Explanation of Abnormal Low Voltage Arcs.

IT is well established that arcs in gases or vapours may be maintained at voltages as low as their ionising potentials, or, in cases where cumulative ionisation is possible, as low as their radiating potentials, provided a hot cathode is used as a source of electrons to stimulate the arc. Considerable discussion has arisen over certain cases in which arcs have been maintained at still lower voltages,[1] since at such voltages the electrons are known not to effect partial or complete ionisation of molecules with which they collide.

Recently Bar, v. Laue and Meyer [2] and, independently, the present writers,[3] have shown that this may be accounted for by the existence of oscillations the peak voltage of which always exceeds the lowest radiating potential of the gas. An experimental and theoretical study of these oscillations has shown them to be in the nature of current interruptions occasioned by the rise in current and consequent drop in voltage occurring when the ionisation is sufficient to create a positive space charge around the filament. Under such conditions there is nothing to prevent a rise in current to its saturation value. With such a rise, the increased potential drop in the series resistance reduces the voltage across the arc. If this reduction takes the voltage to a value below the lowest critical potential of the gas, the current can be maintained only so long as the supply of previously excited atoms persists, after which the current decreases, the voltage rises, and the cycle is repeated. Reactance in the circuit is not, as believed by Bar, v. Laue and Meyer, essential to the oscillations, though it does affect the wave form.

The above phenomenon does not explain all cases of abnormal low voltage arcs, however, for we have maintained arcs in helium, mercury vapour and argon, without oscillations, at voltages well below the lowest critical voltages of the gases. Also Holst and Osterhuis [4] have reported steady arcs in argon at 3·5 volts and neon at 7·5 volts, whereas the lowest critical potentials of these gases are 11·5 and 16·7 volts respectively. To account for this, these authors have proposed a rather elaborate theory of progressive ionisation. The following experiments, however, explain entirely these abnormally low voltages simply on the basis of well-known phenomena.

A short hot-filament cathode and a sheet nickel anode were placed about 1 cm. apart, and a 3 mm. length of 1 mil wire projecting from a glass stem was introduced as an exploring electrode in a bulb filled with pure argon at 2 mm. pressure. This electrode was used according to Langmuir's recent method,[5] and was movable to different points in the discharge by a flexible copper-to-glass seal.

It was found that the arc could easily be maintained at an applied voltage of about 4 volts, without oscillations. Under these conditions, however, *the gas near the filament was found to be at a potential of about 11·5 volts above that of the filament,* and there was an electric field in the direction reverse to the applied field throughout most of the space between the electrodes. Furthermore, the concentration of ions, either positive or negative, was found to decrease from about 100×10^{10} per cc. near the cathode to about 2×10^{10} per cc. near the anode. The average kinetic energy of the electrons outside the region of the cathode drop was found to vary from 2 to 4, in equivalent volts. Analogous results were found in a mercury arc, operating at about 3·5 volts.

Evidently there is *always* a sufficient cathode drop to produce ionisation. If the ionisation is intense, positive as well as negative ions move toward the anode, and at approximately equal rates. To cause this, the reverse electric field, caused by difference in rates of diffusion of electrons and positive ions, takes such a value as to cause the two types of ions to move toward the anode at nearly equal rates. It is easily shown that the number of ions of either sign is at least a million times greater than the excess of one kind over the other, except in the region of the cathode drop.

A fuller treatment of this problem and its significance in the Geissler tube discharge will soon be published.

We are indebted to Dr. Irving Langmuir for suggesting this general line of explanation of the abnormal arc.

KARL T. COMPTON.
CARL H. ECKART.
Princeton University.

[1] Compton, Lilly and Olmstead, *Phys. Rev.*, 4, p. 282, 1920; A. C. Davies, Proc. Roy. Soc., A, 100, p. 599, 1922.
[2] *Zeits. f. Phys.* 20, p. 83, 1923.
[3] *Science*, 59, p. 166, 1923.
[4] *Physica*, 4, p. 42, 1924.
[5] *Gen. Elec. Rev.*, p. 731, Nov. 1923.

De Broglie's Theory of the Quantum and the Doppler Principle.

