long, solitary hours in all manner of wild places, we often find vivid descriptions of their ways and movements far exceeding in interest those of pre-photographic days.

Some of the best work in the book will be found near the end, where the auks are treated of, and photos are fewer. We may specially notice Mr. Lowe's attempt to account for the "wreck" of countless little auks in February, 1912, and on other occasions, by reference to the nature of the bird's oceanic food, which might be sunk too deep for them by sudden currents of cold air reducing the temperature of the surface water; they would thus be driven before the storm in search of their usual supplies. My Pycraft a few pages further on tries to solve the mystery of the guillemot's egg, but confesses that there is no certain explanation.

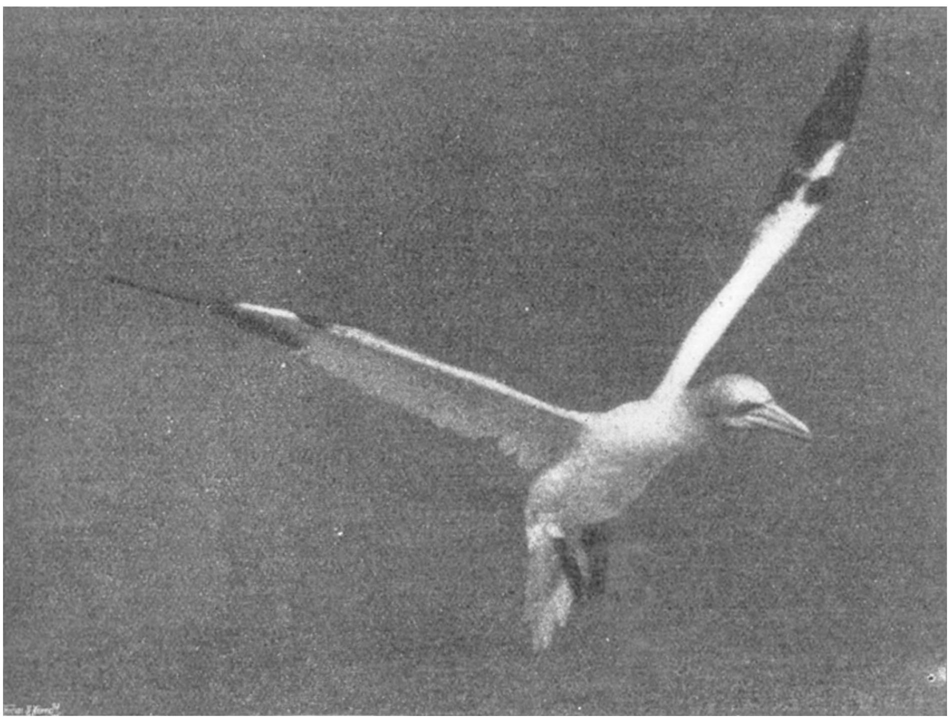

FIG. 2.—Putting on the brake. From "Our Common Sea-birds.'

(2) "Bird-Life throughout the Year," by Dr. J. H. Salter, is a pleasant collection of notes, some of them unusually interesting, *e.g.*, that on the nesting of the dotterel (p. 170). Dr. Salter is a real naturalist, to whom we are mainly indebted for the interest aroused in the preservation of the kite in South Wales, and his book will be a safe and stimulating guide for the young beginner. There are some good photographs in it, but the coloured ones are not always successful.

(3) "Wild Life on the Wing," by M. D. Haviland, is a collection of stories about teal, woodcock, &c., by one who is not deficient in woodcraft. Whether she is equally an adept in the art of telling a tale may be doubted; but the book is a pleasant one, and well adapted for a gift.

THE RADIATION PROBLEM.

THE radiation discussion, which was one of the most notable features of the Birmingham meeting of the British Association, appears to have created a general impression that some radical revision of our ideas as to the nature of radiation must now be regarded as unavoidable. It may therefore be of interest to give a brief summary of the present state of the problem.

Its acute phase has been brought about by the remarkable successes achieved by some forms of what is known as the "theory of quanta." This theory, or rather hypothesis, assumes that not only matter, but energy itself, has an atomistic or discontinuous structure, particularly when it is flung out into space in the form of radiant energy or radiation.

Are we, then, drifting back to a corpuscular emission theory of light, destined to replace the now generally accepted wave theory? Such a return to older views would not be altogether without precedent. History has witnessed similar fluctuations of view as regards the shape and motion of the earth, and as regards the structure of electricity. And the triumphs of atomistic conceptions in other fields, achieved with the aid of radioactivity and of Brownian motions, make the propaganda for a further extension of the atomistic principle easy. R. A. Millikan[1] maintains that the number of atoms and molecules in a given mass of matter may now be counted with as much certainty and precision as we can attain in counting the inhabitants of a city. With the characteristics of these inhabitants we can deal by means of the science of statistics, and the adherents of the new atomistic theory of radiation would have us apply statistical methods to an immense range of physical investigations.

