TABLE I. Theoretical lifetimes and conversion coefficients.

	$\frac{N_{e_K}}{N_\gamma}$	$\frac{N_{e_L}}{N_\gamma}$	$\tau^{a,b}$	$\eta_{K_2}{}^b$	$\frac{N_\gamma{}^b}{N_e+N_\gamma}$
Electric dipole	3	0.41	9.6×10^{-13} sec.	0.68	0.23
Magnetic dipole	6.8	0.63	1.3×10^{-6} sec.	0.80	0.12
Electric quadrupole	17	36	2.0×10^{-7} sec.	0.31	0.018
Present work			$<5\times10^{-8}$ sec.	0.6–0.8	0.15–0.20

[a] Expected lifetime of excited state, corrected for internal conversion.
[b] For the calculation of these values conversion for shells higher than the L-shell has been neglected.

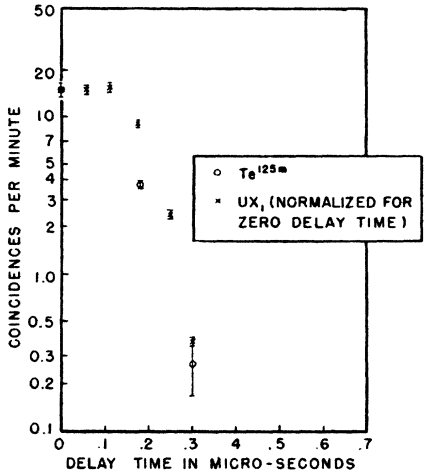

FIG. 1. Delayed photon-photon coincidences from Te^{125m}.

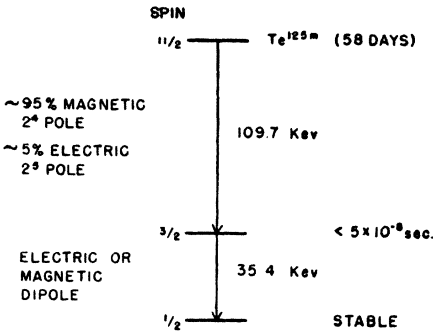

FIG. 2. Proposed decay scheme of Te^{125m}.

Values for ηK_2 between 0.6 and 0.8 and for γ_2 between 0.15 and 0.20 are best compatible with all the data.

3. An attempt was made to measure the lifetime of the 35.4 kev transition. Figure 1 shows the number of photon-photon coincidences, consisting of the coincidences between K x-rays of the 109.3 kev transition and either K x-rays or the unconverted gamma-rays of the 35.4 kev transition, as a function of the delay between two Eck and Krebs counters. The technique used was the same as that described by Bittencourt and Goldhaber.[6] For comparison a "zero-delay" curve obtained by shooting UX_1 beta-rays through both counters is given. No noticeable delay was found, and we can estimate that the half-life is $<5\times10^{-8}$ seconds.

Table I shows the theoretical lifetimes and conversion coefficients[7] to be expected for the 35.4 kev transition, with either an electric dipole or magnetic dipole transition or an electric quadrupole transition. In the last line the experimental results are given.

It is seen that the experimental data are compatible with the first two cases, although the lifetime appears to be somewhat short for a magnetic dipole transition. However, since theoretical lifetimes are uncertain by a factor of the order of 100 this is not sufficient to rule out the possibility of a magnetic dipole transition.[8] The assumption of an electric quadrupole transition, on the other hand, seems to be definitely in disagreement with our data.

The spin of Te^{125} in its ground state has been recently measured by Mr. Fowles[9] in Professor Jenkins' Laboratory at Berkeley, and found to be $\frac{1}{2}$. This permits us to propose the following decay scheme (Fig. 2), which is definitive as far as spin assignments are concerned, but leaves the parity change for the second transition still indefinite.

