Name _____ Chemistry ___/___/___

Gas Density, Vapor Pressure and Phase Diagrams

Calculating Gas Density

Density is defined as the ratio of the mass of a substance to its volume. In order to calculate the density of a gas, you use the gram formula mass and the volume of one mole of the substance at standard temperature and pressure (STP).

For example: Find the density of oxygen gas at STP.

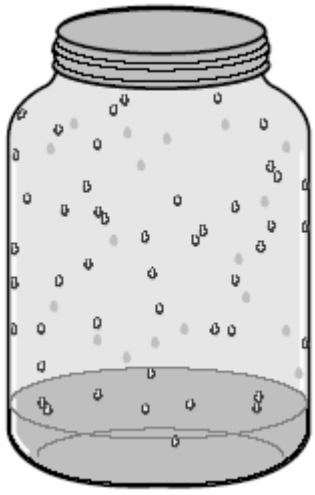
$$d = \frac{m}{v}$$

The gram formula mass of one mole of oxygen (O_2) is 32.0 grams
The volume of one mole of ANY gas at STP is 22.4 L.
To solve: 32.0 g / 22.4 L = **1.43 g/L**

Note that the unit is g/L. Earlier this year when you calculated the density of solids, the unit was g/mL. Gases are much less dense than solids, so the unit reflects this.

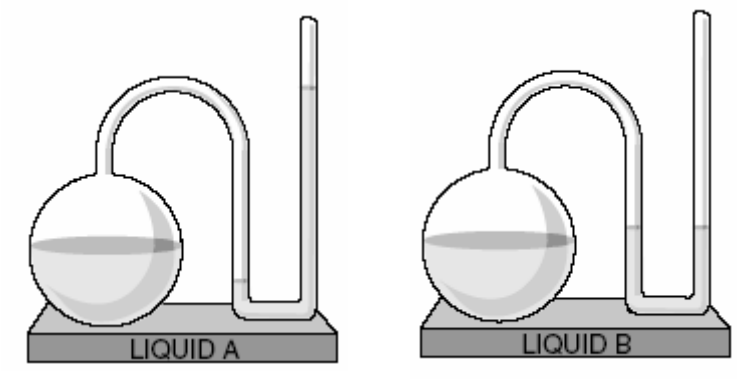
Vapor Pressure

The water level in a glass of water left out will gradually decrease until all of the water has evaporated. This vaporization of water molecules occurs as water molecules gain enough kinetic energy to overcome the attractive forces keeping them in the liquid. Remember that as one molecule evaporates, the particles left behind cool. In order to evaporate a particle must absorb energy. Once this happens, it changes state and the particles left behind have a lower average kinetic energy.



Evaporation in a closed container is different. As particles in a closed container vaporize, they collide with the walls of the container and exert a **vapor pressure** back onto the liquid particles. This pressure produced by the vaporized particles above the liquid in a sealed container on the liquid particles is called vapor pressure. In the process, water molecules continue to vaporize and a dynamic equilibrium results between the liquid and the vapor. At **dynamic equilibrium**, the rate of evaporation is equal to the rate of condensation and both occur simultaneously. The diagram to the right shows the dynamic equilibrium that results.

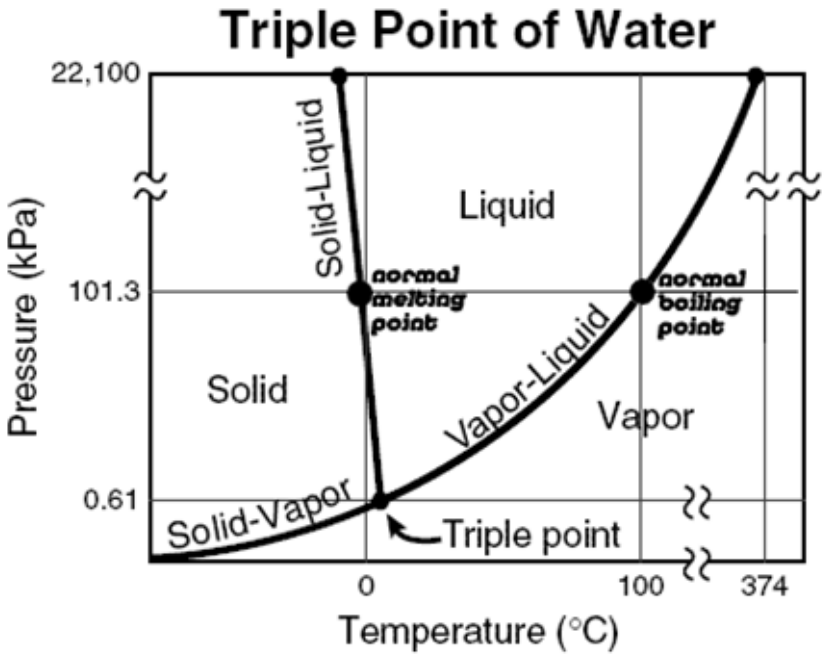
Scientists use an instrument called a manometer (pictured below) in order to measure the pressure exerted by a gas. By comparing the heights of the mercury in the U-tube, scientists can calculate a substance's vapor pressure. In the diagrams below, the first graphic shows a higher vapor pressure than the second. As temperature increases, the vapor pressure of a liquid also increases, so you can assume that the first liquid is at a higher temperature than the second.



