$f(\theta)=1+0.125\cos^2\theta+0.042\cos^4\theta(\mathrm{Ni}^{60})$ and $f(\theta)=1-1.5\cos^2\theta+2\cos^4\theta(\mathrm{Pd}^{106})$, corrected for the finite angular resolution of the instrument. The above angular correlation of the Ni^{60} gamma-rays is to be expected for a quadrupole-quadrupole transition between states of[4] angular momenta $J=4$, 2, and 0. No theoretical explanations for the angular distribution of the Pd^{106} gamma-rays has been given yet.[5, 6]

The angular correlation of the gamma-rays of A^{38} has been measured using sources of Cl^{38} produced by bombarding LiCl with 10-Mev deuterons in the Purdue cyclotron. The results are shown in Fig. 2. The measured points follow, within the experimental error, the angular correlation function $f(\theta)=1-\frac{1}{3}\cos^4\theta$. For comparison all the other known correlation functions[4] for quadrupole or dipole transitions are plotted which give smaller emission probabilities at 180° than at 90°. The deviation from the theoretical curve near 180° may be partly due to internal pair production chiefly of the 2.15-Mev gamma-transition. Nevertheless the correction applied (point P in Fig. 2) using Rose's calculations[7] of the coefficient of internal pair production assuming electric quadrupole transition (see discussion below) is not sufficient to bring the point down to the expected place. Part of this effect is probably due to positron annihilation produced by pair formation of the gamma-rays in the absorbers, which are necessary to stop the rather energetic beta-particles from Cl^{38}.

The correlation function $1-\frac{1}{3}\cos^4\theta$ is characteristic for two quadrupole quanta and angular momenta $J=3$, 2, 0 respectively of the A^{38} levels involved. The parity of the two excited states must be equal since otherwise electric dipole radiation would be possible.

Measurements of Myers and Wattenberg[2] indicating that the direct transition from the second excited level to the ground state of A^{38} occurs in less than 3×10^{-4} of the disintegrations make the assignment of the same parity of the second excited level and the ground state of A^{38} necessary. It must therefore be assumed that both transitions are by electric quadrupole radiation and that all three states of A^{38} involved have the same parity. Even if mixtures of different multipole radiations are admitted giving different correlation functions due to interference effects[8] no other assignments can be found which are compatible with selection rules and the abundance of the cross-over transitions.

According to the measurements of Langer[1] the beta-transition from Cl^{38} to the ground state of A^{38} having zero spin is once-forbidden involving a spin change of two units and change of parity suggesting a spin of 2 for Cl^{38} and odd parity if we assume an even parity of the ground state of A^{38}. The intermediate group of electrons has a ft-value of $\sim10^7$ indicating a once-forbidden transition having a spin change of 0 or 1. This indicates an angular momentum of 1, 2, or 3 and even parity in agreement with the results of our correlation measurements ($J_1=2$). The low energy beta-spectrum is allowed according to its ft-value of 1.2×10^5. The selection rules for allowed beta-transitions ($\Delta J=0$, 1, no) give an angular momentum $J_2=2$, 3, or 4 of the second excited state of A^{38} and odd parity. The angular momentum 3 is also found from our measurements, but an odd parity of this level is not compatible with our results, which indicate the same parity for all levels of A^{38}. The interpretation of the angular correlation would suggest therefore that the low energy spectrum in spite of its small ft-value of 1.2×10^5 is once-forbidden. More direct information concerning the parities of the excited levels of A^{38} will be obtained by polarization-correlations experiments which are intended to be performed in this laboratory.

We wish to thank Dr. D. J. Tendam for his help in bombarding the samples in the Purdue cyclotron.

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* Supported by the ONR.

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Erratum: On the Primary Cosmic-Ray Spectrum

[Phys. Rev. **78**, 819 (1950)]

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In the course of publication certain errors occurred in this Letter to the Editor which requires correction. The units of geomagnetic cut-off, as given in terms of the momentum/charge ratio, pc/Ze, are properly billion volts (Bv), and not billion electron volts (Bev) as printed, and should be so understood throughout, including Tables I and II. Line 13 of the text should read "... charged component to geomagnetic latitude." The heading of column 3 of Table II should be "pc/Ze."

Apparent Error in the Measured Mass of S^{32}

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August 14, 1950

While attempting to calculate the threshold energy for the reaction $\mathrm{S}^{32}(\gamma,d)\mathrm{P}^{30}$ an apparent anomaly between the measured masses of S^{32} and Si^{30} was encountered.

