Similarly, Conwell and Weisskopf's Eq. (19) giving ρ_i, the resistivity due to scattering by ionized impurities may be written as

$$\rho_i = 1.9\times10^3\kappa^{-2}T^{\frac{1}{2}}\log\{1+3.22\times10^6\kappa^2T^2N_i^{-\frac{2}{3}}\}\ \text{ohm-cm.} \quad (10)$$

As an example for comparison of the two resistivities we have calculated ρ_n and ρ_i from Eqs. (9) and (10) for two non-degenerate silicon samples ($\kappa=13$) investigated by Pearson and Bardeen.[2] Table I shows that at temperatures below 100°K, ρ_n is larger than ρ_i for their sample 2 which has a relatively small degree of ionization. In the case of their sample B, however, ρ_i is in the whole range larger than ρ_n owing to very strong ionization of impurities obtaining already at low temperatures.

[1] E. Conwell and V. F. Weisskopf, Phys. Rev. **77**, 388 (1950).
[2] G. L. Pearson and J. Bardeen, Phys. Rev. **75**, 865 (1949).
[3] H. S. W. Massey and B. L. Moiseiwitsch, Phys. Rev. **78**, 180 (1950).
[4] N. F. Mott and H. S. W. Massey, *The Theory of Atomic Collisions* (Clarendon Press, Oxford, 1949), second edition, Chapter X.2.
[5] J. McDougall, Proc. Roy. Soc. **A139**, 549 (1932).

Electron Capture/Beta-Decay Ratio in K^{40}

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WHILE some of the hitherto published results[1–3] on the capture/beta-branching ratio of K^{40} indicate a value of the order of 2, others, deduced from determinations of the argon content in old potassium minerals, seem to yield a value[4–6] smaller than 0.10.

In view of the geophysical significance of this branching ratio,[7,8] it seemed to be of interest to obtain further evidence on its magnitude. The aim of the present letter is to report the preliminary result of experiments started here to that purpose about a year ago.

The intensity of the x-rays accompanying electron capture was measured by using a method of selective detection. An internal-source G-M counter was filled alternately with two gases, one possessing low, the other high efficiency for the K_α x-rays of argon (4.18A). If the counter response to particles and to gamma-rays be assumed to be the same for the two fillings, the difference of the counting rates obtained with them should be proportional to the intensity of the x-rays emitted by the source. The proportionality factor could be calculated fairly accurately by numerical integration over the entire counting volume. As filling gases argon and krypton were used at a total pressure of 20 cm of Hg each, together with ethyl alcohol at 1.5 cm. The absorption coefficient of krypton for x-rays of 4.18A, computed with the help of the tables of Jönsson,[9] turned out to be even higher than that of xenon. Repeated measurements made with the internal source covered with a 2.3-mg/cm² Al foil (to absorb the x-rays), and with external pure beta-sources, showed that for the same overvoltage the counting rates were identical within less than 0.2 percent. The computed mean values of the x-ray efficiency were 8 and 69 percent, respectively (counter diameter 1.34 cm, wire length 7.4 cm).

A layer of KF of about optimum thickness (3.44 mg/cm²) was obtained by evaporation in vacuum.[10] KF being hygroscopic precautions had to be taken to keep the layer dry. The active surface was of 5.92×0.49 cm² on each of the six Al holders which, placed side by side, formed the greatest part of the counter wall. This inside source was covered with a graphite layer of 0.5 mg/cm², which absorbed about eight percent of the x-rays, but appeared at the same time to improve greatly the stability of the counter operation.

Computation yielded a difference of 0.87 count/min., when assuming a branching ratio equal to one. This represents about two percent of the counting rate with argon filling (47 counts/min.). Actually, in three long runs, differences of 0.66±0.16, 0.73±0.13, and 0.43±0.11 count/min. were obtained, with the indicated standard deviations. Their mean value corresponds to a branching ratio of 0.67±0.20, which figure also accounts for electron capture from the L_I shell.[10]

The limits given include no systematic errors. Owing to the higher counter voltage with krypton, small spurious effects, if present, would tend to increase the observed rate difference. Therefore, the value of 0.67 should rather be considered as an upper limit of the branching ratio.

In the computation, 0.12±0.02 was assumed for the fluorescence yield in argon.[11] The branching ratio is given in terms of a specific activity of 26.8±1.2 beta-rays per second per gram of potassium.[12] The latter value, together with the recent result of 0.0119±0.0001 percent[13] for the isotropic abundance of K^{40}, yields (1.50±0.07) $\times10^9$ yr. for the half-life of the beta-decay, and, combined with the above value of the branching ratio, a lower limit of 0.9×10^9 yr. for the total half-life.

