window-bench. This bench, however, is chiefly used for titration work, and therefore shelves are affixed to the wall some distance above it on either side, on which large bottles are placed containing the standard solutions.

It will be seen from Figs. 2 and 3 that a sink is placed at the end of the bench on the one side, and that there is a desk on the opposite side; adjoining this desk is an ice cupboard let into the bench, on the cover of which a balance for weighing out substances used in the experiments is placed. By the provision of such an ice cupboard at every place a great saving of ice has been effected: it is not only available for the storage of ice—nowadays an indispensable laboratory agent—but things can be kept cool in it even over long periods, over Sunday for example.

Four differently coloured pipes for water, gas, compressed air and vacuum run along the ceiling, and from these branch pipes are carried down the columns to the benches; taps are provided in a convenient situation, so that, if necessary, the supply of water, &c., to a bench may be at once shut off. The water pipes are covered with flannel to prevent the water which condenses on them from dropping down. Each working place is provided with 4 taps for compressed air, 4 vacuum taps, 11 water taps, 14 gas taps for heating purposes, and 9 gas burners in case of a failure of the electric light. A steam pipe runs along the wall, from which there are branch pipes connected with "purifiers," conveying steam to each of the large water baths before referred to, and to a valve under the hood adjoining the closet.

A shower bath depends from the ceiling at either end of each of the large laboratories for use in case of the clothes of any of the chemists or laboratory attendants catching fire.

Every bottle on the shelves is not only clearly labelled, but is also numbered, so that it is easy for the lad who has to keep the place clean and in order, however ignorant he may be, to arrange them properly, and moreover, each particular chemical occupies the same position in the row of bottles in every place in the laboratory.

Each chemist has a lad to assist him who washes all vessels, keeps the benches clean and the apparatus in order; in fact, does generally what he is told, even helping in the experiments. In addition, there are three lads under the supervision of an older laboratory servant in each laboratory, who at once avail themselves of any opportunity offered by the absence of the staff to "tidy up" in regions not specially committed to the charge of the young assistants. The order and cleanliness—extending even to keeping the leaden bench tops polished—thus secured is most remarkable.

Each chemist is so completely screened from his neighbour "next door," that he is not only able to work undisturbed, but practically in secret; he is only open to observation from the place on the opposite side of the main gangway, and the chemists are usually so placed that of the two working at these benches either the one is a junior under the direction of the other, or they are working in co-operation.

As a further illustration of the perfection of the arrangements I may quote from an account before me of a visit to the laboratory a description of the steps taken to put out a fire. A crack is suddenly heard and flames and a dense cloud of smoke are seen to ascend from one of the benches; all the chemists in the room at once rush to the spot. The particular chemist is found to be unhurt, but the clothes of his laboratory boy are on fire; instantly he is dragged to the shower bath, and the fire is at once put out. Meanwhile the laboratory servant has given the alarm by means of the electric fire alarm provided in the room, and within two minutes the twelve men on duty of the twenty-four members of the works fire brigade appear in full uniform. Those present, however, by turning on all the water taps in the neighbourhood of the fire and directing the water on to the burning bench had already extinguished the flames. The room is filled with a dense black fog, but by opening the windows and a valve in the main ventilation system near the ceiling this is very soon got rid of. The origin of the accident was simple enough: a young chemist, fresh from the University, unaccustomed to work with large quantities, had allowed his laboratory boy to heat a couple of litres of the hydrocarbon toluene, which he was using in recrystallising a substance, in a glass flask, over a bare flame.

Another striking feature in the large laboratories is a series of brass valves arranged along the wall under a hood opposite the bench for general use; the labels under these valves bear the names oxygen, carbon dioxide, chlorine, sulphur dioxide, phosgene, methyl chloride, hydrogen and ammonia. These various gases, compressed in cylinders enclosed in cupboards in the basement, can be used at any time by communicating through a speaking tube to the man in charge of the store department, who then opens the valve on the cylinder containing the required gas, so that it only remains for the chemist to open the valve in the laboratory.

