August; fresh manure as added is to be treated with ferric sulphate.

In regard to blow-flies, M. Roubaud discusses means of preventing access of flies to dead bodies, and the disinfection of corpses. In the first he states that heavy tar oil is to be used, as it preserves animal tissues when 10 per cent. cresyl, chloride of lime, formol, milk of lime, and 5 per cent. phenol fail to do so. Ferric sulphate is to be used as a protective covering, either powdered on or applied as 10 to 20 per cent. solution. The salt forms stable compounds with the tissues which cannot be attacked by flies, and the solution kills eggs and larvæ; the three substances required at the front then are ferric sulphate, heavy tar oil, and cresol.

Some of the author's statements, which are given without proofs, cannot be unreservedly endorsed; for example, it is practically certain that a dead horse powdered with ferric sulphate will still breed innumerable flies unless it is periodically treated. No superficial treatment will clear a superficially dry manure heap of maggots; only a vapour treatment applied in liquid form. Also, a 10 per cent. solution of ferric sulphate is a very expensive dressing unless the substance is available in enormous amount; and one of the difficulties of the front is the transport of material. Concentrated treatments are required if possible, not 10 per cent. treatments at great bulk.

The problem of dealing with flies is very difficult, and is receiving much attention. One aspect is being carefully dealt with in this country, and the results will be available very shortly. This is the question of the treatment of the great aggregation of stable manure. The War Office have apparently accepted the American view of the value of borax; already a treatment with volatile liquid at a third of the present cost of borax has been found, which is satisfactory in that it spreads in the manure heaps and is not simply a superficial treatment; and it does not affect the value of the manure for horticultural purposes. Plants will stand very strong applications of volatile organic compounds, far stronger than are required to kill fly maggots, but which compounds are the best has yet to be determined.

AIR POLLUTION.

THE Air Pollution Advisory Board of the Sanitary Committee of the Corporation of Manchester has recently issued its first report. We are told that this Board came into existence two years ago as the result of a memorial presented to the Corporation by members of various scientific and other societies in the city with the object of examining the latest and best methods of eliminating the smoke evil and of diffusing information on the subject.

The Board consists of representatives of various committees of the Corporation, distinguished men of science, and influential members of numerous public bodies. It is divided into four sections, namely, the chemical, statistical, administrative, and engineering sub-committees. This is not the first occasion on which the public spirit of Manchester citizens has been inspired by the smoke nuisance and exercised itself in an attempt to suppress it. In 1891 a committee of the town gardening section of the Manchester Sanitary Society issued a report on some of the evils of smoke affecting vegetation and the amount of daylight; and in 1895 a "committee for testing smoke-preventing appliances" published a voluminous and comprehensive report on the various forms of apparatus used in steam boilers which were alleged to diminish or remove smoke.

What the ultimate fate of these two committees was, the writer is unable to say; but though their activities ceased, there is no doubt that they stimulated an interest in the subject which led not only to the formation of the present Board, but had the effect of inducing other municipalities to adopt a similar action. Work of the same character is now being carried on in fifteen other cities. This growing interest which has spread out from Manchester in ever-widening circles also led to the formation of a Local Government Board Committee on Smoke Abatement, which held numerous meetings in the first half of last year.

The present report deals mainly with the amount, nature, and extent of air pollution by smoke. The methods, which need not be described in detail, are based upon previous investigations of this character, and the results are not essentially different from those already recorded by other observers.

Valuable as the information is as indicating the extent of atmospheric contamination (which is as injurious as it is wasteful and unnecessary) and in keeping public interest alive to the importance of the economic use of fuel, the accumulation of statistics of a nature already well authenticated will not of itself bring about any radical reform.