The images to the left show two manometers in which liquid A has a higher vapor pressure than liquid B.

Phase Diagrams

A phase diagram is a graphic representation of the relationship between the physical state of a substance and its pressure and temperature. The phase diagram for water is shown below. A line that separates any two regions gives the conditions at which those two phases exist at equilibrium. Note how the three lines are labeled solid-vapor, solid-liquid and vapor liquid. The point at which the three segments meet is called the **triple point**. The triple point is the point on a phase diagram where all three states of a substance are present. For water, the triple point occurs when the pressure is 0.61 kPa and the temperature is 0.01°C.



A phase diagram can be used to determine the melting point and boiling point for a substance at various temperatures and pressures. The **normal melting point** of a substance is the temperature at which the solid and liquid states have the same vapor pressure under conditions where the total pressure is 101.3 kPa. For water, the normal melting point is 0°C. The **normal boiling point** is the temperature at which the vapor pressure of the liquid is exactly 101.3 kPa. For water, the normal boiling point is 100°C. As you can see from the diagram water can be made to melt or boil at temperature other than its normal melting and normal boiling points. **Boiling point** is the temperature at which the vapor pressure of a liquid is just equal to the external pressure. This phenomenon can be seen in ice skating where the pressure put on the ice by a skater causes ice to melt and form water. This water acts as a lubricant allowing skaters to move easily over the ice. When the pressure is off, the water refreezes.

Homework:

1. Calculate the density of each of the following gases at STP. Be sure to label each with the proper unit.

a. nitrogen _____	b. chlorine _____	c. methane (CH_4) _____
d. ammonia _____	e. sulfur dioxide _____	f. carbon monoxide _____
g. carbon dioxide _____	h. argon _____	i. helium _____

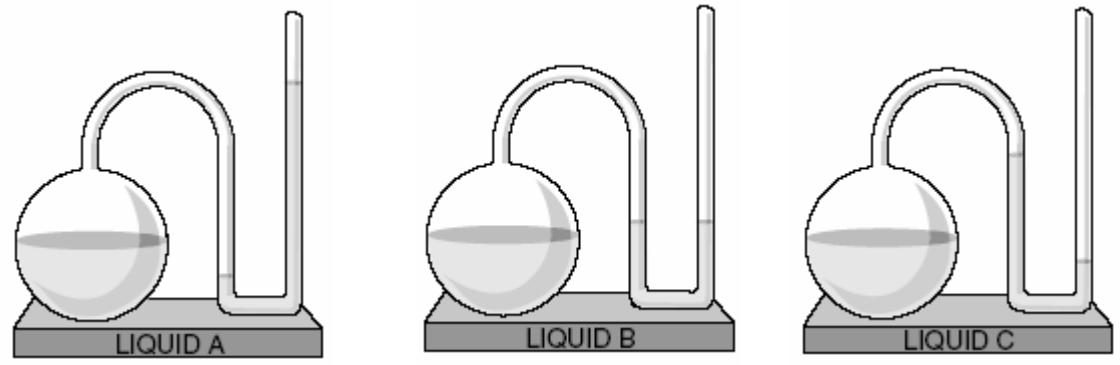
2. What is vapor pressure?

3. How is vapor pressure affected by an increase in temperature?

4. Draw a graph that shows the relationship between vapor pressure and temperature.

5. What is a manometer?

6. Equal quantities of different liquids are placed in closed manometers at 20°C. Which liquid has the highest vapor pressure?



7. Define triple point.

8. What are the triple point values of pressure and temperature for water?

9. Define normal melting point.

10. Define normal boiling point.

11. Define boiling point.

12. What is the difference between boiling point and normal boiling point? (Don't just tell me the definitions!)

13. What can be done to get a substance to boil below its normal boiling point?

14. On the diagram to the right, label all of the following: normal melting point, normal boiling point, solid, liquid, gas, triple point, the solid-vapor border, the liquid-vapor border and the solid-liquid border.