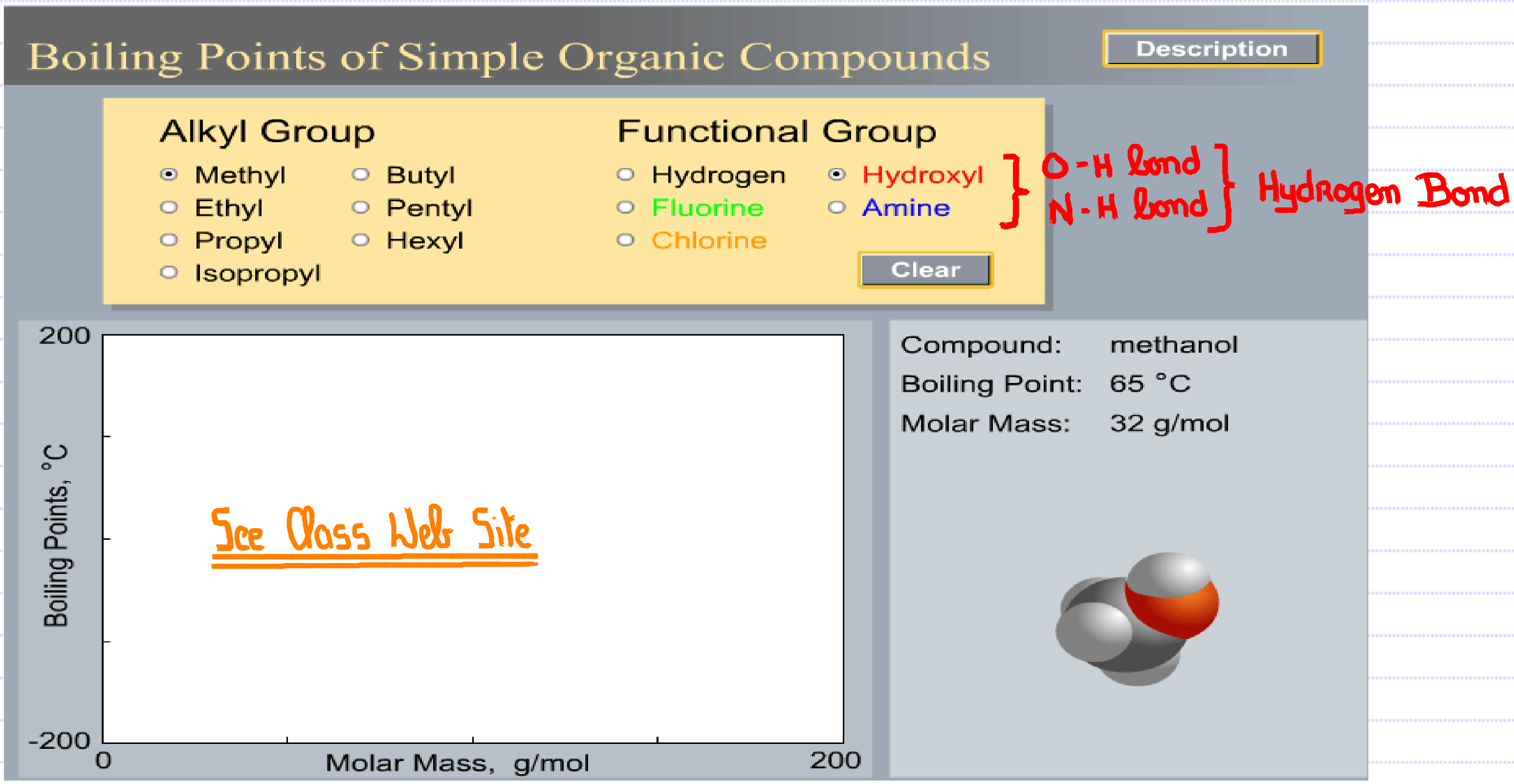
11.4 The Nature of Intermolecular Forces

