in the reversing layer; but faint lines attributed to ionized thorium have recently⁴ been discovered in the Fraunhofer spectrum. Presumably no great abundance of fission nuclei is necessary, since the coronal radiation is, after all, very weak relative to the thermal radiation of the whole sun; it can be observed only during total eclipses or by taking extraordinary precautions against extraneous light at other times. A more difficult point concerns the apparent selection of iron, nickel and calcium as fission products. Why should no lines of, say, highly ionized cobalt, manganese, copper or potassium appear? This is partly a spectroscopic matter: the elements found are better suited for identification than all the others except cobalt, and here, as elsewhere, absence of the spectrum of an element is no guarantee of the absence of the element. A faint coronal line at 4359 Å. is indeed attributed to Co XV. But there is no denying that the iron, nickel and calcium lines represent most of the coronal emission, and the contiguous elements, even if they turn out to be represented among the fainter lines, are likely to be relatively rare. Saha attributes this to the greater probability that fissions will result in even atomic numbers than in odd, the former having many more stable isotopes than the latter. This leaves some doubt concerning chromium and titanium (especially the former, which has predicted forbidden lines in the accessible region), and an alternative explanation put forward by Edlén in his original paper⁵ deserves consideration. He noted there that the observed lines belong to elements common in meteorites, the implication being that coronal matter is not directly of solar origin at all, but is a cloud of meteoritic gas collapsing on to the solar surface. Saha will have none of this on energetic grounds, however, and points out that the velocities involved (622 km./sec. from infinity to the solar surface, less to the corona) are not sufficient to produce the observed ionization.

The fate of Saha's stripped atoms, once they have emitted the coronal lines, is doubtful, for it depends on the ranges of the various particles in a part of the solar atmosphere where the composition is as yet rather uncertain. It might be supposed that the process of electron capture outlined above would go on as the ion continued its progress through the corona, and that accordingly lines due to Fe VIII, Fe VII . . . Fe I and the corresponding nickel and calcium lines should be emitted at greater heights. But between Fe VIII and Fe III the capture is in *d*-orbits, where the capture cross-section is small, so that even where other conditions (for example, presence of deep metastable levels with accessible transitions) are favourable, the lines will be expected to be faint. In fact, the probability of electron capture may be so small that these less highly ionized particles may escape into regions devoid of hydrogen atoms or electrons before they can make further captures. The lower ions will in that event play no part in coronal emission, though they may become of interest to geophysicists!

The value of the new theory, if it can be supported at the many points where observational verification is possible, lies not only in the explanation it affords for the observed high excitation in the inner part of the corona, but also in the light it throws on the spectrum of, and intensity distribution in, its outer parts. That it suggests that the outer corona is not in equilibrium but consists of outward streaming δ -rays continually ejected from solar atoms by fission fragments is an advantage; for questions concerning

the origin, maintenance and stability of the outer corona have hitherto been embarrassments to those who held it to be an atmosphere in equilibrium. Saha's conception of the chromosphere and inner corona as a sort of gigantic cloud chamber, where the tracks of individual particles are invisible but where the particles are so abundant that their recombination spectra are observable, is more than a picturesque illustration. It removes the difficulty of accounting for the extremely high 'temperature' needed to produce the coronal lines. It was always incredible that temperatures of millions of degrees could exist in parts of the solar atmosphere where a black sphere would be expected to reach at most 4,500° C. It is now clear, if Saha is right, that this phenomenon is quite local, and is comparable with the local luminescence produced in our own atmosphere by meteors. (Perhaps a better comparison, in view of the direction of motion of the particles, is with terrestrial rockets.)

Many points remain to be cleared up, of course, and much experimental and theoretical work must be done before the theory can be regarded as more than tentative. But as a first attempt to account for the extraordinary features of the solar corona brought to light by the identification of the emission lines in its spectrum, this theory merits and will receive astrophysicists' serious consideration.

A. HUNTER.

¹ *The Observatory*, 66, 18 (1945).

² Saha, M. N., *Proc. Phys. Soc.*, 57, 271 (1945).

³ Hunter, A., *Nature*, 150, 756 (1942).

⁴ Moore, C. E., and King, A. S., *Pub. Ast. Soc. Pacif.*, 55, 36 (1943).

⁵ Edlén, B., *Ark. Mat. Ast. Fys.*, 28B, No. 1 (1942).

THE CITY AND GUILDS COLLEGE

ENGINEERING AT THE IMPERIAL COLLEGE

By PROF. E. F. D. WITCHELL

THE City and Guilds College forms the engineering section of the Imperial College of Science and Technology, the centenary of which was recently celebrated (see *Nature*, Nov. 3, p. 518 *et seq.*). As its name implies, the City and Guilds College itself owes its existence to the City Livery companies, who met at the Mansion House on July 3, 1876, under the presidency of the then Lord Mayor and decided to devote attention "to the promotion of education throughout the country and especially to technical education". As a result of this meeting, the City and Guilds of London Institute for the Advancement of Technical Education was established in 1878 and was incorporated in 1880. The provisional committee of the Institute recommended "that the objects which the Guilds had in view would be best attained, firstly, by the establishment of a Central Institution or College for the advanced education of those who had already acquired sufficient knowledge of science or the arts to profit by instruction in the industrial application of these; secondly, by conducting examinations in technological subjects; and, thirdly, by the establishment of local schools for artisans and workmen, and by co-operating with and otherwise assisting local effort, more especially, but not exclusively, within the Metropolis".

