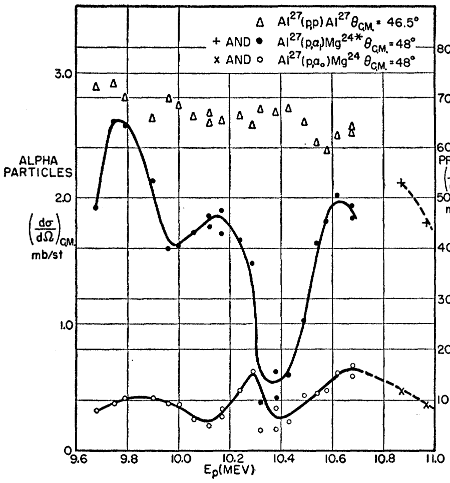

FIG. 2. Differential cross sections for $Al^{27}(p,p)Al^{27}$, $Al^{27}(p,\alpha_0)Mg^{24}$, and $Al^{27}(p,\alpha_1)Mg^{24*}$ at $\theta_{lab}=45°$ as a function of proton energy.

is observed (Fig. 1) and the expression used by Hunting and Wall makes this disagreement worse. That a smaller radius is required to fit $Al(p,\alpha)$ data than $Al(\alpha,p)$ data probably reflects the extent of the incoming particle.

The sharp energy dependence observed for these $Al(p,\alpha)$ differential cross sections was not expected. Two lines of discussion, however, may be advanced to account for these observations:

(1) Direct-interaction theories,[4] calculated by using plane waves, predict a very slow variation with energy. Cross-section expressions derived for (p,p') reactions by Levinson and Banerjee[5] using distorted wave functions are too complex to permit an easy calculation, but single-particle resonances would probably have widths of the order of 1 Mev.[6] Thus, a distorted-wave calculation for $Al(p,\alpha)$ reactions would probably also not yield as sharp an energy dependence as was observed. However, Owen and Madansky[7] obtained a good theoretical fit to their $B^{11}(d,n)C^{12}$ angular distributions, which display a large energy dependence, by including heavy-particle or exchange stripping in a Born approximation calculation. An analogous approach may yield agreement with these $Al(p,\alpha)$ data.

(2) Compound-nucleus processes might be expected to yield a sharp energy dependence if either the continuum or statistical assumptions about the compound nucleus were violated. However, in this case, the continuum assumption is probably valid, since the compound nucleus, Si^{28}, would have up to 22.7 Mev of excitation. Certainly, the mean level spacing[8] is much less than the beam energy spread. If the statistical assumption is not satisfied (e.g., the decay-channel reduced-width amplitudes are correlated), then an energy dependence might be expected from either purely compound-nucleus processes or interference between compound-nucleus and direct-interaction processes.[9] The failure of the statistical assumption has also been suggested by Eisberg and Hintz[10] as a possible explanation of their $A^{40}(p,p')A^{40*}$ angular distributions.

To summarize: the partial fit of the $Al^{27}(p,\alpha_0)Mg^{24}$ data by a curve of the general form $|j_2(Qr)|^2$ suggests that direct-interaction processes play a substantial role in determining the differential cross section. Thus, either interference between various direct-interaction processes or between direct-interaction and compound-nucleus processes, implying a failure of the statistical assumption, or both, are responsible for the sharp energy dependence. Experiments of high resolution are in progress.

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Hyperfine Structure Measurements on Neptunium-239†

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THE atomic-beam magnetic-resonance method has been used to investigate 2.36-day Np^{239} in the low-field or Zeeman region of hyperfine structure. The spin of this nuclide is found to be 5/2 in agreement with the conclusions of Hollander, Smith, and Mihelich from beta- and gamma-spectroscopy[1] and with the predictions of the Bohr-Mottelson model, but apparently in conflict with measurements by the methods of optical[2] and paramagnetic-resonance[3] spectroscopy. The principal observations have been made in a low-lying electronic state with measured $J=11/2$, $g_J=0.6551 \pm 0.0006$, which is probably the ground state of the electronic configuration $(5f)^4(6d)^1(7s)^2$.

