Vapour pressure of water below 100 °C
Molar heat of vaporization

Related topics

Pressure, temperature, volume, vaporization, vapour pressure, Clausius-Clapeyron equation.

Principle and task

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.

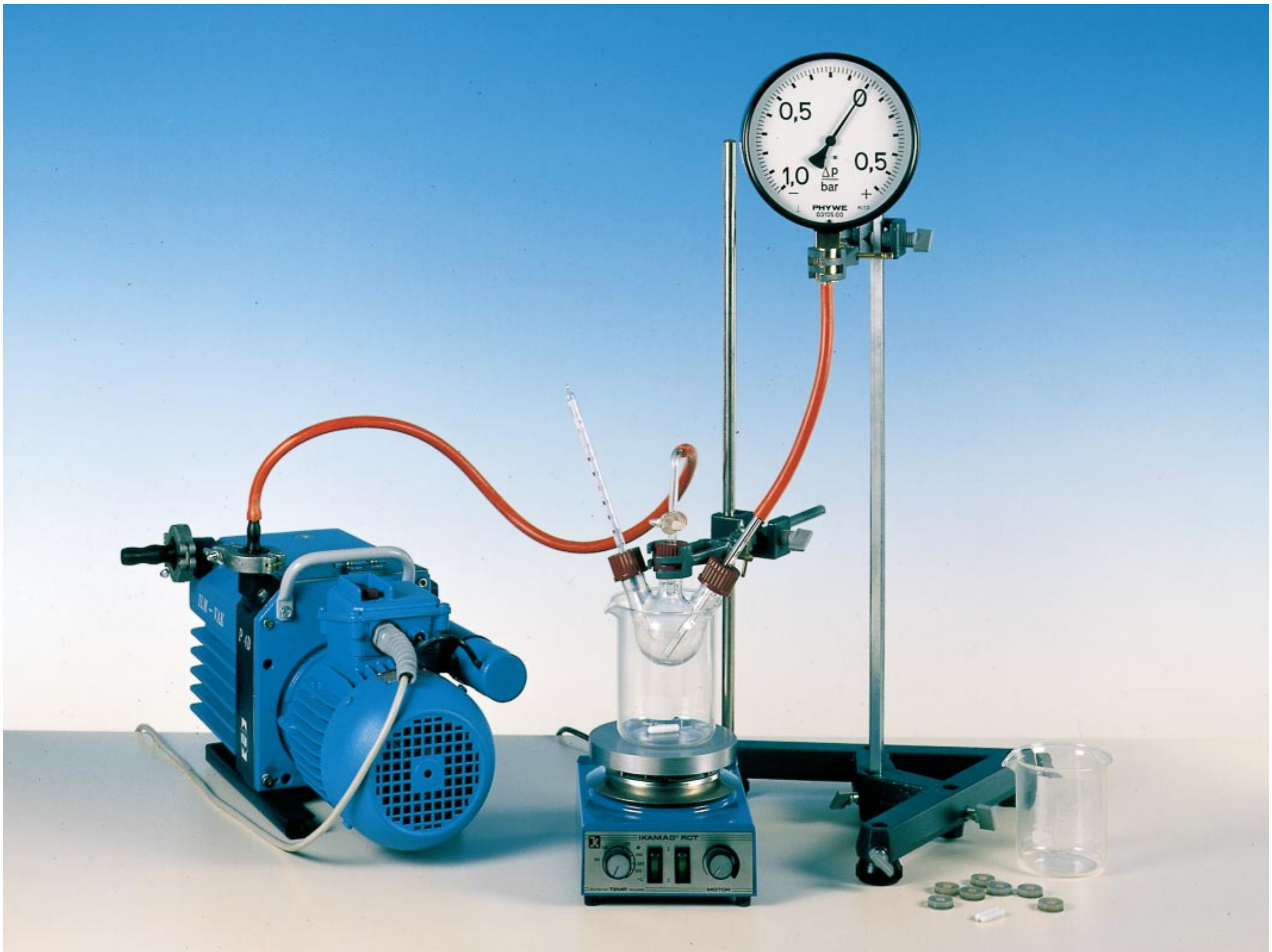
Equipment

Manometer 0-1.6 bar	03105.00	1
Students thermometer, -10...+110 C	38005.02	2
Round flask, 100 ml, 3-n., GL25/2×GL1	35677.15	1
Stopcock, 1-way, r.-angled, glass	36705.01	1
Vacuum pump, one stage	02750.93	1
Magnetic stirrer w. heat., 230 V	35684.93	1
Magn.stirring bar 30 mm, cyl.	46299.02	2
Glass tube 200 mm ext. d = 8 mm	64807.00	1
Jointing f. GL25, 8 mm hole, 10 pcs	41242.03	1
Rubber tubing, vacuum, i.d. 8 mm	39288.00	1
Rubber tubing, i.d. 12 mm	39285.00	1
Support base -PASS-	02005.55	1
Support rod -PASS-, square, l 630 mm	02027.55	1
Support rod, l 500 mm/M10 thread	02022.05	1
Universal clamp with joint	37716.00	2
Right angle clamp -PASS-	02040.55	2
Glass beaker, short, 400 ml	36014.00	1
Glass beaker, short, 600 ml	36015.00	1
Water, distilled, 5 l	31246.81	1

Problems

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.*

Fig. 1: Experimental set-up for measuring the vapour pressure of water below 100°C.



