Physics. — *Penetrating Radiation*. By J. CLAY. (Communicated by Prof. W. J. DE HAAS.)

(Communicated at the meeting of December 17, 1927).

In the following pages the results are communicated of measurements concerning the penetrating (ultra-gamma) rays during the months of February—July 1927 at Bandoeng Java Lat. 6° 45′ S, Long. 107° 16′ E. made at an altitude of 760 meters above the sea-level, and further of measurements at 3024 meters on a mountain-summit and till an altitude of 4300 meters in an aeroplane. The end of these measurements was to ascertain the intensity of the penetrating rays, to measure the absorption of the rays in lead and to trace whether a daily variation exists. Further at the same time the ionisation was measured due to the radio-activity of the ground and of the atmosphere.

§ 1. The two apparatus used for the research were according to KOLHÖRSTER's model made by GÜNTHER and TEGETMEYER. We shall call the two apparatus *A* and *B*. The capacity of *A* is 0.51 cms and that of *B* is 0.61 cms ; the sensitiveness of *A* was 2 volts per scale-division and the maximal tension which could be read, was 350 volts ; for *B* this amounted respectively to 3 volts and 480 volts. Either volume was 4170 cc. The walls of the two apparatus had a thickness of 3 mms of zinc ; their inner surfaces were electrolitically covered with zinc in order to leave the slightest possible residual ionisation in the apparatus due to the radio-active infection of the material.

Initially the measurements were made in the laboratory built of stone up to 4 meters, the rooms of which are covered with eternite, while the roof consists of but a thin layer of iron-wood. However after it had appeared that in the building the ionisation in the electrometers was about 1 I (1 I = 1 ion per cc per sec.) more than in the open field outside the laboratory, all measurements were made out of doors under a small wooden shed of about 6 meters square. As the variation in temperature amounts to at most 12° C. at that place by day and in the night, this was by no means an objection for the measurements, seeing it appeared that the readings of the two apparatus in a thermostat at 30° C. variation in temperature under ionising influence of 1 mgr. of radium at 2 meters, distance did not record any difference at all. Besides it appeared with these measurements that the decrease of volts per sec. for tensions above 100 volts remained constant.

The ionisation due to the presence of 1 mgr. of radium at a distance of

2 meters gave an amount of 166 I fir apparatus A and for apparatus B of 160 I, i.e. EVE's figure for A is $6.6 \,.\, 10^{9}$ ions cm^{-1} gr^{-1} $\mathrm{sec.}^{-1}$ and for B $6.4 \,.\, 10^{9}$ ions.

§ 2. *Earth-radiation.* For a determination of the ionisation due to the gamma-rays of the earth's surface, first one of the electrometers was placed on the earth and the ionisation measured, next on a sheet of lead of a thickness of 10 cms and surrounded by lead in such a way, that no gamma-rays of the earth could reach the apparatus. With electrometer A we found 6.99 I on the earth and 5.55 I on lead, with electrometer B 5.78 I and 4.38 I. Accordingly for the former the earth-radiation yielded 1.44 I and for the latter 1.40 I. Seeing this radiation had penetrated 3 mms of zinc, the amount for the earth-radiation directly above the surface of the earth in the open air may be fixed at 1.55 I.

The values of the ionisation on the surface of the earth were obtained from an average of 7 values with an average deviation of respectively 0.17 and 0.07 I, those on the lead for A from 9 values with an average deviation of 0.15 I and for B from 12 values with an average deviation of 0.07 I.

§ 3. *Atmospheric radiation.* The ionisation due to the emanation in the atmosphere could be neglected. In due correspondence with a former determination of the amount of emanation [1]), I found in new determinations according to the condensation-method by liquid air, that the value lies between 10^{-18} and 10^{-19} CURIE, which causes an ionisation in the electrometers of at most 0.01 I.

