999
SUBENTRY        V73B 3          0                                 V73B 3     1
BIB                  2         11                                 V73B 3     2
REACTION    31P(P,ALPHA0)28SI                                     V73B 3     3
COMMENTS    DATA ARE ACQUIRED FROM TABLE 6 OF THE ARTICLE. ONLY THE V73B 3     4
            RESONANCES LISTED IN TABLE 6 WHICH SHOW MEASURABLE     V73B 3     5
            ALPHA-EMISSION WIDTHS FOR DECAY OF THE COMPOUND NUCLEUS V73B 3     6
            32S ARE INCLUDED HERE. EP = INCIDENT PROTON ENERGY FOR V73B 3     7
            THE RESONANCE. GAMMAP = PROTON WIDTH. ERR-GAMMAP =     V73B 3     8
            UNCERTAINTY IN GAMMAP. GAMALPHA = ALPHA-PARTICLE       V73B 3     9
            WIDTH. ERR-GAMALPHA = UNCERTAINTY IN GAMALPHA. NOTE    V73B 3    10
            THAT FOR THE 1474-KEV RESONANCE, THE VALUE OF GAMMAP   V73B 3    11
            GIVEN IS AN UPPER BOUND WHILE THAT FOR GAMALPHA IS A   V73B 3    12
            LOWER BOUND.                                           V73B 3    13
ENDBIB              11                                            V73B 3    14
DATA                 5          4                                 V73B 3    15
EP          GAMMAP     ERR-GAMMAP GAMALPHA   ERR-GAMALPHA         V73B 3    16
KEV         EV         EV         EV         EV                   V73B 3    17
  1401.9     16.0        6.0        49.0       17.0               V73B 3    18
  1469.0     9.0         4.0        170.0      60.0               V73B 3    19
  1474.3     15.0                   90.0                          V73B 3    20
  1514.7     3800.0      600.0      3800.0     600.0              V73B 3    21
ENDDATA              6                                            V73B 3    22
ENDSUBENT            3                                            V73B 399999
SUBENTRY        V73B 4          0                                 V73B 4     1
BIB                  2         12                                 V73B 4     2
REACTION    31P(P,ALPHA0)28SI                                     V73B 4     3
COMMENTS    DATA ARE ACQUIRED FROM TABLE 6 OF THE ARTICLE. ONLY THE V73B 4     4
            RESONANCES LISTED IN TABLE 6 WHICH SHOW MEASURABLE     V73B 4     5
            ALPHA-EMISSION WIDTHS FOR DECAY OF THE COMPOUND NUCLEUS V73B 4     6
            32S ARE INCLUDED HERE. EP = INCIDENT PROTON ENERGY FOR V73B 4     7
            THE RESONANCE. THP2 = REDUCED PROTON WIDTH MULTIPLIED  V73B 4     8
            BY FACTOR 10**3. ERR-THP2 = UNCERTAINTY IN THP2.       V73B 4     9
            THALPHA2 = REDUCED ALPHA-PARTICLE WIDTH MULTIPLIED BY  V73B 4    10
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            FACTOR 10**3. ERR-THALPHA2 = UNCERTAINTY IN THALPHA2.   V73B 4    11
            NOTE THAT FOR THE 1474-KEV RESONANCE THE VALUE GIVEN    V73B 4    12
            FOR THP2 IS AN UPPER BOUND WHILE THAT FOR THALPHA2 IS   V73B 4    13
            A LOWER BOUND.                                          V73B 4    14
ENDBIB               12                                             V73B 4    15
DATA                  5          4                                  V73B 4    16
EP          THP2       ERR-THP2   THALPHA2   ERR-THALPHA2           V73B 4    17
KEV         NO-DIM     NO-DIM     NO-DIM     NO-DIM                 V73B 4    18
 1401.9      75.0       30.0       60.0       18.0                  V73B 4    19
 1469.0      29.0       13.0      160.0       50.0                  V73B 4    20
 1474.3      3.0                   25.0                             V73B 4    21
 1514.7      79.0       12.0      430.0       60.0                  V73B 4    22
ENDDATA               6                                             V73B 4    23
ENDSUBENT             4                                             V73B 499999
SUBENTRY        V73B  5          0                                  V73B 5     1
