Letters to the Editor.

[*The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, nor to correspond with the writers of, rejected manuscripts intended for this or any other part of* NATURE. *No notice is taken of anonymous communications.*]

Influence of Steam and of Hydrogen on the Burning of Carbon Monoxide.

IN connexion with the different views that have been expressed concerning the relative influence of steam and of hydrogen on the burning of carbon monoxide–air mixtures, may I point out that this influence may be shown in different ways according to the phenomena under observation and the conditions: for example, the rate of pressure rise in a bomb explosion, the temperature of initial ignition, the speed of the flame either in the slow uniform movement or in the explosion wave.

I think all workers are agreed that the rate of the explosion wave in carbon monoxide knall-gas under ordinary pressure is increased as steam is added to the mixture until between 5 and 6 per cent is present; and that a similar percentage gives the fastest uniform slow movement in carbon monoxide–air mixtures. On the other hand, Prof. Bone has found that in a bomb at high initial pressure, the rate of spread of the flame (as indicated by the rate of rise of pressure) increases rapidly on the addition of traces of steam, but reaches a maximum when less than 1 per cent of steam is present. The initial high pressure appears to favour the direct oxidation of carbon monoxide in the flame.

With regard to the effect of hydrogen added to the mixture, Prof. Bone and his colleagues find that the flame in the high-pressure bomb travels more rapidly with 1 per cent of hydrogen than with 1 per cent of steam; and therefore regard as heresy a phrase they quote from a paper by Payman and Wheeler that "moisture is more effective than hydrogen in promoting the combustion of carbon monoxide." Now some years ago it was shown in our laboratory that the explosion wave in carbon monoxide knall-gas was slightly faster with 1 per cent of hydrogen than with 1 per cent of steam (*J.C.S.*; 1923); and in the same year the experiments at Sheffield showed that in order to get a uniform flame in carbon monoxide–air mixtures of maximum speed, 6 per cent of steam was necessary, whereas only 3 per cent of hydrogen was required to produce the same effect. It was not, I take it, the *rates* of the flame, but the difficulty of *starting* the flame in the mouth of the tube containing the dry mixture, when less than about 2 per cent of hydrogen was present (a difficulty not found with a mixture containing much less than 2 per cent of moisture), that led to the words quoted, which had, by the way, the prefix "apparently."

I have recently been experimenting on the effect of hydrogen and steam on the ignition point of carbon monoxide in air by sending a small stream of carbon monoxide (with and without hydrogen) into an atmosphere containing known volumes of steam, both gas and atmosphere being pre-heated before they come in contact. The ignition temperatures so found are largely influenced by the pressure of the atmosphere, and the effect is different in the two cases. When hydrogen is added to the carbon monoxide and the air is dried, the ignition points fall regularly as the pressure is reduced from 1000 mm. down to 200 mm.; whereas when the carbon monoxide is dry, and steam is added to the air, the ignition points *increase* as the pressure is reduced from 1000 mm. to 600 mm. and then decrease. It happens, therefore, that carbon monoxide containing 1 per cent hydrogen may ignite in dry air either above or below the temperature at which carbon monoxide ignites in air containing 1 per cent of steam. It depends on the pressure.

At the other end of the scale, an unexpected result was found here in 1923, namely, that an explosion wave travelling through electrolytic gas when it impinges on carbon monoxide knall-gas (with either steam or hydrogen present) is damped down and loses its 'detonation' character, which it recovers only after an appreciable 'run.' This still wants explaining.

Prof. Bone, in his recent important work on high-pressure explosions, has now given us a new problem. He finds a marked acceleration in the pressure-rise when the hydrogen content exceeds 0·65 per cent in a carbon monoxide–air mixture fired at 50 atmospheres and at room temperature, when the explosion has the character of a detonation; but this sudden rise is not observed when the bomb, filled with the same charge, is heated before firing to 100°, the initial pressure being 64·4 atmospheres.