§ 4. *Residual rays.* In order to measure the residual radiation of the apparatus, they were surrounded on all sides by a lead-armouring of a thickness of 48 cms. It appeared that in this armouring the residual radiation was 4.28 I for A and 3.03 I for B. From this it follows, that the penetrating radiation as far as it is absorbed by 48 cms of lead, is 1.27 I according to apparatus A and 1.35 I according to B, two values, which when we bear in mind that capacity and sensitiveness of the two apparatus differ, correspond beautifully.

From this it follows that the two ionising factors in the open air must together amount to about 3 I. Seeing that prolonged registering has taught us, that the number of small ions, present in the atmosphere amounts to ca 600, it follows for the constant factor of decay (Verschwindungskonstante) according to SCHWEIDLER [2]), in case of equilibrium: $\beta' = \frac{q}{n} = \frac{3}{600} = 5.10^{-3}$.

For this figure SCHWEIDLER gives for INNSBRÜCK: $22 \,.\, 10^{-3}$ and POWER [3]) for MINNESOTA, U. S.: $6.1 \,.\, 10^{-3}$.

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[1]) Proc. Roy. Acad. Amsterdam **28** p. 431 1925.

[2]) E. SCHWEIDLER, Wiener Ber. **133**, p. 23, 1924.

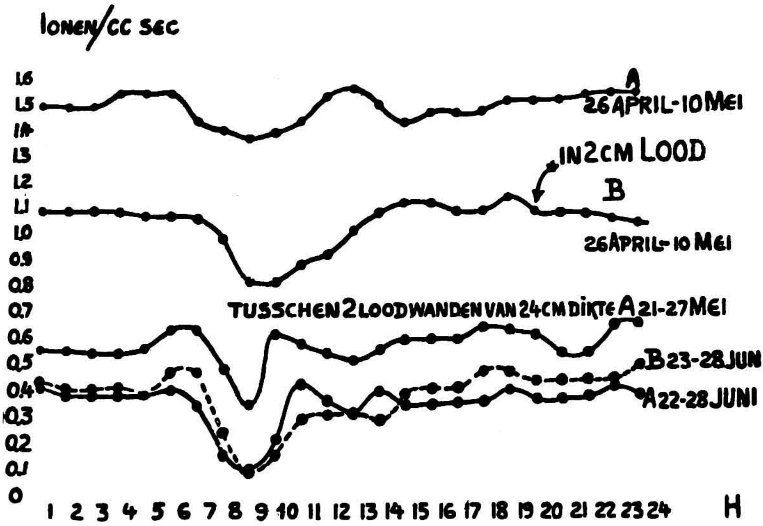
[3]) A. D. POWER, Journal Franklin Inst. **196**, p. 327, 1923.

This proves that the result obtained here, is reliable.

Now it should be at once observed, that identical values are not always found for the intensity of the residual radiation. Owing to the breaking of the tube with hygroscopic substance of the apparatus *A* this apparatus was open for a short time and after that we found 4.87 I for the radiation within a lead-armouring of a thickness of 48 cms. Further for apparatus *B* after the test for temperature-coefficient in which some change of air may have occurred, 3.44 I was found as the value within 48 cms of lead. This change was taken into account in all subsequent measurements.

§ 5. *Variation of the radiation-intensity.* In order to trace whether a daily variation existed, two series of measurements were made. Apparatus *A* was mounted on a layer of 10 cms of lead, surrounded on all sides by a layer of 12 cms of lead, so that the rays of the earth could not reach the apparatus. The apparatus *B* was mounted in a similar way, but surrounded on all sides by an additional layer of 2 cms of lead. The reduction of the charge was measured every 3 to 4 hours and during the latter part of the night usually during a period of 6 to 7 hours. It had already appeared from measurings during a shorter period, that on the whole the ionisation remains very constant, except during the morning-hours from 7 to 9 o'clock.