We are glad to see, therefore, that the Board has in contemplation the study of all domestic coal-consuming grates and their efficiency, and an extensive propaganda by pamphlets, lectures, and exhibitions among builders and tenants in relation to domestic heating by coal, coke, gas, and electricity. Although a good deal of pioneer work has been done in this direction by various smoke abatement societies, it is just one of the subjects on which the views of the community are so firmly welded to the past that unremitting agitation is necessary before the deeply-rooted tradition in the efficacy of the old-fashioned coal fire can be loosened. When this work is complete, the time will be ripe for the consideration of more drastic measures of smoke abatement, and there is no doubt that had not the advent of the war postponed the deliberations of the Smoke Abatement Committee of the Local Government Board, the report of that committee would have greatly strengthened the hands of the municipalities in any future legislation which they may have in view.

In conclusion, we can only congratulate the Manchester Sanitary Committee on the scientific way in which it has set about steadily accumulating evidence and wish it a full measure of success in achieving its ultimate object.

J. B. C.

RADIATIONS FROM EXPLODING ATOMS.[1]

IT is now well established that the radio-active substances are undergoing spontaneous transformation, and that their characteristic radiations—the α, β, and γ rays—accompany the actual disintegration of the atoms. The transformation of each atom results from an atomic explosion of an exceedingly violent character, and in general results in a liberation of energy many million times greater than from an equal mass of matter in the most vigorous chemical reaction.

In the majority of cases the atomic explosion is accompanied by the expulsion of an actual atom of matter—an α particle—with a very high speed. It is known that the α particle is an atom of helium which carries two unit positive charges, and which leaves the atom with a velocity of about 10,000 miles per second. In some transformations no α particle is ejected, but its place is taken by a swift β particle or electron. These β rays carry with them

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[1] Discourse delivered at the Royal Institution on Friday, June 4, by Sir Ernest Rutherford, F.R.S.

a large amount of energy, for in some cases they are expelled very close to the velocity of light, which is the limiting velocity possible for such particles. The expulsion of high-speed β particles is usually accompanied by the appearance of γ rays, which correspond to X-rays, only of greater penetrating power than has so far been obtained from an X-ray tube even when a high voltage is employed. The emission of energy in the form of γ rays is not negligible, for in some cases it is even greater than the energy emitted in the form of high-speed β particles, and may amount per atom to as much as 20 per cent. of the energy released in the form of a swift α particle.

By the application of a high voltage to a vacuum tube it is quite possible to produce types of radiation analogous to those spontaneously arising from radium. For example, if helium were one of the residual gases in the tube, some of its atoms would become charged, and would be set into swift motion in the strong electric field. In order, however, to acquire a velocity equal to the velocity of expulsion of an α particle, say, from radium C, even in the most favourable case nearly four million volts would have to be applied to the tube.

In a similar way, in order to set an electron in motion with a velocity of 98 per cent. the velocity of light, at least two million volts would be necessary. As we have seen, it has not so far been found possible to produce X-rays from a vacuum tube as penetrating as the γ rays. The study of the radiations from radio-active substances is thus of especial interest, not only for the information obtained on the structure of the atoms themselves, but also in providing for investigation special types of radiation of greater individual intensity than can be obtained by ordinary experimental methods. The enormous energy of motion of swift α and β particles must exist in the atom before its disintegration, either in a potential or a kinetic form, and may arise either from the passage of the charged particles through the intense electric fields within the atom, or from the very swift motion of these particles within the atom before their release. In any case, there can be no doubt that electric fields, and possibly magnetic fields, of enormous intensity exist within the very small volume occupied by the essential structure of the atom—fields many million times greater in intensity than we can hope to produce in laboratory experiments.

In order to explain certain experimental results, I have suggested that the main mass of the atom is concentrated within a minute volume or nucleus, which has a positive charge, and is of dimensions exceedingly minute compared with the diameter of the atom. This charged nucleus is surrounded by a distribution of electrons which may extend to distances comparable with the diameter of the atom, as ordinarily understood. The general evidence indicates that the α and primary β particles are expelled from the nucleus, and not from the outer structure of the atom. If this be the case, the α particle which carries a positive charge would have its velocity increased in passing through the strong repulsive field surrounding the nucleus; on the other hand, the β particle which carries a negative charge must be retarded in its escape from the nucleus, and must possess great initial energy of motion to escape at all. There appears to be no doubt that the penetrating γ rays have their origin in some sort of disturbance in the rings of electrons nearest to the nucleus, but do not represent, as some have supposed, the vibrations of the nucleus itself.

