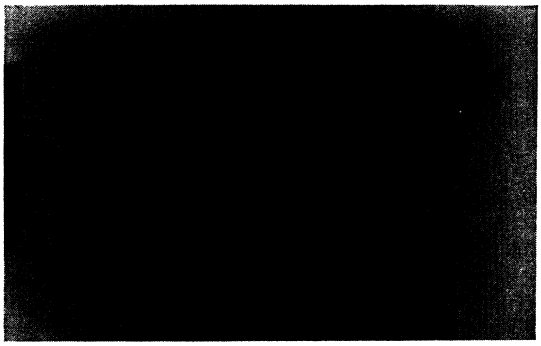

FIG. 2. Short spark shadowgraph of a supersonic jet taken under conditions similar to those of Fig. 1.

of sunlight with rectangular cross section $\frac{3}{8}$ inch wide and 3.5 inches long with the 3.5-inch dimension parallel to the stream. The plane of the beam passed through the axis of the stream. The photograph is a snapshot taken perpendicular to both the stream and incident light. For comparison, Fig. 2 shows a short spark shadowgraph[3] taken under approximately the same conditions. The thickening of the mixing boundary layer of the stream is shown as it extends into the atmosphere.

* This work was supported by Contract NOrd-7873 with the Bureau of Ordnance of the Navy.

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Gamma-Rays from the Reaction $H^1(n, \gamma)D^2$ and the Binding Energy of the Deuteron

R. E. BELL AND L. G. ELLIOTT
Chalk River Laboratories, National Research Council of Canada, Chalk River, Ontario
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THE γ-ray accompanying the capture of a neutron by a proton has been studied in a magnetic lens β-ray spectrometer by photoelectric conversion in a thin U radiator.

The γ-rays were produced in a slab of pure paraffin $5''\times25''\times25''$ placed in the thermal column of the Chalk River pile. A Pb collimator limited the γ-rays to a solid angle having the shape of a thin conical shell of 15° half-angle, converging to a small region outside the thermal column at the end of the β-ray spectrometer. A boron shield prevented the escape of neutrons from the thermal column. By placing a radiator in the γ-ray flux at the end of the β-ray spectrometer, secondary electrons ejected by the γ-rays could be studied. Figure 1 shows the momentum distribution of the photoelectrons and Compton recoil electrons ejected from a U radiator of 142 mg/cm². The counting rate taken with a spectrometer line width of 2.4 percent in momentum is plotted as a function of the focusing current in the lens coil, which is an accurate relative measure of the electron momentum. The effect due to the γ-rays from the paraffin is superposed on a background due to the γ-rays from the graphite in the thermal column. This background is constant over the energy range of this experiment. The peak at 4.800 amp. is due to photoelectrons ejected from the K-shell of U by the γ-rays from the paraffin. The general shape of the Compton background taken with a brass radiator is shown in this region as a broken line. The γ-ray energy deduced from the position of the photoelectron line is 2.236 ± 0.005 Mev, using the ThC″ 2.620-Mev γ-ray as a standard to calibrate the spectrometer. The position of the paraffin γ-ray photoelectron line was determined accurately relative to the standard γ-ray photoelectron line by placing a source containing ThC″ in the Pb collimator behind the radiator and

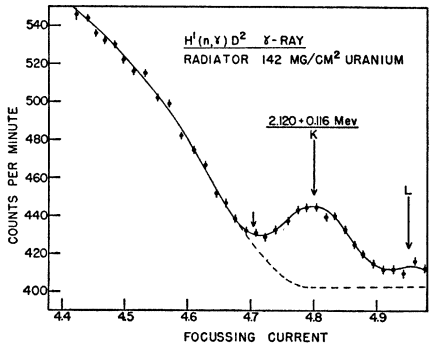

FIG. 1. The momentum distribution of the secondary electrons ejected from a U radiator. The standard deviations of the experimental points are indicated by vertical bars.

carefully determining the position of each line without any change in the arrangement of the apparatus. Any error due to the effect of finite radiator thickness is small because the paraffin γ-ray is close to the standard γ-ray in energy, and is further reduced by calculating the relative position of the two photoelectron lines from their high energy edges.

By adding the nuclear recoil energy to the above γ-ray energy, we obtain 2.237 ± 0.005 Mev for the binding energy of the deuteron, using the ThC″ 2.620-Mev γ-ray as standard. This is surprisingly different from the previously accepted value of the deuteron binding energy.[1] The magnitude of the discrepancy is illustrated in Fig. 1 by the small arrow at 4.704 amp., marking the position the photoelectron peak would occupy were the deuteron binding energy as low as the previously accepted value. As a further check the ThC″ source was replaced by a Ra source and the RaC 2.198-Mev γ-ray was shown to have an energy about 1.5 percent lower than that of the paraffin γ-ray. This precludes the disintegration of the deuteron by that particular γ-ray of RaC and invalidates Kimura's[2] argument leading to a low value of the deuteron binding energy. The low value quoted by Myers and Van Atta[3] could be due either to voltage instability in the electrostatic generator or to non-linearity of the generating voltmeter calibration.