Discussing mass defects in light nuclei, Rosenfeld[1] states, "In the interval $A=29\cdots34$ there is a large unexplained discrepancy between the values derived from nuclear reaction data and those based on the mass spectrograph measurement of S^{32}." The latter mass was used in Rosenfeld's table of mass defects.

This discrepancy can seemingly be attributed to an error in the measured mass of S^{32}. The following calculations are offered in support of this statement.

The reaction energies of five relevant nuclear reactions are given in the isotopic report of Mattauch and Flammersfeld[2] and in a recent paper on thresholds.[3] These values, together with the reaction energy for the reaction $\mathrm{S}^{32}(\gamma,d)\mathrm{P}^{30}$ which was measured in this laboratory, are listed in Table I.

Seaborg's tables[4] give 3.85 and 3.50 Mev for the β-decay energies of S^{31} and P^{30}. Both values were determined by magnetic spectrometer measurements.

Figure 1 illustrates the situation. The reactions considered are shown by solid arrows and the β-decays by dotted arrows.

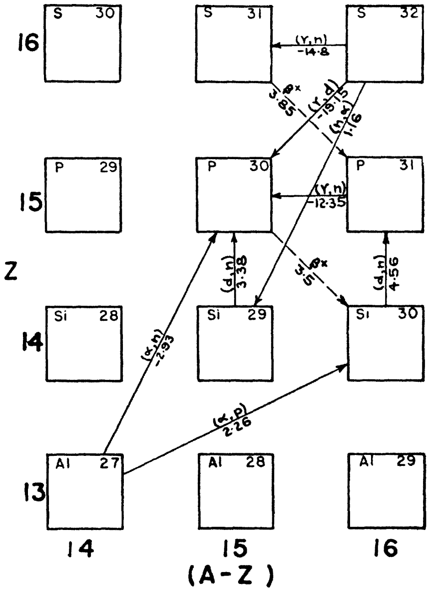

Fig. 1. Sketch showing the reactions, reaction energies, β-decays, and decay energies used in the calculations to determine the mass of S^{32}.

TABLE I. Reaction energies.

Reaction	Reaction energy (Mev)
$S^{32}(\gamma,d)P^{30}$	−19.15
$S^{32}(\gamma,n)S^{31}$	−14.8
$S^{32}(n,\alpha)Si^{29}$	1.2
$P^{31}(\gamma,n)P^{30}$	−12.35
$Si^{30}(d,n)P^{31}$	4.56
$Si^{29}(d,n)P^{30}$	3.38
$Al^{27}(\alpha,n)P^{30}$	−2.93
$Al^{27}(\alpha,p)Si^{30}$	2.26

The mass of Si^{30} is listed by Rosenfeld as 29.98310 ± 0.00032 m.u. A recent measurement by Duckworth[5] giving 29.98290 ± 0.00015 has substantiated this value. The present calculations have been based on the latter value.

The calculations were performed as follows:

$$\left.\begin{array}{l} Si^{30}\rightarrow P^{31}\rightarrow P^{30} \\ Si^{30}\rightarrow P^{30} \\ Si^{30}\rightarrow Al^{27}\rightarrow P^{30} \end{array}\right\}\rightarrow P_{wm}^{30}\ \text{(weighed mean value)},$$

$$\left.\begin{array}{l} P_{wm}^{30}\rightarrow Si^{29}\rightarrow S^{32} \\ P_{wm}^{30}\rightarrow S^{32} \\ Si^{30}\rightarrow P^{31}\rightarrow S^{31}\rightarrow S^{32} \end{array}\right\} S_{wm}^{32}\ \text{(weighed mean value)}.$$

Assuming approximately equal experimental errors in each reaction energy and decay energy used, a one-step calculation was given a weight of one, a two-step calculation a weight of one-half, etc.

The masses of the proton, deuteron, and α-particle were taken from Mattauch and Flammersfeld's tables, while a value of 1.008986 m.u. was used for the mass of the neutron.[6]

The weighed mean value of the mass of S^{32} obtained through these calculations is 31.98199 ± 0.00021 m.u.

This value is in fair agreement with the value 31.98167 ± 0.00017 listed by Mattauch and Flammersfeld, but differs by 0.00110 m.u. (1.02 Mev) from the spectrometric value of 29.98089 ± 0.00007 listed in Rosenfeld's tables.

