

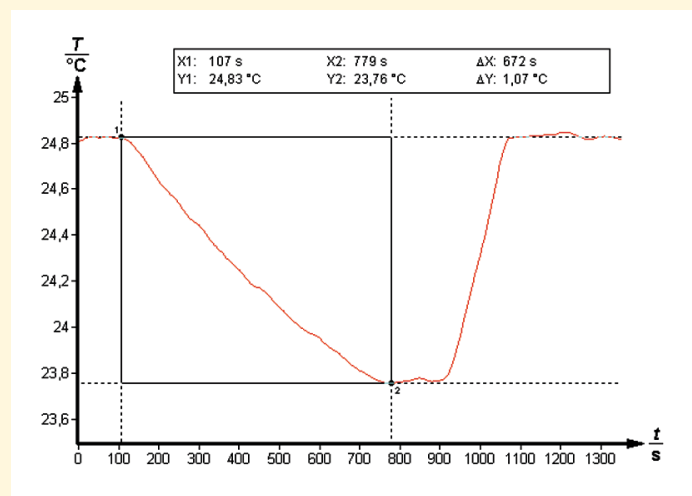
Determination of the enthalpy of vaporization of liquids 02.04

What you can learn about

- Enthalpy of vaporisation
- Entropy of vaporisation
- Trouton's rule
- Calorimetry
- Heat capacity

Principle and tasks

The vaporization of a liquid occurs with heat absorption. To determine the enthalpy of vaporization, a known mass of the liquid which is to be investigated is vaporized in a special vaporization vessel in a current of air. The quantity of heat absorbed which corresponds to the enthalpy of vaporization can be calorimetrically determined.



Temperature-time curve of the vaporisation of diethyl ether and determining the heat capacity of the system.

What you need:

Set calorimetry	43030.88	1
Set data acquisition for set calorimetry	43030.30	1
Evaporation vessel for calorimeter	04405.00	1
Separator for magnetic bars	35680.03	1
Right angle clamp	37697.00	2
Universal clamp	37715.00	2
Retort stand, $h = 500 \text{ mm}$	37692.00	1
Precision balance CPA 623S (620 g/0.001 g), set with software	49224.88	1
Precision balance CPA 6202S (6200 g/0.01 g), set with software	49226.88	1
Safety bottle with manometer	34170.88	1
Water jet pump	02728.00	1
Erlenmeyer flask, 250 ml, wide	36134.00	1
Rubber tubing, vacuum, $d_i = 6 \text{ mm}$	39286.00	1
Rubber tubing, $d_i = 6 \text{ mm}$	39282.00	1
Rubber bulbs	39275.03	1
Hose clip, $d = 12...20 \text{ mm}$	40995.00	5
Air control valve	37003.00	1
Syringe, 20 ml	02591.03	1
Cannula, $0.9 \times 70 \text{ mm}$	02597.04	1
Wash bottle, 500 ml	33931.00	1
Diethyl ether, 250 ml	30007.25	1
Methanol, 500 ml	30142.50	1
Water, distilled, 5 l	31246.81	1
PC, Windows® XP or higher		

Determination of the enthalpy of vaporization of liquids

P3020411

Related concepts

Enthalpy of vaporization, enthalpy of condensation, enthalpy of sublimation, vapour pressure, entropy of vaporization, Clapeyron-Clausius equation, Trouton's rule, laws of thermodynamics, calorimetry.

Principle

The vaporization of a liquid occurs with heat absorption. To determine the enthalpy of vaporization, a known mass of the liquid which is to be investigated is vaporized in a special vaporization vessel in a current of air. The quantity of heat absorbed, which corresponds to the enthalpy of vaporization, can be calorimetrically determined.

Tasks

1. Determine the molar enthalpy of vaporization of diethyl ether and methanol.
2. Calculate the molar entropies of vaporization and discuss the results under consideration of Trouton's rule.

Equipment

Set calorimetry	43030.88	1
Evaporation vessel for calorimeter	04405.00	1

Data acquisition set for set calorimetry	43030.30	1
Separator for magnetic bars	35680.03	1
Right angle clamp	37697.00	2
Universal clamp	37715.00	2
Retort stand, $h = 500$ mm	37692.00	1
Set of precision balance Sartorius CPA623S and measure software	49224.88	1
Set of precision balance Sartorius CPA6202S and measure software	49226.88	1
Safety bottle with manometer	34170.88	1
Water jet pump	02728.00	1
Erlenmeyer flask, 250 ml, wide	36134.00	1
Rubber tubing, vacuum, $d_i = 6$ mm	39286.00	1
Rubber tubing, $d_i = 6$ mm	39282.00	1
Rubber bulbs	39275.03	1
Hose clip, $d = 12 \dots 20$ mm	40995.00	5
Air control valve	37003.00	1
Syringe, 20 ml, Luer	02591.03	1
Cannula, 0.9x70 mm, Luer	02597.04	1
Wash bottle, 500 ml, plastic	33931.00	1
Diethyl ether, 250 ml	30007.25	1
Methanol, 500 ml	30142.50	1
Water, distilled, 5 l	31246.81	1
PC, Windows® 95 or higher		

Fig. 1. Experimental set-up.



