but Lennard-Jones and Corner[5] were able to show, on the basis of dimensional considerations, that the parachor is proportional to $V_c^{\frac{5}{6}}T_c^{\frac{1}{4}}$. For non-associated organic compounds, including those in which the molecules are so unsymmetrical as to restrict rotation in the liquid state, they found that the formula

$$P = 0{\cdot}410\, V_c^{\frac{5}{6}}T_c^{\frac{1}{4}}$$

gave slightly better agreement than that of Ferguson and Kennedy. Examination of the available data for liquids of this type reveals that formula (2) is definitely superior to that of Ferguson and Kennedy, and is in general slightly more accurate than that of Lennard-Jones and Corner.

S. T. BOWDEN

University College,
Cardiff. July 29.

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[1] Guldberg, C. M., *Z. Phys. Chem.*, **5**, 374 (1890). Partington, J. R., "An Advanced Treatise on Physical Chemistry", 1, 646 (Longmans, Green and Co., Ltd., London, 1951).

[2] Corner, J., *Trans. Farad. Soc.*, **36**, 784 (1940).

[3] Walden, P., *Z. phys. Chem.*, **66**, 429 (1909).

[4] Ferguson, A., and Kennedy, S. J., *Trans. Farad. Soc.*, **32**, 1474 (1936).

[5] Lennard-Jones, J. E., and Corner, J., *Trans. Farad. Soc.*, **36**, 1156 (1940).

## Paramagnetic Resonance, a New Property of Coal-like Materials

PARAMAGNETIC resonance, which has given interesting information on several structures[1], can be used for studying coal-like materials. Using a microwave spectrometer (9,000 Mc./s.) for electronic paramagnetic resonance, we have observed a characteristic line for coals[2]. This sharp line is associated with a Landé factor of 2, which is the free electron value. These results lead us to believe that this paramagnetism is linked with the structure of coal-like materials and cannot be attributed to the minerals always present, such as iron. In the present communication we give further details on the results observed for coals[2] and for several coal-like materials in which paramagnetic resonance has been detected.

The samples of coal studied, coming from mines in northern or eastern France, are of different geological ages. They correspond to the following French designations: anthracite, quart-gras, demi-gras, trois-quart-gras, flambant-gras, flambant-sec. The amplitude of the line decreases from the oldest coal (anthracite) to the youngest one (flambant-sec). Roughly, the amplitude gets smaller as the amount of carbon decreases in the samples and as the amount of volatile substances and oxygen increases. Charring modifies the phenomenon considerably. On heating the coals up to 500° C., the line is seen to decrease gradually with increasing temperature. The line disappears quickly on heating the same samples between 500° and 600° C., when graphitization and electrical conductivity appear. After coking is completed (1,000–1,100° C.) no line can be seen. It must be emphasized that several samples of graphite did not give any line with our apparatus, though a weak line has been reported by Castle[3]. With regard to lignites, the line is absent in a sample from Hostens, present but weak in a sample from Fuveau and in both instances it becomes very strong after heating at 300° C. These results have led us to make some experiments with such materials as charcoals, sugar charcoal and pitches.

Charcoal prepared from pine wood and coconut and also some lightly charred sugars (saccharose, glucose) give a fairly intense paramagnetic resonance line. This line disappears in charcoals activated at 900° C. in presence of combustion gases and steam. No line appears in crude oils; but one is found in pitches which are residues from crude oil distillation. It can be said that paramagnetic resonance appears when carbohydrates are damaged either by Nature, as in coals, or artificially by heating, as in charcoals, sugar charcoal and pitches. The same line appears if the samples (woods, sugars) are irradiated by γ-rays, as was found by two of us[4], which suggests the same sort of damage. This paramagnetic resonance cannot be attributed to a specific defined structure at present; but further experimental and theoretical work is being carried out.

J. UEBERSFELD
A. ÉTIENNE
J. COMBRISSON

Ecole Supérieure de Physique et Chimie,
10 rue Vauquelin,
Paris 5. Aug. 2.

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[1] Gordy, W., Smith, W. V., and Trambarulo, R. F., "Microwave Spectroscopy", 236 (Wiley and Sons, New York, 1953).

[2] Étienne, A., and Uebersfeld, J., *J. Chim. Phys.* (June 1954).

[3] Castle, *Phys. Rev.*, **92**, 1063 (1953).

[4] Combrisson, J., and Uebersfeld, J., *C. R. Acad. Sci., Paris*, **238**, 1397 (1954).

## Electroretinal Photopic Sensitivity Curves

SINCE Adrian[1] first suggested the existence of separate rod- and cone-components in the human electroretinogram, there have been attempts to isolate them so as to demonstrate the degree to which their spectral sensitivity curves adhered to scotopic or photopic patterns.

Thus Riggs, Berry and Wayner[2] determined the function for the *B*-wave. With a 7·5° foveally centred stimulus-flash, the curve closely resembled the scotopic function but was displaced toward the blue. Armington, Johnson and Riggs[3] derived a similar curve for the *A*-wave of the dark-adapted eye. Again excess blue-sensitivity appeared. Boynton[4] has supposed this to be related to the part played by stray light. With small stimulus areas a significant portion of the electrical response is due to light scattered over the peripheral retina, outside the focal area. One contributor is Rayleigh scatter, varying as an inverse function of the fourth power of the wave-length, scattering blue more than red. To support this interpretation, Boynton shows that divergence from scotopic values is less when larger areas are used. Johnson and Armington[5] have confirmed this, demonstrating that with full-retinal stimulation, using an integrating sphere, electrical sensitivity curves for the *B*-wave of the dark-adapted eye coincide with the usual scotopic luminosity curve.

Armington[6] has fitted data for the *X*-wave (Motokawa's designation for Adrian's photopic component) to the CIE photopic luminosity curve. With the photopic receptors we would expect stray light to have less effect. Cones are concentrated near the fovea and are supposed (cf. Stiles–Crawford effect[7]) to be directional. It is disconcerting to find that the *X*-wave curve diverges from the photopic curve just as the small-area *B*-wave curve diverges from the scotopic function. No one has used full-retinal stimulation to elicit the *X*-wave. We cannot say whether such a procedure would bring the *X*-wave