TABLE I. *Energies of gamma-rays.*

ISOTOPES	PERIOD	GAMMA-RAYS (MEV)	REFERENCE
Ni^{63}	2.6 hr.	0.280 ±0.007 0.65 ±0.01 0.93 ±0.04	1
Zn^{69}	13.6 hr.	0.440 ±0.006	2, 3
Ga^{67}	83 hr.	0.292 ±0.006	3
Mn^{56}	2.59 hr.	0.800 ±0.015	4, 5

[1] J. J. Livingood and G. T. Seaborg, Phys. Rev. **53**, 765 (1936).
[2] J. W. Kennedy, G. T. Seaborg and E. Segrè, Phys. Rev. **56**, 1095 (1939).
[3] A. C. Helmholz, Phys. Rev. **60**, 415 (1941).
[4] R. H. Bacon, E. N. Grisewood, and C. W. van der Merwe, Phys. Rev. **59**, 531 (1941).
[5] M. Deutsch and A. Roberts, Phys. Rev. **60**, 362 (1941).

distance from the center of this target to the visually observed high energy edge checked within experimental error with the energy value obtained from the corresponding microphotometer trace. This method had been found to be very useful in those cases where the background of the film due to scattered electrons and to the continuous electron spectrum is too dense to permit taking useful microphotometer traces. The magnetic field strength was determined in each case by use of a mutual inductance circuit and fluxmeter. The error in the field strength is believed to be less than 1 percent. A check on these measurements was made by determining the value of the annihilation radiation from Cu^{61} and Cu^{64}. The average value of 20 measurements was found to be 0.512±0.006 Mev, (Table I).

The values tabulated are the averages of at least five separate measurements. In the case of Mn^{56} an attempt was made to find a gamma-ray of energy greater than 2 Mev as reported by Bacon *et al.* but without success because of insufficient intensity. The first two gamma-rays recorded in the case of Ni^{63} have not been previously reported. These values, together with rough intensity measurements, suggest a cascade process in which the upper state decays to the ground state by the emission of either a single 0.93 Mev gamma-ray or two gamma-rays of energies 0.280 Mev and 0.65 Mev, respectively, through an intermediate state.

All of these gamma-ray energies were obtained during the progress of some work which was completed in June, 1941 and is reported in the author's Ph.D. thesis. More recently, the values of some of these gamma-ray energies have been published (references 3 and 5 in Table I) and they agree fairly well with the values tabulated above.

Radioactive Isotopes of Mercury

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WHEN the present investigation was started, the following mercury activities had been reported: a 43–48-minute period, produced by fast neutrons[1–4] and deuterons[4] on mercury, and variously assigned to Hg^{203} or Hg^{197}; a period of between 25 and 40 hours' half-life, produced by slow[5] and fast[3,4] neutrons and by deuterons[4] on mercury, and by deuterons[4,6] on gold, and assigned to Hg^{205} or Hg^{198*}; a 5.5-minute period, assigned to Hg^{205}, and a long period (about 60 days) from deuteron bombardment of mercury.[4]

Very recently, Sherr, Bainbridge and Anderson[7] reported 43-minute, 25-hour and 50-day periods, induced in mercury by fast neutrons. Our results agree in the main with theirs; but, in addition, we have found a new activity of 64 hours' half-life, isomeric with the 25-hour activity, and we have studied the x-rays from these two activities as well as from the 43-minute period by critical absorption measurements. The beta- and gamma-radiations from all activities investigated were studied by absorption methods. Chemical separations were made in all cases, except for the 5-minute period.

Hg^{197}: *25 hours and 64 hours.* Slow and fast neutron bombardments of mercury give rise to a mercury-activity whose half-life seemed to vary between 25 and 45 hours, depending on the thickness of the sample and of the window of the measuring instrument. The mercury fraction from the bombardment of gold with 16-Mev deuterons showed the same behavior; but since, in the latter case, no other periods were present, we were able to resolve the decay curve into 2 straight lines whose slopes corresponded to half-lives of 25 and 64 hours, respectively, provided thin samples and thin windows were used. The chemical identity of both periods was proved by separating gold from the active sample at various times; the gold fraction was always inactive, and the mercury fraction carried all the activity. Absorption in aluminum shows that both activities emit lines of conversion electrons, the maximum energy for the 25-hour activity being about 200 kev, that for the 64-hour activity less than 90 kev. The electron lines were kindly measured for us by Dr. A. C. Helmholz in his magnetic spectrograph; he found 6 lines decaying with a 25-hour and 2 lines decaying with a 64-hour half-life. Valley[7,8] has also reported electron lines from mercury formed in the deuteron bombardment of gold.

Critical absorption measurements of the x-rays emitted were made with tungsten, tantalum, and lead absorbers at various intervals from the time of the chemical isolation of mercury until two weeks later; the curves remained the same at all times and agreed well with calculated curves for the absorption of the K radiations from gold. (L radiation is so soft that it is completely absorbed by the aluminum absorbers used to cut out the electrons.) The mercury fraction from neutron bombardments of mercury gave rise to the same x-ray absorption curves after the 43-minute period had decayed completely. We conclude that both the 25-hour and the 64-hour periods are due to Hg^{197} and that both decay to Au^{197} by K-electron capture. Both periods have complex groups of soft gamma-rays associated with them.

43-minute period. This period is induced strongly in mercury by fast neutrons. Associated with it is a line of electrons of about 460 kev, a group of several gamma-rays, and x-rays which were shown by critical absorption measurements and comparison with calculated absorption curves to be K radiation of mercury. Hence the 43-minute period is probably associated with an isomeric transition in mercury. It cannot be due to Hg^{197} or Hg^{198*}, because neither the Harvard group nor we have found it in deuteron bombardments of gold; if the 43-minute activity[7] reported from alpha-particle bombardment of platinum is identical with this period, the assignment is limited to $Hg^{199\text{ or }201*}$. We failed to obtain a 43-minute mercury from bombardment of lead with neutrons from 16-Mev deuterons on beryllium, but this may not preclude the assignment to Hg^{201*} as Pb^{204} has an abundance of only 1.48 percent, and the cross section for an $n-\alpha$ reaction in this region may be quite small. Both Hg^{199*} and Hg^{201*} should be made by (n, γ) reactions. The yield of the 43-minute period with slow neutrons on mercury was found to be small, in agreement with the Harvard group.[7]

54-day period. This activity was obtained from slow and fast neutron bombardment of mercury and is probably due to Hg^{203}. It emits negative beta-particles with an upper energy limit of 300–350 kev, and gamma-rays of about 300 kev. No x-rays are emitted.

In addition, we found a 5-minute period from slow neutron bombardment of mercury. No chemical separation was made, and the yield was so small that we cannot feel sure that the period is not due to an impurity. It may, however, be identical with the 5.5-minute mercury reported from deuteron bombardment of mercury.[4] Further work on this point is in progress.

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1 Heyn, Nature **139**, 842 (1937).
2 M. L. Pool, J. M. Cork and R. L. Thornton, Phys. Rev. **52**, 239 (1937).
3 E. McMillan, M. Kamen and S. Ruben, Phys. Rev. **52**, 375 (1937).
4 Krishnan and Nahum, Proc. Camb. Phil. Soc. **36**, 490 (1940).
5 Anderson, Nature **137**, 457 (1936).
6 R. S. Krishnan, Proc. Camb. Phil. Soc. **37**, 186 (1941).
7 R. Sherr, K. T. Bainbridge and H. H. Anderson, Phys. Rev. **60**, 473 (1941).
8 G. E. Valley, Phys. Rev. **60**, 167 (1941).