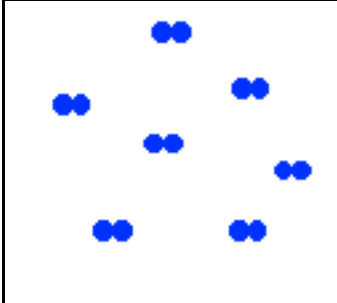

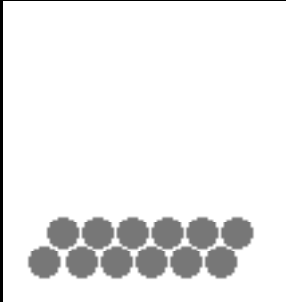


ALL work must be shown to receive full credit. **Due at the beginning of lecture on Wednesday, August 29, 2001.**

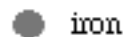
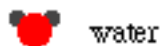
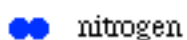
- PS1.1. Using the Pre-Lecture Exploration (<http://intro.chem.okstate.edu/PLE182201/PLMPhase.html>) #1 discussed in class as a source, explain why a gas condenses to a liquid as the temperature is lowered. Base your explanation in terms of the submicroscopic level.

As the temperature of a gas is lowered the kinetic energy of the molecules decreases, i.e. the particles begin to slow down. As the particles slow the collisions with other particles are less elastic as the attractive forces that exist between the particles becomes more important. Eventually the particles slow to such an extent that they begin to aggregate into collections/groups of many particles. The attractive forces are holding the particles together in groups. Condensation occurs as the number of particles that are attracted to each other increase.

- PS1.2. In the boxes below diagram the specified system as viewed at the atomic level in the space provided. Be sure to clearly label each of the substances in your diagram.

		
A sample of nitrogen at 25 °C	A sample of H ₂ O liquid	A sample of iron at 25 °C

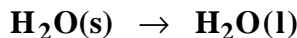
Label Area:



- PS1.3. Explain what the terms heat of fusion and heat of vaporization mean. Provide a chemical equation describing the fusion and vaporization process. Also explain how you could calculate the heat of fusion or heat of vaporization using the table of data in Appendix B on page A-5.

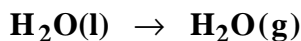
The heat of fusion is the amount of heat required to convert one mol of solid at its normal melting point to one mol of liquid. The heat of vaporization is the amount of heat required to convert one mol of liquid at its normal boiling point to one mol of gas.

A chemical equation which symbolizes the fusion process is;



We have to be a little careful here. Fusion is the phase change from liquid to solid (freezing), but the heat of fusion is generally thought of as the heat required to convert the solid into it liquid.

A chemical equation which symbolizes the vaporization process is;



To calculate either the heat of fusion or the heat of vaporization we can use the relationship;

$$\Delta H^{\circ}_{\text{rxn}} = S(\Delta H^{\circ}_{\text{f}}(\text{products})) - S(\Delta H^{\circ}_{\text{f}}(\text{reactants}))$$

So we can find the $\Delta H^{\circ}_{\text{f}}$ for reactants and the products in Appendix B. Finding the difference is the heat of fusion or heat of vaporization depending on the phases we use.

- PS1.4. a) How much heat is produced when 57.0 g of steam at 115 °C is converted to water at 15.0 °C?

Step 1) steam at 115°C to steam at 100°C.

Step 2) steam at 100°C to liquid at 100°C.

Step 3) liquid at 100°C to liquid at 15°C.

$$\begin{aligned} 1) \quad & 1.84 \frac{\text{J}}{\text{g}\cdot\text{C}} \times 57.0 \text{ g} \times 15^{\circ}\text{C} & = & 1570 \text{ J} & (1.57 \times 10^3 \text{ J}) \\ 2) \quad & 2259 \frac{\text{J}}{\text{g}} \times 57.0 \text{ g} & = & 129,000 \text{ J} & (1.29 \times 10^5 \text{ J}) \\ 3) \quad & 4.184 \frac{\text{J}}{\text{g}\cdot\text{C}} \times 57.0 \text{ g} \times 85^{\circ}\text{C} & = & 20300 \text{ J} & (2.03 \times 10^4 \text{ J}) \end{aligned}$$

Total heat released is $1.51 \times 10^5 \text{ J}$ or 151 kJ

- b) How much heat is required to convert 128.0 g of ice at -10.0 °C to liquid at 95.0 °C?

Step 1) solid at -10°C to solid at 0°C.

