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INVESTIGATION OF THE CHARACTER OF SOME OF THE JUMPS IN ACTIVATION ENERGY OF VISCOUS FLOW IN PURE LIQUIDS AND SOLUTIONS

Part I.—Some Measurements at Small Thermal Intervals on (a) Dilute Aqueous Alcohol (11%) and (b) Pure Water

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The occurrence of sharp jumps (of magnitude of the order of 5%) in the activation energy of viscous flow E_η, for several pure liquids and solutions is now well-established. A preliminary attempt has also been made to apply order⇌disorder phenomena to estimate specific heat anomalies expected to be associated with any second-order transitions at these jumps. Examination of temperature variations of (1) coefficient of dilatation and (2) index of refraction have supported the existence of some type of changes occurring at the temperatures of these jumps, and the present communication gives a further study of the nature of these jumps by remeasuring typical steps in 11 % dilute aqueous ethyl alcohol and in water at the much closer intervals of 0.5 C. and 0.2°C., with improved experimental technique.

For 11 % aqueous alcohol, the measurements give temperature ranges of 0.19°±0.03°C. for the jumps, which is almost equal to the smallest temperature interval (0.2°C.) used. Similar measurements for water give an average of 0.16°C. for the widths of the jumps. The conclusion is drawn that these widths are entirely due to the experimental interval and because $\delta T/T_c$ is less than 1/1000 in this case, therefore, for practical purposes, these jumps may be considered as *discontinuous* changes in activation energy E_η.

Introduction

A series of accurate experiments carried out over a period of five years by Qurashi and various co-workers [1-4] (Rauf and Qurashi, 1959; Qurashi and Ahsanullah, 1961; Ahsanullah and Qurashi, 1962: Ahsanullah, Ali and Qurashi, 1962) have established the occurrence of a series of sharp jumps in the activation energy of viscous flow of several pure liquids as well as simple solutions. The magnitude of these jumps is of the order of 0.1 unit of $(E_\eta/R)/1000$, i.e. about 200 cal./mole in E_η, while the standard deviations of the experimentally measured values are approximately one-twentieth to one-tenth of these. In an effort to develop the theoretical implications of these experiments, a preliminary attempt was also made to apply the theories of order⇌disorder phenomena [5] to these jumps, and thereby to estimate the magnitude of specific-heat anomalies to be expected on the basis of a "second-order transition" at each jump.

Lately, it has been possible in this laboratory to examine accurately the temperature variation of (1) coefficient of dilatation and (2) refractive index, for water, ethylene glycol and aqueous alcohol. These preliminary investigations have supported the existence of changes of some sort at the temperatures of the jumps in E_η, and have indicated that the transitions might well be of the "third order", i.e. correspond to discontinuities in the *third derivatives* of the Gibbs Function.

Analysis of Previous Data

Inorder to throw further light on this, it was considered worthwhile to examine more closely the character of the jumps in activation energy itself. Thus, for example, Fig. 1(a) reproduced from an earlier paper,[6] dealing with aqueous alcohol solutions containing 2.5% to 30% alcohol, shows a plot of careful overlapping measurements with $\Delta T = 1°C.$ on 20.2% alcohol solution in the range of 32°C. to 41°C. Four resettings, differing by 1.3°C. each, of the Beckmann thermometer were made, and the different symbols indicate

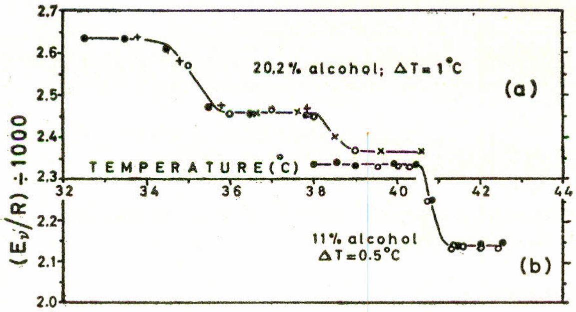

Fig. 1 (a).—Reproduction of graph of an earlier experiment for 20.2% alcohal performed with overlaping measurements, using $\Delta T = 1°C$. Four resettings of Backmann thermometer differing by 1.3°C. in the range of 32 to 41°C. were made, and the different symbols indicate different settings.

