great importance. It seems certain that we cannot regard the α-rays as having the same relation to β-rays as cathode-rays have to Röntgen rays which they produce; for we have shown that the separated active products from uranium and thorium contain all the substance responsible for the β-rays. The radioactive material, which has thus been temporarily freed from β-rays, still, however, retains its power of giving out, in the case of uranium a large proportion, and in the case of thorium about 30 per cent. of the original α-rays.

This α-radiation persists, in the case of uranium, several days, and, in the case of thorium several hours, without any appreciable change in intensity. If the α-rays are due directly to the β-rays, it is necessary to assume that the radiation persists for long intervals after its exciting cause is removed. This view also fails to explain, without additional assumptions, why the radiation from Ur.X. does not excite similar α-radiations in itself.

Without, at this stage, going into views on the mechanism of radioactivity, it seems probable that most of the deviable rays from uranium and thorium are given out by a secondary product produced by a disintegration of the uranium or thorium atom or molecule. These secondary products differ in chemical properties from the uranium and thorium, and can be separated from them by chemical means, and thus give rise to Ur.X. and Th.X. The non-deviable radiation may be either due to the other secondary product of the reaction, or may be due to an action of the product responsible for the deviable rays in the mass of the radioactive material.

McGill University, Montreal.
May 7, 1902.

XXXV. *On the Ebullition of Rotating Water.—A Lecture Experiment.* By T. C. Porter, *Eton, Bucks.**

If the water in a beaker, having approximately vertical sides, be caused to rotate about an axis concentric with the vertical geometrical axis of the beaker, it is obvious that in any horizontal section of the water the pressure is least in the centre, and increases from the centre outwards. It is also a well-known fact that the temperature at which water boils depends upon the pressure to which it is subjected, being lower the lower this pressure is. Thus if a beaker of water were at a temperature just below the boiling-point, and it could be *suddenly* made to rotate throughout its mass without cooling it, the water would turn into vapour in and about the axis of least pressure, from the surface downwards, forming, at all events for the moment, a thin core of steam in the middle of the water. In practice, however, water cannot be made to rotate throughout its mass suddenly; and if the rotation is generated gradually, the water-vapour is also, as a rule, gradually formed, and is given off from the surface without ebullition, in the quantity sufficient to relieve the tension of those particles of water for which the pressure is diminished. The very form taken by the water as it rotates, increases its surface area, and thus tends to promote evaporation, and so to check ebullition. For these reasons the writer has failed to exhibit the experiment to be described in this its simplest form. If, however, the water is supplied with heat whilst it is rotating, the steam is formed only in the region of least pressure, forming a gaseous core in the rotating water, as in fig. 1. The experiment is an exceedingly simple one both to make and to photograph; it may be well to give a few details as to its performance, though the four figures given are only careful drawings from four of the original photographs.

* Communicated by the Physical Society: read May 23, 1902.

