Energy Levels and Transitions in ^{75}As from the $(n, n'\gamma)$ Reaction*

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High-resolution measurements of the deexcitation γ rays from the ^{75}As$(n,n'\gamma)$ reaction have been made at 0.1-MeV intervals for incident neutrons between the energies of 0.8 and 2.2 MeV. These γ rays are assigned to energy levels up to an excitation of 1606 keV in ^{75}As. The level scheme is compared with that obtained in a recent resonance scattering experiment, and several new levels are proposed. Branching ratios and differential γ-ray production cross sections at 95° are determined.

I. INTRODUCTION

The energy levels in ^{75}As below 822 keV have been studied extensively by means of the decay of ^{75}Se and ^{75}Ge. References to the experimental data prior to 1967 are given by Pancholi and Ikegami of the Nuclear Data Group.[1] High-resolution radioactive decay studies using Ge(Li) detectors have been reported by Rao *et al.*,[2] Speidel *et al.*,[3] and Ng *et al.*[4] The low-lying levels have also been studied by Coulomb excitation[5] and neutron inelastic scattering.[6] The available information on levels above 822 keV is scanty.[7] During the course of this work Moreh and Shahal[8] reported measurements of the energy levels of ^{75}As using nuclear resonant scattering of iron-capture γ rays and obtained information on levels up to an excitation of 2687 keV. The resonance scattering experiment selectively populates only those levels which have large dipole matrix elements, with the consequence that only levels in ^{75}As with spin $\frac{1}{2}$ or $\frac{3}{2}$ are observed. Neutron inelastic scattering is not subject to this restriction, and all levels should be populated regardless of their specific nuclear character.

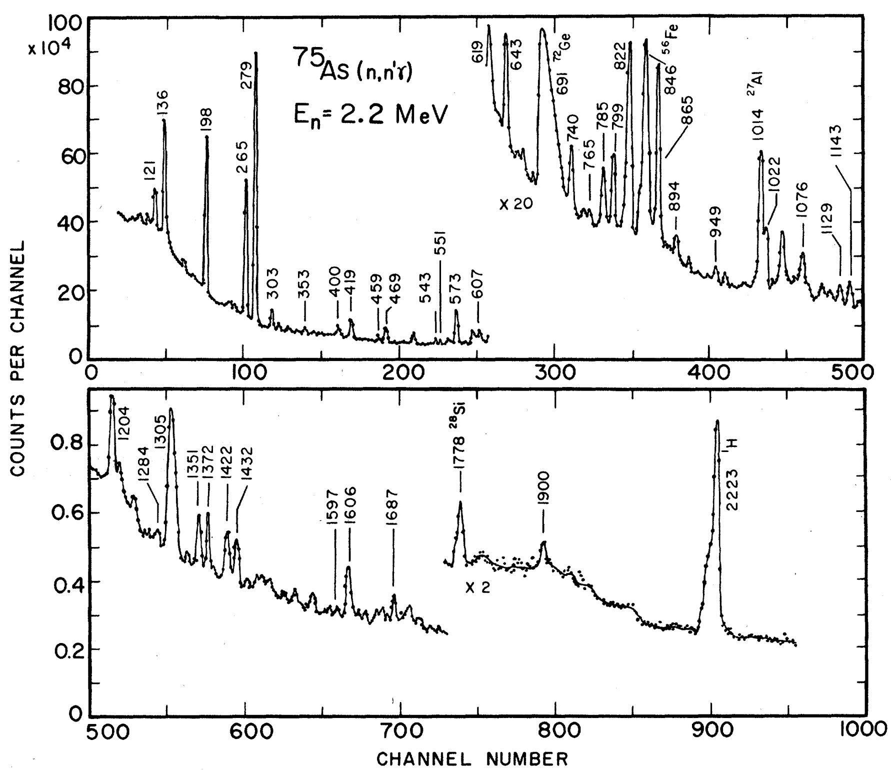

FIG. 1. The γ-ray spectrum of ^{75}As produced by 2.2-MeV neutron bombardment of a metallic arsenic scatterer. The background has not been subtracted from this spectrum. The γ rays attributed to inelastic scattering in ^{75}As are labeled together with a few prominent background peaks.

