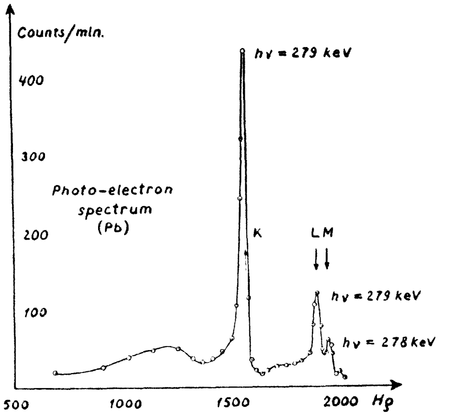

FIG. 3. Photoelectron spectrum from 3-μ Pb converter, released by the 279-kev Hg^{203} γ-ray.

γ-energy we can use $E_\gamma = 279 \pm 2$ kev. The corresponding value of Saxon is 286 ± 5 kev.

Another point of interest is that the 279-kev excited level in Ta^{203} can also be obtained in a different way. A. Lutz, M. Pool, and J. Kurbatov[4] when examining the β-radiation from 52-hour Pb (ascribed by them to Pb^{205}) found internal conversion lines corresponding to γ-rays of 270 and (possibly) 470 kev (explained as Compton electrons). Since the 270-kev radiation is very probably the same γ-line as our 279 kev, it is then almost certain that the 52-hour Pb has the mass 203 and decays by K-capture to Ta^{203} with emission of a γ-ray of 279 kev. A fuller description will appear in Arkiv. f. Mat., Astr. o. Fys.

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Single Crystal Growth of Scheelite

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SCHEELITE, $CaWO_4$, has been shown to be one of the most efficient crystals for gamma-ray counter applications.[1] For this purpose clear, transparent, single crystal material of reasonable size (~0.5 cc) is required. Since natural scheelite of sufficient purity and size is quite rare, it is necessary to resort to some laboratory growth technique.

Our experiments show that scheelite of sufficient purity and size can be grown by either of two techniques: (a) by flame fusion, the Vernueil process, and (b) from the melt by the gradient technique.

The flame fusion process, such as is used for production of synthetic sapphires, has been described elsewhere.[2] In this process the feed material is carried, as a fine powder, into one of the lines of an oxygen-hydrogen burner and caused to melt in the flame. The molten material is collected on a refractory support and is caused to grow into a single crystal by suitable manipulation of the flame, feed, etc. The conditions necessary to cause satisfactory growth unfortunately cannot be precisely stated and contain a large personal factor. Our burner was of standard design and consisted of two concentric cylindrical tubes, 25 mm and 2.5 mm I.D., respectively. The central tube extended to within 25 mm of the outer tube face. It was through this central tube, connected to an overhead hopper, that the powder (−200 mesh) was introduced into the flame. $CaWO_4$ of fluorescent grade, made either by sintering or precipitation, was first used as a feed material and yielded cloudy polycrystalline boules. We attribute this result to the WO_3 deficiency of the powder or to volatilization of WO_3 or to both of these factors. Clear boules were first obtained after 4–10 percent by weight of WO_3 (−200 mesh) was mechanically incorporated into the feed, thus reducing the loss of WO_3 during growth. Any excess was apparently volatilized although best results were obtained with 4 percent WO_3 addition. Considerable trouble was experienced with cracking of the boules during cooling. This cracking was reduced by the use of a smaller radiation space around the boule. Material of the size $4 \times 4 \times 4$ mm was obtained by this method.

Much larger and more satisfactory material was grown from the melt by the gradient technique. In this process a melt of the material in a cone-shaped crucible was slowly lowered through a temperature gradient.[3] Platinum crucibles, 18 or 31 mm in diameter with 60-degree cone tips, have been used in our work. The crucible, filled with the melt, was held in a platinum resistance furnace at 1625°C* and slowly lowered through the furnace gradient (an average of 59 degrees/cm for an elevator lowering of 125 cm) at a speed of 3.2 hours/cm. The raw material was fluorescent grade $CaWO_4$ without any addition.

We have obtained satisfactory single crystal boules yielding fragments $5 \times 5 \times 5$ mm by this process but as described above serious cracking of the boules was experienced unless it was allowed to cool quite slowly after solidification.

The fluorescent and counter behavior of scheelite by either technique was entirely satisfactory.