α *Rays.*

A brief account was given of the recent work of Rutherford and Robinson in determining with accuracy the velocity of expulsion of the α particles from certain radio-active substances. This was done by measuring the deflection of a pencil of α rays in strong magnetic and electric fields. With the aid of intense sources of radiation, it was found that the value of E/M—the ratio of the charge carried by the α particle carried to its mass—was 4820 units, a value to be expected if helium has an atomic weight 4 and carries two unit charges. This experiment also shows that the mass of the flying positive particle is not affected appreciably by its swift motion. From known data the initial velocity of the expulsion of the α particles from all other radio-active substances can be deduced with accuracy.

If the expulsion of an α particle from an atom is the result of an internal explosion, we should anticipate, from the analogy of a shot from a gun, that the residual atom would recoil in a direction opposite to the escaping β particle. The existence of these "recoil" atoms can be shown in a variety of ways, for the velocity of recoil is sufficient to cause the atoms to leave the surface on which they are deposited and to pass through a considerable distance in air at a pressure of one millimetre before they are stopped. It is to be anticipated that the momentum of a recoiling atom should be equal and opposite to that of the escaping α particle. Since the deflection of a charged particle in motion in a magnetic field is inversely proportional to its momentum, the deflection of a stream of recoiling atoms should be the same as for the α particles if the atoms carry the same charge. Dr. Makower has examined the deflection of a pencil of recoil atoms in a magnetic field, and found it to be exactly half of that due to the α particle, proving definitely that the recoiling atom carries only one unit of positive charge in place of two for the α particle.

We thus see that the simple application of momentum enables us to deduce the mass and energy of the recoiling atoms. Since the mass of the radio-active atoms is about fifty times that of the α particle, the velocity, and also the energy, of recoil is only about 1/50th of that of the escaping α particle. In a similar way, it can be shown that the ejection of a swift β particle should cause a vigorous recoil of the atom, though not so marked as in the case of the more massive α particle.

β *Rays.*

During the last few years notable advances have been made in our knowledge of the mode of emission of β particles from radio-active atoms. The work of Baeyer, Hahn, and Meitner, and of Danysz, has shown that the β rays from a radio-active substance like radium B or radium C contain a number of definite groups of rays which are expelled with definite velocities. This is best shown photographically by examining the deflection of a pencil of β rays in a magnetic field. In a uniform field, each of the groups of rays describes a circular path the radius of which is inversely proportional to the momentum of the β particle. By the application of special methods it has been found possible to obtain a veritable spectrum of the β rays. The spectrum of the β rays from radium B and radium C has been very carefully examined by the writer and Mr. Robinson, and found to give a large number of well-marked bands, each of which represents a group of β rays, all of which are expelled with identical speed. It was at first thought that most of the energy of the β rays was comprised in these groups, as some of the bands on the photographic plate were very marked. Chadwick, however, has recently shown that the fraction of the rays which give a line spectrum is only a few per cent. of the total radiation. The general evidence shows that the β radiation from these substances gives a *continuous* spectrum due to β rays of all possible velocities, on which is superimposed a *line* spectrum due to a small number of β particles of definite velocity comprising each group.

Lines in the β-ray spectrum have been observed for particles which have a velocity not far from that of light, but the photographic effect of the particles becomes relatively feeble for such high speeds.

It is known from direct measurement that each atom of radium B or of radium C in its disintegration emits *on an average* one β particle. In the β-ray spectrum of radium C at least fifty definite bands are observed, differing widely in intensity. It is thus clear that a single atom in disintegrating cannot provide one β particle for *each* of these numerous groups. It is thus necessary to conclude that each atom does not emit an identical β radiation. The results are best explained by supposing that the β-ray spectrum is the statistical effect due to a large number of atoms, each of which may only give one or two of the groups in its disintegration. In this respect a β-ray transformation is distinguished from an α-ray transformation, for in the latter case each atom emits one α particle of characteristic speed. It will be seen later that there is undoubtedly a very close connection between the emission of β and γ rays from radio-active atoms, and the probable explanation of the remarkably complex β-ray spectrum will be discussed later.

