The other economy is to cool the air, before compression, by means of a subsidiary (ammonia) refrigerating plant. When the two modifications are used together, the efficiency is raised from about 0·1 gallon per kwh. to 0·3 gallon per kwh.

As mentioned above, Linde undertook the design of a liquid-air plant originally with the idea of using it to extract oxygen from the air, as an improvement on the chemical method then in use. His first really successful apparatus was described in 1902, and utilized the principle of the familiar rectifying column. This depends for its action on the facts that liquid and vapour in equilibrium with each other have different compositions, and that the boiling point of oxygen is higher than that of nitrogen. Thus a liquid with 20 per cent nitrogen and 80 per cent oxygen is in equilibrium with a vapour containing 52 per cent nitrogen and 48 per cent oxygen, while liquid with 80 per cent nitrogen and 20 per cent oxygen corresponds to a vapour with 95 per cent nitrogen and only 5 per cent oxygen.

In a simple rectifier for the production of oxygen, the liquid air, at a temperature just below its boiling point, enters the top of the column, consisting of a chamber stacked with glass balls, over which it trickles to the bottom. The liquid in the column meets a rising stream of oxygen, which is itself cooled and condensed, thereby giving up heat which evaporates nitrogen from the down-flowing liquid. The latter thus becomes progressively richer in oxygen, until at the bottom it consists of nearly pure oxygen. Arrangements are made to draw off the gas from the liquid which collects at the bottom. In its path, it is used to cool the incoming air, and similarly the nitrogen which escapes from the top of the column is made to act as a cooling medium before it finally escapes. By the nature of the process, if pure oxygen is required, the escaping nitrogen is far from pure; conversely, if the rectifier is operated so as to obtain pure nitrogen, then the oxygen is impure. To obtain both elements pure would require multiple rectification, in which the products from both ends were separately redistilled, and it is not at present commercial practice to make both gases in one plant.

It should be noted that the operation of a rectifying column so as to produce pure nitrogen involves appreciable modification. Instead of collecting the desired product as a liquid at the bottom, and allowing some to evaporate, it is then necessary to collect the gas at the top and to condense some of it to provide a downflow of the liquid. The device suitable for this purpose was introduced by Linde some eight years after his first rectifier, and is described as the Linde double-column rectifier.

In the early days of this subject, the only product of commercial importance was oxygen, which is now used (for example, in welding) on an enormous scale. In the last twenty years, however, the demand for nitrogen has become equally important, in view of its use in synthesizing ammonia. When it is required for this purpose, the plant which liquefies and rectifies the air is invariably on the site of the synthetic ammonia works, and the nitrogen merely flows along a pipe line from the rectifier to the point where it is used. Nitrogen of purity 99·96 per cent is now manufactured commercially, without the necessity for any chemical treatment.

This development would have astonished Linde, to whom the nitrogen was not only a troublesome impurity, but the more so on account of its being present to the extent of four fifths of the whole raw material.

His astonishment at the rise of nitrogen to an importance such that the two gases are now prepared in roughly equal quantities, would be small compared with his amazement if he could learn that some air is now liquefied for the sole purpose of extracting argon from it, and that there is every likelihood of a thriving industry growing up to extract krypton and xenon—gases which are present in the atmosphere to the extent of 1·1 and 0·08 parts in a million by volume.

Up to the present, the demand for argon arises solely from the needs of the gas-filled lamp, where its high molecular weight makes it of value in preventing the evaporation of the filament, and thus enables the latter to run at a high temperature and a correspondingly high luminous efficiency. Although the gas-filled lamp was only introduced about twenty years ago, its importance may be gauged from the fact that some thousand million such lamps are now made annually.

To separate argon from air, the latter is first fractionated into two components, an argon-oxygen mixture free from nitrogen and an impure nitrogen, which is rejected. The mixture of argon and oxygen is then rectified, by apparatus of the same type as that used in simple rectification; the argon so produced contains the residual nitrogen from the oxygen-argon mixture, the oxygen being practically free from nitrogen and containing about 0·2 per cent argon. The oxygen, of course, is not wasted; it is in fact an economic necessity to obtain a second product when the necessary large volumes of air are being treated to extract the 1 per cent argon which they contain.