The averages were taken from the observations during a fortnight between April 13 and May 10 and from these averages we derive the two



Ionen/cc sec = Ions/cc sec; 26 April—10 Mei = April 26—May 10; in 2 cm lood = in 2 cms of lead; tusschen 2 loodwanden van 24 cm dikte A 21—27 Mei = between 2 lead-walls of a thickness of 24 cms A May 21—27; B 23—28 Juni = B June 23—28; A 22—28 Juni = A June 22—28.

Fig. 1. Variation of the penetrating rays during the day. Electrometer unprotected, in lead and between lead-walls.

curves given in fig. 1. It is evident from the two curves, that there is a variation in the radiation with a minimum at ca 8 o'clock in the morning.

A second measurement was made as follows. The electrometer *A* was put on a sheet of lead of a thickness of 10 cms, protected on both sides by two lead-walls of a thickness of 24 cms, a length of 75 cms and a height of 70 cms, arranged in the direction of the meridian.

The electrometer was read during 6 days with intervals from 2 to 4 hours. The results of these observations are likewise given in fig. 1. The upper of these two curves gives the observations from May 21 to May 30. The lower curve gives the observations from June 22 to June 28. These two curves give another distinct minimum and this has not shifted with siderial time. Moreover the intensity (much less now, as only about a fourth part of the radiation could reach the apparatus) has been modified again between May and June and this variation is apparently identical for the whole sky. This result also evidently tends in the same direction.

A similar minimum was also found with apparatus *B*, placed between the lead-walls during the days from June 23 to 28.

An important observation should however be made. Taking the average values of different rays, we find for intensity of the penetrating rays with apparatus *A* and *B* on various days the following values, expressed in I :

	A	*B*	*B* in 2 cms of lead
Beginning of March	1.27	1.35	
2 May	1.47		0.97
4 „	1.43		0.95
7 „	1.57		1.20
9 „	1.63		1.23
10 „	1.61		1.17
31 „	1.86	1.75	

The observations of May 2 up to and including May 10 were made with both apparatus constantly under identical circumstances, whilst the apparatus stood on different sheets of lead at ca 4 meters' distance from each other. Every value given in the table is the average computed for a whole day. There are no striking mutual deviations in these values in the course of the day.

The values of May 31 are found after the lead-pile was reconstructed. Here therefore is a change of circumstances, though at present there is no occasion to suppose, that this has exercised any influence.

The variation between May 2 and May 10 renders it improbable, that the source of the rays must be found in celestial bodies. For, if this radiation should be generated by definite, limited parts of the sky, a distinct difference should arise between the periods, in which the rays reach the electrometer and those in which they are checked by protection. Now it might be assumed, that the rays were diffused in such a way, that the direction has absolutely got lost at the surface of the earth, as for instance in a dense haze the sunlight grows so diffuse that the direction of the sunbeams cannot be perceived any more. This however is in opposition with COMPTON'S hypothesis of the scattering, in which it appears that the secondary rays with rays of a very short wave-length lie within a very narrow cone, the axis of which lies in the direction of the primary rays.

Another possibility is that the rays should be emitted by a great many nebulae or celestial bodies, scattered over the entire sky. In that case it is possible that in the course of the day there is hardly any variation in the intensity. But in that case the observation from May 2 to May 31 indicates, that a change of intensity may arise, which change is about equally great *in all directions*. That this change should occur simultaneously in all radiating celestial bodies, cannot possibly be assumed.

If therefore the observed change is actually due to the penetrating radiation from above, as must be accepted without doubt, *it cannot but be generated in the higher regions of the atmosphere*. This supposition is confirmed by the observations, given in the 3 lower curves of fig. 1. For, indeed, it also appears from these observations, that after a month the distinct minimum is found in the same place, while the entire value over all the twenty-four hours has increased with an equal amount. Here too there is an identical change in all directions. It is clear, that also the position of the milky way had no influence on the intensity of the radiation.

