8×10^6 electron-volts if Aston's data are as accurate as is assumed by Chadwick.[3] In disintegrations of this type the kinetic energies of B^{10} and He^4 commonly amount to 1 to 3×10^6 electron-volts, so that in all about 9×10^6 electron-volts should be obtained from the loss of kinetic energy of the neutron. There is thus at present no good explanation from the energy standpoint as to how such disintegrations by non-capture are able to occur, particularly in the work of Feather, who used the comparatively slow α-particles from polonium, and thus obtained neutrons of energy 8×10^6 electron-volts.

Fig. 1 shows two views of a disintegration of a nitrogen nucleus, seemingly without capture of the neutron, since the plane of the event is such that the neutron could not have had a straight line path from the source if the event had occurred with capture.

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[3] Chadwick, Proc. Roy. Soc. **A136**, 692 (1932).

A New Kind of Radioactivity

The complexity of the process by which neutrons are produced and their energy measured invites a careful analysis of the data obtained. Such an analysis has bearing on several other problems but the present note will deal only with the application to the Be^9 nucleus. A more complete account will soon be published.

It appears that the experiments so far used to determine the upper limit to the range of protons produced by neutrons lead to an underestimate. The error may well be greater than twenty percent of the maximum range observed. It follows that Be^9 has more energy than two alpha-particles and a neutron.[1] From general considerations and especially on quantum theoretical grounds we are led to the conclusion that Be^9 should decompose spontaneously, giving off alpha-particles and possibly a neutron. If a He of mass five is temporarily stable no neutron would appear for awhile at least.

This matter has been investigated and the prediction verified. After a little trouble some radium-free Be was obtained. The activity was low enough to explain the failure of older workers to notice the effect. The contamination by the radium family as measured by radon content was less than enough to produce one percent of the activity. The thoron content showed, however, that the thorium family might have contributed twenty-five percent of the ionization measured. It can then be argued that the actinium family was also harmless. However, the question was decided definitely by range determinations with Al foils. The range proved to be about one centimeter in air and therefore quite easily distinguishable from the ordinary alpha-disintegrations.

The corresponding half-life turns out to be about 10^{14} years. This is in striking accord with the helium content of certain Beryls which has puzzled geologists since Rayleigh's[2] measurements. The explanation which has been offered for the abnormally high helium content of Beryls in terms of the radioactivity of Be^8 is now unnecessary and in fact certain strong objections can be offered against it. That is to say, we can estimate the mass of Be^8 from that of Be^9 or from the energy of the short range group of particles emitted in the bombardment of Li by protons. From these data it seems that the half-life of Be^8 would be extremely short and that this isotope could play absolutely no part in the chemistry of beryllium, it would have disappeared before any Beryl crystal could have been formed. The helium contained in Beryl may prove extremely interesting in connection with the existence of He^5. This isotope would exist in vanishing proportions in He from ordinary sources but might be a large fraction of the helium which results from the decomposition of Be^9.

Further investigations with counters and especially with the expansion chamber will, it is hoped, lead to results which will help to determine accurately the masses of the neutron and all the other light nuclei. Such information is essential to the development of the theory of the nucleus. In particular, alpha-disintegration can now be studied in an almost ideally simple case and defects in the present theory should be brought to light.

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[1] In an article which has just come to hand, K. T. Bainbridge (Phys. Rev. **43**, 367 (1933)) announces a mass-spectroscopic determination of Be^9. His value is rather higher than we predicted but it is conceivable that our present determination of range is off enough to account for the discrepancy.

[2] Cf. Bulletin of the National Research Council, *Physics of the Earth* IV, p. 405.

The Equilibrium Theory of the Abundance of the Elements

It is possible to consider by statistical mechanics an assembly containing radiation, atomic nuclei, electrons, and neutrons; when all possible transmutations of the nuclei occur without the "annihilation" of any ultimate particles. One can calculate the abundances of the nuclei of the various sorts in such an assembly, when it is in equilibrium, in terms of the atomic masses and packing fractions. The simplest procedure is possible if the nuclei (and neutrons) are made of electrons and protons; in this case three independent parameters, of which one is the temperature, suffice to determine all the equilibrium properties of the assembly. If the nuclei are made, on the other hand, of protons and neutrons as the ultimate particles, very nearly the same treatment will suffice. In the simpler of these two cases, a parameter ξ is associated with the extranuclear electrons in the assembly and a parameter η with the extranuclear protons. Corresponding to any nucleus of mass number M_s and atomic number N_s there exists a parameter μ_s given by