With the exception of one element, radium E, and possibly uranium X, all the radio-active substances which emit primary β rays give a line spectrum. For the majority of elements the strong lines in the β-ray spectrum have been determined by Baeyer, Hahn, and Meitner, but more intense sources of radiation will be necessary to map accurately the weaker lines.

γ *Rays.*

The earlier experiments on the γ rays were mainly confined to a determination of the absorption of the more penetrating radiations by different kinds of matter. It was early observed, however, that some of the radiations appeared to be complex. This was shown by anomalies in the initial part of the absorption curve. In the meantime, a notable advance in our knowledge of X-rays had been made by the work of Barkla. He found that under certain conditions each element when bombarded by X-rays of suitable penetrating power gave rise to a strong radiation which was characteristic for that element, *e.g.*, the lighter elements from aluminium to silver emitted characteristic radiations called the "K" series, which increased rapidly in penetrating power with the atomic weight of the radiator. It was found that the heavier elements emitted in addition another characteristic radiation of softer type, which was called the "L" series. These results showed clearly that there must be definite structures within the atom which gave rise to a definite radiation under suitable conditions of excitation. From these results it seemed probable that the γ rays from radio-active matter must consist of the characteristic radiations of these heavy elements, analogous in type to the corresponding radiations observed in ordinary elements when excited by X-rays or kathode rays. These conclusions were confirmed by a series of investigations made by Rutherford and Richardson. The γ rays were analysed by means of their absorption by aluminium and by lead, the disturbing effects of the primary β rays being eliminated by means of a strong magnetic field. It was found, for example, that the γ rays from radium B, when examined by their absorption in aluminium, consisted of at least two types, one easily absorbed, and the other eighty times more penetrating. By further observations of the absorption of the γ rays by lead, Richardson found that the rays from radium B could be divided into at least four definite types, each of which was absorbed exponentially by lead. Similar results were obtained for all the radio-active elements which emitted γ rays. In some cases the soft γ rays, *e.g.*, those from radium B, corresponded to the characteristic radiation of the "L" series, and others to the "K" series. The general results, however, indicated that several additional series of characteristic radiations are present in some cases. It was clear from these experiments that the γ rays corresponded to the natural modes of vibration of the inner structure of the radio-active atoms. In the meantime the experiments of W. H. Bragg and W. L. Bragg, and of Moseley and Darwin, had shown that the characteristic X-radiations of the elements gave definite and well-marked line spectra. These spectra were simply determined by reflecting the rays from crystals. If this were the case, it seemed probable that the γ rays from the radio-active atoms would also give line spectra, and thus allow the natural frequencies of vibration of these atoms to be determined. During the past year, a number of experiments have been made to test this point by Rutherford and Andrade, using radium B and radium C as the source of γ radiation. As was anticipated, it was found that the γ rays from radium B and radium C gave well-marked line spectra. The general method employed was to use an α-ray tube containing a large quantity of emanation as a source of radiation. The γ rays were reflected from a crystal of rock salt, and the position of the spectrum lines determined photographically. Usually twenty-four hours were necessary to obtain a marked photographic effect. Special difficulties arose in these experiments which are absent in an investigation of a similar kind with X-rays. In addition to γ rays, the radio-active matter emits very penetrating β rays which have a strong photographic action; while the γ rays in their passage through matter themselves give rise to high-speed β rays. The disturbing effect of these radiations has to be eliminated by placing the whole apparatus between the poles of a powerful electromagnet. In this way it was found that the spectrum of radium B consisted of a large number of lines, of which the most intense were deflected at angles of 1° 46′, 10°, and 12°. The more penetrating radiation from radium C gave a strong line of 1° and a fainter line at 43′. The strong lines at 10° and 12° are due to easily absorbed γ rays, and undoubtedly correspond to the "L" radiation of radium B. The line at 1° corresponds to a very penetrating radiation which has a wave-length less than 1/10th of an Angström unit. The penetrating γ rays from radium C have by far the shortest wave-length so far observed. It does not seem probable that such short waves can be produced artificially in an X-ray tube unless possibly an exceedingly high voltage be applied.