Therefore, it is desirable to study ^{75}As by means of the $(n, n'\gamma)$ reaction in order to obtain additional information on the levels and transitions in this nucleus, particularly with regard to possible high-spin states not observable in the (γ, γ') reaction. A preliminary account of the present work has been reported previously.[9]

II. EXPERIMENTAL PROCEDURE

The experimental arrangement is similar to that described previously.[10] Neutrons between 0.8 and 2.2 MeV were obtained with the ^{3}H$(p, n)^{3}$He reaction in a tritium-titanium target using the proton beam from the Tulane 3-MV Van de Graaff accelerator. The energy spread of the neutrons was between 70 and 100 keV over the energy range used in the measurements. The neutrons impinged on a ring scatterer which surrounded the cryostat of a 32-cm^3 Ge(Li) detector. The scatterer, which consisted of 446 g of 99.9% pure arsenic metal powder in a thin Lucite ring, received neutrons at an angle of 5° with respect to the accelerator beam. The deexcitation γ rays were incident on the Ge(Li)

TABLE I. Energy levels, γ-ray transitions, and γ-ray differential production cross sections for ^{75}As.

Energy level (keV)	Observed γ-ray transition (keV)	$d\sigma/d\Omega$(95°) (mb/sr ± 25%)			
		E_n=0.8 MeV	E_n=1.3 MeV	E_n=1.8 MeV	E_n=2.2 MeV
198.6±0.5	198.6±0.5	24	22	16	15
264.7±0.5	264.7±0.5	41	29	23	22
279.0±0.5	279.0±0.5	42	35	35	37
303.2±0.6	303.2±0.6	0.66	1.2	1.9	2.4
400.3±0.5	121.2±0.5	4.9	4.3	4.0	3.9
	135.9±0.5	13	10	10	11
	400.2±0.5	3.5	2.9	2.5	2.6
468.8±0.7	468.8±0.7	6.6	8.6	6.8	5.7
572.8±0.4	572.8±0.4	4.8	16	14	14
617.9±0.6	352.6±0.6	<0.5	1.3	0.96	0.87
	419.1±0.5	2.0	7.7	5.8	5.7
	618.6±0.4	1.9	3.1	2.9	4.8
821.8±0.6	542.5±0.4		1.0	0.95	1.1
	822.4±0.6		5.0	4.8	5.7
864.5±1.0	864.5±1.0		8.0	10	10
1043.6±1.0	643.8±0.4		1.4	3.0	3.8
	739.5±0.6		0.83	3.2	3.4
	765.1±1.0		<0.2	0.26	0.20
1063.8±1.0	784.7±1.0		0.85	1.9	2.2
	799.1±0.5		0.39	1.6	2.4
1076.4±1.1	459.4±1.1		0.98	1.3	1.1
	607.3±0.4		1.0	2.5	2.3
	1076.2±0.9		1.5	3.0	2.1
1129.3±0.9	1129.3±0.9		0.26	1.2	1.0
1204.4±1.1	1204.4±1.1		1.3	2.3	2.2
1349.7±1.3	948.8±1.0			0.70	0.45
	1350.7±1.3			1.9	3.3
1422.1±1.2	1022.3±0.6			1.5	1.7
	1142.6±1.2			1.2	1.7
	1422.1±0.8			<0.2	0.44
1431.9±1.1	1431.9±1.1			0.62	1.0
1503.2±2.0	1304.8±2.0			15	5.1
1595.4±2.0	550.6±0.6			0.38	0.44
	1596.9±2.0			<0.2	0.46
1606.4±1.3	1606.4±1.3			<0.2	2.0
Unassigned	1283.7±1.0				0.63
	1372.3±1.9			0.95	1.5
	1655.0±2.0				0.28
	1686.6±0.8				1.8
	1900.1±1.2				<0.1

detector at a mean angle of 95° with respect to the neutron direction, with an angular spread of ±23°. An iron shadow cone shielded the detector from the direct neutrons from the source. For monitoring purposes a standard long counter was placed at a distance of 1 m from the neutron source at an angle of 90° to the beam direction.