Again, the study of the radiation of carbon monoxide flames in Prof. Garner's laboratory has shown the marked effect of hydrogen in lowering the radiation while it accelerates the rate of the flame: and here also there appears to be a sudden change, giving a step-like curve, as if two different mechanisms were at work.

It was an active hare that was started in that Oxford laboratory fifty years ago.

H. B. DIXON.
University, Manchester.

The Quantum Theory of Nuclear Disintegration.

IN a very interesting letter published in NATURE of Sept. 22, p. 439, Gurney and Condon have used wave mechanics to give a qualitative explanation of many features of natural α-ray disintegration. It may be of interest to point out that using very similar assumptions, it is possible to give a quantitative explanation of these features and also to throw light on the phenomenon of artificial disintegration. I should therefore be glad to be permitted to give a short account of these investigations here.

In the model of the nucleus adopted (G. Gamow, *Zs. f. Phys.*, Bd. 51, p. 204) the region of the inverse square law forces extends inwards, without serious perturbations, to a critical distance r_0 which is appreciably less than the closest distance of approach of the α-particles, calculated on classical mechanics, for which inverse square law scattering at large angles is still observed. For distances less than r_0 there exist attractive forces which vary very quickly with the distance. An α-particle of suitable energy can stay inside the nucleus for long periods of time, periods which on the classical theory would be infinite, since the α-particle could never pass over the potential barrier. On the wave picture, on the other hand, no such barrier can ever completely prevent a gradual leaking out of the waves, representing the process of escape of α-particles.

The theory enables one to express the radioactive decay constant, λ, in terms of the velocity of the α-particle and the atomic number Z of the element. The approximate solution of the problem (G. Gamow u. F. Hautermans, *Zs. f. Phys.* in course of publication) gives the quantitative theory of the Geiger-Nuttall relation, including the explanation of the main deviations from it. In Fig. 1 the observed values of the logarithm of the decay constant λ are plotted against the velocity of the emitted α-particle v_a and connected by a continuous line. The dotted line

connects the theoretical values of log λ, calculated on the assumption that the critical distance r_0, where the very rapid potential fall takes place, has the value $7{\cdot}4 \times 10^{-13}$ cm. for the whole family. An almost perfect fit can be obtained if r_0 is taken to vary as the

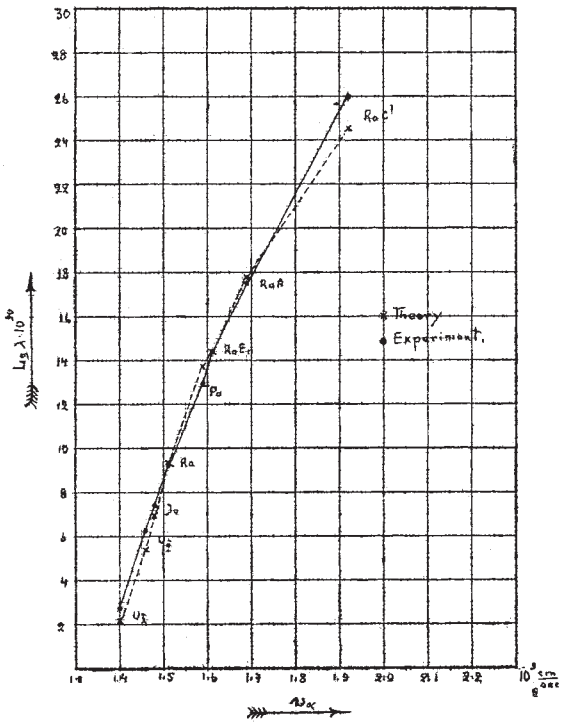

FIG. 1.

cube root of Z. Such values of r_0 make the internal nuclear volume nearly proportional to the total number of α-particles contained in the nucleus, and if extrapolated to light elements fit well with the critical distance $3{\cdot}4 \times 10^{-13}$ cm. deduced by Bieler from the deviations from inverse square law scattering in aluminium.