There is one interesting result of these investigations that should be mentioned. The two strong lines of the radium B spectrum deflected at 10° and 12° were found to correspond exactly in position to the X-ray spectrum of lead. These experiments thus confirmed the view based on chemical evidence that radium B and lead were isotopic, *i.e.*, they were elements of practically identical chemical and physical properties, although their atomic weight differed by seven units.

Connection between β and γ Rays.

Before considering in detail the difficult problem of the connection between β and γ rays, it is desirable to summarise the main facts that have been established in regard to the relations between kathode rays and X-rays:—

(1) A small part of the energy of kathode rays falling on a radiator is converted into X-rays, the average frequency of the latter increasing with the velocity of the kathode particle.

(2) X-rays in passing through matter give rise to a β radiation. The initial energy of the escape of the electrons increases with the frequency, and is probably proportional to it.

(3) Electrons or X-rays of appropriate energy are equally able to excite the characteristic radiations in an atom.

The results which have been shown to hold for the X-rays hold equally for the β and γ rays, which have much greater individual energies, *e.g.* Gray and Richardson have shown that the β rays from radio-active matter are able to excite the characteristic radiations of the elements in a number of substances, while γ rays in passing through matter give rise to high-speed electrons. It was long ago suggested by Bragg that β rays and X-rays are mutually convertible forms of energy, *e.g.* a β particle falling on matter may be converted into an X-ray of the same energy, and the latter in passing through matter may in turn be converted into an electron of identical energy. This assumes that the energy of an X-ray and an electron are mutually convertible, and the energy may appear under suitable conditions in either of the two forms. While the general evidence indicates that this point of view may hold closely for the conversion of the energy of a single X-ray into that of a swift electron, it is very doubtful whether it holds for the converse case of the excitation of an X-ray into an electron. We shall see later from experimental evidence that in general the energy of the electron required to excite an X-ray of definite frequency is always greater than the corresponding energy carried off in the form of an X-ray.

It was early observed that there appeared to be a close connection between the emission of β and γ rays from radio-active matter. In all cases, the two types of radiation appeared together. A closer examination, however, showed that there were very marked differences between the relative energies of the β and γ rays from different radio-active elements. For example, radium C emits intense β rays and also intense γ rays; on the other hand, radium E emits intense β rays over a wide range of velocity, but exceedingly weak γ rays. Differences of a similar kind were observed amongst a number of the radio-active elements. One striking distinction, however, was to be noted. All the radio-active substances which give a marked line spectrum of β rays also emitted intense γ rays. On the other hand, a substance like radium E, which gave scarcely any γ rays at all, gave a continuous spectrum of β rays in which no lines have so far been observed. It thus appeared probable that the line spectrum of the β rays was intimately connected with the emission of γ rays, and this conclusion has been completely established by recent experiments. As we have seen, γ rays in passing through matter give rise to high-speed β rays. Using radium B and radium C as a source of γ rays, the β radiation excited in a number of metals by the passage of γ rays was analysed in a magnetic field by Messrs. Robinson and Rawlinson and the writer, and was found to consist in part of definite groups of β rays. When lead was the absorbing material, the magnetic spectrum of the β rays excited by the γ rays was found to be nearly identical with the primary β-ray spectrum of radium B. This striking result shows that those β rays escaping from the radio-active atom which give rise to a line spectrum must result from the conversion of γ rays into β rays in the radio-active atom. The slight differences observed in the spectrum for different metals is probably connected with the energy required to excite one of the characteristic radiations of the element used as absorber.