Helium and neon have boiling points far below those of argon, oxygen and nitrogen. Hence they remain in the gaseous form, and accumulate at the top of the separating column. It is in some works found profitable to collect these gases from time to time, since neon is, or was until the black-out, in demand as a filling for the gas discharge tubes of striking red colour widely used for advertising purposes.

It is clear from what has been said above that Linde was one of those pioneers whose work was so well done that it could bear extension in many directions: for many of the later developments, carried out since his death, have retained his methods with only minor modifications.

OBITUARIES

Sir Joseph Larmor, F.R.S.

JOSEPH LARMOR was born at Magheragall, Co. Antrim, on July 11, 1857. In his schooldays at the Royal Belfast Academical Institution, he is described as a "thin and delicate black-haired boy of most precocious ability both in mathematics and classics". He gained a scholarship at Queen's College, Belfast, where he graduated with the highest honours. From there he proceeded to St. John's College, Cambridge. A severe illness made it necessary for him to lose a year; but he took the Mathematical Tripos in 1880 and came out Senior Wrangler, J. J. Thomson being second. Larmor was at once appointed professor of natural philosophy in Queen's College, Galway. He was there during 1880–85, and then returned to St. John's College as lecturer. In 1903 the Lucasian professorship fell vacant through the death of Sir George Stokes; Larmor succeeded him, and held the famous chair of Newton until his retirement in 1932. His last years were spent at Holywood, Co. Down, where he died on May 19.

The researches by which Larmor will chiefly be remembered belong to the years about 1895–1905, which are now looked upon as a transition period. The great wave of expansion of physical science in mid-Victorian times, in which Maxwell, Kelvin, Stokes, Rayleigh and others were prominent, had spent its force. Apart from one or two 'small clouds on the horizon', the classical theories seemed to have been well rounded off; and it was beginning to be said that the possibilities of progress were approaching exhaustion. Later the new conceptions associated with quantum theory and the theory of relativity were to arise, and wake theoretical physics into another outbreak of feverish progress. In the interim, two names stand out prominently, Lorentz and Larmor. Their work has not been effaced by the newer developments. Larmor's results are accepted as fundamentally sound, and are now turned to account in ways which must have greatly perturbed the conservative mind of their originator. The magnitude of his achievement was recognized by the award of the Copley Medal of the Royal Society in 1921.

Of the two rivals in the Tripos of 1880, Thomson was the first to achieve wider eminence, originally as a theoretical physicist but later in experimental researches. Larmor, who always remained on the theoretical side, developed more slowly, and it was not until 1892 that his work gained him election into the Royal Society. From 1894 until 1897 he published a notable series of memoirs on electromagnetic theory in the *Philosophical Transactions*; these form the foundation of his book "Aether and Matter", published in 1900. The purpose was to work out systematically the idea, then gaining ground, that matter is essentially an electrical structure. In particular, the continuous electric fluid of Maxwell was replaced by a particle theory which recognized that electricity, like matter, is atomic in structure. A particle theory of electricity was very much in keeping with the experimental advances of the time, but that seems to have been partly a coincidence. The electron was not discovered experimentally until 1897. In "Aether and Matter" the term electron is used indiscriminately for positive and negative charges, although it was not until twelve years later that this view of the nature of positive electricity became reconciled with experimental knowledge.

"Aether and Matter" is, in substance, one of the greatest of scientific books. It is a difficult book, because Larmor's habitual obscurity of style often makes his published work almost as unreadable as his handwriting. But to the student of the period 1900–5 it was the one gateway to new thought, inspiring and revolutionary. It must not be inferred from the title that it represents a wholly antiquated form of thought. Scientific writers nowadays have to bow to the prejudice which does not allow the ether to be named, and are obliged to use a periphrasis; but the 'resonators' and the 'particles in negative energy levels', now employed to fill the space where the ether used to be, expose the error of those who thought the ether had become unnecessary. Modern progress has modified Larmor's "Aether" no more and no less than Larmor's "Matter".