The first of these recommendations led to the establishment of the College in Exhibition Road. The foundation stone of the building was laid in 1881 by

the Prince of Wales, who opened the new building three years later.

The College was known as the Central Institution, and its declared objects were "to afford practical, scientific and artistic instruction which shall qualify persons to become: (I) technical teachers; (II) mechanical, civil and electrical engineers, architects, builders and decorative artists; (III) principals, superintendents and managers of chemical and other manufacturing works.

"The main purpose of the instruction to be given in this Institution will be to point out the application of the different branches of science to various manufacturing industries, and opportunities will be afforded for the prosecution of original research with the object of the more thorough training of the students and for the elucidation of the theory of industrial processes."

It was proposed to carry out these objects by instituting five departments, namely: (1) Chemical Technology; (2) Engineering; mechanical, civil and electrical; (3) General Manufactures; (4) Architecture and Building Construction; and (5) Applied Art.

Students were required to pass an entrance examination in mathematics, pure and applied; chemistry; physics; drawing and modern languages. The courses in all departments were to be of three years duration, and the diploma of the College (A.C.G.I.) was to be awarded to those who had studied satisfactorily during the course and passed the various examinations with credit.

Three professors were appointed in April 1884, namely: Henry Edward Armstrong, as professor of chemistry; William Cawthorne Unwin, professor of engineering; and Olaus Henrici, professor of mechanics and mathematics. Later in the year, William Edward Ayrton was appointed professor of physics. These four professors were charged with devising the schemes of education which should be adopted for training students following diploma and special courses in the various departments. The general scheme proposed for diploma students provided that the first-year course should be a common course for all students no matter in which department the student wished to graduate. The subjects studied were mathematics, chemistry, physics, engineering drawing and engineering workshop practice. In the second year a small amount of divergence from the common course was permitted, especially for students in chemistry; but for engineering students almost all the course in electrical, civil and mechanical engineering was substantially the same. In the third year the student spent the whole time in the department of his choice, with the exception that during the winter term one day per week had to be devoted to study in another department. Mathematics was studied by all students throughout the three years of the course.

It will be seen that the scheme recognized the importance of making a fairly wide training in general and applied science the basis for a satisfactory course in technological studies, and it deliberately discouraged too early specialization in any one branch of learning.

Evidence that the course as devised was sound in principle is provided by the fact that the alterations in the scheme during the last sixty years have been comparatively few. Perhaps even more convincing is the testimony of past students, who affirm how useful in their professional careers they have found the general training received in the College.

The original proposals of the City and Guilds of London Institute envisaged giving instruction in general manufactures, architecture and building and applied art, as well as in chemistry, technology and engineering. A School of Art Wood Carving was instituted and lectures were given in architectural and allied subjects; but it soon became evident that the College buildings, although judged to be large and capacious by the standard of those days, could not adequately house classes in all the intended subjects. In 1887 Prof. Ayrton estimated that the new College was providing for little more than half the work for which it was originally intended, and only two years later Prof. Unwin reported that experience indicated that the resources of the Institution, both as to staff and apparatus, would be considerably taxed by the two hundred students for which the building was designed.

In 1893 the name of the College was changed from the "Central Institution" to the "Central Technical College". Under this name the College continued to function until it became part of the Imperial College in 1910, when it was renamed the "City and Guilds (Engineering) College", and eventually the "City and Guilds College". The style under which it was known during the first twenty-five years of its existence is still retained in "Old Centralians", the name of the Association of past students of the College.

By 1893 the number of students following the courses in engineering and chemistry exceeded two hundred, and it seemed obvious that the whole of the accommodation in the College would be required for the proper teaching of these subjects. In 1897 the School of Art Wood Carving was transferred to the Imperial Institute, and the rooms which it had occupied were used for a laboratory for mathematics and mechanics. The basement of the Royal School of Art Needlework, which was built in 1901 on the site immediately south of the College, afforded much-needed accommodation for the Electrical Machines Laboratories, which had previously been inadequately housed; and the transference of the Electrical Laboratories in turn enabled an extension of the Civil and Mechanical Engineering Laboratories.

In 1900 the 'internal' side of the University of London was established and the College became a School of the University in the Faculty of Engineering.

The chief event in the College history since that date has been its incorporation with the Royal College of Science and the Royal School of Mines to form the Imperial College of Science and Technology. The immediate effects of the amalgamation occurred in 1913, and were the closing of the Chemical Department, the fusion of the Mathematical Departments of all three Colleges into one department, and the division of the Civil and Mechanical Engineering Department into Departments of Mechanical Engineering and Civil Engineering. Further facilities for research were provided, and the size of the College was approximately doubled by the building of engineering workshops in the rear of the building and the erection of the Goldsmiths Extension on the land immediately to the north of the original building. Most of the design of the general lay-out of these extensive laboratories is due to Prof. W. E. Dalby, who had succeeded Prof. Unwin as University professor of engineering in 1904. The foundation stone of the Goldsmiths Extension was laid in 1909 by King Edward VII and the building was finished in 1914. Owing to the War, the official opening of the building was postponed until 1926, when the

ceremony was performed by the present King, then Duke of York. A much later addition to the College was the transference of the Aeronautical Department from the Royal College of Science, and still more recently the formation of a Department in Chemical Engineering.

