parities as explained below. The arguments are based on two assumptions: (1) Gamow-Teller selection rules govern the beta-decay process, and (2) the nuclear shell model[1] is a reliable guide in the region $Z\sim 40$ and $N\sim 50$.

The nucleus $_{40}Zr^{90}$ contains closed shells of 40 protons and 50 neutrons. Thus, $I=0$ and the parity is even in the ground state.

$_{39}Y^{90}$ is an odd-odd nucleus. It is characterized by a $(3p)^{-1}(4d)^1$ configuration in the notation of Feenberg and Hammack. Thus, the ground state parity is *odd*.

$_{38}Sr^{90}$ is an even-even nucleus. It is characterized by a $(3p)^{-2}(4d)^2$ configuration. In the ground state the parity is even and, most probably, $I=0$.

Both beta-transitions are associated with change of parity. Thus by G-T rules, both are first-forbidden or both are third-forbidden. The *ft* product for the first transition is $\sim 10^9$ and for the second $\sim 10^8$. These values are appropriate for first-forbidden transitions with $\Delta I=\pm 2^{(1-2)}$, but are too small for third-forbidden. Consequently, $I=2$ in the ground state of $Y^{90}$.

Thus the two beta-transitions of Fig. 1 should produce peculiar energy distributions similar to those found in $Y^{91}$, $Cs^{137}$, $K^{42}$, and $Rb^{86}$ by various investigators.[2-7] In such cases the energy distribution differs[8] from the allowed form by a factor $G\sim(W_0-W)^2+(W^2-1)$.

A carrier-free sample of $Sr^{90}$ was obtained from Oak Ridge. This sample had been aged to permit an associated 55-day activity of $Sr^{89}$ to die out. Three spectra were measured: (1) $Sr^{90}$ and $Y^{90}$ in equilibrium together, (2) $Sr^{90}$ alone, and (3) $Y^{90}$ alone. For the latter two runs, the isotopes were chemically separated by a method due to Kurbatov and Kurbatov.[9] Samples were prepared for the spectrometer by evaporation from solution on thin Zapon films, following the insulin technique of Langer.[10]

The spectra were measured in the double-focusing spectrometer described by Kurie, Osoba, and Slack.[11] In the interests of higher counting rates, a wide counter window (0.25 in.) was used, which dropped the resolving power to 1 percent. The window was Zapon film of 3- to 4-kev stopping power, and was supported lengthwise by a single 5-mil wire. A pressure regulator[12] was used to avoid loss of counter pressure caused by window leakage.

The results are shown as FK (Fermi-Kurie) plots in Fig. 2 for $Sr^{90}$ and in Fig. 3 for $Y^{90}$. As indicated in Fig. 2, the $Sr^{90}$ data was obtained by subtracting the $Y^{90}$ distribution curve from that for an equilibrium mixture of both $Sr^{90}$ and $Y^{90}$.

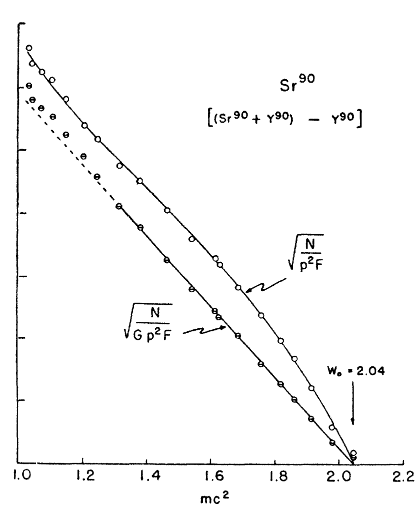


FIG. 2. $Sr^{90}$ FK plots. "Allowed" plot (upper) and "forbidden" plot (lower), with ordinates as indicated.

