which Soddy has recently introduced the term *isotope*, by which he defines very closely related elements which are chemically inseparable but have different atomic weights. The non-separability of isotopes by chemical methods has recently been confirmed by Richards and his co-workers, who found that the atomic weight of lead obtained from Australian carnotite (containing uranium-lead) was unaltered even after the nitrate into which the lead was converted had been subjected to more than a thousand fractional crystallisations. Furthermore, Richards has determined the atomic weight of uranium-lead, and the number found (206.08) is less by as much as 0.25 per cent. than that of ordinary lead, which differs from it in other physical properties involving weight. It is possible that lead descended from thorium (208) and lead descended from uranium (206) have enough in common to be each called lead, but are varieties or isotopes of the same element, common lead (207.2) being a mixture of the two.

We may conclude, therefore, that in radioactive substances there is a continual transformation of one element into another of lower atomic weight, such transformation (apparently quite independent of temperature and external electrical conditions) being accompanied by the liberation of enormous amounts of energy, compared with which the magnitudes of energy of chemical reactions fade

to insignificance. Has the earth passed through its element-building epoch? Instead of spinning "for ever down the ringing grooves of change," are we mounting backwards up the spiral as our larger empires of matter disintegrate into smaller and perhaps more stable states?

Just as the beginning of the last half-century was marked by the epoch-making discovery of the periodic system of the elements, so in effect is the close of it marked with another—namely, Moseley's discovery of the atomic numbers of the elements, the importance of which we have as yet scarcely realised.

The atomic number of an element as suggested by van der Broek defines the place-number occupied by the element in the periodic table, and at the same time is the number of electrons in the atom or nuclear charge of it. Moseley showed from a spectroscopic examination of the frequencies of characteristic X-rays emitted when X-rays bombard anticathodes of various metals, that the square roots of the frequencies are proportional to the atomic numbers. The latter are known for all elements up to uranium—thus, hydrogen one, helium two, lithium three, and so on until finally uranium 92, and the anomalies which appear in Mendeléeff's table disappear, as in all cases the correct chemical order is maintained. The atomic numbers appear to be even more fundamental than the atomic weights.

PHYSICAL CHEMISTRY—PAST AND PRESENT.

By PROF. J. C. PHILIP, F.R.S.

THE cultivation of the border-lands between the various sciences, so actively prosecuted in the last few decades, has nowhere led to more notable results than on the frontiers of physics and chemistry. This particular field of investigation, covering phenomena in some measure common to both these sciences, has gradually taken shape, and has attracted crowds of workers, keen to apply the exact methods of physics to the wealth of problems and material presented by chemistry. With the passing of the years physical chemistry has ultimately emerged as a definite branch of natural knowledge, full of intrinsic interest, but comprising also much that is of value for other sciences.

Fifty years ago the foundations of physical chemistry had to some extent been already laid. Faraday's experiments on electrolysis and the liquefaction of gases, Graham's observations on gaseous and liquid diffusion, and Hittorf's investigations of electrolytic migration had been put on record, although in some cases, notably the last-mentioned, the full significance of the work was not to be realised for many years to come. Avogadro's hypothesis and the kinetic theory were also before the scientific world, and the Brownian movement of minute particles

suspended in water, destined ultimately to figure so prominently in the physical chemistry of recent years, had been not only recorded but, for the time, forgotten.

During the period in which NATURE first appeared, new methods of investigating chemical change, and new conceptions of chemistry as a quantitative science were being developed. The work of Harcourt and Esson, of Guldberg and Waage, on the action of mass as a factor in equilibrium and velocity, as well as Horstmann's application of thermodynamics to chemistry, inaugurated a new epoch, with which, in both directions, the name of van't Hoff was afterwards so brilliantly associated. It was van't Hoff who put the science of chemical dynamics on a secure experimental basis, and thus prepared the way for a rational study of catalysis, a particular development of vital significance for the growth of important chemical industries. It represents part of the contribution which physical chemistry has made to the advance of chemical knowledge from the purely descriptive to the rational and quantitative stage.

