nuclei in emulsion and for lead, and corresponding solutions $\bar{n}(E)$ are being computed in an investigation of the effect of mass number of the target nucleus. It is hoped that a complete account can be published shortly.

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## Half-Life and Radiations of $Tc^{100}$

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SEVERAL years ago a preliminary report[1] was made on an 80±10-second activity which appeared to follow the chemistry of technetium. Subsequent 14-Mev deuteron and 7-Mev proton bombardments of 90.2 percent $Mo^{100}$ by the present senior author, however, showed the half-life to be 70±2 sec, and the charged particle energy to be 2.1±0.2 Mev. Magnetic deflection measurements, in addition, indicated these particles were positrons. Although positron emission in $Tc^{100}$ was unexpected, the possibility of its occurrence could not be excluded since this radionuclide is isobaric with stable $Mo^{100}$ as well as with $Ru^{100}$.

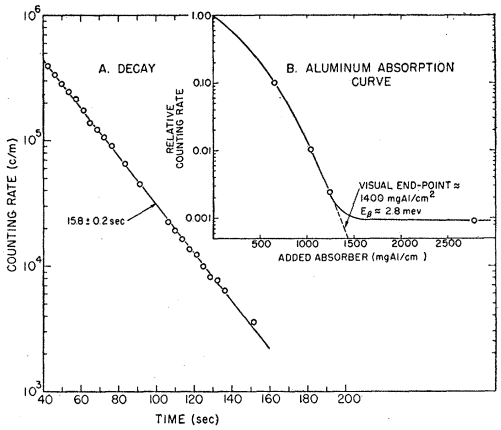


FIG. 1. A. Decay of gamma-radiations from $Tc^{100}$ measured through 1.96 g Pb/cm². B. Aluminum absorption curve for 15.8-sec $Tc^{100}$ constructed from isochrone on decays through varying thicknesses of aluminum.

Additional chemical tests were made, since the half-life and radiations of the ostensible technetium activity were very similar to those reported for $F^{17}$ ($T_{\frac{1}{2}}$=69 sec; 2.1-Mev positrons). The rapid volatility procedure employed earlier to separate Tc from irradiated $Mo^{100}$ metal was modified to include a separation of HF. The 70-second period was then found only in the fluoride fractions. Presumably the 70-sec $F^{17}$ activity previously confused with technetium resulted from $(d, 2n)$ and $(d, n)$ reactions on very small amounts of oxygen remaining in the probe target after the reduction of $Mo^{100}O_3$ to molybdenum metal with hydrogen.

Additional proton and deuteron irradiations of $Mo^{100}$ were then made in a careful search for $Tc^{100}$. After chemistry no new technetium activities were observed with a Geiger counter, from which it was concluded that the half-life of $Tc^{100}$ was either less than 30 seconds, or greater than several years. Because of the time required for chemistry, it was not possible to decide if a reported[2] 18-second beta-emitting activity produced in natural molybdenum by 7-Mev protons should be assigned to technetium. Recently, however, the preparation of $Tc^{100}$ without the need for ultra-rapid chemical separations has become possible by reason of the availability of fractional gram amounts of long-lived, fission product $Tc^{99}$. Milligram amounts of purified Tc metal[3] and $TcO_2$ were irradiated with thermal neutrons for 20 to 30 second periods in the Oak Ridge graphite pile. The decay of the induced activity was measured through varying thicknesses of aluminum and lead using a mica end-window beta-proportional counter as a detector and strip chart recording. A typical decay curve of the gamma radiations is shown in Fig. 1A, while a rough aluminum absorption curve taken from an isochrone is given in Fig. 1B. It has been concluded that $Tc^{100}$ decays with a 15.8±0.2 second half-life and that beta-rays of 2.8±0.2-Mev maximum energy are emitted together with gamma-radiations. Almost certainly the beta- and gamma-spectrum of $Tc^{100}$ is complex.[4] Numerous levels in $Ru^{100}$ have been seen in the decay of 20-hr $Rh^{100}$, while the log$ft$ value for 15.8-sec $Tc^{100}$ is but 4.45 when it is assumed that no other beta-rays than the 2.8-Mev group occur in the decay. Quantitative measurements of the radiations of $Tc^{100}$ are in progress.

