

each of the U samples were converted to uranyl nitrate, dissolved in alcohol, and mixed with a one percent solution of lacquer and thinner. Six Al foils 17 cm in diameter weighing 4.9 mg/cm<sup>2</sup> were coated and baked to a thickness of 1 mg/cm<sup>2</sup> of U<sub>3</sub>O<sub>8</sub>.

The foils were placed in an argon-filled ionization chamber and counts were made of fission particles from slow neutrons from a 50-mg Ra—Be neutron source embedded in paraffin above the foil. The fission counts so obtained are shown in Table I.

It is readily seen that any real difference in the U<sup>235</sup> isotope composition of the two sources of U must be less than six percent.

<sup>1</sup> J. B. Orr, Phys. Rev. **76**, 155 (1949).

### Masses of Si<sup>28</sup>, Si<sup>29</sup>, Mn<sup>55</sup>, Fe<sup>56</sup>, Ni<sup>58</sup>, Pd<sup>110</sup>, Cd<sup>110</sup>, Cd<sup>112</sup>, Cd<sup>116</sup>, and Sn<sup>116</sup>

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MASS spectrographic mass measurements made in this laboratory have been extended to include Si<sup>28</sup>, Si<sup>29</sup>, Fe<sup>56</sup>, Ni<sup>58</sup>, Pd<sup>110</sup>, Cd<sup>110</sup>, Cd<sup>112</sup>, Cd<sup>116</sup>, and Sn<sup>116</sup>. From the mass of Fe<sup>56</sup> that of Mn<sup>55</sup> can be deduced by using disintegration data.

**Si<sup>28</sup> and Fe<sup>56</sup>.**—A spark between two metal electrodes, slightly contaminated with iron as a result of earlier sparking against stainless steel, has been used as source when photographing the Fe<sup>56</sup>—Si<sup>28</sup>—Co—C<sub>2</sub>H<sub>4</sub> quadruplet occurring at mass number 28. Measurements of the C<sub>2</sub>H<sub>4</sub>—Si<sup>28</sup> spacing on six photographs showed this packing fraction difference<sup>1</sup> to be 19.45±0.06. Meanwhile, from five photographs, the CO—Si<sup>28</sup> packing fraction difference was found to be 6.45±0.03. Assuming the packing fractions<sup>2</sup> of C<sub>2</sub>H<sub>4</sub> and CO to be 14.37±0.015 and 1.38±0.007, respectively, that of Si<sup>28</sup> is computed to be, first, -5.08±0.06 and, second, -5.07±0.04. Mattauch and Flammersfeld<sup>3</sup> and Alburger and Hafner<sup>4</sup> both list the value -5.20±0.04.

From eight photographs of the CO—Fe<sup>56</sup> doublet, Δ*f*=9.80±0.02, while from seven photographs of the C<sub>2</sub>H<sub>4</sub>—Fe<sup>56</sup> doublet, Δ*f*=22.93±0.07. The packing fraction of Fe<sup>56</sup> computed from these is, first, -8.42±0.03 and, second, -8.56±0.08. A third value for Fe<sup>56</sup> can be got by combining with the above Si<sup>28</sup> value a previously reported<sup>5</sup> packing fraction difference for the Si<sup>28</sup>—Fe<sup>56</sup> doublet of Δ*f*=3.32±0.02. This gives for Fe<sup>56</sup> *f* = -8.39±0.05.

**Ni<sup>58</sup> and Si<sup>29</sup>.**—A spark between stainless steel and zirconium gave a good triplet at mass 29 consisting of Ni<sup>58</sup>—COH—C<sub>2</sub>H<sub>4</sub>. From five photographs, the COH—Ni<sup>58</sup> packing fraction difference was found to be 12.09±0.04. From eleven photographs of the C<sub>2</sub>H<sub>4</sub>—Ni<sup>58</sup> pair, Δ*f*=24.73±0.04. Assuming packing fractions for COH and C<sub>2</sub>H<sub>4</sub> of 4.132±0.016 and 16.67±0.018, respectively, that of Ni<sup>58</sup> is computed to be, first, -7.96±0.05 and, second, -8.06±0.05. This value is to be compared with -8.5±0.35, -6.97±0.07, and -8.29±0.07 obtained by Aston,<sup>6</sup> Okuda *et al.*,<sup>7</sup> and Shaw,<sup>8</sup> respectively.

