

The following results for the particular case of low energy and high temperature ($E \ll \theta$, $T \gg \theta/2\pi$), which is of frequent experimental interest,^{2,5} may serve to illustrate the advantages of the method, which of course come even more fully into play at higher energies.

$$\begin{aligned} \sigma^{(1)} &= s \sum_{n=0,2,3,4} \lambda^{1-n} (a_n T - b_n + c_n T^{-1}) + O(\lambda^{-5}), \\ \sigma^{(2)} &= s \sum_{n=0,2,4,5} \lambda^{1-n} (d_n T^2 - e_n T + f_n + g_n T^{-1}) + O(\lambda^{-5}). \end{aligned} \quad (5)$$

Here T is measured in units of θ , and $\lambda = (\theta/E)^{1/2}$ is the neutron wavelength in dimensionless units. The coefficients are given in Table I.

For Mg, taking $\lambda = 5.94$, $T = 2.05$, Squires² calculates σ by using six terms in (1). The terms with $l > 1$ amount to 46 percent of σ_1 . His result is in agreement with that obtained from (4) and (5), with the $\sigma^{(2)}$ term amounting to only half a percent of the $\sigma^{(1)}$ term.

The results for general energy and temperature, which will be given in a forthcoming paper, provide a detailed answer to questions previously raised⁶ about the energy dependence of the cross section.

The author is indebted to L. Van Hove and G. C. Wick for valuable discussions.

¹ In the Debye approximation, expressions for σ_l for $l=0$ and 1 have been given by J. M. Cassels [Progr. Nuclear Phys. 1, 185 (1950)] and for general l by Squires (reference 2).

² G. L. Squires, Proc. Roy. Soc. (London) A212, 192 (1952).

³ G. Placzek and L. Van Hove, Phys. Rev. (to be published).

⁴ G. Placzek, Phys. Rev. 86, 377 (1952).

⁵ H. Palevsky and D. J. Hughes, Phys. Rev. 92, 202 (1953).

⁶ A. Akhiezer and I. Pomeranchuk, J. Phys. (U.S.S.R.) 11, 167 (1947).

Color Centers in Alkali Silicate Glasses

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THE study of color centers in quartz and fused quartz was reported elsewhere.¹ We have extended our study to the color centers in silicate glasses which contain alkali ions.

We melted the glass from the purest chemicals (Merck for analysis except in the case of rubidium carbonate which is cp grade) in a platinum crucible in an electric furnace whose heater is platinum ribbon. The glass was annealed and polished. The increase of absorption resulting from irradiation with x-rays (45 kv, 10 ma, tungsten target) at room temperature was measured with a Beckman DU spectrophotometer at room temperature.

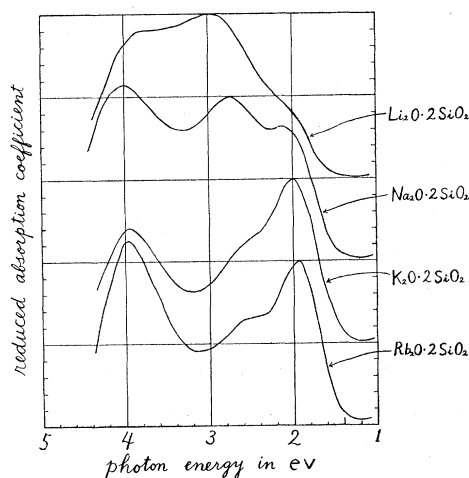


FIG. 1. Induced absorption bands in alkali disilicate glasses. The ordinate is the reduced absorption coefficient.

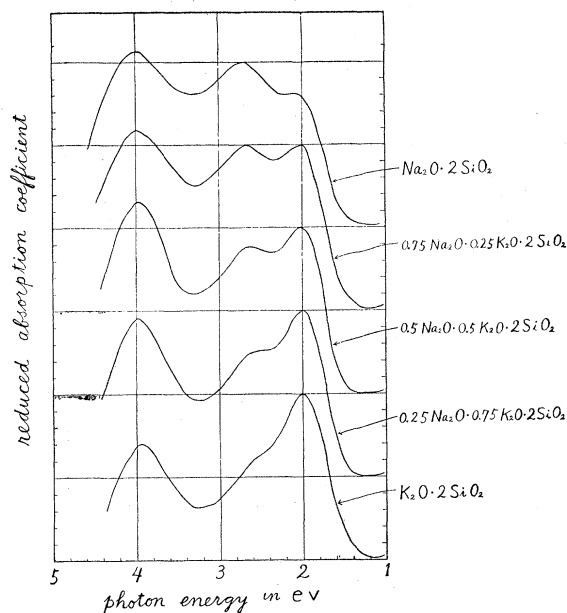


FIG. 2. Induced absorption bands in mixed alkali disilicate glasses. The ordinate is the reduced absorption coefficient.

