Similar crystal effects were observed in Be and also in Bi in spite of the fact that both atoms have a nuclear spin different from zero.

In the case of water a fourfold increase in the cross section over the value[3] 21×10^{-24} cm^2 measured at 1.44 ev (indium resonance) was observed as was to be expected from the effects of chemical binding.[4] The effect of chemical binding is presumably also responsible for the increase in the cross section of D_2O.

Sulphur proved interesting. Sulphur prepared in the amorphous state gave a cross section of 7.06×10^{-24} cm^2 for the filtered neutrons, a value twice as high as the value obtained for the same sample with the unfiltered thermal neutrons. This increase is believed caused by the cooperative scattering in aggregates of sulphur atoms with dimensions small compared to the neutron wave-length. In such aggregates of n atoms the scattering is proportional to n^2 rather than to n. The next day the same specimen, having partially crystallized, showed a smaller cross section.

To show the effects of the thermal motion of the atoms in a crystal on the interference conditions, the scattering cross section for 15.4 g/cm^2 of graphite was studied with filtered neutrons as a function of temperature of the scatterer. The scatterer was heated with an oxyacetylene torch and the temperature measured using a thermocouple. Temperature equilibrium was not perfectly established in these experiments but the effect is evident. The results are given in Table II. These experiments show clearly that the thermal motion of the crystal atoms tends to destroy the interference conditions.

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[3] H. B. Hanstein, Phys. Rev. **59**, 489 (1941).

[4] E. Fermi, Ricerca Scient. **7**, 13 (1936). H. A. Bethe, Rev. Mod. Phys. **9**, 127 (1937).

PHYSICAL REVIEW VOLUME 70, NUMBERS 11 AND 12 DECEMBER 1 AND 15, 1946

Some Mesotron Observations by Simultaneous Registration at Two Stations

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(Received September 9, 1946)

Two cosmic-ray telescopes were used in these investigations, each being screened against the softer vertical component by 20 cm of lead. One telescope, permanently located at the lower station 142 feet above sea level, served as a "control" with reference to which readings of the second telescope were corrected for fluctuations caused by variations in atmospheric temperature, barometric pressure, and magnetic effects. The second telescope, after having recorded intensities at the lower station, was moved to a platform atop the Empire State Building, 1125 feet above sea level. Intensities here were measured both with and without a compensating layer of lead equivalent to the 35-millibar pressure difference between stations. Estimated mean life range of the mesotron was 9.7±3 km, accuracy being limited chiefly by the comparatively short differential in height between stations. In the second part of this paper a series of correlations of ground values of mesotron intensities with the height variations of the 1000-, 850-, 700-, 500-, 300-, 200-, and 100-millibar pressure levels of the atmosphere is described. From these observations the existence of two production levels for mesotrons is inferred from the position of two peaks in the value of the correlation coefficients, peak values being found for the 500- and 100-mb observations. Mesotron decay coefficients for these two levels were approximately the same and equal to -0.0705 km^{-1}, thus giving a mean life range of 14.2 ± 1.4 km consistent with an effective mesotron spectrum of 2.37×10^9 ev assuming the rest lifetime of the mesotron as 2×10^{-6} sec.

INTRODUCTION

THE determination of the mean life range of the mesotron by height differential compensating-mass-absorber methods has been made by several observers.[1,2] As a check on this decay phenomenon over a short interval near sea level, it was deemed advisable to repeat this type of

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[1] B. Rossi and D. B. Hall, Phys. Rev. **59**, 223 (1941).