A detailed discussion of the methods used for data analysis and cross-section determination has been reported previously,[10] and only a brief account will be given here. The γ-ray spectra were accumulated in 1024 channels of a Nuclear Data 2201 multichannel analyzer. In addition to spectra obtained with the arsenic scatterer, additional measurements were made at each neutron energy with a carbon ring scatterer. The carbon spectra were used only for identification of background peaks arising from neutron interactions in the Ge(Li) detector and surrounding materials, and were not used for subtraction purposes. The spectral data were computer-analyzed to obtain photopeak yields. The analysis consisted of individual stripping of each peak from the background, correcting of the neutron monitor counts for effects of neutron angular distribution and counter efficiency, normalization of data to the monitor counts, and correcting for Ge(Li) detector efficiency and γ-ray attenuation in the scatterer. Corrections were not made for neutron attenuation in the scatterer or for multiple scattering.

Differential γ-ray production cross sections were obtained using an iron ring scatterer and by comparing the γ-ray yields from the sample with that of the 847-keV line from the $^{56}Fe(n, n'\gamma)$ reaction. The recent value of 32.6 ± 6.5 mb/sr for the 90° differential production cross section of the 847-keV γ ray at a neutron energy of 1.5 MeV served as the reference cross section.[11] Absolute cross-section errors arise mainly from the statistical uncertainties associated with the photopeak yields (typically 15%) and the 20% uncertainty in the cross section of the 847-keV γ ray of ^{56}Fe.

III. RESULTS AND DISCUSSION

γ-ray spectra were obtained at 0.1-MeV intervals for neutron energies E_n between 0.8 and 2.2 MeV. Measurements at lower neutron energies

