$E=0.476$ mc² there is no longer a singly scattered beam; the solution has the appearance of a wave running across as the energy decreases. Not all the departure from isotropy at these lower energies is due to the beam which is scattered twice—there is still a slight "wave" in existence when the second scattered beam is eliminated. This is largely due to photons which are scattered every time except once through angles close to 0° or to 180° and thus have some remembrance of their original direction.

The solution in the case of lead has the same general features, except that the low orders of scattering are much more important, due to the increased competition which pair production and photoelectric effect give to Compton scattering. Also, instead of a build-up in the total density of photons at lower energies, there is a sharp decrease, due to photoelectric effect.

A more detailed account of this work will appear in the Journal of Research of the National Bureau of Standards.

We should like to thank Dr. U. Fano for suggesting this problem and for many valuable discussions during the course of the work.

* Work supported by an ONR grant.
[1] See e.g. M. Verde and G. C. Wick, Phys. Rev. 71, 852 (1947).
[2] P. R. Karr and J. C. Lamkin, Phys. Rev. 76, 1843 (1949). This is paper III of the series; papers I and II are quoted there.

Radioactive Lanthanum 140

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THE single natural isotope of lanthanum of mass 139 should, on neutron capture in the pile, yield the radioactive isotope of mass 140. This emitter has been previously studied by many investigators.[1] Because of the difficulty of chemical purification, impurities are likely to be present. A highly purified sample separated by Dr. G. E. Boyd was kindly made available and irradiated in the Oak Ridge pile.

This specimen shows a remarkably pure decay through eight octaves with a half-life of 41.4 hours. In photographic beta-spectrometers, many electron conversion lines are observed, about 16 in all, with energies less than 500 kev. These are shown in Table I, together with their proposed interpretation and the values of the resultant probable 12 gamma-rays. The $K-L$ differences where observed are characteristic of cerium, indicating that gamma-emission follows the loss of a beta-particle from the lanthanum nucleus.
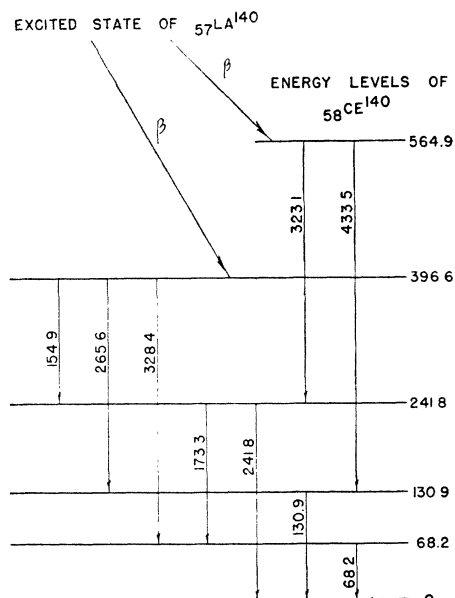
EXCITED STATE OF $_{57}$LA^{140}

FIG. 1. A possible level scheme associated with $_{57}$La^{140}.

The observed gamma-rays may be fitted into a level scheme as shown in Fig. 1. The sums of all possible combinations agree as expected to within about 0.2 kev. The gamma-rays observed at 109.1 and 487.1 kev do not, however, fit into the level diagram. The only positions they could occupy and remain consistent with the scheme would be either above or below the group of levels shown in Fig. 1. The electron line at 483.2 kev may also be interpreted as a K line, in which case the gamma-energy is 523.5 kev. This value happens to be almost exactly the sum of three observed gamma-rays of 109.1, 173.3, and 241.8 kev. The presence of these two anomalies indicates that some ultimate revision of the proposed level scheme may be necessary, to include also the higher energy gamma-rays.

TABLE I. Conversion electron and probable gamma-ray energies.

Electron energy	Probable identification	Energy total	Gamma-energy
27.9 kev	K_1	68.2 kev	68.2 kev
68.7	K_2	109.0	109.1
90.7	K_3	131.0	130.9
103.0	L_2	109.2	
107.9	M_2	109.3	
114.6	K_4	154.9	154.9
124.5	L_3	130.7	
133.0	K_5	173.3	173.3
201.5	K_6	241.8	241.8
225.3	K_7	265.6	265.6
282.8	K_8	323.1	323.1
288.2	K_9	328.5	328.4
322.0	L_9	328.2	
393.2	K_{10}	433.5	433.5
446.8	K_{11}	487.1	487.1
483.2	K_{12} or	523.5	523.5
	L_{11}	489.4	

The beta-emission had been previously shown to be complex. Higher energy gamma-radiation is present which by absorption in lead had an energy of 1.88 Mev. The long-lived 140-day activity previously reported does not appear to be present in this specimen.