(b).—The plot of 11% alcohal (solid and hollow circles) shows two different experiments now performed with the interval of 0.5°C.; the jump occurs at 40.9±0.3°C. in a range of 0.6°C.

values of (E/R)/1000 obtained with different settings. The two steps at 35° and 38°C. are both seen to occur over an interval of 1.1°C. A statistical analysis of the data on some 60 steps, observed from about 300 experimental points at $\Delta T = 1°C$. with various dilute alcohol solutions, shows that only 15 experimental points lie on the sloping part of a jump, thus confirming that the apparent spread of the sloping part is less than 15/60 × mean interval between jumps, i.e. 15/60 × 5°C. = 1.2°C. The present communication gives an account of a remeasurement of this activation energy at intervals of 0.5°C. and 0.2°C. in regions of 3°–8°C. including upto three separate jumps for (a) some dilute aqueous alcohol solutions and (b) pure re-distilled water.

Experimental Technique

$E\eta/R$ is obtained from the differential method developed in this laboratory, [1,2] and based on differentiation of Andrade Equation, viz.

$$E\eta/R = \Delta \ln \eta / \Delta (1/T)$$
$$= -T^2 \Delta \ln \eta / \Delta T \quad \ldots\ldots (1)$$

where T is absolute temperature. Equation (1) gives the mean slope of $\ln\eta$ versus $1/T$ curve in a small temperature interval T and $T+\Delta T$. The previously reported work on pure liquids and solutions, such as water, ethylene glycol and aqueous ethyl alcohol, etc., has clearly justified the superiority of our technique. The experimental procedure in the present series is to find with a high degree of precision the Kinematic viscosity at more close intervals, ΔT, namely 0.5°C. and 0.2°C. with a carefully calibrated differential Beckmann Thermometer, and thence to evaluate E/R by equation (1). It is to be noted that

$$E\eta/R = -T^2 \Delta \ln (\nu \times \rho)/\Delta T$$
$$= -T^2 \Delta \ln \nu/\Delta T - T^2 (\Delta\rho/\Delta T)/\rho$$
$$= E_\upsilon/R + T^2\beta$$

where $T^2\beta$ is a small varying correction term. We have generally given only E_υ/R directly, and some values of the term $T^2\beta$ are given in the bottom of some Tables.

The measurements were carried out with U-tube viscometer of British Standard specification pattern, rigidly supported by clamp and holder especially designed for it, so as to minimize vibrations, disturbances and tilt from vertical. The temperature of the thermostatic bath was read by ordinary mercury thermometer graduated to 0.1°C., while the values of ΔT were determined with a calibrated differential Beckmann thermometer.

The correction for the kinetic energy loss, and the change in the position of equilibrium level of the liquid has been previously discussed by Qurashi.[7] The equilibrium levels of liquid were measured with a cathetometer giving an estimate to the third place of mm. With certain precautions, the thermostatic bath recently designed by Townson and Mercer with thermistor bridge control gives a temperature control to ±0.002°C. or better. Five to eight readings of flow time were taken at each temperature, and were measured to ±0.004 second or better by using a calibrated stop-watch, started and stopped by electrical impulses, thus giving an estimate to the 3rd place of decimal in seconds. All these factors together ensure a reproducibility of one part in 50,000 or more in flow time, which varied from 200 seconds to 1800 seconds depending upon the liquid and viscometer used.

The aqueous ethyl alcohol solutions were prepared by adding calculated quantity of absolute alcohol (special for spectroscopy, BDH) to thrice-distilled water in a stoppered flask and shaking thoroughly. The percentage of alcohol was re-determined at the begining and at the end of experiment by (1) viscosity determination at two suitable temperatures viz. 25°C. and 30°C., and (2) density measurements.

Measurements with 11% Aqueous Ethyl Alcohol

The first set of measurements was carried out to reinvestigate the large jumps noted at 41°C. for 11% aqueous ethyl alcohol by Ahsanullah, Ali and Qurashi.[4] Readings were taken in the range of 38° to 43°C., at the interval of 0.4° to 0.5°C. with viscometer No. 'O' (constant 0.000,736), giving flow times of 800 seconds, so that an ordinary stop-watch could be used. Fig. 1(b) is the plot of values of (E/R)/1000 versus temperature, where the hollow circles are the means for rising and falling sequences of experiment No. 1, and solid circles are the same for experiment No.2. The jump in E/R is seen to extend from 40.6° to 41.2°C. i.e. over 0.6°C. (The (E/R)÷1000 values are higher by 0.05 units than the previously reported ones). Comparison with the reproduction of the graph for 20.2% alcohol in water (Fig. 1(a)) carried out in the range of 32°C. to 41°C. shows that in each case, the apparent extent of the jump is only just a little greater than the measuring interval, thus suggesting that the apparent width is entirely due to the thermal interval used.

