

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

A. K. SOLOMON

*Biophysical Laboratory, Harvard Medical School,\* Boston, Massachusetts*

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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.

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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 $\text{Ag}^{110}$

JOHN MISKEL

*Department of Chemistry, Brookhaven National Laboratory,\*  
Upton, Long Island, New York*

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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.