

TROUTON'S RULE

1. PURPOSE OF THE WORK

Determination of heat of vaporization and ebullioscopic constant of water using Trouton's rule.

2. THEORETICAL NOTIONS

The **specific latent heat of vaporization** of a liquid, noted l_v , is the amount of heat required to convert the unit mass of the substance from the liquid state to the gaseous state at constant temperature and pressure. This quantity is usually determined at boiling point and atmospheric pressure.

The latent heat of vaporization can be determined directly by a calorimetric method. Precision calorimetric methods are complicated. However, the calorimeter can be modified so that the execution of the work can be accessible and sufficiently accurate. To determine the latent heat of vaporization, the liquid is introduced into a thermally insulated vessel and evaporated, consuming a measured amount of electricity. The resulting vapors are condensed and measured directly.

From the value of the latent heat of vaporization, certain physico-chemical quantities characteristic of the liquid can be calculated. The ebullioscopic constant of the liquid represents the increase of the boiling temperature when 1 mole of substance dissolves in 1000 g of liquid used as solvent. It is calculated with the formula

$$K_{eb} = \frac{R \cdot T^2}{1000 \cdot l_v} \quad (1)$$

where: K_{eb} - ebullioscopic constant;

T - boiling temperature (K);

l_v - latent heat of vaporization per 1 g of substance (J / g).

To calculate the molar heat of vaporization, $\Delta^v H$, of different liquids, at boiling temperature and atmospheric pressure, we can use its direct proportionality with boiling temperature, expressed in absolute degrees, T_f . This rule was established by Trouton (Trouton's Rule):

$$K_T = \frac{\Delta^v H}{T_f} \approx 85 - 88 \left(\frac{J}{mol \cdot K} \right) \quad (2)$$

The coefficient of proportionality is approximately equal to 88 for most liquids and is

called the *Trouton constant*. In substances with a very low boiling point the constant has lower values, and in substances with a high boiling point it has higher values. The rule is checked quite well for liquids with a boiling point between 0-200 °C. But even in the case of these liquids there are individual deviations from which conclusions can be drawn on the molecular state of the substances. If the substance is combined, both in the liquid and in the vapor state, lower values are obtained for the Trouton constant, because the molar heat of vaporization calculated on the basis of the simple molar mass is too low (e.g. formic acid 61.97 J / (mol·K). On the contrary, if the substance is associated only in the liquid phase, then the heat of vaporization will also contain the energy needed to dissociate the associated molecules, and its value, so also of Trouton's constant will be higher (e.g. ammonia 97.97 J / (mol·K); water 108.86 J / (mol·K); alcohol 113.88 J / (mol·K).

3. EXPERIMENTAL PART

3.1. APPARATUS AND SUBSTANCES

- 2000 cm³ thermally insulated vessel, 300-500 W heater, thermometer, condenser, stopwatch, a direct current source, voltmeter, ammeter, 500 mL graduated cylinder, 50 mL graduated cylinder.

3.2. PROCEDURE

Fill the thermally insulated vessel almost completely with water (approximately 1 cm below the level of the inner ring). Mount the distillation head as tight as possible. Fix the condenser and turn on the water supply, ensuring a moderate flow of liquid through the condenser. Turn on the heating with a current value of 2.5 A and wait until the water starts to boil. When the distillation is uniform (~ 5-10 minutes after it starts to boil) place the 50 mL graduated cylinder at the end of the condenser to collect the distillate. After 10-15 mL of distillate were collected, it can be considered that the thermal equilibrium has been reached, the cylinder is emptied and the collection of the distillate begins. At the same time, the stopwatch is started. The values for voltage (U) and current intensity (I) are recorded.

When 10 mL of distillate has been collected, the stopwatch is stopped. Empty the cylinder. Repeat the procedure reducing the current intensity to the following values: 2.4 A; 2.3 A; 2.2 A.

Attention:

- not to exceed the current value of 2.5 A;
- the installation must be emptied after the end of the experiment.

4. EXPERIMENTAL DATA PROCESSING

4.1. The experimental results are recorded in the table:

No.	<i>U</i> , V	<i>I</i> , A	<i>t</i> , s	<i>v</i> , mL	<i>m</i> , g	<i>l_v</i> , J/g
1.		2,5		10		
2.		2,4		10		
3.		2,3		10		
4.		2,2		10		

4.2. Calculate the specific latent heat of vaporization (*l_v*) for each sample:

$$l_v = \frac{U \cdot I \cdot t}{m}, \quad \text{J/g}$$

where: *U* = voltage (V)

I = current intensity (A)

t = time (s)

m = distilled water mass (g)

4.3. With the average of the four values for the latent heat of vaporization \bar{l}_v , is calculated

K_{eb} (ebullioscopic constant);

4.4. Calculate the molar enthalpy of vaporization: $\Delta^v H = \bar{l}_v \cdot M_{H_2O}$. Then the Trouton

constant of formula (2) is calculated. Depending on the result obtained, the existence of a molecular association phenomenon can be signaled.

Data from the literature

$$M_{H_2O} = 18,03 \text{ g/mol} \quad ; \quad \rho_{H_2O} = 998,2 \text{ g/L}$$

5. QUESTIONS

5.1. Can the enthalpy of vaporization be calculated for a substance based on Hess's law, knowing the enthalpies of melting and sublimation?

5.2. What is the thermodynamic significance of the Trouton constant?