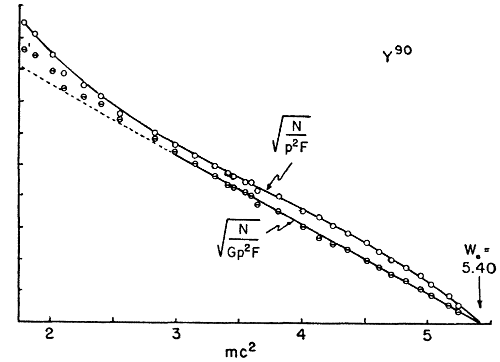


FIG. 3. $Y^{90}$ FK plots. "Allowed" plot (upper) and "forbidden" plot (lower), with ordinates as indicated.

The upper curve in each figure (labeled $[N/p^2F]^{\frac{1}{2}}$) is a conventional or "allowed" FK plot, i.e., computed as though the transition were allowed. The lower curve in each figure (labeled $[N/Gp^2F]^{\frac{1}{2}}$) is a "forbidden" FK plot, i.e., computed as though the transition were first-forbidden, with $\Delta I=\pm 2$ (yes). The near-straightness of the latter pair of plots confirms the assignment of spins and parities shown in Fig. 1.[13]

* Assisted by the joint program of the ONR and the AEC.

1 E. Feenberg and K. C. Hammack, Phys. Rev. **75**, 1964 (1949).
2 F. B. Shull and E. Feenberg, Phys. Rev. **75**, 1768 (1949).
3 L. M. Langer and H. C. Price, Jr., Phys. Rev. **75**, 1109 (1949).
4 A. C. G. Mitchell and C. L. Peacock, Phys. Rev. **75**, 1272 (1949).
5 J. S. Osoba, Phys. Rev. (in press).
6 A. C. G. Mitchell (private communication); see also Zaffarano, Kern, and Mitchell, Phys. Rev. **74**, 682 (1948), especially Fig. 4.
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8 E. J. Konopinski and G. E. Uhlenbeck, Phys. Rev. **60**, 308 (1941).
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10 L. M. Langer, Rev. Sci. Inst. **20**, 216 (1949).
11 Kurie, Osoba, and Slack, Rev. Sci. Inst. **19**, 771 (1948).
12 Ter-Pogossian, Townsend, and Robinson (to be published in Rev. Sci. Inst.).
13 Similar results and conclusions are reported by L. J. Laslett and E. Jensen and by L. M. Langer (private communications).


## The Forbidden Beta-Decay of $Sr^{89}$*

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THE isotope $Sr^{89}$ decays by $\beta^-$ emission to $Y^{89}$ with a half-life of $4.75\cdot 10^6$ seconds. The energy release, including rest mass, is 3.93 mc², so that the maximum electron kinetic energy is 1.50 Mev. No gamma-radiation is observed. The *ft* product for the beta-transition is $4.9\cdot 10^8$.

Using the nuclear shell model notation of Feenberg and Hammack,[1] the $Sr^{89}$ ground state is characterized by a $(3p)^{-2}(4d)^1$ configuration, so its parity is even. The ground state of $Y^{89}$ is characterized by a $(3p)^{-1}$ configuration, so its parity is odd. The beta-transition between ground states, therefore, involves a parity change, and the transition is first-forbidden by Gamow-Teller rules. The large *ft* value favors a spin change of 2 units.[1,2]

A beta-transition for which $\Delta I=\pm 2$ (yes) yields an electron energy distribution which differs from that for an allowed transition by a factor $G\sim(W_0-W)^2+(W^2-1)$, if it is assumed that Gamow-Teller rules apply to the beta-process.[3] Such distributions have been observed previously for $Y^{91}$, $Cs^{137}$, $Rb^{86}$, $Sr^{90}$, $Y^{90}$, and $K^{42}$.[2,4-10] If the above reasoning is correct, the $Sr^{89}$ spectrum should display a similar forbidden "shape."

