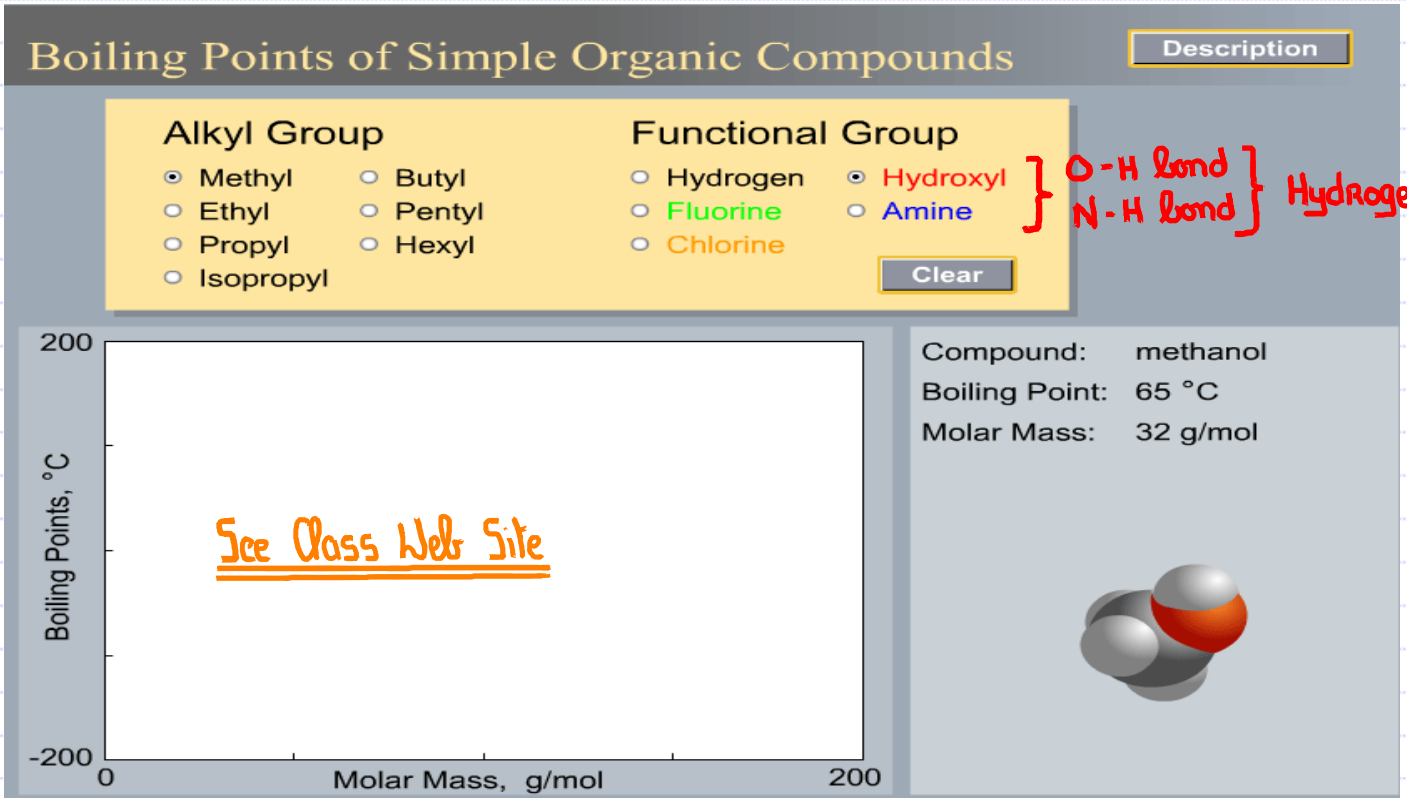
## 11.4 The Nature of Intermolecular Forces

