forward calculation then shows that the resulting quadrupole moment of the deuteron contains the factor $g_1g_2 + f_1f_2$. The constants referring to the pseudoscalar meson fields are only restricted by the conditions that $|f_2| = |g_2|$ and that $|f_1|$ should not be very much larger than $|g_1|$ or $|g_2|$; the adjustment of the theory to the known energy spectrum of the deuteron fixes the order of magnitude, but not the signs, of g_1 and g_2. Thus, in contrast to the vector meson theory, in which the two cases studied by Bethe correspond to definite values of the quadrupole moment, of opposite signs and very different magnitudes, the theory discussed in the present note would be able to account for any sign and for a wide range of magnitudes of the effect in question. It does not seem possible at present to derive from the measurements an entirely reliable estimate of the effect, owing to the insufficient knowledge of the electronic wave-functions of the hydrogen molecule, which enter in such a derivation. Anyhow, the order of magnitude following from our theory, if we make, for example, the simplest assumption $f_1 = 0$, agrees reasonably well with the provisional empirical value given by Rabi and his collaborators.

A fuller account of the problems discussed in this note and in the previous one will appear in the *Proceedings of the Copenhagen Academy.*

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* This circumstance was pointed out to one of us in the course of valuable discussions on the subject with Prof. Rabi and Prof. Bethe.

[1] Kellogg, Rabi, Ramsey and Zacharias, *Phys. Rev.*, 55, 318 (1939).
[2] Bethe, H., *Phys. Rev.*, 55, 1130 (1939).
[3] Kemmer, N., *Proc. Camb. Phil. Soc.*, 34, 354 (1938).
[4] Møller, C., and Rosenfeld, L., NATURE, 143, 241 (1939).

Effect of Temperature on the Intensity of X-ray Reflections from Copper

IN a recent letter in NATURE[1], Prof. E. A. Owen and Mr. R. W. Williams have given results for the effect of temperature on the intensity of X-ray reflections from copper. They find that throughout the range of temperature from 290° to 840° A., the decline of intensity with temperature is greater than predicted by the usual Debye-Waller formula, exp. $-2M$, where M has the well-known expression involving the characteristic temperature Θ which occurs in the Debye theory of specific heats, and that their results agree closely with a temperature factor of the form exp. $-3M$.

The fact that deviations from the Debye-Waller formula occur at the higher temperatures is not surprising, but so large a deviation near room temperature would not be expected. An alternative explanation of the results would be that the value of Θ to be used in the expression for M is not identical with that given by specific heat data. Since M is approximately proportional to $1/\Theta^2$, it follows that instead of changing the numerical factor from 2 to 3, we may take

$$\Theta\,(\text{X-ray}) = \Theta'(\text{sp. heat}) \times \sqrt{2/3} = 315° \times 0{\cdot}816 = 257°.$$

To test this result we have examined the intensities of reflections from copper at room temperature and liquid air temperature, using two methods to arrive at the temperature factor. (1) Using a mixture of copper and aluminium powders, we have measured the change in the copper intensities in terms of the aluminium intensities, the latter having previously been determined. (2) The second method is to use the relative intensities from the copper powder at the two temperatures and, with cubic metals, these data alone are sufficient to give the temperature factor. Method (1) is probably the more accurate but involves a second substance; method (2) is less accurate but eliminates any comparison substance.

Our results by the two methods are: (1) Θ = 310° Abs. (2) Θ = 297° Abs. The uncertainties in these figures are of the order of 4 per cent; that is, about ± 12°. Comparing these with the specific heat value, 315° Abs., we see that while there is a tendency for the X-ray value to be smaller than the specific heat value, there is no marked discrepancy.

Note added after writing the above letter. Prof. Owen and Mr. Williams have kindly informed us of their more recent work on gold, which has yielded results in close agreement with theory (see following letter). This result, considered in conjunction with our own measurements on copper at low temperatures, indicates that no abnormalities are to be expected for copper at higher temperatures, and we think that the suggestion which they make regarding the tarnishing of the copper is quite likely to prove correct.

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[1] Owen, E. A., and Williams, R. W., NATURE, 142, 915 (1938).

Effect of Temperature on the Intensity of X-ray Reflections from Gold

IN a previous letter[1] we referred to some measurements that we carried out on the effect of temperature on the intensity of reflection of X-rays from copper, from which it was concluded that over the range of temperature from about 20° C. to 570° C., the intensity decreased with rise in temperature more nearly in accordance with the temperature factor exp.$(-3M)$ instead of the factor exp.$(-2M)$.

Looked at from another point of view, the characteristic temperature of copper, assuming the exp. $(-2M)$ factor, works out to be 261° K., which is well removed from the accepted value of 315° K. The main difficulty with the measurements was to keep the surface of the copper untarnished, and to meet the difficulty the material was exposed to X-rays when it was maintained at a given temperature in an evacuated chamber.

Similar measurements have now been completed with gold, the surface of which can more easily be kept clean when maintained at high temperature. The results obtained with gold agree more closely with the exp.$(-2M)$ factor, the characteristic temperature working out to be 161 ± 9° K. when the temperature of the material is 445° K. This is in close agreement with the characteristic temperature of 166° K. calculated by Debye from the elastic constants of gold and not far removed from the experimental values of 170° and 175° deduced respectively from specific heats at low temperatures and from electrical conductivity measurements. At higher temperatures the characteristic temperature of gold on the basis of the exp.$(-2M)$ factor turns out to be somewhat lower.