Letters to the Editor.

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The Isotopes of Germanium.

USING the improved method of accelerated anode rays I have been successful in obtaining the mass-spectrum of germanium. The anode contained a fluorine compound made by the action of HF on a pure specimen of germanium oxide for which I am indebted to Prof. Dennis of Cornell University.

The effects are somewhat feeble, but satisfactory evidence of three isotopes has been obtained. Their mass-lines are at 70, 72, 74, and appear to be whole numbers though the accuracy of measurement is not so high as usual. The intensities are roughly in the proportion 2:4:5, which agrees reasonably well with the value 72.5 for the chemical atomic weight at present in use.

These values conform to the general rule connecting even atomic number with even atomic weight. It will be noticed that Ge^{70} is isobaric with the weakest and heaviest component of zinc discovered by Dempster, and Ge^{74} isobaric with the lightest and weakest isotopes of selenium announced in NATURE of November 18, 1922, p. 664.

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Cambridge, May 23.

The Wave Theory and the Quantum Theory.

IN a letter published in NATURE on December 23, 1922, I put forward a theory of dispersion which attempted to begin the reconciliation of the quantum theory with the wave theory. I have received several letters criticising my hypothesis, and it seemed to me that it would be well to acknowledge the justice of the criticism. By a small change it is possible to meet the objection, but this change carries certain important implications. In my former letter, in order to be concise, I had to get as quickly as possible to the positive results, but here I wish to set out the train of thought from which the hypothesis started, and to indicate some of its consequences. It is perhaps well at once to say that in its present shape the hypothesis is in rather severe difficulties over one phenomenon, but nevertheless the argument leads to a good many criticisms of existing theories which may be of interest.

It must be taken as absolutely certain that both the electromagnetic theory and the quantum theory are valid in their respective fields, and equally certain that the two descriptions are incompatible. We can only conclude that they are parts of an overriding system, which would give rise to mathematical formulæ identical with those of the present theories. It is true that from the present theories predictions can be made which are verified; this does not confirm the physical pictures associated with those theories, but only shows that the limits of their validity have not been reached. Now although the developments of the quantum theory in the past ten years have been enormous, and though there is no sign of their ceasing, yet these developments have not tended in the very smallest degree towards closing the gap which separates it from the wave theory. For this reason it seemed to me that the only hope of finding a reconciliation must lie in some other

direction, and that it would be best deliberately to give up thinking of details and to go back to fundamentals.

In starting to modify existing theories it is obviously best to change as little as possible, and therefore we have at once to choose whether it shall be the wave theory or the quantum theory which shall serve as basis. On this question there will be a great diversity of opinion, but to me it seems that the wave theory is undoubtedly to be preferred. The chief reason for this is that, so far as we know, the classical theory gives correctly the observed results in the interference of light, no matter how high the frequency or how feeble the intensity; so that even if we could find a new language in which to describe interference, it would be possible exactly to transform the mathematics which expressed it into the present language of waves. In other words, the wave equations imply an infinite number of degrees of freedom and it can make no difference by what name these degrees are called. The main objection to the electromagnetic theory is that it claims to present a *complete* system of mechanics, and it is this completeness that is its fault; but the wave theory is only a part of the electromagnetic theory, and we can get a large latitude for modification by retaining only this part and altering the part which describes the interaction of waves with matter.

In the quantum theory it must be conceded that, for such things as resonance potentials or the hydrogen spectrum, it is extraordinarily difficult to conceive of any alternative explanation; but, even allowing for the danger of being over-critical of an avowedly incomplete theory, it is not too much to say that from first to last the associated physical picture is in great difficulties. In the first place frequency, which plays such a leading part in the theory, is not at all the same thing as it is in mechanics, and is not susceptible of any clear definition. Then there is the difficulty that the quantum conditions determining the permissible Bohr orbits can only be explained physically by attributing to the electrons a knowledge of the future. Again there is the extreme formalism of the Correspondence Principle, a most powerful method of advance, but one which even by itself would force one to believe in the inadequacy of the quantum picture. A great part of the success of the theory of spectra has lain in the demonstration that the properties of the atom can be described in terms of whole numbers, but the dynamical concepts associated with these numbers are chiefly derived from analogy with the case of hydrogen, and could be reinterpreted in conformity with any new interpretation that was found for hydrogen. For all these reasons it is natural to suppose that the complete picture will resemble the classical theory much more closely than it will the quantum theory.

In my former letter I brought up the point that there is no reason to believe in an exact conservation of energy, but only in a statistical balance. The point is not at all new, but from much discussion of the subject I think there is no doubt that many physicists consider a breach of the law of conservation as a serious objection to any theory. If we are to believe at all in the wave theory it is much more reasonable to maintain the exact opposite. The photoelectric effect is an impossibility in conjunction with the wave theory if energy is exactly conserved, but if only a statistical balance is required, then it becomes nothing more than one unexplained problem among others. Again there exist rigorous proofs that no system of differential equations can give the observed law for the partition of energy among a large number of degrees of freedom; but these