* The melting point of scheelite has not been reported in the literature. As determined by us it is 1576° ±5°C.
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Nuclear Shell Structure and Isomerism*

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THE shell structures[1–4]

$$(1s)^2$$
$$(1s)^2\,(2p)^6$$
$$(1s)^2\,(2p)^6\,(2s)^2$$
$$(1s)^2\,(2p)^6\,(2s)^2\,(3d)^{10}$$
$$(1s)^2\,(2p)^6\,(3d)^{10}\,(4f)^{14}\,(5g)^{18}$$

are suggested by the fact that proton or neutron numbers 2, 8, 10, 20, and 50 are associated with particularly stable and abundant nuclear species. The $2s$ and $3p$ levels must be omitted to form the shell at 50, although the rectangular well potential would place both lower than $5g$.

The apparent upward drift of the $2s$ and $3p$ levels with increasing N and Z may be accepted as a working hypothesis and utilized in the interpretation of the spins, magnetic moments, quadrupole moments, radioactive transitions, and isomerism of nuclei containing one particle outside of closed shells or with one particle missing from a closed shell.[5]

A closed shell of 40 particles having the structure

$$(1s)^2\ (2p)^6\ (3d)^{10}\ (4f)^{14}\ (3p)^6\ (2s)^2$$

is suggested by the properties of odd nuclei, containing 37, 39, and 41 neutrons or protons. Accordingly, one infers that the $3p$ and $2s$ levels rise above $5g$ shortly after the closing of the "40" shell. If the spacing of $3p$, $2s$, and $5g$ levels is small at N or $Z=40$, the closed shell should not be marked by exceptional stability and, hence, should not be revealed by studies of stability and abundance. The evidence from isomerism for the proposed shell structure is summarized in Table I.

TABLE I. Correlation of isomerism with spin values predicted by the shell model.*

N or Z	Nucleus	Shell structure	Isomerism**	Spin: Shell model	Spin: Experimental**
37	$_{28}\mathrm{Ni}^{65}$	$\langle 3p\rangle^{-1}$	no	⟨1/2, 3/2⟩	——
37	$_{30}\mathrm{Zn}^{67}$	$\langle 3p\rangle^{-1}$	no	⟨1/2, 3/2⟩	5/2
37	$_{37}\mathrm{Rb}^{85}$	$\langle 3p\rangle^{-1}$	no	⟨1/2, 3/2⟩	5/2
37, 50	$_{37}\mathrm{Rb}^{87}$	$(3p)^{-1}$	no	1/2, 3/2	3/2
37	$_{37}\mathrm{Rb}^{89,91,97}$	$\langle 3p\rangle^{-1}$	no	⟨1/2, 3/2⟩	——
39	$_{30}\mathrm{Zn}^{69}$	$(2s)^{-1}$	yes	1/2	——
39	$_{32}\mathrm{Ge}^{71}$	$(2s)^{-1}$	yes	1/2	——
39	$_{39}\mathrm{Y}^{87}(B)$	$(2s)^{-1}$	yes	1/2	——
39, 50	$_{39}\mathrm{Y}^{89}$	$(2s)^{-1}$	no	1/2	(1/2)
39	$_{39}\mathrm{Y}^{91}(B)$	$(2s)^{-1}$	yes	1/2	——
39	$_{39}\mathrm{Y}^{95,97}$	$(2s)^{-1}$	no	1/2	——
41	$_{32}\mathrm{Ge}^{73}$	$(5g)'$	no	7/2, 9/2	——
41	$_{34}\mathrm{Se}^{75}$	$(5g)'$	no	7/2, 9/2	——
41, 50	$_{41}\mathrm{Cb}^{91}(B)$	$(5g)'$	no	7/2, 9/2	——
41	$_{41}\mathrm{Cb}^{93}$	$(5g)'$	no	7/2, 9/2	9/2
41	$_{41}\mathrm{Cb}^{95}(B)$	$(5g)'$	yes	7/2, 9/2	——
41	$_{41}\mathrm{Cb}^{97}(B)$	$(5g)'$	no	7/2, 9/2	——
49	$_{34}\mathrm{Se}^{83}$	$(5g)^{-1}$	yes	7/2, 9/2	——
49	$_{36}\mathrm{Kr}^{85}$	$(5g)^{-1}$	yes	7/2, 9/2	——
49, 38	$_{38}\mathrm{Sr}^{87}$	$(5g)^{-1}$	yes	7/2, 9/2	9/2
49, 40	$_{40}\mathrm{Zr}^{89}$	$(5g)^{-1}$	yes	7/2, 9/2	——
49	$_{49}\mathrm{In}^{111,117}$	$(5g)^{-1}$	no	7/2, 9/2	——
49	$_{49}\mathrm{In}^{113}$	$(5g)^{-1}$	yes	7/2, 9/2	9/2
49	$_{49}\mathrm{In}^{115}$	$(5g)^{-1}$	yes	7/2, 9/2	9/2
51	$_{36}\mathrm{Kr}^{87}$	$(4d)'$	no	3/2, 5/2	——
51, 38	$_{38}\mathrm{Sr}^{89}$	$(4d)'$	no	3/2, 5/2	——
51, 40	$_{40}\mathrm{Zr}^{91}$	$(4d)'$	no	3/2, 5/2	——
51	$_{42}\mathrm{Mo}^{93}(C)$	$(4d)'$	yes	3/2, 5/2	——
51	$_{51}\mathrm{Sb}^{121}$	$(4d)'$	no	3/2, 5/2	5/2
51	$_{51}\mathrm{Sb}^{123}$	$(4d)'$	no	3/2, 5/2	7/2
51	$_{51}\mathrm{Sb}^{125}(B)$	$(4d)'$	no	3/2, 5/2	——
51	$_{51}\mathrm{Sb}^{127,129}$	$(4d)'$	no	3/2, 5/2	——
51, 82	$_{51}\mathrm{Sb}^{133}$	$(4d)'$	no	3/2, 5/2	——