In the lower laboratory one place only is distinguished from all the others, being fitted up for electro-chemical work with the necessary current-measuring instruments, a series of about fifty glow lamps being arranged as resistances.

In the balance-room, besides balances, there is a large arc lamp with special lenses designed by Prof. von Perger, of Vienna, used in ascertaining the effect of light on colours—in these days sunlight can no longer satisfy the needs of German industrial enterprise! Colorimeters, spectroscopes, and other apparatus are also to be found in this room. Colour chemists are not fond of making analyses if it be possible to characterise substances by any other means; the combustion furnaces are therefore but little used, and a number of ovens in which pressure tubes are heated have supplanted most of them.

Adjoining the research laboratories there is a "technical laboratory" full of apparatus exactly like that in use in the works, but of much smaller size. Here experiments are carried out on a somewhat larger scale than in the laboratory prior to the processes being effected on the large scale in the works; and the staff in this laboratory are also engaged in making many of the chemicals required to replenish the stores for use in the research laboratories.

The stores are in charge of two superintendents, one of whom is educated as a glass-blower. It is worth mentioning also that all thermometers, prior to their issue from the store, are there compared with a normal thermometer.

The laboratory was designed by my friend Dr. C. Duisberg, the director, the necessary architectural assistance being afforded by Herr Bormann, architect to the works.

The foregoing is but a very imperfect account of this marvellous works research laboratory. A more typical and concrete illustration of the appreciation of the value of science by German manufacturers, however, could not possibly be found. but yet it is only one of many that might be brought forward. Personally I can only say, that while lamenting the criminal short-sightedness of my countrymen, I am lost in admiration of the enterprise displayed by their foreign competitors: it cannot be denied that they deserve to succeed!

HENRY E. ARMSTRONG.

## ELECTRO-OPTICS.

THE experimental and theoretical investigations of the last twenty years have lent a new interest to what, I venture to think, is one of the most fascinating branches of physical optics, namely, the action of an electromagnetic field upon light. The discoveries which have hitherto been made may be classified under four heads: (1) Faraday's experiments, which show that when plane polarised light is transmitted through a *transparent* magnetised medium, a rotation of the plane of polarisation is produced; (2) Kerr's experiments, which show that the effect of electrostatic force on a *transparent* medium is to convert it into one which is optically equivalent to a uniaxal crystal whose axis is in the direction of the force; (3) Kerr's experiments on the reflection of plane polarised light at the surface of a magnetised iron reflector, which show that a rotation of the plane of polarisation of the reflected light takes place, which in certain cases is in the same and in others in the contrary direction to that of the amperean current which may be conceived to produce the magnetic force; (4) Kundt's experiments on the reflection of light from magnetised iron, cobalt, and nickel, and also on the transmission of light through thin magnetised films of these metals. There is also another series of experiments by Kundt, in which polarised light is refracted at the upper surface of a plate of glass, is then reflected at the lower surface, and again refracted at the upper surface. The results of these experiments show that the plane of polarisation of the ultimately emergent light is rotated in the *contrary* direction to that produced by an iron reflector.

There seems to be a fair amount of evidence to lead to the conclusion that Hall's effect is intimately connected with the action of a magnetic field upon light, but further evidence is required before it can be asserted that both phenomena are due to the same ultimate cause. Up to the present time Hall's effect has, I believe, only been detected in conducting media; but if it be assumed to be capable of existing in transparent media, theory furnishes results which, as far as they have been worked out, are in agreement with experiment. Hall's effect is capable of explaining the experiments of Faraday, and it also gives a result in accordance with Kundt's experiments on reflection and refraction from a plate of magnetised glass in the case in which the magnetisation and incidence are normal. It would be quite possible to apply this theory to the case of oblique incidence, but the work would be laborious and the final results complicated. The experiments of Prof. Dewar on liquid oxygen would seem to provide a more promising way of testing this theory, for, on account of the high susceptibility of this substance to magnetic action, it is possible that an effect might be observed in the case of *direct* reflection.[1] According to theory, Hall's effect ought to be positive in the case of glass and gaseous oxygen, and negative in the case of a solution of perchloride of iron; and a repetition of Kundt's experiments, in which the latter liquid is employed in the place of glass, ought to show that the rotation takes place in the *same* direction as that produced by metallic iron. Such experiments would be valuable as a further test of the theory, but they do not appear to have been made.