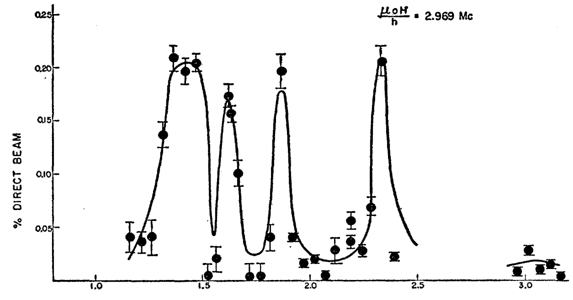

FIG. 1. Low-field search in Np^{239}. Resonances in the states $F=8$ through $F=4$ are shown. The $F=8$ and $F=7$ states are unresolved at 1.4 Mc/sec; succeeding peaks (left to right) are from $F=6$, $F=5$, and $F=4$.

The material is produced in curie amounts by neutron activation of depleted (0.4% U^{235}) uranium. A beam is detected in one of two ways: (a) the beam is collected on a sulfur surface and counted in scintillation counters with low beta-detection efficiency but with high efficiency for gamma rays between 20 and 200 kev, or (b) the beam is collected on a flamed platinum foil and detected in flow proportional counters sensitive to beta particles above about 5 kev.

An initial attempt to form a beam of neptunium was made by vaporizing the material directly from the uranium. Although the relative vapor pressures are suitable, this technique failed as a result of uranium creep. At beam temperatures the uranium interacts with the tantalum oven slits to form a low-melting-point alloy. The resulting destruction of the slits invariably leads to an intolerable background count at the detector.

A beam of neptunium is, however, successfully made by a high-temperature decomposition of neptunium carbide, which is in turn formed by an intermediate-temperature reduction of neptunium oxide by carbon. The gross target material is oxidized in air, mixed with a large excess of graphite powder, and placed in a tantalum oven. The reduction stage is signaled by the liberation of large quantities of CO, starting at a temperature of about 1000°C. When this stage is completed, the oven temperature is raised to 1800–2500°C to obtain a beam. The temperature dependence of neptunium effusion rate in this region is typically a factor of 4 per 100° temperature rise.

Low-field runs covering a considerable range of g values (Fig. 1) indicate that prominent resonances arise from the system $J=11/2$, $I=5/2$ and that there are probably other electronic states in the beam. The accuracy in the assignment of g values from these data is, however, too low to convincingly establish this assignment. Therefore each of the five prominent resonances has been followed to a magnetic field of 25 gauss. All observations of the six resonances associated with $J=11/2$ are given in Table I. The sixth resonance associated with the state $F=3$ is very weak relative to the other five because of apparatus discrimination, and is included for completeness only; the reliability of observations on this state is probably no better than five to one.

The essential conclusions that may be drawn from Table I are that, to the accuracy of measurement, the system is in the Zeeman region of hfs; that relative and absolute resonance intensities are consistent with the assumption that $J=11/2$, $I=5/2$ comprises a major fraction of the beam; and that, to an accuracy of one part in a thousand, all six transitions fit the system $J=11/2$, $I=5/2$, $g_J=0.6551$. With the electronic angular momentum and g value thus established, a search was made for the spin 1/2 previously reported for this nucleus. When detection system (b) is used, and at a time 5 days after production of the sample, the product of relative decay rate and detection efficiency for spin 1/2 is found to be conservatively less than 5% of that for the spin-5/2 state.

TABLE I. Summary of data.

	Magnetic field (μ_0H/h), Mc/sec	Total angular momentum $F=8$	$F=7$	$F=6$	$F=5$	$F=4$	$F=3$
Experimental observations (g_F)	1.443					0.76±0.02	1.04±0.02
	1.985	0.43±0.015	0.479±0.015	0.534±0.015	0.635±0.015		
	2.969	0.451±0.010	0.485±0.010	0.543±0.010	0.624±0.010	0.788±0.010	
	5.880	0.451±0.005		0.540±0.005			
	11.544	0.449±0.003	0.484±0.003				
	18.786		0.4841±0.0015				
	27.386			0.5379±0.0010	0.6222±0.0010	0.7697±0.0010	1.0649±0.0010
	35.535	0.4505±0.0008	0.4856±0.0008	0.5379±0.0008	0.6223±0.0008	0.7686±0.0008	
Mean experimental value (g_F)		0.4504±0.0008	0.4853±0.0007	0.5379±0.0006	0.6223±0.0006	0.7692±0.0006	1.065±0.0010
Calculated g_F values; $J=11/2$, $I=5/2$, $g_J=0.6551$, $g_I=0$		0.4504	0.4855	0.5381	0.6223	0.7697	1.0645
Mean observed resonance intensity in percent direct beam		0.3%	0.3%	0.25%	0.15%	0.15%	0.04%
Calculated intensity for only $J=11/2$, $I=5/2$ in beam		0.47%	0.47%	0.47%	0.45%	0.36%	0.12%

