Vapour pressure of water below 100°C - molar heat of vaporisation

Physics	Thermodynamics	Temperature & Heat
Physics	Thermodynamics	Kinetic gas theory & gas laws

Difficulty level	Group size	Preparation time	Execution time
medium	2	45+ minutes	45+ minutes

This content can also be found online at:

http://localhost:1337/c/60054d2027aa1c00038a1482

General information

Application

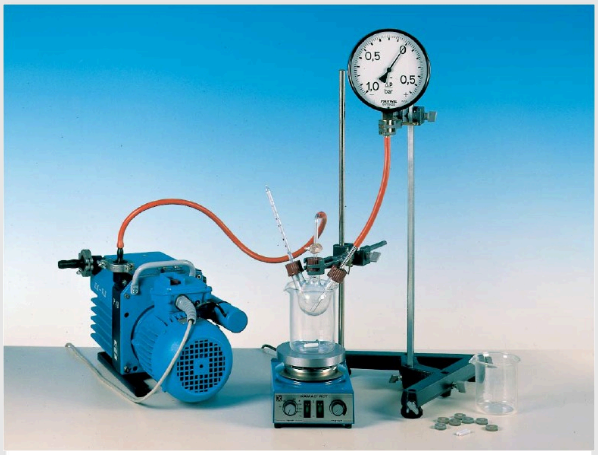

Fig 1: Experimental set-up

The pressure exerted by the gas in equilibrium with a solid or liquid in a closed container at a given temperature is called the vapor pressure. It is a cornerstone of thermodynamics and as such an understanding of it is fundamental for the energy industry, especially because of the use of vapor turpines.

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Other information (1/2)

Prior knowledge

The prior knowledge for this experiment is found in the Theory section.

Main principle

The vapour pressure of water in the range of 40°C to 85°C is investigated. It is shown that the Clausius-Clapeyron equation describes the relation between temperature and pressure in an adequate manner. An average value for the heat of vaporization of water is determined.

Other information (2/2)

Learning objective

The goal of this experiment is to investigate the vapor pressure of water below 100° C.

Tasks

1. About 250 ml of de-mineralized water are allowed to boil for about 10 minutes to eliminate all traces of dissolved gas. The water is then cooled down to room temperature.
2. The 3-neck round flask is filled about three-quarters full with gas-free water and heated. At 35 °C the space above the water within the round flask is evacuated. Further heating causes an increase in pressure p and temperature t of water within the round flask. p and t are read in steps of 5 °C up to a maximum of t = 85 °C.

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Theory

Water at a normal pressure of 1013 h Pa boils at 100 °C, that means that the vapour pressure of water at 100 °C is 1013 h Pa. The vapour pressure of water decreases with decreasing temperature T (T = t + 273) and amounts to only a few hectopascal at room temperature. The Clausius-Clapeyron equation describes the relation between temperature and pressure.

$$p = \frac{\lambda}{R} \cdot \left(\frac{l}{T}\right) \qquad (1)$$

λ is the molar heat of vaporization and R the general gas constant. In the present experiment p is given by the expression

$$p = p_0 - p_{reading} + p_{initial} \qquad (2)$$

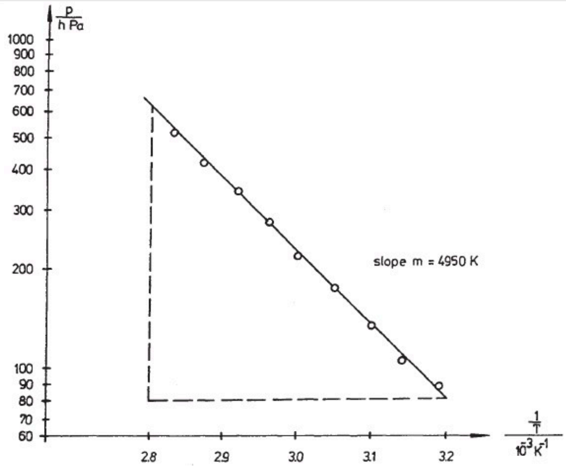

Fig. 2: Semilogarithmic representation of vapour pressure p as a function of 1/T.