To examine this further, the two sharp steps previously observed in 11% alcohol solution at 14°C. and 41°C. were re-measured with a thermal interval of (i) 0.5°C. to 1.0°C. and (ii) 0.2°C. A fresh solution of 10.8% aqueous ethyl alcohl was prepared, and since viscometer No. 'O' was replaced by No. 1, the stop-watch, started and stopped by electrical impulses, was used, giving an estimate to the third place of the decimal in seconds. Tables 1(a) and 1(b) give the temperatures, Beckmann readings, and times of flow, together with values of (E/R)/1000; the standard deviation as estimated for each group of measurements is of the order of ±0.004. The top of Fig. 2 is a plot of (E/R)/1000 values in the range of 12° to 16°C. using the same vertical scale for E/R as before, but a temperature scale ten times of that in the previously reported work. The solid circles indicate the mean of heating and cooling sequences of the 1st set of experiments with $\Delta T=0.5$°C. to 1.0°C., the inclined crosses are the points for the heating sequence of the second set (Table 1(b)) using the thermal interval of 0.2°C. to 0.3°C., the vertical crosses being for the cooling sequence readings for the same interval, staggered in such a manner as to fall in between the previous points. The jump is seen to occur at 14.04°C.±0.08°C. i.e. it falls within 0.16°C., an interval which is *a little smaller* than the actual thermal interval used in the experiment.

With the same solution, the measurements were extended to the region of 39°C. to 42.5°C., to re-examine the second jump at 41°C. The bottom of Fig. 2 is a plot of these E/R values versus temperature, the solid circles being for the measurements taken at 0.5°C., and the crosses for the points taken at the interval of 0.2 to 0.3°C. Table 1(c) gives the values of (E/R)/1000 together with mean temperature, Beckmann reading and time of flow for various temperatures in this range. The jump occurs at 41.3°C.±0.11°C. Here the maximum spread in temperature is 0.22°C., which compares with 0.16°C. found for the jump at 14°C., giving a mean figure of 0.19°±0.03°C. for the width of these jumps. This is almost exactly equal to the smallest measuring interval of 0.2°C. used.

It may be concluded that by reducing the thermal interval, the observed jumps become more and more sharp, and their widths remain within the limits of the measuring interval used.

Experiments with Water

At this stage, it was considered worthwhile to re-examine some of the typical steps observed in water by Qurashi and Ahsanullah,[2] for example the prominent jump occurring at 21.5°C. which is also traceable in the standard data of ICT. Thrice-distilled water was used, and its purity was confirmed by its conductivity and pH values at the begining and at the end of the experiment. Table 2(a) gives the data, and Fig. 3 (top) is a plot of (E/R)/1000 versus temperature (using the enlarged scale) for the experiment performed in the range of 19°C. to 23°C., where a large jump is known to occur. As in the case of 11% aqueous alcohol, the solid circles indicate the measurements taken at the interval of 0.5°C., and the crosses are for the interval of 0.2°C. to

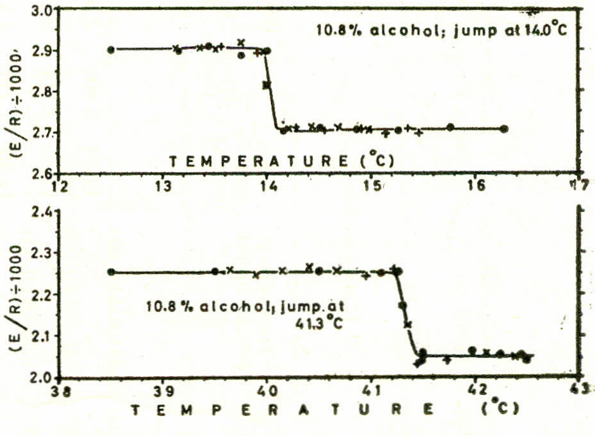

Fig. 2.—(Top) Plot of (E/R)/1000 versus temperature for for 10.8 % aqueous alcohol in the range of 12° to 16°C.; solid circles show new measurements taken at 0.5° to 1.0°C. The vertical crosses are the data obtained with $\Delta T=0.2$°C. in falling temperature and inclined cross the same in rising temperature sequence. The jump occurs at 14.04±0.08°C. (Bottom) Similar plot in the range of 39° to 42.5°C., with the same measuring intervals; the jump occurs at 41.30±0.11°

