Vapour Pressure and Temperature

1 Objective

- Show that the boiling temperature varies with pressure.
- Find the boiling point of water at normal atmospheric pressure by extrapolation.
- Find the molar heat of vaporisation.

2 Prelab Questions

1. What are the *Free Energies* and how are they important? Discuss each briefly.
2. What is the atmospheric pressure in units of: bar, mmHg and in SI units?
3. Why is mercury used when measuring atmospheric pressure?
4. What happens to the boiling temperature with pressure? How do we know this?
5. Write the first law of thermodynamics in differential form for revesible processes then derive the thermodynamic potential that shows the Gibbs Free Energy as a function of P and T?

3 Principles

- The chamber is filled with distilled water making sure that no air bubbles are trapped in the line leading to the manometer (pressure gauge).
- The chamber is then sealed off with copper washers to prevent the steam from escaping and placed on the electric heater.
- The water is heated and the pressure and temperature are recorded at different equilibrium points.

4 Apparatus

- High pressure vapour unit.
- Heat conductive paste.
- Heating apparatus.
- Tripod base and support rod.

5 Precautions

1. Steam should not escape from the chamber.
2. Do not touch the chamber while it is hot.
3. Do not touch the conductive paste.

6 Experimental Steps

1. Dip the thermometer in the conductive paste, coating it liberally.
2. Place the thermometer in the hole and let the conducting paste fill the empty gap in the hole.
3. Record the temperature T_{lab} of the lab and the pressure P_i on the pressure gauge.

4. Place the heater under the high pressure chamber, keeping it very close to the chamber but not touching it.

5. Connect heater and switch it on.

6. The temperature will begin to rise and so will the pressure.

7. Switch off the heater when the temperature reaches 240°. Note that the temperature should not exceed this value.

8. As the temperature begins to drop inside the pressure chamber, record the temperature T and the pressure P for every bar.

7 Evaluation

1. Calculate $\ln(P)$.

2. Plot $\ln(P)$ vs. $1/T$ for the entire temperature range. Notice that the relationship is not perfectly linear, the curve is slightly convex owing to differences in the heat of vaporisation as the temperature increases [1].

3. Extrapolate the graph to get the boiling point of water at normal pressure.

4. Plot two $\ln(P)$ vs. $1/T$ graphs for the following temperature ranges: [240°C - 200°C] and [190°C - 150°C].

5. Using Vant Hoff's equation and the slope of the lines of the two plots, calculate the molar heat of vaporisation Λ for each temperature range.

8 Postlab Questions

1. Explain why the resultant boiling pressure of water you obtained is slightly lower than the normal value.

2. From your observations, what can you say about the thermal energy needed for one mole to change from the liquid phase to the vapour phase at constant temperature, explain and justify?

[1] For more information, check *Engineering and Chemical Thermodynamics* by *Milo D. Koretsky*, P(260-262)

3. Sketch the phase diagram of pure water indicating the different regions and the important points, explain breifly what the lines on the skecth signify.

4. Derive the Clausius-Clapeyron equation and invoke the Ideal Gas Law using the opproximation $V_{liq} << V_{vap}$ to get Vant Hoff's equation $\ln(P) = -\frac{\Lambda}{R} \times \frac{1}{T} + C$ [2].

5. In no more than a few sentences, what does Clausius-Clapeyron equation discribe?

9 Helpful Sites (clickable links)

- Vapour pressure of water at high temperature.

[2] For more information, check *An Introduction to Thermal Physics* by *Daniel V. Schroeder*, P(172-173)