Letters to the Editor

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Cosmic Rays and the Magnetic Disturbance of September 18, 1941

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October 21, 1941

THE "magnetic storm effect" on cosmic rays, well established and recognized as a world-wide phenomenon by S. E. Forbush, V. F. Hess, J. Clay, Th. A. Johnson and others[1] is a phenomenon which consists in a positive correlation between the horizontal magnetic intensity and cosmic-ray intensity. In the recent strong display of aurora borealis field changes of 1200 gamma (from 17,700 to 18,900 gammas) of the horizontal magnetic intensity occurred. Since we have been registering cosmic rays with different instruments in New York for a long time it seemed of interest to analyze our results and to compare them with former reports on cosmic-ray changes during aurora displays.

A large twin counter telescope has been in operation since March, 1941 at Fordham University. Designed by W. F. G. Swann it consists of two independent but interlocked triple coincident sets of counter tubes, with a total of 108 G.M. tubes. This instrument, with 22 cm of lead between the counter trays, automatically registers the number of mesotrons traversing the apparatus in bi-hourly intervals.

Another much simpler apparatus, consisting of two unshielded counters in a vertical plane, has been in operation since 1939.

Finally a large Compton model C cosmic-ray meter was set up on the upper deck of the *S. S. Santa Ana* (Grace Line) to register cosmic-ray ionization between New York and Valparaiso, Chile. As the ship happened to be in New York on the day of the aurora, the registrations of this meter (shielded with 12 cm lead-equivalent) could also be used.

All three instruments simultaneously showed a decrease of the rate of cosmic radiation after the onset of the magnetic disturbance (at approx. 2 A.M., September 18, 75th meridian time). All the rates were previously corrected for atmospheric pressure changes and for the atmospheric temperature effect, taking the average or "mass" temperature from an integration of the p, T curves as obtained from daily high altitude sounding balloon flights at Lakehurst, up to 80 percent of the atmosphere. The coefficient had been found to be -0.46 percent per degree C.[2]

The correlation between bi-hourly rates of the mesotron counting set and simultaneous mean values of H (horizontal geomagnetic component) gives a correlation coefficient of $+0.50\pm0.23$ and a magnetic storm coefficient $H\Delta I/I\Delta H=+1.3\pm0.6$ percent C.R. intensity per percent horizontal geomagnetic intensity (H) which is positive and of the same order of magnitude as found during previous magnetic storms. During the subsequent very rapid rise of H, between 8 A.M. and 4 P.M., on September 18 the mesotron rates showed a relatively small increase. During the evening when the aurora was most brilliant, H and the mesotron intensity were relatively low and showed erratic fluctuations.

The double coincidence set, which yields only daily mean values, gave a rate of 98.7 counts per hour on September 18 as compared with 105.8 on September 17 and 104.3 on September 19.

Hourly rates of the Compton meter were correlated with hourly magnetic intensities, giving a correlation coefficient of $+0.54\pm0.21$ and a magnetic storm coefficient $H\Delta I/I\Delta H=+0.72\pm0.27$ in sufficient agreement with the one found with the mesotron counter, but somewhat smaller, perhaps because of the lack of directional selectivity (the mesotron counter registers vertical rays only).

Compared with the aurora of January 25–26, 1938[3] the above cosmic-ray fluctuations are less pronounced and this is in accordance with the belief that, if electronic ring currents at distances of several earth's radii around the globe cause a diminution of incoming particles, then the radii of these currents may differ considerably from storm to storm or even during a storm.

We wish to thank the staff of the Cheltenham Observatory, U. S. Coast and Geodetic Survey, for kindly supplying us with the magnetic data.

[1] For complete bibliography, see Th. A. Johnson, Rev. Mod. Phys. **10**, 229 (1938).
[2] V. F. Hess and F. A. Benedetto, Phys. Rev. **60**, 610 (1941).
[3] V. F. Hess *et al.*, Nature **141**, 686 (1938).

Energies of Gamma-Rays from Ni^{63}, Mn^{56}, Zn^{69}, Ga^{67}

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October 21, 1941

IN many cases, the best method available for the determination of gamma-ray energies is a study of the secondary electrons by means of a magnetic spectrograph. Perhaps the simplest and most commonly used form of this instrument is that with semi-circular focusing.

In the work here described, a semi-circular focusing spectrograph of standard design was used. Photoelectrons from a thin layer of lead (from about 5 mils to 60 mils) wrapped around the source were recorded on Eastman x-ray film and a standardized procedure was used in developing the film. The position of the high energy edge appearing on the film was determined in all those cases where it was feasible by use of a microphotometer. It was observed that the energies obtained by measuring the

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