L. DE BROGLIE (*Phil. Mag.*, Feb. 1924) has recently suggested a theory of the quantum in which the quantum is supposed to be a corpuscle of exceedingly small rest mass M which moves with a velocity βc, where β is less than unity by an exceedingly small amount. The momentum of such a corpuscle is $M\beta c/\sqrt{1-\beta^2}$, and is equal to that of the light quantum $h\nu/c$. Since β is so nearly unity, the momentum may be written as $Mc/\sqrt{1-\beta^2}$. Different values of the frequency ν are explained as being due to different values of β.

Let us suppose that an atom is moving towards the observer with a velocity $\beta_1 c$, and that while moving with this velocity the atom ejects a quantum in the direction of the observer, the frequency of the quantum being ν_0 and its velocity $\beta_0 c$ relative to an observer on the atom. The momentum of the quantum relative to the atom is then $h\nu_0/c = Mc/\sqrt{1-\beta_0^2}$. By applying the relativity theorem of the addition of velocities, we have that, if βc is the velocity of the quantum corpuscle relative to the stationary observer,

$$\beta c = (\beta_0 + \beta_1)c/(1 + \beta_0\beta_1).$$

Hence
$$1 - \beta^2 = \frac{(1-\beta_0^2)(1-\beta_1^2)}{(1+\beta_0\beta_1)^2}.$$

Remembering that β_0 very nearly equals unity, and assuming that β_1 is small, we have

$$1 - \beta^2 = (1-\beta_0^2)(1-\beta_1)^2.$$

Hence if ν is the frequency relative to the stationary observer we have

$$h\nu/c = Mc/\sqrt{1-\beta^2} = Mc/(1-\beta_1)\sqrt{1-\beta_0^2} = h\nu_0/c(1-\beta_1).$$

If now we put $\beta_1 = v/c$, where v is the velocity of the atom relative to the stationary observer, we have

$$\nu = \nu_0 c/(c - v),$$

which is the equation expressing the Doppler principle when the velocity v of the radiating atom is small compared with c.

G. E. M. JAUNCEY.
Washington University,
St. Louis, Mo., May 23.

THE result obtained by Mr. Jauncey seems to be quite correct, and I already knew that it was possible to explain *all the forms* of Doppler effect by means of my "light quantum" conception.

By studying the collision of a moving electron with a light quantum, I have also obtained a formula for the change of frequency which involves both the Doppler effect and the Compton effect.

In a recent number of the *Phil. Mag.* (May 1924) Mr. William Anderson has stated a curious and perhaps not very probable consequence of my views.

I think that the *isolated* quantum of radiant energy can only be considered in radiations of very high frequency (when Wien's law is valuable), but that for radiations of mean or low frequencies we must conceive a sort of aggregation of light quanta. This idea suggested by the form of Planck's law would perhaps allow us to imagine a transition between light quanta and electromagnetic theory and to avoid Mr. Anderson's conclusion.

June 14. LOUIS DE BROGLIE.

Cell Inclusions in the Gametogenesis of Scorpions.

SINCE last winter I have been engaged on the study of cell-inclusions in the gametogenesis of scorpions, and it was, therefore, with some interest that I read the note of Profs. D. R. Bhattacharya and J. B. Gatenby on the spermatogenesis of an Indian scorpion (Palamnæus) published in NATURE, June 14.

I have studied mitochondria in the spermatogenesis of *Palamnæus fulvipes madraspatensis*, and can confirm the following statements of the writers:

(1) "The mitochondria are sorted out whole during the maturation stages." This is true of both the meiotic divisions.

(2) "The number of mitochondria varies in the spermatid."

In *Palamnæus fulvipes madraspatensis* the number varies from four to thirteen.

I am, however, unable to support the statement that "the mitochondria form the sperm tail directly. . . ." During a certain stage in spermateleosis the mitochondria are grouped together at the base of the elongated nucleus. To a large extent they lose their individuality and form a curious oval body—the mitosome—which stains characteristically with crystal violet, Altman's acid fuchsin and iron hæmatoxylin. I have not been able to detect the mitochondria after this stage. Nor have I seen them at any stage descending down the axial filament.