Table 1 (a).—Beckmann Readings, Flow Times and Calculated Values of $(E/R)/1000 = -T^2(\Delta \ln \nu/\Delta T)/1000$ for Dilute 10.8% Aqueous Ethyl Alcohol, in the Range of 12° to 16°C. with $\Delta T = 0.5$°C. to 1.0°C.

Heating sequence						Cooling sequence						
				(E/R)/1000						(E/R)/1000		
Temperature °C.	Beckmann readings	Time of flow (secs.) corrected for level	Mean temperature °C.	Uncorrected	Corrected for Beckmann	Temperature °C.	Backmann readings	Time of flow (secs.) corrected for level	Mean temperature °C.	Uncorrected	Corrected for Beckmann	Mean (E/R)1/000
12.00	1.651±0.0000	541.033±0.003				12.00	2.671±0.0010	540.636±0.004				
			12.50	2.900	2.900±0.004				12.50	2.901	2.901±0.004	2.901±0.001
13.00	2.666±0.0002	521.864±0.006				13.00	2.682±0.0010	521.569±0.005				
			13.50	2.913	2.898±0.004				13.50	2.912	2.898±0.004	2.898±0.000
14.00	3.670±0.0018	503.586±0.005				14.00	3.687±0.0000	503.319±0.003				
			14.50	2.710	2.713±0.004				14.50	2.710	2.714±0.004	2.714±0.001
15.00	4.669±0.0010	487.386±0.005				15.00	4.668±0.0000	487.399±0.006				
			15.35	2.691	2.707±0.004				15.35	2.700	2.715±0.004	2.711±0.004
15.70	5.377±0.0000	476.357±0.004				15.70	5.388±0.0000	476.149±0.003				
13.00	2.645±0.0015 —	522.320±0.007				13.00	2.644±0.000	522.460±0.007				
			14.00	2.822	2.815±0.002				14.15	2.701	2.699±0.002	
15.00	2.645±0.0015 —	487.681±0.006				15.30	4.976±0.0010	484.060±0.005				
14.10	3.771±0.0000	501.603±0.005										
			14.90	2.707	2.711±0.002							
15.70	5.365±0.0010	476.204±0.006										
											2.708±0.002	2.709±0.002
15.00	3.542±0.0015	486.734±0.005				15.00	3.543±0.0005	486.695±0.005				
			15.25	2.738	2.711±6.002				15.25	2.735	2.712±0.002	2.714±0.001
15.50	4.052±0.0010	478.645±0.004				15.50	4.053±0.001	478.615±0.006				
			15.75	2.732	2.716±0.002				15.75	2.736	2.706±0.002	2.712±0.006
16.00	4.510±0.0005	471.513±0.005				16.00	4.510±0.000	471.489±0.004				
			16.25	2.736	2.714±0.002				16.25	2.727		
16.50	5.009±0.0010	463.896±0.005				16.50	5.009±0.001	463.897±0.005				

TABLE 1(b).—BECKMANN READINGS, FLOW TIMES AND CALCULATED VALUES OF $(E/R)/1000 = -T^2(\Delta \ln \nu/\Delta T)/1000$ IN THE RANGE OF 13° TO 16°C. WITH $\Delta T = 0.2°$ TO 0.3°C.

