Disintegration Scheme of Br^{80} (18 min)

GERTRUDE SCHARFF-GOLDHABER AND MICHAEL MCKEOWN
Brookhaven National Laboratory, Upton, New York*

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The 18-min isomer Br^{80} is shown to emit γ rays of 620-kev energy which follow a low intensity (9 ± 2 percent) β-ray branch. Beta-gamma coincidences are observed, indicating that the gamma transition takes place in Kr^{80}. No γ-ray transition was found to follow the positron or K capture branch. The intensity observed is compatible with a spin and parity assignment $1+$ for the ground state of Br^{80}, while the 620-kev state in Kr^{80} is probably $2+$. The gamma-ray energy observed fits well into the pattern for the energy of the first excited state of even-even nuclei.

THE 18-min isomer of Br^{80} has been reported by several authors[1,2] to have a complex beta-ray spectrum. The two most energetic β rays showed an energy difference of about 0.9 Mev. A recent search,[3] by means of a scintillation spectrometer, for the γ transition going to the ground state of Kr^{80} following the low-energy beta-ray branch, revealed no γ rays except annihilation radiation due to a low-intensity positron branch. The mean of the values reported[1,2] for the ratio β^+/β^- is 0.03.

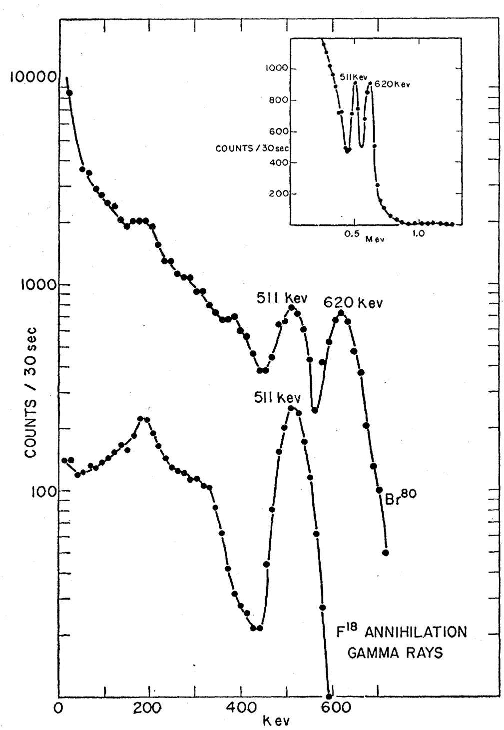

FIG. 1. Pulse-height distribution of Br^{80} (18-min) γ radiation obtained with a scintillation spectrometer. For calibration purposes, the pulse-height distribution of the annihilation gamma rays from F^{18} is shown (lower curve). The peaks below 200 kev are the result of reflection of the gamma rays. The inset shows the continuation of the spectrum at higher energy.

A survey of first excited states of even-even nuclei[4,5] shows that an excited state in Kr^{80} of about 0.6 Mev might be expected. Consequently, a new effort was made to detect the corresponding γ rays with a high resolution scintillation spectrometer. For this purpose a 1-cm^3 NaI(Tl) crystal was used. A Br^{80} sample produced by a 1-sec irradiation of 1-mg NH_4Br in the Brookhaven reactor served as a source. A (620 ± 10) kev γ radiation was indeed detected. Figure 1 shows a spectrogram obtained with a single channel pulse-height analyzer. The annihilation γ rays are clearly resolved from the 620-kev peak. For calibration purposes a similar curve was taken for the annihilation γ rays of F^{18}. Figure 2 gives the decay curves for the 511-kev and the 620-kev peaks of Br^{80}, showing that 90 percent of the radiations initially emitted decay with a half-life of 18 min. The intensity of the 620-kev γ rays, after correction for efficiency, is found to be 50 percent higher than that of the annihilation γ rays. Using the ratio $\beta^+/\beta^-=0.03$ mentioned above, we arrive at a branching ratio $\gamma_{620\ \mathrm{kev}}/\beta^-=0.09\pm0.02$.

In order to show that the 620-kev radiation follows indeed a beta-ray branch, beta-gamma coincidences were studied. The 620-kev γ-ray pulses were again selected by means of a differential pulse-height analyzer. Figure 3 shows a decay curve of the $\beta-\gamma$ coincidences which is in good agreement with $T_{1/2}=18$ min. The coincidence efficiency per beta ray was calibrated with a source of Au^{198}. The branching ratio $\gamma_{620\ \mathrm{kev}}/\beta^-$ deduced from the coincidence rate per beta ray, after correcting for the γ-ray efficiency, agrees within limits of error with the value obtained from a comparison of the intensity of the 620-kev γ rays with that of the annihilation radiation.

In order to exclude the possibility that the γ rays follow the positron or K capture branch, a search for 511-kev–620-kev γ-γ coincidences as well as for coincidences of the 620-kev γ rays with Se K x-rays was made. No coincidences were found.