Set-up and procedure

The experiment is set up 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 one-way 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.

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

$$P_{\text{reading}} = P_{\text{initial}}$$

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.

Theory and evaluation

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.

$$\ln p = \frac{\lambda}{R} \cdot \frac{1}{T} \qquad (1)$$

λ is the molar heat of vaporization and R the general gas constant.

In the present experiment p is given by the expression

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

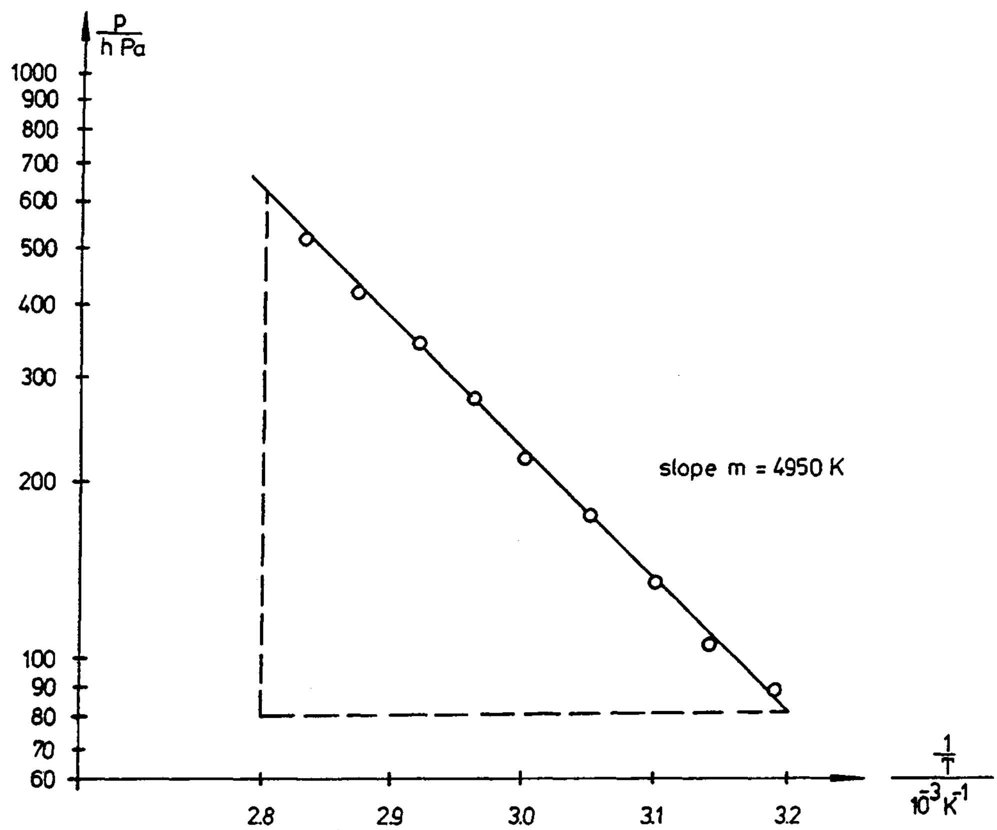


Fig. 2: Semilogarithmic representation of vapour pressure p as a function of $^1/_T$.

In a series of measurements the following values were found:

$\frac{t}{°C}$	$\frac{p}{hPa}$
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 semi-logarithmically 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

$$m = 4950 \text{ K}$$

With the value of 8.3144 J/Mol K for the general gas constant we get a value of

$$\lambda = m \cdot R$$

$$\lambda = 41.2 \frac{\text{kJ}}{\text{Mol}}$$

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.