at between 8 and 10 cm/sec. per volt/cm for + ions at the lower frequencies, (500 cycles to 2000). Above frequencies of 2000 cycles the values of the mobilities increased, reaching a maximum of about 21 cm/sec. per volt/cm above 5000 cycles and remaining there up to 25,000 cycles. Between the lower and higher frequency values the curves indicated by their slopes the probable existence of two carriers present in varying proportions, which made the accurate assignment of mobilities uncertain. This uncertainty will have to remain until the new and somewhat difficult techniques involved shall have been perfected. Hence the results can be considered only as preliminary. The reduced mobility depends primarily on frequency and does not appear to depend on pressure. The correction of the results for temperature was not attempted, first, because the temperature correction for mobility is very uncertain[9] and, secondly, it was not desired to encumber this already complex apparatus at this stage with the necessary added refinements. Since this work was done at constant density the temperature effects will not be great.

The results indicate that Na^+ ions in H_2 within 2×10^{-5} seconds (reciprocal of twice the frequency) after liberation have a little more than double the value of the mobility of the normal ions. These are probably the Na^+ atoms moving in the gas and impeded by their electrostatic attractions only. In 10^{-3} seconds these ions have in part either exchanged charges with other molecules or attached to molecules of H_2, H_2O vapor (present in traces), or some other molecules to form molecular ions. Their mobility is of the order to be expected of the normal positive ions in H_2 as measured by an absolute method.[6] The process (judging from the nature of the

curves) appears to be a process similar to that observed by Erikson[2] in his ageing experiments, that is a process which takes place in a single step. The present results differ from Erikson's in the much greater change in mobility occurring, an action which could be ascribed to the use of initial relatively stable Na^+ ions.

Note: Temperature measurements made since this letter indicate average temperatures of less than 130°C in the gas space between the plates. This lowers the average density by a factor of about 0.7 between the plates and indicates that all mobility values reported may be too high in absolute magnitude by a factor less than 1.43. It does not alter the relative changes with frequency.

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[1] L. B. Loeb, Phys. Rev. **32**, 81 (1928) and **35**, 192 (1930).
[2] H. A. Erikson, Phys. Rev. **33**, 403 and **34**, 635 (1929).
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The Interaction Between Excited and Unexcited Hydrogen Atoms at Large Distances

Eisenschitz and London[1] have recently pointed out that when two similar atoms in different quantum states interact with one another a first order calculation of their mutual energy yields an inverse R^3 term corresponding to a dipole interaction. This term is the controlling one for large values of the internuclear distance R and may yield an energetic order for the different molecular terms at large distances quite different from that which occurs at short distances. As an example they cite the two quantum II

states of the hydrogen molecule whose potential energy curves were computed in first order approximation by Kemble and Zener.[2] For small internuclear distances the energetic order of the states is $H_{12}{}^{12} > H_{10}{}^{10} > H_9{}^9 > H_{11}{}^{11}$ as shown by Kemble and Zener, while for large distances the predominance of the $1/R^3$ term leads to the energetic order

[1] Eisenschitz and London, Zeits. f. Physik **60**, 491 (1930).
[2] Kemble and Zener, Phys. Rev. **33**, 512, (1929).

$H_{12}{}^{12} \gtrsim H_9{}^9 > H_{10}{}^{10} \gtrsim H_{11}{}^{11}$. The state $U_9({}^1\Pi_+$ in the notation of Eisenschitz and London) whose potential energy curve shows a marked minimum in the region of small values of R has a positive energy of interaction for large values of R corresponding to a repulsive force between the atoms. Similarly the state $U_{10}({}^1\Pi_-)$ which shows marked repulsion at short distances, yields a weak attraction at very large distances.

the exact first order computations of Kemble and Zener to the internuclear distances $R = 5, 6, 7, 10$. The results are shown in the accompanying table and figure.

The curves show that the crossing-point of the "potential" energy curves for the states *9* and *10* occurs farther out than supposed by Eisenschitz and London. Also the maximum in the potential energy of the state *9* and the minimum for the state *10* are less

TABLE I

R	$H_9{}^9$	$H_{10}{}^{10}$	$H_{11}{}^{11}$	$H_{12}{}^{12}$
	(volts above E_0)			
5	−0.21	0.27	−0.44	0.43
6	−0.038	0.057	−0.181	0.162
7	0.016	0.008	−0.081	0.068
10	0.014	−0.014	−0.016	0.016

As the computations of Kemble and Zener were not extended to internuclear distances larger than $R = 4$ (here the unit of distance is the radius of the innermost Bohr orbit for the H atom) Eisenschitz and London made a necessarily crude interpolation between the asymptotic $1/R^3$ formula and the curves
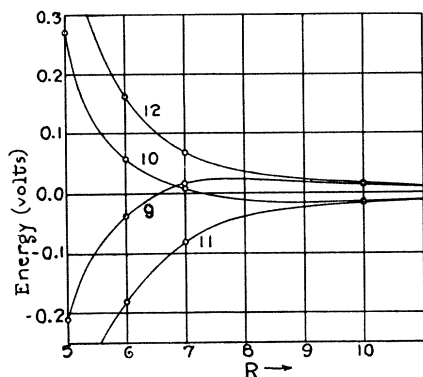

Fig. 1.

given by Kemble and Zener for short distances. This interpolation enabled them to estimate the positions and values of the minimum point in the $H_{10}{}^{10}$ curve and the maximum in the $H_9{}^9$ curve. At London's suggestion, however, the writers have now extended

pronounced than their interpolation would indicate, being almost imperceptible when plotted on the scale of the original graph of Kemble and Zener.

In the course of the computation here reported we have found the following misprints in the paper of Kemble and Zener.

Errata to paper by Kemble and Zener, Phys. Rev. **33**, 512 (1929).

p. 525, Eq. (28): the second term in square brackets should be multiplied by 1/4 to read

$$\frac{1}{4}\left(1 + R + \frac{R^2}{3}\right)\left(1 + \frac{R}{2} + \frac{R^2}{12}\right)$$

p. 526, Eq. (29): the sign of the third term in the right hand member should be positive. p 530, Eq. (35): should read

$$K_2{}^{(2)} = \frac{R^4}{3840}\int_1^\infty (\lambda^2 - 1)(\lambda^2 + 1/7)\left\{(3\lambda + R)e^{-3\lambda R/2}\right.$$

$$-\left(\frac{3\lambda^2 - 1}{2}\right)e^{-\lambda R/2}\left[S'Ei\{-(\lambda+1)R\} - SEi\right.$$

$$\left.\left\{-(\lambda-1)R\} - S\ln\left(\frac{\lambda+1}{\lambda-1}\right)\right] - 3S\lambda e^{-\lambda R/2}\right\}d\lambda.$$

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