SURFACE TENSION OF FREONS

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In spite of the growing use of freons in industry, their properties have not been sufficiently investigated. Data on the surface tension of the majority of freons, except for a few of these, are not available.

In this paper the dependence of surface tension of freons F-11, F-12, F-21, F-22, and F-142 on temperature is investigated by the combined method [1] over a wide range of temperatures in an atmosphere of saturated vapors of these.

A diagram of the experimental setup is shown in Fig. 1. Capillaries 1 and 2 are inserted in tubes 4 and 5 of cylinder 3 which is held in sleeve 7 attached to socket 8. The sleeve is connected to a priming and evacuating unit by a set of pipes. The third capillary 6 is intended for recording the beginning and end of a working cycle. The polished plunger 9 is sealed in the lower part of the socket by a teflon gland. The whole is mounted on the heavy bottom plate 10 of thermostate 17 of 15-l capacity. High temperatures are produced by two heaters of 700 and 1300 W, respectively, and low ones by means of an FAK-0.7M refrigerator 18.

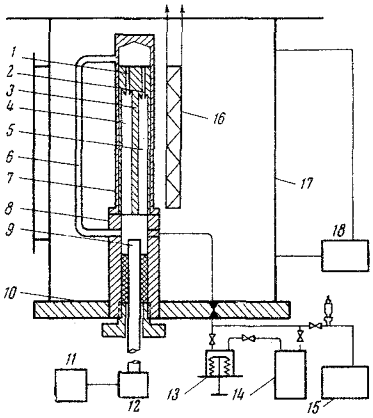

Fig. 1

A TPP 16 platinum thermometer is used for temperature measurement.

Displacement of the liquid level is by means of the polished plunger actuated by the dc electric motor 11 through the reduction box 12. The priming and evacuating unit comprises a tank 14 containing the investigated liquid, a bellows-type priming pump 13, and a VN-2M-G15 vacuum roughing pump.

All components of this apparatus were made from 1Cr18Ni9Ti stainless steel, with the exception of capillary 6 which is of molybdenum glass.

For these experiments capillaries 1 and 2 were of the same diameter but different length (15 and 17 mm). The formula used in the method of calculation, which takes into consideration the different length of capillaries and the corrections for vapor density, is of the form

$$\frac{\sigma}{\rho' - \rho''} = g\Delta V\left[\frac{2\pi}{r^2 + R^2 + r_3^2}\left(\frac{1}{r} - \frac{1}{R}\right)\left(1 - \frac{h'}{h}\right)\right]^{-1} - g\Delta\left[2\left(\frac{1}{r} - \frac{1}{R}\right)\left(1 - \frac{h'}{h}\right)\right]^{-1} = C_1\Delta V - C_2 \quad (1)$$

Here σ is the surface tension of the liquid, $\rho' - \rho''$ is the difference of the liquid and vapor densities, and C_1 and C_2 are constants dependent on the geometrical dimensions of the apparatus.

An analysis of optimum relationships between geometrical dimensions of the apparatus is given in [1]. For these experiments capillaries of the following dimensions were chosen: $r = 0.3$ mm, $R = 2$ mm, and $r_3 = 1.15$ mm.

Prior to the experiment the complete set was carefully washed, dried, and evacuated. Freon was fed from a cylinder to the small supply tank, and from there the required quantity of the liquid was supplied to the working part of the apparatus by means of the priming pump. Further displacement of the liquid level was made by the plunger.

The volume of liquid drawn off between strokes was determined by the number of revolutions n of the motor. A six-prong star wheel which actuates the electromechanical revolution counter is mounted on the motor shaft, and increases the measurement accuracy of n. One revolution of the motor shaft gives six impulses to the counter. The final calculation formula is

$$\frac{\sigma}{\rho' - \rho''} = C_1 n - C_2 \qquad (2)$$

where n is the number of impulses to the counter, and C_1 and C_2 are constants. These constants were determined in preliminary experiments with ethyl and butyl alcohols and, also, with carbon tetrachloride. The results of calibration are shown in Fig. 2. The values of constants were as follows: $C_1 = 0.0618$ and $C_2 = 4.7$. The scatter of points around the calibration line was below 1%.

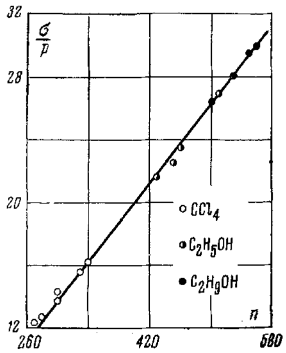

Fig. 2

Measurements were always made under steady temperature conditions. The electromechanical revolution counter was switched on at the instant of the first stroke, and off at the second. The temperature was measured. The cycle time of one measurement was from two to three minutes. The plunger speed was 0.04 cm/sec, which corresponds to 4–5 impulses per second. The error of a single measurement was estimated to be 1.5–2%. The surface tension of freons was calculated by formula (2), and the values of density were taken from [2].

It became clear in the course of experiments that results obtained under conditions of slow temperature reduction were the most steady. This seems to be related to the absence of vapor generation.

The dependence of surface tension of freons F-11, F-12, F-21, F-22, and F-142 on temperature was obtained with the use of reasonably pure substances. A mass spectrometric analysis of the F-11 and F-12 freons had shown the absence of contaminants. Chromatographic and mass spectrometric analysis of the F-21 and F-142 freons had shown a moisture content of not more than 0.19%, and 0.004% of nonvolatile matter in freon 21, while 0.28% of F-12 and 0.06% of other contaminants were found in freon 142. The freon F-22 was of commercial quality.