Heating sequence						Cooling sequence					
Tem-perature °C.	Beackmann readings	Time of flow (secs.) corrected for level	Mean tempera-ture°C.	(E/R)/1000		Tem-perature °C.	Beckmann readings	Time of flow (secs.) corrected for level	Mean temperature °C.	(E/R)/1000	
				Uncorrected	Corrected					Uncorrected	Corrected
13.00	2.673±0.000 0	521.342±0.004				13.00	2.693±0.001 0	520.969±0.005			
			13.15	2.918	2.903±0.004				13.14	2.935	2.910±0.004
13.30	2.962±0.000 5	515.996±0.005				13.25	2.927±0.001 5	516.613±0.003			
			13.45	2.955	2.907±0.004				13.35	2.970	2.905±0.004
13.60	3.266±0.001 0	510.375±0.003				13.45	3.129±0.000 5	512.851±0.004			
			13.75	2.954	2.890±0.004				13.55	2.964	2.905±0.004
13.90	3.537±0.000 8	505.421±0.004				13.65	3.527±0.000 5	509.209±0.004			
			14.00	2.967	2.899±0.004				13.75	2.981	2.923±0.004
14.10	3.748±0.001 5	501.603±0.005				13.85	3.516±0.001 5	505.728±0.004			
									13.97	2.895	2.895±0.004
14.10	3.779±0.000 0	501.401±0.006				14.10	3.783±0.001 5	501.008±0.003			
			14.25	2.700	2.711±0.004						
14.40	4.069±0.001 5	496.643±0.005				14.10	3.774±0.000 0	501.344±0.005			
			14.55	2.670	2.707±0.004				14.20	2.718	2.709±0.005
14.70	4.364±0.001 0	491.947±0.004				14.30	3.994±0.001 0	499.714±0.004			
			14.85	2.672	2.712±0.004				14.42	2.709	2.718±0.005
15.00	4.634±0.000 0	487.687±0.003				14.55	4.251±0.000 0	493.545±0.003			
			15.14	2.668	2.702±0.004				14.67	2.664	2.714±0.005
15.29	4.954±0.000 0	482.703±0.003				14.80	4.475±0.000 0	490.002±0.003			
			15.45	2.669	2.702±0.004				14.97	2.672	2.708±0.005
15.62	4.277±0.001 0	477.733±0.004				15.10	4.800±0.001 0	484.902±0.004			

Temperature°C.	12.5	17.5	22.5	27.5	32.5	37.5
$T^2\beta \div 1000$	0.016	0.022	0.027	0.032	0.037	0.039

TABLE I (c).—BECKMANN READINGS, FLOW TIMES (SECS.) AND CALCULATED VALUES OF $(E/R)/1000 = -T^2(\Delta \ln \nu/\Delta T)/1000$ FOR DILUTE 10.8% AQUEOUS ETHYL ALCOHOL, IN THE RANGE OF 39°C. TO 42°C. WITH $\Delta T = 0.2$°C. TO 0.3°C.

Heating sequence						Cooling sequence					
				E/R ÷ 1000						E/R ÷ 1000	
Temperature °C.	Beackmann readings	Time of flow corrected for level	Mean temperature °C.	Uncorrected	Corrected	Temperature	Beckmann readings	Time of flow corrected for level	Mean temperature	Uncorrected	Corrected
39.50	0.740±0.001	240.341±0.004				40.80	2.039±0.000	233.127±0.004			
	o		39.65	2.255	2.261±0.004		o		40.95	2.256	2.256±0.004
39.80	1.013±0.000	238.833±0.004				41.10	2.332±0.001	231.627±0.005			
	o		39.90	2.245	2.245±0.004		o		41.22	2.304	2.266±0.004
40.00	1.213±0.000	237.741±0.004				41.35	2.585±0.000	230.266±0.003			
	o		40.15	2.246	2.260±0.004		o		41.48	2.066	2.030±0.004
40.30	1.518±0.001	236.088±0.005				41.60	2.823±0.001	229.173±0.004			
	o		40.40	2.230	2.261±0.004		o		41.72	2.083	2.044±0.004
40.50	1.737±0.000	234.918±0.004				41.85	3.090±0.000	227.891±0.003			
	o		40.65	2.232	2.256±0.004		o				
40.80	2.029±0.001	233.368±0.003				42.35	3.597±0.000	225.338±0.004			
	o						o		42.45	2.099	2.063±0.005
41.85	3.099±0.000	227.722±0.004				42.55	3.825±0.000	224.258±0.005			
	o		41.98	2.110	2.063±0.005		o				
42.10	3.346±0.000	226.529±0.004									
	o		42.22	2.080	2.052±0.005						
42.35	3.598±0.001	225.336±0.004									
	o										