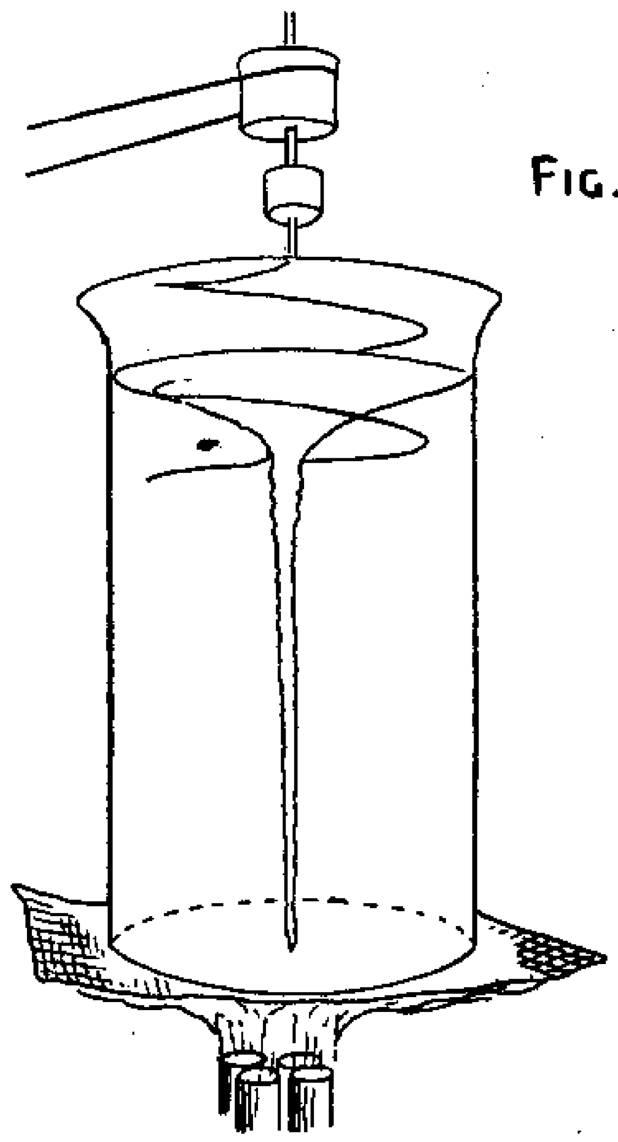


Fig. 1.

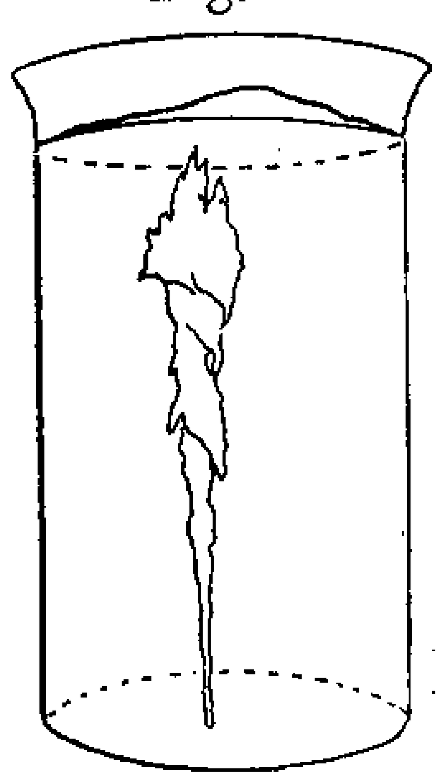
In fig. 1 the spiral wire stirrer used is seen near the surface of the water; whilst beneath the wire gauze, on which the large beaker rests, and which serves to distribute the heat more evenly, are visible the flames and upper parts of the four Bunsen burners employed to heat the water. The spiral stirrer was driven by a small motor; but experience soon proved that results as good, if not better, could be obtained by stirring the water *by hand*, using a long glass rod completely covered by a piece of indiarubber tubing in order to avoid the risk of breaking the glass vessel. After giving to the water throughout its depth the necessary and rapid rotation, and before taking the photographs, this rod was rapidly withdrawn from the beaker, its stirring motion being carefully maintained during the act of withdrawal. Some of the photographs were taken by diffused daylight combined with that of the electric arc, the latter being concentrated by a lens, so as to illuminate the whole of the beaker and its contents as brightly as possible. The plates were Edwardes's Isochromatic Instantaneous, and the exposures were about the $\frac{1}{40}$ of a second. A dilute developer should be used, and as much as 30 min. or more allowed for development.

Thus far the experiment illustrates in an apparently simple and beautiful way the lowering of the boiling-point of water under reduced pressure; but there are some very curious phenomena to be presently described, which are shown by the column of steam, if the water is first stirred and then left to come to rest, whilst the heating is continued. Just after the stirrer has been removed, the appearance presented is that recorded in fig. 1.

The lengths of the multitude of curved lines, shown in the original photographs near the bottom of the beaker, and formed by the rotation of small stray bubbles, are an index to the speed with which the water is rotating when the duration of the exposure for the photograph is remembered; and in fig. 1 the rate of rotation is much higher than in the subsequent figures, which are taken at later stages. In fig. 1 there is a markedly concave surface to the water in the beaker, and the column of steam is practically continuous from base to summit where it joins the air. This phase lasts about a minute, when the water has been stirred as rapidly as is possible by hand, and then it will be noticed that *pulsations* set in: at first these are feeble, and succeed each other with great rapidity; but their period rather rapidly lengthens till it may last four seconds or more, and at the same time they become more and more violent.

