

becoming paramagnetic, as has been occasionally reported<sup>1</sup>. There is, however, an appreciable temperature variation of susceptibility of the cold-worked specimen, which appears to differ somewhat from that of the annealed metal; this is being investigated separately.

The simplest interpretation of the present results would appear to be that the magnetic susceptibility is strain-sensitive. Self-recovery takes place, slowly at room temperatures and more rapidly as the temperature is raised, although at sufficiently low temperatures the self-recovery appears to be arrested. Kussmann and Seemann<sup>6</sup> have attempted to show that the apparent change of magnetic susceptibility with cold-working in non-ferrous metals is really due to the presence of minute amounts of ferromagnetic impurity in the metals. The X-ray evidence of self-recovery, in the form of decrease in line-broadening<sup>2</sup> and the appearance of distinct spots in the lines<sup>3</sup>, coupled with the fact that the magnetic susceptibility itself shows a self-recovery, appears to support the idea that susceptibility is in fact strain-sensitive. The theoretical implications of this conclusion are of obvious importance, and more extensive magnetic investigations may be expected to throw additional light on the nature of cold-work and internal strain in metals.

Details of further work will be published elsewhere.

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- <sup>1</sup> See, for example, Shimizu, Y., *Sci. Rep. Tōhoku Univ.*, **22**, 915 (1933).
- <sup>2</sup> Megaw, H., Lipson, H., and Stokes, A. R., *Nature*, **154**, 145 (1944).
- Megaw, H., and Stokes, A. R., *J. Inst. Metals*, **71**, 279 (1945).
- <sup>3</sup> van Reijen, L. L., *Nature*, **157**, 371 (1946).
- <sup>4</sup> Cook, M., and Richards, T. L., *J. Inst. Metals*, **70**, 159 (1944).
- <sup>5</sup> Hutchison, T. S., and Reekie, J., *J. Sci. Inst.*, in the press.
- <sup>6</sup> Kussmann, A., and Seemann, H. J., *Z. Phys.*, **77**, 567 (1932).

**Barium Titanate : a New Ferro-Electric**

I HAVE earlier discussed the high permittivity of barium titanate and its temperature behaviour<sup>1</sup>. Additional experimental results such as the dependence of permittivity on the electrical field strength, the dielectric hysteresis loops and the maximum in the thermal capacity at the permittivity peak temperature show that this substance is a new type of ferro-electric. It should be noted that, as distinct from other known ferro-electrics, barium titanate does not contain hydrogen. For practical purposes, it is important to note that it may be used as an electrical insulator in which the ferro-electric properties are manifest over a wide temperature range. A detailed article will be published in the *Journal of Physics*.

Prof. W. Jackson and W. Reddish<sup>2</sup> have recently announced that the peak permittivity-temperature behaviour observed in barium titanate is also characteristic of the solid solution of BaTiO<sub>3</sub>-SrTiO<sub>3</sub>. It seems very probable that solid solutions of BaTiO<sub>3</sub>-SrTiO<sub>3</sub> are ferro-electrics, as it is known<sup>3</sup> that mixed isomorphous crystals of Rochelle salt NaKC<sub>4</sub>H<sub>4</sub>O<sub>6</sub>·4H<sub>2</sub>O and NaNH<sub>4</sub>C<sub>4</sub>H<sub>4</sub>O<sub>6</sub>·4H<sub>2</sub>O are ferro-electrics.

In my former communication<sup>1</sup>, I mentioned the experimental result that the dielectric constant of titanates of perovskite structure were found to grow with an increase in the size of the alkaline-earth ion. It was clear that this referred to pure materials, and should not be extended to the permittivity-temperature behaviour of a mixed ferro-electric substance near the Curie point.

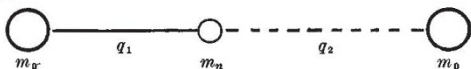
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- <sup>1</sup> Wul, B., *Nature*, **156**, 480 (1945).
- <sup>2</sup> Jackson, W., and Reddish, W., *Nature*, **156**, 717 (1945).
- <sup>3</sup> Eremeyew, M., and Kurtschatow, B., *Phys. Z. Sowjetunion*, **3**, 304 (1933).

**Interpretation of the Regularities in the Spectra of Molecules Forming the Intermolecular Hydrogen Bond by the Predissociation Effect**

A most effective method of investigation of the hydrogen bond is the study of changes in vibrational spectra when the molecules are forming complexes. The results may be easily explained with the help of the predissociation theory and the Frank-Condon principle both applied to the energy-levels and transitions between them in the system:



where  $q_1$  is the change of the distance OH for the chemical bond,  $q_2$  is the change of distance between the oxygen and the hydrogen atoms for the hydrogen bond. The energy operator for such a system has the form

$$H(q_1) + H(q_2) + H(q_1q_2).$$

Omitting  $H(q_1q_2)$ , we obtain as a solution of the corresponding Schrödinger equation a system of levels of the molecule OH and a system of levels for the hydrogen bond. The magnitude of the fundamental vibrational quantum of the molecule OH is 3,650 cm.<sup>-1</sup>. The magnitude of the quanta of the system H . . . O is very small; they are quickly converging to the dissociation limit (3,000 cm.<sup>-1</sup>). If the influence of the operator  $H(q_1q_2)$  is taken into account, the interaction of the level V-1 for the group OH with the set of continuous levels of the group H . . . O, lying higher than the dissociation limit, leads to the broadening of the level and to the disappearance of the discrete structure that is observed in the spectrum.

