explained by the finite relaxation time. It is this case that exhibits the nuclear polarization given by $\eta \simeq \epsilon \simeq g_e \mu_0 H/2kT$. This may be readily seen from the figure by merely adding the occupancy of the $m_I = +\frac{1}{2}$ levels and comparing it with that of the $m_I = -\frac{1}{2}$ levels.

Figure 1(c) shows what happens if we induce both nuclear transitions by sweeping the rf through the 52–65 Mc/sec range. We see from the level diagram that the population of the levels is just opposite to the ones in Fig. 1(a). We should observe therefore a reversal of the electron spin line, which indeed is verified experimentally.

It should be noted that it is the magnetic field in which the nuclei come to thermal equilibrium that enters into the polarization formula. This may be several times larger than the magnetic field in which the spin transitions occur, as long as the field is changed to the resonance field in a time short compared to the relaxation time.

[1] Fletcher, Yager, Pearson, Holden, Read, and Merritt, Phys. Rev. **94**, 1392 (1954).
[2] Feher, Fletcher, and Gere, Phys. Rev. **100**, 1784 (1955); G. Feher and R. C. Fletcher, Bull. Am. Phys. Soc. Ser. II, **1**, 125 (1956).
[3] G. Feher, Rev. Sci. Instr. (to be published).
[4] A. Honig, Phys. Rev. **96**, 234 (1954); A. Honig and J. Combrisson, Phys. Rev. **102**, 917 (1956).
[5] F. Bloch, Phys. Rev. **70**, 460 (1946).

Lowest Odd-Parity States in Even-Even Nuclei*

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Although they are much less common than the even-parity states,[1,2] quite a few odd-parity states have been identified in even-even nuclei. Such states are expected to arise from configurations different from the ground-state configurations. In order to see if there is any general trend in these states, the lowest experimentally identified odd-parity states were compiled and their energies were plotted against A. The result is shown in Fig. 1. Most of the points were obtained from known beta- or gamma-ray decay schemes except for the very light nuclei. In many of the cases it is not very certain that the experimentally identified lowest odd-parity states are actually the lowest odd-parity states. In each case where the level scheme is well established there are usually several odd-parity states in a cluster, so that in the not-well-established cases the observed odd-parity states are probably close to being lowest. This situation might not occur in some light nuclei. Among 41 points plotted, the identification of the parity is quite certain for more than 30 points and the rest are more likely to be odd-parity states than even-parity states.

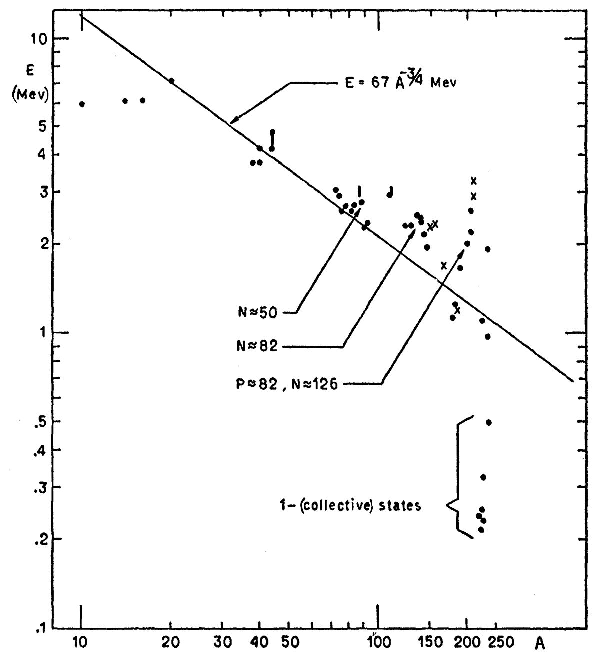

FIG. 1. Excitation energies of the lowest odd-parity states in even-even nuclei plotted against A. The dots represent the cases where parity assignments are quite certain and the crosses represent the less certain cases. The straight line represents the empirical pairing energy $E = 67\ A^{-3/4}$ Mev.

The results indicate quite marked trends as follows:

(1) These states have, where the identification of the angular momentum is certain, odd angular momentum, predominantly 3, and there is no case where even angular momentum is assigned positively. This confirms the rule found by Glaubman[3] and treated theoretically by Talmi.[4]

(2) These states appear not too far from the line $E = 67A^{-3/4}$ Mev (a semiempirical formula which is used to describe the separation of two mass parabolas in even-A nuclei[5]), with two kinds of exceptions: (a) anomalies at the Pb isotopes (and also around $N = 82$), and (b) the low-lying 1^- states in very heavy nuclei which are considered to be collective odd-parity states.[6] This fact indicates, in other words, that in general the lowest odd-parity states lie on the odd-odd mass parabola. It is interesting to see that at $A = 208$, where an anomaly takes place, the 3^- state (the lowest odd-parity state) of Pb^{208} lies closer to the odd-odd empirical mass parabola than its ground state lies to the even-even curve, indicating that the ground state is anomalously stable.

(3) The points appear in groups, around oxygen, around calcium, around strontium, etc. These are the places where the jump in the oscillator shells takes place, i.e., $1p_{3/2}$ to $1d_{5/2}$ and $2s_{1/2}$, $1d_{3/2}$ and $2s_{1/2}$ to $1f_{7/2}$, $2p_{1/2}$ to $1g_{9/2}$, etc. This might seem to be due only to the fact that in this region the states of the parent nuclei that undergo beta decay mostly have odd parity.