The present result indicates that the values of the branching ratio of references 1 to 3 are much too high. On the other hand, the values deduced from argon determinations[4–6] are smaller than the lower limit of the branching ratio. This limit is given by the gamma/beta-ratio, and its value, 0.127±0.012, seems to be fairly well established.[12]

A more detailed account will be given in a paper on the radioactivity of K^{40}, to be published in *Arkiv f. Fysik*.

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[1] F. C. Thompson and S. Rowlands, Nature **152**, 103 (1943).
[2] E. Bleuler and M. Gabriel, Helv. Phys. Acta **20**, 67 (1947). For corrected results see reference 12.
[3] L. H. Ahrens and R. D. Evans, Phys. Rev. **74**, 279 (1948).
[4] P. Harteck and H. Suess, Naturwiss. **34**, 214 (1947).
[5] H. E. Suess, Phys. Rev. **73**, 1209 (1948).
[6] L. T. Aldrich and A. O. Nier, Phys. Rev. **74**, 876 (1948).
[7] E. Gleditsch and T. Gráf, Phys. Rev. **72**, 641 (1947).
[8] T. Gráf, Phys. Rev. **74**, 831 (1948).
[9] E. Jönsson, Inaugural dissertation, Uppsala (1928). Also in M. Siegbahn, *Spektroskopie der Röntgenstrahlen* (Berlin, 1931), p. 470.
[10] The author is indebted to Mr. J. E. Flinta for help with the evaporation.
[11] M. E. Rose and J. L. Jackson, Phys. Rev. **76**, 1540 (1949).
[12] See, for example, A. H. Compton and S. K. Allison, *X-Rays in Theory and Experiment* (London, 1935), second edition, p. 477.
[13] T. Gráf, Phys. Rev. **74**, 831 (1948).
[14] A. O. Nier, Phys. Rev. **77**, 789 (1950).

A Note on 11.5-Day Tl^{202}

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THIS well-known[1] isotope has been re-examined to check on the possibility of negative beta-particle decay. The activity was produced by deuteron bombardment of mercury. The target consisted of dental amalgam (five parts commercial alloy to nine parts of mercury by weight) pounded into a channel in a water-cooled copper plate; no loss was apparent during several hours bombardment with a 10 μamp. deuteron beam. After dissolving the target in nitric acid, the solution was made $>6N$ in hydrochloric acid and the thallium extracted by ether. The ether was evaporated, holdback carriers added and the thallium re-extracted. No carrier was added. After four extraction cycles additional chemistry on a portion of the sample showed this to be pure thallium.

The aluminum and lead absorption curves taken on carrierless samples mounted on very thin backing showed electrons range 100 mg/cm² aluminum (0.35 Mev), L and K x-radiation and a gamma-ray of half-thickness 3.7 g/cm² lead (0.43 Mev). The ratios of the radiations corrected for absorption in counter windows, fluorescence yield, counting efficiency, etc. were 0.35 Mev e^-:L x-ray:K x-ray:0.43 Mev $\gamma=\sim0.1:\sim1.7:1:0.6$. Assuming that both L and K x-radiations are produced from conversion, then ~0.9 of the measured K x-radiation represents one

disintegration by K-electron capture. Since only 0.7 L rays are to be expected for each K shell electron removed it appears that the isotope decays almost equally by L and K orbital electron capture.

From a study on a 257° mirror focusing spectrometer, the γ-ray energy was determined as 0.427 Mev. No evidence for a continuous beta-spectrum could be determined either in absorptions or on the spectrometer, and decay by beta-emission is less than 1/200 that by orbital electron capture.

The decay of electrons and electromagnetic radiations followed separately through over eight periods gave a value of 11.50±0.05 days for the half-life after subtraction of background due to the 2.7-year Tl^{204}.

Note added in proof:—The limits in the value of the energy of the gamma-ray should read 0.435±0.005 Mev.

* This work was performed under the auspices of the AEC.

[1] G. T. Seaborg and I. Perlman, Rev. Mod. Phys. **20**, 585 (1948).

Induced Absorption Bands in MgO Crystals

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ABSORPTION bands induced in single crystals of MgO by pile radiation and by high voltage electrons have been reported by Boyd, Rich, and Avery.[1] In this note we wish to report, without attempt at interpretation, measurements we have made of the optical absorption bands induced by 40-kv x-rays. We have found three distinct induced bands as shown in Fig. 1,