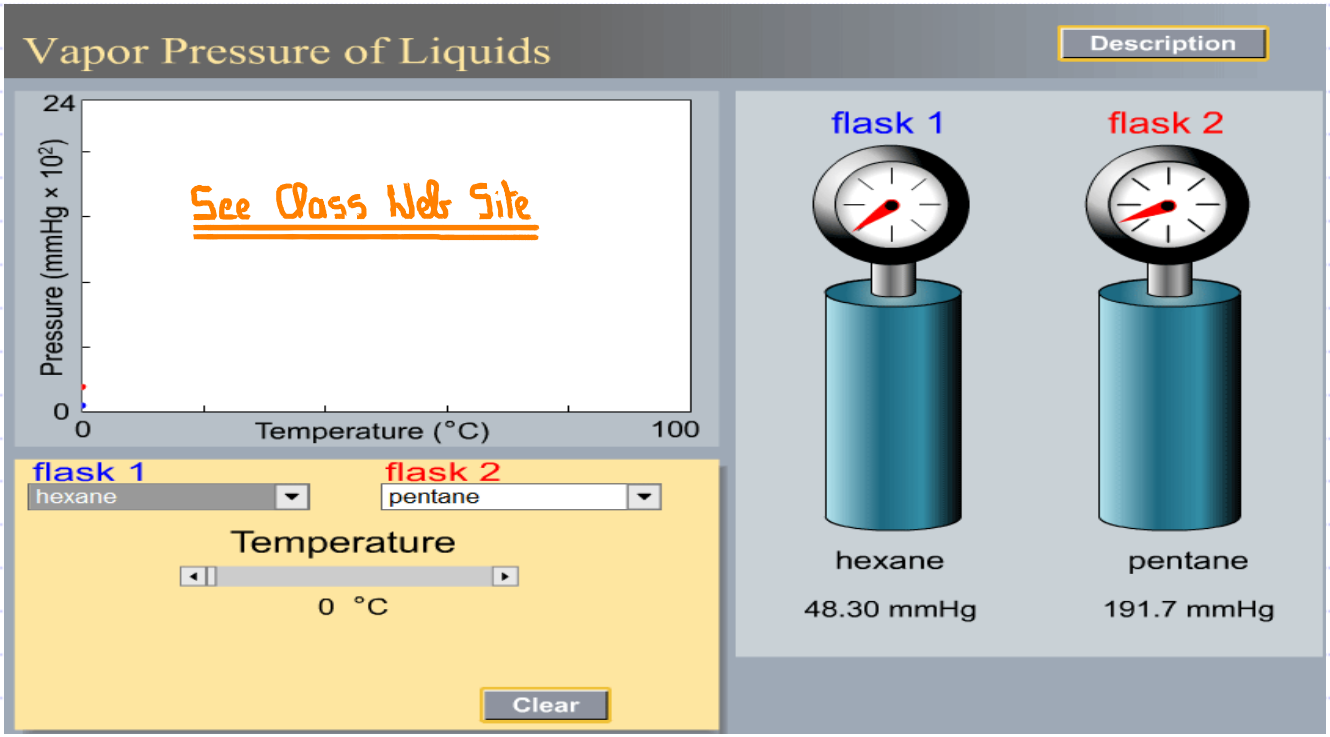
### London Dispersion Forces – Stronger than you might think

***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: $\Delta H^\circ_{VAP}$

**Which of the following molecules would you expect to have the smallest $\Delta H^\circ_{vap}$**

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 $\Delta H^\circ_{vap}$ – Clausius-Clapeyron Equation

$$\ln P = \frac{-\Delta H^\circ_{VAP}}{RT} + C$$

$\Delta H^\circ_{VAP}$ = 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

$$\text{Slope} = \frac{-\Delta H^\circ_{VAP}}{R}$$

b) QUANTITATIVELY :