* ⟨ ⟩—shell model unreliable; (1/2)—experimental determination uncertain; (B)—Z certain, N probable; (C)—Z certain, N limited to a few possibilities.

** Experimental information from charts by E. H. Segrè (revised April 1948) and G. Friedlander and M. L. Perlman (revised to April 1948).

TABLE II. Correlation of isomerism with odd N and Z in even-odd and odd-even nuclei.*

N or Z	Number of known stable and radioactive odd nuclei	Number of cases of isomerism
29	7–8	1(A), 1(B)
31, 33, 35, 37	22–26	0(?)
39	6	2(A), 2(B)
41	4–6	1(A)
43	3–5	3(A), 1(B)
45	3	2(A)
47	5	4(A)
49	9	6(A)
51, 53, 55, 57, 59, 61	37–47	0(?)
63	5–6	1(A)

* (A)—Z and N certain; (B)—Z certain; N probable.

The spin values listed in the table are based on the assumption that all the angular momentum is supplied by the odd particle or hole. Considering the evidence from isotopes and isotones differing by two mass units, one expects the assumption to hold in 4 out of 5 cases; in particular, it should hold when only one particle is missing from closed shells or when only one particle is present outside of closed shells. When the assumption fails, the computed spin is not likely to be off by more than one unit.

The numbers 37, 39, 41, 49, and 51 appearing in column 1 represent values of N or Z at the beginning and end of closed shells for which predictions of spin are possible. Known stable and radioactive nuclei are listed in column 2. The incomplete structure symbols in column 3 denote the level occupied by the odd particle or hole. "Yes" in the 4th column means that the nucleus in question possesses an isomeric state. The computed spin appears in the 5th column.

The shell model may fail at N or $Z=37$ because of the large number of low configurations having even parity ($2s$, $5g$, and $4d$ orbits all even) while there is only one configuration, $(3p)^{-1}$, of odd parity. It, therefore, is likely that configuration interaction produces a ground state of even parity and unpredictable spin (in this connection note that $_{37}\mathrm{Rb}^{85}$ and $_{30}\mathrm{Zn}^{67}$ have spin 5/2). In one case, $_{37}\mathrm{Rb}^{87}$, the association of the very stable closed shell at $N=50$ with $Z=37$ greatly reduces the number of low even configurations, thus, perhaps, accounting for the success of the shell model in predicting the spin and magnetic moment of $_{37}\mathrm{Rb}^{87}$ (spin 3/2, moment 2.75, a predominantly $^2P_{3/2}$ state).

The occurrence of many examples of isomerism when the predicted spin values are 1/2, and 7/2, 9/2 provides strong support for the proposed shell structure. Equally important is the fact that isomerism is rare (one doubtful example) when the predicted spin is 3/2 or 5/2. Table II exhibits the distribution of isomerism against the odd number of the pair N, Z. From the large number of isomeric nuclei at N or $Z=39$ one may infer that the two closely spaced configurations

$$(1s)^2\ (2p)^6\ (3d)^{10}\ (4f)^{14}\ (2p)^6\ (2s)^1$$
$$(1s)^2\ (2p)^6\ (3d)^{10}\ (4f)^{14}\ (2p)^6\ (5g)^1,$$

assisted by configuration interaction, determine the ground state and the first excited state of such systems. An occasional inversion of the two levels (spin 7/2 or 9/2 in the ground state) is not unlikely and would not prejudice the occurrence of isomerism.

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* This research was supported in part by U. S. Navy Contract N6ORI 117.