A search was also made for a possible long-lived isomeric state of $Tc^{100}$ with negative results. Ten milligrams of technetium metal were irradiated with slow neutrons until an integrated flux, $nvt$, of $1.8\times10^{18}$ neutrons/cm², was accumulated. The irradiated metal was converted to pertechnetate, and the latter purified by anion exchange chromatography. Sources were prepared and examined within 32 hours after bombardment using a (Tl+Na)I scintillation spectrometer and a krypton-filler beta-proportional spectrometer. No quantum radiations other than those which could be attributed to very small amounts of 92.8-hr $Re^{186}$ and 26.8-hr $As^{76}$ impurity were seen. This finding appears to be consistent with the observed absence of $Tc^{100}$ in mass spectrographically analyzed fission product $Tc^{99}$.[5]

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## High Energy Photodisintegration of the Deuteron*

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RECENT experiments[1–3] on the photodisintegration of the deuteron by high energy quanta have indicated that above the meson threshold the cross section for this process rises appreciably over the photoelectric cross section of the phenomenological theory.[4,5] The excitation function and angular distribution in this region are of considerable interest in connection with meson theory and current speculation about an isobaric state of the nucleon. We therefore felt it desirable to extend to higher energy the measurements of Benedict and Woodward[1] who investigated the photodisintegration up to 160 Mev.

Bremsstrahlung from the Cornell 310-Mev electron synchrotron was allowed to strike equivalent targets of $H_2O$ and $D_2O$. Charged particles emitted at a given laboratory angle were detected in a coincidence-anticoincidence counter telescope which defined their ranges and selected protons by means of their specific ionization. Figure 1 shows the ranges of angle and energy used for the experiment. By subtracting the $H_2O$ count from the $D_2O$ count, one obtains an effect that can be due only to the process $D(\gamma, n)p$, since the contribution from the oxygen cancels out and meson production cannot give recoil protons in the ranges selected. We have so far examined the disintegration produced by quanta of about 180 and 260 Mev in the laboratory, corresponding to 165 and 230 Mev in the center-of-mass system. The gamma flux was measured with an ionization chamber placed behind 1 cm of lead. This had previously been calibrated against a pair spectrometer[6] and by means of a shower curve analysis.[7] The estimated error

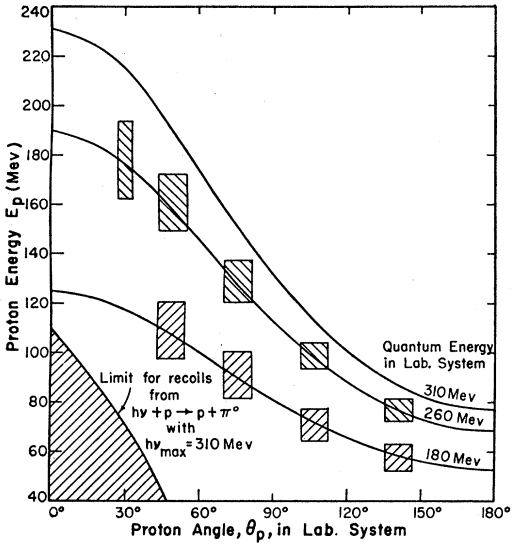


FIG. 1. Kinematics of the photodisintegration.

in the beam calibration obtained this way is ±15 percent, which we believe to be the main uncertainty in the absolute scale of cross sections of this experiment.

Figure 2 shows the cross sections for photodisintegration measured at the two energies as a function of proton angle in the c.m. system. For comparison, we have plotted the points obtained by Benedict and Woodward[1] at 160 Mev on the same figure. Except for a point in the back hemisphere, agreement is seen to be good.

The statistical errors make it impossible to determine the angular distributions very well. The points are consistent with an isotropic distribution at both energies, and it would be difficult to accommodate anisotropic terms to more than about 50 percent. For lack of better information, we have computed the total cross sections under the assumption that the angular distributions are isotropic. This contrasts with the treatment of Benedict and Woodward, who fitted a distribution of the form $\sin^2\theta(a+b\cos\theta)+c$ to their experimental points. At 160 Mev, they found $b\sim c\sim 0.4a$, subject to some uncertainty because only three points in the angular distribution were measured.