The results of measurements are presented in Table 1. In Table 2 are given: the range of temperature measurements ΔT, the number n of readings taken for each freon, the rms of scatter of $\delta\%$, and the coefficients in the interpolation formula for the investigated freons,

$$\sigma = a - bt \ [\text{erg/cm}^2] \qquad (3)$$

As previously noted, data on the surface tension of freons are meager, and their reliability is not very high. Laine [3] had obtained two values for F-12: $\sigma = 8.1$ dyne/cm^2 at $t = 30°$ C and $\sigma = 11.7$ dyne/cm^2 at $t = 0°$ C, which coincide with the obtained results. Steinle [4] had measured the surface tension of F-12 and F-22 by the method of capillary rise, and his data coincide with the data obtained by us within the error (8%) admitted in his paper. No data

Table 1 [erg/cm^2]

F-11		F-12		F-21		F-22		F-142	
t° C	σ	t° C	σ	t° C	σ	t° C	σ	t° C	σ
97.8	8.2	61.8	3.8	85.0	9.6	49.9	3.6	68.0	6.4
92.8	9.2	58.6	4.4	81.0	10.5	48.6	4.7	61.0	7.2
84.1	10.4	51.6	4.8	70.0	11.7	36.8	5.6	57.2	7.6
80.8	10.9	45.9	6.0	68.0	11.6	32.3	6.6	53.0	7.9
76.0	11.4	40.5	6.8	59.0	12.3	31.2	5.8	48.6	8.6
70.2	12.1	39.0	6.8	50.6	13.7	26.4	6.4	41.1	8.9
62.4	12.9	34.7	7.5	42.0	14.4	20.5	7.6	37.3	9.9
54.5	14.0	32.3	7.3	40.0	14.7	20.0	8.7	32.2	10.6
48.8	14.7	29.2	8.2	38.7	15.8	19.1	7.5	31.0	10.7
40.8	15.3	25.9	8.5	33.7	16.2	17.8	8.8	30.6	10.4
32.5	16.4	22.2	8.5	31.0	16.8	12.9	8.9	25.5	10.7
29.9	16.6	22.0	9.0	22.5	18.3	6.4	10.5	25.9	11.4
24.6	17.3	21.0	9.0	20.0	18.3	1.5	11.2	23.4	11.1
24.5	17.5	18.1	9.3	18.5	18.7	—1.7	11.2	21.5	11.3
22.5	18.6	17.5	9.5	17.0	19.7	—4.6	11.7	14.5	12.9
18.0	17.8	13.5	9.9	16.0	19.3	—11.1	12.8	10.2	12.5
18.1	18.3	12.8	9.6	14.1	19.9	—16.4	15.1	4.0	13.5
7.4	20.1	10.9	10.3	6.2	20.4	—24.7	15.6	0.9	14.4
0.3	20.8	5.0	10.8	—8.2	22.5	—28.4	17.0	—5.0	15.0
—9.4	22.4	—2.0	11.6	—11.3	22.5	—32.9	17.6	—11.7	16.0
—15.5	23.3	—4.6	12.4	—24.8	25.0	—37.7	19.2	—16.5	16.5
—17.0	23.9	—12.5	13.8	—29.2	25.6	—40.9	18.7	—22.9	18.0
—26.9	24.0	—25.0	14.9					—28.6	18.6
—35.0	25.9	—35.6	16.3					—36.1	19.4
—39.0	25.2	—46.4	18.0					—40.7	20.4
—34.0	25.4								

Table 2

	ΔT, °C	n	δ%	a	b
($CFCl_3$) F-11	—40—96	26	1.9	20.9	0.128
(CF_2Cl_2) F-12	—46—62	25	2.0	11.7	0.129
($CHFCl_2$) F-21	—30—85	23	2.2	21.4	0.141
(CHF_2Cl) F-22	—41—50	23	5.4	11.6	0.170
($C_2H_3F_2Cl$) F-142	—41—68	25	2.3	14.6	0.128

are available on the surface tension of freons F-11, F-21, and F-142.

Use of the parachor method for calculating the surface tension of freons was suggested by Plank [5]. However, there is no experimental confirmation of that method. The surface tension of the investigated freons was calculated by using the atom parachors given in [5], and the results agreed to within 5% with our experimentally obtained data. Hence such calculations may be recommended for engineering purposes.

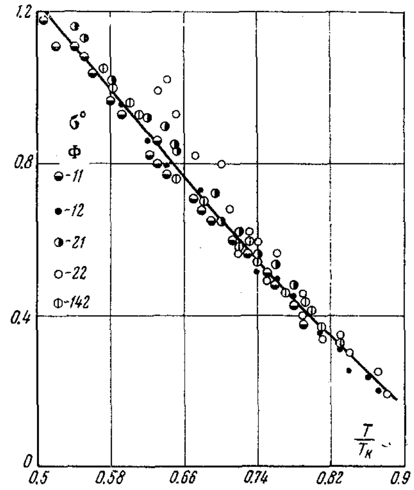

Fig. 3

Since freons belong to a group of thermodynamically similar substances, it is interesting to compare the obtained results in dimensionless coordinates. The form of the latter was taken from [6], and the results are shown in Fig. 3. The obtained readings can be approximated by function

$$\sigma^\circ = \left(1 - \frac{T}{T_k}\right)^{1.27}, \quad \sigma^\circ = \frac{10^6 \sigma}{3\,(\mu R T_k p_k^2)^{1/3}} \tag{4}$$

The scatter rms was 4%. Data on F-22 were not included, since at temperatures below zero these deviate considerably from the general pattern, which could have been due to the use of F-22 of commercial grade, i.e. containing contaminants, while the remaining freons can be considered as pure. It should be noted that published data on CCl_4 are also well defined by Eq. (4). All this makes it possible to recommend the derived formula for calculating the surface tension of other freons.

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