LETTERS TO THE EDITOR.

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The Radio-Elements and the Periodic Law.

I AM grateful to Prof. Schuster for the opportunity he has afforded by his letter (NATURE, March 13) for the discussion of the wide generalisations that have been made with regard to the position of the radio-elements in the periodic table, consequent on the recent experimental work of A. Fleck and of the theoretical suggestions of A. S. Russell and K. Fajans. The whole question is one in which it is important that there should not be any doubt as to the real nature of the evidence adduced. Prof. Schuster's criticism of my views on the subject could scarcely be more sympathetic or helpful, and can only result in a maturer outlook on this important question.

Granting for the sake of argument the possibility of the existence of groups of elements not necessarily of identical atomic mass, with identical chemical properties and spectra, the only known direct manner in which the existence of the members of these groups could be separately recognised is radio-active evidence, in which one member is formed from another, not directly, but through the intermediary of other elements, possessing, necessarily as now appears, completely different chemical properties. Hence it is natural that at first direct evidence should be confined practically to the subject of radio-activity, and much depends upon whether that evidence is considered real evidence approaching experimental proof, or whether it is regarded as merely negative in character.

In the first place, I admit when I wrote the expression, "non-separable by any known process," I had in mind chemical processes. It is unusual and illustrative of the peculiarities of the problem that the relatively rough and partial means of physical analysis, to which Prof. Schuster refers, may be expected ultimately to succeed where the most refined and delicate methods of chemical analysis may be expected to fail. But so it is, and I agree with Prof. Schuster that it should ultimately be possible partially to separate by purely physical methods certain members of these chemically identical groups by virtue of the slight differences in their molecular masses. In fact, a year ago I commenced an experiment to try to effect a partial separation of the two uraniums by diffusion in solution. This case is an exceptionally favourable one as an alteration in the relative concentration of the two uraniums by only a few per cent. should be detectable without any uncertainty by radio-active methods.

Although the term "non-separable" I think connotes present inability, without implying, necessarily, anything as regards what may be possible in the future, I do, however, think that there are good grounds for believing that the *chemical* non-separability of elements occupying the same place in the periodic table is due to the general character of chemical methods rather than the state of refinement and delicacy attained at any particular time. The chemical analysis of matter has given us the periodic law, and there is no case known of two or more ordinary elements with claims to the same place in the periodic table. In this connection the case of the rare-earth group of elements is necessarily excluded, as these elements certainly do not obey the law without modification. In all other parts of the table the rule is that there is only one element for each place, and each place signifies a separate chemical type differentiated in a regular manner from its neighbours. But now the radio-active series have shown that different elements, not necessarily of identical atomic mass, do occupy the same place, and that when this occurs these elements possess identical chemical nature. It is therefore an inference supported by the known facts of chemical analysis that the single place in the periodic classification represents the limits of the analysis of matter by chemical methods, rather than the ultimate analysis into homogeneous types, such as is usually implied in the conventional view of elements.

Prof. Schuster admits that the chemical properties of these non-separable groups of radio-elements are probably more nearly equal than those of the longer-known elements, but claims that there is a vast interval between "very similar" and "identical." I do not like the term "very similar." It is ambiguous, and may mean nothing more than that the experimental examination has been neither skilled nor exhaustive enough to disclose the differences, if any exist. Unless this is the case, I feel that the proper term to use is "identical." Otherwise the word "identical" ought to be expunged from scientific language altogether. Unless there is some reason to foresee a qualification being required by the further progress of knowledge, a definite statement ought to be preferred in science to an ambiguous one, which on account of its vagueness must necessarily remain true for all time. Scientific statements can only express present knowledge, including in this term reasonable inferences from the whole field of such knowledge.

The term "chemically identical" has not been applied until after an examination, not, of course, in every case, but in every possible case, and in sufficient numbers of cases to reveal the general law, as skilled and exhaustive as the present art of chemical analysis allows, and, what is equally of importance, by the use of methods for detecting changes in relative concentration as delicate as any that exist. The example quoted of praseodymium and neodymium ought to be more closely examined. These elements proved to be separable as soon as optical methods of revealing their separate existence became known. In the case of the radio-elements the separate radio-active nature of each individual of the group is exactly known, the proportion of each in any mixture can be quantitatively evaluated. Yet they are non-separable. That some mixture to-day may still be classed as a homogeneous element because no means exist for the separate identification of its components does not affect the fact that some mixtures of elements capable of separate identification are chemically non-separable.

Difficulties of chemical analysis are often not connected with the methods of separation at all, but with the means of determining whether or not a separation has been effected, which, in the case of the difficult rare-earth group are relatively crude and sometimes misleading.

The suggestion, that in the disintegration process a mass equal to that of the α particle previously lost may be picked up, is not a probable one, but even if it is admitted, and it is supposed that parent and product have the same mass, it does not affect the view that they are two absolutely distinct types of matter, disintegrating at different speeds and in certain cases with expulsion of different kinds of rays. The attempt to meet this by supposing that the particular instability which determines their future may depend on their past is equivalent to admitting the

essential difference between the two types. Besides it can be stated definitely that for any one kind of instability, or for any one radio-active change, the past exercises absolutely no influence upon the events of the future. The period of average life of an atom depends neither upon how long it has already been in existence nor upon any other known condition. It is independent of concentration or the environment in which the atom disintegrates. These features of radio-active change are against the view that anything of the nature of atomic synthesis is going on concurrently with the disintegration, or that disintegration is conditioned by the drain of energy from the atom by radiation, as is so often affirmed.

