A candidate desiring to offer any of the subjects 42–54 or 59 must produce evidence satisfactory to the Commissioners of laboratory training in an institution of university rank. For (40) astronomy, (41) statistics, (55) geography, (56) physical anthropology, etc., and (58) agriculture, other equivalent training will be required. There will be no laboratory test as a part of the examination.

Extra Numerum.

Candidates may take, in addition to the above, one of the translation papers of Section A in a language not already taken by them in that section, not more than one of the Scandinavian languages, nor more than one of the three, Spanish, Italian, Portuguese, being offered by the same candidate; for this 100 marks will be awarded, not included in the 800 of Section A or the 1000 of Section B.

RADIO-ACTIVE HALOS.[1]

II.

WE shall now see that the thorium halo follows faithfully the same laws of development as the uranium halo, whatever we may assume as to the nature of these laws.

By plotting the seven α-ray curves of ionisation which must contribute to the formation of a halo in the medium surrounding a particle containing the parent element thorium, and then, as before, adding up the ordinates, we get for the total ionisation responsible for the thorium halo the next curve (Fig. 6).

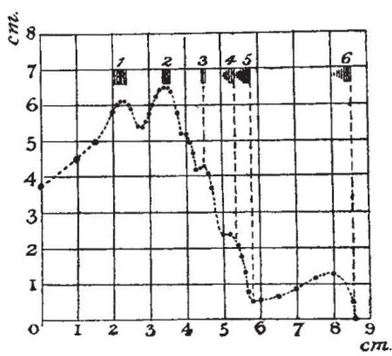

FIG. 6.—Integral curve for thorium halo.

Note that the single conspicuous maximum displayed by the corresponding curve for the uranium halo is now replaced by two maxima, the one which is nearer the centre being a little the lower. Beyond these two maxima the curve descends steeply with two excrescences before the minimum of ionisation is reached. Then the curve reascends to the low maximum due to ThC_1.

Now, the first beginning of the thorium halo shows two rings, and the radial dimensions of these rings are in good agreement with the positions of the two maxima of the curve. The inner ring has not been found alone. Next we find the space within and around these rings growing darker, accompanied by the early appearance of the outer ring due to ThC_1, just as in the case of the uranium halo we observe the early appearance of the ring due to RaC_1. The next stage, so far certainly observed, shows the loss of the internal features, the resulting halo exhibiting much the same appearance as the uranium halo in the final stage of development.

Above the ionisation curve for the thorium halo I have marked the several features of the halo. The agreement of the observed with the theoretical features is even closer than in the case of the uranium halo.

When we consider the successive steps in the genesis of the radio-active halo, which I have now laid before you, we can only come to the conclusion that some cause exists which tends to accentuate the effects going on in the outer regions of the halo. Could we assign a cause for the strengthening of the outer effects of ionisation, or, what comes to the same thing, for the weakening of the inner effects, every feature of the halo becomes explained by the curve of integral ionisation—that is, by the curve which simply sums the effects of the several Bragg curves. We would then find an explanation of the appearance of successive rings and of the appearance of the effects of the extreme or limiting ray at such an early stage of development.

If we assume that the process which results in the formation of a halo under the influence of the α ray is essentially similar in nature to that which is responsible for the photographic image under the stimulus of light, the desired explanation of the weakening of the inner features is forthcoming. For the phenomenon of reversal or of solarisation, well known to photographers, would assuredly lead to the weakening of the inner parts of the image. The repetition of stimuli at or near the same spôt is necessarily more marked in the inner than in the outer parts of the halo, and the ionisation accumulating in the region traversed by the external limiting α rays is to a large extent exempt from the effects of repetition.

Now there are features in common between the halo image and the photographic image. Both are brought about by ionisation in a sensitive medium. There is so much indirect evidence for this view that we can scarcely doubt its truth. The salts of iron in many forms have been found to be photographically sensitive. In the photochemistry of chlorophyll they appear to play a fundamental part in Nature. Again, we may interpret the fact that the halo may be obliterated by heat, as proof of instability. Finally, the photographic plate is affected by the α ray in a manner not readily distinguished from that due to light.