[2] W. M. Nielsen, C. M. Ryerson, L. W. Nordheim, and K. Z. Morgan, Phys. Rev. **59**, 547 (1941).

experiment utilizing the moderate altitude afforded by the observation platform of the Empire State Building in New York City. Since the height differential effect caused by mesotron decay could easily be masked by other variations such as temperature, pressure, and magnetic effects, it was necessary to have a "control" station operating simultaneously with the upper station and in close enough proximity to it so that each station should be influenced equally by the same disturbing factors mentioned above. The control station was located at Fordham University on the roof of the physics building, 142 feet above sea level; the upper station was located on the roof of the Observation Platform of the ESB, 1125 feet above sea level. In previous experiments of this nature, observers utilizing the greater height differentials afforded by mountain ridges, approximately 2000 m, were able to accumulate sufficient data in a comparatively shorter time and consequently were able to measure without the need of a control station.

In addition to serving as a control station the Fordham apparatus was also used in conjunction with radiosonde data to study the effect of variations in height of certain pressure levels from 1000- to 100-mb on the intensity of mesotrons measured at sea level. This study was undertaken in the attempt to discover some level, or levels as results indicated, exerting greater influence on ground mesotron intensities. In the study of various cosmic-ray and mesotron experiments Rathgeber[3] concluded to the existence of two mesotron originating levels, one around the height of 6 km and the other above 17 km. Since the time of Blackett's paper on the temperature effect,[4] it has become customary to assume a single production level around 16 km. Correlation studies such as those described in this paper are expected to aid more directly in the solution of this problem.

APPARATUS

Two similar cosmic-ray telescopes were used in this investigation. The aperture of each was the same and was determined such that the one destined for use on the ESB would not be screened by the tower structure of that building. Each telescope consisted of three trays of argon-oxygen filled Geiger counters. Each tray had nine counters overlapping so as to form a continuously sensitive area 11 cm wide and 19.3 cm long; the distance between bottom and top trays was 62 cm. Trays were supported by sturdy steel frames and were screened against the softer component by 9.5 cm lead between the top and middle trays, and by 10.5 cm lead between the middle and bottom trays. The ESB telescope was also screened against possible side showers originating in the tower structure by a 10-cm iron screen arranged about the periphery of the lowest tray. High potential of −900 volts for the counters, and the power for the coincidence circuits were obtained from stabilized power packs which were fed from self-regulating transformers. Voltages were checked daily, no noticeable drift being observed during the course of the investigation. Each telescope and its associated equipment was housed in demountable thermostated huts. The original dual telescope from which these two separate telescopes were made is described in a previous paper.[5] No anticoincidence tubes were used in the present arrangement, and the original recorders were replaced by watch movement recorders driven by 6N7 multivibrators. Visual readings were taken every 24 hours.

METHOD OF OBSERVATIONS

The loss of mesotrons through decay $-dN$ over a path dh, representing the difference in altitude between two stations that are beneath the same total mass absorber equivalent, is given by

$$-(dN/N) = -(dh/L),$$

consequently

$$L = dh/\log (N_1/N_2),$$

where L = mean life range of mesotrons; N_1 = observed mesotron intensity at the higher station; and N_2 = observed mesotron intensity at the lower station.

The procedure thus resolved itself into measuring first the intensity (A) recorded by the ESB telescope while it was located at Fordham,

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[3] H. D. Rathgeber, Phys. Rev. **61**, 207 (1942).

[4] P. M. S. Blackett, Nature **142**, 692 (1938).

[5] F. A. Benedetto, G. O. Altmann, and V. F. Hess, Phys. Rev. **61**, 266 (1942).

then moving it to the higher location and measuring the intentisy (*B*) at that elevation. The ratio (*B*/*A*) gives the increase in intensity caused by the fact that less mass absorber is above the higher station and also caused by the shorter path for decay. (*B*/*A*) must be corrected however for variations in temperature, pressure, etc., that occurred during the measurements; during the same interval of time that (*A*) was being measured the control telescope recorded an intensity (*A′*), likewise the intensity (*B′*) was measured simultaneously with the intensity (*B*). (*B′*/*A′*) gave the decrease of intensity caused by the extraneous disturbances. Correction of (*B*/*A*) was made by dividing by (*B′*/*A′*), thus corrected this ratio is designated (*I*).