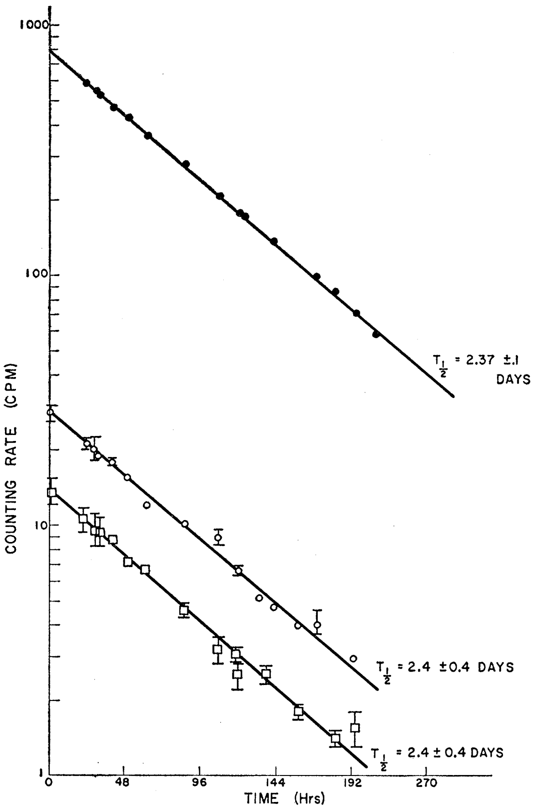

FIG. 2. Np^{239} decay curves for a direct beam (2.37±0.1 days) and for resonances from the states $F=8$ (upper 2.4÷0.4 days) and $F=6$ (lower 2.4±0.4 days).

Samples have been shown in several ways to be Np^{239}. First, aliquot fractions of the target and intense direct beam exposures have been shown to have a gamma spectrum essentially identical to that reported for this isotope,[4] and, secondly, half-lives have been taken on the target and on a direct beam and two resonances (Fig. 2).

If we assume that the ground-state configuration of neptunium contains only $5f$ and $6d$ electrons,[5] only the configurations $(5f)^4(6d)^1$ and $(5f)^2(6d)^3$ have, from Hund's rule, ground-state angular momenta $J=11/2$. The configuration of uranium has been found[6] to be $(5f)^3(6d)^1$ and that of plutonium is[7] probably $(5f)^6$. It is therefore highly probable that the ground-state configuration of neptunium is $(5f)^4(6d)^1$. The g value of this state in pure Russell-Saunders coupling is 0.615; however, results of optical spectroscopic investigations in this region clearly show that this coupling scheme is inadequate to describe configurations involving unpaired $5f$ and $6d$ electrons. A much better approximation that has been found to give considerable success in interpreting the g values of uranium is that the electrostatic coupling between $5f$ and $6d$ electrons is small in comparison to the fine-structure coupling in each shell. In this approximation the two shells are individually in Russell-Saunders coupling, and the electrostatic interaction between $5f$ and $6d$ electrons removes the degeneracy in the total angular momentum. Thus under this approximation the ground-state wave function is $({}^2D_{3/2}-{}^5I_4)_{11/2}$, giving a g value of 0.6547 if diamagnetic corrections and the relativistic breakdown of Russell-Saunders coupling are neglected.

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Chirality of Tensors and Parity-Nonconserving Interactions

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It is shown that there necessarily exist two independent chirality operators, X, Y, in tensor calculus, and that any Lagrangian has to be invariant under the combined transformation $X\cdot Y\cdot P$, where P is the parity operator. The requirement that any interaction Lagrangian should be invariant under one of these three and noninvariant under each of the remaining two seems to delimit the possible types to a reasonable number of varieties as necessitated by experiments.

The group G of congruent transformations in the Minkowski space is divided into a class I including no space inversions and a class P including space inversions.[1] The factor group G/I consisting of I and P satisfies the following relations:

$$I\cdot I=I,\quad P\cdot P=I,\quad P\cdot I=I\cdot P=P. \tag{1}$$

If L is a faithful representation of the group G, then IL and PL will also be a faithful representation of G.

A chirality operator X should be defined by[2]

$$X\cdot X=I,\quad X\cdot I=I\cdot X=X,\quad X\cdot P=-P\cdot X. \tag{2}$$

The lowest possible rank of the representation of this group consisting of I, P, and X is two.[3] If the representation PL with a second-rank P is used, it is obvious that