The induced absorption bands in alkali disilicate glasses whose molecular compositions are $\text{Li}_2\text{O} \cdot 2\text{SiO}_2$, $\text{Na}_2\text{O} \cdot 2\text{SiO}_2$, $\text{K}_2\text{O} \cdot 2\text{SiO}_2$, and $\text{Rb}_2\text{O} \cdot 2\text{SiO}_2$, respectively, are given in Fig. 1.

From Fig. 1 it may be concluded that the visible bands are due to electrons trapped by oxygen vacancies which neighbor alkali ions.

To verify the above, we prepared the mixed alkali disilicate glasses whose molecular composition is represented as $x\text{Na}_2\text{O}$

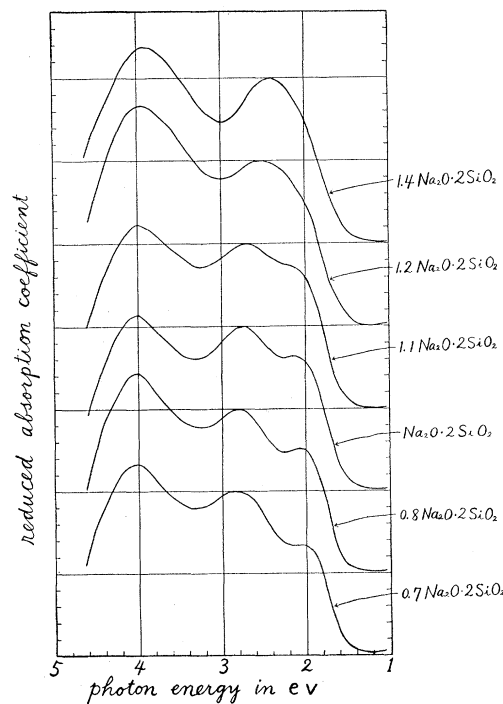


FIG. 3. Induced absorption bands of $\text{Na}_2\text{O}-\text{SiO}_2$ glasses. The ordinate is the reduced absorption coefficient.

$\cdot(1-x)\text{K}_2\text{O}\cdot 2\text{SiO}_2$ ($x=0-1$). The induced absorption bands are given in Fig. 2.

Figure 2 shows clearly that the relative intensity of the two visible bands is nearly proportional to the molecular ratio of Na_2O to K_2O .

Moreover the induced absorption bands of $\text{Na}_2\text{O}-\text{SiO}_2$ series glasses are given in Fig. 3. Therefore it is concluded that the visible bands in alkali silicate glasses are due to electrons trapped by oxygen vacancies which neighbor alkali ions.

The ultraviolet band is bleached with the visible bands by irradiation with visible light and the visible bands are bleached with the uv band by irradiation with 313 $m\mu$ light.

Further, in $\text{K}_2\text{O}\cdot 2\text{SiO}_2$ glass which was prepared in the reducing condition, the uv band decreases and the visible bands increase in intensity compared with the intensities observed in the specimens prepared in the neutral condition.

On the other hand, the uv band in all glasses studied has its peak at about 3.98 ev. Moreover, this peak position does not change in the mixed alkali silicate glasses.

Therefore it is concluded that the uv band is the one characteristic of "oxygen," that is, it arises from positive holes trapped by alkali vacancies neighboring oxygen.

In the alkali silicate glasses studied, the three absorption bands are always observed, although in some cases they are difficult to resolve. A remarkable regularity in the peak position and the relative intensity of the two visible bands was found, as shown in Figs. 1 and 3.

A full account will appear in the *Journal of the Physical Society of Japan*.

¹ Ryosuke Yokota, *J. Phys. Soc. Japan* 7, 316 (1952); 7, 222 (1952); *Phys. Rev.* 91, 1013 (1953).

Submillimeter Wave Spectroscopy*

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AN extension of microwave spectroscopy into the submillimeter wave region has been achieved. A spectrum line at 0.77-mm wavelength (389 kMc/sec) has been precisely measured with harmonics from a 5-Mc/sec marker monitored by the standard 5-Mc/sec signal broadcast by the National Bureau of Standards. This and other submillimeter wave lines of OCS which have been measured are listed in Table I.