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Equipment

Position	Material	Item No.	Quantity
1	Manometer -1.0...0.6 bar	03105-00	1
2	Students thermometer,-10...+110°C, l = 180 mm	38005-02	2
3	Three neck round bottom flask, 100 ml	MAU-27220501	1
4	Stopcock,1-way,r.-angled, glass	36705-01	1
5	Rotary valve vacuum pump, two stages, 115 V / 230 V	02741-95	1
6	Hotplate magnetic stirrer with connection for electronic contact thermometer, 3 ltr., 230 V	35760-93	1
7	Magnetic stirring bar 30 mm, cylindrical	46299-02	2
8	Glass tubes,straight, 200 mm, 10	36701-66	1
9	Gasket for GL25, 8mm hole, 10 pcs	41242-03	1
10	Vacuum tube, NBR, 6/14mm, 1 m	39289-00	2
11	Support base DEMO	02007-55	1
12	Support rod, stainless steel, 750 mm	02033-00	1
13	Support rod, stainless steel, l=370 mm, d=10 mm	02059-00	1
14	Universal clamp with joint	37716-00	2
15	Right angle clamp expert	02054-00	2
16	Beaker, Borosilicate, low-form, 400 ml	46055-00	1
17	Beaker, Borosilicate, low form, 600 ml	46056-00	1
18	Water, distilled 5 l	31246-81	1

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Setup and Procedure

Setup

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- Set up the experiment as shown in Fig. 1.

The manometer is fixed about 40 cm above the round flask. The manometer is connected to the round flask by means of a 200 mm long straight glass tube. The second opening of the round flask holds the thermometer while the central opening is linked to the vacuum pump by means of a right-angled oneway stop-cock. The contents of the round flask can be completely sealed off from the outer atmosphere by jointings.

The 600 ml beaker which is filled with ordinary tap- water acts as a thermo-bath for the round flask. The round flask is filled about three-quarters full with gas-free water and sealed. The thermometer is within the lower part of the round flask.

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Procedure

Initially the lower end of the straight glass tube is moved upwards so that it is above the surface of the gas-free water. The space above the water is now evacuated. The straight glass tube is lowered till its lower end enters the gas-free water. The atmospheric pressure within the round flask is then established and the manometer and the tube automatically fill with water. This procedure avoids creation of “dead- volume” within the manometer. The initial reading of the manometer – mainly due to the presence of the water column – is

$$P_{reading} = P_{initial}$$

The pressure within the round flask is now p_0. p_0 is the atmospheric pressure. It can be read from a standard barometer. The water within the flask is heated up. At a temperature of 35 °C the space above the gas-free water is evacuated. The stop cock is then closed and the flask completely sealed off while heating continues. At t = 40 °C, and subsequently in steps of 5 °C, the temperature and pressure are recorded. All readings should be completed within about 15 minutes to avoid falsification of the results by leakage.

Evaluation

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Results

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In a series of measurements the following values were found:

T [°C]	p [hPa]
40	88
45	103
50	133
55	173
60	218
65	273
70	343
75	413
80	513
85	683

In Fig. 2 the vapour pressure p has been represented semilogarithmically versus 1/T. It is evident that the graph is a straight line which proves the validity of Clausius-Clapeyron's equation if λ is considered a constant. By linear regression we find for slope m of the straight line a value of m = 4950 K. With the value of 8.3144 J/Mol K for the general gas constant we get a value of

$$\lambda = m \cdot R, \lambda = 41.2 \frac{\mathrm{kJ}}{\mathrm{mol}}$$

for the heat of vaporization λ. This is a reasonably good average value for the heat of vaporization of water. The heat of vaporization of water increases in reality with decreasing temperature. The literature value for t = 20 °C is 44.15 kJ/Mol and 40.6 kJ/Mol for 100 °C.

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