BIB                   2          7                                  V73B 5     2
REACTION    31P(P,ALPHA0)28SI                                       V73B 5     3
COMMENTS    DATA ARE ACQUIRED FROM TABLE 7 OF THE ARTICLE. EP =     V73B 5     4
            INCIDENT PROTON ENERGY FOR THE RESONANCE. STRENG =      V73B 5     5
            RESONANCE STRENGTH FOR ALPHA-PARTICLE EMISSION. IT      V73B 5     6
            IS DEFINED AS STRENG = (2*J+1)*GAMMAP*GAMALPHA/GAMMA.   V73B 5     7
            REFER TO ARTICLE FOR MORE DETAILS. ERR-STRENG =         V73B 5     8
            UNCERTAINTY IN RESONANCE STRENGTH.                      V73B 5     9
ENDBIB                7                                             V73B 5    10
DATA                  3          4                                  V73B 5    11
EP          STRENG     ERR-STRENG                                   V73B 5    12
KEV         EV         EV                                           V73B 5    13
 1402.0      85.0       17.0                                        V73B 5    14
 1469.0      49.0       10.0                                        V73B 5    15
 1474.0      66.0       13.0                                        V73B 5    16
 1515.0      4500.0     900.0                                       V73B 5    17
ENDDATA               6                                             V73B 5    18
ENDSUBENT             5                                             V73B 599999
ENDENTRY              5                                             V73B9999999
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W+92

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ENTRY             W+92           0                                  W+92 0     1
SUBENT         W+92  1           0                                  W+92 1     1
BIB                 13          58                                  W+92 1     2
INSTITUTE   (USATNL)                                                W+92 1     3
REFERENCE   (J,NP/A,549,223,1992)                                   W+92 1     4
AUTHORS     (J.F.WILKERSON,T.M.MOONEY,R.E.FAUBER,T.B.CLEGG,H.J.     W+92 1     5
            KARWOWSKI,E.J.LUDWIG,W.J.THOMPSON)                      W+92 1     6
TITLE       ISOSPIN-NONCONSERVING PARTICLE DECAYS IN LIGHT NUCLEI   W+92 1     7
FACILITY    (VDG) TANDEM VAN DE GRAAFF ACCELERATOR, TRIANGLE        W+92 1     8
            UNIVERSITIES NUCLEAR LABORATORY, DURHAM, NORTH          W+92 1     9
            CAROLINA, U.S.A.                                        W+92 1    10
INC-PART    (P) PROTONS.                                            W+92 1    11
TARGET      RED PHOSPHORUS EVAPORATED ONTO 3-10 MICROGRAM/CM**2     W+92 1    12
            THICK CARBON BACKINGS.                                  W+92 1    13
METHOD      UNPOLARIZED PROTON BEAMS WERE PROVIDED BY THE TUNL      W+92 1    14
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             VAN DE GRAAFF ACCELERATOR. BEAMS WERE OBTAINED FROM     W+92 1    15
             A DIRECT-EXTRACTION ION SOURCE. THE PROTON BEAMS WERE   W+92 1    16
             MOMENTUM ANALYZED WITH MAGNETS, PASSED THROUGH NARROW   W+92 1    17
             SLITS, AND FOCUSED ONTO THE TARGET AT THE CENTER OF A   W+92 1    18
             61-CM DIA. SCATTERING CHAMBER. THE WASTE PROTON BEAM    W+92 1    19
             WAS DUMPED INTO AN ELECTRON-SUPPRESSED FARADAY CUP      W+92 1    20
             DOWN STREAM FROM THE TARGET. THE TARGET ITSELF WAS      W+92 1    21
             ISOLATED ELECTRICALLY FROM ITS ENVIRONMENT AND WAS      W+92 1    22
             CONNECTED TO A D.C. POWER SUPPLY THAT COULD BE VARIED   W+92 1    23
             CONTINUOUSLY OVER A 10-20 KV RANGE WITH VERY GOOD       W+92 1    24
             STABILITY AND REPRODUCIBILITY. THE PROTON-BEAM ENERGY   W+92 1    25