* Supported jointly by ONR and AEC.
[1] Hill, Scharff-Goldhaber, and Friedlander, Phys. Rev. **75**, 324 (1949).
[2] R. D. Hill, Phys. Rev. **76**, 186 (1949).
[3] Friedlander, Goldhaber, and Scharff-Goldhaber, Phys. Rev. **74**, 981 (1948).
[4] R. D. O'Neal and G. Scharff-Goldhaber, Phys. Rev. **62**, 83 (1942).
[5] R. Katz, unpublished.
[6] P. T. Bittencourt and M. Goldhaber, Phys. Rev. **70**, 780 (1946).
[7] M. H. Hebb and E. Nelson, Phys. Rev. **58**, 486 (1940); S. D. Drell, Phys. Rev. **75**, 132 (1949); P. Axel and S. M. Dancoff, in course of publication.
[8] It may be pointed out here that present ideas on the nuclear shell model seem to favor a magnetic dipole transition in this case (see R. D. Hill's discussion for Te^{122}, reference 2).
[9] Private communication from Professor A. C. Helmholz.

On the Energy Band Structure of Insulators

G. H. WANNIER
Bell Telephone Laboratories, Murray Hill, New Jersey
June 16, 1949

IT is a well-known fact that an insulator may become an n- or p-type semiconductor upon the introduction of a sufficient number of impurities. These "donors" and "acceptors" are known to stabilize the location of the Fermi level close to the conduction band or the uppermost filled band. Discussions of these phenomena often imply that the Fermi level of a good insulator is located in the center of the forbidden band. This letter wants to point out that this last possibility is rather remote and that an attempt to realize it is more likely to lead to uncontrolled spatial oscillations of the Fermi level between its n and p positions.

If we take, for instance, the case of diamond, we find that the product of electron and hole densities equals 10^{-8} cm^{-6}. Thus the electrons and holes which tend to stabilize the Fermi level in the center of the forbidden band are far too small in number to have any influence. Their role is restricted entirely to preventing the entry of the Fermi level into the filled or empty band. Within the forbidden region itself the location of the level becomes thus entirely dependent on the crystal imperfections and becomes subject to the fluctuations which they undergo. If we assume, for instance, that there exists, at a certain place, a number of low lying acceptors (as might be found in the neighborhood of a crack) then we will find that these acceptors will tend to attract negative charge. This negative charge cannot be supplied by the filled band unless the Fermi level approaches the latter closely. Thus the region acquires a net negative charge whose field lines must end up on the same donor impurity in the neighborhood. The potential which the negative region thus acquires is about equal to

$$V=-\frac{ne}{\epsilon a}+\frac{ne}{\epsilon d}$$

where n is the number of negative charges making up the imperfection, a the linear dimension of the region and d the mean distance to compensating positive charges. It is reasonable to assume $d\sim10^{-5}$, $a\sim10^{-8}$ and n a few units. The voltage thus obtained is considerably larger than 3.5 volts. The actual voltage drop will of course stop at the latter figure or earlier either because the

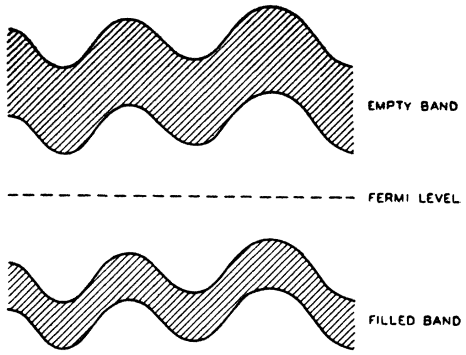

FIG. 1.

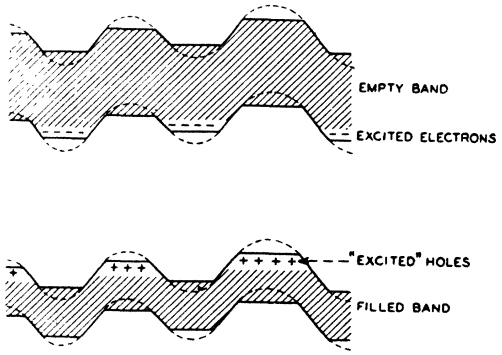

FIG. 2.

