parable with that of the earth. Our sun and our nearest stellar neighbour, α Centauri, are marked as typical dwarfs of type G, and Sirius is a representative A-type star.

From the known luminosity and surface temperature of any star it is easy to calculate its surface and so its density. Giants of types G and K are found to have densities of the order of 0·004 and 0·0005 respectively, agreeing with the known densities of binary stars of these types. Sirius, with a luminosity of forty-eight times, and a surface temperature about one and a half times, those of our sun, must have a surface nine times as great. Its mass is 3·4 times the solar mass, so that its density must be about 0·2. In general it is found that all giant stars must be gaseous, of

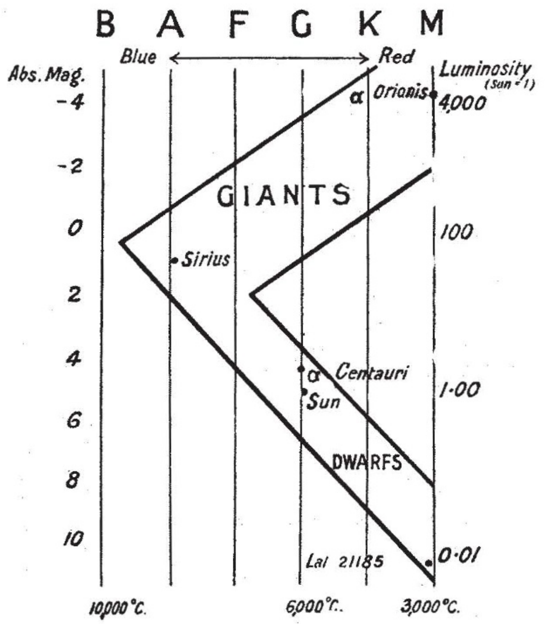

FIG. 2.—Luminosity-temperature diagram.

density so low that the ordinary gas-laws will be approximately obeyed. Dwarf stars may be gaseous or liquid or solid, but, if gaseous, they are so dense that the gas-laws will be nowhere near the truth. It is now easy to see why, in the giant stars, increase of temperature and density go together; this is merely a consequence of Lane's law. But the dwarfs may be thought of as approximating rather to masses of fixed dimensions, and for these the luminosity falls off as the temperature decreases.

Our sun radiates light at a rate of about 2 ergs per second per gram of its mass. Gravitational contraction, as Lord Kelvin showed, could provide energy at this rate for only about 20,000,000 years, and radio-active and chemical energy could only slightly lengthen this period. For a giant star, radiating at 1000 times the rate of the sun, the maximum period would be only a few thousand years. This period is far too short, and it is now generally accepted that, so far from gravitation and known sources of energy providing the whole of a star's radiation, they can provide only an insignificant fraction. Energy of adequate amount can originate only from sub-atomic sources, as, for instance, from internal rearrangements in the positive nuclei of the atoms or from the transformation of a small fraction of the star's mass into energy. It is a matter of simple calculation to show that all other stores of energy in a star can constitute only an insignificant reservoir of energy which, unless continually replenished from sub-atomic sources, would be exhausted in, astronomically, a moment. Thus the rates of radiation and of generation of sub-atomic energy must be practically equal, and the luminosity of a star will be determined by the latter rate at any instant.

We may now think of the evolution of the stars as represented by the march of a vast army through our diagram (Fig. 2), the individuals keeping, for the most part, within the marked belt. Each individual takes his marching orders from the supply of sub-atomic energy, and so long as we remain in ignorance of the exact source and nature of this we cannot be certain whether the motion of the army is up or down, or even that it is all in the same direction. But if we are right in conjecturing that the stars were born out of a nebula of very low density, the order of march will be from low density to high; our army will be marching downwards in the diagram. Its tail, except for a few stragglers, is about at absolute magnitude −4, its head is lost in darkness. In the next lecture we must study the incidents which may occur during the march of this army of stars.

(To be continued.)

Obituary.

DR. A. M. KELLAS.

BY the death of Dr. A. M. Kellas we have lost one of the best authorities on the effect of high altitudes on the human system. No one else had so great a practical knowledge, or worked scientifically at the subject with more persistence than he.

Born in Aberdeen, he was educated there, and afterwards went to Edinburgh, London, and Heidelberg. For some time he was assistant to Sir William Ramsay, and afterwards lecturer on chemistry at Middlesex Hospital.

As a teacher he was most successful, taking endless trouble in helping backward students. In pure chemistry he did little research, his chief contribution being a long and careful investigation on "The Determination of the Molecular Complexity of Liquid Sulphur," published in 1918. But during the last ten years he gave up most of his spare time to study the physiological and physical difficulties connected with the ascents of high mountains.