Figure 3 gives the total cross sections as a function of quantum energy in the c.m. system. We have shown the data of Benedict and Woodward as well as our own, together with a curve taken from the paper by Schiff.[4] The experimental errors shown are

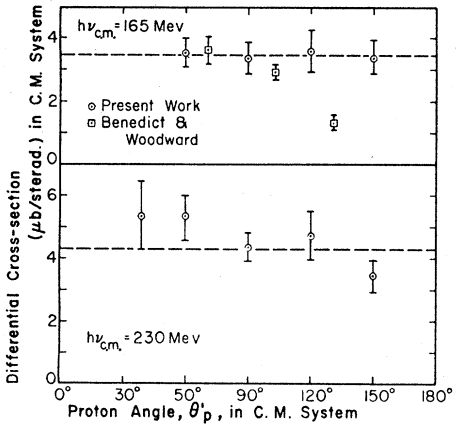


FIG. 2. Differential cross sections in the c.m. system.

statistical; in addition, there is an over-all uncertainty of about ±20 percent in the absolute scale for our data and ±30 percent for that of Benedict and Woodward.[8] Most of the disagreement between the two points at 160 Mev can be traced to the difficulty of angular integration pointed out above and indicates the extent to which the total cross section is uncertain at present.

Our values are considerably lower than those reported by Gilbert and Rose,[2] who, however, allow an error of a factor of two in their absolute cross sections. The recent data of Kikuchi,[3] obtained by multiplying the 90° differential cross section by $4\pi$, agrees with our results, although the stated error is a factor of three. Kikuchi also reports a forward asymmetry of the photoprotons in the c.m. system, for which we have here not found any strong indication.

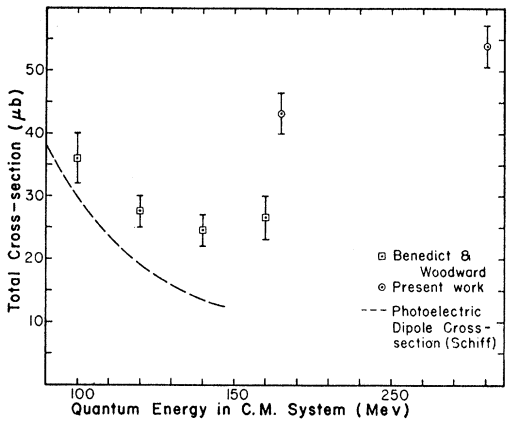


FIG. 3. Total cross sections in the c.m. system.

In summary, it appears at present that the photodisintegration cross section begins to deviate from the phenomenological electric dipole cross section in the region of the meson threshold, and thereafter rises slowly with increasing quantum energy. The total cross section at 230 Mev is of the order of 50 $\mu$b. The angular distribution of the photoprotons shows no very marked anisotropy.

* Work done under contract with the ONR.
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[7] Dr. A. M. Perry undertook most of the shower curve measurements.
[8] Since the same beam calibration was used for the two experiments, however, these errors are not entirely independent.

## Radiation Loss by Electrons in Large Orbits*

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DOUBT has recently been raised[1] concerning the validity of the classical calculations[2] of radiation loss by electrons moving in large orbits in a uniform magnetic field. Parzen's[1] quantum mechanical calculations indicated a much smaller total energy loss than is given by classical theory.

The radiation loss can be measured by observing how the orbit radius in a synchrotron changes with time when the radio frequency accelerating voltage is removed. We have $E=300H\rho$ and $H=H_0(\rho_0/\rho)^n$, where $E$ is measured in electron volts, $H$ in gauss, and $\rho$ in cm. When both the orbit radius and time are allowed to vary we have

$$\dot{E}/E=(1-n)\dot{\rho}/\rho+\dot{H}/H.$$

Here $\dot{E}$ is the total rate of change of the electron's energy:

$$\dot{E}=\dot{E}_{rf}+\dot{E}_{\beta}+\dot{E}_{rad}+\dot{E}_{0},$$