§ 6. *Number of ions, conductivity, earth-charge*. The minimum that appears to occur at Bandoeng at about 8 o'clock in the morning in the intensity of the penetrating radiation, must of course make itself felt in the number of ions, found in the atmosphere. This will also amount to a minimum at that point of time. Together with this the conductivity of the air will be reduced. And finally this will influence the earth charge, which will be temporarily increased by it.

These magnitudes were being recorded at Bandoeng for over a year and the curves indicating the daily variations have been jointly given in fig. 2 in a monthly average. The details of these measurements were previously communicated [1]). The measurements over the whole year will shortly be published. The upper, solid lines in figure 2 denote the conductivity, the value of which has been given to the right of the graph. The two solid lines lower down in the figure, give the number of recorded ions. The value of these per cc has been denoted to the left of the graph.

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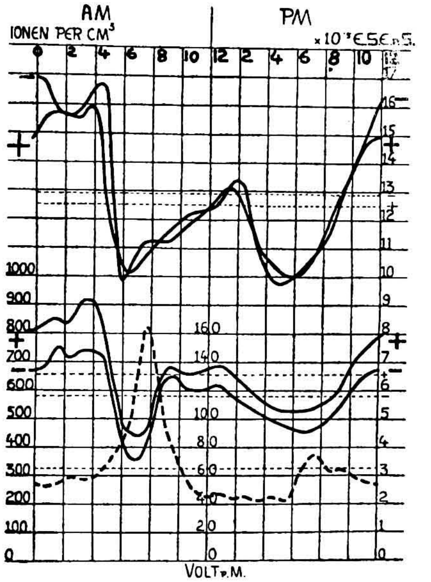
[1]) J. CLAY, Record of electrical conductivity and content of ions of the atmosphere. Proc. Nat. Sc. Congr. Weltevreden 1926, p. 128.

In these curves the strong minimum at about halp past seven is in evident accordance with the minimum found for the penetrating rays. Lastly the dotted curve at the foot of the figure gives the potential gradient in Volts per meter.



Ionen per cm² = ions per cc.

Figure 2. Conductivity and number of ions in the atmosphere. Potential gradient.

The scale of the graph has been drawn in the middle. The maximum is particularly clear in this line.

Finally it may be observed that the course of these curves is fairly identical over the whole year. This is connected with the uniform atmospheric condition during the whole year.

§ 7. *Absorption.* With both apparatus absorption measurements were made. The electrometers were placed on a sheet of lead of a thickness of 10 cms and surrounded at the sides and at the top by a layer of lead of successively 3.5, 7, 10.5, 14, 24, 36 and 48 cms. This lead had been employed in the boilers of stearine-factories for some years, removed, fused into loaves of about 25 Kgrs and next planed off to equal dimensions. The results of these measurements are found in figure 3. The solid line gives the series of measurements with apparatus *A*, in which the average of a day is taken for every value, whilst the dotted line renders the series of measurements made with *B* between May 22 and June 11, where every value represents the average of two or more days.

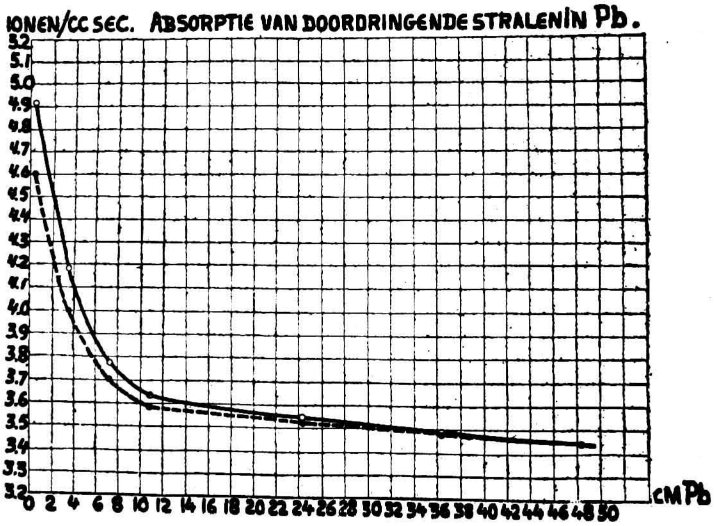
On the whole the mutual deviations of the measurements obtained with apparatus *B* are slighter than those with apparatus *A*. Of the 109 observations made with *B* during these measurements, the deviation of the averages as calculated separately for each absorption-layer, amounts to 0.078 I.