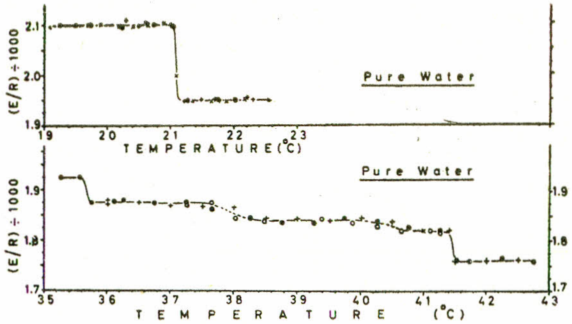

Fig. 3.—Some new measurements of E/R for water using the measuring intervals 0.2°C. to 0.3°C. and 0.5°C. At the top is the portion in the range of 19° to 23°C., in which the jump is found to occur at 21.09+0.06°C.

At the bottom is a similar plot for range of 35° to 43°C., the jumps occurring at 35.7°±0.06, 38.0±0.15°C. and 41.45±0.04°C.

Table 2 (a).—Beckmann Readings, Times of Flow, Mean Temperature °C. and Calculated Values of (E/R)/1000 for Redistilled Water in the Range of 19° to 23° C., with $\Delta T = 0.2°$ to 0.3°C.

Heating sequence						Cooling sequence					
Tempera-ture °C.	Beckmann readings	Time of flow (secs.) corrected for level	Mean temp-erature °C	E/R ÷ 100 Uncor-rected	E/R ÷ 100 Corrected	Tempera-ture °C.	Beckmann readings	Time of flow (secs.) corrected for level	Mean tempe-rature °C.	E/R÷1000 Uncor-rected	E/R÷1000 Corrected
19.00	0.702±0.0000	1399.96±0.01				20.20	1.926±0.0000	1360.01±0.02			
			19.10	2.101	2.088±0.004				20.30	2.127	2.112±0.004
19.20	0.900±0.0000	1393.16±0.00				20.40	2.131±0.0002	1353.15±0.01			
			19.30	2.100	2.100±0.004				20.52	2.090	2.097±0.003
19.40	1.104±0.0010	1386.20±0.01				20.65	2.376±0.0007	1345.18±0.00			
			19.50	2.096	2.097±0.004				20.77	2.124	2.099±0.003
19.60	1.313±0.0000	1379.16±0.00				20.90	2.631±0.0015	1334.79±0.01			
			19.70	2.089	2.105±0.004						
19.80	1.519±0.0018	1372.48±0.01				20.94	2.641±0.0005	1335.50±0.02			
			19.95	2.072	2.105±0.004				21.04	2.126	2.098±0.005
20.10	1.815±0.0005	1362.73±0.00				21.13	2.874±0.0016	1327.88±0.01			
									21.26	1.998	1.949±0.005
20.10	1.823±0.0000	1362.38±0.00				21.40	3.128±0.0015	1320.19±0.01			
			20.20	2.096	2.096±0.004				21.50	2.021	1.957±0.005
20.30	2.021±0.0010	1355.86±0.01				21.60	3.339±0.0000	1313.75±0.00			
			20.42	2.102	2.100±0.004				21.70	2.028	1.953±0.005
20.55	2.285±0.0000	1347.16±0.00				21.80	4.526±0.0005	1308.02±0.01			
			20.63	2.132	2.106±0.004						
						21.65	3.385±0.0015	1307.29±0.01			
20.80	2.531±0.0000	1339.00±0.01							21.77	2.004	1.954±0.003
						21.90	3.658±0.0000	1299.11±0.01			
20.80	2.525±0.0005	1337.87±0.00							22.01	1.996	1.957±0.003
			20.90	2.085	2.107±0.004	22.12	3.867±0.0003	1292.89±0.01			
21.00	2.731±0.0018	1331.23±0.01							22.22	1.970	1.960±0.003
			21.14	2.032	2.005±0.004	22.35	4.063±0.0000	1287.19±0.00			
21.25	2.981±0.0008	1323.45±0.01							22.52	1.928	1.950±0.003
			21.37	1.998	1.958±0.004	22.70	4.436±0.0015	1276.63±0.00			
									22.85	1.925	1.958±0.003
21.50	3.228±0.0005	1316.11±0.00				23.00	4.730±0.0005	1268.41±0.00			
21.55	3.286±0.0000	1311.18±0.00									
			21.67	2.048	1.957±0.005						
21.80	3.533±0.0010	1303.57±0.02									
			21.90	2.041	1.954±0.005						
22.00	3.740±0.0000	1297.26±0.01									

TABLE 2 (b).—BECKMANN READINGS, TIMES OF FLOW, TEMPERATURE °C. AND CALCULATED VALUES OF $(E/R)/1000 = -T^2(\Delta \ln \nu \Delta T)/1000$ FOR PURE REDISTILLED WATER FROM 35° TO 43° C., USING $\Delta T = 0.5°$ TO 0.3°C., USING VISCOMETER NO. "Θ".