This investigation was made possible by the joint support of the ONR and the AEC.

[1] Weimar, Pool, and Kurbatov, Phys. Rev. 63, 67 (1943); R. Osborne and M. Peacock, Phys. Rev. 69, 679 (1946); C. Mandeville and M. Scherb, Phys. Rev. 73, 1434 (1948); Mitchell, Langer, and Brown, Phys. Rev. 71, 140 (1947); Cork, Shreffler, and Fowler, Phys. Rev. 74, 240 (1948).

Ferroelectricity in the Ilmenite Structure

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SINGLE crystals of LiTaO₃ and LiCbO₃ have been found to be strongly ferroelectric as is indicated by the existence of a saturation polarization in their dielectric hysteresis loop. The saturation value increases rapidly with temperature as shown in Fig. 1. LiCbO₃ exhibits a similar behavior at higher temperatures.
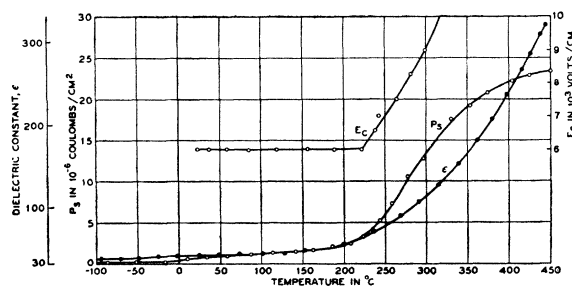

FIG. 1. Saturation values in a single crystal of LiTaO₃ as a function of temperature.

LiCbO₃, with which LiTaO₃ is isomorphous, was described by Zachariasen[1] as belonging to the ilmenite structure, which is centro-symmetric. The existence of a spontaneous polarization, however, indicates the absence of a center of symmetry. A further

proof hereof is that the crystals are piezoelectric, which effect cannot occur if there is a center of symmetry.

In the perovskite system and in WO_3 it appeared that ferroelectricity occurred when the metal oxygen octahedra fulfilled certain conditions for size and electronic configuration.[2,3] A comparison between metatitanates, columbates and tantalates showed that the ferroelectric behavior was much more sensitive to a change of lattice constant in the case of Ti than in that of Cb or Ta, because all metacolumbates or tantalates of the perovskite system were ferroelectric. This fact now seems to extend even to a quite different crystal system such as the ilmenite structure. There the octahedra do not share corners with each other as in perovskite, but edges and faces, and the crystal symmetry is lower. It might be added that none of the ferroelectric crystals mentioned fits into the scheme of adding over-all polarizabilities, which was first suggested by Jonkers and van Santen[4] and then extended to non-ferroelectric crystals by Roberts.[5]

Any investigation of $LiTaO_3$ and $LiCbO_3$ has to be carried out with single crystals because ceramics show hardly any effect. The reason for this is the rather low crystal symmetry, compared to the perovskite system; another consequence of the low symmetry is the absence of domains.

We are very grateful to Dr. E. A. Wood for doing all the x-ray work.

[1] W. H. Zachariasen, Skr. Norske Vid.-Akad., Oslo, Mat. Naturv. No. 4 (1928).
[2] Matthias, Wood, and Holden, Phys. Rev. 75, 1771 (1949).
[3] B. T. Matthias, Phys. Rev. 76, 430 (1949).
[4] G. H. Jonkers and J. H. van Santen, Chem. Weekbl. 43, 672 (1947).
[5] S. Roberts, Phys. Rev. 76, 1215 (1949).