The deviations within thick lead-armourings are as a rule still slighter, which is also connected with the fact that the measurings were continued over longer periods, e.g. from 4 to 6 hours. So the average deviation of the average was but 0.02 I in a lead-armouring of 48 cms.

In order to compare the measurements with the apparatus *A* with those made with *B*, the value found was every where reduced with an amount of 1.19 I, which made the amount of the ionisation in the 48 cm. lead-armouring identical for apparatus *A* and *B*. (In a previous determination (see § 4) 1.25 I was found as the difference in residual radiation between *A* and *B*).

From the course of the curves it is evident, that we have to deal with a mixture of at least two kinds of rays, as was also stated by Millican and Cameron 1). For this reason two absorption-coefficients were computed, one for the absorption by layers up to 10 cms of lead, and one for the absorption by layers from 24 to 48 cms of lead. The values found are: $\mu_1 = 0.198$ cm^{-1} and $\mu_2 = 0.045$ cm^{-1}.

The mass-absorption-coefficients, usually given, are: $\frac{\mu_1}{\varrho} = 17.10^{-3}$ cm^{-1} and $\frac{\mu_2}{\varrho} = 4.10^{-3}$ cm^{-1}. These values are greater than those found by Millican and Cameron. For water they found a mass-absorption-coefficient of $3.0 \cdot 10^{-3}$ cm^{-1} and of $1.8 \cdot 10^{-3}$ cm^{-1}. If we assume, that



ionen = ions; Absorptie van doordringende stralen in P_b = Absorption of penetrating rays in P_b

Figure 3. Absorption of the penetrating rays through lead.

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1) R. A. Millican and G. Harvey Cameron, Phys. Rev. Vol. **28**, p. 851, 1926.

the scattering (the proper direct absorption is of secondary importance in these short waves) depends on the number of electrons present in the substance per volume-unit, the value must be multiplied with the ratio of the atomic number divided by the atomic weight to enable us to compare with the diffusion in lead ; the figures for water therefore should have to be multiplied by 0.72, so that the mass-absorption-coefficient for lead should become in Millican : $2.2 \,.\, 10^{-3}$ cm^{-1} and $1.3 \,.\, 10^{-3}$ cm^{-1}. These values have been obtained at an altitude of 760 meters.

In his synoptic paper Büttner 1) gives for his measurements for lead the values lying between $12.4 \,.\, 10^{-3}$ cm^{-1} and $3.4 \,.\, 10^{-3}$ cm^{-1}.

For the hardest rays Hoffmann and Steinke 2) found still slighter values for the absorption in lead, when they had previously been purified by a layer of lead from the soft part due to scattering.

Hoffmann found : $\frac{\mu}{\varrho} = 0.41 \,.\, 10^{-3}$ cm^{-1} in layers from 20 to 40 cms of lead.

Steinke gives: $4.5 \,.\, 10^{-3} < \frac{\mu}{\varrho} < 7.0 \,.\, 10^{-3}$ for layers from 0 to 10 cms of lead.

$0.40 \,.\, 10^{-3} < \frac{\mu}{\varrho} < 1.0 \,.\, 10^{-3}$ for layers from 20 to 60 cms of lead.

For comparison it may serve, that the gamma-rays of radium C, which have a wave-length of 0.022 Angström, have for lead a mass-absorption, coefficient : $\frac{\mu}{\varrho} = 46 \,.\, 10^{-3}$ cm^{-1}, from which it appears, that also the softer component of the penetrating radiation is considerably harder than the gamma-rays of radium C.

