was silvered over the central portion to increase the intensity by multiple reflection. The light leaving the tube transversally through a slit in the silvering was reflected out of the solenoid by a 45° prism. The Zeeman pattern was photographed with a Fabry-Perot interferometer crossed with a prism spectrograph. By placing a thin calcite plate with proper orientation behind the spectrograph slit, each spectral line appeared separated into its π and σ components.

At a field of 2580 gauss and an interferometer separation of 0.6159 cm, the auroral line was resolved into four components. The displacement of the inner components was $0.92\Delta\nu_{\mathrm{norm}}$, that of the outer components was $1.96\Delta\nu_{\mathrm{norm}}$. The theoretical factors are 1 and 2, respectively. As was predicted the undisplaced line did not appear. We found that the outer components were polarized perpendicular to the field, and that the components displaced by $\Delta\nu_{\mathrm{norm}}$, which in the normal effect are polarized perpendicular to the field, are in this case polarized parallel. This is in complete agreement with the theory of Rubinowicz.

We intend to investigate the Zeeman effect of other forbidden lines.

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June 9, 1930.

Mobility of Na^+ Ions in H_2

The results of studies of mobilities of ions in mixtures showing the great importance of traces of impurities on mobilities,[1] the studies of Erikson[2] on the change of mobilities of positive ions with age at atmospheric pressures including the effects of impurities, and the prominence recently given the change of charge of initially ionized atoms and molecules in gases reported by Kallman and Rosen,[3] indicating as previously emphasized the total ignorance as to the nature of the ionized carrier,[4,1] led to the present investigations the first results of which it is desired to report at this time.

It seemed essential by as nearly an absolute a method as possible to measure the mobilities of a type of initially ionized carrier which would only reluctantly alter its charge in gases of reasonable purity over very short time intervals. To this end it was attempted to measure the mobilities of positive Na^+ ions from a Kunsman[5] source, using a high frequency square wave form oscillator in fairly pure gases at low pressures. From the nature of the Kunsman sources the gas chosen was hydrogen purified by a process previously used by the writer.* A Kunsman source of positive ions with a square wave form oscillator, using the original Rutherford A.C. method with positive ions instead of negative ions, should: (1) give absolute values of the mobilities with no disturbing effects of gauzes as encountered in other A.C. methods,[6] and with ions definitely emerging from one plane of the parallel plate electrode system; (2) give ions which retain their positive charge in H_2 because of their low ionization potential; and (3) be capable of extension to very short time intervals. The chamber used was a brass one of a type previously described[7] with electrodes altered to suit the Kunsman source. The source was a coating of Na catalyst, kindly sent the writer by Dr. Kunsman, on a thin Pt foil, spot welded onto a small oven of Ni containing a Pt spiral heating element insulated from it by "Insolute" cement. In practice it was heated to about 700°C and gave a copious supply of + ions. It was mounted in the center of the upper plate of a parallel plate condenser in the gas, the lower plate going to ground through an electrometer system. The plate distance was 1.2 cm. By means of an oscillator first designed by J. L. Bowman,[8] built here by Mr. J. E. McVay and adapted by the writer, good square wave form alternating potentials of from 10 to 150 volts with frequencies varying from 500 to 25,000 cycles per second have been achieved. It is probable that the upper frequency limit can be considerably extended. The first results covered a range of pressures from 0.5 to 7 cm of Hg and appeared of sufficient importance to report at this time, as the work will be interrupted for the period of a month or two by external demands on the writer.

Mobilities in H_2 were observed, beginning

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* The H_2 was passed over hot Cu, NaOH, $CaCl_2$, two meter long tubes of P_2O_5 and a special double liquid air trap immersed in liquid air.

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 5000cycles and remainingthere 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 byan 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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June 4, 1930.

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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).

[3] Kallman and Rosen, Zeits. f. Physik. **58,** 52 (1929) and **61,** 61 (1930).

[4] Loeb and Marshall, Jour. Franklin Inst. **208,** 386 (1929).

[5] C. H. Kunsman, Phys. Rev. **25,**892 (1925).

[6] L. B. Loeb, Jour. Franklin Inst. **196,** 537 and 771 (1923).

[7] Loeb and Cravath, Jour. Opt. Soc. Am. **16,** 191 (1928).

[8] J. L. Bowman, Phys. Rev. **24,** 31 (1924).

[9] L. B. Loeb, Internat. Crit. Tables, **VI,** 114 (1929).

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 Π 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

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[1] Eisenschitz and London, Zeits. f. Physik **60,** 491 (1930).

[2] Kemble and Zener, Phys. Rev. **33,** 512, (1929).