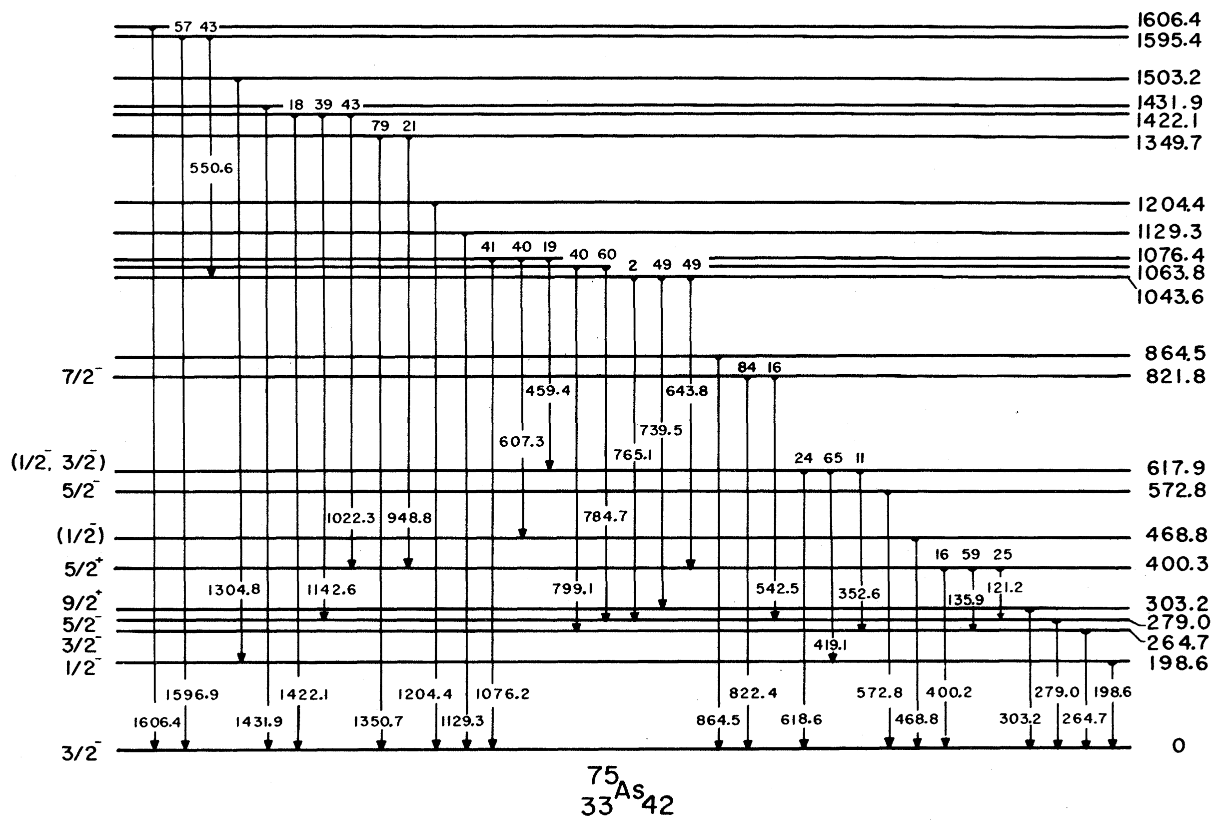

FIG. 2. Energy levels (keV) and observed γ-ray transitions in ^{75}As. The γ-ray transitions shown are those observed in the present work and are mean values determined from all the spectra. Spins and parities are from Ref. 7. Values above transitions are branching ratios measured in percent of total decays from each level.

were not made, since the levels in that region have been well established. A typical spectrum of γ rays observed at $E_n = 2.2$ MeV is shown in Fig. 1. The γ rays attributed to inelastic scattering in ^{75}As are labeled in the figure together with a few prominent background peaks. The unlabeled peaks are either background or capture γ rays. A total of 40 γ rays resulting from inelastic scattering in ^{75}As were observed at $E_n = 2.2$ MeV, of which all but five could be assigned to transitions in ^{75}As up to an excitation energy of 1606 keV. Table I lists these γ rays, their level assignments, and differential γ-ray production cross sections at 95°. The γ-ray energies are the mean values of the energies determined from all the spectra.

The energy-level diagram for ^{75}As, as determined in this experiment, is shown in Fig. 2. Included in this figure are the branching ratios for the decay of each level for which multiple transitions were observed. The levels up to 618 keV are those populated in radioactive decay, and the present work is in excellent agreement with recent high-resolution studies of the decay of ^{75}Se[2,12–14] and ^{75}Ge.[4] The 97-keV γ ray (400-303-keV level) and the 67-keV γ ray (265-198-keV level) observed in radioactive decay are not shown in the decay scheme as they were below the detection threshold in this measurement.

The 822 ($\frac{7}{2}^-$) state has previously been observed in Coulomb excitation.[7] Evidence for a level at