I may here add a note on the mitochondria of the oocyte of the same species. They are remarkably different in their reaction to osmic acid from those of the male germ cells. There is no case on record where the mitochondria are blackened by chrome-osmium alone. Where they are blackened, it is only after prolonged osmication (Kopsch). But the mitochondria in the oocyte are intensely blackened by chrome-osmium alone in ten hours. They are even preserved and blackened by Fleming-with-acetic acid. They can be decolorised by turpentine, but subsequent staining is impossible. They are completely destroyed by Bouin's fluid. These facts undoubtedly suggest the presence of a large amount of unsaturated fat in the mitochondria.

The Golgi apparatus in the oocyte of the same species consists of rods and crescents distributed in patches.

I hope to publish in due course a paper on the cell inclusions in the gametogenesis of Palamnæus (Madras), *Buthus judaicus* and *Heterometrus maurus* (Palestine), and *Euscorpius napoli* (Naples).

VISHWA NATH.

Zoological Laboratory, Cambridge,
June 20.

Art-Forms in Nature.

PERMIT me to thank Mr. Edward Heron-Allen for the very generous reference to my work published in his review of Haeckel's "Kunstformen der Natur" (NATURE, June 14, p. 847). Mr. Heron-Allen says: "A law only approximates to the facts, and every time we use it we have to make appropriate additions and corrections; the real value of deviations is not that they make it necessary to discard a theory, but that they enlarge our laws and thereby advance our knowledge." This sentence formed part of an appreciation of my book, "The Curves of Life," which was published in 1914. With your permission I will quote a short passage from this book which gives an excellent example of the process mentioned, an example which in 1924 we can all read with a startling verification in our minds.

"The principle enunciated by Newton," I wrote on pp. 429 and 430, "may 'simplify' the phenomena of our solar system sufficiently to enable us to talk about the movements of the earth and the celestial bodies. But that simplicity, we may feel sure, is only apparent. Newton himself, as far as I am aware, never ventured to suggest any 'cause' for his great principle. We may well consider that its value as a working hypothesis outweighs the possibilities of its inexactness. But we must be equally prepared to realise that it may not fit all the facts which future science may discover. It is, in H. Poincaré's admirable phrase, *une règle d'action qui réussit*; or, in other words, we have added (1914) so few phenomena of real importance to those known by Newton that the basis furnished by his 'law' has not yet been disintegrated. But it is easily conceivable that a broader foundation will be needed, even in the present century; and we need have no fear that men of science will shrink from the endeavour to provide it. The sterile reprobation of Auguste Comte (who was obsessed by sociological ideas of 'Order') has long ago become inoperative."

These lines were written ten years ago, and I freely admit that logic had more to do than special knowledge with a prophecy which Einstein was so soon and so brilliantly to fulfil. THEODORE A. COOK.

Savile Club, 107 Piccadilly, W.
June 19.

The Oogenesis of Lithobius.

THE oogenesis of the Arthropoda is the least well understood, because it has presented considerable technical difficulties. In this country Hogben has investigated successfully the oogenesis of dragonflies, and has shown that the nucleolus takes important direct part in the production of the yolk spheres.

The oogenesis of Lithobius appears to be much like that of Hogben's examples, and is probably general for Arthropoda. Yolk formation is from nucleolar extrusion, of which two phases can be distinguished; first, an early extrusion of particles budded off from the large central nucleolus, which retains its individuality, and, secondly, an extrusion of particles derived from the fragmentation of this nucleolus. These particles multiply both in the nucleus and in the cytoplasm. The fate of the first nucleolar extrusions has not been determined, but the later extrusions enlarge after proliferation to form the definitive yolk spheres. The Golgi apparatus behaves in the usual way, being excentric and juxta-nuclear in the youngest oocytes, then spreading out through the cell, and breaking eventually into very fine grains. The mitochondria are diffuse in the earliest stages, then become concentrated to a cloud near the nucleus; this breaks up into a number of clusters, some of which become active centres of proliferation. These form curious round mitochondrial bodies, which later fragment, the mitochondria passing out to become evenly distributed through the cytoplasm. The clouds which did not take part in the rapid proliferation also become scattered at the same time.

A full account of the oogenesis will be published later. S. D. KING.

Zoological Department,
Trinity College, Dublin.