An explanation of the marked differences in the character of the β and γ radiation from different radio-active atoms can, I think, be given on the following lines. Some of the γ rays are broken up in their escape from the atoms, and the energy of each converted γ ray is transferred to an electron which escapes with a definite velocity dependent on the frequency of the γ radiation. Taking into account a large collection of disintegrating atoms, each of the possible modes of characteristic vibration of the atom gives rise to an electron of definite speed. In this general way we may account for the line spectrum of the β rays which is so commonly observed. On this view, we should expect to obtain a well-marked line spectrum of β rays when a substance emits strong γ rays—a result in accord with observation.

In order to account for the marked differences in the types and intensity of γ rays from different radio-active substances, it seems necessary to suppose in addition that the primary β particle always escapes from the nucleus in a *fixed* direction with regard to the structure of the atoms under consideration. For example, we have already pointed out that radium E, although it emits intense β rays which give a continuous spectrum over a wide range of velocity, emits very weak γ rays. Since there can be no doubt that the β rays have sufficient speed to excite the characteristic modes of vibration which must be present in the atom, we are driven to the conclusion that the β particle escapes in such a direction that it does not pass through these vibrating centres. On this view, the type of characteristic γ rays which are excited, and consequently also the corresponding speed of the β rays which arise from the converted γ rays, will depend entirely on the direction of escape of the primary β particle. The definite direction of escape of the primary β particle, which varies for atoms of different substances, also suffices to explain a number of other differences observed in the mode of release of energy from various radio-active atoms. It is supported by many other observations which indicate that the atoms of a particular radio-active substance break up in an identical fashion.

We have so far considered only in a qualitative way the relation between the groups of rays in a β-ray spectrum and the emission of characteristic γ rays. During the last few years there has been a growing body of evidence that the energy E carried off in an X-ray of frequency ν is proportional to this frequency, and is given by $E = h\nu$ where h is Planck's fundamental constant. If the whole of the energy of an X-ray can be given directly to an electron, the energy communicated to the latter should be $h\nu$. There is no doubt that in many cases this simple relation holds very approximately, but the measurements so far available are not sufficiently precise to settle definitely whether a part of the energy may not appear in another form.

Assuming that the transfer of the energy from an X-ray to an electron is complete, we should expect to find groups of β rays of energy corresponding to $h\nu$ where ν is the frequency of the γ rays found experimentally. Such a relation is found to hold within the limit of experimental error for three marked groups of low velocity β rays emitted from radium B. On the other hand, it is found that many of the high-velocity groups of β rays from both radium B and radium C have energies many times greater than correspond to any observed frequency. Not the slightest evidence, however, has been obtained that corresponding high frequencies of vibration exist in the radio-active atom; in fact, all the evidence points to the fact that these high-speed electrons arise from one or more of the observed frequencies in the γ-ray spectrum.

In order to account for such results, it seems necessary to suppose that the γ rays of high frequency are not necessarily emitted as single pulses, but consist of a train of pulses either produced simultaneously or following one another at very short intervals. Each of these pulses has an energy $h\nu$ corresponding to the frequency ν, but the total energy in the train of waves is $ph\nu$ where p is a whole number, which may have possible integral values 0, 1, 2, 3, . . . etc., depending on the structure of the atom and the conditions of excitation. The penetrating power of such a train of waves corresponds to that of a single wave of frequency ν, but on passing through matter the energy of the whole train of p waves occasionally may be transferred to an electron which consequently is expelled with an energy $ph\nu$. There is very strong evidence of the general correctness of this point of view, for most of the stronger lines in the β-ray spectrum of radium C have energies which correspond to an *integral* multiple of the energy corresponding to the strong lines actually observed in the γ-ray spectrum It seems probable that under the ordinary conditions of excitation by kathode rays in a vacuum tube, the X-ray contains only one pulse or wave, but under the far more powerful stimulus of the very swift β particle escaping from the atom, a long train of waves, each of the same frequency, is produced. The energy of the whole train of waves may under suitable conditions be given to an electron, which consequently has a speed very much greater than that impressed upon it by a single wave of the same frequency.

Limit to the Frequency of Vibration of the Atom.