Appreciable progress towards the recognition of physical chemistry as a distinct branch of knowledge resulted, at a somewhat later date,

from van't Hoff's study of osmotic pressure, and his extension of the gas laws to solutions. This remarkable work was followed, at a short interval, by Arrhenius's hypothesis of electrolytic dissociation, a conception that has left its mark deep on the physico-chemical research records of the past thirty years. This hypothesis has been the guiding principle in countless investigations, and although it presents difficulties not yet satisfactorily solved, and appears to require modification in some respects, notably in regard to the rôle of hydration, it holds the ground to-day as the most acceptable and intelligible interpretation of the properties of electrolyte solutions. The history of the electrolytic dissociation theory may be fairly described in Larmor's words: "In the case of every successful scientific theory the time must come when its first easy triumphs become exhausted, and what prominently confronts the investigator are its outstanding defects and difficulties." Such is the present position in regard to the ionisation theory, and during recent years there has been a concentration of effort on such outstanding problems as the application of the mass action law to strong electrolytes, the catalytic action of ions, and the differences existing between the values of the ionisation ratio deduced for one and the same electrolyte by the osmotic and conductivity methods respectively.

The decade in which the theories of van't Hoff and Arrhenius were propounded saw also the establishment of the first journal exclusively devoted to the record of physico-chemical research. The first number of the *Zeitschrift für physikalische Chemie* appeared in 1887, and an inspection of the early volumes reveals the extraordinary variety and attractiveness of the problems that were being attacked under the ægis of the new science, and on the more definitely quantitative lines for which this branch of chemistry stands. It was not long before the influence of physical chemistry began to be apparent beyond its own borders in a renaissance of inorganic chemistry which continues to the present day. Important reactions between well-known substances, regarded as completely worked out, have been explored afresh in the light of physico-chemical principles, and have yielded an extraordinary amount of valuable quantitative data. In this

connection one might refer to the phase rule and its practical utility in connection with the conditions of existence of salt hydrates, the constitution of alloys, and various technical problems.

Prominent among the later developments of physical chemistry has been the examination of matter in a condition coarser than that corresponding with the molecular state. The study of mechanical suspensions, and the investigation of colloidal solutions with the aid of the ultramicroscope, have opened up a whole new world of fascinating phenomena, and bridged the gap between the visible particle and the molecule. Perrin's epoch-making count of the particles at different levels in a vertical column of a mechanical suspension, and the evaluation of the Avogadro constant which follows therefrom, have notably extended the validity of the gas laws, and supplied at the same time definite quantitative proof of the molecular movements postulated by the kinetic gas theory. Of extraordinary interest also in this connection is the fact that purely physical evidence, based on the atomic character of electricity and depending on measurements of the elementary electric charge, gives strong support to the Avogadro conception.

At the present moment fresh means of attacking the still unsolved problems of the physico-chemical field are being developed. Planck's quantum theory, for example, coupled with such experimental work as that on the heat capacity of solids at low temperatures, and on the origin and relationship of spectral lines, appears likely to have a notable influence on the future of physical chemistry. The thorough investigation of colloids along physico-chemical lines, which is actively proceeding to-day, promises to throw light on many problems which are of interest not only from the purely scientific point of view, but also to the industrial chemist. The sister sciences, too, are vitally concerned in the exploitation of this field, and, indeed, the physical chemist of to-day may point with legitimate pride to the fact that the principles of his science are welcomed by the metallurgist, the physiologist, the geologist, and others, as valuable aids in the elucidation of their respective problems. This ever-widening influence is the guarantee of the future vitality of physical chemistry.

THE INFLUENCE OF INVESTIGATIONS ON THE ELECTRICAL PROPERTIES OF GASES ON OUR CONCEPTIONS OF THE STRUCTURE OF MATTER.

By SIR J. J. THOMSON, O.M., PRES. R.S.

ALL workers in science owe much to NATURE, and so I am glad to comply with the request of its Editor to write a few words on the progress of some branch of physics in the fifty years since NATURE was started. I shall confine myself to the effect which results obtained by investigations

on the electrical properties of gases have had on our conceptions of the structure of matter and the potentiality of further applications of these results to increase our knowledge of physical and chemical problems. In these investigations we study atoms and molecules when they are charged with electri-