Figure 1 shows a recording of several rotational lines in the sub-millimeter range obtained with different harmonics of a *K*-band klystron (Raytheon 2K33). Because of centrifugal stretching the rotational lines are not exactly integral multiples as are the harmonics from the oscillator. For this reason, the different rotational lines are separated on the tracing. The tuning was such as to optimize the lines of highest frequency. Therefore, this recording does not indicate the optimum performance which

TABLE I. Observed lines of $\text{O}^{16}\text{C}^{12}\text{S}^{32}$.

Oscillator harmonic	Transition	Frequency in Mc/sec		Wavelength in mm
		Calculated ^a	Observed ^b	
12	23-24	291 839.27	291 839.23 ± 0.60	1.03
13	25-26	316 145.59	316 144.7 ± 1.0	0.949
14	27-28	340 448.64	340 449.2 ± 1.0	0.881
15	29-30	364 748.16	364 747.5 ± 1.5	0.823
16	31-32	389 043.12	389 041 ± 2.0	0.771

^a Calculated with $B_0 = 6081.494$ Mc/sec and $D_J = 1.310$ kc/sec.

^b The two lower-frequency lines were measured on the scope, and the others on the recorder.

was obtained on the lower-frequency lines. With tuning to maximize it, the line at 0.88 mm could be recorded with a signal-to-noise ratio of 30 to 1; that at 0.95 mm, with 60 to 1; that at 1.03 mm, with 100 to 1.

The highest frequency previously recorded by electronic methods is the 1.03-mm line of OCS for which a signal-to-noise ratio of 7 to 1 was obtained.¹ The signal-to-noise ratio obtainable

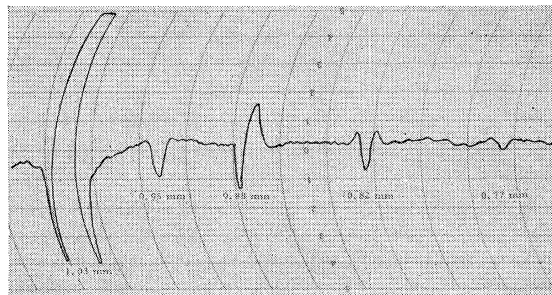


Fig. 1. Recording of the 24th, 26th, 28th, 30th, and 32nd rotational lines of OCS with the 12-16th harmonics of a *K*-band klystron. A phase sensitive lock-in amplifier tuned to 4000 cps was used with 2000-cps repeller modulation of the klystron. Cell length 15 cm, cell volume 0.2 cc. Wavelength of lines are indicated on the chart; frequencies range from 291 to 389 kMc/sec.

at one millimeter has now been increased by a factor of at least 10. Figure 2 shows a scope tracing of the 1.03-mm line obtained with a 60-cps video sweep spectrometer. A recording of it is included in Fig. 1.

The present results have been made possible by a further reduction in size and by refinements of the crystal multiplier and detector units already described by King and Gordy.^{1,2} More experimental details will be given in a full length report to be written later. It is evident that the coherent electronic methods

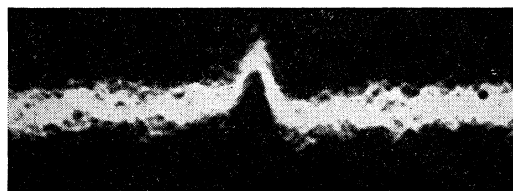


Fig. 2. Cathode-ray oscilloscope trace of the 24th rotational line of OCS at 1.03-mm wavelength (291 kMc/sec). An ordinary crystal video receiver was employed with a 60-cps sweep and an amplifier band width of 6 kc/sec.

of the radio region now overlap effectively the noncoherent optical or heat methods customarily employed in the far infrared region. Rotational lines of such light diatomic hydrides as DCl and HI now fall within the microwave region. Already lines of DBr have been measured in the one-millimeter region.³

Although there are many obvious uses of high-resolution spectroscopy in the 1-mm region, one advantage which probably is not generally realized is the small quantity of material required for spectral examination in this region. The total volume of the wave-guide cell used in the present work is 0.2 cc. In this cell with a pressure of only 5×10^{-3} mm of Hg, the signal-to-noise ratio of 100 to 1 could be obtained at 1-mm wavelength. This represents a total of 5×10^{13} molecules, or one hundredth of a microgram of OCS, neglecting that adsorbed on the cell walls. Actually the lines could easily be detected with only 5×10^{12} molecules or one-thousandth microgram of OCS in the absorbing path. We have in progress a cooperative program with Dr. Ralph Livingston's group at the Oak Ridge National Laboratory for utilizing