Step 2) solid at 0°C to liquid at 0°C.

Step 3) liquid at 0°C to liquid at 95°C.

$$\begin{aligned} 1) \quad & 2.09 \frac{\text{J}}{\text{g}\cdot\text{C}} \times 128.0 \text{ g} \times 10^{\circ}\text{C} & = & 2680 \text{ J} & (2.68 \times 10^2 \text{ J}) \\ 2) \quad & 334 \frac{\text{J}}{\text{g}} \times 128.0 \text{ g} & = & 42,800 \text{ J} & (4.28 \times 10^4 \text{ J}) \\ 3) \quad & 4.184 \frac{\text{J}}{\text{g}\cdot\text{C}} \times 128.0 \text{ g} \times 95^{\circ}\text{C} & = & 50,900 \text{ J} & (5.09 \times 10^4 \text{ J}) \\ & & = & 96.3 \text{ kJ} & \end{aligned}$$

PS1.5. Ethyl alcohol melts at $-114\text{ }^{\circ}\text{C}$ and boils at $78\text{ }^{\circ}\text{C}$. The enthalpy of vaporization for ethyl alcohol at $78\text{ }^{\circ}\text{C}$ is $870\frac{\text{J}}{\text{g}}$ and the enthalpy of fusion is $109\frac{\text{J}}{\text{g}}$. If the specific heat of solid ethyl alcohol is taken to be $0.97\frac{\text{J}}{\text{g}\cdot^{\circ}\text{C}}$, and that for the liquid $2.3\frac{\text{J}}{\text{g}\cdot^{\circ}\text{C}}$, how much heat is required to convert 10.0 g of ethyl alcohol at $-120\text{ }^{\circ}\text{C}$ to the vapor phase at $78\text{ }^{\circ}\text{C}$?

Step 1) solid at $-120\text{ }^{\circ}\text{C}$ solid to $-114\text{ }^{\circ}\text{C}$ soln

Step 2) solid at $-114\text{ }^{\circ}\text{C}$ to liquid at $-114\text{ }^{\circ}\text{C}$

Step 3) liquid $-114\text{ }^{\circ}\text{C}$ to liquid $78\text{ }^{\circ}\text{C}$

Step 4) liquid at $78\text{ }^{\circ}\text{C}$ to vapor at $78\text{ }^{\circ}\text{C}$

$$1) \quad 0.97\frac{\text{J}}{\text{g}\cdot^{\circ}\text{C}} \times 10.0\text{ g} \times 6^{\circ}\text{C} \quad = \quad 58.2\text{ J}$$

$$2) \quad 109\frac{\text{J}}{\text{g}} \times 10.0\text{ g} \quad = \quad 1090\text{ J}$$

$$3) \quad 2.3\frac{\text{J}}{\text{g}\cdot^{\circ}\text{C}} \times 10.0\text{ g} \times 192^{\circ}\text{C} \quad = \quad 4,416\text{ J}$$

$$4) \quad 870\frac{\text{J}}{\text{g}} \times 10.0\text{ g} \quad = \quad 8700\text{ J}$$

$$\text{Heat required} = 14\text{ kJ}$$

PS1.6. Define the term equilibrium vapor pressure.

the pressure due to particles of a substance in the vapor phase above its liquid in a closed container at a given temperature.

- b) Use a vapor-pressure table (check the Database link on the class web site) to look up the equilibrium vapor pressure of a sample of water at $90\text{ }^{\circ}\text{C}$ and at $80\text{ }^{\circ}\text{C}$.

The vapor pressure of water at $90\text{ }^{\circ}\text{C}$ is 525.8 mmHg and at $80\text{ }^{\circ}\text{C}$ the vapor pressure is 355.1 mmHg .

- c) Consider two closed containers each partially filled with liquid water one at $95\text{ }^{\circ}\text{C}$ and the other at $80\text{ }^{\circ}\text{C}$. Can the pressure of water vapor in the gas phase in either container ever exceed the equilibrium vapor pressure at the particular temperature? Explain why or why not.

No. At a given temperature we cannot have a pressure due to the vapor above a liquid greater than the equilibrium vapor pressure. If we attempt to add additional water, in the vapor phase, to a system already at equilibrium, the rate of condensation increases until the vapor pressure re-establishes equilibrium. The net result is there is no change in the vapor pressure.

PS1.7. A sample of water in the vapor phase (no liquid present) in a flask of constant volume exerts a pressure of 508 mm Hg at 100 °C. The flask is slowly cooled.