The calculations also give 28.98568 m.u. for the mass of Si^{29} which is in excellent agreement with the value 29.98567 recently obtained by Duckworth.[7] These values do not agree with the value listed by Rosenfeld.

It is concluded that the measured mass of S^{32} is too low by 0.00110 m.u. and that the correct value is 29.98199 ± 0.00021 m.u.

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Detection of Beta-Induced Scintillations from Crystals with a Photo-Sensitive Geiger-Mueller Counter*

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IN a previous communication,[1] the writers described experiments in which immediate fluorescent scintillations from crystals of NaCl-Ag were detected in a photo-sensitive Geiger-Mueller counter. The scintillations were produced when the crystals were irradiated by the alpha-particles of polonium. It was also stated that a long period ultraviolet *phosphorescence* was observed when the same crystals were bombarded by beta-particles. All of the above-discussed measurements were carried out with the use of the photo-sensitive scintillation Geiger counter, which was described as "relatively insensitive."

Since the time of the early alpha-particle measurements, the behavior of NaCl-Ag under beta-ray and gamma-ray bombardment has been observed in conjunction with a 1P28 photo-multiplier tube. Contrary to the experience with the scintillation Geiger counter, a copious emission of short decay-time fluorescent ultraviolet was observed when NaCl-Ag was irradiated by both beta-rays and gamma-rays. These pulses were not observed in the early scintillation Geiger counter because of insufficient quantum efficiency. Only the very large light pulses of the polonium alpha-particles could be detected. Consequently, a wire gauze photon counter was sensitized in the manner described by Scherb.[2] By repeated and prolonged discharges at liquid air temperature, an extremely responsive photon counter was obtained. Its sensitivity in the ultraviolet was several orders of magnitude greater than that of the photon counter used for the first alpha-particle detection.

This newly prepared scintillation Geiger counter was found to respond satisfactorily when it was coated with crystals of NaCl-Ag and irradiated by the beta-rays of RaE. The glass sidewalls of the photon counter were sufficiently thick to exclude even the highest energy beta-rays of RaE. Moreover, since the RaE was in equilibrium with its parent and daughter elements, 20 mg/cm² of aluminum were placed between the source and the counter to exclude the possibility of counting any alpha-particles from polonium. Aside from a faint gamma-ray background, coming perhaps from RaD, the entire counting rate arose from the ultraviolet scintillations produced in NaCl-Ag by the beta-spectrum of RaE. Using a relatively crude geometry, an efficiency of ten percent for beta-rays was obtained. This value can be improved upon tremendously. It is thought that an efficiency of one hundred percent can be reached.

To ascertain whether the counter would respond to fluorescent scintillations resulting from gamma-rays on NaCl-Ag, the ultra-sensitive photon counter was placed in a double-walled jacket made of Corning 9741 glass. The space within the concentric cylinders was filled with NaCl-Ag crystals, forming a cylindrical layer of thickness 1.5 cm about the cathode of the counter. Using radioactive Sc^{46} as a source, the counter enclosed by the layer of crystals was irradiated by million-volt gamma-rays. Taking all precautions to maintain a constant geometry, a cylinder of thin black paper was slipped over the counter between the counter and the layer of scintillating crystals. No appreciable change in the counting rate was observed, indicating that even higher quantum efficiencies in the ultraviolet must be obtained before scintillations resulting from gamma-ray bombardment can be detected.

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* Assisted by the joint program of the ONR and AEC.
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The Scattering Lengths of the Deuteron

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August 14, 1950

THE angular variation of neutron scattering by deuterium gas has been measured. A new spectrometer, especially designed for such work, was used instead of earlier equipment.[1] Neutrons, of wave-length 1.063A, were selected by crystal diffraction from a well-collimated beam leaving the Chalk River reactor. They passed through a cell containing deuterium gas at liquid nitrogen temperature and 21 atmospheres pressure. Scattered neutrons were measured by a BF_3 proportional counter every eight degrees in the angular range 11.2° to 67.2°. Sixteen angular sweeps were made with gas in the cell, 1000 counts being taken at every stop so that 16,000 counts were taken at each angle. Background, which ranged from 10 percent to 15 percent, was determined with the cell evacuated.

The experimental counting rates were corrected for background, for hydrogen content of the deuterium, and for double scattering. The resulting quantities were transformed to relative differential cross sections by dividing by the effective scattering volume. Com-