London Dispersion Forces – Stronger than you might think

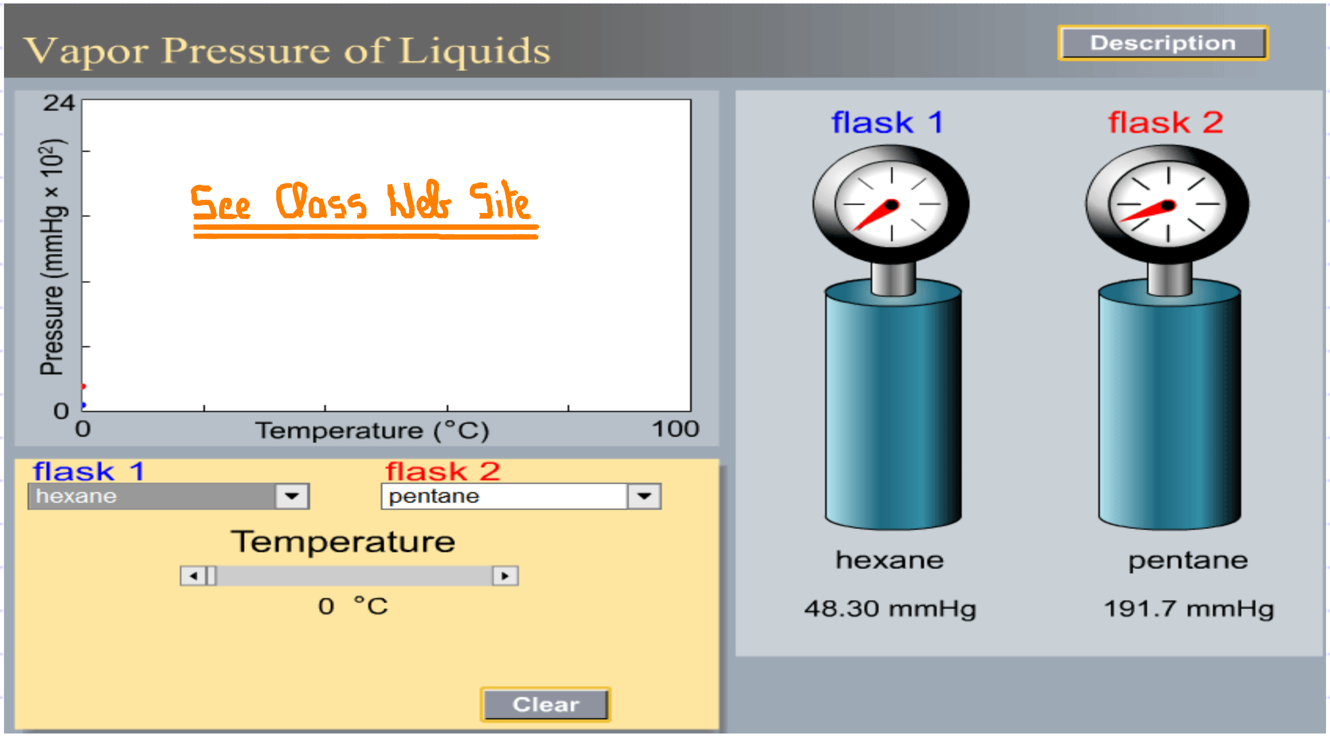
Boiling Points of Simple Organic Molecules



Dipole - Dipole Vs Induced Dipole - Induced Dipole

(London Dispersion Forces)

11.2 Vapor Pressure



VP = Vapor Pressure

a) VP Vs T

b) VP Vs Molar Mass (non-polar)

c) VP in polar molecules Vs VP in nonpolar molecules.

11.2 Vapor Pressure

Heat of Vaporization

→ The amount of heat required to convert a liquid to a gas: ΔH°_{VAP}

Which of the following molecules would you expect to have the smallest ΔH^{o}_{vap}

a) CH_3OH b) C_2H6 ✓ c) C_4H_{10}

→ Why?

Non-polar with a smaller Molar Mass than C_4H_{10}, which is also non-polar.

CH_3OH is polar.

11.2 Vapor Pressure

Relationship Between P, T, and ΔH^o_{vap} – Clausius-Clapeyron Equation

$$\ln P = \frac{-\Delta H^o_{vap}}{RT} + C$$

ΔH^o_{vap} : Heat of Vaporization.
R : $8.314\ J.mol^{-1}.K^{-1}$ (Ideal Gas Constant)

a) Graphically :

Plot $\ln P$ vs $1/T$: T must be in K

$$\text{Slope} = \frac{-\Delta H^o_{vap}}{R}$$

b) Quantitatively :

$$\ln P_1 = -\frac{\Delta H^o_{vap}}{RT_1} + C \quad : \quad \ln P_2 = -\frac{\Delta H^o_{vap}}{RT_2} + C$$

$$\ln P_2 - \ln P_1 = -\frac{\Delta H^o_{vap}}{RT_2} + C + \frac{\Delta H^o_{vap}}{RT_1} - C$$