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

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

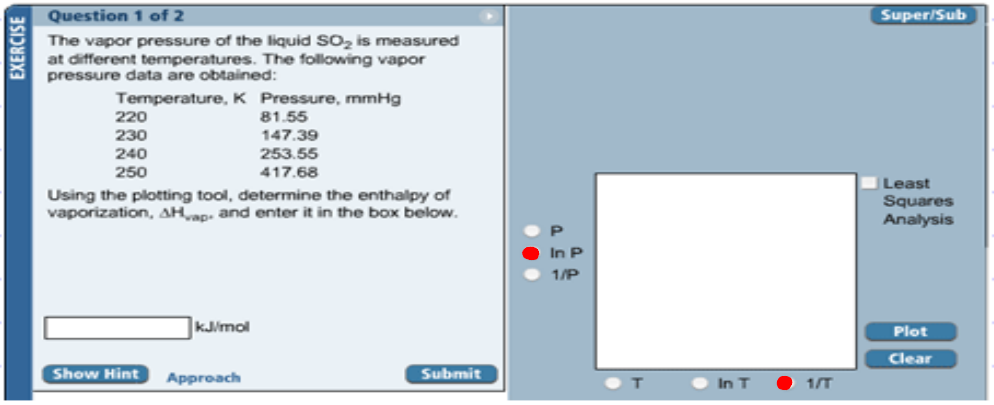
$$\ln P_2 - \ln P_1 = \frac{\Delta H^\circ_{VAP}}{RT_1} - \frac{\Delta H^\circ_{VAP}}{RT_2}$$

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

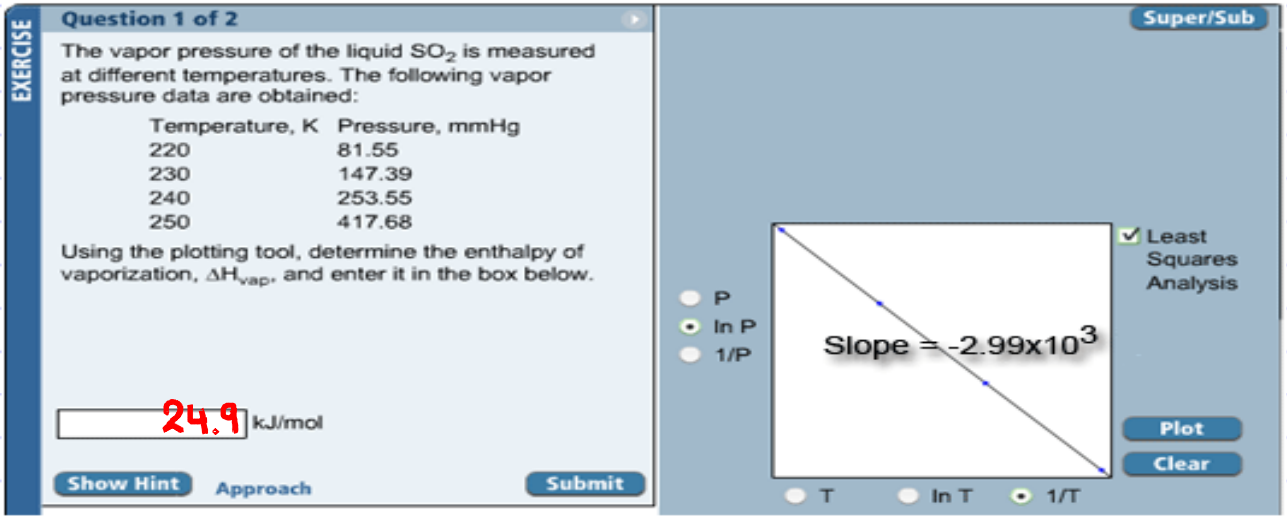
# 11.2 Vapor Pressure

## 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 |

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

$P_1 = 100$ $\quad T_1 = 315$

$P_2 = 400$ $\quad T_2 = 351$

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

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

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

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

OR

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

# 13.1 Quantitative Expressions of Concentration

## Units of Concentration – Molarity, Molality, Mole Fraction, Weight %

**Solution =** Solute + Solvent

→ that which is present in the greatest amount

### Molarity:

→ the only one you met in Chem 111

$$M = \frac{\text{Moles of solute}}{\text{Volume of the solution in L}}$$

DRAWBACK: We know nothing quantitative about the solvent.

### Mole Fraction:

$$X = \frac{\text{moles of solute}}{\text{moles of solute + moles of solvent}}$$

### Molality:

$$m = \frac{\text{moles of solute}}{\text{mass of solvent (kg)}}$$

DRAWBACK: We know nothing quantitative about the solution.

### Weight %:

$$\text{Wt \% of A} = \left(\frac{\text{mass of A}}{\text{mass of A + mass B + ...}}\right) 100$$