TABLE I. Comparison of fluorescence for various excitations.

Substance	Intensity α particles[a]	β particles[b]	γ rays[c]
Anthracene crystal	4.3	44	71
Anthracene powder	2.5	41	61
Calcium tungstate	3.3	47	46
Diphenyl	1.1	14	22
Radelin (PFG)[d]	30	47	42
Terphenyl (3 g/l) in phenylcyclohexane	...	20	...
ZnS (Type D)	100	100	100

[a] Polonium source.
[b] Strontium 90; values corrected for equal stopping power.
[c] Radium; values corrected for equal mass.
[d] Radelin is also a ZnS-type phosphor.

single crystal (specially purified). Special precautions were taken with the ZnS powders to attain saturation before measurements, and thus maximum light efficiency was obtained.

The crystal values provide the most favorable comparison for the true anthracene fluorescence with that of ZnS. Anthracene of different degrees of purity were found to have practically the same yield, though anthracene powder with just a noticeable yellow color due to oxidation had a light intensity of only 60 percent of that of the pure material. The difference between gamma-ray and beta-particle values for substances like anthracene and $CaWO_4$ may be due to the portion of electrons with smaller energy than the maximum and, therefore, higher energizing power for which the light efficiency is smaller.

The liquid also showed no self-absorption and demonstrated a high efficiency for beta particles. (Its high efficiency for gamma rays was previously determined.[5]) If corrected for zero self-quenching, this efficiency is only 30 percent smaller than that of solid anthracene.

If the absolute yield for ZnS is assumed to be 20 to 25 percent,[1,4] these results show that the absolute yield for anthracene lies between 8 and 10 percent as previously reported. The occurrence of only a small difference between the crystal and powder values for electrons and gamma radiations again shows the very slight absorption even in the powder.

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[1] Broser, Kallmann, and Martius, Z. Naturforsch. **4a**, 204 (1949).
[2] H. W. Leverenz, *An Introduction to the Luminescence of Solids* (John Wiley and Sons, Inc., New York, 1950), p. 317.
[3] Furst, Kallmann, and Kramer, Phys. Rev. **89**, 416 (1953).
[4] A. Bril and H. A. Klasens, Philips Research Repts. **7**, 401 (1952).
[5] M. Furst and H. Kallmann, Phys. Rev. **85**, 816 (1952).

A Metastable State of V^{52}

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VANADIUM is found to have two stable isotopes,[1] V^{50} and V^{51}. After neutron bombardment of vanadium, Amaldi *et al.*[2] found an activity with a 3.75-min half-life. Later Renard[3] reported a 2.6-min state which he ascribed to V^{52}. Cork *et al.*[4] found a half-life of 16 hours.

Spectroscopically pure V_2O_5 was irradiated in the JENER-pile for approximately 30 hours. The half-life was measured and the 16-hour activity was verified.

In order to identify the 16-hour activity, the gamma spectrum was measured with a scintillation spectrometer. Two gamma rays with energies of 59 kev and 96 kev were obtained. Further, eight other lines were detected:

0.539±0.008 Mev,	1.40±0.04 Mev,
0.739±0.010 Mev,	1.76±0.07 Mev,
0.850±0.010 Mev,	2.33±0.07 Mev,
1.00 ±0.06 Mev,	3.2 ±0.1 Mev.

The three lines 0.739 Mev, 1.00 Mev, and 1.40 Mev have been reported[5] for Cr^{52}. The other five also fit the disintegration scheme

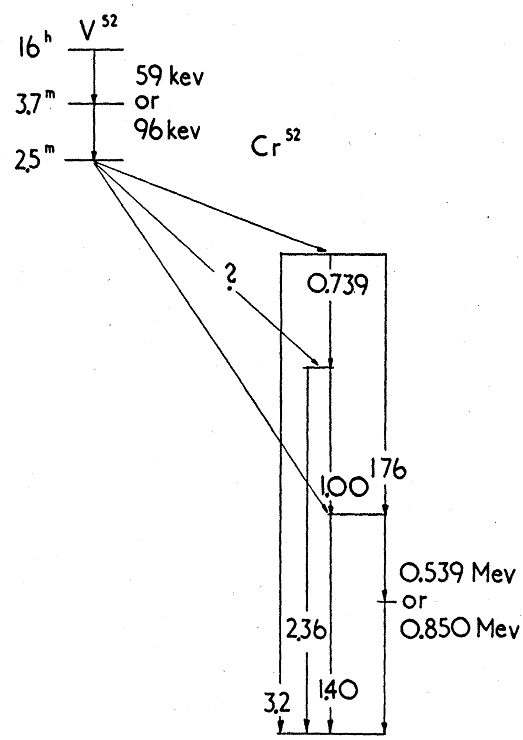

FIG. 1. Tentative decay scheme of V^{52}.

