Letters to the Editor.

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Soft X-Rays from Crystal Faces.

THESE experiments originated in an attempt to improve and extend those of Richardson and Chalklin on the generation of soft X-rays from surfaces of tungsten formed by deposition *in vacuo* on carbon (*Proc. Roy. Soc., A*, **119**, p. 71; 1928). In that investigation difficulties were met with owing to the deposition of impurities on the carbon target by the bombarding process necessary to secure the requisite high vacuum. To avoid this difficulty we made a target like two doors folded together on a hinge. We could bombard this target with the doors shut, and then open it out and so make the X-ray tests on the inner surface which had been heated but not exposed to the residual gases in the tube.

The tests are made by measuring the photoelectric current generated by the soft X-rays when they fall on a nickel plate, dividing this by the primary thermionic current, plotting the fraction so obtained against the exciting voltage, and looking for discontinuous changes of slope in the resulting curves. On making this experiment we were surprised to find a large number of discontinuities extending all over the range from 20 to 560 volts. These discontinuities are mostly well defined and quite persistent, and they repeated with a second target made from a specimen of spectroscopically pure arc carbon kindly supplied to us by Dr. R. C. Johnson. In this case the carbon was so soft that the hinge could not be made, and the surface of the target was protected during bombardment by a sliding shutter made from the same carbon.

In the hope of simplifying the problem, we decided to try experiments in which the X-rays were generated by bombarding a single crystal face of crystalline carbon. Through the kindness of Prof. W. T. Gordon we were able to obtain a diamond with a large natural face and some large pieces of natural crystalline graphite. Unfortunately, the diamond was found to be unsuitable for the experiment, as an attempt to determine its electrical resistance showed it to be immeasurably high. This would suggest that little confidence can be placed in the results of Lukirsky (*Zeits. für Physik*, **22**, p. 351; 1924) which were made with this substance. A repetition of his experiments with the substitution of graphite carbon for diamond in this laboratory by Miss L. P. Davies led only to data which were very difficult to interpret, and, furthermore, his results are incapable of reconciliation with the very reliable conclusions of Rudberg (*Proc. Roy. Soc., A*, **120**, p. 385; 1928).

After some trials we were able to split off a piece of graphite with a surface large enough to be suitable for testing. The surface used was that at which natural graphite cleaves most easily (the 0001 plane). On testing the graphite surface between about 70 and 320 volts, seventeen discontinuities have been found, each of which either agrees with a value or with the mean of two values a few volts apart, found previously with carbon. Fifteen discontinuities which were present in this range with the carbon target are absent with the graphite target. It should be added that the surface used was by no means perfect, so that it is possible that a still further reduction in the number of discontinuities might be effected if a more perfect

surface could be obtained. From these experiments there seems no doubt that the number of discontinuities from a single crystal surface is smaller than from a polycrystalline surface. It is satisfactory to note that the *K* level discontinuity is not one of those which disappears.

We should be grateful to any readers of NATURE who could supply us with any specimens of conducting crystals suitable for these experiments. The materials must be capable of withstanding a bright red heat *in vacuo*.

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Soft X-Rays from a Single Nickel Crystal.

AT the suggestion of Prof. O. W. Richardson, an investigation was made on the excitation of soft X-rays from a single crystal of nickel, kindly lent by Dr. H. H. Potter, of the University of Bristol. The face chosen was the [100] face and the range of potential was from 0 to 300 volts. The experiment was conducted with an all-quartz tube similar to the one used by Richardson and Chalklin (*Proc. Roy. Soc., A*, **110**, p. 247; 1926). Curves were drawn between the applied potential and the energy of the soft X-ray excited as measured by the usual photoelectric method. When the bombarding current was maintained at about 1.5 milliamperes, definite and strong inflections appeared at 63.8, 72.2, 106.2, and 116.0 volts. A very weak inflection was also noted at 94.4 volts. No other inflections were obtained. If, however, the thermionic current was increased to about 3 milliamperes, there appeared also, besides the four strong ones noted above, weak inflections at 129.0, 144.8, 155.9, 179.9, 186.0, and 217.7 volts (all of which appear in the results of Thomas for nickel), while the inflection at 94.4 volts became stronger.

As could be seen from the published microphotograph of the surface of a nickel crystal by Davisson and Germer (*Phy. Rev.*, **II**, **30**, p. 710; 1927), it is very difficult to obtain an ideally crystalline surface over an area of as much as 12 mm. × 6 mm. (the area used in these experiments), and there are bound to be some irregularities on the surface. It looks, therefore, very probable that when an ideal crystal surface is used only four inflections appear, these being at 63.8, 72.2, 106.2, and 116.0 volts. The first two can be associated with transitions from the $M_{II,III}$ level in the nickel atom, 63.8 volts representing the energy necessary to shift an electron from that level to the periphery of the atom and 72.2 representing the energy necessary to remove the electron altogether from the atom. The emission data of Thoraeus (*Phil. Mag.*, **vii**, 2-2, p. 1007; 1926) gives for the $M_{II,III}$ level the value of 73.2 volts. In the same manner, the values 106.2 and 116.0 volts may be associated with similar transitions from the M_I level, the energy of which is 112.4 volts according to the same authority.

It is well known that when a metal target (non-crystalline) is heated strongly by electronic bombardment, the surface looks altered, probably because of the formation of small metallic crystals. These crystals may in some manner be the origin of the large number of inflections observed by recent investigators. Further, it would be interesting to determine the effect of a crystal surface on the secondary emission of electrons, since Prof. Richardson has shown that there is a close similarity between the excitation of soft X-rays and the emission of secondary electrons (*Proc. Roy. Soc., A*, **119**, p. 531; 1928). Farnsworth (*Phy. Rev.*, **II**, **31**, p. 419; 1928) has