Taking the $H^1H^1-D^2$ separation[4] as 1.433 ± 0.002 Mev together with the value of the deuteron binding energy

reported here, we obtain 1.008992 ± 0.000010 amu for the mass of the neutron. The probable error given includes an uncertainty of 0.3 percent in the absolute energy value for the ThC'' γ-ray. This neutron mass value is 0.051 mmu greater than the value quoted by Stephens[1] and gives a value for the $n-H^1$ difference of 0.804 ± 0.009 Mev. The theoretical lifetime of the neutron is reduced by a factor of 1.3 when this new value for the $n-H^1$ difference is used.

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On the Radioactivity of K^{40}

O. Hirzel and H. Wäffler
Swiss Federal Institute of Technology, Zurich, Switzerland
September 13, 1948

SOME years ago we published measurements of the quantum energy and the upper limit of the beta-ray spectrum of K^{40}. The values found by us are, respectively,[1]

$$E_\gamma = 1.54 \pm 0.1 \text{ Mev}, \quad E(\beta_{\max}) = 1.41 \pm 0.02 \text{ Mev}.$$

These data are in good agreement with later measurements by Meyer *et al.*,[2] Gleditsch and Gráf,[3] Dželepow *et al.*,[4] and Henderson.[5] Recently, Franchetti and Giovanozzi,[6] using the cloud-chamber method, obtained a much higher value for the maximum beta-ray energy of K^{40}, namely, 1.7 ± 0.1 Mev. We believe that with respect to our measurements such a high beta-ray energy is rather improbable. Figure 1 gives the absorption curves obtained by us with P^{32} ($E_{\max} = 1.71$ Mev), Na^{24} ($E_{\max} = 1.41$ Mev), and K^{40} in the same geometrical arrangement. The points for K^{40} are taken up to 1/500 of the initial intensity and are all lying on the Na^{24} curve.

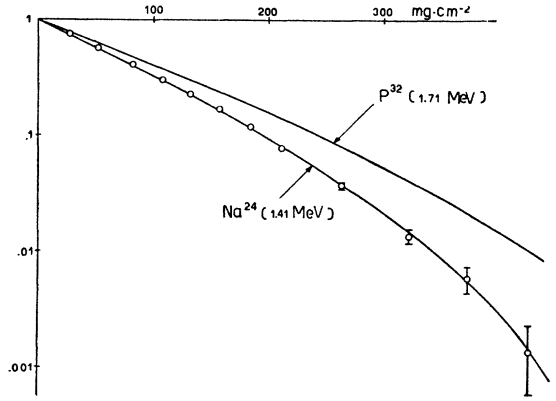

FIG. 1. Absorption curves in aluminium of P^{32} and Na^{24}. The points refer to K^{40}.

In addition we have determined the number Γ of quanta emitted per 100 beta-rays. For this purpose, the radiation from a thick KCl sample (cylindrical arrangement) was measured (a) with a thin-walled (27 mg/cm² Al) G-M counter and (b) with a cylindrical absorber, thick enough to absorb all the beta-rays, between the sample and the counter. The same measurements were performed with Al^{28}, which is known to emit one quantum of 1.8 Mev per beta-ray. The ratio of the sensitivities for γ-rays of 1.54- and 1.8-Mev quantum energies is 0.84 for Al counters, as computed by Bleuler and Zünti[7] and obtained experimentally by Bradt *et al.*[8] Taking into account the self-absorption of the beta-rays in the samples and their absorption in the counter wall, we obtain for Γ

$$8.7 \pm 1.2 \ \gamma\text{-quanta per 100 beta-rays.}$$

Furthermore we have determined the half-life of the transition $K^{40} \rightarrow Ca^{40}$. The number of counts from a thin sample (4 mg/cm²) of purified KCl (cylindrical arrangement) was compared with a very thin (<1 mg/cm²) U_3O_8 sample. The back-scattering from the holder (0.01-mm Al foil) was determined to be smaller than 1 percent. Taking into account the somewhat different absorption of the two beta-spectra in the wall of the G-M counter, as well as the very weak intensity of UX_1 and UY radiation passing through the counter wall, we get

$$T_{\frac{1}{2}}(K^{40}) = T_{\frac{1}{2}}(U^{238}) \times 0.246$$
$$T_{\frac{1}{2}}(K^{40}) = (11.1 \pm 1.9) \times 10^8 a.$$

The greatest contribution to the error in $T_{\frac{1}{2}}$ is given by the incertainty in the relative abundance of K^{40} (0.011 ± 0.001 percent).[9]

We are very indebted to Professor P. Scherrer for his stimulating interest in this work.

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Observations of Naphthalene Scintillations Caused by Tritium Beta-Rays*

R. F. Taschek and H. T. Gittings
Los Alamos Scientific Laboratory, Los Alamos, New Mexico
September 27, 1948

IT seems desirable to report here some preliminary observations on the scintillations produced in commercial naphthalene by the beta-rays from tritium and by the bremsstrahlung coming from tritium occluded in tantalum. Of immediate interest is the lower limit set on the conversion efficiency from beta-ray to visible light energy.

A small amount of gaseous tritium was put in direct contact with finely powdered naphthalene crystals in a 15-cm³ glass Kjeldahl flask, an identical flask but without tritium being used as a control, to find the direct action of the betas. A tantalum disk containing tritium occluded throughout its volume was placed near a solid piece of