INVESTIGATION OF THE THERMAL CONDUCTIVITY OF FREONS OF THE ETHANE SERIES

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The thermal conductivities of Freons 113, 114, 115, and 152A are investigated experimentally. Based on the assumed relations, the coefficients of thermal conductivity are calculated for Freons 122 and 132, which were not studied.

One of the most important characteristics of refrigeration agents is the coefficient of thermal conductivity. In recent years there has been a sharp increase of interest in the Freons — substances which possess a whole series of properties suitable for refrigeration technology. In this paper we raise the problem of obtaining the magnitudes of the coefficients of thermal conductivity λ of the fluorethane group, namely, Freons 122, 132, and 152A, for which there are no data or there are limited data about the melting point, boiling point, and density [3].

The thermal conductivity of liquid Freon 152A has been studied experimentally on a facility using the stationary hot-wire method, where a platinum capillary with an internal diameter of 1.1 mm served as the external resistance thermometer of the measurement cell and a platinum wire with a diameter of 0.1 mm served simultaneously as the heater and as the internal resistance thermometer. The procedure for carrying out the experiments and the calculation of λ take into consideration phenomena which might distort the measurement results. Control experiments on reference liquids (toluene, CCl_4) confirm the reliability of operation of the equipment and the reality of the error estimates of the experimental data with a magnitude of ±1.5%. In addition, the thermal conductivities of Freons 114 and 115 were investigated. Comparison of the results obtained with the most accurate experimental data on the line of saturation [7] showed that the discrepancies do not exceed 2%, i.e., they fall within the limits of the total error of the quantities compared. The values of λ for Freon 152A were measured on the apparatus described over the temperature range −60 to +60°C. The results obtained for Freons 152A, 115, and 114 are described by the equation

$$\lambda = A - Bt, \tag{1}$$

the coefficients of which are given in Table 1.

In order to determine λ for the little-studied Freons 122 and 132, we carried out a special investigation. It is well known that in order to predict the thermal properties of

TABLE 1. Coefficients of Eq. (1)

Freon	A, W/(m·deg)	B·10⁴, W/(m·deg²)	Temperature range, °C
113	0,083	2,0	−20÷+120
114	0,070	2,6	−60÷+60
115	0,061	3,1	−60÷+60
122	0,092	2,0	0÷+120
132	0,097	2,5	−60÷+120
152A	0,114	5,1	−60÷+60

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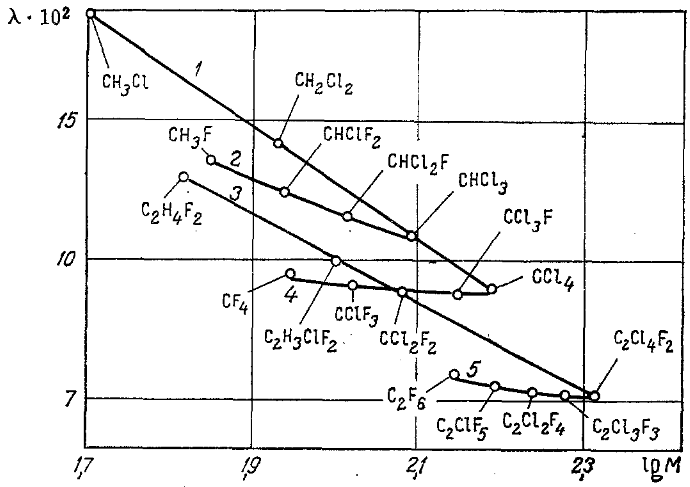

Fig. 1. Dependence of coefficient of thermal conductivity [W/(m•deg)] at the normal boiling point on the molecular weight of the Freons: 1) Freons 40, 30, 20, 10; 2) 23, 22, 21, 20; 3) 152, 142, 112; 4) 14, 13, 12, 11, 10; 5) 116, 115, 114, 113, 112.

liquids on the line of saturation, empirical and semiempirical methods exist. However, such efficient methods for the thermal conductivity are lacking. For example, the method of Sheffy and Johnson [2], which uses only data on the melting point and the molecular weight, gives errors of up to 50-100% and more for Freons (F-12, F-112). Another method requires the availability of a considerable amount of a different kind of data. The prospects of methods based on the correlation of λ with other properties of the substance, using a limited number of starting data, should be mentioned. In particular, it will be of interest to establish the relation between the thermal conductivities of the Freons and their molecular weights. Analysis of the extensive data on the coefficients of thermal conductivity of the most different classes of organic liquids given in [4] has allowed the author to formulate a number of quite clear trends. The most interesting among them is that which mentions that an increase in the molecular weight of the Freons leads to a decrease in thermal conductivity, and the effect appears more strongly, the larger the atoms substituted.