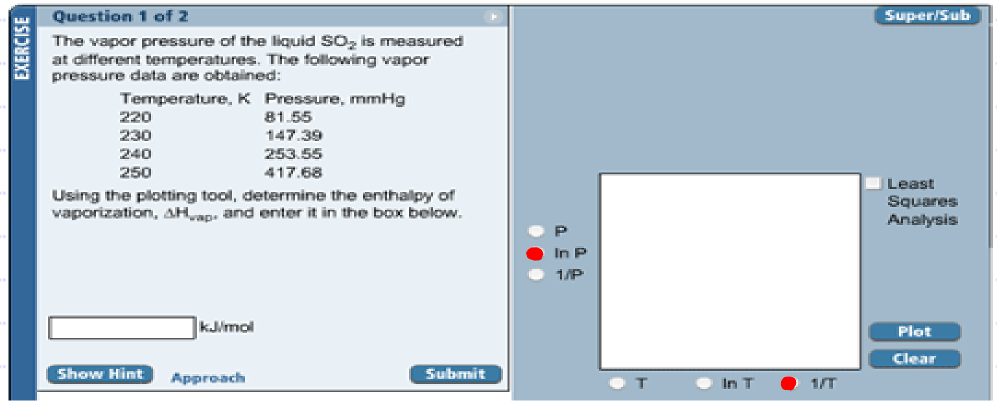
$$\ln P_2 - \ln P_1 = \frac{\Delta H^o_{vap}}{RT_1} - \frac{\Delta H^o_{vap}}{RT_2}$$

$$\ln \frac{P_2}{P_1} = \frac{\Delta H^o_{vap}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

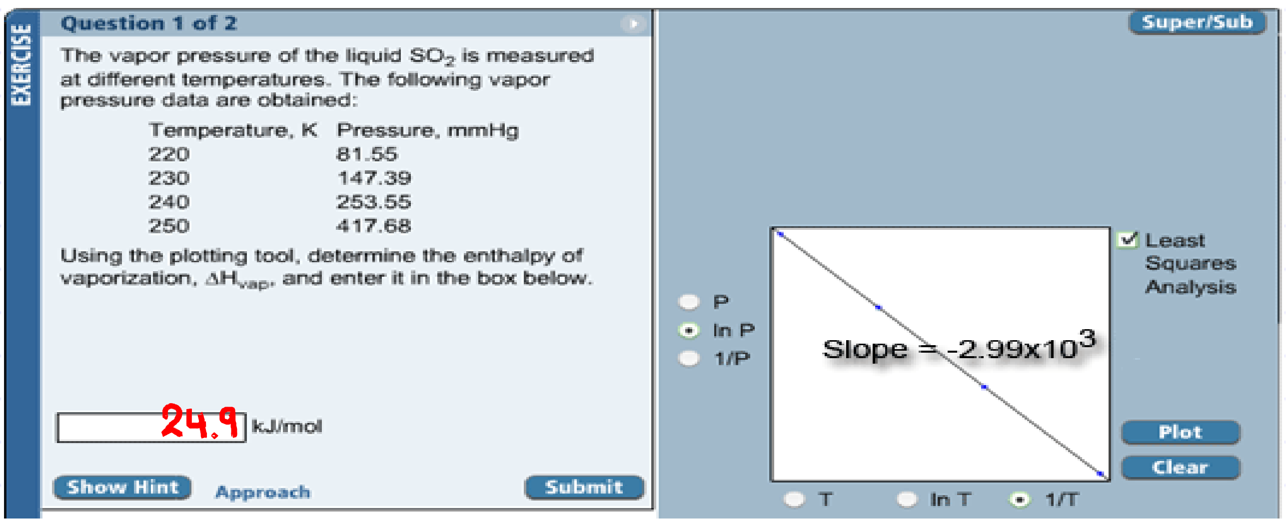
11.2 Vapor Pressure

Clausius-Clapeyron Equation – Graphical Method

Determine enthalpy of vaporization graphically



Determine enthalpy of vaporization graphically



$$-\frac{\Delta H^\circ_{vap}}{R} = \text{Slope}$$
$$= -2.99 \times 10^3$$

$$-\Delta H^\circ_{vap} = -2.99 \times 10^3 (8.314)$$
$$= -2.49 \times 10^4\ J.mol^{-1}$$

$$\Delta H^\circ_{vap} = 2.49 \times 10^4\ J.mol^{-1}$$
$$= 24.9\ kJ.mol^{-1}$$

11.2 Vapor Pressure

Clausius-Clapeyron Equation – Quantative

From the following vapor pressure data for heptane, an estimate of the molar heat of vaporization of C_7H_{16} is

P, mm Hg	T, Kelvins
100	315
400	351

$$\ln \frac{P_2}{P_1} = \frac{\Delta H^\circ_{vap}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$P_1 = 100$ $T_1 = 315$

$P_2 = 400$ $T_2 = 351$

$$\ln \frac{400}{100} = \frac{\Delta H^\circ_{vap}}{R}\left(\frac{1}{315} - \frac{1}{351}\right)$$

$$\ln 4\,(R) = \Delta H^\circ_{vap}\,(3.26 \times 10^{-4})$$

$$\Delta H^\circ_{vap} = \frac{1.39\,(8.314)}{3.26 \times 10^{-4}}$$

$$= 3.54 \times 10^4 \text{ J. mol}^{-1}$$

OR

$$35.4 \text{ kJ. mol}^{-1}$$