crust,[20] or the time back to the melting and layering in Urry's hypothesis. Katcoff's considerations can be applied equally well to a seven-billion-year-old earth, and give an age of the elements slightly greater than that.

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Effects of the Atmosphere on the Penetrating Component of the Cosmic Radiation

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MEASUREMENTS made on the penetrating component of cosmic radiation near sea level for a period of 45 days have been utilized for statistical correlation with data from the daily ascents of two nearby radiosonde stations. The measuring equipment consisted of three trays of G-M tubes mounted as a vertical telescope. The telescope was operated under 12 inches of concrete in floors and roof, and a 10-cm Pb absorber was placed between trays 2 and 3. The pulses from the trays were fed into pulse amplifiers and into a coincidence circuit employing pulse shaping prior to the coincidence measurement. Threefold coincidence pulses were applied to a scaler-pen recorder arrangement which recorded the coincidence through a scale of eight. This allowed continuous monitoring of equipment performance.

To account for the fluctuations of the penetrating intensity at the ground, Duperier[1] introduced the temperature of the μ-meson production layer to be used in addition to the atmospheric pressure and the height of the production layer, the effects of which were already known.[2] According to Duperier's model, the probability that a π-meson will decay into a μ-meson is dependent on the density of the region in which the π-meson finds itself. Therefore, the μ-meson intensity at the ground depends on the temperature of the production region.

The telescope was arranged to have approximately spherical symmetry over the solid angle subtended, so no zenith angle correction was applied. The maximum angular aperture of the arrangement was 17°7′ from the vertical. Hourly counting rates were obtained from the observed data, and the mean rate for each day was computed for the 45 days extending from October 9 to November 22, 1950, which were free from electronic failures.

The mean hourly counting rate, the daily average of the tempertture and height of the 100-millibar level, and the daily mean barometric pressure obtained from the filed radiosonde observations of the Portland, Maine, and Nantucket, Massachusetts, Weather Bureau Stations were analyzed for statistical correlation. A linear regression equation

$$\delta I_c = \alpha\delta T + \beta\delta B + \gamma\delta H \tag{1}$$

was hypothesized, where δI_c is the deviation of the counting rate from its mean, δT the deviation of the temperature of the 100-millibar level from its mean, δB the deviation of atmospheric pressure, δH the deviation of the height of the 100-millibar level, and α, β, and γ the appropriate coefficients.

Numerical values of the coefficients α, β, and γ were computed by imposing the requirement that $(\delta I - \delta I_c)^2$ be a minimum, where δI_c is the deviation computed from (1) of the counting rate from its mean, and δI the actual observed deviation of the counting rate. Partial correlation and total correlation coefficients were computed using the methods described by Ezekiel.[3] The square of the partial correlation coefficient, $r_{\mathrm{IT\cdot BH}}$, represents that fraction of the variance, or square deviation of the counting rate, which can be accounted for by the temperature of the 100-millibar level with the effects of the other variables theoretically removed. The multiple correlation coefficient, $R_{\mathrm{I\cdot TBH}}$, expresses the extent to which all three independent variables succeed in accounting for the variance of the counting rate. The errors in the regression coefficients are the root-mean-square deviations expected in those coefficients. The following values of the quantities above were obtained:

$$\begin{array}{ll}
R_{\mathrm{I\cdot TBH}} = 0.84 & \alpha = -0.023(\pm 0.027)\ \text{percent/°C} \\
r_{\mathrm{IT\cdot BH}} = -0.13 & \beta = -0.102(\pm 0.011)\ \text{percent/millibar} \\
r_{\mathrm{IB\cdot TH}} = -0.82 & \gamma = 0.954(\pm 0.264)\ \text{percent/1000 ft} \\
r_{\mathrm{IH\cdot TB}} = -0.49 &
\end{array}$$

The significance of the correlation coefficients can be judged from the basis that, if the correlation coefficient were truly zero, 68 percent of the values obtained from 45 days' random sampling would lie in the range $-0.158 = r = 0.158$, or from the fact that if the correlation were truly 0.84, 95 percent of the values obtained from 45 days' sampling would lie in the range $0.64 = r = 0.87$. The correlations of the counting rate and the pressure and the height are significant, while that with the temperature is not. The mean counting rate was 918 coincidences/hour. The expected root-mean-square deviation in the average of 24 such measurements is 6.2. The residual root-mean-square deviation in the counting rate when the effects of the three meteorological variables are removed is 5.9. Assuming exponential absorption of the radiation, the above value of β leads to a mean absorption thickness of 1160 g/cm².