The mean value for Ni<sup>58</sup>, -8.01±0.05, may be combined with a packing fraction difference of 3.07±0.02 reported earlier<sup>5</sup> for the Si<sup>29</sup>—Ni<sup>58</sup> doublet to get for Si<sup>29</sup> *f* = -4.94±0.05. Mattauch and Flammersfeld, and Alburger and Hafner both list the value -5.02±0.04.

**Cd<sup>112</sup>, Cd<sup>116</sup>, Sn<sup>116</sup>.**—With a spark sometimes between a stainless steel and a cadmium electrode, and at other times between a stainless steel and a tin electrode the Cd<sup>112</sup>—Fe<sup>56</sup>, Cd<sup>116</sup>—Ni<sup>58</sup>, and Sn<sup>116</sup>—Ni<sup>58</sup> doublets were photographed at mass numbers 56 and 58. The packing fraction differences were, respectively, 3.06±0.02 (five photographs), 3.01±0.02 (seven photographs), and 2.66±0.01 (nine photographs). These values, when combined with the above values for Fe<sup>56</sup> and Ni<sup>58</sup>, give for Cd<sup>112</sup>, *f* = -5.36±0.04; for Cd<sup>116</sup>, *f* = -5.00±0.06; and for Sn<sup>116</sup>, *f* = -5.35±0.05.

On many photographs it was possible to measure the Cd<sup>110</sup>—Mn<sup>55</sup> and Cd<sup>114</sup>—Fe<sup>57</sup> packing fraction differences. These were found to

be 2.53±0.03 (seven photographs) and 2.88±0.03 (seven photographs).

**Mn<sup>55</sup>, Pd<sup>110</sup>, Cd<sup>110</sup>.**—Accurate *Q*-values are available for the Mn<sup>55</sup>(*d,β*)Mn<sup>56</sup> reaction. Martin<sup>9</sup> has found 4.76±0.11 Mev, while Whitehead and Heydenburg<sup>10</sup> have obtained 5.01 Mev. Using *Q*=4.95 Mev with 2.86 and 0.84 Mev for the energies of the beta- and gamma-rays from Mn<sup>56</sup>, leading to the ground state of Fe<sup>56</sup>, as listed by Mattauch and Flammersfeld, the Mn<sup>55</sup>—Fe<sup>56</sup> packing fraction difference is calculated to be 0.32±0.03. This with the above value for Fe<sup>56</sup>, gives for Mn<sup>55</sup> *f* = -8.10±0.05. This value can be combined with the Δ*f*'s for the Pd<sup>110</sup>—Mn<sup>55</sup> (Δ*f*=2.70±0.05, previously reported<sup>11</sup>) and Cd<sup>110</sup>—Mn<sup>55</sup> doublets to give for Pd<sup>110</sup>, *f* = -5.40±0.07 and for Cd<sup>110</sup>, *f* = -5.57±0.06.

Table I is a summary of the new mass values.

TABLE I. Summary of new mass values.

Nuclide	Packing fraction	Mass
Si <sup>28</sup>	-5.07±0.03	27.99581±0.00008
Si <sup>29</sup>	-4.94±0.05	28.98567±0.00014
Mn <sup>55</sup>	-8.10±0.05	54.95545±0.00027
Fe <sup>56</sup>	-8.42±0.03	55.95285±0.00016
Ni <sup>58</sup>	-8.01±0.05	57.95354±0.00029
Pd <sup>110</sup>	-5.40±0.07	109.94060±0.00077
Cd <sup>110</sup>	-5.57±0.06	109.93873±0.00066
Cd <sup>112</sup>	-5.36±0.04	111.93997±0.00045
Cd <sup>116</sup>	-5.00±0.06	115.94200±0.00070
Sn <sup>116</sup>	-5.35±0.05	115.93794±0.00058

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<sup>1</sup> The factor  $\times 10^{-4}$  will be understood and not written in expressing the numerical value of the packing fraction.

<sup>2</sup> K. T. Bainbridge, Isotopic Weights of the Fundamental Isotopes, Preliminary Report No. 1, National Research Council (June, 1948).

<sup>3</sup> J. Mattauch and A. Flammersfeld, "Isotopic report—1948," Verlag. d. Zeits. f. Natur., Tübingen, Germany (1949).