- a) Assuming no condensation, use the Ideal Gas Law to calculate the pressure of the vapor at 90 °C; at 80 °C.

$$\text{@90}^\circ\text{C } P_2 = \frac{P_1 \cdot T_2}{T_1} = \frac{508 \text{ mmHg} \cdot 363 \text{ K}}{373 \text{ K}} = 494 \text{ mmHg}$$

$$\text{@80}^\circ\text{C } P_2 = \frac{P_1 \cdot T_2}{T_1} = \frac{508 \text{ mmHg} \cdot 353 \text{ K}}{373 \text{ K}} = 481 \text{ mmHg}$$

- b) Will condensation occur at 90 °C; 80 °C?

The calculated pressure of the sample, assuming the sample is completely in the vapor at 90 °C is 494 mmHg. This is less than the equilibrium vapor pressure at 90 °C, 525 mmHg, so no condensation occurs. Condensation occurs at 80 °C because the calculate pressure exerted by the vapor (481 mmHg) is greater than the equilibrium vapor pressure at that temperature (355 mmHg).

- d) On the basis of your answers in a) and b), predict the pressure exerted by the water vapor at 90 °C; at 80 °C.

The pressure due to the vapor at 90 °C is 494 mmHg, at 80 °C the vapor pressure is 355 mmHg.

Can you determine the volume of water which has condensed at 80 °C?

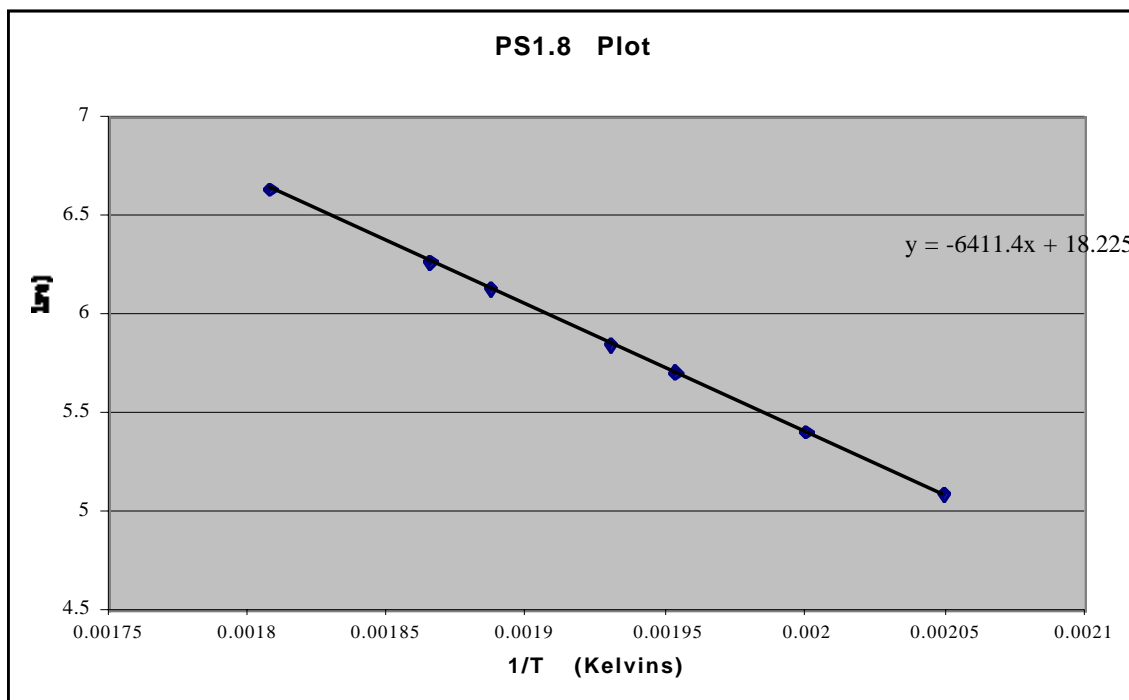
PS1.8. Consider the following data for the white phosphorus (P₄):

T(°C)	vapor pressure (mmHg)
215	162
227	222
239	300
245	346
257	459
263	525
280	759

- a) Use graphing software (Microsoft Excel) to plot $\ln(P_v)$ vs. $\frac{1}{T}$ for white phosphorus and use your graph to determine the slope of the best line through the data. The heat of vaporization of a liquid can be obtained from such a plot. The relationship is given as,

$$\text{slope} = -\frac{\Delta H^\circ_{\text{vap}}}{8.314 \frac{\text{J}}{\text{mol}\cdot\text{K}}}$$