Of special interest was Larmor's result that, if matter is electrically constituted, any moving object must suffer a minute contraction in the direction of its line of motion. The first suggestion of such a contraction was a brilliant guess proposed by FitzGerald to explain the unexpected result of the Michelson-Morley experiment. In the light of Larmor's theory it becomes no longer a hotly disputed hypothesis, but an immediate deduction from the electromagnetic laws universally accepted. In this and in other developments it is difficult to disentangle the shares of Larmor and Lorentz; and perhaps it is of no great moment to separate contributions which have now become woven together. But, from the account given in Whittaker's "History of the Theories of Aether and Electricity", it appears that the well-known Lorentz transformation was originally given by Lorentz in the form of a first-order approximation, afterwards extended by Larmor to the second order, and finally shown by Lorentz to be exact. Since it is in the second order approximation that the contraction effect is found, it was Larmor's contribution which elucidated it; and we shall perhaps do justice between Holland and Ireland if we speak of the "Lorentz transformation" and the "FitzGerald-Larmor" contraction.

Among Larmor's outstanding contributions were two results continually quoted and used in present-day researches, namely his formula for the radiation of energy by an accelerated electron, and his theory of the precession of electron orbits in a magnetic field. He wrote valuable papers on a variety of subjects including hydrodynamics, waves and the Heaviside layer. He was an enthusiast for the Principle of Least Action as the key-stone of physics, and wrote extensively on the transformation of electrodynamics and other branches of physics into that form.

After his own revolutionary outbreak, Larmor became decidedly conservative in his scientific views. It was difficult to ascertain how much he appreciated the new developments in relativity theory and quantum theory, because he was accustomed to adopt a pose which exaggerated his aloofness. In examining dissertations with him one had always to listen to a tirade against the wild kind of problem on which the modern young man spends his time; but he was generally well informed on the actual subject-matter. My impression is that he followed the new theories very attentively, but always cherished the hope of finding a weak spot in them.

Although his heart was with the physicist of the nineteenth century, Larmor must be counted as the harbinger in England of the new ideas which mark the present century. He was the first to throw off the obsession which possessed an earlier generation—that everything must be explained as though the universe had been made from materials and contrivances similar to those of an engineering workshop. The ether of "Aether and Matter" (a development of MacCullagh's rotationally elastic ether) was not a material fluid possessing density, compressibility or other characteristics of gross matter; it was an entity of a different order with properties describable symbolically, in which the "freely mobile intrinsic strains" were shown to give birth to the commonly recognized properties of matter. It was tempting, after his conservative outbursts, to chaff him as having been the moving spirit in the revolutionary ideas which so much disturbed him—and it is undoubtedly true that his teaching had had great influence in that direction—but it was plain that he did not like the accusation.

Larmor had a strong attachment to his native country. It is no coincidence that "Aether and Matter" is so largely a development of the work of his countrymen MacCullagh, Hamilton and FitzGerald. It was probably his intense feeling over the Irish question which persuaded him to enter Parliament, where he represented the University of Cambridge as a Unionist from 1911 until 1922. He can scarcely have found the position congenial; and it was clearly not the right field for his abilities. His most important work outside the University was as secretary of the Royal Society from 1901 until 1912. As a University teacher, his lectures were obscure, ill-ordered and difficult to follow; but they were well worth the effort to follow. There are doubtless many who can, like the writer, testify to the inspiration which they imparted.

A. S. EDDINGTON.

WE regret to announce the following deaths:

Dr. H. A. Des Vœux, president of the National Smoke Abatement Society, on May 20.

Prof. A. R. Forsyth, F.R.S., emeritus professor of mathematics at the Imperial College of Science and Technology, on June 2, aged eighty-three.