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Cross Section for the Reaction $Cu^{65}(\gamma, \alpha)Co^{61}$*

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THE successful determination of the $Rb^{87}(\gamma, \alpha)Br^{83}$ cross section[1] by obtaining the residual activity of Br^{83} has led the authors to undertake the measurement of the $Cu^{65}(\gamma, \alpha)Co^{61}$ cross section by the same method.

Twenty-gram samples of reagent grade $CuCl_2 \cdot 2H_2O$ were irradiated in the University of Saskatchewan betatron beam for periods ranging from 5 minutes at high energies to 90 minutes at low energies. Tantalum strips, used as monitors, were irradiated along with the copper chloride. The irradiated copper chloride was dissolved and, after adding a cobalt carrier, the copper was removed as CuSCN. The cobalt was then precipitated and obtained for counting as CoS. By using a Co^{60} tracer and chemical spot tests, this separation was found to be better than 99 percent efficient.

The activation curve, Fig. 1, was obtained after applying the usual counting corrections. The high energy part of the curve is dotted to indicate that the energy was not as accurately controlled as it was for the lower part of the curve. No attempt was made to obtain activation points at energies lower than 15 Mev. The calculated binding energy is 6.1 Mev; however, in order for α-emission to compete with γ-de-excitation one might expect that an additional energy of 5 or 6 Mev would be necessary, putting the apparent threshold at 11 or 12 Mev. A check on the absolute value of the activation point at 22 Mev was made by monitoring a run with the $Cu^{63}(\gamma, n)Cu^{62}$ activity arising from the irradiated copper chloride. Agreement within 5 percent was obtained. It was determined that nickel impurity in the irradiated copper chloride could account at most for 0.001 of the Co^{61} activity measured at 23 Mev. Also the possibility of the $Cu^{63}(\gamma, 2p)Co^{61}$ reaction making a substantial contribution to the Co^{61} activity is ruled out by reason of the masses and energies concerned. At 24 Mev the yield is 2.3×10^4 alpha-particles per mole of Cu^{65} per roentgen, which is in satisfactory agreement with the value 4×10^4 alpha-particles per mole of natural copper per roentgen, obtained by Byerly and Stevens.[2] Their experiment did not allow differentiation between alpha-particles produced in (γ, α) reactions and in $(\gamma, \alpha n)$ or other similar reactions producing α-particles, which, however, would go undetected in our experiment.

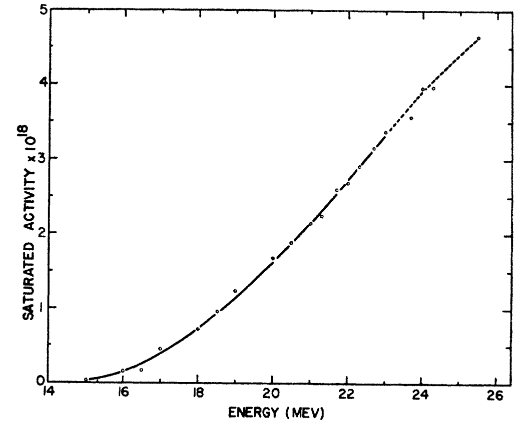

FIG. 1. Activation curve for the reaction $Cu^{65}(\gamma, \alpha)Co^{61}$ showing activations $\times10^{18}$ per atom of Cu^{65} per 100 roentgens *vs* maximum betatron energy in Mev.

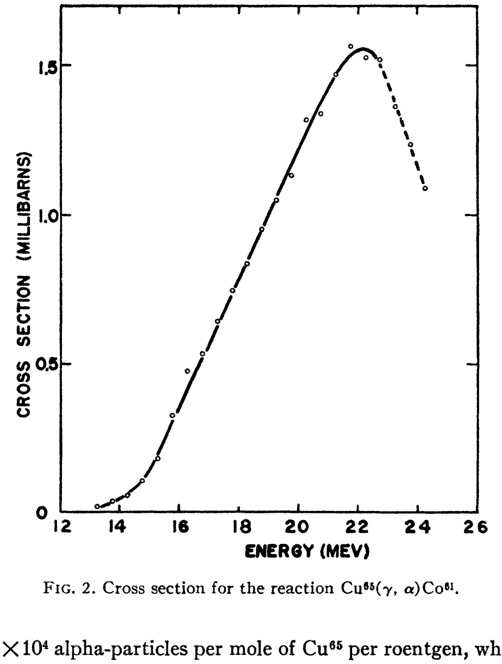

FIG. 2. Cross section for the reaction $Cu^{65}(\gamma, \alpha)Co^{61}$.

