CONCLUSION

From the experimental data that have been presented here on the ratios of photodisintegration excitation to electrodisintegration cross section for Cu^{63} and Mn^{55}, the following statements can be made about the nuclear photon absorption cross section for elements near copper. The giant resonance peak near 20 Mev appears to be due to an electric dipole process with a mixture of 3% of an electric quadrupole process. Nuclear size effects might make the experimental results compatible with a larger proportion of electric quadrupole process. The high-energy tail of the photon absorption cross section near 42 Mev appears to be due to either an electric dipole or a magnetic dipole process, but does not appear to be due to an electric quadrupole process.

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Half-Lives of Sc^{46}, Co^{60}, Zn^{65}, Ag^{110m}, Cs^{134}, and $Eu^{152,154}$

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The half-lives of six gamma-emitting nuclides were determined by comparison with radium standards, using a lead-shielded ionization chamber. The following results were obtained: Sc^{46}: 83.89±0.12 days; Co^{60}: 5.24±0.03 years; Zn^{65}: 243.5±0.8 days; Ag^{110m}: 252.5±1.5 days; Cs^{134}: 2.07±0.02 years; $Eu^{152,154}$: 12.2±0.2 years. The errors quoted are twice the standard deviation calculated from a least-squares analysis.

THE half-lives of radioactive nuclides that emit hard gamma radiation can be determined with considerable accuracy by comparison with radium on a lead-shielded ionization chamber. Because of its long half-life (1600 years), radium provides an almost constant reference intensity, while the use of a detector insensitive to beta and soft gamma radiation eliminates the effects of a large number of possible radioactive impurities. Half-life measurements have been carried out by this method on six gamma-emitting nuclides.

The investigated nuclides were produced by neutron irradiation in the Chalk River NRX-reactor. The initial activities of the samples were between 100 and 300 mC. Details on composition and purity are given in Table I. The gamma radiation was measured with a one-atmosphere, air-filled, parallel-plate ionization chamber[1] made of aluminum and shielded by 0.6 cm of lead. Saturation properties were studied by the two-source method but no effects within the experimental errors of ±0.15% could be found.

Sources were placed in a light-weight V-shaped hod at distances from 20 to 150 cm from the face of the ionization chamber. The ionziation current was measured by a null method using a Lindemann-Ryerson electrometer as an indicator. The ionization produced by the nuclide under investigation was compared with the ionization from a radium standard of such a strength that the ionization ratio was always between 2 and $\frac{1}{2}$. With one radium standard, therefore, the decay could be observed for about two half-lives, after which a standard of about $\frac{1}{4}$ the strength was chosen. For the half-life calculation no attempt has been made to make use of the relative values of the standards, which were known to ±0.15%, as the half-life would be very sensitive to this ratio. Half-lives were calculated separately for each standard. The standard deviation for a ratio determination between nuclide and standard was ±0.25%. Measurements were made in approximately equal intervals of between 0.08 and 0.2 half-lives according to nuclide. A least-squares analysis of the data was carried out which for none of the nuclides showed a significant deviation from a simple exponential decay.

The results, corrected for the decay of radium ($T_{\frac{1}{2}}$=1600 yr), are given in Table I, together with some of the more recent measurements of previous authors. Since the standards contained only a commercial grade of radium salt, they were compared periodically among themselves and with the Canadian primary radium standard.[2] Their values remained constant within the experimental error of ±0.15%. The standard deviations in the half-life figures, as calculated from the least-squares analyses, have been

[1] W. S. Michel, National Research Council of Canada, Ottawa, Report No. 3675, June, 1955 (unpublished).

[2] C. Garrett and K. W. Geiger, Can. J. Phys. 34, 1075 (1956).

TABLE I. Half-lives of several gamma-emitting nuclides.

Nuclide	Sample	Decay followed over half-lives	Half-life	Previous measurements	Reference
Sc^{46}	Sc_2O_3 "Specpure"	5.5	83.89±0.12 days	85 ±1 days	a
				84 days	b
Co^{60}	Co 99% purity Main impurities Ni, Fe, C	1.3	5.24±0.03 yr	5.21±0.04 yr	c
				5.27±0.07 yr	d
Zn^{65}	Zn "Specpure"	1.9	243.5 ±0.8 days	245.0 ±0.8 days	d
Ag^{110m}	Ag "Specpure"	2.1	252.5 ±1.5 days	270 ± 4 days	e
				225 ±20 days	f
Cs^{134}	Cs_2AlF_5 "Reagent grade"	0.8	2.07±0.02 yr	2.3 ±0.3 yr	g
				1.7 ±0.1 yr	h
$Eu^{152,154}$	Eu_2O_3 purity 99.9%	0.4	12.2 ±0.2 yr	12.4 ±0.4 yr	i
				15.6 ±1.5 yr	j

[a] H. Walke, Phys. Rev. **57**, 163 (1940).
[b] F. T. Porter and C. S. Cook, Phys. Rev. **81**, 640 (1951).
[c] See reference 3.
[d] See reference 4.
[e] J. R. Gum and M. L. Pool, Phys. Rev. **80**, 315 (1950).
[f] J. J. Livingood and G. T. Seaborg, Phys. Rev. **54**, 88 (1938).
[g] L. E. Glendenin, in *Radiochemical Studies: The Fission Products* (McGraw-Hill Book Company, Inc., New York, 1951), National Nuclear Energy Series, Plutonium Project Record, Vol. 9, Div. IV, p. 1931.
[h] D. C. Kalbfell and R. A. Cooley, Phys. Rev. **58**, 91 (1940).
[i] See reference 7.
[j] See reference 5.

doubled to take account of this uncertainty and also of other possible systematic errors.

COMMENTS ON TABLE I

Sc^{46}: The decay was successively compared with two different radium standards and half-lives 83.88±0.12 days and 83.91±0.17 days found. The close agreement excludes the possibility of any radioactive contamination.

Co^{60}: This is a continuation of a measurement which had been started in 1949; a value of 5.21±0.04 yr was published four years ago by Kastner and Whyte.[3] The present value is in close agreement with this earlier value and with the second precision determination by Tobailem.[4] The investigation is being continued.

Zn^{65}: The decay was compared successively with two different radium standards and the values 244.0±1.0 days and 242.9±1.0 days were found. The mean is slightly below the recent determination by Tobailem.

Ag^{110m}: The new value for the half-life is not in agreement with either one of the two figures published previously. The decay of Ag^{110m} will be studied further although a contribution from a gamma-emitting impurity is thought to be unlikely.

Cs^{134}: Although the decay of Cs^{134} has not yet been followed for a full half-life, the present value is much more accurate than the figures published previously.

$Eu^{152,154}$: The measurements initiated by Kastner[5] have been continued and still show no deviation from exponential decay although this is a mixture of radioactive nuclides. According to Karraker, Hayden, and Ingram,[6] Eu^{152} decays with a half-life of 13±2 yr and Eu^{154} with a half-life of 16±4 yr. As the thermal neutron activation cross section is approximately 20 times higher for the production of Eu^{152} than for the production of Eu^{154} and as both isotopes emit energetic gamma radiation with similar intensities, the half-life measured here is presumably due to mainly Eu^{152}, which would agree with the above figure. It is also in good agreement with the value measured for $Eu^{152,154}$ by Lockett and Thomas.[7]

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[7] R. E. Lockett and R. H. Thomas, Nucleonics **11**, No. 3, 14 (1953).