Heating sequence						Cooling sequence					
Tempera-ture °C.	Beckmann readings	Time of flow (secs.) corrected for level	Mean temp-erature °C.	E/R ÷ 1000 (Uncor-rected	E/R ÷ 1000 Corrected	Temp-erature °C.	Beckmann readings	Time of flow (secs.) corrected for level	Mean temp-erature °C	E/R ÷ 1000 Uncor-rected	E/R ÷ 1000 Corrected
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
35.00	2.484±0.0010	984.46±0.02									
			35.25	1.937	1.921±0.004						
35.50	2.985±0.0000	974.46±0.01									
			35.75	1.910	1.878±0.004						
36.00	3.890±0.0000	964.91±0.01									
			56.10	1.931	1.880±0.004						
36.20	4.087±0.0000	961.10±0.00									
36.00	−0.051±0.0000	961.85±0.01									
			36.25	1.892	1.880±0.004	35.20	2.694±0.0000	980.26±0.00			
36.50	0.449±0.0015	952.56±0.02									
			36.75	1.886	1.873±0.004						
37.00	0.945±0.0086	943.40±0.00							35.50	1.925	1.930±0.004
			37.25	1.870	1.875±0.004	35.80	3.276±0.0000	968.80±0.01			
37.50	1.436±0.0007	934.46±0.01									
			37.75	1.871	1.860±0.004	37.10	1.054±0.0012	947.25±0.01			
38.00	1.949±0.0000	925.24±0.01							37.27	1.887	1.870±0.005
			38.25	1.848	1.845±0.004	37.45	1.408±0.0005	940.78±0.00			
38.50	1.538±0.0015	916.65±0.01							37.65	1.865	1.875±0.005
			38.75	1.852	1.836±0.004	37.85	1.800±0.0010	936.54±0.01			
39.00	2.029±0.0005	908.12±0.01							38.05	1.850	1.844±0.005
			39.25	1.851	1.835±0.004	38.25	2.203±0.0005	926.54±0.00			
39.50	2.517±0.0000	899.76±0.01									
			39.75	1.852	1.844±0.004	38.25	2.212±0.0000	924.16±0.00			
40.00	2.995±0.0010	891.66±0.02							38.47	1.836	1.840±0.004
			40.25	1.829	1.836±0.004	38.70	2.654±0.0015	916.47±0.01			
40.50	3.515±0.0005	883.06±0.01									
			40.75	1.817	1.825±0.004	38.70	2.644±0.0005	916.57±0.01			
41.00	4.019±0.0015	874.89±0.02							38.92	1.840	1.834±0.004
			41.25	1.802	1.815±0.004	39.15	3.074±0.001	909.10±0.01			
41.50	4.523±0.0005	866.89±0.01									

(*Continued on next page*)