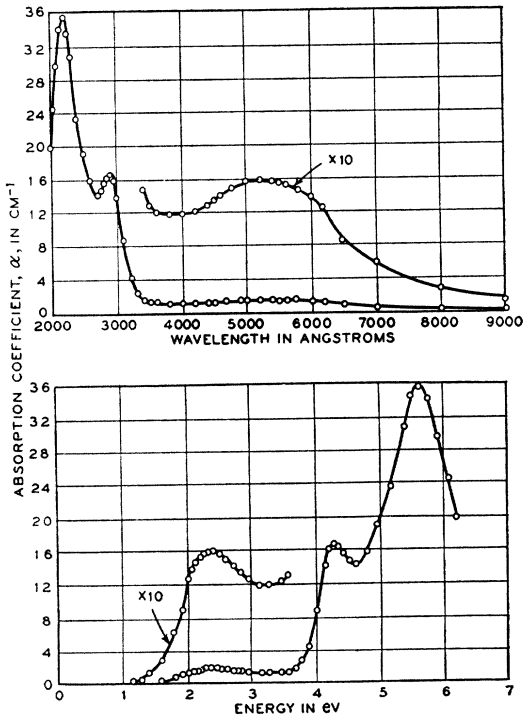

FIG. 1. Absorption bands induced in MgO crystals by 40-kv x-rays.

two in the ultraviolet with peak absorption at 2200A and 2850A and a weaker broad band at 5250A. The visible band gives the exposed crystal a weak purplish tinge. This coloration, produced by exposure to ultraviolet light, has been reported by Hibben.[2] The two ultraviolet bands maintain a constant ratio of intensity which is equal to 2.1 at the wave-lengths given above for the peak absorption. There appears to be no fixed ratio between the intensity of 5250A band and the ultraviolet bands.

The build-up of absorption with time of x-ray exposure is shown in Fig. 2. We were able to fit the data for the 5250A band to an

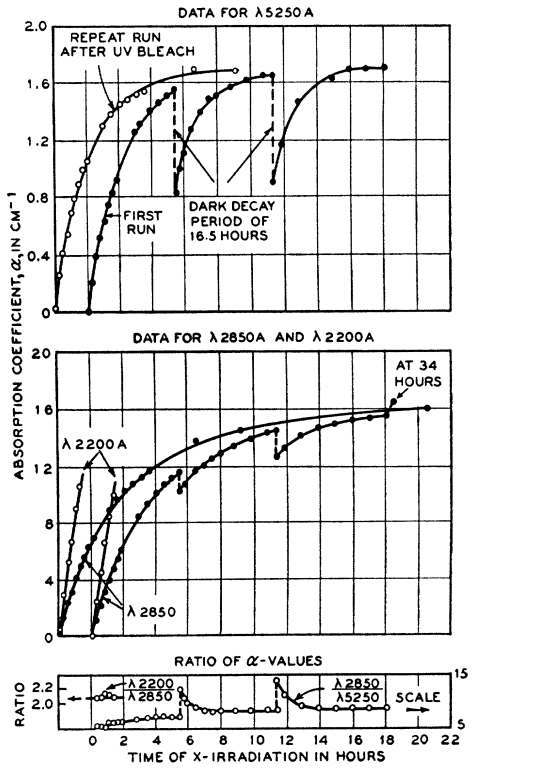

FIG. 2. The upper two plots give the induced absorption at the wave-lengths indicated as a function of the time of exposure of the crystal to x-rays. The lowest plot gives the ratio of the absorption coefficients for the wave-lengths indicated.

exponential formula of the type $\alpha=\alpha_0(1-e^{-kt})$, but the build-up of the ultraviolet bands proceeds slowly even after long exposure to x-rays, so no fit could be made to such a formula. The curves in Fig. 2 show also the decay in absorption which occurs when the crystals are kept at room temperature in the dark.

Light of wave-length anywhere in the range of the induced absorption bands will cause *all* bands to decrease in intensity. This experiment can be carried out most unambiguously when light in the wave-length range above 6900A is used. The data obtained in such an experiment are shown in Fig. 3. The absorption at 2850A and 5250A are seen to decrease with time of exposure, with, however, the absorption at 5250A decreasing more rapidly. The amount of decrease in the absorption coefficient, $\Delta\alpha$, at the two wave-lengths was found to be in constant ratio, thus suggesting that for each center giving rise to the 5250A absorption which is destroyed in the bleaching process, a constant number of centers giving rise to the 2850A absorption are destroyed. During the bleaching process the ratio of the intensities of the two ultraviolet bands remained constant.

When the induced absorption bands were measured on a crystal reduced in temperature to that of liquid nitrogen, only a very slight sharpening of the bands was found. The bleaching effects were qualitatively the same as at room temperature.

The x-rayed crystals were weakly luminescent. The light emitted could be detected by laying the crystal on a photographic film in the dark. The rate of decay of light emission seemed roughly comparable to the rate of change of the 5250A absorption band in the dark. The wave-length of emitted light was found, by interposing filters, to be in the range from 5000 to 6000A.