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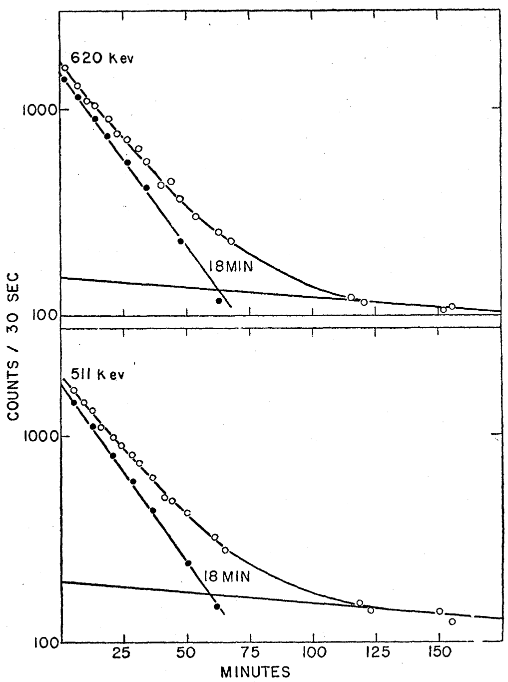

FIG. 2. Decay curves of the 620-kev γ rays (upper curve) and annihilation radiation (lower curve) from Br^{80}. The curves show that about 90 percent of these radiations decay with a half-life of 18 min.

Figure 4 shows the disintegration scheme[6] for Br^{80}. A spin of 1+ for the Br^{80} ground state is compatible with the logft values for the two β^- branches. That the logft value for the transition from Br^{80} to Se^{80} is much

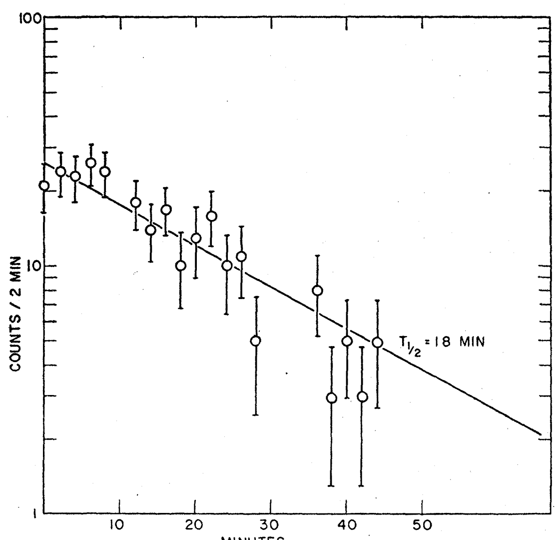

FIG. 3. Decay curve of the $\beta-\gamma_{620\ \mathrm{kev}}$ coincidences from Br^{80}. At least 90 percent of the coincidences decay with a half-life of 18 min.

[6] For spin assignments of the Br^{80} states see M. Goldhaber and R. D. Hill, Revs. Modern Phys. 24, 179 (1952).

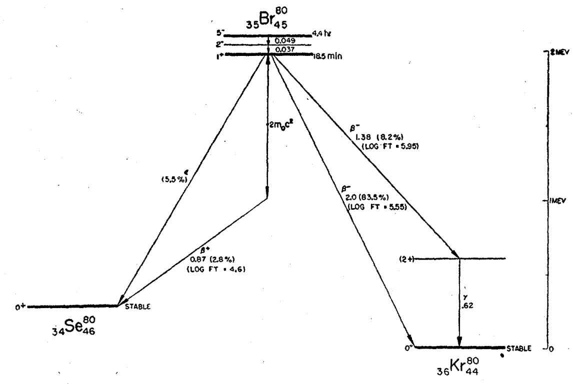

FIG. 4. Disintegration scheme of Br^{80}.

lower than that for the transitions to Kr^{80} is due to the fact that in both Se^{80} and Kr^{80} one may expect to find a $p_{1/2}$ neutron pair with high probability.[7] Consequently, the transition from the ground state of Br^{80} with, presumably, a $p_{3/2}$ proton and a $p_{1/2}$ neutron to Se^{80} will be favored, whereas the transition to Kr^{80} can only take place to the much less probable neutron configuration $g_{9/2}{}^6p_{1/2}{}^0$.—From the generally observed regularity[5] we may assume that the 620-kev state is 2+.

Figure 5 represents the trend, with increasing neutron number, of the energy of the first excited state of

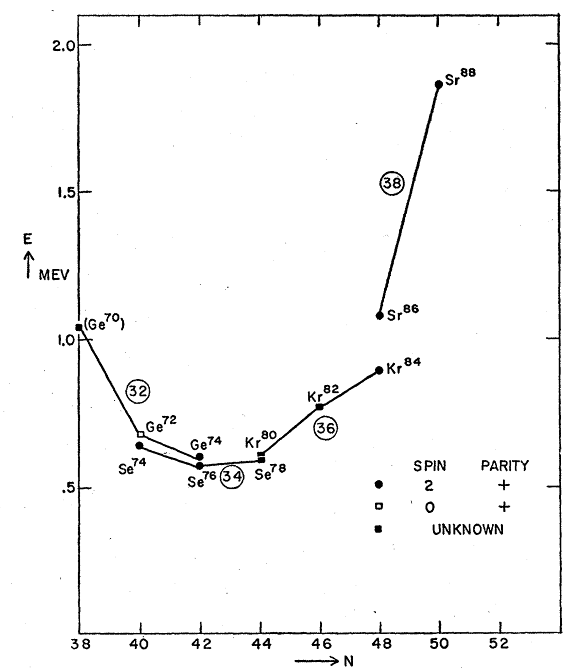

FIG. 5. Energy of first excited state, plotted against number of neutrons in even-even nuclei for N below 50. Points for isotopes of an element are connected with straight lines. The encircled numbers indicate the atomic number.