Fermi level has dropped below the acceptor levels or because it has approached the filled band sufficiently closely to form localized holes. In either case the Fermi level has been upset by the imperfection. The disturbance calculated here is localized, but this will not be the case for surface type imperfections which are suggested by some experiments.[1]

We arrive thus at a picture of an insulator as having a band structure whose height varies somewhat like a roller coaster (Fig. 1). Now let such material be flooded with electron hole pairs either by a rise in the temperature or by light or electron bombardment. The electron hole pairs produced will flow into the regions of unbalanced charge and gradually straighten out the band structure (Fig. 2). The conduction properties of the material will thus improve beyond what can be explained as primary photo-current. We have therefore a reasoning which offers a possibility of explaining the secondary photo-current observed in many insulators.[2]

The writer is indebted to Dr. P. W. Anderson for some clarifying discussions on the subject.

[1] Rose, Weimer, and Forgue, Phys. Rev. **76**, 179 (1949).
[2] Gudden and Pohl, Zeits. f. Physik. **6**, 248 (1921). F. C. Nix, Rev. Mod. Phys. **4**, 742 (1932). N. F. Mott and R. W. Gurney, Electronic Properties in Ionic Crystals, p. 185.

Computed Binding Energies of Some Light Nuclei

J. SAMUEL SMART
Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland
June 13, 1949

A QUANTITATIVE theory of the mass defects of light nuclei was first proposed by Wigner.[1] Shortly thereafter, Barkas[2] employed Wigner's theory to compute the atomic masses of about 150 nuclear species with A 50. His method was to determine certain functions empirically from experimental data on a few nuclei, and then to use these functions in computing masses for the remainder. In this way, good agreements with experimental values were obtained for both stable and unstable nuclei.

Since the publication of Barkas' paper, some of the accepted mass values used by him in evaluating the binding energy functions have changed considerably. In particular, the experimental masses of the sulfur isotopes have been revised downward about 1.3 mMU, due to the accurate measurements of Okuda and Ogata.[3] For this reason, it is of interest to redetermine the main binding energy function, Eo, using experimental values listed in Bethe's text.[4] The results are shown in Fig. 1. In order to depict more clearly the variations in binding energy with A, the quantity $-Eo-8A$ is plotted as ordinate. To avoid using any more empirical constants than necessary in determining Eo, only points obtained from the experimental mass values of the $A=4n$, (000), nuclei are plotted. For these nuclear species, the atomic mass may be written

$$M(\text{mMU})=1008.5A+\frac{125}{A}+Eo. \qquad (1)$$

The resulting curve indicates that closed shells occur at masses 20 and 32. The existence of a closed shell at Ne^{20} has been suggested by Wigner, Barkas, and others, but the evidence for S^{32} has apparently not been reported before. However, M. G. Mayer[5] has recently suggested that the experimental facts concerning shell structure in heavy nuclei can be explained better by jj-coupling than by Russell-Saunders coupling. If one assumes that the $2s$ level in nuclei lies below the $3d$, then the jj-coupling theory predicts closed shells for 10 and 16 neutrons and protons, or for Ne^{20}

TABLE I. Comparison of calculated and experimental mass values.

Nucleus	Experimental	Calculated (corr.)
O^{19}	19.0093	19.0102
O^{20}		20.0125
F^{22}		22.0103
Na^{26}		25.9998
Al^{30}		29.9903
P^{34}	33.9826	33.9829
Cl^{38}	37.979	37.9777

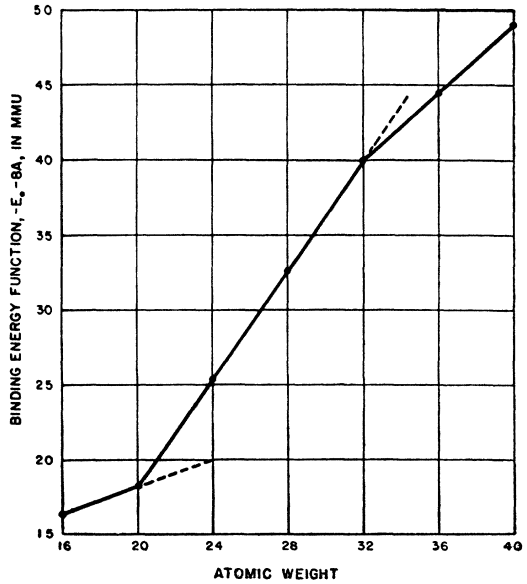

FIG. 1. The binding energy function, $-Eo-8A$, plotted as a function of A for the $n\alpha$-nuclei.