But the hypothesis of "quanta" or irreducible and indivisible elements of energy is not merely atomism gone mad. There are certain undeniable and undoubted facts which find their simplest

[1] *Science*, vol. xxxvii., p. 119, January 24, 1913.

explanation in the hypothesis of a discrete structure of radiant energy.

Chief of these is the observed mode of transfer of energy from kathode-rays to X-rays, and *vice versâ*. Kathode rays are electrons projected with enormous velocities. The stoppage of an electron by the target in the Röntgen tube generates an X-ray pulse. All electrons are stopped within a time, which is the shorter the greater their energy of motion. Hence the X-ray pulse generated is "thin" in proportion as its energy is great. The more rapid the kathode rays, the thinner, "harder," and more penetrating are the X-rays.

Now the beautiful recent work on the reflection and interference of X-rays, often referred to in NATURE, has proved that these rays are covered by the wave-theory of light. The X-ray waves are some 10,000 times shorter than the shortest ultra-violet light waves known. They have, like ordinary light, a wave-length, or rather a range of wave-lengths, and the energy of every X-ray wave is *proportional to its frequency*, since the thinner and "harder" pulses have the smaller wave-lengths.

But this is not all. When X-rays impinge on a target, electrons are projected from it; they in turn constitute kathode rays. The velocity of these electrons is independent of the intensity of the X-ray beam. It only depends upon its "hardness," *i.e.*, its frequency, or the reciprocal of its wave-length. To put it in the language of visible light, the velocity with which an electron is expelled from the target depends, not upon the "brightness" of the X-rays, but solely upon their "colour," and is the greater the more that colour tends towards the "blue" end of the spectrum.

Moreover, those electrons which are not expelled from the material exposed to the X-rays appear to be quite unaffected, and they form the vast majority of the electrons present, unless a particular "characteristic frequency" is used for the existing rays, whereupon the electrons come out in enormous numbers.

The handing on of a quantity of energy intact from X-ray to kathode-ray and back to X-ray was used to support an atomistic view of the X-rays themselves, until it was found that the same rules apply to the liberation of electrons by ultra-violet light. Here arose a dilemma: either ultra-violet light itself (and probably all radiation) is atomic, or there is some mechanism by which radiant energy can be absorbed until a definite quantity (proportional to the frequency) is accumulated, whereupon an electron is expelled. The remarkable thing is that this energy of the electron is actually derived from the light, so that the latter does not simply liberate internal energy by some sort of "trigger" action.

All this might not have ensured a hearing for an atomistic hypothesis of energy had not Prof. Max Planck (now rector of Berlin University) put forward a theory of radiation based upon quite other considerations, which also involved an atomic structure of energy, at least when radiated.[2] He was endeavouring to explain the experimental fact that the total heat of all wave-lengths radiated by a black body (not a blackened body, but the "ideal" black represented, say, by the mouth of a deep cave) is proportional to the fourth power of its absolute temperature, and found that no formula completely representing the relation between the frequency and the amount of energy associated with it could be written down unless the energy was flung out by each molecular radiator in definite amounts or "quanta" proportional to the frequency, *i.e.*, inversely proportional to the "wave-length." This immediately accounted for the fact that, as a body gets hotter, it passes from "red" heat to "white" heat (*i.e.*, towards higher frequencies) until, when we reach the temperature of the sun, the maximum energy is well within the visible spectrum.

The actual magnitude of the supposed quanta is excessively small. For a frequency of 1 vibration per second, it would only amount to 6×10^{-27} erg, a quantity known as the "action constant." For frequencies like that of green light (600 billion per second) it would still only amount to some billionths of an erg, but such is the marvellous sensitiveness of the eye, that it can detect light (say, from a star of the sixth magnitude) when the amount of energy passing through the pupil is only some 300 or 400 quanta per second.

What, then, is the mechanism of this radiation by quanta? Are we to suppose that it resembles the sound waves proceeding from the incessant but irregular rifle fire of a large army, in which each soldier gradually accumulates sufficient powder to fire his shot? Or is it atomistic, like the bullets? Or must we fall back upon Sir J. J. Thomson's bold but rather appalling conception of a gigantic web of countless threads pervading the universe, in which each thread connects a positive and a negative electric atom, and bears its trembling message along with the speed of light in a single direction?

Whichever view may be finally adopted, we may be sure that the investigation of this fascinating problem will teach us a great deal about the interstellar æther which conveys the messages. The recent German attempt to explain away the æther, known as the electromagnetic "Principle of Relativity," has failed in its main object. Gehrcke, in his preface to Drude's "Lehrbuch der Optik," describes that principle and its temporary sway as "the most notable case of mob suggestion since the days of the N-rays." The hypothesis of quanta is saved from a similar failure by keeping in close touch with experiment. In the hands of Nernst and Lindemann and Debye it has been used with brilliant success for investigating and explaining the fall in the specific heat of all bodies as we approach the absolute zero of temperature. The specific heat probably begins by being proportional to the cube of the absolute temperature, so that the heat energy of the body is proportional to the fourth power, thus recalling the Stefan-

2 "Vorlesungen über Wärmestrahlung," 2nd edition. (Leipzig, Barth.)