The course of events during a single pulsation is as follows:—1st phase, the surface-curve of the water flattens, and in the later stages of the experiment the curvature disappears; whilst, so far as can be judged by eye and from the photographs, at the instant when the surface of the water is most nearly level, or just before it, a column of steam springs up with great rapidity from the base of the beaker to the surface of the water, heaving this up in its central portion, and in the later stages of the experiment often causing the ejection of water from the beaker. This phase is shown in fig. 2, where the reversal of the surface curvature is very evident. Immediately after the eruption of the steam, and whilst the steam-column still stretches from the base of the beaker to the surface of the water, follows the 2nd phase. The steam-column seems to condense and breaks up, leaving only a few small bubbles, which either hang stationary or move *downwards* in the liquid; whilst if the water has dust in it the motion of the dust particles shows that a curious kind of annular wave, concentric with the steam-

Fig. 2.



column and at any moment occupying a horizontal plane, traverses the water *from top to bottom*, and spreads out in so doing, apparently causing in its course the partial or almost complete condensation of the steam and the curious brief *downward* movement of the bubbles left: at the same time the surface of the water in the beaker becomes deeply indented, perhaps sinking in to take the place of the steam which has condensed, (though the writer does not feel at all certain that this is the cause of the depression formed). This second part of the pulsation is illustrated by fig. 3. After this the apex of the surface vortex rises, and the first phase of the phenomenon recurs. This state of pulsations continues for perhaps three or four minutes: the eruptions of steam are very violent towards the close of the period, especially if the water has been boiled for long, or is made slightly alkaline (the conditions for boiling with bumping), and fig. 4 shows the effect of such a condition of things. The original photograph was taken midway through the pulsation period and in the 2nd phase. In this photograph it will be noticed that the point where the steam was first formed is not on the surface of the beaker as it generally is, but in the water itself. Some other photographs were taken at the close of the pulsation period, when the axis of rotation of the water begins to "wobble," and consequently the point where the steam is formed is not, as a rule, in the geometrical vertical axis of the beaker. Soon after this "wobbling" sets in the steam begins to be formed anywhere, at, or near, the bottom of the beaker—and all evidence of the effects of rotation vanishes.

Fig. 3.

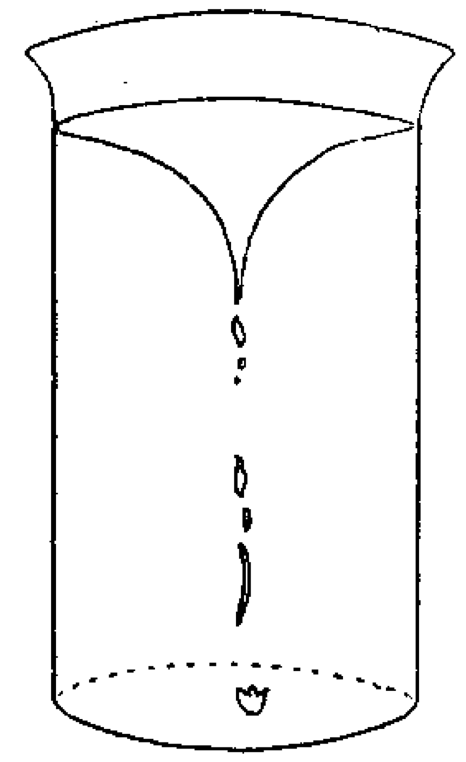
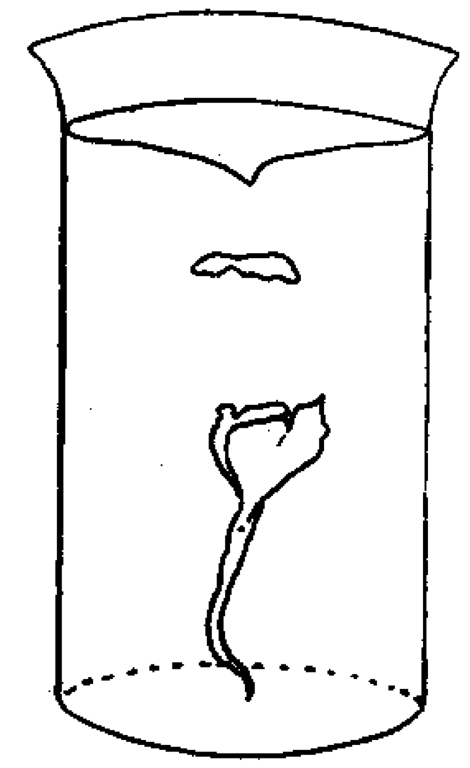


Fig. 4.