The mass of evidence that has been accumulated that different elements have identical chemical nature is not accurately described as purely negative in character. The statement that A is non-separable from B is negative in form only. It contains explicitly an infinite number of definite positive statements that A is separable from C or D, or any other of the hundred or more known elements, or any conceivable mixture of them, by chemical methods, which are exactly indicated by the statement. It is not necessary that A and B should in every case coexist, though in certain cases—the two uraniums is a good example—they have never been obtained apart. Mesothorium-II. ordinarily occurs free from actinium, and the putting in of the latter substance is a voluntary experimental device to show that once mixed these two elements are chemically non-separable. The complete chemical nature of either, or of any other of the radio-elements, could be described in detail *ab initio*, but the negative form is brief and complete.

I do not think there are weaknesses in this part of the argument. It has been a slowly growing theoretical development, and I do claim for it something approaching experimental proof.

As regards the view that chemically identical groups of elements have the same spectrum, this admittedly I put forward on a single case, that of ionium and thorium. It rests entirely on the validity and generality of the α and β ray change rules, but, if these are true, ionium must be the direct product of uranium-II.; its period cannot be less than 100,000 years, and its proportion in the preparations spectroscopically examined less than 16 per cent. and 10 per cent. respectively. Any other view requires the assumption that one or more α ray and twice as many β ray changes remain to be discovered in the series, and it can be stated with some certainty that no such changes remain unknown.

Frankly, I do not expect Prof. Schuster or anyone else to accept a view of this kind, put forward on a single thread of evidence. The value of the view is merely that it suggests definite new lines of work, difficult and costly, but still experimentally feasible.

Prof. Schuster points out that the members of the thallium group, for example, ought to give the thallium spectrum in absence of thallium in the material. The latter condition is easy to ensure. But the case is not a very favourable one on the radio-active side, as thorium-D, the best example of the group to select, has a period of average life of only 4·5 minutes. The case, however, might be within the resources of some radium institute.

Since Prof. Schuster made this suggestion, I have gone into the experimental feasibility of getting evidence of this kind, and have decided to concentrate on the case of thorium-X, the spectrum of which should be identical with that of radium. It is a particularly crucial case. The spectrum reaction of radium is excessively delicate, and the amount of this element can be easily evaluated in quantities thousands of times less than can be spectroscopically detected. The chemical work is complicated, but really exceptionally favourable and elegant.

Mesothorium-I. is non-separable from radium, and radiothorium from ionium, the parent of radium, so that if radiothorium is grown from ionium-free mesothorium it can be purified from radium to any extent and left to produce thorium-X. Naturally, however, the work will require some years, but it should be within the resources of the individual investigator. At the same time, it will be possible to try during the course of the work a large number of similar cases, if a sufficient supply of the primary material, mesothorium-I. can be obtained. This inference as to the spectra is purely a personal view, and is to be taken merely as a suggestion until further evidence is forthcoming. But I would not have made it if I thought it inconsistent with any known evidence.

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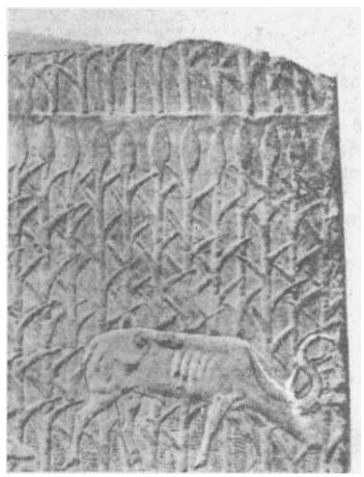
March 15.

An Unknown Assyrian Antelope.

MY attention has been directed by the Rev. A. Paterson to a plate in a portfolio of photographs from Assyrian bas-reliefs published at Haarlem, but now out of print. This plate represents a bas-relief in the great hall of Sinnacherib's palace at Nineveh, and consists of an upper and a lower portion. The latter depicts the monarch in his chariot, while the upper shows a reed swamp with wild animals. This swamp is believed to be part of a pleasure-ground made by Sinnacherib in the neighbourhood of the palace, into which wild animals were turned. It is divided in the bas-relief into an upper and a lower portion. In the left-hand corner of the lower half is shown a wild sow with a litter of young, as they might appear at the present day in the reed-brakes of the Euphrates. The other animals are three ruminants, about half as big again as the sow, but with longer legs. The two in the upper half of the scene — of which one is lying down—are hornless, and therefore females, but the third, in the right-hand corner of the lower half, carries spirally twisted horns, recalling those of the African kudu, nyala, and situtunga, although not corresponding exactly in curvature with any of them. The tail is relatively short, as in the nyala. The buck is represented with its head down, nibbling the stem of a reed; on its body, in addition to parallel lines representing the ribs, are certain patches, which may be intended for broken pieces of reeds. These animals have been regarded as deer, but the buck carries horns, and not antlers, and antlered deer are not inhabitants of reed-brakes. On the other hand, such situations are the resort of several African antelopes, notably the situtunga, and it therefore seems prac-



The male antelope in the bas-relief of Sinnacherib's Swamp at Nineveh.