The breadth of the band and its shift in the frequency scale compared with a line of the gas (3,650-3,400 cm.<sup>-1</sup>) is explained in the following way. In absorption the most probable transitions are those for which the positions of the heavy oxygen atoms change least. As the average distance between the oxygen and the hydrogen atoms for the transition V-0→V-1 increases due to the anharmonicity of the OH bond, the distance between the atoms of oxygen and hydrogen forming the hydrogen bond decreases, the decrease being of the same magnitude  $dq$ . To this change  $dq$  in the set of energy-levels of the hydrogen bond correspond only those transitions for which the energy of the system decreases.

These conceptions also make it possible to explain the dependence of the shift and of the band-breadth on temperature, the behaviour of the solutions of molecules connected one with another by a hydrogen bond, the properties of the spectra of molecules connected by a deuterium atom, and the properties of overtones of the frequencies 3650.

A detailed account of this investigation will be published in the *Journal of Physical Chemistry* (U.S.S.R.).

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**Quantization of the Solar System**

CONSIDERATIONS having no bearing on the present subject lead to the conclusion that the spin of elementary particles can be computed if the gravitational constant and the velocity of light are known; and further that the protonic spin is slightly greater than the electronic spin. Should these considerations prove correct, the two conditions mentioned suggest that the Planck constant has not the meaning of a universal physical constant, and that its numerical value is always dependent on the value of the spin of the elementary particle taking part in the physical phenomenon in question. Accordingly, to mention only a simple example, in the case of Bohr's atom model, the principal quantum number does not correspond to the equation

$$n = \frac{\text{orbital impulse}}{\hbar}; \dots \dots \dots (1)$$

but to

$$n = \frac{\text{orbital impulse}}{2 \times \text{electronic spin}} \dots \dots \dots (2)$$

The question arises whether equation (2) is not applicable to the orbits of the planets in the modified form:

$$n = \frac{\text{orbital impulse}}{2 \times \text{planetary spin}} \dots \dots \dots (3)$$

Quantization of the orbits has not yet been thought of as equation (1) leads to extremely high numbers. The quantum numbers obtained with the aid of equation (3) are still very high. On closer examination, however, it becomes evident that the quantum numbers thus obtained are 1, 2, 3, 4 . . . times the integral powers of Sommerfeld's fine structure constant; divided by this factor, the orbits of the planets can be quantized on the basis of the equation:

$$n = \frac{\text{orbital impulse}}{2 \times \text{planetary spin}} \cdot 137 \cdot k \dots \dots \dots (4)$$

Planet	n	k	Time of revolution (24)* hours
Venus	0.97 ~ 1	3	(24)* "
Earth	1.04 ~ 1	3	24 "
(Vulcanus)	~ 2	3	(24) "
Pluto	3.04 ~ 3	3	(11.7) "
Mercury	4.00 ~ 4	3	(24) "
Mars	5.15 ~ 5	3	24.6 "
Jupiter	1.08 ~ 1	2	9.9 "
Saturn	2.10 ~ 2	2	10.2 "
Uranus	1.87 ~ 2	2	10.8* "
Neptune	3.01 ~ 3	2	15.8 "

It is assumed that inside the planets the distribution of the density is identical with the distribution of density of the earth<sup>2</sup> (moment of inertia  $T = 0.28 MR^2$ ). In the case of Pluto the time of revolution was taken to be identical with the average value of the time of the revolution of the other outer planets, and further that its density does not exceed that of the earth.

It seems as if Pauli's rule would be valid even for planets, that is, that the values of  $k$  and  $n$  cannot be the same for any two planets, except if they revolve in opposite senses as is the case for Saturn and Uranus; but then we must infer that the revolution of Venus must be also retrograde.

According to the table, a planet with  $k = 3$  and  $n = 2$  does not seem to exist; it is possible that the innermost hypothetical planet Vulcanus, situated between the sun and Mercury—the existence of which is suggested by the anomalies in the orbital motion of Mercury—should fulfil these conditions. Taking its distance from the sun as  $30 \times 10^6$  km., we get, according to equation (4), about 6,000 km. for its diameter.

It must be stressed that the role of the factor 137, the occurrence of which elsewhere in physics is inexplicable, is also here incapable of explanation. Nevertheless, the results enable one to estimate the time of revolution for the planets Venus, Mercury and Pluto, which are as yet incomputable by astronomical observations. Besides Kepler's law, reduced by Newton to general laws, and the Bode-Titus rule, computed theoretically by Weizsäcker<sup>2</sup>, the above quantization may serve as a third correlation for the definition of the elements of planetary motions.

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- <sup>1</sup> Eucken, *Naturwiss.*, **112** (1944).
- <sup>2</sup> Weizsäcker, C. F., *Z. Astrophys.*, **22**, 319 (1943).