Layers of sheet lead were next placed above the ESB station to compensate for the difference in mass between this and the lower station. This layer was 35.49 g/cm^2 and approximated the average 35-mb difference in pressure between stations. Intensity as measured at the higher station and under the compensating absorber is designated (*C*). (*B*/*C*) corrected for extraneous disturbances by reference to the corresponding ratio (*B′*/*C′*) gives the increase in intensity at the higher station that was attributable to the smaller mass above this station and is designated (*II′*). To convert the absorption in the lead absorber to the corresponding absorption in carbon the ratio (II′) was multiplied by the factor 4.960/4.908 which was the rate ratio found by Rossi and collaborators[6] in lead and carbon, (II′) corrected is designated (II). Intensities (*B*) and (*C*) as well as (*B′*) and (*C′*) were measured alternately and for a total of 13 and 10 days, respectively. Intensity measurements are given in Table I; the various rate ratios are given in Table II.

TABLE I. Mesotron intensities at both stations.

Minutes	Counts	Rate	Experimental condition	
29,890	160,278	5.362	ESB telescope at Fordham, no added lead.	(*A*)
29,700	162,688	5.478	Control telescope at Fordham.	(*A′*)
18,959	104,294	5.501	ESB telescope at ESB, no added lead.	(*B*)
18,606	98,339	5.285	Control telescope at Fordham.	(*B′*)
14,240	77,268	5.426	ESB telescope at ESB with added lead.	(*C*)
14,346	76,273	5.317	Control telescope at Fordham.	(*C′*)

TABLE II. Uncorrected, and corrected, rate ratios for both stations.*

Increase due to less mass, and shorter decay path	1.026±0.004	(*B*/*A*)
Control decrease, due to extraneous variations	0.965±0.004	(*B′*/*A′*)
Corrected value of (*B*/*A*)	1.063±0.006	(I)
Increase due to less mass	1.014±0.005	(*B*/*C*)
Control decrease, due to extraneous variations	0.994±0.005	(*B′*/*C′*)
Corrected value of (*B*/*C*)	1.020±0.007	(II′)
(II′) corrected to carbon equivalent	1.031±0.008	(II)

* Errors indicated are the standard statistical fluctuations.

The ratio N_1/N_2 desired for the calculation of L is, therefore, effected by correcting (I) for the 3.1 percent increase indicated by (II), this value is

$$N_1/N_2 = 1.0314 \pm 0.01.$$

Since $dz = 983$ feet $= 0.2996$ km, the mean life range is given by

$$L = 0.2996 \text{ km}/\log 1.0314 = 9.7 \pm 3 \text{ km},$$

for mesotrons reaching sea level with sufficient momentum to penetrate 20 cm of lead. The statistical error is larger by a factor of two than that given by measurements taken over larger path differentials; for comparable accuracy an excessive amount of time would be required in using the short differential in height afforded for this experiment.

CORRELATIONS OF GROUND MESOTRON INTENSITIES WITH HEIGHT VARIATIONS OF ATMOSPHERIC PRESSURE LEVELS FROM 1000 TO 100 MILLIBARS

Data accumulated by the control telescope from February 19 through June 10, 1946 were used for these correlations with the upper air data obtained from the Buffalo, New York, radiosonde reports. Mesotron intensity readings were taken once per day and were averaged over the whole 24-hour period centered around 21:00 EST. For the most part air data were taken from the midnight balloon ascents; however missing data from the midnight reports were supplied for by taking the noon radiosonde data. In Table III the number of days is indicated for which the noon reports were used.

Barograph records for each day were averaged over the 24-hour interval centered about 21:00 EST; correlation of mesotron variations with barometric variations gave a coefficient of −1.24

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[6] B. Rossi, N. Hilbury, and J. B. Hoag, Phys. Rev. **57**, 461 (1940).