This surely makes the identification easy (or possible), but it is not the only reason why such states are found in this region. In the intermediate region, the lowest odd-parity states could not appear so low; for example, in Mg^{24} one can exclude 3^-, 4^-, and 5^- states up to about 8 Mev, since the 9.4-Mev 4^+ ($T=1$) state does not decay into such states (no evidence of three or more gamma rays in cascade).

(4) In the heavy-element region, the effects of cores are very pronounced (around Pb, around $N=82$, and around $N=50$).

(5) Surprisingly enough, the points in light nuclei fall fairly well on the line, suggesting that these states are probably of shell-model nature like those in heavier nuclei. This is in agreement with the shell-model picture of the lower odd-parity states in O^{16}.[7]

The general trend shows the similarity of the lowest odd-parity states in even-even nuclei to the ground-state configurations of odd-odd nuclei in their symmetry character, namely, the existence of two unpaired nucleons (which interact rather weakly with each other).

This rule seems to be quite useful for the investigation of decay schemes. So far there seems to be no definite violation. There are some decay schemes where much lower lying odd-parity states have been considered. These seem to need further investigation.

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* This work was started at Purdue University and preliminary results were reported at the New York Meeting of the American Physical Society (January 1956) as a post-deadline paper.
[1] G. Scharff-Goldhaber, Phys. Rev. **90**, 1105 (1953).
[2] P. Preiswerk and P. Stähelin, Helv. Phys. Acta **24**, 623 (1952).
[3] M. J. Glaubman, Phys. Rev. **90**, 1000 (1953).
[4] I. Talmi, Phys. Rev. **90**, 1001 (1953).
[5] See, for example, N. F. Ramsey, in *Experimental Nuclear Physics*, edited by E. Segrè (John Wiley and Sons, Inc., New York, 1953), Vol. 1, p. 539.
[6] Stephens, Asaro, and Perlman, Phys. Rev. **100**, 1543 (1955).
[7] B. H. Flowers (private communication).

Radioactive Isotopes Cl^{40} and Ga^{74}†

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In order to look for more odd-parity states in even-even nuclei,[1] two previously unknown isotopes Cl^{40} and Ga^{74} were made and investigated. The ground states of these nuclei are most likely negative-parity states according to the shell model, and therefore allowed transitions to some of the negative-parity states would compete well with the transitions to lower even-parity states even though such odd-parity states have a relatively high energy. Moreover, the forbiddenness of the high-energy beta component can keep the half-life of these isotopes fairly long in spite of the high decay energy which is expected from beta energy systematics.

In order to produce Cl^{40}, solid argon was bombarded by fast neutrons from a beryllium target bombarded by 10-Mev deuterons from the Purdue cyclotron. Gamma-ray measurements made after the neutron irradiation showed gamma rays with energies of 1.46 Mev, 2.75 Mev, and 6.0 Mev, in addition to the 1.37-Mev gamma ray attributed to the 110-min A^{41} produced by the (n,γ) reaction on A^{40} and the 3.1-Mev radiation due to S^{37} produced by the (n,α) reaction on A^{40}. From both gamma-ray measurements with a NaI scintillator and beta-ray measurements with a GM counter, the half-life of this new activity was found to be about 1.4 min. Since Cl^{40} is the only unknown isotope which could be produced by irradiating argon and since moreover the energy of one of the gamma rays (1.46 Mev) coincides with the energy of the first excited state of A^{40},[2] this new activity is attributed to Cl^{40}. Also, the assignment of this activity to chlorine is confirmed by chemical separation.

The beta spectrum of this activity was investigated with the aid of a $2\times2\times2$ in. Plastifluor scintillator and was found to extend up to about 7.5 Mev. There is also at least one strong lower energy component which has its end point between 3.0 and 3.5 Mev. The intensity of the 2.75-Mev gamma ray is found to be close to that of the 1.46-Mev gamma ray by comparison of the spectrum with that of Na^{24} taken by the same spectrometer. These characteristics suggest a decay scheme as given in Fig. 1(b). The decay energy is in good agreement with the beta energy systematics.

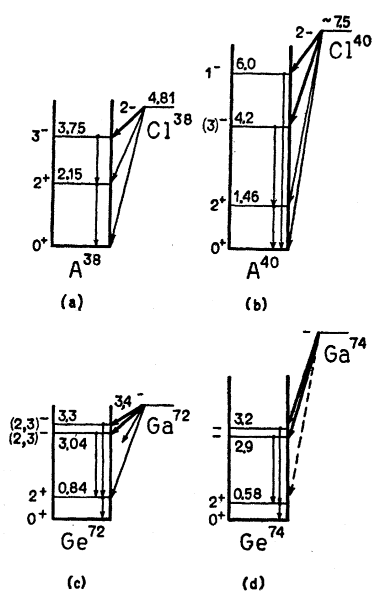

Fig. 1. Proposed decay schemes of Cl^{40} and Ga^{74} compared with known decay schemes of Cl^{38} [Kraushaar, Mihelich, and Sunyar, Phys. Rev. **95**, 456 (1954)] and Ga^{72} [Kraushaar, Brun, and Meyerhof, Phys. Rev. **101**, 139 (1956)]. In the decay scheme of Ga^{72} (c), only the major components of the beta and gamma radiations are shown. For the fit with the systematics of odd-parity states, see the figure in reference 1.