

where f is the degree of freedom of an oxygen molecule, R the gas constant and T the absolute temperature. Since Eq. (2) can be written in the form

$$\frac{1}{c_1} = \frac{Q}{E - \frac{1}{2}fRT} + \frac{E}{E - \frac{1}{2}fRT}, \quad (3)$$

Eq. (2) or (3) is another expression of Eq. (1). From Eq. (2) or (3), the activation energy E and the temperature coefficient of c_1 was estimated as shown in the next table.

Table 1. Temperature coefficients of lower limit and heat of activation.

Combustible	Q Kcal/mole	Temp. Coeff. ($\times 10^5$)		E (Kcal/mole) from Eq. (3)
		$\Delta C_1/\Delta T$ obs.	$fR/2Q$ calc.	
Hydrogen	58	$(\frac{0.034}{350})$: 9.5	12	7.7(8.8%; 100°C)
Carbon monoxide	68	$(\frac{0.030}{200})$: 15	12	12.8(15%; 100°C)
Ammonium	76	$(\frac{0.045}{400})$: 11	9	15.9(17.5%; 100°C)
Methane	196	$(\frac{0.022}{500})$: 4.4	4	13.1(5.5%; 100°C)
Pentane	775	$(\frac{0.0031}{233})$: 1.1	0.9	13.8(1.53%; 17°C)
Benzene	751	$(\frac{0.0024}{150})$: 1.6	0.9	12.8(1.37%; 100°C)
Toluene	892	$(\frac{0.0023}{100})$: 2.3	0.8	13.8(1.26%; 100°C)
Ethylene	311	$(\frac{0.0095}{383})$: 2.5	2.3	12.7(3.45%; 17°C)
Acetylene	302	$(\frac{0.0071}{283})$: 2.3	2.3	10.6(2.90%; 17°C)
Methanol	150	$(\frac{0.016}{200})$: 8.0	4.7	13.4(7.5%; 50°C)
Propylalcohol	438	$(\frac{0.007}{150})$: 4.7	1.6	13.4(2.45%; 100°C)
Acetone	395	$(\frac{0.0008}{100})$: 8.0	1.8	13.8(3.0%; 25°C)

Mean value of E : 1208.

3. Theory of Limit of Inflammability. (III)

Upper Limit

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Similarly to the case of lower limit, the energy of combustion (ϵ) equally distributed to every degree of freedom of molecules in an unit volume per

one molecule of oxygen at the upper limit C_2 was given by the relation

$$\varepsilon = \frac{Q_{O_2}}{F} + \frac{1}{2}RT \quad (1)$$

Where Q_{O_2} is the heat of combustion per mole of oxygen, F the total degrees of freedom in the unit volume (the value of Q_{O_2} for most of combustibles takes almost constant value 100 Kcal). Now it was assumed that inflammation can occur when the energy distributed to every one molecule of oxygen in the unit volume exceeds the activation energy E . Thus the condition for inflammation at the upper limit C_2 was given by the relation

$$f_0\varepsilon = f_0 \left(\frac{Q_{O_2}}{F} + \frac{1}{2}RT \right) = E \quad (2)$$

or

$$E = f_0 \left\{ \frac{1}{2}RT + \frac{Q_{O_2}}{5f_0} + \frac{C_2}{1-C_2} \cdot f_B \right\} \quad (3)$$

or

$$\frac{1}{C_2} = 1 + \frac{5(E - \frac{1}{2}f_0RT)}{Q - 5(E - \frac{1}{2}f_0RT)} \cdot \frac{f_{B_0}}{f_0} \quad (4)$$

where f_0 is the degree of freedom of an oxygen molecule and f_B that of combustible gas molecules. From Eq. (3), E was estimated to be 8~16 Kcal, as shown in Table 1.

Table 1. Upper limit and activation energy.

Combustible	f_B	C_2 (%)	E (Kcal)
Hydrogen	7	71.5 (20°C)	7.7
Carbon monoxide	7	70.0 (20°C)	8.4
Acetylene	18	55.0 (17°C)	6.9
Ammonia	18	25.5 (20°C)	12.6
Methane	24	13.0 (20°C)	15.4
Pentane	96	4.5 (17°C)	14.0
Benzene	66	5.3 (100°C)	16.1
Ethylene	30	13.7 (17°C)	14.0
Methanol	30	25.0 (100°C)	16.6

Further, experimental results showed qualitative agreement with the tendency given by Eq. (4), i. e. $\frac{1}{C_2}$ increases with f_B and decreases with the temperature rise. Fig 1 shows the correlation between upper limit and degrees of freedom of fuels.

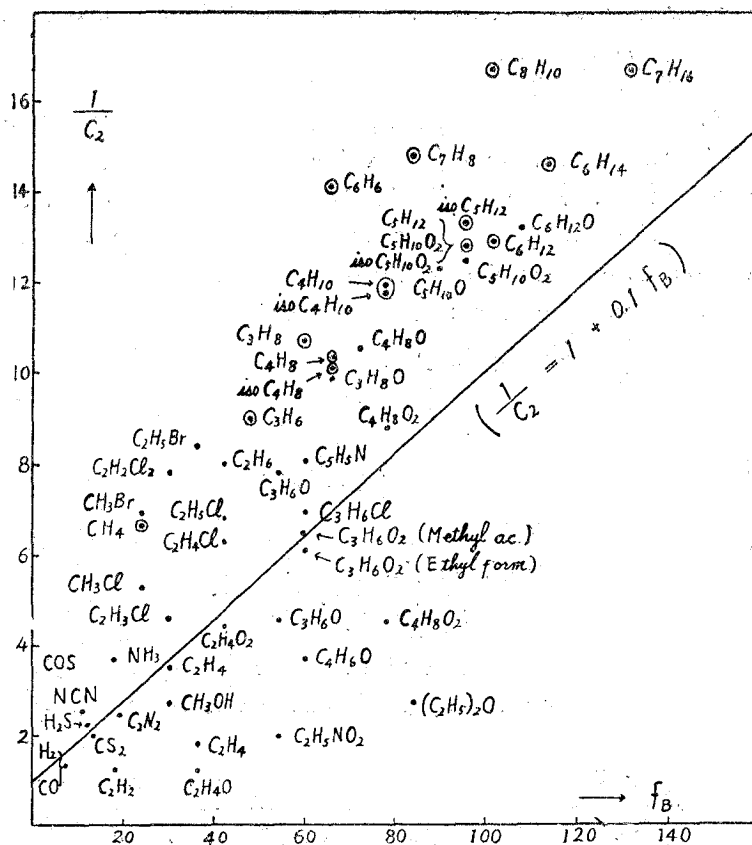


Fig. 1. Correlation between upper limit and degrees of freedom of fuels.

4. The Dielectric Constant of Liquids at Microwave Frequencies. (II)

Measurements of the Dielectric Constant at 3 cm Wavelength

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The method of measurement of the complex dielectric constant ($\epsilon^* = \epsilon' - j\epsilon''$) at 3 cm wavelength with the waveguide apparatus was discussed and some measurements were made on aliphatic alcohols.

The block diagram of the test apparatus is shown in the figure. The details about waveguide components have been already reported (This Bulletin, 28, 55 (1952)).