For a determination of the wave-length by means of the absorption-coefficient we can use Compton's theory for the scattering of X-rays, if we may assume that the very short wave-lengths with which we have to deal here, the phenomenon is of the same nature as for X-rays. According to Compton the scattering will predominate over the so-called absorption with short wave-lengths and the relation between absorption and wave-length may be expressed by the formula :

$$\sigma = \sigma_0 \frac{1}{1 + 2\alpha}$$

in which σ_0 represents the scattering according to the classic theory of J. J. Thomson and

$$\alpha = \frac{h}{cm\lambda} = \frac{\Lambda}{\lambda} = \frac{0{,}0242}{\lambda}$$

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1) K. Büttner, Z. f. Geophysik **3**, p. 161, 1927.

2) E. Steinke, Z. f. Physik. **42**, p. 601, 1927.

The relation will presumably be better rendered by DIRAC's [1]) formula, which is reduced for the very short wave-lengths to [2]) :

$$\sigma = \sigma_0 \frac{3}{4\,a}.$$

For the short wave-lengths with which we have to deal here, the difference between this formula and COMPTON's is evident, which is essential as soon as the cause of the radiation is sought for.

We can now compute the wave-length from the formula :

$$\frac{\mu}{\varrho} = \sigma_0 \frac{ZN}{A} \cdot \frac{3}{4a}.$$

Here $\sigma_0 = 6.60 \,.\, 10^{-25}$, as has appeared from the measurements concerning the scattering of the X-rays. Z is the atomic number. $N = 6.06 \,.\, 10^{23}$, the AVOGADRO-constant. A is the atomic weight, ϱ the density. For lead is

$$\mu = 1{,}80 \,.\, \frac{3}{4}\frac{\lambda}{0{,}0242} = 60\,\lambda.$$

therefore :

$\lambda_1 = 3\,X$ units ($X = 10^{-11}$ cms), according to COMPTON $\lambda_1 = 6\,X$.
$\lambda_2 = 0.8\,X$ according to COMPTON's formula $\lambda_2 = 1.3\,X$.

§ 8. *Measurements at a greater altitude.* Measurements were made with the apparatus on two different days with the aid of an aeroplane kindly put at our disposal by the Military Air-department of Bandoeng. Apparatus A was unprotected during these measurements, apparatus B was protected by a lead-armouring of a thickness of 2 cms. On April 7 measurements were made, whilst each time the machine was kept at the same level for half an hour. During the second flight on June 15 the machine was constantly kept at a level of 3000 meters for an hour and 20 minutes. This latter was done because on May 13 and 14 measurements had been taken on the summit of the extinct volcano the Pangerango near Buitenzorg, the summit of which is 3024 meters high and because the values bound there did not conform with the observations in the air by aeroplane at the same level. During the second flight however the observation during the first flight was corroborated.

In the table on the next page the values have been given of the intensity of the radiation after being reduced by the ionisation of earth-radiation as found in the vicinity of the laboratory and the residual radiation.

On this subject various remarks can be made. Firstly it is strange that the radiation-intensity at an altitude of 1000 and 2000 meters is less than

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[1]) P. A. M. DIRAC, Proc. Roy. Soc. A. **111**, p. 422, 1926.

[2]) H. A. KRAMERS kindly pointed this out to me.

