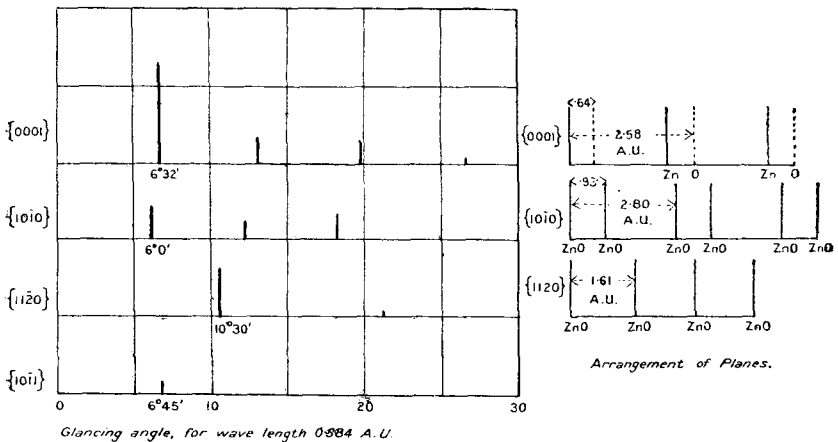


LXIII. *The Crystalline Structure of Zinc Oxide.* By
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 Physics, Manchester University*.*

ZINC oxide crystallizes in the hexagonal system. The crystals are of the dihexagonal polar type, with an axial ratio $a:c=1:1.608$. Natural crystals of zinc oxide, or zincite, are rare, and the material used for this investigation consisted of a platy mass of zincite of irregular shape. The direction of the cleavage and etching of the surface showed that the mass was composed of crystals which were very nearly parallel in their orientation. By noting the direction of the facets produced by etching it was possible to grind surfaces on the material which were approximately parallel to the principal faces of the crystal. The basal plane (0001), the first-order prism face (10 $\bar{1}$ 0), the second-order prism face (11 $\bar{2}$ 0), and the pyramid face (10 $\bar{1}$ 1) were prepared in this way.

The reflexions from these faces of the X-rays from an anticathode of palladium were examined with the X-ray spectrometer †, and the results are shown in fig. 1.

Fig. 1.



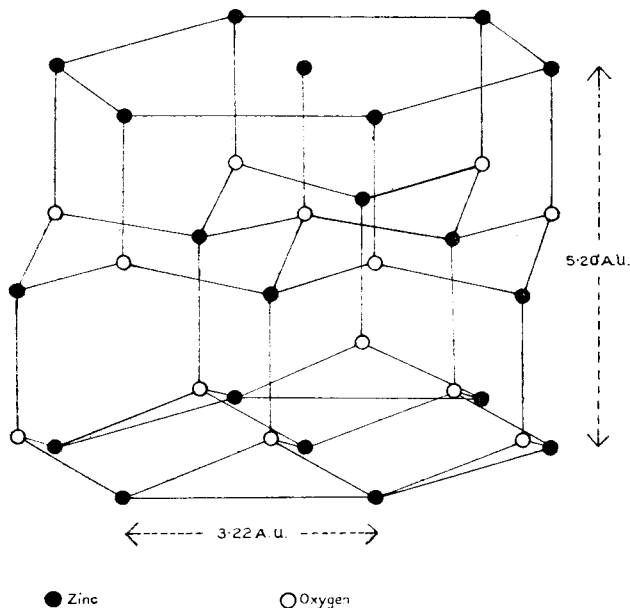
The structure assigned to the crystal by these results is shown by fig. 2, the positions of the centres of the zinc and

* Communicated by the Author.

† W. H. Bragg and W. L. Bragg, Proc. Roy. Soc. A. vol. lxxxviii. April 1913.

oxygen atoms being indicated by the small circles in the figure.

Fig. 2.



The atoms of zinc are arranged on two hexagonal space-lattices, their centres corresponding very closely with those of a set of equal spheres in hexagonal close-packing. For a close-packed hexagonal arrangement of equal spheres, the axial ratio may be calculated to be

$$a : c = 1 : 1.632.$$

The axial ratio in the case of zinc oxide is

$$a : c = 1 : 1.608.$$

The positions of the zinc atoms are identical with those of the hexagonal close-packed arrangement of spheres, if the latter be supposed to contract in the direction parallel to the hexagonal axis so as to reduce the ratio c/a from 1.632 to 1.608.

The oxygen atoms are light compared with the zinc atoms, and the spectra cannot be held to determine their positions exactly. In so far as they do this, they are in agreement with the supposition that the oxygen atoms are on two hexagonal space-lattices identical with those on which the

zinc atoms are situated, and derived from these latter by a movement of translation parallel to the c axis, which brings every oxygen atom into the centre of four zinc atoms arranged at the corners of what is very nearly a regular tetrahedron.

The dimensions of the structure are given in fig. 2. They are calculated from the axial ratio $c/a=1.608$ and the density of zinc oxide 5.78. That they agree with the dimensions measured by the angles of reflexion is shown by the following table:—

Plane.	Calculated Spacing.	Observed Spacing.
(0001)	$\frac{c}{2} = 2.60$ A.U.	2.58 A.U.
(1010)	$\frac{a\sqrt{3}}{2} = 2.79$ A.U.	2.80 A.U.
(1120)	$\frac{a}{2} = 1.61$ A.U.	1.61 A.U.
(1011)	2.46 A.U.	2.47 A.U.

