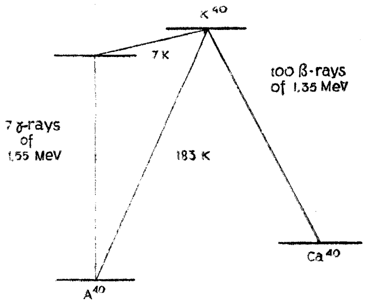

FIG. 1. Disintegration scheme for the decay of K^{40} with relative branching intensities.

the value of Běhounek. However, they cite this latter value erroneously as 1.3×10^{-11}. This fact renders it extremely likely that their own value also was taken too low by a factor ten.

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Significance of the Radioactivity of Potassium in Geophysics

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August 11, 1947

CONSIDERING recent data on the radioactivity of K^{40}, such as greater gamma-ray intensity,[1] higher beta-ray energy,[2] as well as a shorter half-value period[3] than previously admitted, some interesting consequences in geophysics are apparent to us. We should like to point out two of these consequences, the first concerning the ionization balance of the atmosphere, the second the radioactive heat production of K^{40} in rocks and, more generally, in the earth's crust. Recent measurements by V. F. Hess[4] with a thick-walled ionization chamber disclose a large discrepancy between the value of the ionization in air, produced by the gamma-rays of the different radioactive substances contained in Quincy granite, and that computed from the concentrations of these substances known by the measurements of Evans and Goodman.[5] Assuming, according to Gray and Tarrant,[6] that one gram of potassium is equivalent in its gamma-ray effect to 1.6×10^{-11} g of radium, Hess computes the value of 0.50 I (where I is a symbol for "ion pairs per cm^3 per sec.") for the ionization of the air due to the potassium contained in Quincy granite. Uranium and thorium will produce in the same case 0.64 I and 0.92 I, respectively. The total of 2.06 I, computed for a point above an infinite layer of rock, compares with the measured value of 5.18 I obtained on a ground of crushed granite. With the use of our recent value[1] for the gamma-ray intensity of K^{40}, for potassium alone we obtain 2.6 I, which gives a total of 4.16±1.25 I, in satisfactory agreement with the experimental result. Thus, in the case of granites, the gamma-rays of potassium play a more important part in the ionization of the air than those of the uranium and thorium families together.

For the radioactive-heat production of potassium, Evans and Goodman[5] compute the value of $(5\pm2)\times10^{-6}$ cal. per year per gram. If we admit $(7\pm1)\times10^{8}$ years for the period of the beta-decay of K^{40}, we find 52.5 beta-rays per second for one gram of potassium. Their average energy[2] being 0.49±0.06 Mev we compute for the beta-rays alone a heat production of $3.15\times10^{7}\times52.5\times0.49\times0.382\times10^{-13}=(31\pm6)\times10^{-6}$ cal per year per gram of potassium (1 year$=3.15\times10^{7}$ sec.). For 3.6±0.8 gamma-quanta[1] of 1.55±0.05 Mev, the heat production amounts to $3.15\times10^{7}\times3.6\times1.55\times0.382\times10^{-13}=(7\pm2)\times10^{-6}$ cal. per year per gram of potassium. We thus arrive at a total heat output of $(38\pm7)\times10^{-6}$ cal. per year per gram of potassium. In the case of acidic igneous rocks, Evans and Goodman[5] compute, for average uranium, thorium, and potassium contents, the respective values of $(2.2\pm0.2)\times10^{-6}$, $(2.6\pm0.4)\times10^{-6}$, and $(0.14\pm0.06)\times10^{-6}$ cal per year per gram of rock. We obtain in the same case for potassium alone $(1.1\pm0.2)\times10^{-6}$ cal per year per gram of rock. This is about 20 percent of the total heat production in acidic igneous rocks. Much more important must have been the role played by potassium in the early history of the earth. Considering the total period of K^{40}, only $(2.4\pm0.5)\times10^{8}$ years[3] as a result of its dual decay, it is easy to see that 2.4×10^{9} years ago, for example, a time which corresponds to 10 periods of K^{40} and leads us back to the beginning of the earth's history, $2^{10}=1024$ times more K^{40} was present than today. The heat produced by K^{40} alone was about 200 times that generated at present by all the radioactive elements in the earth together. Of course, the heat output due to uranium and thorium then was also larger than now, but the difference did not exceed 50 percent of the present value. The tremendous source of energy, constituted by the active isotope of potassium, was diminishing continuously, but even 1.2×10^{9} years ago was still about 6 times larger than the present disintegration energy of all radioactive elements in the earth's crust.