Dr. Emil von Grósz, honorary fellow of the Royal Society of Medicine and president of the International Campaign against Tuberculosis, aged seventy-six.

Dr. John Lindsay, professor of physiology and histology at the Glasgow Veterinary College, aged seventy-seven.

Mr. E. Hesketh, a well-known refrigeration engineer, on May 18.

Mr. R. G. McConnell, director of the Geological Survey of Canada and Deputy Minister of Mines during 1914–20, on April 1, aged eighty-five.

NEWS and VIEWS

National Institute for Medical Research

Sir Henry Dale, P.R.S.

SIR HENRY DALE, who retires from the post of director of the National Institute for Medical Research on September 30, has long been the central figure in some of the most active fields of physiological and pharmacological research. During the years 1906–14, he was director of the Wellcome Physiological Research Laboratories, where he gathered around him a very brilliant team of workers. He then joined the staff of the newly formed Medical Research Committee, which became the Medical Research Council in 1920. He has been the effective head of the Council's laboratories at the National Institute at Hampstead since they were first opened. Under his leadership these laboratories have become world-famous.

Much of Dale's early work centred around the pharmacological analysis of extracts of ergot, which were found to contain, among other things, ergotoxine, tyramine, histamine and acetylcholine, all of which had interesting properties and all of which served as the origins of broadening advances. With various collaborators he showed that histamine and acetylcholine are both normal constituents of the body of mammals, and he has done more than anyone else to establish the significance of these discoveries. The work which demonstrated the relation between acetylcholine and nerve endings won the Nobel Prize for Physiology in 1936, which he shared with Otto Loewi. Many other fields of work have been illuminated by his clear brain and genius for experiment, which have done great service to British medical research not only through his own work and that of his immediate colleagues, but also through advice and help freely given to a very large number of people. He has mainly been responsible for the success of the League of Nations in establishing international standards for the biological standardization of bacteriological products, hormones and vitamins, and a large proportion of the actual international standards are kept at the National Institute.

Prof. C. R. Harington, F.R.S.

PROF. C. R. HARINGTON, professor of chemical pathology in the University of London, and director of the Graham Research Laboratories at University College Hospital Medical School, who is to succeed Sir Henry Dale as director of the National Institute for Medical Research, became well known through his work on the active principle of the thyroid gland, which he started with Prof. George Barger in Edinburgh and continued in University College, London. Thyroxine had been isolated by E. C. Kendall but not in sufficient quantities for accurate chemical work. With various collaborators Harington devised an improved method of isolation, determined its structure, synthesized it, resolved it into its optical isomers, showed that the natural isomer was lævorotatory, synthesized a number of allied substances some of which had similar pharmacological actions, isolated from the thyroid gland a simple polypeptide which differed from thyroxine in its absorption from the intestine, and showed that di-iodotyrosine was also present in the thyroid. These different aspects of work on a new active principle are generally shared among many different laboratories, and it is remarkable that one man could do so much.

Later, Harington and his colleagues did important work on crystalline insulin and synthesized glutathione. Recently they have been working on the preparation of antibodies which counteract the effects of substances such as thyroxine and aspirin, by combining these comparatively simple substances with proteins and using the compounds thus formed as antigens. Prof. Harington was appointed a member of the Medical Research Council in 1938; he has been editor of the *Biochemical Journal* for some years. His outstanding qualities certainly justify the Council in appointing, as the director of its laboratories, a man who happens to have no medical degree.

Award of James Watt International Medal

THE Council of the Institution of Mechanical Engineers has unanimously awarded the James Watt International Medal to Mr. A. G. M. Michell, of Melbourne, on the nomination of the Institution of Engineers, Australia, the South African Institution of Engineers, and the Engineering Institute of Canada. The Medal was founded by the Institution in 1936 to commemorate the bicentenary of the birth of James Watt on January 19, 1736, and is awarded every two years to an engineer of any nationality who is deemed worthy of the highest award that the Institution can bestow and that a mechanical engineer