The increase in the number of students has more than kept pace with the increase in accommodation. As mentioned above, the College was originally designed to accommodate two hundred students. This figure was exceeded in 1893 and kept steadily rising until, in 1911, it reached a total of 589 registered students, of whom 430 were working full time.

From the beginning, the teaching given in the College was fashioned on an experimental approach to knowledge rather than on precept. Lecture courses were, of course, given in all the subjects selected for study, but in all departments the importance of experimental work performed by the student was emphasized and the need for accuracy in such work was stressed. This point is well illustrated by extracts from the programme of the Central Institution for the session 1892-93. In the course of instruction in the Department of Mechanics and Mathematics, we read: "In the laboratory the experiments are performed by the students themselves. The experiments are all quantitative; that is to say, in each experiment the student has to make some definite measurement . . ."

Again, it is stated of the Department of Physics and Electrical Engineering: "The instruction is given largely by tuition in the laboratories, the lectures being rather for the purpose of aiding the students in their laboratory practice than of forming a distinct course by themselves". In the Chemical Department the object of the general first-year course is thus described: "The object aimed at in this part of the course will be to encourage habits of accuracy and thoughtfulness and to teach the art of experimenting with a logical purpose rather than to impress mere facts".

In the experimental sciences instruction by inquiry and experiment must always be slower than that given by lectures, but there can be little doubt which method is the better from an educational point of view. Training in careful habits of thought and logical deduction is an important part of any system of education, and the student is more likely to learn these by the success or failure of his own experimental work than by listening to lectures, however clear or eloquent they may be.

Experimental work also teaches the student that accuracy in observation and performance is needful for success. He learns the degree of accuracy which can reasonably be expected in such work and, what is perhaps quite as important, the limit of that accuracy. For this reason laboratory work has always occupied an important place in the College curriculum, and there has been insistence upon the writing of careful and complete records of the work.

It is difficult to assess the influence which the College has exerted on the practice and profession of engineering. It would, however, be easy to compile an impressive list of past students who have taken and are taking a leading part in the profession both in Great Britain and abroad, and who acknowledge the benefit to themselves of the training they received. They are to be found in all branches of engineering, administrative, executive, commercial and professional. Most graduates naturally practice in that part of the profession in which they were

trained, but many who were trained in one branch now occupy responsible positions in some other branch. Thus men trained in mechanical engineering are to be found as wireless broadcasting engineers, electrical graduates are in charge of mechanical plant and so forth. The facility with which the men pass from one branch of engineering to another, and seem to acquit themselves worthily in each, is a tribute to the soundness of the College tradition of insisting on a training in general engineering before allowing specialization in any one branch.

It must be remembered that, when the College was founded, technical education was only just beginning, and the students passing from the College in the early days had the responsibility of proving to the profession that technical training was really worth while; to-day the need for such training is taken for granted and every town of reasonable size has some sort of technical institute. Even thirty-five years ago the students often found it wise when seeking employment with an engineering firm to conceal the fact that they were university graduates; now, a degree is becoming a *sine qua non* for employment.

It would be extravagant to claim that the College is responsible for this change in the general outlook in Britain of the engineering profession, but it can be justly claimed that it has contributed largely to this more satisfactory state of affairs.

THE UNITY OF SCIENCE

ON October 20 a meeting of the Association of Scientific Workers was held at Gas Industry House, S.W.1, "to explore the inter-relations between the natural and social sciences". The chair was taken by Sir Robert Watson-Watt, and the chief speakers were Prof. J. D. Bernal, Mrs. J. Robinson and Mr. Dennis Chapman. In his opening remarks, the chairman explained that the meeting had been convened to examine the implications of the increasingly closer relations which were growing between workers in the natural and social fields of science. He therefore stressed the indivisibility of science in furthering what he called the "engineering efficiency" of the community. He announced that the Lord President of the Council, the President of the Board of Trade, and the Minister of Supply and Aircraft Production had been invited to attend the meeting, and all three Ministers had expressed their keen interest in the matter under consideration. The Lord President had replied that he would consider sympathetically any proposals formulated at the meeting which would be conveyed to him; the Minister of Supply and Aircraft Production was represented at the meeting by one of his directors of scientific research.

Prof. J. D. Bernal distinguished two aspects of the principle of the indivisibility of science. The phrase might be used in the philosophical sense of the unity of all knowledge, or in the highly practical sense of employing all the resources of scientific method regardless of the material to which it was applied. By establishing this principle in the practical sense, the artificial barriers hitherto separating 'natural' and 'social' scientists would be broken down. Prof. Bernal remarked that the demarcation between the natural and social sciences was of relatively recent origin; in seventeenth-century England, when