The spectrum was measured in the magnetic double-focusing spectrometer.[11] A source of $Sr^{89}$, containing also some $Sr^{90}$

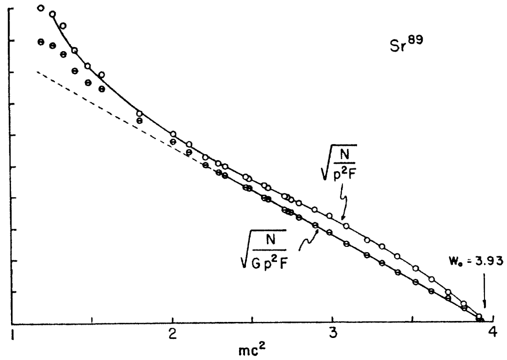


FIG. 1. $Sr^{89}$ FK plots. "Allowed" plot (upper) and "Forbidden" plot (lower), with ordinates as indicated.

and $Y^{90}$, was obtained from Oak Ridge. Contributions to the spectrum from $Sr^{90}$ and $Y^{90}$ have been subtracted from the data. The data are shown in Fig. 1 in the form of FK (Fermi-Kurie) plots. The ordinate for the upper curve ("allowed" plot) is $(N/p^2F)^{\frac{1}{2}}$ and for the lower ("forbidden" plot) is $(N/Gp^2F)^{\frac{1}{2}}$. No attempt has been made to use a closer approximate form of $G$ because of the relatively high value of $W_0$.[6] The upper curve shows the characteristic upward bulge for energies higher than $W_0/2$. The lower curve is satisfactorily straight, and confirms the prediction made above.[12]

Goldsmith and Inglis[13] list the spin of $Y^{89}$ as 1/2(?), (original source of this value is not mentioned). If true, the spin of $Sr^{89}$ ground state is 5/2. These spin values are in harmony with the nuclear shell model.

* Assisted by the joint program of the ONR and the AEC.
[1] E. Feenberg and K. C. Hammack, Phys. Rev. **75**, 1964 (1949).
[2] F. B. Shull and E. Feenberg, Phys. Rev. **75**, 1768 (1949).
[3] E. J. Konopinski and G. E. Uhlenbeck, Phys. Rev. **60**, 308 (1941).
[4] L. M. Langer and H. C. Price, Jr., Phys. Rev. **75**, 1109 (1949).
[5] A. C. G. Mitchell and C. L. Peacock, Phys. Rev. **75**, 1272 (1949).
[6] J. S. Osoba, Phys. Rev. (in press).
[7] Braden, Slack, and Shull (preceding letter).
[8] Zaffarano, Kern, and Mitchell, Phys. Rev. **74**, 682 (1948), and private communication from Dr. Mitchell.
[9] K. Siegbahn, Arkiv. f. Math., Astr. o. Fysik **34B**, No. 4 (1946).
[10] Private communications from L. J. Laslett and E. Jensen.
[11] Kurie, Osoba, and Slack, Rev. Sci. Inst. **19**, 771 (1948).
[12] Similar results have been observed by L. J. Lazlett and L. M. Langer (private communication).
[13] H. H. Goldsmith and D. R. Inglis, *The Properties of Atomic Nuclei I.*, Brookhaven National Lab. (1948).

## Measurements Concerning the Vapor-Liquid Equilibrium of Solutions of $He^3$ in $He^4$ below 2.19°K

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A SMALL vessel having a volume of 0.33 cm³ had condensed in it a known amount of helium in which the $He^3$ concentration was about $5\times10^{-4}$. The vessel was placed in a bath of normal liquid helium and the vapor pressure difference, $\Delta p$, between the vessel and bath was measured while the vapor and liquid in the vessel were effectively stirred. In the top of the vessel we inserted a ground copper plug just below the capillary tube which connects the vessel with the apparatus outside the cryostat. The plug gives the helium film sufficient means for creeping out of the vessel, leaving the $He^3$ below the plug.[1] The film helium could be pumped out of the capillary by means of a Toeppler pump, and mass spectrometric analysis of this gas confirmed that no measurable amount of $He^3$ was going out. Thus the pumping effected a very considerable increase in the $He^3$ concentrations inside of the vessel.