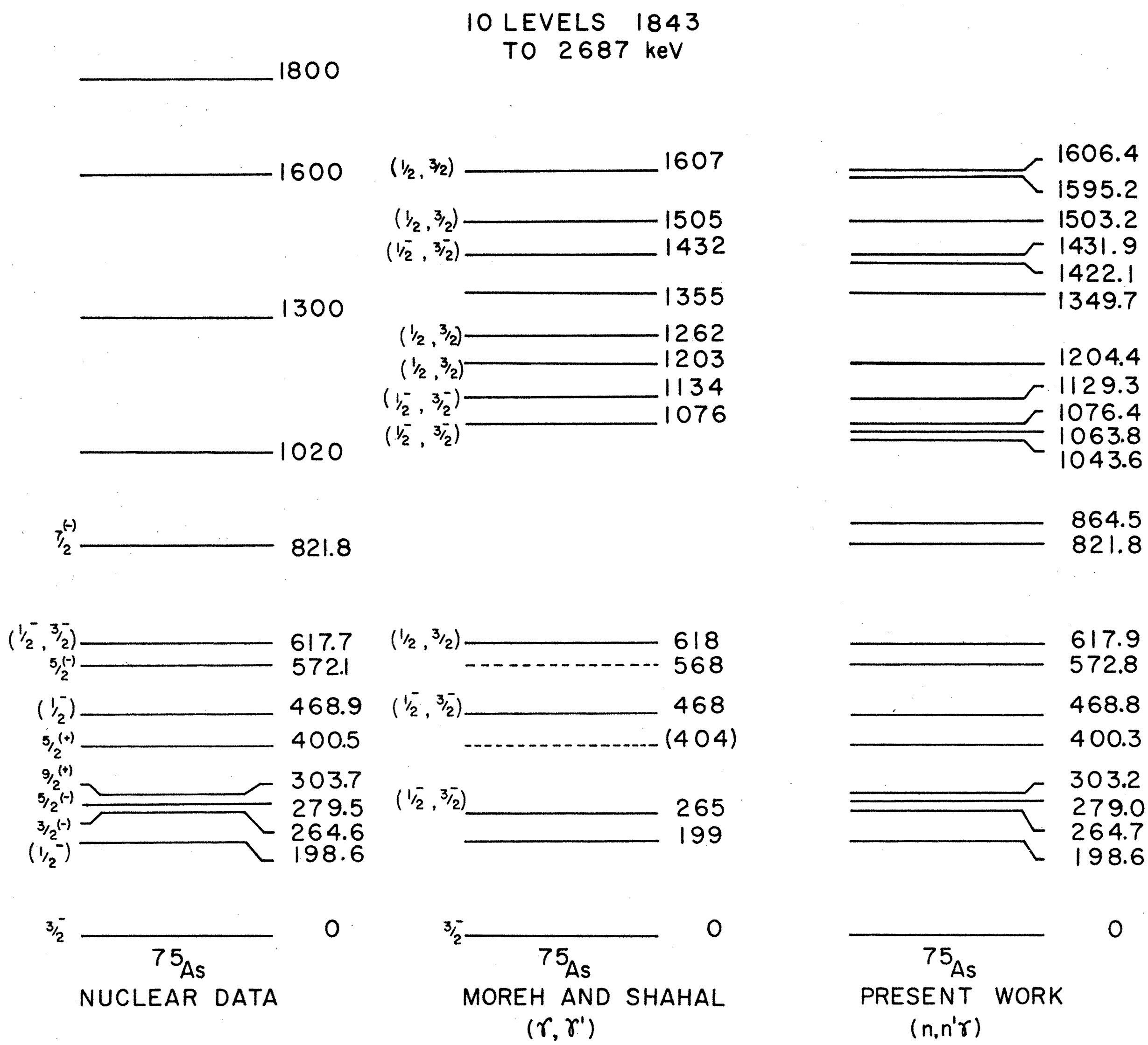

FIG. 3. A comparison of the energy levels of ^{75}As as presented in *Nuclear Data Sheets* (Ref. 7), the results of Moreh and Shahal (Ref. 8), and the present work.

865 keV was recently presented by Smith,[6] who studied levels in ^{75}As up to this energy using neutron inelastic scattering with the time-of-flight method. The present work confirms the existence of the 865-keV level.

Above 865 keV, the data are consistent with 11 levels between 1044 and 1606 keV. 20 γ rays were assigned to transitions from these levels. A comparison of the energy levels of the present work with those given in *Nuclear Data Sheets*[7] and the (γ, γ') experiments of Moreh and Shahal[8] is shown in Fig. 3. The (γ, γ') experiment requires observation of the deexcitation γ rays from the 7.646-MeV $(\frac{1}{2}^+)$ resonance level in ^{75}As which has been excited by iron-capture γ rays. The location of the lower levels is based on the justifiable assumption that strong high-energy γ lines are all due to primary γ-ray transitions deexciting the resonance level. Since the resonance scattering experiment is best suited for populating only those levels with spin $\frac{1}{2}$ or $\frac{3}{2}$, then transitions to states with spin $>\frac{3}{2}$ will usually not be observed. Moreh and Shahal[8] do not observe transitions to the known levels at 279, 303, and 822 keV which have spins and parities of $\frac{5}{2}^-$, $\frac{9}{2}^+$, and $\frac{7}{2}^-$, respectively, while the 400-keV $(\frac{5}{2}^+)$ and 573-keV $(\frac{5}{2}^-)$ levels are uncertain. All the high-lying levels below 1606 keV that are reported in Ref. 8 are confirmed in this investigation, with the exception of the level at 1262 keV which is not observed. In addition, new levels are proposed at 1044, 1064, 1422, and 1595 keV. These levels may have spins greater than $\frac{3}{2}$, thus explaining their absence in the (γ, γ') experiment.

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