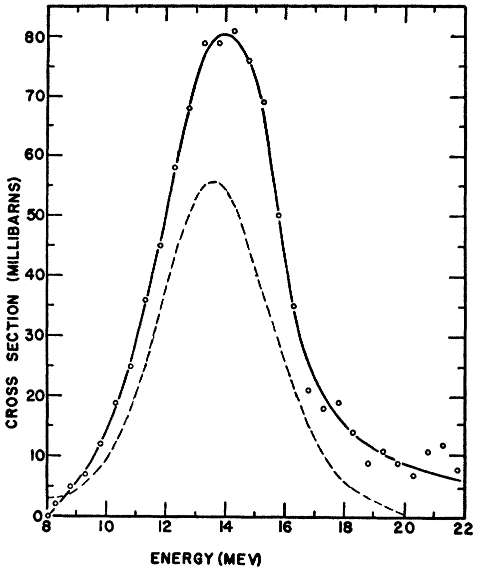

FIG. 3. Minimum cross section for the reaction $Ta^{181}(\gamma, n)Ta^{180}$ (uncorrected for decay scheme). The dotted curve shows the previous determination (see reference 4).

The cross section, Fig. 2, was derived from the activation curve using the "photon difference" method.[3] This cross section has a maximum value of 1.5 millibarns at 22 Mev, and the integrated cross section to the peak is 6.2×10^{-3} Mev-barns. The falling off of the cross section above 22 Mev may be the result of the cascade competition of the $(\gamma, \alpha n)$ process.

Before obtaining the above activation curve, the activation curve for $Ta^{181}(\gamma, n)Ta^{180}$ was redetermined since Ta was used to monitor the dosage rate. As this curve was somewhat different from that previously reported,[4] the modified $Ta^{181}(\gamma, n)Ta^{180}$ and $Rb^{87}(\gamma, \alpha)Br^{83}$ cross section curves are reproduced in Fig. 3 and Fig. 4 (the latter reaction was also monitored by Ta). Data concerning these two curves have already been reported.[3] Comparison

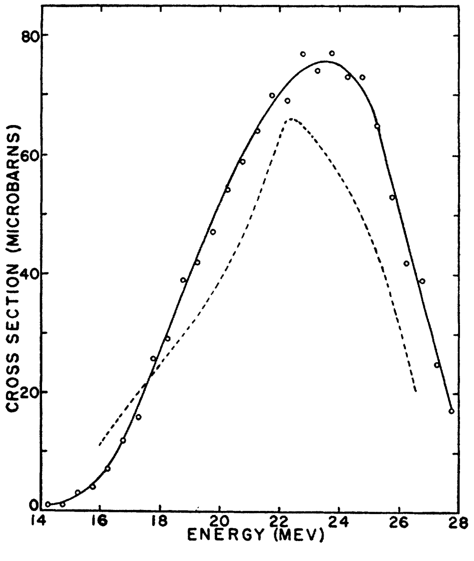

FIG. 4. Cross section for the reaction $Rb^{87}(\gamma, \alpha)Br^{83}$. The dotted line shows the previous determination (see reference 1).

of Fig. 2 and Fig. 4 shows that the cross section for the (γ, α) reaction in Cu^{65} is an order of magnitude greater than that in Rb^{87}.

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The Decay of Co^{61}*

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During the course of experiments to determine the Cu^{65}(γ, α)Co^{61} cross section[1] decay curves of Co^{61} which could be followed over ten half-lives were obtained. A typical curve is shown in Fig. 1. From an analysis of eleven such curves a half-life of 99.0±0.3 minutes was obtained. This is considerably lower than previously reported values[2,3] but should be more accurate because of the high counting rates obtained here.

To analyze the decay of Co^{61}, activities were obtained by two reactions, $Cu^{65}(\gamma, \alpha)Co^{61}$ and $Ni^{62}(\gamma, p)Co^{61}$. Both methods gave the same results from the analyses of the absorption curves in aluminum. An aluminum absorption curve is shown in Fig. 2 and the corresponding analysis by the *n*th power method[4-6] is given in Fig. 3.

It is obvious that two β's are present. The average of two determinations of the maximum beta-energies by the foregoing method showed (55±10) percent of the disintegrations with a maximum energy of 1.42±0.02 Mev and (45±10) percent with a maximum energy of 1.00±0.02 Mev. To search for a possible gamma-ray the Co^{61} was counted with a scintillation counter. Alternately the sample was counted with no filter and with one of two filters, each thick enough to absorb all the betas, (860 and 1340 mg/cm²). The count through the thick filters decayed with the same half-life as without a filter so a Co^{61} gamma-ray was indicated. A rough lead absorption curve obtained during the same experiment indicated a gamma-energy of about 0.5 Mev. During the chemical separation for absorption experiments, holdback carriers were used to reduce the amount of copper contamination as much as possible.