<sup>4</sup> D. E. Alburger and E. M. Hafner, "The properties of atomic nuclei—III. Nuclear energy levels, Z=11–20," Brookhaven National Laboratory (July 1, 1949).

<sup>5</sup> Duckworth, Johnson, Preston, and Woodcock, Phys. Rev. **78**, 386 (1950).

<sup>6</sup> F. W. Aston, *Mass Spectra and Isotopes* (Edward Arnold and Company, London, England, 1942), p. 151.

<sup>7</sup> Okuda, Ogata, Kuroda, Sima, and Shindo, Phys. Rev. **59**, 104 (1941).

<sup>8</sup> A. E. Shaw, Phys. Rev. **75**, 1011 (1949).

<sup>9</sup> A. B. Martin, Phys. Rev. **72**, 378 (1947).

<sup>10</sup> W. D. Whitehead and N. P. Heydenburg, Phys. Rev. **78**, 338 (1950).

<sup>11</sup> Duckworth, Woodcock, and Preston, Phys. Rev. **78**, 479 (1950).

### The Electrons in Cosmic Rays\*

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SEARCH for primary electrons in cosmic rays was made by Hulsizer and Rossi,<sup>1</sup> who investigated the bursts produced in a lead-shielded ionization chamber at balloon altitudes. They obtained a value for the burst-producing radiation of 0.0082 particle cm<sup>-2</sup> sec.<sup>-1</sup> sterad.<sup>-1</sup>. Assuming a primary flux of 0.2 particle cm<sup>-2</sup> sec.<sup>-1</sup> sterad.<sup>-1</sup>, this sets an upper limit on the electron and photons of four percent of the primary flux. Our cloud-chamber data indicate that electrons cannot constitute more than 0.2 percent of the primaries and probably represent an even smaller fraction than this.

We have examined 1625 random expansion cloud-chamber pictures taken at 20 g/cm<sup>2</sup> atmospheric depth. All of the experiments were made with at least two ¼-in. lead plates in the cloud chamber so that a 1-Bev electron shower is easily discernible. This energy was chosen for study because it is just below the electron cut-off at our geomagnetic latitude of 55°N. The cloud-chamber sensitive time was 0.2 sec., and the geometric factor of the lead detectors was 39.0 sterad. cm<sup>2</sup>. Eight electron showers of

1 Bev or greater unaccompanied by ionizing penetrating particles have been observed. Six other showers were accompanied by ionizing penetrating particles and were therefore believed to be of secondary origin. If the eight unaccompanied showers were due to primary electrons, the number of primaries necessary to account for them would be  $0.0004 \text{ cm}^{-2} \text{ sec.}^{-1} \text{ sterad.}^{-1}$ . In this estimate we have taken multiplication in the  $20 \text{ g/cm}^2$  of air into account. The above figure together with the previously assumed proton flux gives an upper limit for the number of electrons of 0.2 percent of the primary intensity. If one assumes that air showers are generated by primary electrons with an integral number spectrum<sup>2</sup>

$$N(>E) = CE^{-1.8},$$

one finds that the constant  $C$  which fits our data is at least 600 times too small to agree with the value of the same constant as determined from air shower experiments. It seems unlikely then that air showers are generated by primary electrons.

Because roughly half of the showers contained penetrating particles, we investigated the assumption that all the electrons observed are due to the decay of neutral mesons produced by the primary protons. We have used Chew's semi-empirical formula for the production of charged mesons<sup>3</sup> to make the calculations. The result of the theory is that the observations fix the ratio  $\lambda/H$ , where  $H$  is the fraction of the energy which goes into the neutral mesons, and  $\lambda$  is the mean free path for energy loss by the protons. Since one cannot determine accurately the energy of an electron shower, we used the estimated upper limit of 2 Bev. The ratio  $\lambda/H$  then becomes  $2400 \text{ g/cm}^2$ . A possible pair of values would be  $\lambda = 120 \text{ g/cm}^2$  with one-twentieth of the energy absorbed in making neutral mesons. The calculations will be described in a later publication.

Assuming that all the primaries of energy greater than 15 Bev can contribute neutral mesons to this energy range, the total production cross section  $\sigma$  is  $\sigma = 1.8 \times 10^{-26} \text{ cm}^2$ . This is to be compared with the geometric cross section for air which is  $39 \times 10^{-26} \text{ cm}^2$ .

