connexion with the valency rules of the chemist, and *chemical homopolar forces* are elucidated to this extent —that they are seen to be a consequence of the same mathematical and physical principles which have been formulated for other branches of physics. This result may conceivably come to be regarded as one of the greatest achievements of the present formulation of quantum mechanics.

The new theory has been successful in explaining other forces, the nature of which was formerly little understood. For a long time it has been known that atoms, which are chemically inert, exert attractions on each other; so much so, that they aggregate together as liquids and solids if the temperature is lowered sufficiently. These attractive forces, usually called *van der Waals forces*, have now in one or two simple cases been calculated deductively from the electronic structure of the atoms. These attractive forces seem to be due not to a static polarisation of the atoms by each other but rather to a rapidly fluctuating mutual polarisation. Atoms are not actually continuous distributions of space charge. They are only to be regarded so on the average. When two atoms are subject to each other's influence, the motion of the electrons in one modifies that of the electrons in the other. They tend on the average to move in phase.

Suppose, for the sake of illustration, that an atom were represented by a linear oscillator, that is by an electron vibrating along a line through the nucleus. Such a system requires only one co-ordinate z to specify it. Then the probability-distribution of the electron in its lowest energy state is a Gaussian error curve ($e^{-\alpha z^2}$), symmetrical about the origin. If two such electronic systems, vibrating along the line joining the nuclei and specified by co-ordinates z_1 and z_2, are allowed to interact, the new probability-distribution is not simply a combination of the two undisturbed probability-distributions of the isolated systems. Calculation shows that as a result of interaction the probability of finding z_1 and z_2 with the same sign has increased, while that of finding them with the opposite sign has decreased. Now dipoles which point in the same direction attract, and those which point in the opposite direction repel. The net result is that the two electronic systems on the average attract. The attractive force for this model and for actual atoms proves to be proportional to the inverse seventh power of the distance.

All atoms and molecules exert on each other an attractive field of this type, but usually this attraction is masked by other larger attractive fields. Only in the case of inert gases or saturated molecules does it become predominatingly important. It is likely that many substances, such as the halogen hydrides, are held together in the solid state by forces of this type. There is a growing recognition, too, of the importance of van der Waals fields in many phenomena at surfaces such as in adsorption.

The problem of *ionic cohesion* largely resolves itself into explaining why some atoms have an affinity for electrons. Such atoms are usually unsymmetrical charge distributions and the nature of the affinity can be understood, though actual calculation of the magnitude is difficult.

Metallic cohesion seems to be due partly to the Coulomb interaction of space charge distributions (the Coulomb attraction referred to above), partly to the 'exchange' phenomenon, and partly to van der Waals attraction. Little is as yet known as to the relative extent to which these various factors contribute to the cohesion of a metal. The general principles seem to be understood. What is now required is a mathematical technique capable of applying them to particular cases.

Selection of Engineering Apprentices.*

HOW far is it practicable to use psychological tests in the selection of boys for the engineering trade? An attempt to provide an answer to this question has recently been made by the Birmingham Education Committee, under the auspices of which an investigation was conducted by Miss E. P. Allen and Mr. Percival Smith. A report describing the tests used, the methods adopted, and the results obtained has now been published.

Such a report will be of especial value to local education authorities responsible for juvenile employment. Indeed, the Malcolm Committee on Education and Industry has already directed attention to the necessity for this kind of research by authorities upon whom that responsibility rests. The present report deals with one aspect of the wide problem with which such authorities are faced: its authors have also been engaged upon a second experiment, involving still wider issues—the extent to which a series of psychological tests can be of practical use in offering vocational guidance to children when they leave elementary schools.

So far as the engineering trade is concerned, however, one of the first points to be decided was what that all-embracing term meant. In Birmingham, as elsewhere, it covers a multiplicity of occupations, ranging from those followed by practically unskilled manual workers to those needing highly skilled technical experts. For the former, the chief requirement is a varying amount of manual dexterity, and tests of such dexterity would, in their case, probably be sufficient. For those engineering branches which require skilled apprentices, however, the qualities to be sought are a combination of intelligence, mechanical aptitude, ability, and dexterity. With that combination in mind, the report uses throughout the term 'apprentice ability'. Tests were therefore used which would depend *inter alia* on mental processes, but would be definitely associated with mechanical ability.

This primary difficulty of deciding the type of qualities to be sought in connexion with so wide an industry as engineering is, of course, well known to engineers. We stress it here not merely to show its complications, but also as an indication of the care with which the investigators dealt with their problem—a care which will go far towards building up methods and results upon which confidence may fairly be placed.

The groups of individuals selected included third and fourth year apprentices (average age nineteen years) attending part-time courses at the Birmingham Central Technical College; entrants and leavers (fourteen to sixteen years of age) of a school with an engineering bias (Handsworth Junior Day Technical School); of a school with a commercial bias (Aston Commercial School); and of a general secondary school (Yardley Secondary School).