Halos have been found which show all the appearance of reversal. In them we find the penumbra replaced by a band which is darker than the region lying within. Normal halos in its neighbourhood, by contrast, well show the peculiar change which affects the reversed halo. It is the negative of a halo. What is this appearance due to, if not to reversal? The effect must arise from very intense ionisation. The reversal has cleared the inner pupil more or less, but the repetition of stimuli has not been sufficient to affect the penumbra in the same manner. If these views are correct we may claim to know something of the nature of the phenomena which lead to the building up of the halo. We may regard the radio-active nucleus as emitting, for countless ages, radiations which slowly act, according to the laws affecting the latent photographic image, upon the surrounding medium. We must suppose the electric charge upon the α ray to affect the stability of the sensitive mineral, ionising the constituent atomic systems, and, finally, producing stresses and, possibly displacements, which are revealed in the increased colour absorption.

Hitherto I have more especially dwelt upon the points of agreement between the observed and the theoretical halo. I venture to think that the agreement sets beyond any doubt not only the radio-active origin, but also the general mode of development of halos. I shall now refer to some details in which the observed halo is not in perfect agreement with the curve of ionisation.

In the case of the thorium halo the measured dimensions of the halo are in very perfect accord with the ionisation curve. The agreement seems generally as perfect as we could expect. There is, however, a very small appearance of misfit in the location of the first ring. The estimates I have made of the radius of

[1] Discourse delivered at the Royal Institution on Friday, May 11, by Prof. J. Joly, F.R.S. Continued from p. 458.

this first ring have consistently shown a small deficit. Small as it is, we should not ignore it. For there is some reason to suspect that our knowledge of the range of the α ray of thorium itself, which is largely responsible for the position of the first maximum upon the curve, is incomplete. The facts appear to show that the accepted range of the ray from thorium is too large. The evidence for this is both interesting and important.

Rutherford long ago pointed out that there appeared to exist a connection between the range of an α ray and the duration of life of the element from which it originates. The speed of the α particle seemed to be greater the shorter the period of transformation. Geiger and Nutall re-investigated the accepted ranges of the α rays of the radio-active elements, and established Rutherford's inference. Plotting the logarithms of the range and of the period of transformation against each other, they ascertained that for each family of elements there is a straight line along which the points found for the several α rays lie, and—in nearly every case—lie with astonishing accuracy. There is only one notable discrepancy. That exception is in the case of the range of the α ray from thorium itself. It is a few per cent. too great according to the observations. It is also, admittedly, the most difficult to measure with accuracy.

Translated into the distances obtaining in the halo, the few per cent. are almost beyond the limits of accuracy which may be fairly claimed. But the evidence for the slight misfit is based on many observations and may be significant.

In the case of the uranium halo there is also a discrepancy between the curve and the observations as regards the position of the first ring; but the magnitude of the discrepancy is more considerable than the misfit referred to above in the case of the thorium halo. And here we have no reason to throw the blame on any error in the accepted value of the ranges of the rays of U_1 and U_2. The curve of ionisation due to the α rays of these chemically inseparable elements has been investigated by Geiger and Nutall. The results obtained are explained on the assumption that U_1 has a range of 2·5 cm. and U_2 a range of 2·9 cm. in air. And these determinations accurately fit the logarithmic curve. The position of the maximum on the halo-ionisation curve is mainly determined by these results.

Careful measurements of the first ring of the uranium halo reveal this small but definite discordance between the radius of the ring and the position of the maximum of the curve. It will be seen that the section of the ring—the feature numbered 1 in Fig. 3—does not lie accurately above the centre of the maximum. The ring has a radius which is distinctly too great. That the ring essentially corresponds with the first great maximum of the curve seems beyond doubt. We find no other record of this maximum. There seems no apparent escape from the conclusion that the ring which is so largely due to the rays from U_1 and U_2 has been formed by rays of greater range than the average range of the rays now emitted by these elements.