             WAS CALIBRATED USING NARROW RESONANCES. THESE           W+92 1    26
             RESONANCES WERE ALSO USED TO DETERMINE THE EFFECTIVE    W+92 1    27
             MEASUREMENT RESOLUTION. BY CAREFULLY RECYCLING THE      W+92 1    28
             ANALYZING MAGNETS, HYSTERESIS EFFECTS WERE MINIMIZED.   W+92 1    29
             REPRODUCIBILITY OF +/- 2 KEV IN PROTON ENERGY WAS       W+92 1    30
             ACHIEVED IN THIS MANNER. BEAM RESOLUTION WAS 600 EV.    W+92 1    31
             MAGNET CURRENT WAS VARIED IN ONE DIRECTION ONLY         W+92 1    32
             (INCREASED) DURING EACH MEASUREMENT OF AN EXCITATION    W+92 1    33
             FUNCTION FOR THE SAME REASON. EMITTED PROTONS AND       W+92 1    34
             ALPHA-PARTICLES WERE DETECTED WITH SILICON SURFACE-     W+92 1    35
             BARRIER DETECTORS. FOUR TO EIGHT ANGLES WERE MEASURED   W+92 1    36
             SIMULTANEOUSLY. NARROW ISOSPIN-NONCONSERVING RESONANCES W+92 1    37
             WERE LOCATED BY VARYING THE PROTON-ENERGY ON TARGET     W+92 1    38
             IN MODEST STEPS (A FEW KEV). ONCE ISOLATED, A FINE-     W+92 1    39
             RESOLUTION SWEEP OF A 10-20 KEV INTERVAL WAS MADE       W+92 1    40
             WITH STEPS OF ABOUT 200 EV USING THE TARGET-VOLTAGE     W+92 1    41
             RAMP SYSTEM. EXCITATION FUNCTIONS WERE ANALYZED USING   W+92 1    42
             A HELICITY-AMPLITUDE FORMALISM DESCRIBED IN THE         W+92 1    43
             ARTICLE. TOTAL, PROTON AND ALPHA-PARTICLE WIDTHS WERE   W+92 1    44
             EXTRACTED FROM THE DATA.                                W+92 1    45
DETECTORS    (SOLST) SILICON SURFACE-BARRIER DETECTORS. EACH ONE     W+92 1    46
             SUBTENDED =/- 1 DEG. IN THE SCATTERING PLANE. FROM      W+92 1    47
             TO EIGHT ANGLES WERE USED SIMULTANEOUSLY IN THESE       W+92 1    48
             MEASUREMENTS.                                           W+92 1    49
MONITOR      (CI) BEAM CURRENT INTEGRATOR. MONITORED PROTON-BEAM     W+92 1    50
             CHARGE DUMPED INTO AN ELECTRON-SUPPRESSED FARADAY CUP.  W+92 1    51
CORRECTION   DATA WERE CORRECTED FOR VARIOUS EFFECTS CONTRIBUTING    W+92 1    52
             TO FINITE RESOLUTION, NAMELY, PROTON BEAM ENERGY        W+92 1    53
             RESOLUTION, PROTON AND ALPHA-PARTICLE STRAGGLING IN     W+92 1    54
             THE TARGET, THERMAL LATTICE VIBRATIONS, AND ATOMIC-     W+92 1    55
             ELECTRON EXCITATION.                                    W+92 1    56
ERR-ANALYS   A NORMALIZATION UNCERTAINTY OF LESS THAN 10 PERCENT IN  W+92 1    57
             ABSOLUTE CROSS SECTION IS ESTIMATED BY THE AUTHORS.     W+92 1    58
STATUS       PUBLISHED IN NUCLEAR PHYSICS A. NUMERICAL DATA ARE      W+92 1    59
             AVAILABLE FROM TABLES 1 AND 2 IN THE ARTICLE.           W+92 1    60
ENDBIB               58                                              W+92 1    61
ENDSUBENT             1                                              W+92 199999
SUBENT         W+92   2          0                                   W+92 2     1
BIB                   2          8                                   W+92 2     2
REACTION     31P(P,ALPHA)28SI                                        W+92 2     3
COMMENTS     DATA ACQUIRED FROM TABLES 1 AND 2 OF THE ARTICLE. ER =  W+92 2     4
             RESONANCE ENERGY (ESSENTIALLY THE INCIDENT PROTON       W+92 2     5
             ENERGY). EX = EXCITATION ENERGY IN THE COMPOUND NUCLEUS W+92 2     6
             32S. JPI = SPIN/PARITY OF THE RESONANCE. A NEGATIVE     W+92 2     7
             VALUE OF JPI INDICATES NEGATIVE PARITY. GAMMA = TOTAL   W+92 2     8
             WIDTH OF THE RESONANCE. ERR-GAMMA = UNCERTAINTY IN      W+92 2     9
             GAMMA.                                                  W+92 2    10
```

```
ENDBIB              8                                               W+92 2    11