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<sup>1</sup> R. Hulsizer, Phys. Rev. **76**, 164 (1949); also, Proceedings of the Echo Lake Cosmic-Ray Symposium, p. 218.

<sup>2</sup> W. Heisenberg, *Cosmic Radiation* (Dover Publications, New York, 1946), p. 39.

<sup>3</sup> G. Chew, Phys. Rev. **73**, 1128 (1948).

## The Half-Life of Sodium 24

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IN the course of biological experiments using  $\text{Na}^{24}$  as a tracer, half-life values appreciably longer than 14.8 hr., as given by Van Voorhis,<sup>1</sup> were obtained consistently. As a consequence the half-life has been redetermined on samples of radioactive sodium procured from the Isotopes Division of the AEC at Oak Ridge, Tennessee.

The material, after receipt from Oak Ridge, was purified by the use of ion exchangers. First, the material was absorbed on a Dowex 50 column and then eluted with  $0.15N \text{ HCl}$ , according to the method of Cohn and Kohn.<sup>2</sup> This procedure effects a quantitative separation between sodium and potassium, and may, therefore, be expected to separate the sodium from all other cationic contaminants. However, sodium purified in this fashion still contained about 0.15 percent of a long-lived impurity. The eluate from the Dowex 50 column was, therefore, further purified by passage through a column containing the anion absorption resin, Amberlite 1R-4B. A sample so purified was followed for a period of 13 half-lives, from 103,000 to 17 counts per min., with

TABLE I.  $\text{Na}^{24}$  half-lives.

Experiment number	Half-life
1	14.95
2	15.06
3	15.06
4	15.03
5	15.04
6	14.98
7	15.12
Average $15.04 \pm 0.06$	

no departure from a logarithmic dependence of activity on time. All samples were purified by the same method.

Samples were counted on a windowless proportional counter developed by Robinson.<sup>3</sup> Since proportional counters have no deadtime correction, counts were made up to rates of 100,000 counts per min. No departure from linear behavior has been observed up to this rate. The low background of the counter, 3 to 4 counts per min., permitted accurate counting at low activities. The disintegration constant was determined by fitting the data using the method of least squares. The average half-life is 15.04 hr. with a standard deviation of 0.06 hr. Results of individual runs are given in Table I.

The author wishes to express his thanks to Dr. C. V. Robinson for his assistance and counsel and to Miss E. White for making the counts.

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<sup>1</sup> S. N. Van Voorhis, Phys. Rev. **49**, 889 (1936).

<sup>2</sup> W. E. Cohn and H. W. Kohn, J. Am. Chem. Soc. **70**, 1986 (1948).

<sup>3</sup> C. V. Robinson, Science (to be published).

## The Genetic Relationship in $\text{Ag}^{110}$

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RECENT studies<sup>1</sup> of the radiations emitted by  $\text{Ag}^{110}$  have indicated that the 270-day activity is caused by a level isomeric with the 24-sec. ground state. This genetic relationship has been confirmed by the separation of a short-lived activity from a sample of  $\text{Ag}^{110}$  obtained from Oak Ridge.

The separation was effected by collection of activity on copper electrodes immersed in an ether solution of silver tetraphenylporphyrin.<sup>2</sup> Two copper electrodes separated by about 3 mm were immersed in the solution and a potential difference of 600 volts was applied. After about 3 min., one of the electrodes was removed, washed with ether, and then counted with an end-window G-M tube. The G-M tube was connected to an Autoscaler and a Brush recording oscillograph. The sample was followed to constant background (3 to 4 min. after separation). Figure 1 shows a plot  $\log t$  of the logarithm of the total number of counts observed between  $t=t$  and  $t=\infty$  (3 min.), minus the number of counts due to the constant background in this time interval. The background, which accounted for about 80 percent of the total counting rate at  $t=0$ , was due principally to the 270-day activity. Repeated experiments gave half-lives between 21 and 30 sec. A typical curve is shown in Fig. 1. The time between the removal of the electrode from the active solution and the start of counting was about 12 sec.

Separation occurred at both the anode and cathode with about equal efficiency although the background was generally lower on the anode. Separation was also obtained when a copper electrode was immersed in the solution with no potential applied, but the separation was not as clean. No separation was observed when an uncharged platinum electrode was introduced.