TABLE III. Correlations of mesotron intensities with height variations of various pressure levels of the atmosphere.

Pressure level (mb)	Total days	Noon raob days	Average height ($\bar{z}$) (feet)	Correlation coef. (r)	Decay coef. (β) (km^{-1})
1000	79	10	481.6	-0.014 ± 0.11	-0.008
850	100	10	4757.8	-0.31 ± 0.09	-0.12
700	101	10	9821.2	-0.26 ± 0.09	-0.068
500	97	13	18,252.6	-0.62 ± 0.06	-0.0705
300	96	15	29,905.2	-0.36 ± 0.09	-0.045
200	93	21	38,645.6	-0.43 ± 0.08	-0.050
100	73	44	53,243.6	-0.45 ± 0.09	-0.060
100	56	56	53,339.7	-0.48 ± 0.1	-0.070

percent/in. Hg. Average barometric pressure for the entire period was 29.859 in. Hg, and the daily values of mesotron intensities were corrected to this pressure using the above coefficient.

The radiosonde reports gave directly the heights at which the 1000-, 850-, 700-, 500-, 300-, 200-, and 100-millibar levels occurred; accordingly, these were the barometric levels whose height variations were studied in this investigation. It has been pointed out[3, 5] that the mean life range L can be determined from height variations of mesotron producing levels by the following relation

$$L=-1/[(1/N)(dN/dz)]=-1/\beta,$$

where N = mesotron intensity, z = height of mesotron producing layer, and β = decay coefficient.

In 1941 the author and collaborators[5] made a study similar to this in which only two levels were considered, *viz.*, the heights of the atmospheric "center of gravity" and the height of the 400-mb layer. It is believed that the present study is the first to comprise data extending over the much wider range here considered. The correlation coefficients (r), decay coefficients (β), average heights of pressure levels over the period investigated ($\bar{z}$), the numbers of days for which data were available, and the numbers of days for which noon raob were used, are tabulated in Table III.

DISCUSSION OF CORRELATION RESULTS

As is seen from Table III there is a sharp rise to a maximum value of $r=-0.62$ at the 500-mb level as one considers the various levels of progressively higher altitudes. Beyond the 500-mb level there is a diminution in r which however appears to tend towards a second maximum of -0.45 or -0.48 around the 100-mb level. This is taken as an indication that at least two production levels for mesotrons exist at the altitudes of approximately 5.5 km and 16 km, respectively. These two altitudes are in very good agreement with the altitudes of approximately 6 km and 17 km obtained by Rathgeber[3] by an altogether different approach.

Since the mean life range L can be determined by taking the reciprocal of the decay coefficient, the value $L=14.2\pm1.4$ km is estimated from the decay coefficient obtained from variations of the 500-mb level. Approximately the same value is obtained from the less accurate 100-mb measurements. Assuming the lifetime of the mesotron as 2×10^{-6} sec. the value of $L=14.2$ km is consistent with an effective mesotron spectrum of 2.37×10^{9} ev.

It is believed that this method of correlation analysis offers definite possibilities in the study of the complex phenomena of mesotron production and absorption in the atmosphere. Longer periods of observation should considerably improve the accuracy of the estimate of L, and should also help define more sharply the production levels for mesotrons.

In conclusion, the author wishes to express his appreciation to Professor V. F. Hess for many valuable suggestions and for his continued encouragement throughout this investigation; to Professor W. F. G. Swann for suggesting the first part of this experiment and for furnishing the facilities of the Bartol Research Foundation, Swarthmore, Pennsylvania, in the repair of counters. Space for the upper station was generously furnished through the courtesy of the Empire State, Inc., New York City, Mr. J. H. Tarry being most cooperative by granting much time and assistance in this regard. Radiosonde reports were furnished through the kindness of Mr. Garrett of the La Guardia Field Weather Bureau. Financial aid was granted through the Penrose Fund of the American Philosophical Society of Philadelphia, Pennsylvania.