This subject he was particularly fitted to investigate, for he had probably climbed to heights above 20,000 ft. more often than anyone else. For instance, in 1910, in the Sikkim Himalaya, he was nine times above 20,000 ft., the highest altitudes being the first and only ascents of Pawhunri, 23,180 ft., and Chumiomo, 22,430 ft.

He also visited other parts of the Himalaya, the Nanga Parbat district, north of Kashmir, and Garwhal, where last summer he reached 23,600 ft. on Kamet. It was, however, in Sikkim that he did most of his mountaineering.

From time to time he published papers and reports in the Journal of the Royal Geographical Society and in the *Alpine Club Journal*. But as he was of a retiring disposition, there are few accounts of his extraordinary mountaineering record. Perhaps his most important paper was on "A Consideration of the Possibility of Ascending the Loftier Himalaya" (Journal of the Royal Geographical Society, 1917), in which he discussed all the factors conditioning acclimatisation to high altitudes, and the question whether it was possible to climb Mount Everest. His conclusion was: "A man in first-rate training, acclimatised to maximum altitude, could make the ascent of Mount Everest, without adventitious aids (*i.e.* oxygen), provided that the physical difficulties above 25,000 ft. are not prohibitive."

Dr. Kellas had a unique knowledge of the Sikkim Himalaya, and his death has deprived the Mount Everest expedition of one of its most valuable members, for he had studied the geography of the country round Mount Everest more deeply than anyone else.

WE regret to report the death, on June 26, of MR. WILLIAM SHACKLETON, at the age of fifty. Mr. Shackleton received his early training at the Keighley Institute, and after completing a three years' course at the Royal College of Science, became an assistant to the late Sir Norman Lockyer. By his skill and enthusiasm he contributed largely to the success of the early work at South Kensington on the photography of stellar spectra. In 1893, in company with Mr. Albert Taylor, he observed the total eclipse of the sun in Brazil, and was one of the first to obtain photographs with a prismatic camera of adequate power. In 1896, with Dr. E. J. Stone, he took part in the expedition which was conveyed to Novaya Zemlya by Sir George Baden-Powell in his yacht *Otaria*. Favoured by a brief interruption in a snowstorm, he then achieved a notable success in photographing for the first time the complete "flash" spectrum, with perfect definition, notwithstanding that an accident to the yacht had left but little time for preparation. On this occasion some admirable photographs of the corona were also obtained under his supervision. This expedition was further memorable for a meeting with Nansen at Hammerfest on his return from the polar regions.

For some years Mr. Shackleton was occupied with the late Dr. Common in the design of range-finders and other optical instruments, and a special interest in optics was added to that in astronomy during the remainder of his life. In 1905 he took up an appointment at the India Stores Depôt as Inspector of Scientific Supplies, and scientific workers in India have profited much from his extensive technical knowledge and careful supervision of their requirements. Mr. Shackleton was elected a fellow of the Royal Astronomical Society in 1893, and of the Optical Society in 1913. He was secretary of the Optical Society from 1916 to 1920, and rendered valuable services to the society in that capacity, besides contributing papers of practical importance; he was a vice-president of the society at the time of his death. Mr. Shackleton's health had not been good for several years, but his death came unexpectedly, and will cause deep regret to his many friends in scientific and technical circles.

Notes.

A CHEMICAL laboratory of a new type was opened at the Imperial College of Science and Technology by Mr. A. J. Balfour on June 24. The laboratory is fitted with apparatus of a size which will render it necessary for chemical processes to be carried out under conditions closely resembling those which are present on the large scale. Just as the ordinary scientific laboratory contains specimens of all types of apparatus necessary for small-scale work, the new laboratory contains appliances which will enable the student to carry through the corresponding large-scale operations in a manner which will render it possible for him to study the influence of those factors, such as heat exchange, etc., which are not of vital importance in ordinary laboratory work. Students, and especially research students, whether they intend to follow an academic or an industrial career, will thus obtain a knowledge of large-scale conditions which it has hitherto been possible to acquire only by actual works experience. Moreover, the means for preparing initial material in large quantities will be of the greatest value for the research workers in the chemistry department of the college. It is hoped that a full description of the new laboratory, with illustrations, will appear in a forthcoming number. The equipment was provided by Mr. W. G. Whiffen, an old student of the college.

WE learn from the *Times* of June 24 that the West London Hospital is in possession of electrical plant capable of delivering current at 200,000 volts for X-ray purposes. The X-rays are of a penetrating character, and are being used for the treatment of patients suffering from malignant disease, on the lines laid down by the Bavarian doctors Seitz and Wintz. The