Table 2 (*b*).—*Continued*:—

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
41.00	0.196±0.0010	875.19±0.01									
			41.25	1.821	1.821±0.005						
41.50	0.673±0.0005	867.53±0.02									
			41.75	1.759	1.759±0.005						
42.00	1.177±0.0005	859.81±0.01									
			42.25	1.757	1.760±0.005				39.37	1.857	1.842±0.004
42.50	1.672±0.0025	852.33±0.03				39.60	3.525±0.0000	901.34±0.00			
			42.75	1.755	1.764±0.005				39.80	1.865	1.832±0.004
43.00	2.174±0.0005	844.84±0.01				40.10	4.000±0.0010	893.18±0.02			
									40.25	1.814	1.827±0.004
41.00	0.174±0.0000	875.33±0.01				40.40	4.293±0.0000	888.36±0.02			
			41.15	1.833	1.818±0.003				40.65	1.792	1.820±0.004
41.30	0.466±0.0015	870.59±0.01				40.90	4.802±0.0010	880.19±0.02			
			41.45	1.843	1.820±0.003				41.10	1.813	1.822±0.004
41.60	0.766±0.0005	865.74±0.01				41.30	5.203±0.0000	873.77±0.01			
			41.71	1.761	1.761±0.003						
41.90	1.062±0.0000	861.21±0.02				41.10	0.280±0.0010	873.83±0.02			
			42.05	1.749	1.760±0.003				41.30	1.836	1.818±0.004
42.20	1.371±0.0005	856.52±0.01				41.50	0.671±0.0000	867.51±0.01			
			42.35	1.741	1.761±0.003				41.40	1.839	1.820±0.004
42.50	1.656±0.0005	852.26±0.01				41.30	0.450±0.0010	870.79±0.00			
			42.65	1.741	1.758±0.003				41.50	1.770	1.758±0.004
42.80	1.978±0.0000	847.49±0.02				41.70	0.854±0.0003	864.54±0.01			
			42.95	1.768	1.763±0.003				41.95	1.749	1.760±0.004
43.10	2.275±0.0010	843.05±0.01				42.20	1.364±0.0003	856.79±0.00			
42.00	1.171±0.0010	859.90±0.02									
			42.50	1.756	1.763±0.005						
43.00	2.172±0.0005	844.84±0.01									

TABLE 2 (b).—BECKMANN READINGS, TIMES OF FLOW, TEMPERATURE °C. AND CALCULATED VALUES OF (E/R)/1000= – T^2 (ΔlnνΔT […] 1000 FOR PURE REDISTILLED WATER FROM 35° TO 43° C., USING ΔT=0.5° TO 0.3°C., USING VISCOMETER No. "Θ" […]

Heating sequence						Cooling sequence					
Tempera-ture °C.	Beckmann readings	Time of flow (secs.) corrected for level	Mean temp-erature °C.	E/R ÷ 1000 (Uncor-rected	E/R ÷ 1000 Corrected	Temp-erature °C.	Beckmann readings	Time of flow (secs.) corrected for level	Mean temp-erature °C	E/R ÷ 1000 Uncor-rected	E/R ÷ 1000 Correcte[…]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
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			35.25	1.937	1.921±0.004						
35.50	2.985±0.0000	974.46±0.01									
			35.75	1.910	1.878±0.004						
36.00	3.890±0.0000	964.91±0.01									
			56.10	1.931	1.880±0.004						
36.20	4.087±0.0000	961.10±0.00									
36.00	–0.051±0.0000	961.85±0.01									
			36.25	1.892	1.880±0.004	35.20	2.694±0.0000	980.26±0.00			
36.50	0.449±0.0015	952.56±0.02									
			36.75	1.886	1.873±0.004						
37.00	0.945±0.0086	943.40±0.00							35.50	1.925	1.930±0.
			37.25	1.870	1.875±0.004	35.80	3.276±0.0000	968.80±0.01			
37.50	1.436±0.0007	934.46±0.01									
			37.75	1.871	1.860±0.004	37.10	1.054±0.0012	947.25±0.01			
38.00	1.949±0.0000	925.24±0.01							37.27	1.887	1.870±0.
			38.25	1.848	1.845±0.004	37.45	1.408±0.0005	940.78±0.00			
38.50	1.538±0.0015	916.65±0.01							37.65	1.865	1.875±0.
			38.75	1.852	1.836±0.004	37.85	1.800±0.0010	936.54±0.01			
39.00	2.029±0.0005	908.12±0.01							38.05	1.850	1.844±0.
			39.25	1.851	1.835±0.004	38.25	2.203±0.0005	926.54±0.00			
39.50	2.517±0.0000	899.76±0.01									
			39.75	1.852	1.844±0.004	38.25	2.212±0.0000	924.16±0.00			
40.00	2.995±0.0010	891.66±0.02							38.47	1.836	1.840±0.
			40.25	1.829	1.836±0.004	38.70	2.654±0.0015	916.47±0.01			
40.50	3.515±0.0005	883.06±0.01									
			40.75	1.817	1.825±0.004	38.70	2.644±0.0005	916.57±0.01			
41.00	4.019±0.0015	874.89±0.02							38.92	1.840	1.834±0.
			41.25	1.802	1.815±0.004	39.15	3.074±0.001	909.10±0.01			
41.50	4.523±0.0005	866.89±0.01									

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