$$\mu_s=\xi^{M_s-N_s}\eta^{M_s}\exp\left(-Q_s/kT\right)$$

where Q_s is the energy required to build the nucleus s out of electrons and protons. The number of nuclei present (in the equilibrium state) of sort s is then

$$\overline{X}_s=\mu_s(\partial/\partial\mu_s)\Sigma\log f[\mu_s\exp\left(\epsilon/kT\right)]$$

and there are other familiar expressions for the other equilibrium properties.

It may happen that these equilibria are established nearly perfectly in the stars. The writer hopes to publish the theory shortly.

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Conductivity of Rare Gases Irradiated by Their Own Resonance Radiations

At the Atlantic City meeting of the American Physical Society the writers[1] reported on an investigation of the conductivity of rare gases irradiated with their own resonance radiations and on the effect of the addition of small traces of impurities on this conductivity. The conductivity was determined by the volt-ampere characteristics of a pair of parallel plane disk collectors in the irradiated gas. The currents obtained do not reach a saturation value at any of the pressures or voltages used (1–12 mm; 0–150 v). This observation was also indicated by Penning[2] and has been recently confirmed by Kenty.[3] The writers have attributed this lack of saturation to the collection of those ions formed in the outer volume of the gas as well as those formed in the region between the collectors. To test this hypothesis volt-ampere characteristics were taken for a pair of parallel plane disk collectors fitted with guard rings. The collectors which were 5 mm in radius and had guard rings 5 mm wide were separated 5 mm. Collectors and leads were insulated with glass except on the adjacent faces of the collectors and rings. When they were mounted at right angles to the tube axis so that the space between them was shielded from the direct radiation, then, except at the lowest pressures, no measurable current ($<10^{-10}$ ampere) flowed between the guarded collectors. The total current (to collectors and guard-rings), however, was the same as that previously observed between unguarded collectors. When the collectors were turned so that the primary radiation illuminated the space between them, appreciable currents were obtained and the much larger total current was of the same order of magnitude as before. In no case were the collector surfaces exposed to the primary beam.

These results lead to two conclusions: first, that the ions which give rise to the observed conductivity must be formed in the space between the collectors; and second, that any metastable atoms which may produce these ions must also be formed in this space. It is difficult to reconcile these results with the propagation of resonance radiation through the gas by diffusion. In previously reported experiments, where collectors were found to receive measurable currents when shielded from the direct primary radiation, the collectors were unguarded and the observed currents probably were due to the collection of ions formed in the space surrounding the collectors. These ions could reach the collector edges. Hence the difference between the currents received by such an unguarded collector when turned parallel and then perpendicular to the primary beam is not to be attributed solely to the effects of the direct and scattered radiations. In Ne which contains a trace of A, with the collectors floating with respect to the discharge, the currents measured to the guard rings may be ten to fifty times those measured to the inner disks. Moreover, the currents measured between the guarded collectors exhibit decided maxima for small collector voltages (<10 v). These were first observed by Penning[2] who attributed them to ions diffusing in from the surrounding volume when the field between the collectors was so small that the ions were not trapped by the guard rings. This explanation the writers believe to be correct. Penning's use of guarded cylindrical collectors did not involve a change in their orientation with respect to the primary radiation.

If resonance radiation is not propagated to any considerable extent by scattering or absorption and reradiation in cases such as these where impurities are present which dissipate the energy of the scattered radiation, one must look for a new explanation for the conductivity observed in a side tube at right angles to the main discharge tube. It is possible that some of the primary radiation may be reflected into the side tube by the tube walls. In this case the degree of reflection by the tube walls must be greater than has generally been supposed so that less of the primary radiation is absorbed by the walls than has been supposed. Kenty[3] has already suspected that this may be true. If the observed conductivity is due to the action of the direct primary beam rather than to that of

[1] Duffendack and Smith, Phys. Rev. **43**, 374 (1933).
[2] Penning, Zeits. f. Physik **78**, 7 and 8, 454 (1932).
[3] Kenty, Phys. Rev. **43**, 181 (1933).