Altitude in meters	Apparatus *A* unprojected		Apparatus *B* in 2 cms of lead	
	April 7	June 15	April 7	June 15
700	1.67		2.16	
1000	0.95		4.01	
2000	0.80		1.92	
3000	4.73	4.84	3.63	3.77
4000	10.95		6.99	
4300	14.05			

at an altitude of 700 meters on the ground. We get a strong impression that there is a secondary radiation, also radiated upwards by the earth, or that the earth also emits a penetrating radiation. Secondly the values for the apparatus placed in lead are also peculiar at an altitude of 2000 meters, the more so, as the values found during the second flight at 3000 meters, which are especially trustworthy, because the machine continued at the same altitude so long, entirely corroborate the first values. New experiments must necessarily be made to explain this behaviour in the lower regions of the atmosphere. It might be, that we have to deal here with an increase of ionisation owing to a check on the swift electrons, which may be produced by the scattering of the primary rays. V. Hess [1]) had searched for this effect, but all his experiments have had a negative result, just as Büttner's [2]), nor did I find this increase in other experiments with 0.5 and 1 cm. of armouring. For the rest the values observed at 3000 meters correspond very well with V. Hess's, the discoverer of the rays, in 1911/1913 [3]), Kolhörster's in 1913, Millican's in 1923 and Büttner's in 1927. From the difference of the ionisation, found in the two apparatus, we can compute for the absorption in 2 cms of lead an absorption-coefficient : $\mu = 0.13$ at 3000 meters.

The second series of measurements was made at Tjibodas at the foot of the Pangerango at 1400 meters and on the summit at an altitude of 3024 meters. By means of a sheet of lead of 3 cms under the apparatus the earth-radiation was determined in the two places. Assuming the absorption-coefficient to be identical with that of the gamma-rays of *Ra C*, we found 0.83 I for the earth-radiation at an altitude of 1400 meters and 0.88 I on

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[1]) V. F. Hess, Sitzungsberichte der Ak. d. Wiss. Wien, p. 634, 1927.

[2]) K. Büttner, Zeitschrift f. Geophysik 3, p. 883, 1927.

[3]) Verg. V. F. Hess, Die elektrische Leitfähigkeit der Atmosphäre und ihre Ursachen 1926, p. 115 and following.

the summit. This is uncommonly little, but easily explained by the young-volcanic character of the mountain.

At Tjibodas 4 observations were made with apparatus *A* before climbing the mountain, which yielded an average of 1.51 I with an average deviation of 0.03 I and after the descent 7 observations were made, yielding an average of 1.50 I with an average deviation of 0.16 I. On the summit 13 observations were made during 36 hours, yielding an average of 3.28 I with a deviation of 0.32 I, i.e. the variations found here were greater than those regularly occurring at Bandoeng, but amounted to 20 % at most.

With apparatus *B* 4 measurements were made at 1400 meters, yielding a value of 1.30 I with an average deviation of 0.13 I, whilst on the Pangerango with apparatus *B* 3.15 I was found due to the penetrating radiation with an average deviation of 0.10 I.

In an armouring of 3 cms of lead 1.03 I was found with the same apparatus at 1400 meters and 2.88 I at 3024 meters. From these values combined with the data for apparatus *A* an absorption-coefficient was computed of $\mu = 0.10$ at 1400 meters and $\mu = 0.095$ at 3024 meters.

At the same altitude in the flying-machine there were observed 1.56 I more than on the mountain-top. Of course it is possible, that the intensity is changed during those various days, though it is to be doubted that the amount would be so high. With subsequent measurements it will be necessary, that regular control-measurements are made at a definite station. Finally it should be observed, that the minimum ever present on the Bandoeng plateau was *not* perceived here. On another side of the mountain at 1230 meters from an average of 5 observations 1.23 I was found for the penetrating radiation. That the value in this case and as mentioned above, at Tjibodas at 1400 meters was found to be so slight, will doubtlessly be attributable to the protection of the mountain, which intercepts the radiation of a considerable part of the sky.

§ 9. *Observations in other places.* In order to determine to how much the residual rays of the apparatus *B* precisely amounted, I took it to Europe for the purpose of making a determination in a rock-salt-mine, which might be expected to be quite free from radiation.

On the way a series of measurements was made on the boat-deck of the steamer *Slamat*, about 14 meters above the sea-level, from the Red Sea to and partly including the Mediterranean. It is a remarkable fact, that an increasing value of the radiation was stated, which may be partially the result of increased gammaradiation of the emanation in the atmosphere.