Optical Absorption in Barium Oxide Films

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November 3, 1949

MEASUREMENTS of the optical absorption of small single crystals of barium oxide[1] indicated that any information concerning structure in the absorption band could only be obtained from the study of thin films. Absorption in such films has recently been measured as part of the study of photo-conductivity and optical properties of BaO.
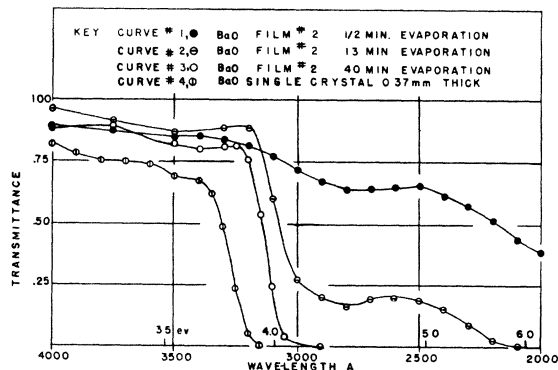

FIG. 1. Transmittance as a function of wave-length for a BaO film at different thicknesses and for a BaO single crystal.

BaO films from 2×10^{-5} cm to 4×10^{-5} cm thick were evaporated from a coated platinum filament onto a quartz plate. Evaporation and subsequent measurements were carried out in the same vacuum system. The filament was initially coated with c.p. $BaCO_3$ in nitrocellulose and amyl acetate. This was converted to BaO and outgassed before the quartz plate was moved into position to receive the film. After the absorption measurements were completed, the quartz plate was removed from the vacuum and the film was weighed as $Ba(OH)_2$. The thickness of the original film was then obtained by assuming a density of 5.7 for BaO. Film thicknesses for intermediate evaporation times
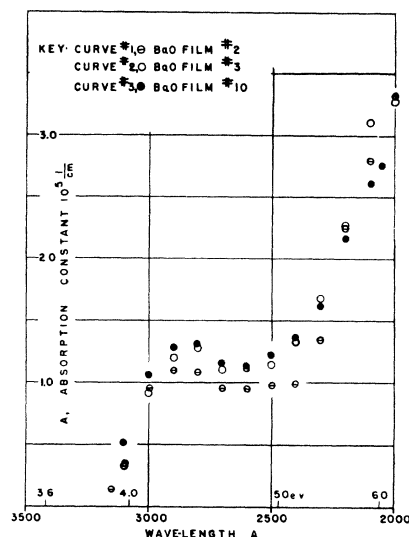

FIG. 2. Absorption constant as a function of wave-length for three different BaO films.

were obtained by using the absorption data to interpolate between zero thickness and final thickness. Film thickness was nearly proportional to evaporation time for all films studied. The transmission of the film was measured by moving the quartz plate so that the light beam passed through the quartz alone and then
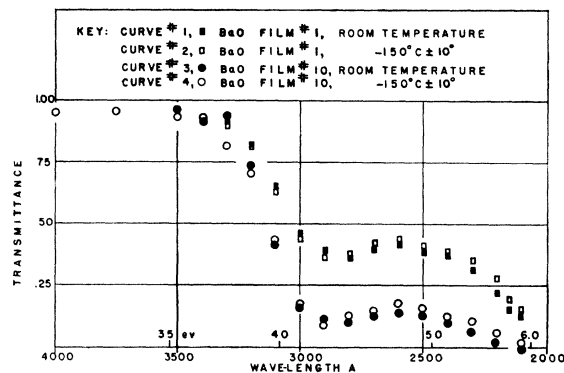

FIG. 3. Transmittance as a function of wave-length for two BaO films showing temperature dependence.

through quartz plus the BaO film. A Hanovia hydrogen discharge tube and a Bausch & Lomb quartz ultraviolet monochromator provided fairly continuous monochromatic radiation in the spectral region from 4000A to 2000A. At several wave-lengths, a high pressure Hg arc was used to study the effect of changing light intensity on the absorption constant. The detector used was an RCA 1P28 photo-multiplier tube.

Curves 1, 2, and 3 of Fig. 1 show the transmittance of a BaO film as a function of wave-length for three different thicknesses. The crossing over of transmission curves in the region from 3200A to 4000A as the film is built up has been observed in all of the films studied and is probably due to interference effects. Curve 4 of Fig. 1 shows the transmittance of a 0.37-mm single crystal of BaO. The agreement between transmission data for evaporated films and single crystals indicates that the BaO film is deposited in the form of small crystals of the same form as the larger single crystals studied. Figure 2 shows the absorption constant A as a function of wave-length for three different films. A is defined by the expression $T=\exp(-Ax)$ where T is the transmittance and x the thickness of the film. A has been calculated from the transmission curves without correcting for reflection and interference