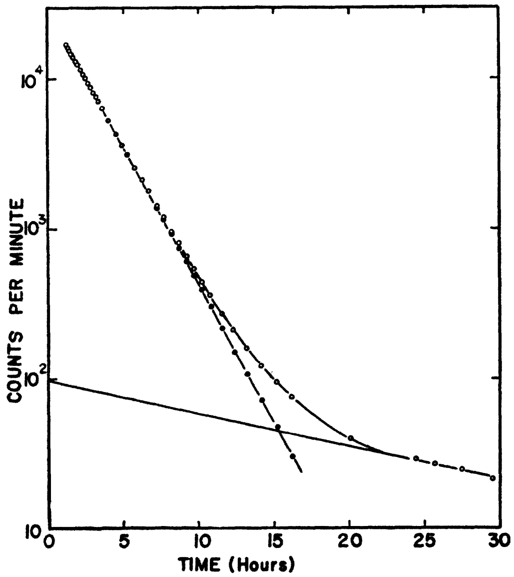

FIG. 1. Decay curve of 99.0-minute Co.^{61} The background activity is 12.9-hour Cu^{64}.

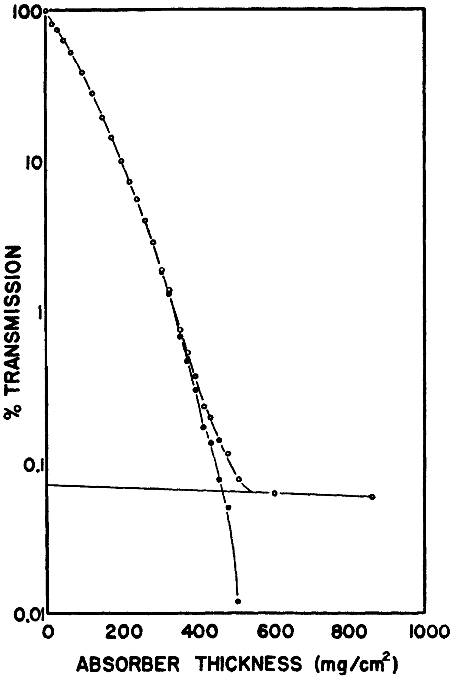

FIG. 2. Aluminum absorption curve for Co^{61}.

The simplest decay scheme on the basis of the above results is that the 1.42-Mev β goes from the ground state of Co^{61} to that of Ni^{61}, and the 1.00-Mev β leads to an excited state of Ni^{61} which decays to ground emitting a 0.42-Mev gamma-ray. The possibility that the complex spectrum is the result of an isomeric state of Co^{61} is ruled out by the nuclear shell model,[7] by the fact that both transitions have *ft* values corresponding to allowed transitions, and in view of the branching ratio.

Since both Co^{61} and Cu^{61} decay by allowed transitions to Ni^{61}, it is necessary to assign spin orbit values other than those predicted by the nuclear shell model.[7] Nordheim has suggested $j = 5/2$ for the spin orbit values of Ni^{61} but this makes the Cu^{61} decay l forbidden.[8] Since the energy level reported here, 0.42 Mev, does not occur in the decay of Cu^{61},[9] and those which do occur in the Cu^{61} decay did not appear in the Co^{61} decay, it might be possible to assign spin values to some of the excited energy levels of Ni^{61}.

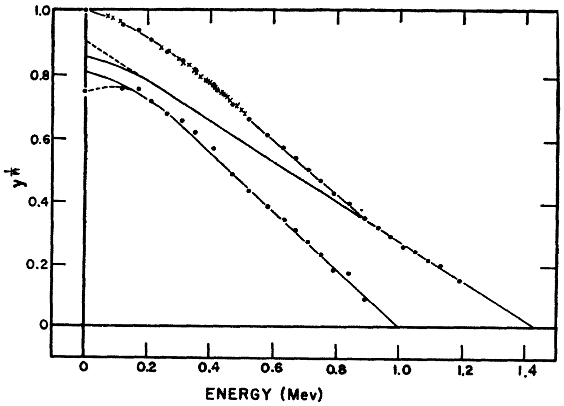

FIG. 3. *n*th power plot for Co^{61} showing β end point energies of 1.43 Mev ($n = 4.72$) and 1.00 Mev ($n = 3.26$).