This selection of pupils from differing types of post-primary schools possesses a special interest in view of the present reorganisation of education, which

* City of Birmingham: Education Committee. Selection of skilled Apprentices for the Engineering Trades. Report of Research. By E. Patricia Allen and Percival Smith. Pp. iv+35. (Birmingham: Education Committee, 1931.)

is striving to relate the work of such schools to the needs of industry and commerce. Each has recently tended to make special claims concerning the aims and results of its syllabus. The following summary, taken from Section IV. of the report, would appear, so far as the engineering trades are concerned, to support the claims already made by the junior technical school: "(1) Boys who have had a purely academic training do not improve in ability to tackle these tests to the same extent as boys of a somewhat lower intellectual level who have received further education with an engineering bias. (2) Boys who have had further education with a different vocational bias (commercial) do not improve in ability to tackle these tests to the same extent as boys of a slightly lower intellectual level who have received further education with an engineering bias."

It is to be noted that the investigators did not use only the method of 'tests'. Criteria of apprentice ability of the individuals were supplied by instructors and the test results were compared with the respective criteria.

Priestley as a Pioneer.

UNDER the title, "Joseph Priestley and his place in the History of Science", Sir Philip Hartog delivered a discourse at the Royal Institution on April 24, a reprint of which, with a postscript dealing with some additional points, has been received. Sir Philip traces the main events in Priestley's life, bringing out the fact that he was more than a man of science; he was a teacher, theologian, politician, and defender of liberal thought. His scientific work has been variously assessed and perhaps some aspects have tended to have been overshadowed by his discovery of oxygen. Priestley made some important experiments in electricity, and his work on the "History of Electricity" includes, among other matters, a statement that the inverse square law is contained in the experimental fact that there is no electrification inside an electrified metal vessel. This was probably the starting point of Cavendish's better known investigations. Priestley also made experiments on electric discharges, which are now seen to have raised fundamental issues.

Priestley's attitude to hypotheses in science is examined, and in his indifference to his own theories and those of others, he is thought to have been influenced by Franklin. In his chemical investigations he accepted the phlogistic theory as a pupil, with docility, since he was "no professed chemist". His practical investigations of gases, although preceded by important publications of Cavendish, led to the acquisition of much new knowledge on gases. This formed the basis of Lavoisier's theoretical revolution in chemistry. Sir Philip Hartog is inclined to allow Lavoisier more originality in the matter of the discovery of oxygen than has been usual, although he admits in more than one instance that the memoirs of Lavoisier as they finally appeared had been amplified from the original communications, a circumstance which makes it necessary to use the greatest care in dealing with this author. Although Priestley's intelligence "remained intact, bright and lively to the end", Sir Philip thinks his memory was failing him when he wrote his well-known complaint of Lavoisier's claims some years before his (Priestley's) death.

Sir Philip Hartog's discourse makes it clear that Priestley more than once was tempted to adopt Lavoisier's new view of the chemistry of combustion, but that he was restrained by the results of experiments, these being either faulty in themselves or wrongly interpreted. He nearly reached a true conception of the composition of water from his own experiments, but says he "was taught by Mr. Watt to correct this hypothesis", an event which does not help in the attempts which have been made to credit Watt with the discovery of the composition of water. One of Priestley's greatest stumbling-blocks was his confusion of the two inflammable airs, hydrogen and carbon monoxide, which was only cleared up by Cruickshank in 1801. Priestley's work on respiration and that on the growth of plants were the starting points for investigations of others, the first for Lavoisier's great researches on animal respiration.

Sir Philip Hartog believes that it is easy to understand why Priestley's work and his character have been under-estimated in the past. His electrical work and his clear views on the use of hypothesis and on scientific theory generally have been eclipsed by his chemical work, in judging which it is no simple task to divest his language of the enveloping veil of the phlogistic theory. He deserves a greater place in the history of science than he has hitherto been accorded.

Some Phenomena of the Upper Atmosphere.

THERE are three layers in the upper atmosphere in which dissociation is produced by the absorption of solar radiation. These are the layer of ozone, with its maximum concentration at about 50 km., and the two ionised layers at about 100 km. and 220 km. The absorption of solar radiation of any kind in a gas of which the density varies exponentially with height $h(ae^{-h/H})$ has a definite distribution relative to the level of maximum absorption; this distribution depends only on H. It is shown that the main regions of absorption associated with the three layers are well separated, though the dissociation of molecular oxygen which results in the formation of the ozone layer has an important influence on the whole of the overlying atmosphere, in which atomic oxygen is a permanent constituent, its concentration increasing with height. The concentration of ozone, on the other hand, must decrease with height above a certain level, a conclusion which bears on the maintenance of a high temperature in the upper atmosphere.

Milne's theory of photoelectric ionisation is applied to the earth's atmosphere, assuming that the sun's radiation even in the far ultra-violet is that of a black body at 6000°. It suggests that the ionisation of the upper layer is due to the absorption of ultra-violet radiation, probably by atomic oxygen.

Considering both magnetic and radio evidence, it is inferred that the agent responsible for ionising the lower layer consists of neutral atoms from the sun, emitted from the sun at the same time as the charged atoms that are responsible for magnetic disturbance, the number of the two kinds of particles varying in unison, from time to time. They travel together from the sun until within a few earth-radii distance from the earth, when the charged particles are deflected by the earth's magnetic field towards the polar regions, there producing auroræ, while the neutral atoms travel straight on and ionise the sunlit hemisphere.

On considering the origin of the green light of the night sky, making use of Rayleigh's recent measure-