DATA                5          1                                    W+92 2    12
ER         EX        JPI        GAMMA      ERR-GAM                  W+92 2    13
MEV        MEV       NO-DIM     EV         EV                       W+92 2    14
 3.288      12.049    0.5        40.0       15.0                    W+92 2    15
ENDDATA             3                                               W+92 2    16
ENDSUBENT           2                                               W+92 299999
SUBENT         W+92 3          0                                    W+93 3     1
BIB                 2          6                                    W+93 3     2
REACTION   31P(P,ALPHA)28SI                                         W+93 3     3
COMMENTS   DATA ACQUIRED FROM TABLES 1 AND 2 OF THE ARTICLE. ER =   W+93 3     4
           RESONANCE ENERGY (ESSENTIALLY THE INCIDENT PROTON        W+93 3     5
           ENERGY). GAMMAP = PROTON WIDTH. ERR-GAMMAP = UNCERTAINTY W+93 3     6
           IN GAMMAP. GAMALPHA = ALPHA-PARTICLE WIDTH. ERR-GAMALPHA W+93 3     7
           = UNCERTAINTY IN GAMALPHA.                               W+93 3     8
ENDBIB              6                                               W+93 3     9
DATA                5          1                                    W+93 3    10
ER         GAMMAP    ERR-GAMMAP GAMALPHA   ERR-GAMALPHA             W+93 3    11
MEV        EV        EV         EV         EV                       W+93 3    12
 3.288      36.0      16.0       6.5        2.7                     W+93 3    13
ENDDATA             3                                               W+93 3    14
ENDSUBENT           3                                               W+93 399999
ENDENTRY            3                                               W+929999999
```

Appendix B: Unused References from NSR

The individual references which were identified in our survey of Nuclear Science References (NSR), but were not found and/or used in the present compilation, are listed below for the convenience of readers of this report who might wish to try and locate and consider them. The entries appearing here are in exactly the same format in which there were extracted from NSR.

70GaZZ
REPT 1970 Ann Rept IPN(Paris) P14

<KEYWORDS>NUCLEAR REACTIONS 31P(p,gamma),(p,p),(p,alpha),E=1.4-1.6 MeV; measured sigma(E;E gamma,theta(gamma-gamma)). 32S deduced resonances,level-width,J.

73AlYI
REPT COO-3496-29 P35

<KEYWORDS>NUCLEAR REACTIONS 31P(p,p'),(p,alpha); analyzed data. 32S levels deduced level-width.

73PrZF
REPT INDC(SEC)-35/L P89

<KEYWORDS>NUCLEAR REACTIONS 31P(p,alpha); measured sigma(E alpha).

79HoZA
REPT MPI Heidelberg,1978 Annual,P122,Hoyler

<KEYWORDS>NUCLEAR REACTIONS 11B(p,alpha),E=12.4 MeV; 15N(p,alpha), E=16.5 MeV; 19F(p,alpha),E=12.5 MeV; 23Na(p,alpha),E=18.4 MeV; 27Al(p,alpha),E=19.2 MeV; 31P(p,alpha),E=18.7 MeV; measured sigma(theta); deduced reaction mechanism.

86ErZY
CONF Kharkov,P53,Eremin

<KEYWORDS>NUCLEAR REACTIONS 27Al,31P(p,alpha),E not given; measured sigma(E),shadow effect. 28Si,32S resonances deduced GAMMA.

88MiZR

Triangle Univ.Nuclear Lab., Ann.Rept., p.83 (1988); TUNL-XXVII (1988)

G.E.Mitchell, E.G.Bilpuch, D.F.Fang, J.R.Vanhoy, C.R.Westerfeldt, F.Yang

Astrophysical Reactions through 24Mg and 32S

<KEYWORDS>NUCLEAR REACTIONS 23Na(p,p),(p,p'),(p,alpha),E=1.08-4.15 MeV; 31P(p,p),(p,p'),(p,alpha),E=1-4 MeV; measured sigma(theta); deduced sigma,inverse reaction rates. 24Mg deduced levels,resonance parameters.

90FaZV

Triangle Univ.Nuclear Lab., Ann.Rept., p.19 (1990); TUNL-XXIX (1990)

R.E.Fauber, T.B.Clegg, H.J.Karwowski, E.J.Ludwig, W.J.Thompson

Isotensor Symmetry-Breaking Resonances in Light Nuclei

<KEYWORDS>NUCLEAR REACTIONS 24Mg(alpha,alpha),E not given; 31P(p,p),(p,alpha),E=3.284-3.292; measured sigma(theta) vs E. 32S,28Si deduced level,T,GAMMA-alpha,GAMMA.