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Excess-Defect Semiconductor Contacts

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August 22, 1947

TWO recent papers[1,2] have dealt with the theoretical aspects of silicon-germanium rectifiers. Impurity centers giving rise to both excess and defect conductivity are shown to exist with corresponding energy levels only

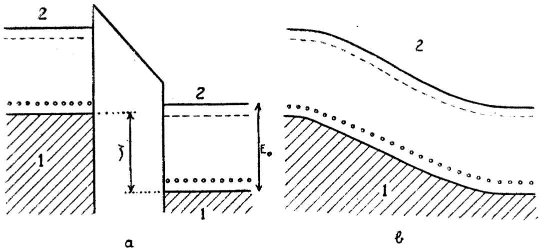

FIG. 1. Potential barriers at the contact between excess and defect semiconductors.

slightly removed from the ground or conduction bands. It may be of interest to note that lead sulfide shows an analogous distribution of levels, the metallic centers being connected with excess lead and the electronegative centers with oxygen impurity. In the course of work on the photo-effects in lead sulfide[3] it was found at this establishment that a thin layer of the material could exhibit photo-voltaic and rectifying properties that are not associated with a contact with metallic electrodes.[4, 5] A theory of the contact between excess and defect semiconductors has been developed to account for these phenomena.[6] In particular, the case of the rectifying effect appears to be worth brief mention here.

Figure 1 gives the energy-level distribution at the boundary between regions of excess and defect conductivity. Case (a) corresponds to imperfect contact between, for example, two crystals, while case (b) would correspond to a continuous variation of impurity concentration. The width of the transition region in case (b) will be given by $(\epsilon\zeta/\pi Ne^2)^{\frac{1}{2}}$ where ϵ is the dielectric constant and ζ is the displacement of the levels. As long as the width of this region is comparable with the mean free path of the electrons (about 100A in lead sulfide), both cases can be subjected to the same mathematical treatment. In fact experimental results indicate a value of about 30A.

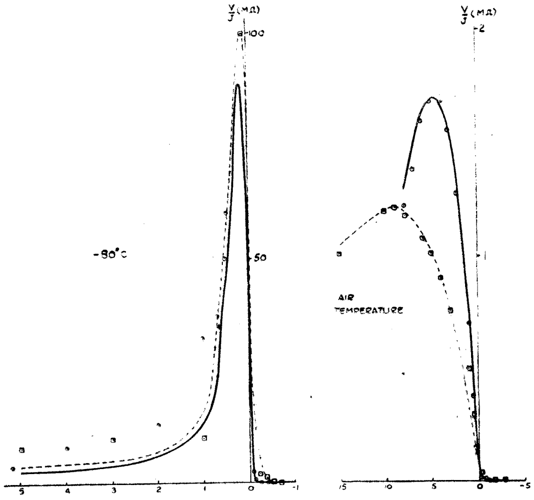

FIG. 2. Theoretical rectifying curves at air temperature and −80°C with experimental points added.

There are three contributions to the current across the boundary, the flow of electrons between conduction bands, J_{22}, between ground bands, J_{11}, and between the top of the ground band on the left of the boundary and the conduction band on the right, J_{12}. The latter component is present only when the applied voltage is sufficient for the appropriate bands to overlap. The following approximations can be obtained for the three components of current density:

$$J_{11}=(kTe^2/2\pi m)^{\frac{1}{2}}n_hD_{11}e^{-\zeta/kT}(1-e^{-eV/kT}),$$
$$J_{22}=(kTe^2/2\pi m)^{\frac{1}{2}}n_eD_{22}e^{-\zeta/kT}(1-e^{-eV/kT}),$$
$$J_{12}=(2\pi em/h^3)D_{12}(\zeta-E_0-eV)^2;\quad J_{12}=0\quad\text{for}\quad V<0.$$

n_h is the concentration of holes on the left of the boundary and n_e the concentration of electrons on the right. D_{11}, D_{22}, and D_{12} are the appropriate penetration probabilities.

Figure 2 shows the theoretical rectifying curves at room temperature and −80°C based on these formulae, together with experimental points. The broken curves apply to a cell containing five elements in series.

In view of the similarity in energy-level distribution between lead sulfide and silicon-germanium, it should be possible to apply the theory advanced for lead sulfide to the latter materials, and also, if sufficiently close contact could be made between N- and P-type samples of, say, silicon, to observe rectifying and photo-voltaic effects. The results briefly reported by Brattain[7] seem to indicate that such effects do occur.

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Determination of the Molecular Law of Force from Self-Diffusion Coefficients

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August 8, 1947

EXPERIMENTAL results have recently appeared for the room temperature self-diffusion coefficients of uranium hexafluoride[1] and methane.[2] In both cases, the authors relate the molecular-force law to the ratio $\rho D/\eta$, where ρ is the density, D the self-diffusion coefficient, and η the coefficient of viscosity. It seems desirable to point out that force laws based on values of the above ratio are likely to be incorrect.

If the molecules of a gas are considered to be point centers repelling with a force C/r^ν, where C and ν are constants and r is the separation distance between two molecules, $\rho D/\eta$ may be evaluated for certain values of ν from tables given by Chapman and Cowling.[3] For example, for $\nu=5$, $\rho D/\eta=1.551$; for $\nu=\infty$, $\rho D/\eta=1.204$; and for intermediate ν values, the ratio lies between the above