In the case of the basal plane (0001) the successive planes are arranged as shown in fig. 1, oxygen and zinc atoms being arranged on alternate planes. The oxygen planes divide the distance between the zinc planes approximately in the ratio 1:3, thus explaining the small second-order reflexion and the large third-order reflexion.

The first-order prism face shows an abnormally large third-order reflexion, corresponding to the spacing of the planes parallel to that face. The planes represent the centres of equal numbers of zinc and oxygen atoms, and are so spaced that the distances between successive planes are alternately 0.93 A.U. and 1.87 A.U., thus reinforcing the third-order reflexion.

The symmetry of the crystal structure is dihexagonal polar. The polar nature of the hexagonal axis is shown by the arrangement of the planes (0001).

Cadmium sulphide, CdS, and wurtzite, ZnS, are isomorphous. Like zincite, their symmetry is of the dihexagonal polar type, and the axial ratio is very nearly the same for the three crystals.

ZnO	$a : c = 1 : 1.608$
ZnS	$a : c = 1 : 1.635$
CdS	$a : c = 1 : 1.622$

Close packed structure ... $a : c = 1 : 1.632$

The analysis of the structure of wurtzite is of especial interest, as zinc sulphide crystallizes in another form, zinc-blende, which is cubic.

If CdS and ZnS possess the same structure as ZnO, calculation shows that the reflexion from the basal plane should occur at the following angles:—

Plane (0001)	ZnS	5° 17'
„	„	CdS 5° 0'

Wurtzite occurs naturally only as a fibrous crystalline mass, and a crystal sufficiently large to measure was not available. Greenockite is a rare mineral occurring as very small crystals. Dr. Gordon, of King's College, London, very kindly lent an unusually large crystal of greenockite for this investigation, and a well-defined reflexion from the basal plane was found at an angle of 5° 2', thus affording confirmation of the assumption that the structure is the same as that of zinc oxide. It is hoped to make further measurements on this crystal.

Wurtzite shows a platy structure parallel to the fibres of the crystalline mass, and when this material was mounted in the spectrometer a faint reflexion at a glancing angle of 5° 20' was obtained, indicating that the basal planes of the crystals were parallel to the fibres. The effect was so small that very little reliance can be placed on this measurement; further observations are necessary to confirm it.

It is of interest to compare these structures with that of zinc-blende. In zinc-blende the zinc atoms are arranged on a face-centred cubic lattice, of side 5·42 A.U. The oxygen atoms are on a similar lattice, derived from the former by a movement of translation which brings each oxygen atom into the centre of four zinc atoms arranged on the corners of a regular tetrahedron. The trigonal axes in zinc-blende are polar. If the structure of wurtzite is the same as that of zinc oxide, as would appear to be the case, then in the crystals both of zinc-blende and wurtzite, every atom of sulphur is surrounded by four atoms of zinc at the corners of a regular tetrahedron, and every atom of zinc by four sulphur atoms similarly arranged. The dimensions of the structures are also almost identical. In wurtzite, for example, the distance between neighbouring zinc atoms is 3·85 A.U., in zinc-blende it is 3·83 A.U. The arrangement of the planes parallel to the plane (0001) of wurtzite is the same as that of the planes (111) in zinc-blende, the axis perpendicular to the planes being in each case polar.

The experiments described in detail in this paper were for the main part carried out in 1914, and a short reference to the results was made in "X Rays and Crystal Structure."

I wish to express my gratitude to Dr. Hutchinson, of the Mineralogical Laboratory, Cambridge, and Dr. Gordon, of King's College, London, for their kindness in supplying the material used, and to Mr. W. R. James, who assisted me in making some of the observations.

LXIV. *A Fluid Analogue for the Æther.* By DR. G. GREEN,
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THE purpose of the present paper is merely to illustrate by means of an analogy certain points of resemblance (especially with reference to wave-propagation) between the æther and ordinary fluids, to some of which particular attention has not hitherto been drawn. The conception of the æther as a fluid medium has already been very fully discussed † and it is known to be subject to important limitations. Nevertheless it is desirable at the present time that the relations of matter and æther should be examined in every possible aspect, and the analogy now to be considered, though in itself incomplete, may be of interest as an illustrative system, and possibly also in its bearing upon some problems of the æther still requiring solution. Recent experimental observations have compelled us to modify certain ideas regarding the physical characteristics to be associated with the æther, in proving that the æther is capable of acting as a very slightly refracting medium in strong gravitational fields. This discovery has to some extent suggested the line of comparison between æther and ordinary matter which is followed in the present paper.

One of the main functions to be fulfilled by the æther is the apparently two-fold function of conveying waves of light and of electric and magnetic force at a constant velocity and of propagating the forces of gravitation. There have been associated with the æther certain elastic qualities enabling it to transmit transversal vibrations and at the same time to transmit a stress analogous to tensional stress in elastic material; and it is natural to

* Communicated by the Author.

† See FitzGerald, Proc. Roy. Dublin Soc. vol. ix. (1899).