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Comparison of Atmospheric Methane Content above Flagstaff, Arizona, and Columbus, Ohio

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A CONTINUOUS, high resolution map of the infra-red solar spectrum, 2 microns to 14 microns, was obtained by the author in 1940, at the Lowell Observatory. The experiment was performed with a 2400-line-per-inch grating in a Pfund type, automatically recording spectrometer of aperture f:5 and focal length of 30 inches. That portion of the map between 7 microns and 14 microns has been published, with a reference to the unpublished segment between 2 microns and 7 microns.[1]

Early in 1948, M. Migeotte[2] identified absorption lines of the methane fundamentals ν_3 (3.3 microns) in solar spectra recorded at Columbus, Ohio, and ν_4 (7.7 microns) in the solar spectrum map recorded at Flagstaff.

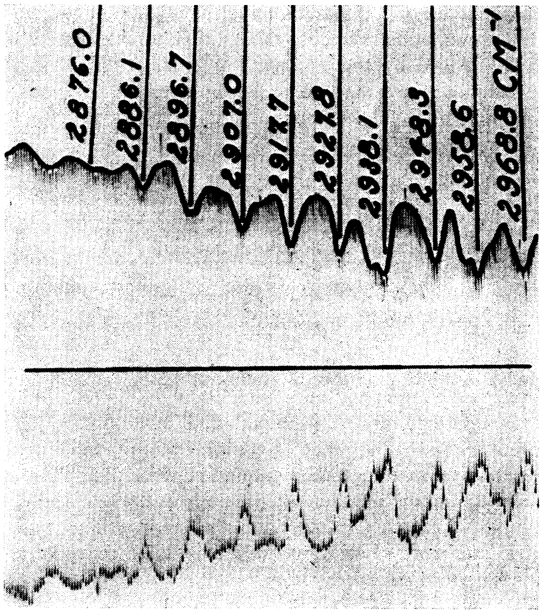

FIG. 1. The grating solar spectrum near 3.4 microns, observed at Flagstaff, Arizona, on the morning of October 28, 1940. It shows ten lines in the P-branch of ν_3 of methane (CH_4). Reproduction of the original record of galvanometer deflection *versus* grating position.

The fundamental ν_3 (3.3 microns) is clearly resolved in the unpublished portion of the Flagstaff map and it serves importantly in drawing a comparison between the amounts of methane above Flagstaff and Columbus. ν_3 is far superior to ν_4 for the purposes of such a comparison, because of the much heavier absorption by water vapor at 7.7 microns and the far greater water vapor content of the atmosphere over Columbus relative to Flagstaff.

Figure 1 shows ten lines in the P-branch of ν_3 of methane as observed in the solar spectrum at Flagstaff on the morning of October 28, 1940. The detailed agreement between this curve and the one obtained by Migeotte[2] is remarkable. The central intensities of the latter do not exceed those of the former by as much as one might have expected in view of the fact that the work at Columbus was done with a 7200-line-per-inch grating. It is significant that the fractional energy absorption is closely the same for the two spectra, thus indicating a widespread and uniform distribution of methane above the earth.

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The Isotopic Constitution of Ytterbium

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THE isotopic constitution of ytterbium was first investigated by Aston.[1] Using anode rays from ytterbium bromide, he observed isotopes at masses 171, 172, 173, 174, and 176 and estimated their abundances photometrically. Later Dempster[2] using his Tesla spark ion source found isotopes at masses 168 and 170. He gave estimates for the abundances of these two isotopes but not for the abundances of the other isotopes. Dempster's figures for 168 and 170 and Aston's values for the other isotopes, corrected for the presence of the lighter isotopes, are given in the first row of Table I. In 1941 Wahl[3] investigated ytterbium using careful photometric mass spectrographic methods. His results are given in the second row of Table I. He did not observe the 168 isotope and so he assumed Dempster's value in his calculation of percentages. He did not quote limits of error but he did give his mean mass, uncorrected for packing fraction, as 173.068±0.006. This would indicate that he believed his abundance ratios good to 1 percent.

Because of the historical unreliability of photometrically measured isotopic abundances, an electrometric determination seemed desirable. The ion source used was a tungsten surface ionization filament similar to that pre-

TABLE I. Isotopic abundances (percent) of the ytterbium isotopes.

Investigator	168	170	171	172	173	174	176
Aston and Dempster	0.06	2	9	23	17	37	12
Wahl		4.21	14.26	21.49	17.02	29.58	13.38
Authors	0.140 ±0.002	3.034 ±0.030	14.34 ±0.14	21.88 ±0.22	16.18 ±0.16	31.77 ±0.32	12.65 ±0.13