[7] In support of this argument see Sunyar, Mihelich, Scharff-Goldhaber, Goldhaber, Wall, and Deutsch, Phys. Rev. 86, 1023 (1952) and A. de Shalit and M. Goldhaber, Phys. Rev. (to be published).

even-even nuclei in the region with which we are concerned here. It is seen that the point found for Kr^{80} fits well into the general pattern. Moreover, it further supports the rule[5] that addition of 2 protons to a nucleus has only a slight effect on the energy of the first excited state except for proton numbers near a closed shell: Se^{78} has a first excited state of 0.60 ± 0.025 Mev, deduced by Kinsey and Bartholomew[8] from the energy difference of the two capture γ rays of highest energy observed from $(Se^{77}+n)$.

[8] B. B. Kinsey and G. A. Bartholomew (private communication). This will appear in the *Canadian Journal of Physics.*

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Neutron Total Cross Sections at 20 Mev

ROBERT B. DAY AND RICHARD L. HENKEL
Los Alamos Scientific Laboratory, Los Alamos, New Mexico

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With the $T(d,n)He^4$ reaction as a monoenergetic source of neutrons of about 20 Mev, the total cross sections of 13 elements have been measured by a transmission experiment. These cross sections vary approximately as $A^{\frac{2}{3}}$ as is to be expected from the continuum theory of nuclear reactions. The cross section for hydrogen at 19.93 Mev is 0.504 ± 0.01 barn. This result, together with other results at lower energies, seems to require a Yukawa potential in both the singlet and triplet *n-p* states and a singlet effective range that is lower than that obtained from *p-p* scattering data.

INTRODUCTION

UNTIL very recently most work on neutron cross sections at energies from 10 to 25 Mev was done with sources such as $Li^7(d,n)Be^8$ which do not produce monoenergetic neutrons. Therefore, to obtain results ascribable to a particular neutron energy it was necessary to use an energy-sensitive detector. The two methods most commonly used were (1) detection of recoil protons of a particular energy emitted in a given direction from a hydrogenous radiator[1] and (2) use of a threshold detector such as $C^{12}(n,2n)$.[2,3] Both of these methods suffer from rather severe defects. The first has very low efficiency if one wishes to obtain good energy resolution, while the second gives only a complicated average of the cross section over the energy region above the effective threshold.

With the production of sufficient quantities of tritium, the $T(d,n)He^4$ reaction can now serve as an intense source of high-energy monoenergetic neutrons, thus releasing one from the troublesome detector problem. With a 3.5-Mev accelerator, for example, it is possible to obtain neutrons from 12 to 20 Mev with a homogeneity that is determined essentially by the target thickness and hence by the source strength required. Because of the low-energy resonance in $T(d,n)$, Cockcroft-Walton accelerators are particularly well suited to produce high intensities of 14-Mev neutrons by this reaction. Coon *et al.*[4] have recently published a survey of the total cross sections of over 50 elements for 14-Mev neutrons, while Poss *et al.*[5] have also reported a few measurements of total cross sections at this energy.

Using this reaction as a source of monoenergetic neutrons in the 20-Mev region, we have measured the total cross sections of a number of elements to an accuracy of about 3 percent and the total cross section of hydrogen to 2 percent. The results vary approximately as $A^{\frac{2}{3}}$, as is to be expected from the continuum theory of nuclear reactions of Feshbach and Weisskopf.[6]

PROCEDURE

Fast neutrons of the order of 20-Mev energy were obtained by bombarding a tritium gas target with deuterons from the large Los Alamos electrostatic accelerator. To obtain a sufficiently high neutron flux, the tritium pressure was usually such that it produced an energy loss of about 200 kev for the deuterons traversing the target. This variation in deuteron energies throughout the target produced a corresponding spread in neutron energies which was much larger than the spread due to other causes. The average neutron energy was calculated from the dynamics of the reaction, including a small correction for relativistic effects. The corrections to the deuteron energy for the energy loss in the target and the nickel entrance foil were calculated from calibrations made with the proton beam.

The detector was a stilbene scintillation counter placed 148 cm from the target at 0° to the deuteron beam. To keep the background low the counter was biased to count only neutrons of about 14 Mev or higher. A similar scintillation counter at 30° to the

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[6] H. Feshbach and V. F. Weisskopf, Phys. Rev. **76**, 1550 (1949).