molecule as a whole, but by the sub-molecules containing one iron atom.

Q. H. GIBSON
D. C. HARRISON

Department of Biochemistry,
Queen's University,
Belfast.
April 20.

[1] Gibson, Q. H., and Harrison, D. C., *Lancet*, ii, 941 (1947).
[2] Darling, R. C., and Roughton, F. J. W., *Amer. J. Physiol.*, **137**, 56 (1942).
[3] Evelyn, K. A., and Malloy, H. T., *J. Biol. Chem.*, **126**, 655 (1938).

Crystal Structure of Nitronium Perchlorate

WE have made an X-ray examination of the nitronium perchlorate of Goddard, Hughes and Ingold[1] and find, in agreement with Millen's observations on its Raman spectrum[1], that the crystal structure contains the ions NO_2^+ and ClO_4^-.

The crystals are monoclinic, the unit cell having dimensions $a = 9 \cdot 25$ A., $b = 6 \cdot 99$ A., $c = 7 \cdot 34$ A., with $\beta = 113 \cdot 5°$, and containing four molecules of $NClO_6$. The existence and general arrangement of the ions was discovered from two-dimensional Patterson syntheses of the intensities of X-ray reflexions in the three principal zones, and confirmed by comparison of observed and calculated structure amplitudes ; the chlorate and nitronium ions are arranged alternately along twofold axes, in accordance with the space group $C\,2/c$, the nitrogen and chlorine atoms lying on the twofold axes, with all the oxygens in general positions. By using $\{hkl\}$ structure amplitudes in sectional projections[2] we find that the NO_2^+ ion is linear with $N{-}O \sim 1 \cdot 1$ A., and the ClO_4^- ion approximately tetrahedral, with $Cl{-}O \sim 1 \cdot 5$ A. Successive Fourier refinement is now being applied to obtain more accurate values of these bond-lengths.

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E. G. COX
G. A. JEFFREY
M. R. TRUTER

Chemistry Department,
University, Leeds.
April 23.

[1] *Nature*, **158**, 480 (1946).
[2] Booth, *Trans. Farad. Soc.*, **41**, 434 (1945).

Emissivity of Small Particles in Flames

IT is a striking fact that solid (or massive) carbon behaves as a black body, whereas small carbon particles which are responsible for the luminosity of hydrocarbon flames have an absorption coefficient which is strongly dependent on wave-length. This difference is important in the measurement of the colour temperature of luminous flames. It has been shown theoretically by Mie[1] that the absorption coefficient is strongly dependent on wave-length when particles are smaller than a wave-length, an effect which is analogous though not identical with the dependency of scattered light on wave-length.

We have made some optical measurements on a stationary flame of aluminium flakes in air. These experiments differed from the often repeated measurements on photo-flashes since the flame had a greater depth (5–10 cm. diameter). The intensity distribution in the flame was unusual. The radiation consisted of weak AlO bands and a strong continuum which extended from the red far into the ultra-violet regions. The colour temperature was about 3,600° C. It may be shown theoretically that the enthalpy of the exhaust gases permits the temperature of the flame to reach the boiling point of aluminium oxide (Al_2O_3), which is $2,980° \pm 60°$ C., and that nearly all the oxide is vaporized. When we threw an image of the anode of the carbon arc on to the aluminium–air flame, we observed very weak absorption in the visible and increasing absorption towards the violet region. At 3100 A. all light from the arc was absorbed. The emission coefficient, therefore, became very nearly equal to unity in the ultra-violet. By comparing the brightness of the flame at 3100 A. with the brightness of the carbon arc anode, we estimated a brightness temperature which was a little below the calculated (theoretical) temperature. Line reversal measurements (ordinarily a little high on account of the scattering effect) gave a slightly greater value than the calculated temperature.

The close agreement of these results satisfied us that the temperature of the flame was actually the boiling point of aluminium oxide. If we adopt this value, however, an explanation is needed for the high colour-temperature observed, or in other words, for the strong dependency of emissivity on wave-length. We believe that most of the aluminium oxide formed in the flame is initially in the gaseous state. The radiation may therefore originate from gaseous aluminium oxide or other gaseous products (excited thermally or by chemiluminescence), but no continuum of gaseous origin is known which extends so far. Moreover, it is perhaps significant that the conditions are very similar to those in the luminous hydrocarbon flame, where emission is undoubtedly due to small particles.

We suggest, therefore, that small droplets of aluminium oxide are the emitters in the aluminium flame, and that these particles are formed by condensation in the flame. Produced in this way, the particles are finely dispersed and very small. Their temperature is identical with the gas temperature, even if catalytic reactions occur on the surface, because the heat transfer numbers of such particles are extremely high. Some of these particles are no doubt smaller than the wave-length of light (Shechter *et al.*[2] have produced evidence of this), and the absorption and emission characteristics of such particles will behave in the same way as radiant soot. The abnormally high colour-temperature is again attributed to the optical properties of very small particles. Moreover, the colour temperature depends upon the thickness of the optical layer, because the thicker the layer the more the radiation will approach black-body conditions.

Magnesium behaved in a similar manner.

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H. G. WOLFHARD
W. G. PARKER

Chemistry Department,
Royal Aircraft Establishment,
South Farnborough, Hants.
April 12.

[1] Mie, *Ann. d. Phys.*, **25**, 377 (1908).
[2] Shechter, Roginsky and Sakharova, *Acta Physicochim. U.R.S.S.*, **21**, 3, 463 (1946).