Set-up and procedure

Set up the experiment as shown in Fig.1 but for the time being do not connect the heating coil to the work and power meter. Connect the temperature probe to T1 of the measuring module. Call up the 'Measure' programme in Windows and enter <Temperature> as measuring instrument. Set the measuring parameters as shown in Fig. 2. Under <Diagram 1> select Temperature T0a, the appropriate range for the temperature and the X bounds and 'auto range'. Now calibrate your sensor under <Calibrate> by entering a temperature value measured with a thermometer and pressing <Calibrate>. After having made these settings, press <Continue> to reach the field for the recording of measured values. Arrange the displays as you want them.

Place the clean and dry evaporation vessel in an Erlenmeyer flask and fill it through the straight inlet tube with 15 ml of the liquid to be evaporated using a syringe with a cannula. Following this, attach a 5 cm length of rubber tubing to the air inlet tube and connect it to the air control valve. Only then, close off the right-angled air outlet tube with a rubber cap to prevent loss of substance due to vaporization. Subsequent to this, determine the mass of the evaporation vessel, which has been thus prepared (weighing accuracy: 0.0001 g). The Erlenmeyer flask serves merely as a support for the evaporation vessel. Fill the calorimeter with 900 g of distilled water which is at room temperature (weighing accuracy = 0.1 g). Put the oval magnetic stirrer bar into the calorimeter and switch the magnetic stirrer on (*Caution: Do not mistakenly switch on the heating unit!*). Insert the heating coil, the temperature probe and the evaporation vessel into the lid of the calorimeter and fix them in position. Take off the rubber cap and connect the evaporation vessel to the filter pump via the safety bottle.

Wait until a temperature equilibrium has been reached (approximately 10 min). Start the measurement with <Start measurement>. Ensure that the equilibrium temperature has been reached in the calorimeter, i.e. the temperature remains constant or shows only a slight drift, then turn on the water jet pump and start the vaporization process by carefully opening the air control valve on the air inlet. Avoid vigorous sputtering and delayed boiling. When the temperature of the water has decreased by approx. 1°C, close the air control valve and shut off the water jet pump (let air into the safety bottle!). Immediately remove the vacuum tubing from the air outlet tube of the evaporation vessel and close this outlet tube with the rubber cap.

Continue to measure and record the temperature of the system until a new equilibrium has been reached or until the alteration only occurs slowly and linearly.

Now, perform electrical calibration to determine the total heat capacity of the calorimeter. To do this, supply 10 V AC to the work and power meter for the electric heating. Push the <Reset> button and then put the free ends of the heating coil connection cables into the output jacks. The system is now continuously heated and the supplied quantity of energy is measured. When the work and power meter shows approximately 4000 Ws, switch off the heating and read off the exact quantity of electrical energy that has been supplied. Continue to measure for another three minutes, then stop temperature recording with <Stop measurement>.

Fig. 3 shows the graph as it is presented by the programme when the measurement is stopped. If you use <survey> from the toolbar you can read the temperature difference data.

Subsequently remove the closed evaporation vessel, carefully dry it, then weigh it in the Erlenmeyer flask which was previously used. From the two weighings, i.e. before and after vaporization, the quantity of vaporized substance can be calculated. Always thoroughly clean and dry the evaporation vessel before performing a new measurement.