of Cr^{52}. Since the vanadium isotope investigated is a negatron-emitter and thus goes over into Cr, and because the lines detected seem to agree with those of Cr^{52} obtained from the positron-emitter Mn^{52}, it seems probable that the 16-hour activity belongs to an excited state of V^{52}. Thus the low-energy lines probably belong to excited states of V^{52}, the highest level of which has a lifetime of 16 hours and the lower one 3.7 minutes.[3]

The new high-energy lines detected in Cr^{52} make it possible to give the order of the γ rays with energies 0.74 Mev and 1.0 Mev (Fig. 1).

The investigation of vanadium will continue.

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[1] W. T. Leland, Phys. Rev. **76**, 1722 (1949).
[2] Amaldi, D'Agostino, Fermi, Pontecorvo, Rasetti, and Segrè, Proc. Roy. Soc. (London) **A149**, 522 (1935).
[3] G. A. Renard, Ann. phys. **5**, 385 (1950).
[4] Cork, Keller, and Stoddard, Phys. Rev. **76**, 575 (1949).
[5] W. C. Peacock and M. Deutsch, Phys. Rev. **69**, 306 (1946).

Total Cross Sections of 408-Mev Protons for Hydrogen and Light Elements*

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THE total cross sections of several light elements for 408-Mev protons have been measured by a transmission method. The cross sections given here were measured in such a way that they include all processes except the Coulomb scattering. A proton beam scattered from the Chicago 170-inch synchrocyclotron was highly collimated and deflected with an auxiliary magnet. Range measurements in copper indicated a mean proton energy of 408±10 Mev at the scatterer.

Two one-inch square×$\frac{1}{4}$-inch thick crystal scintillation counters were connected in fast coincidence to define and monitor the beam. A $9\frac{1}{2}$-inch diameter liquid scintillator counter was placed coaxial with the beam defined by the first two counters and at variable distance L. It was connected in anticoincidence with the coincidence output of the first two counters so as to count directly the number of particles removed from the beam. Thin scatterers (of 90–95 percent beam transmission) were placed directly after the second crystal counter.

The variable distances L between the thin scatterer and the anticoincidence counter determined the minimum angle θ, by which a proton (and any secondary charged particles) would have to be deflected from the forward direction in order to allow an anticoincidence event to register. The angle θ was varied in each case over a range of small angles, but no angles were used which were so small as to introduce any large effect from Coulomb scattering. Corrections were applied to the results from measurements at the smallest values of θ for the Coulomb scattering. The corrected experimental values were plotted against θ, and in each case lay on a straight line. These straight lines were extended to $\theta=0$ to obtain the total cross sections.

For the determination of the total cross section of liquid hydrogen, the transmission was measured for laboratory angles of 1.5° to 6°. The straight line drawn through the experimental points showed a steep slope in the case of hydrogen, due to the deuterons formed in pion production. These deuterons have about 4-Mev energy in the baricentral system, and of the order of 200 Mev in the laboratory system. Consequently they all come forward within an angle of 8° to the beam giving rise to the observed increase of counting rate with decreasing angle of the large counter. An angular dependence of $0.2+\cos^2\theta$ was assumed for the deuteron production in the baricentral system. The corresponding effect on counting rate calculated as a function of angle (assuming 2 mb for the deuteron production cross section) accounted for most of the slope of this line. The data were corrected for deuteron production and plotted against θ; the line through the corrected points was extrapolated to zero angle, and the assumed deuteron cross section was added to the intercept to give a total hydrogen cross section of 24 mb. This number is insensitive to the quantity assumed for the deuteron production cross section, the final result of 24 mb being obtained for choices of 2, 3, or 4 mb.

For Li, Be, and C, θ was varied from 3.5° to 14° and for D_2O and H_2O, from 2.5 to 8°. In no case was the Coulomb correction more than a few percent. The straight lines determined by the corrected transmissions plotted *versus* θ were extended to $\theta=0$, to give the total cross section for 408-Mev protons not including Coulomb scattering. The values so obtained are as follows:

$$\sigma(\mathrm{H})=24.0\pm1 \text{ mb (liquid hydrogen)}$$
$$\sigma(\mathrm{Li})=194\pm8 \text{ mb (lithium metal)}$$
$$\sigma(\mathrm{Be})=242\pm6 \text{ mb (beryllium metal)}$$
$$\sigma(\mathrm{C})=285\pm14 \text{ mb (graphite)}$$
$$\sigma(\mathrm{D-H})=\tfrac{1}{2}[\sigma(\mathrm{D_2O})-\sigma(\mathrm{H_2O})]=31.6\pm2 \text{ mb}$$
$$\sigma(\mathrm{O})=\sigma(\mathrm{H_2O})-2\sigma(\mathrm{H})=406\pm3 \text{ mb}$$
$$\sigma(\mathrm{D})=\sigma(\mathrm{D-H})\pm\sigma(\mathrm{H})=55.6\pm2.2 \text{ mb.}$$