It might have been that the residual radiation in the apparatus increased. As will presently appear this is however unlikely.

On Oct. 31 and Nov. 11 I had the privilege of collaborating with W. KOLHÖRSTER in the Berlepsch Schacht of the Stassfürter-salt-mine. On the ground over the mine an ionisation was found of successively 7.95 I, 7.98 I, and 7.99 I and after the measurements in the mine of 8.14 I. In the mine

400 M. below the earths surface surrounded by a layer of rock-salt of 80 to 100 meters we found 4.90 I and 4.93 I in the large „Festsahl" and in a part, where there was some salt of potassium in the vicinity, we found

Date	Time	Place	Ionisation + residual radiation
23 July '27	14 h. 3 m.—17 h. 7 m.	Red Sea	5.17
	17 h. 7 m.—19 h. 27 m.	"	4.83
	19 h. 27 m.—24 h.	"	5.22
24 July	0 h. — 5 h. 26 m.	"	5.82
	5 h. 16 m.— 8 h. 40 m.	"	5.98
	8 h. 52 m.—14 h. 28 m.	Bay of Suez	6.68
	14 h. 29 m.—17 h. 42 m.	"	6.18
	17 h. 43 m.—19 h. 42 m.	Canal of Suez	6.21
	19 h. 42 m.—24 h.	"	6.50
25 July	0 h. — 3 h. 55 m.	"	6.77
	11 h. 58 m.—14 h. 54 m.	Mediterranean	6.56
	17 h. 12 m.—18 h. 49 m.	"	6.56
26 July	8 h. 38 m.—12 h. 9 m.	"	7.20
	12 h. 11 m.—16 h. 31 m.	"	7.16
	16 h. 31 m.—19 h. 7 m.	"	7.38
27 July	8 h. 33 m.—10 h. 52 m.	"	7.00
	10 h. 52 m.—14 h. 16 m.	"	7.62
	14 h. 16 m.—17 h. 5 m.	"	7.14
	17 h. 15 m.—20 h. 37 m.	"	7.42
28 July	8 h. 26 m.—11 h. 13 m.	"	7.75
	11 h. 13 m.—13 h. 10 m.	"	7.72
	13 h. 10 m.—14 h. 50 m.	"	8.03

5.13 I. Seeing formerly at Bandoeng in a lead-armouring of 48 cms 3.44 I was found, there were two possibilities, either the residual radiation of the electrometer had increased (the apparatus had never been open during any measurement), or that the rock-salt was not free from radiation. Lucky circumstances however enabled me to exclude the first possibility as highly improbably.

In Prof. V. HESS's laboratory at Graz Prof. HESS kindly gave me the opportunity of making a measurement in an iron-armouring of a thickness of 8 cms, through which according to Prof. HESS' experience the gamma-rays of radium do not penetrate.

In this armour on Nov. 10 I found the values 5.37 I, 5.4 I, 5.25 I and 5.20 I, averagely 5.31 I. Seeing that according to Prof. HESS the value of the penetrating radiation at that place should be about 1.9 I, the residual radiation of the apparatus *B* would have a value of about 3.4 I, which is in perfect accordance with the values found at Bandoeng. From this it would follow, that the value of the radiation has gradually increased with the geographical latitude, a result that may correspond with former expectations of various investigators, who searched for the origin of the radiation in the higher regions of the atmosphere [1]).

But besides this proves that the rock-salt in Stassfürt is not free from radiation, but that there still exists an ionisation of 1.5 I. KOLHÖRSTER's measurements may also be expected to give a decisive answer to that question.

Bosscha Lab. Bandoeng, 1927.

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[1]) V. F. HESS, Die elektrische Leitfähigkeit der Atmosphäre und ihre Ursachen. 1926, p. 123 and following.