The granite in which this halo-ring has been measured is very ancient, certainly not younger than the Devonian period. Similar rings, but not so sharp and easily measured, have been found in the Carboniferous granite of Cornwall. In younger granites I have not succeeded in finding them. It would be important to measure this ring in the younger granites, supposing they have been formed in these rocks. Such measurements would make quite clear whether or not the abnormal dimension of this first ring is really due to the former existence of a longer average range of the rays responsible. If the misfit of the first ring proves to be inexplicable in any deficiency of our knowledge of the ranges of the uranium isotopes, and especially if we are able to get evidence that it is confined to the more ancient rocks, then it will be difficult to escape the direct conclusion that, however brought about, there was a former greater range of the α ray of the parent element of the uranium family.

There is a certain temptation to accept such a conclusion, for there is a strange contradiction in the evidence advanced for the duration of geological time. The conclusion that the halo reveals a former greater range for the α ray from U_1 carries with it the former more rapid decay of that element. All the difficulties and contradictions respecting the age vanish if this indeed occurred. It will only require a few words to state the present position of the matter.

From measurements of the rates of denudative processes at the earth's surface, and of the quantities accumulated, the evidence is, with wonderful consistency, in favour of a period of about 100 millions of years having elapsed since those processes came into existence. By making certain assumptions some 150 millions of years might be claimed, and even, not inconceivably, somewhat more. What other evidence have we? The only major limit which astronomy appears to give us would be in favour of an age even less than 100 millions of years. I refer to the duration of solar heat. It is quite certain that the earth was bathed in abundant sunshine even in Cambrian times; but solar heat of the present intensity cannot be accounted for on any known source of supply for 100 millions of years. From lunar theory we do not seem able to get a major limit. We must remember that we are not discussing the age of the earth as an astronomical unit. The geological age is the period of denudation only. Well, then, a generation ago very brilliant work was done by Kelvin on the period since the solidification of the surface rocks. But the thermal data involved became invalidated in the light of Strutt's discovery that heat-producing radio-active elements exist all over the earth's crust.

But if radio-active science in this way has closed one avenue of approach to the age problem, it has opened up another. Rutherford pointed out that the accumulation of radio-active products of decay in ancient rocks and minerals should afford a measure of the age in much the same manner as, from the amount of sand which has fallen through, we compute time by the hour-glass. In this connection Strutt's work on the amount of helium accumulated in materials of various geological ages will ever be memorable. The amount of accumulated lead, however, possesses, in some respects, less liability to error. The measurement of the ratio of the quantity of lead to the quantity of parent radio-active element in the case of uranium has occupied the attention of several investigators. The conclusion as regards the accumulation of lead in uranium bearing minerals seems to be—although not without conflicting evidence—that the earth's geological age is not less than some 1500 millions of years.

Now, while we must admit the possibility of considerable variations in the rate of denudation over the past, yet the statement that the rivers are now pouring some ten times as much dissolved matter into, and transmitting some ten times as much sediment to, the ocean as they did in past times is, I think, quite inadmissible. All efforts to explain so extraordinary an increase—whether we suppose it to be temporary or permanent—have so far failed.

But the uranium series of radio-active elements is not the only one available in the application of Rutherford's method of computing the age. There is quite as good evidence that the thorium series ends in an isotope of lead as there is for the same conclusion respecting the uranium series.

Now, in dealing with the atomic weight of the lead found in Ceylon thorite, Prof. Soddy recently carried out, on a large scale, a very careful chemical analysis of this mineral, and determined the quantity of lead present. When we calculate, on the basis of his results, the age of the mineral, we get about 140 millions of years. The rocks to which this determination applies are very ancient—certainly pre-Cambrian. The result is, therefore, in good agreement with the conclusion derived from denudation. Is this a mere coincidence?

Before this recent result it was known that the indications of thorium-derived lead were opposed to those of uranium-derived lead, and those who upheld the longer age urged that the lead derived from thorium must be unstable, and must turn into something else over geological time. But the view that thorium lead is not permanent is one beset with difficulties.