A paper recently communicated to the Cambridge Philosophical Society (May 1) still further confirms the view which I have put forward. In this paper I have transformed the formulæ for reflection at a magnetised *transparent* medium by assuming that the refractive index is a complex quantity. The resulting formulæ for the amplitudes of the reflected vibrations agree very well with Kerr's experiments so far as qualitative results are concerned, provided the values and signs of certain quantities are supposed to be determined by optical, as distinguished from electromagnetic methods. They are, moreover, the same *as regards their form* as those deducible from Maxwell's theory by taking into account the conductivity combined with Hall's effect; but unfortunately the values of certain constants, when expressed in terms of electrical quantities, differ from the values which are required by optical experiments, in a manner which prevents a perfectly satisfactory electromagnetic theory being constructed in this way, and I doubt whether it will be possible to attain the end in view until a theory based upon the mutual reaction of ether and matter has been discovered in which quantities, upon which the motion of matter depends, enter into combination with electromagnetic quantities.

Although the sign of Kerr's effect in nickel is the same as in iron and cobalt, the sign of Hall's effect is different. This difficulty is apparent rather than real, for a theory based upon the mutual reaction of ether and matter might very well introduce a factor containing the free periods of the vibrations of the matter which would change the sign of the magnetic terms. Some light might be thrown on this point by determining the principal incidence and azimuth for nickel and cobalt.

The generally received theory, that reflection and refraction are materially influenced when any of the free periods of the vibrations of the matter fall within the limits of the visible spectrum, suggests that the sign of Kerr's effect may be different in the case of the ultra-violet and the infra-red portions of the spectrum from what it is in the luminous portion. Experiments on this branch of the subject are needed, and possibly the employment of a fluorescent substance, such as quinine, in the case of the ultra-violet waves, or of a solution of iodine in disulphide of carbon, in conjunction with Prof. Langley's bolometer,[2] when the infra-red waves are experimented upon, might furnish important information on this point.

The experiments of Kerr on the effect of electrostatic force suggest that if light were reflected from a strongly electrified metallic conductor, certain peculiarities would be observed. In the absence of experiments, which do not appear to have been made, it would be impossible to predict with certainty what these effects are likely to be; but it would seem probable that an electrified metallic reflector would behave like a doubly-refracting metallic medium having a *single* optic axis which is perpendicular to the reflecting surface. When light is reflected from the surface of a uniaxal crystal which is cut perpendicularly to the axis, the component vibration at right angles to the plane of incidence is reflected in the same manner as if the medium were isotropic. Under these circumstances we should anticipate that in the case of an electrified metallic reflector, the component vibration *in* the plane of incidence would be much more strongly affected by electrification than the component at right angles to this plane. If this speculation should be verified by experiment, it would follow that the principal incidence and azimuth, and also the difference between the changes of phase of the two components, would be affected by electrification in a manner which could be observed.

In conclusion I would point out that further experiments are required of the following nature:—

(1) Experiments on the reflection of light from magnetised *transparent* media, such as glass, perchloride of iron, and also if possible from liquid oxygen.

(2) Experiments on reflection from and transmission through magnetised metals, special attention being paid to the effects produced by the non-luminous portion of the spectrum.

(3) Experiments on reflection from *electrified* metallic reflectors.

A. B. BASSET.

[1] The effect produced by a *single* reflection from magnetised glass would be too feeble to be detected; but Dr. Kerr suggested to me that an effect might possibly be observed by employing the method of multiple reflections.

[2] I do not know whether the bolometer is more sensitive to heat than a pair of average eyes are to light; if it is, experiments on the infra-red waves ought to be easier than experiments on luminous waves.