If one assumes (a) perfect solution, i.e. independence of the energy of one atom of $He^3$ or $He^4$ of the concentration, (b) liquid helium to be a two fluid system with $He^3$ soluble in the normal fluid only, and (c) helium to act as a perfect gas in the vapor phase, then a determination of $\Delta p$ as a function of the known $He^3$ content at constant temperature (below the λ-point) enables one to test the relations which follow.

According to Henry

$$p_3=N_3^L\pi_3/(N_3^L+N_4^{nL}) \quad (1)$$

and

$$p_4=N_4^{nL}\pi_4/(N_3^L+N_4^{nL}) \quad (2)$$

in which $p_3$ and $p_4$ are the partial pressures of the two isotopes in the vapor, $N_3^L$ and $N_4^{nL}$ the number of molecules of $He^3$ and normal fluid $He^4$ in the liquid, $\pi_3$ and $\pi_4$ the saturated vapor pressures. We derive from (1) and (2):

$$p_3/p_4=N_3^L\pi_3/N_4^{nL}\pi_4 \quad (3)$$

and

$$\Delta p=p_3+p_4-\pi_4=N_3^L(\pi_3-\pi_4)/(N_3^L+N_4^{nL}). \quad (4)$$

Accepting provisionally Tisza's relation $N_4^{nL}/N_4^L=\alpha=S/S_\lambda$ ($S$ is the entropy of the pure $He^4$ at the temperature used and $S_\lambda$ its entropy at the λ-point), we were able to calculate from the measured value of $\Delta p$ at each temperature the absolute and relative concentrations in liquid and vapor, i.e.: $C_L=N_3^L/N_4^L$, $C_V=p_3/p_4$, $X_L=N_3^L/(N_3^L+N_4^L)$ and $X_V=p_3(p_3+p_4)$.

TABLE I. $T=1.75$°K.

| $\Delta p$ mm Hg | $K_L10^4$ | $X_V10^3$ | $N_3^L\cdot10^8$ | $N_3^V\cdot10^8$ | $N_3^{tot}\cdot10^8$ |
|---|---|---|---|---|---|
| 0.16 | 5 | 16 | 435 | 22 | 457 |
| 0.33 | 10 | 35 | 284 | 88 | 372 |
| 0.54 | 17 | 58 | 221 | 172 | 393 |
| 0.67 | 21 | 70 | 189 | 219 | 408 |
| 0.78 | 24 | 80 | 168 | 258 | 426 |
| 0.84 | 26 | 85 | 130 | 280 | 410 |
| 0.91 | 28 | 91 | 84 | 306 | 390 |
| 1.11 | 35 | 112 | 35 | 390 | 425 |

The so calculated values of $X_L$ and $X_V$ together with the known volumes of vapor and liquid in the vessel made it possible to compute the total number of molecules $He^3$ present in the vessel. We could finally compare this number with our original amount of $He^3$, *viz.*: $440\times10^{-8}$ mole.

Table I shows in column 6 the number of $N_3^{tot}$ at 1.75°K, which is, considering the accuracy of measurement, quite satisfactory. Similar isotherms were investigated at 2.0 and 1.9°K and analogous results were obtained. Lowering the temperature at constant filling gave again a good confirmation of our assumption. At 1.2°K we reached concentrations in the vapor as high as about 70 percent for a liquid concentration of 2 percent.

On the whole our chief assumption that $He^3$ is soluble in the normal fluid fraction of helium II appears to be remarkably well realized. Details will be published in Physica.

[1] Daunt, Probst, Johnston, Aldrich, and Nier, Phys. Rev. **72**, 502 (194.7)

## A Search for Crystals That Exhibit Conduction Pulses Under Alpha-Particle Bombardment

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AFTER conduction pulses were observed in diamond[1] under polonium alpha-particle bombardment, a search was made for other crystals that exhibit this phenomenon. The choice of crystal species that were selected for test was