Fig. 2: Measurement parameters

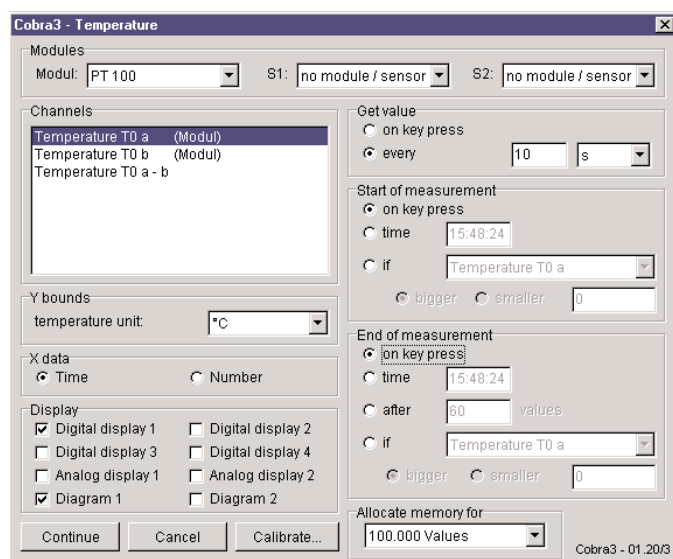
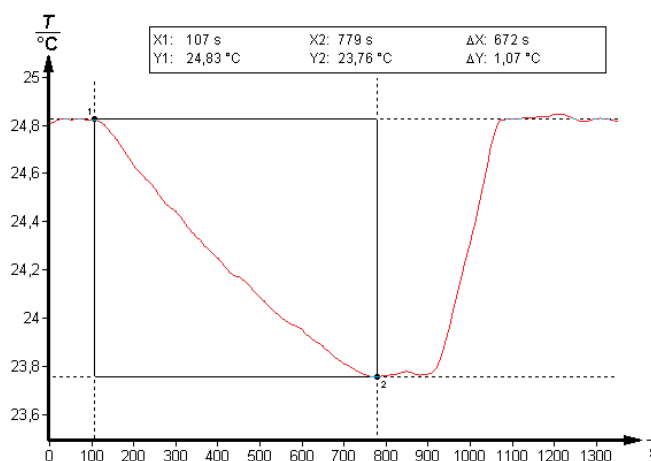


Fig. 3: Temperature- time curve of the vaporisation of diethyl ether and for determining the heat capacity of the system



Theory and evaluation

When liquids are heated at constant pressure, a certain temperature is reached at which the substance is converted from the liquid to the vapour phase. This boiling point remains constant under further addition of heat until the liquid phase has been completely vaporized. If a mole of liquid is vaporized, its molar enthalpy H increases by the amount of heat absorbed Q_V . This difference in enthalpies is termed the enthalpy of vaporization $\Delta_V H$ and is explained by the energy required to break the bonds between the molecules in the liquid and the constantly changing pressure that the vapour formed must exert against the existing external pressure. If the vapour is cooled, condensation occurs at the same temperature – the process is reversible. Consequently, the increase in entropy $\Delta_V S$ which accompanies the vaporization can be formulated by applying the second principle of thermodynamics:

$$\Delta_V S = \frac{\Delta_V H}{T_V} \quad (1)$$

In many liquids the molar enthalpy of vaporization lies in the range between 80 and 90 J · mol⁻¹ · K⁻¹. This rule was named after Trouton and is especially valid for non-associated liquids. Strong interactions between the molecules of liquid, such as hydrogen bonds, result in higher entropies of vaporization.

In the present experiment, the liquid is vaporized in an airstream below the boiling point of the liquid. In doing so, the equilibrium between the liquid and the vapour phase is disturbed by the continuous removal of the vapour phase. The enthalpy of vaporization is equal to the amount of heat which is withdrawn from the calorimeter.

$$\Delta_V H = \Delta_V S \cdot T_V \quad (1.1)$$

$$\Delta_V H = \frac{\Delta_V h}{n} \quad (2)$$

$$\Delta_V h = -C_K \cdot \Delta T_V \quad (3)$$

$$W_{el} = C_K \cdot \Delta T_{el} \quad (4)$$

$$C_K = \frac{W_{el}}{\Delta T_{el}} \quad (4.1)$$

$$\Delta_V H = -C_K \cdot \Delta T_V \cdot \frac{M}{m} \quad (5)$$

$$\Delta_V H = -W_{el} \cdot \frac{\Delta T_V}{\Delta T_{el}} \cdot \frac{M}{m} \quad (5.1)$$

ΔT_V	Temperature difference during vaporization
ΔT_{el}	Temperature difference during calibration
W_{el}	Electrical work
C_K	Heat capacity of the calorimeter
n	Quantity of vaporized substance (m/M)

Data and results

Molar mass of methanol:	32.04 g · mol ⁻¹
Molar mass of diethyl ether:	74.12 g · mol ⁻¹
Boiling point of methanol:	337.7 K
Boiling point of diethyl ether:	307.7 K

Enthalpy of vaporization of methanol:	33.8 kJ · mol ⁻¹
Enthalpy of vaporization of diethyl ether:	25.6 kJ · mol ⁻¹
Entropy of vaporization of methanol:	100.0 J · mol ⁻¹ · K ⁻¹
Entropy of vaporization of diethyl ether:	83.2 J · mol ⁻¹ · K ⁻¹

