Letters to the Editor.

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The Raman Effect with Liquid Oxygen, Nitrogen, and Hydrogen.

In some experiments we recently made to see if a Raman effect could be observed with homopolar molecules, we found that the spectrum of the light scattered by liquid air included six sharp and clearly defined lines not included in the irradiating light, which was that from the mercury arc. The wave-lengths of these lines were approximately 4317·7 A., 4674·3 A., 5026·5 A., 4468·9 A., 4849·3 A., and 4980·3 A. They with their frequencies are given below.

Element.	Exciting Radiation.		Scattered (Raman) Radiation.			$\Delta\nu$ observed.	$\Delta\nu$ calculated from Band Spectra Data.
	λ (A).	ν (vac.).	λ.	Int.	ν (vac.).	cm.$^{-1}$	cm.$^{-1}$
Oxygen	4046·6	24,705	4317·7	1	23,154	1552	1554
	4358·3	22,938	4674·3	2	21,387	1551	1554
	4358·3	22,938	5026·5	0	19,889	3049	3085
Nitrogen	4046·6	24,705	4468·9	1	22,371	2335	2331
	4358·3	22,938	4849·3	00	20,616	2322	2331
	4046·6	24,705	4980·3	0	20,073	4632	4633

The experiment was repeated with pure liquid oxygen and again with pure liquid nitrogen, and it was found that the wave-lengths 4317·7 A., 4674·3 A., and 5026·5 A. only were obtained with liquid oxygen, and the wave-lengths 4468·9 A., 4849·3 A, and 4980·3 A. only with liquid nitrogen. The existence of two of the Raman lines with each liquid can be explained by supposing them to arise from irradiation by light of the two wave-lengths 4358 A. and 4047 A. The frequency difference for the mercury line 4047 A. and the Raman oxygen line 4317·7 A. is 1552 cm.$^{-1}$, and for the mercury line 4358 A., and the Raman oxygen line 4674·3 A. is 1551 cm.$^{-1}$. With the nitrogen lines, the one, 4468·9 A., has a frequency difference with the mercury line 4047 A. of 2335 cm.$^{-1}$, and the other, 4849·3 A. with the mercury line 4358 A., one of 2322 cm.$^{-1}$.

It would seem that a mean vibration frequency of approximately 1551·5 cm.$^{-1}$ was involved in the Raman effect with liquid oxygen and a mean vibration frequency of approximately 2328·5 in the Raman effect with liquid nitrogen.

From the *Bulletin of the National Research Council*, vol. 11, Part 3, No. 57, on "Molecular Spectra in Gases," p. 232, 1554 cm.$^{-1}$ is indicated as the primary vibration frequency of the oxygen molecule in its normal state, and 2331 cm.$^{-1}$ as that of the nitrogen molecule in its normal state. The two-quantum vibration state of oxygen would appear to be 3085 cm.$^{-1}$ and that of nitrogen 4633 cm.$^{-1}$.

Our results would suggest that the primary vibration frequencies are the ones involved in the production of four of the Raman lines observed by us. The other two lines, it would seem, are produced by absorptions corresponding to the frequencies of the second vibration states of the two elements, for if with oxygen the exciting mercury line is taken to be 4358 A., the frequency difference between it and the Raman line at 5026·5 A. is 3049 cm.$^{-1}$, and with nitrogen, if 4046·6 A. of mercury is taken as the exciting line, the frequency difference between it and the Raman line at 4980·3 A. is 4632 cm.$^{-1}$.

In experiments with liquid hydrogen irradiated with light from the mercury arc, we found that in addition to the usual mercury lines there were included in the spectrum of the scattered light lines corresponding to wave-lengths 4426·6 A., 4473·1 A., and 4863·5 A. These with their frequencies are given below.

Element.	Exciting Radiation.		Scattered (Raman) Radiation.			$\Delta\nu$ observed.	$\Delta\nu$ calculated from Band Spectra Data.
	λ (A.).	ν (vac.).	λ (A.).	Int.	ν (vac.).	cm.$^{-1}$	cm.$^{-1}$
Hydrogen	4358·3	22,938	4426·6	2	22,584	354	347
	4358·3	22,938	4473·1	4	22,350	588	578
	4046·6	24,705	4863·5	1	20,556	4149	4159

By the use of suitable light screens, it was found that 4426·6 A. and 4473·1 A. were excited by the radiation 4358·3 A., and 4863·5 A. by radiation 4046·6 A. The available data on the band spectra of hydrogen enable one to show that 347 cm.$^{-1}$ and 578 cm.$^{-1}$ are the frequencies corresponding respectively to $0 \rightarrow 2$ and $1 \rightarrow 3$ rotational transitions for hydrogen molecules in the zero vibrational state. It can be shown, too, that 4159 cm.$^{-1}$ is the frequency of a $0 \rightarrow 1$ vibrational transition for hydrogen molecules in the zero vibrational state. From the numbers given in the table it will be seen that the Raman effects we observed with hydrogen were due to these three transitions.

The results are interesting in that they constitute a series of violations of generally accepted selection rules. They show (1) that Raman effects can be obtained with homopolar molecules; (2) that part of the energy of light quanta can be taken up directly as rotational energy, the balances appearing as quanta degraded in frequency; and (3) that two-quantum rotational transitions can be demonstrated in connexion with light-scattering phenomena.

The results of the experiments, moreover, constitute experimental proof of the correctness of Dennison's view that hydrogen at low temperatures must be regarded as a mixture of two effectively distinct sets of molecules, symmetrical and antisymmetrical. According to our results, we have in liquid hydrogen (1) some molecules in the zero vibrational and zero rotational states, and (2) others in the zero vibrational and first rotational states. Our intensity measurements show that there were in the latter states considerably more (about twice as many) molecules than in the former ones. The 'distinctness' of the two states is emphasised by the fact that no Raman effects were obtained corresponding to $0 \rightarrow 1$ or $1 \rightarrow 2$ rotational transitions.

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University of Toronto, Dec. 20.

The Understanding of Relativity.

May I have space for a last letter about the difficulties of the ordinary man with respect to relativity and kindred puzzles? Of course there is such a thing as relativity. We take it into account in daily life. But I cannot believe that modern mathematicians have overthrown fundamental axioms of thought. Such dictionaries as I have consulted define parallel lines as those which keep equidistant from each other. But a spiral wound around a straight line might keep equidistant, and yet not be parallel. Presumably parallel lines are those which keep equidistant on the