Boltzmann law of total radiation already mentioned.

Planck's "action constant" has turned out a most useful quantity in all sorts of investigations, and although its actual nature is somewhat doubtful,[3] it may yet turn out to be, like the velocity of light, one of the fundamental constants of nature.

But before any quantum theory of radiant energy can be accepted, it must make its peace with those phenomena (chiefly diffraction and interference) which overthrew Newton's emission theory, and established the wave theory of light. That has not yet been done, or even attempted, so there is but little prospect as yet of a decisive battle. E. E. FOURNIER D'ALBE.

TRANSPARENCE OR TRANSLUCENCE OF THE SURFACE FILM PRODUCED IN POLISHING METALS.[1]

IN a communication to the British Association (B.A. Report, 1901, p. 604) it was suggested that all smooth metal surfaces are covered with an enamel-like transparent layer. In a subsequent communication to the Royal Society (vol. lxxii A, p. 218) the actual formation of a surface layer or skin by polishing was demonstrated. Two of the photo-micrographs in the latter paper, Figs. 5 and 6, plate 9, showed that minute pits on a polished surface of antimony had been covered over by a film of this description. It was suggested that the diminished reflecting power of the film covering the pits probably indicated that it had become translucent, but no direct evidence of this translucence was afforded by these particular observations. It was also suggested that the film might have been carried across the pits on a support provided by small granules or flakes which had filled up the pit to the level of the general surface. The purpose of the present communication is to record and illustrate certain recent observations which show:—

(1) That the film which covers the pits is transparent, or at any rate highly translucent, and

(2) That in the case of the smaller pits the mobile film has been carried across the empty pit without any support from below.

In the casting and working of copper, unless certain precautions are taken, the metal is always more or less spongy owing to the presence of gas bubbles. When the surface of this metal is ground and polished some of the gas bubbles are laid open and appear on the surface as tiny pits. If the cast metal has been subjected to cold working, by rolling or otherwise, the larger bubbles are distorted and take elongated and other varied forms.

By any method of polishing which will give a fair surface the pits are flowed over and obliterated, but by lightly etching the surface with a solvent the surface skin can be removed, and the pits are again disclosed. By careful regulation of the action of the solvent it is possible to remove the surface layer step by step, and the film covering the pits can be reduced to extreme thinness. Through this thin film one seems to be looking right into the pit. In polishing metal surfaces the amount of the metal which is removed by the polishing agent can be varied through wide limits under conditions which need not be specified here. It is sufficient for the present purpose to state that by suitable methods the skin developed on the surface may be raised to a maximum thickness or reduced to a minimum. For the present inquiry it was desirable that the film produced should be as thin as possible. The copper used in these experiments received its final polishing on fine linen stretched over a hard, flat surface, and moistened with one of the ordinary commercial brass polishing liquids. On the copper surface prepared in this way the pits, as seen under high magnification, appear as blue spots on the pale rose-coloured ground of the solid metal. While some of the film-covered pits appear uniformly blue, others show patches of red at various parts of their surface. When these red patches were first noticed it was supposed that they indicated a thickening of the film at these points to the extent necessary for normal reflection. More careful study has shown that the red patches are due to reflections from the inner concave surface of the pit. The beam of light from the vertical illuminator behind the back lens of the object glass of the microscope passes through the film covering the pit, strikes the concave metallic surface, and is reflected back through the film to the object glass and thence to the eyepiece. The reflecting surface of the pits is evidently far from optical perfection, and the reflected beam is therefore more or less broken up by irregularities of the reflecting surface.

By the use of autochrome plates it has been possible to obtain high power photo-micrographs in natural colours of pits on a copper surface. Four of these transparencies have been reproduced by the three colour process, and are shown on the plate issued as a supplement to this week's NATURE. Figs. 1 and 2 are at a magnification of 800 diameters, and 3 and 4 at 1800 diameters. In Figs. 1 and 3, the pits are covered by a blue film, but show patches of red on the blue. Figs. 2 and 4 show the same pits after the film has been dissolved and removed by a 10 per cent. solution of ammonium persulphate acting for 20 to 30 seconds. On comparing the members of each pair, 1 with 2, and 3 with 4, it is seen that the red patches in 1 and 3 correspond with the spots of light reflected from the concave surfaces of the uncovered pits as shown in 2 and 4.

It is clear that the pits which show these reflections from the under surface must have been practically empty when they were covered by the film, so that the film during its flow was quite unsupported from below.

The thickness of the films covering the pits is probably of the order of 10 to 20 micromillimetres.

[3] It is an energy divided by a frequency, but has also been regarded as an angular momentum.

[1] Paper read before the Royal Society on February 12 by Dr G. T. Beilby, F.R.S.