to form a twin transmission line roughly a quarter wave-length long, and surrounded, to eliminate radiation losses, by a cylindrical sheath, which was either silver-plated or lined with lead-foil to minimize resistive losses. Measurements of the width of the resonance curve of the system by a controlled variation of the oscillator frequency gave a value for the skin resistance of the specimen.

The accompanying graph shows the skin resistance R of tin and mercury, relative to its value R_n for the normal metal just above the transition point, as a function of temperature. The shape of the curve for tin is in good agreement with London's published curve, measured at the slightly different frequency of 1,500 Mc./sec.; there are no previous results with which to compare the curve for mercury. For both metals the curves appear to tend to zero at 0° K., though there is some uncertainty in the values of the skin resistance at the lowest temperatures, due to dielectric loss in the quartz, which limits the Q of the resonator to about 250,000. By comparing the results for two wires of different diameter, the dielectric loss may be estimated, and the curves here shown have been corrected for this effect as well as possible.

The absolute skin resistance of the specimen may be determined from the Q and the geometry of the resonator, and from this, by application of the standard theory of the skin effect, the specific conductivity of the metal can be deduced. The value obtained for normal tin at 3.8° K. was $2.1 \pm 0.2 \times 10^9$ ohm⁻¹ cm.⁻¹ (the large probable error arises from the approximations used in performing the calculation rather than from the measurements, which were consistent within 1 per cent); a D.C. measurement of the specific conductivity gave 15×10^9 ohm⁻¹ cm.⁻¹, more than seven times as great. A discrepancy of the same magnitude was noted by London. For mercury the effect is not so pronounced, the specific conductivity as deduced from the radio-frequency measurements being 0.92×10^9 , compared with the D.C. value⁴ of 2.1×10^9 .

Although the shape of the specimen was not very suitable, an attempt was made to discover whether the skin resistance was affected by the presence of a constant magnetic field. Up to one half the critical field, no variation of skin resistance was detected, which by London's theory (see below) may be interpreted as evidence for the constancy of the penetration depth in small fields. No useful readings could be taken in stronger fields, since a portion of the specimen passed into the intermediate state.

The variation of the skin resistance of mercury with temperature is particularly interesting, since with the aid of London's¹ theory of the effect it is possible to deduce the variation with temperature of the penetration depth λ , which has been studied for mercury more directly by other methods; it is, however, too much to expect agreement with these other results, since they do not agree among themselves. Appleyard and his collaborators³, from the properties of thin films, and Shoenberg⁴, by measurements on colloids, found an increase in λ as the critical temperature is approached from below, whereas

Casimir⁵, using a mutual inductance method with macroscopic specimens, found no such change. In order to apply London's theory to the radio-frequency measurements, it is necessary to assume only one parameter λ_0 , the penetration depth at 0° K. Taking $\lambda_0 = 1.0 \times 10^{-3}$ cm., as found by Appleyard *et al.*, the value of λ at any other temperature may be calculated to agree within 10 per cent with Appleyard's figures. It would be unwise to regard this agreement as very significant, in view of the assumptions involved in London's theory, which need to be tested by an extensive investigation of the behaviour of both normal metals and superconductors over a wide range of temperatures and frequencies.

Royal Society Mond Laboratory,
Cambridge.
July 22.

A. B. PIPPARD

¹ London, H., *Proc. Roy. Soc., A*, **176**, 522 (1940).

² Kamerlingh Onnes and Tuijn, "Intern. Crit. Tables", **6**, 124 (1929).

³ Appleyard, Bristow, London, H., and Misener, *Proc. Roy. Soc., A*, **172**, 540 (1939).

⁴ Shoenberg, *Proc. Roy. Soc., A*, **175**, 49 (1940).

⁵ Casimir, *Leid. Comm.*, 261, c (1940).

Investigations of Near Infra-Red Radiations by Means of Image Converters

FOR rapid examinations of near infra-red light up to 15,000 Å., image converters are very useful. Their main advantage lies in enabling one to 'see' immediately what infra-red sensitized plates show only after involved processing. The spectrum under test is projected on to a photo-electric cathode of the type (Ag) — Cs₂O, Cs, Ag — Cs. The number of photo-electrons released is proportional to the intensity of radiation on that particular part of the cathode; they are focused by an electronic lens and form a picture on the fluorescent screen, which can either be studied visually or photographed. The accompanying illustration shows a photograph ($\times 1.5$) of the mercury spectrum. In addition to the visible lines a number of lines in the near infra-red part of the spectrum have appeared. On the original photographic plate we can also see some lines of longer wave-length, which cannot be seen on the reproduction.

It should be mentioned that the converter used had a convex cathode, so that only a part of the image could be focused; but it appears probable that, with an improved apparatus of this type, a number of important problems could be attacked.

Physical Institute of Charles' University,
Praha II.
July 6.

A. VASKO

Long Wave-length Absorption Bands of Aromatic Molecules

CALCULATIONS of the long wave-length absorption bands of aromatic molecules, such as those carried out by Sklar¹ and Förster², give good agreement with the experimental values of absorption maxima even when only nearest-neighbour exchange effects are taken into account (as in Förster's work). In these calculations, it almost always happens that the lowest two totally symmetric levels (of which the ground-state is one) are separated by an unsymmetric level, and the transition to

this from the ground-state is permitted in molecules having, at most, twofold axes of symmetry: experimentally, the long-wave absorptions of these molecules have intensities compatible with an allowed transition—anthracene, for example, has $\epsilon_{\max}$ of about 10^4 .

Phenanthrene, however, provides an interesting departure from this usual situation. Here the energy-level calculation shows that there is no unsymmetric level between the ground-state and the lowest excited symmetric level, and consequently the transition of lowest energy is one between levels of the same symmetry. The usual symmetry considerations show that the transition moment for such a change will be very small and will lie along the axis of symmetry of the molecule. In fact, the absorption of phenanthrene does show a weak long wave-length absorption between 3000 Å. and 3600 Å., having its centre at about 3400 Å., and with $\epsilon_{\max}$ about 300. This band is comparable in intensity with the forbidden $A_{1g} \rightarrow B_{2u}$ transition in benzene (2600 Å.) and is, apparently, to be associated with the symmetric-symmetric transition discussed above. Förster associated his calculated value of 3000 Å. with the strong phenanthrene band at 2950 Å.; it now appears that it should be assigned to the 3400 Å. weak band, and that the

2950 Å. band is due to a symmetric-unsymmetric transition of higher energy. The poor agreement between the calculated and experimental values for the forbidden transition is connected with the fact that Förster's empirical exchange integral was estimated as an average for a number of inter-symmetry transitions and is too large for a symmetric-symmetric change.

The above assignment receives confirmation from the fact that the 3400 Å. band is greatly increased in intensity ($\times 10$) when the C_{2v} symmetry is destroyed by the substitution of a nitrogen atom for a carbon atom, to give the skew benzquinolines. The situation is in marked contrast to the anthracene-acridine-benz-*g*-quinoline case, where the transition moment (this is an allowed transition) is scarcely altered when the symmetry is lowered.

Further details, together with some related work, will be published, soon.

Department of Chemistry,
University of Sydney.
July 10.

D. P. CRAIG

¹ Sklar, A. L., *J. Chem. Phys.*, **5**, 669 (1937).

² Förster, Th., *Z. Elektrochem.*, **45**, 548 (1939).