These total cross sections for 408-Mev protons are closely equal to the corresponding total cross sections for 400-Mev neutrons,[1] in agreement with the hypothesis of charge symmetry. The (p,p) cross section, however, is significantly lower than the (n,p) cross section at the same energy. In order to compare this transmission cross section with (p,p) scattering cross sections it must be corrected for a sizeable meson production, which may be as much as 2 millibarns. The scattering cross section implied here is therefore in agreement with the Berkeley value[2] of 3.5±0.4 mb/sterad at 340 Mev, and with one-half the Carnegie Institute of Technology value[3] of 45±10 mb at 435 Mev. (The factor ½ is needed to allow for the definition of scattering cross section in the case of identical particles.)

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[1] V. A. Nedzel, Phys. Rev. **90**, 169 (1953).
[2] O. Chamberlain (private communication).
[3] Clark, Grandey, Kao, and Mann, Bull. Am. Phys. Soc. **28**, No. 3, 43 (1953).

Gamma Radiation from Inelastic Scattering of 2.7-Mev Neutrons

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We have performed some preliminary observations of gamma radiation arising from bombardment of various materials with 2.7-Mev neutrons produced by the $D(d,n)He^3$ reaction. A scatterer, made of the material of interest, was placed 25 cm from the accelerator target and in line with the deuteron beam. Gamma radiation was detected by a Compton spectrometer placed about 10 cm from the scatterer. Some shielding of the spectrometer crystals was provided by a lead bar placed between the accelerator target and spectrometer. The spectrometer crystals were arranged such that the angle of scattering of the incident quanta was 135 degrees. With this arrangement the resolution was about 12 percent full width at half-maximum. Calibration was performed with standard sources of Na^{22}, Cs^{137}, and Co^{60}. Experiments indicated that the energy calibration was essentially independent of the position of the sources from points within the volume normally occupied by the scatterer.

Pulse-height distributions were taken first with the scatterer in position and then removed. The accelerator rate was held constant during the runs so that the neutron yield was the same during both source and background runs. The net counting data in counts per channel per neutron monitor count is plotted in the accompanying figures. Sample probable errors are indicated at a few points. Generally the error was large for small pulse heights due to a large accidental rate produced by neutrons penetrating the spectrometer shield.

Figure 1 shows pulse-height distributions produced by bombardment of a copper scatterer as well as a typical Co^{60} calibration curve. Ordinates, for the latter, are in counts per second per chan-

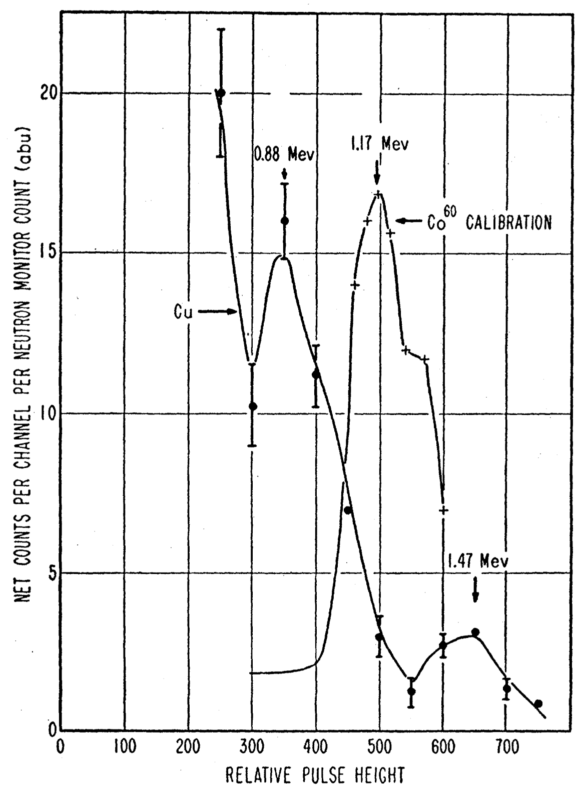

FIG. 1. Compton spectrometer pulse-height distribution produced by gamma rays arising from neutron bombardment of copper.