and give rise to cells which are more or less removed from their normal places. Thus polar bodies and ectoderm cells may be caused to form at the vegetative pole or at any other point on the surface of the egg instead of at the animal pole; nevertheless the protoplasmic portions of the yolk-containing cells return to the animal pole when centrifuging ceases unless otherwise prevented. In some instances in which centrifuging took place in the two cell stage the normal positions of protoplasm and yolk are regained in one of the cells but not in the other. All such cases indicate that it is difficult but not absolutely impossible to change the polarity of eggs and cleavage cells, and that the persistence of polarity in centrifuged eggs and the restoration of dislocated parts to their normal positions is connected with a somewhat resistant framework of protoplasmic strands which preserve the relative positions of nucleus and centrosphere in the cell axis.


THE EMISSION QUANTA OF CHARACTERISTIC X-RAYS

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Received by the Academy, January 15, 1916

At the meeting of the American Physical Society last April, Duane and Hunt announced that X-rays of any given length would be excited as a part of the general radiation from a tungsten target only if the potential applied to the tube was enough to give an electron a kinetic energy as large as the Planck quantum of that wave length. This law was confirmed and extended to a potential of 100 kv by Hull. Off hand one would expect it to apply to characteristic rays also; but, since some work of Whiddington suggests an exception here, it seemed desirable to test such rays with the spectrometer.

This was done with a rhodium target in a tube which Dr. Coolidge very kindly had made with one of his hot wire cathodes. The potentials were supplied by a storage battery of 20,160 cells, and could be measured to about 1%. Neighboring potentials could be compared to about 0.1%.
The part of this work dealing with the general radiation of rhodium confirms Duane and Hunt's law exactly, and leads to a value of \( h \) of \( 6.52 \times 10^{-27} \) erg sec, taking \( e \) as Millikan's value \( 4.774 \times 10^{-20} \) esu. and the calcite spacing as Bragg's value 3.025 A. This lies above the values given by Duane and Hunt\(^1\) and Planck\(^2\) and below the values given by Millikan and Hull.\(^3\) If the spacing of the calcite planes is recomputed on the basis of Millikan's \( e \), it is 3.03 A, and the value of \( h \) is \( 6.53 \times 10^{-27} \) erg sec. The wave lengths and \( h \) values given with the graphs in this paper are computed from this value of the spacing.

As a consequence of Duane and Hunt's law, if the spectrometer is set to receive one of the characteristic lines, some radiation is received as soon as the quantum potential is reached; but it is found that the intensity is at first only what one would expect from the general radiation at that wave length of no lines existed. With these rays, however, at a definite higher potential the intensity suddenly starts to increase more rapidly than before. This point therefore is the lowest potential at which any characteristic lines appear.

This effect is shown in figure 1, the upper graph giving the intensity as a function of potential for the \( \alpha \) doublet. The first part of the curve and its dotted continuation are due to general radiation alone, while the part to the right of the corner is due to the combined general radiation

\[ b \text{doublet, } 486 and 495 \text{ A,} \]

\[ 584 to 586 \text{ A,} \]

\[ 656 \text{ to } 658 \text{ A,} \]

\[ 544 to 546 \text{ A,} \]

\[ 354 to 356 \text{ A,} \]

\[ 334 to 336 \text{ A,} \]

\[ 6.53 \times 10^{-27} \text{ erg sec,} \]

\[ 3.03 \text{ A,} \]

\[ 6.53 \times 10^{-27} \text{ erg sec.} \]

Fig. 1
and $\alpha$ doublet. The critical potential is very sharply defined, and has a value 23.3 kv, while the quantum potential, at which radiation of that wave length first begins to appear, is 20.05 kv. The same effect is shown by the $\beta$ line, as one may see by comparison of its intensity-potential curve (fig. 1) with that of the general radiation of a neighboring wave length. The effect is less pronounced because the line is weaker than $\alpha$. The critical potential, as nearly as one can tell, is the same in both cases.

![Fig. 2]

To prove that the corner in the $\alpha$ curve really does mean the first appearance of the $\alpha$ lines, photographs of this part of the spectrum have been taken at different potentials above and below the critical one. These show that the ratio of the intensity of the lines to that of the background, as well as the absolute intensity of either, increases rapidly with the potential, and that, while the lines are visible against the background within 1% above the critical potential, they are absolutely invisible below it.

The next point to consider is the ratio of intensities of any two lines and its dependence on potential. From numerous photographs with different exposures it appears that the ratio of $\alpha_1$ and $\alpha_2$ is constant, as
nearly as one can tell, from the critical potential to the limit of the battery’s capacity, at about 42 kv. The ratio of the β line to the α doublet can be estimated only by allowing for the general radiation that appears in the spectrometer with each of them. This can be done, only roughly,

by the use of the intensity-potential graphs for the combined lines and general radiation and the comparison of them with the graphs for the general radiation at neighboring points in the spectrum. The resulting graphs, for the lines alone, and the graph of their ratio against potential, are shown in figure 2. The constant ratio indicated there differs from
the experimentally determined points by less than the limits of error, which are of course much larger at low potentials than at high. Since it is really a ratio of ionizations in an arbitrary amount of ethyl bromide, no importance can be attached to its absolute value, but its constancy seems very significant.

Another way of testing this point is that of plotting the spectra at different potentials as in figure 3. For various reasons this method is even less accurate than the other, but the ratios of increase of the $\alpha$ and $\beta$ lines are again approximately the same, and here it appears that even the $\gamma$ line increases similarly.

These spectra are of interest in showing also the influence of a small impurity of ruthenium in the rhodium target in producing its own characteristic lines; but the most important information they contain is the location of the wave length whose quantum potential is the critical value. Its position, 1.3% short of the $\gamma$ line, is independent of any errors entering uniformly in these potential measurements. Now this part of the spectrum is known to be marked by a sudden rise of absorptive power with decreasing wave length, and indeed the drop in the general radiation at this point is undoubtedly due to the influence of this absorption on the rays leaving the target, as they do, at a very small angle to its surface. This increased absorption, moreover, is known to be accompanied by a strong characteristic fluorescence, indicating that when a higher frequency oscillator has acquired whole quantum by absorption it undergoes a drop to the characteristic frequencies for emission.

Now the results of this work show that to obtain any characteristic radiation by the impact of cathode rays, each of the latter must have have energy enough to satisfy one of these higher frequency oscillators. Hence it seems probable that in this case as well as in fluorescence the characteristic rays are produced by direct excitation of the higher frequency oscillators and their subsequent drop in frequency on emission.

To sum up, these experiments show three points. First, to excite any characteristic radiation it is necessary to use a potential above a critical value which is the value required for general radiation of a wave length 1.3% shorter than that of the $\gamma$ line. Second, the lines all increase in the same ratio for any given increase of potential. Third, there is reason to believe that the characteristic rays are always a result of excitation of higher frequency oscillators, as in the case of fluorescence.

3 Amer. Phys. Soc., Dec., 1915. These values are 6.57 and 6.59 respectively.