In this paper we consider the Freon groups of the methane and ethane series, which are characterized by the following structural—chemical principle of molecule construction. In consequence of the successive substitution of atoms of hydrogen or halogen by atoms of another halogen, a regular change of molecular weight of the Freons is observed in these groups. For example, the difluorethane group (Freons 152A, 142, 132, 122, and 112) is characterized by the successive replacement of hydrogen atoms in the molecules by atoms of chlorine, with an unchanged number of fluorine atoms ($C_2H_4F_2$, $C_2H_3ClF_2$, $C_2H_2Cl_2F_2$, $C_2HCl_3F_2$, and $C_2Cl_4F_2$).

As a result of processing of the existing experimental data on the thermal conductivities for the various groups of Freons, a clear dependence is found of the coefficient of thermal conductivity at the normal boiling point of the liquid $\lambda_{n.bp}$ on the molecular weight.

The function $\lambda_{n.bp} = f(M)$, constructed on the experimental data of [3, 6, 7] and also by the results of measurements of the thermal conductivity of Freons 10 and 113 on the apparatus described in [1], is shown in Fig. 1 in logarithmic coordinates for groups of Freons. Analysis showed that these dependences are linear, and, as a result, a decrease of λ with increase of M is observed. These relations can be explained qualitatively starting from elementary models for representing the transfer of heat in the liquids by means of molecular collisions. It can be supposed that the thermal conductivity is determined mainly by the velocity of this process, which, conditions being equal, takes place intensively in liquids containing lighter molecules. From the physical point of view, this fact is conditioned by the regular reduction of the molecular weight in the groups of Freons considered, caused by the successive replacement of atoms of chlorine by fluorine or by hydrogen atoms in the molecules. The values of $\lambda_{n.bp}$ of these Freons were found by interpolation of the curve 3 (Fig. 1) for Freons 112 and 132.

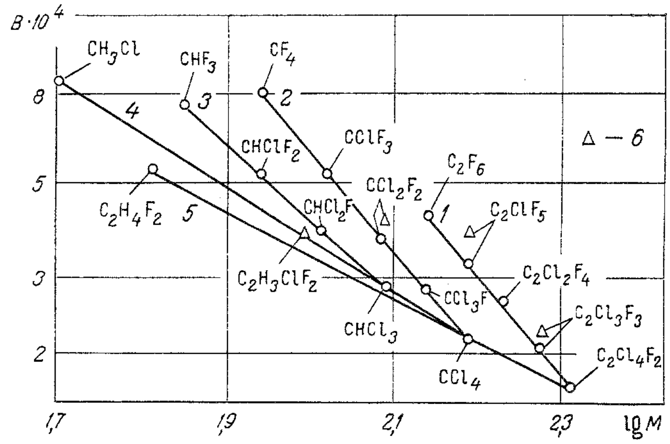

Fig. 2. Dependence of temperature coefficients of thermal conductivity [W/(m•deg²)] on the molecular weight of the Freons: 1) Freons 116, 115, 114, 113, 112; 2) 14, 13, 12, 11, 10; 3) 23, 22, 21, 20; 4) 40, 20, 10; 5) 152, 142, 112; 6) data from [5].

In order to determine the temperature coefficient of thermal conductivity $B = d\lambda/dt$ of Freons 122 and 132, we used a similar correlation of the stated quantity on the molecular weight of the Freons. In the logarithmic system of coordinates, the groups considered above display a linear dependence — $B = f(M)$ (Fig. 2). These graphs are plotted from experimental data and, consequently, express the specific relationships which are characteristic for each of the groups of Freons listed. Data from [5] for values of B of Freons 12, 113, 115, and 142 deviate systematically from the linear dependence mentioned and we have not taken them into consideration. Despite the limited number of points for group 5 (Fig. 2), it should be assumed that by analogy with the other groups of Freons (Figs. 1 and 2) a linear correlation also is valid for them, the use of which allowed values of B to be determined for Freons 122 and 132.

Based on the results obtained on $\lambda_{n.bp}$ and $d\lambda/dt$, the coefficients of the equation of the form of (1) were found for Freons 122 and 132 (see Table 1). An analysis of the extensive quantity of experimental data shows that the stated linear dependence $\lambda = \lambda(t)$ is valid for the given temperature range $T/T_{cr} \approx 0.5$ to 0.85. The data obtained for the first time on the thermal conductivities of Freons 122, 132, and 152A, together with an estimate of the other thermophysical quantities, will enable the possible ranges of application of these substances to be judged.

NOTATION

λ, coefficient of thermal conductivity; t, temperature; A, B, coefficients of the equation; $\lambda_{n.bp}$, coefficient of thermal conductivity at the normal boiling point; M, molecular weight.

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