The curve of the surface of the water throughout is never a *parabola*, as it would be if the angular velocity of the water were everywhere equal: thus the divergence from the parabolic form indicates how very much more rapidly the water rotates as it nears the axis of rotation. This fact is also evident from the inspection of the lines formed by the small bubbles rotating near the base of the steam-column as already mentioned. One might naturally expect that the outbursts of steam, (those which occur during the pulsation period), would occur when the surface vortex was deepest,—instead of which the exact opposite is the case. At times, too, large bubbles of steam form suddenly in the water and condense, without the surface-level of the water in the jar being *simultaneously* visibly disturbed: at any rate, if it be so—and it would seem that it must be, considering the high elasticity and incompressibility of water,—the disturbance is anything but easy to observe.

With respect to the cause of the pulsations already alluded to, it may be well to state that by stirring *cold* water in a beaker-shaped jar, having a small hole in its bottom through which a stream of air-bubbles can be blown (to imitate the generation of the steam, but not its condensation), there is abundant evidence from the motion of small bubbles that pulsations set in in this case also, and indeed there is some evidence of a similar phenomenon when an ordinary glass of water is stirred: hence it does not seem likely that in the case of the hot water the pulsations are directly caused by either the formation or condensation of the steam, although this may reinforce them when once they have been set up.

Lastly, the form of the steam-columns often presents an unmistakable likeness to those of solar prominences, which can scarcely be altogether fanciful; for there is every reason to believe that the latter are explosive emissions of gaseous matter projected through and above the solar atmosphere. May not their immediate cause be the diminution of pressure on the sun's surface at and near the centre or centres of "depressions" caused by violent cyclonic disturbances in the solar atmosphere? The enormous velocity with which such ejected matter is seen to rise, and also the rapidity with which it is dispersed, have their counterparts in the experiments which have been described: no one who sees these last for himself can fail to be impressed by the great velocity with which the steam-column rises in the water, and by the suddenness with which it condenses, and that, too, in water at, or at any rate very near to, its boiling-point,—whilst the hanging filaments such as appear in fig. 3 recall most vividly some well-known drawings of solar prominences as they die out: the fact that in both cases the filaments hang with their length vertical, and do not lie horizontally, seems to the writer very significant.

This short paper is little more than a description of a phenomenon of which the writer has never seen any account given elsewhere; it makes hardly any attempt to explain much of it; still it is offered in the hope that some one more conversant with hydrodynamics than the author may give the true solutions to the questions it suggests.

Eton, Bucks, May 1902.

XXXVI. *On the Comparison of Vapour-Temperatures at Equal Pressures.* *By* Professor J. D. EVERETT, *F.R.S.**

RAMSAY and YOUNG seem to have been the first to call attention (Phil. Mag. Jan. 1886) to the fact that the ratio t/t' of the absolute temperatures at which two vapours (at saturation) have the same pressure p remains nearly constant for changes of p of very considerable magnitude. In the case of vapours of kindred constitution, their results show that a twentyfold increase of p only changes t/t' by about $\frac{1}{2}$ per cent.

They further lay down, for the comparison of vapours generally, the law—now known as "Ramsay and Young's law"—that if t_1, t_2 denote the absolute temperatures of one vapour at the pressures p_1 p_2, and t_1' t_2' those of another vapour at the same pressures, we shall have

$$\frac{t_2}{t_2'} - \frac{t_1}{t_1'} = c(t_2 - t_1), \quad . \quad . \quad . \quad . \quad . \quad (1)$$

c being a small positive or negative constant multiplier, depending on the substances compared.

To the eye of the mathematician there is an awkward one-sidedness about this formula; it is not symmetrical as between t and t'. It can, however, be rendered symmetrical by first writing it in the form

$$\frac{t}{t'} - ct = k,$$

(k being a constant), and then dividing by ct. We thus obtain an equation of the form

$$\frac{x}{t} + \frac{y}{t'} = 1, \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

x and y standing for $-k/c$ and $1/c$, which are constants. A

* Communicated by the Physical Society.