The same model of the nucleus allows us to calculate an upper limit to the probability of artificial disintegration by bombardment with α-rays, on the natural assumption that such disintegration is only possible if the incident α-particle enters the inner region of the nucleus (G. Gamow, *Zs. f. Phys.* in course of publication). We must again remember that on the wave picture the incident α-particle can penetrate the potential barrier even if its energy is less than the maximum opposing potential. We thus get a probability of penetration depending for a given element exponentially on the velocity of the incident particles and decreasing very rapidly with the atomic number of the element. These probabilities expressed in numbers of penetrations per cm. track in standard air per million incident α-particles are given in Fig. 2 as a function of the atomic number of the element bombarded; the full and dotted curves correspond to the initial velocities of α-particles from ThC′ and RaC′ respectively. In this calculation the critical distance r_0 is taken to have Bieler's value for aluminium. For light elements the difference between the opposing potential and the energy of the α-particle is small. The results therefore depend largely on the model adopted, as the largest atomic number for which classical penetration is possible can be estimated only approximately. The general shape of the curves will, however, remain the same, giving a very rapid decrease in the probability of artificial disintegration for heavier elements. Rutherford's observations for nitrogen and aluminium are shown by dots and circles for the two velocities.

Taking into account the approximate character of the calculations and the experimental uncertainties, the close agreement of the observed points with the curves may be taken to indicate that for these elements the ejection of a proton almost always follows immediately on the penetration of the α-particle into the central nuclear region. That no artificial disintegration was observed by Rutherford for certain other light elements is in no way contradictory to the theory, for it merely means that no proton is ejected even after penetration, and this is especially natural for the elements of atomic weight $4n$, where the nucleus in all probability is built up entirely of α-particles.

Such penetration without disruption of the nucleus can only result in the ejection of the α-particles approximately evenly distributed in all directions (induced radioactivity), and will probably be found to explain the remarkable increase of the scattering for large velocities of α-particles observed by Rutherford for the light elements. The remarkable feature of curves in Fig. 2 is the steepness of the fall to zero for larger atomic number (for example, for iron the probability of disintegration falls to 10^{-5} and for iodine to 10^{-16}). This is in most satisfactory agree-

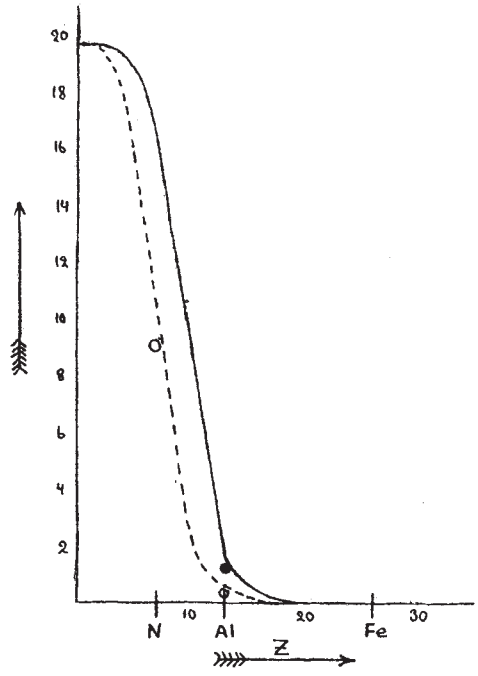

FIG. 2.

ment with Rutherford's observations, in which no artificial disintegration has been observed for any element heavier than phosphorus. On the other hand, it is quite impossible to bring the theory into agreement with the observations of Petterson and Kirsch, which not only show numbers of disintegration ten or more times as great as Rutherford's for light elements, but also show a considerable probability of disintegration for elements as heavy as iron.

G. GAMOW.

Institute for Theoretical Physics,
Copenhagen, Sept. 29.