From this we see that the uranium and the thorium families of elements give, at the present time, contradictory evidence respecting the age of the earth. The latter apparently agrees in a remarkable manner with the indications of the surface changes of the globe; the former does not. And now the measurements of the uranium halo admit of the interpretation that they indicate the failure of uranium-derived lead as a true indicator of geological time. For if the range of U_1 was, indeed, in remote times longer than it now is, then we must suppose that its rate of decay was at that period faster than it is to-day. Or we may suppose that, however derived, in remote times relatively short-lived uranium isotopes existed which have died out during geological time. I am far from contending that this view is free from difficulties. On the other hand, our ignorance of the mode of origin of radio-activity and of its possibilities is very considerable.

If we have to admit that the evidence of the halo on the age problem is not yet complete, we can refer to a still more important matter upon which the testimony of the halo admits of no uncertainty. Until the radio-active origin of halos was ascertained it was impossible to pronounce on how far, in remote periods of earth-history, radio-activity might have affected the chemical elements. Thus it would have been a quite allowable speculation to suppose many of the elements to have been derived as end-products of radio-active families the activity of which has only comparatively recently become extinct. The halo enables a very general answer to be given to such speculations. A substance such as brown mica—and this is one of the most widely diffused of rock minerals—is sensitive to α radiation, and integrates its effects with the same certainty as the photosensitive plate integrates the effects of light. A mineral containing a minute trace of a radio-active substance beams, throughout the ages of geological time, upon the medium in which it is contained. If the medium is sensitive the accumulated effects in general persist for our inspection, and in the halo we are, in consequence, able to identify the presence of quantities of radio-active substances of almost inconceivable minuteness. Imagine that stellar magnitude which would be recorded upon a photographic plate exposed uninterruptedly for scores of millions of years!

We see from this that the *unaffected* plate of mica is evidenc for the absence of even the feeblest α radiation from surrounding or included elements, just as the blank photosensitive plate is proof of the absence of luminous influence. No definite halo-producing effects have been observed other than those which may be referred to the known radio-active elements.

Thus we find that the study of the conditions which call the halo into existence affords a criterion for determining the absence of any general elemental evolution during the period of geological time. When geological time began any earlier evolutionary process must have already come to an end, with the sole exceptions of the known families of radio-active substances. This result, which is *a priori* by no means evident, is of importance to our views on the physical history of the earth. Only from the minute hieroglyphics we have been considering could such information have been derived.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

OXFORD.—The Rhodes trustees have decided to make a grant of 1000*l.* towards the fund which is being raised for the endowment of a permanent professorship of forestry in the University, and the trustees of the University Endowment Fund are allowing the payment of 250*l.* per annum, which they have hitherto made towards the payment of an assistant professor, to be carried this year to the professorship of forestry fund.

A CHAIR of zoology has been established in the University of Manitoba, Winnipeg, and applications for the filling of it are invited.

THE following bequests have been made to American educational institutions by Col. O. H. Payne:—200,000*l.* each to Yale University and the New York Public Library; 100,000*l.* each to the Cornell University Medical College and Phillips Academy, Andover, Mass.; 40,000*l.* each to Hamilton College, Clinton, N.Y., and the University of Virginia.

THE Ellen Richards research prize, value 200*l.*, is offered by the Naples Table Association for Promoting Laboratory Research by Women for the best thesis written by an American woman embodying new observations and new conclusions based on independent laboratory research in biology (including psychology), chemistry, or physics. The competing essays must be received before February 25 next. Application forms are obtainable from Mrs. A. W. Mead, 823 Wayland Avenue, Providence, R.I., U.S.A.

LORD HALDANE presided at a meeting of University Extension students at Oxford on August 6, and delivered an address in which he urged that in education, as in most other things, unless we have a devolution of powers to those who are able and willing to do the work in the various localities, we shall not make very much progress. He suggested the inauguration of from seven to ten educational provinces in Great Britain. The general object should be to break down the gulf between elementary and post-elementary education. They should be unified into one great organic whole of national education, and the universities should exert a permeating influence in every province—no province without a university at one extreme, and representatives of the local education authority at the other. The best men in the locality should be co-opted on the provincial councils, and the teachers, secondary and elementary, should also have an important place on them. The Board of Education should give as much latitude as possible to the provincial authorities. If we can get rid of the network of rigid regulations, we shall have got a great deal done.