There is one question of fundamental importance which arises in considering the modes of vibration of the atom, viz. whether there is a definite limit to the frequency of the radiation which can be excited in a given atom. Theory does not provide us with an answer to this problem, since little is known about the conditions of excitation, nor even of the nature of such high-frequency vibrations. A study of the frequency of the γ rays from radio-active substances is of great importance, as it throws much light on this problem.

As we have seen, the energy of the β particle escaping from the nucleus of radium C is equivalent to that acquired by an electron moving in an exhausted space under a potential difference of several million volts. This high-speed electron passes through the electronic distribution in its escape from the atom. Notwithstanding such ideal conditions for the excitation of high-frequency radiations of the atom, the highest frequency in the radiation emitted by radium C is only about twice that obtainable from an ordinary hard X-ray tube excited by 100,000 volts. It thus appears probable that there is a definite limit to the frequency of the radiation obtainable from a given atom, however high the speed of the disturbing electron. This limiting frequency is determined not by the speed of the electron but by the actual structure of the atom. Since the γ radiation from radium C gives a line spectrum, it would appear that the highest frequency obtainable is due to a definite system of electrons which is set into characteristic vibration by the escape of a β particle. In order to throw further light on this point, Prof. Barnes, Mr. H. Richardson and myself have recently made experiments to determine the maximum frequency obtainable from an X-ray tube for different constant voltages. The Coolidge tube, which has recently been put on the market, is ideal for this purpose, as it provides powerful radiation at any desired voltage. The anti-kathode is of tungsten of atomic weight 184, so that we are dealing in this case with the possible modes of vibration of a heavy atom. The maximum frequency of the radiation was deduced by measuring the absorption by aluminium of the most penetrating rays emitted at different voltages. The absorption of X-rays of different frequencies by aluminium has been examined over a very wide range, and can be expressed by simple formula. It was found that for 20,000 volts the frequency of the radiation was slightly lower than that to be expected if Planck's relation held. With increasing voltage there is a rapid departure from Planck's relation. The frequency reaches a maximum at about 145,000 volts, and no increase was observable up to the maximum voltage employed, viz. 175,000 volts. The experiments thus show that the frequency of radiation reaches a definite maximum, which is no doubt dependent on the atomic weight of the particular radiator employed. It is of interest to note that the maximum penetrating power of the X-rays from the Coolidge tube in aluminium is about the same as the γ rays from radium B, but is about 3/10 of the γ rays from radium C. There is evidence which suggests that the very penetrating γ rays from radium C correspond to the octave of the "K" characteristic radiation of that element. If this be the case, it may prove possible that a still more penetrating radiation might be obtained from tungsten, but in order to excite it a voltage of the order of a million volts would probably be required. In any case, it seems clear that Planck's relation does not hold for excitation of high frequencies by swift electrons, but may hold very approximately for lower frequencies corresponding to the radiation excited by a few hundreds or thousands of volts. On the other hand, the evidence obtained from a study of the β rays excited by X-rays or γ rays certainly indicates that the relation $E = ph\nu$ holds at any rate very approximately for the highest frequency examined. It is thus obvious that the emission of β and γ rays from the radio-active atoms is clearly connected with the general theory of radiation, and it seems likely that a close study of these radiations will throw much light on the mechanism of radiation in general.

There can be little doubt that the penetrating γ rays from active matter have their origin in the vibration of electronic systems in the structure of the atom outside the nucleus. The nucleus itself, however, must be violently disturbed by the expulsion of an α or β particle. If this leads to the emission of a γ radiation, it must be of exceedingly high frequency, as the forces holding together the component parts of the nucleus must be exceedingly intense. We should anticipate that this radiation would be extraordinarily penetrating, and difficult to detect by electrical methods. So far no experimental evidence has been obtained of the existence of such very high frequency radiations, but it may be necessary to devise special methods before we can hope to do so.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—Reference is made in the *Times* of June 25 to the large number of Cambridge men now on active service; from a "War List" which has just been issued it appears that 8885 members of the University are with the colours. The official list gives the names of those who have been killed or wounded in action, and it appears that for every four who have been wounded three have been killed. This is due to the fact that most of the Cambridge men serving are either 1st or 2nd lieutenants.