Calculate the heat of vaporization for white phosphorus. (Note: Be sure to clearly label the graph.)



$$\text{Slope} = -6411 \text{ K}^{-1}$$

$$\text{slope} = -\frac{\Delta H^\circ_{\text{vap}}}{8.314 \frac{\text{J}}{\text{mol}\cdot\text{K}}}$$

$$-6411 \text{ K}^{-1} \cdot -8.314 \frac{\text{J}}{\text{mol}\cdot\text{K}} = \Delta H^\circ_{\text{vap}}$$

$$\Delta H^\circ_{\text{vap}} = 53.3 \text{ kJ}$$

b) Using the graph, determine the temperature of a sample of white phosphorus when the vapor pressure is 324 mmHg.

$$y = -6.41 \times 10^3 x + 18.2 \quad \text{or} \quad \ln(\text{vp}) = -6.41 \times 10^3 \left(\frac{1}{T} \right) + 18.2$$

$$\ln(324) = -6.41 \times 10^3 \left(\frac{1}{T} \right) + 18.2$$

$$5.78 = -6.41 \times 10^3 \left(\frac{1}{T} \right) + 18.2$$

$$6.41 \times 10^3 \left(\frac{1}{T} \right) = 18.2 - 5.78$$

$$\frac{1}{T} = \frac{12.4}{6.41 \times 10^3} = 1.94 \times 10^{-3} \quad T = 516 \text{ K}$$

c) Using the graph, determine the vapor pressure of a sample of white phosphorus at 270. °C.

$$y = -6.41 \times 10^3 x + 18.2 \quad \text{or} \quad \ln(\text{vp}) = -6.41 \times 10^3 \left(\frac{1}{T} \right) + 18.2$$

$$\ln(\text{vp}) = -6.41 \times 10^3 \left(\frac{1}{543} \right) + 18.2$$

$$\ln(\text{vp}) = 6.40$$

$$e^{\ln(\text{vp})} = e^{6.40}$$

$$\text{vp} = 599 \text{ mmHg}$$

PS1.9. The normal boiling point of acetone, $(\text{CH}_3)_2\text{CO}$ is 56.2°C and its $\Delta H^\circ_{\text{vap}} = 32.0 \frac{\text{kJ}}{\text{mol}}$. Draw a Lewis structure for acetone and calculate the temperature at which acetone has a vapor pressure of 415. mmHg.

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

$$\ln \frac{415}{760} = \frac{-32000 \frac{\text{J}}{\text{mol}}}{8.314 \frac{\text{J}}{\text{mol} \cdot \text{K}}} \left(\frac{1}{T_1} - \frac{1}{329.2\text{K}} \right)$$

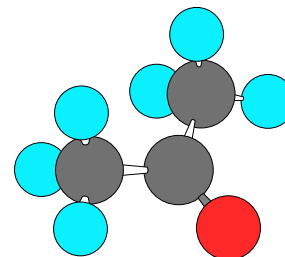
$$\ln (0.546) = -3848.9 \left(\frac{1}{T_1} - \frac{1}{329.2} \right)$$

$$-0.605 = -3848.9 \left(\frac{1}{T_1} - \frac{1}{329.2} \right)$$

$$1.57 \times 10^{-4} = \left(\frac{1}{T_1} - \frac{1}{329.2} \right)$$

$$\frac{1}{T_1} = 3.19 \times 10^{-3} \qquad T_1 = 313 \text{ K}$$

Lewis structure



b) Using data in part a of this problem, calculate the vapor pressure of acetone when the temperature is 25.0°C .

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

$$\ln \frac{\text{VP}}{760} = \frac{-32000 \frac{\text{J}}{\text{mol}}}{8.314 \frac{\text{J}}{\text{mol} \cdot \text{K}}} \left(\frac{1}{298} - \frac{1}{329.2\text{K}} \right)$$

$$\ln \frac{\text{VP}}{760} = -3848.9 (3.18 \times 10^{-4})$$

$$\ln \frac{\text{VP}}{760} = -1.224$$

$$e^{\ln \frac{\text{VP}}{760}} = e^{-1.224}$$

$$\frac{\text{VP}}{760} = 0.294$$

vapor pressure @ $25^\circ\text{C} = 223 \text{ mm Hg}$