ANSWER KEY

Chapter 13-14 Cumulative Practice: Solids, Liquids, Gases

Chapter 13: KMT/Manometers/Partial Pressure/IMF/Liquids & Solids/Phase Changes/Phase Diagrams

1. List the **four** assumptions/characteristics made by the kinetic molecular theory (KMT) of gases:
   a. Tiny particles with kinetic energy moving in constant, rapid, random straight-line motion. Average kinetic energy is directly proportional to Kelvin temperature.
   b. Particle sizes are much smaller than distance between them. Most volume of gas is empty space and particles travel far apart from each other.
   c. No forces of attraction or repulsion (no IMF & no interaction) between particles and container wall upon collision.
   d. All collisions are perfectly elastic where there is no energy gained or lost during collision. (Law of Conservation of Energy)
2. What are the **four** factors that determine the physical behavior of gases?
   Pressure, volume, temperature, amount of gas (moles)
3. The greater the temperature, the more __Kinetic__ energy a gas will have.
4. A change in volume of a gas will change the amount of __moles__ and pressure of that gas.
5. The force per unit area is known as __pressure__.
6. List all the possible numerical **values AND its units** that can be used to describe 1atm pressure.
   760 mmHg / 760 Torr / 101.3 kPa / 14.7 psi = 1atm

Pressure Conversions:

a. 412 mmHg = __0.542__ atm

b. 760. KPa = __5.70×10^3__ mmHg

c. 14.7 atm = __1490__ kPa

★ d. 101.325 psi = __698__ kPa

e. 18.4 atm = __1.40×10^4__ mmHg

f. 383 Torr = __51.1__ kPa

Manometers:

1. In a ***closed end manometer***, the mercury level is 690. mm higher on the closed end than on the gas side. What is the pressure of the gas in **kPa?**

   * $P_{gas} = \text{"h"}$

   $$P_{gas} = \frac{690.\text{ mmHg}}{1} \times \frac{1\text{ atm}}{760\text{ mmHg}} \times \frac{101.3\text{ kPa}}{1\text{ atm}} \rightarrow \boxed{P_{gas} = 92.0\text{ kPa}}$$

2. ***Open end manometer***: atmospheric pressure is 760. mmHg, and the mercury level is 120. mm higher on the open end than the gas end. What is the gas pressure in **ATM?**

   * $P_{gas} = P_{atm} + \text{"h"} \rightarrow P_{gas} = (760.\text{ mmHg}) + (120.\text{ mmHg}) = 880.\text{ mmHg}$

   $$\frac{880.\text{ mmHg}}{1} \times \frac{1\text{ atm}}{760\text{ mmHg}} \rightarrow \boxed{P_{gas} = 1.16\text{ atm}}$$

3. ***Open end manometer***: atmospheric pressure is 101 kPa, and the level of mercury is 75.0 mm higher on the gas end. What is the gas pressure in **mmHg**?

   $$\frac{101\text{ kPa}}{1} \times \frac{1\text{ atm}}{101.3\text{ kPa}} \times \frac{760\text{ mmHg}}{1\text{ atm}} = 758\text{ mmHg}$$

   * $P_{gas} = P_{atm} - \text{"h"} \rightarrow P_{gas} = (758\text{ mmHg}) - (75.0\text{ mmHg}) \rightarrow \boxed{P_{gas} = 683\text{ mmHg}}$

Dalton's Law of Partial Pressure:

1. Define ***Dalton's Law of Partial Pressure*** →
   Total pressure of gases in a mixture is equal to the sum of the independent gas pressures in the mixture. → $P_{Total} = P_1 + P_2 + P_3 ...$
2. The total pressure in a closed container of three mixed gases is 76.6 kPa. The partial pressure of hydrogen in the mixture is 25.3 kPa and the partial pressure of oxygen is 32.3 kPa. The third gas in the mixture is methane; what is its partial pressure?

   * $P_{Total} = P_{H_2} + P_{O_2} + P_{CH_4} \rightarrow P_{CH_4} = P_{Total} - P_{H_2} - P_{O_2}$

   $P_{CH_4} = (76.6\ kPa) - (25.3\ kPa) - (32.3\ kPa) \rightarrow \boxed{P_{CH_4} = 19.0\ kPa}$

3. Find the total pressure **(in atm)** for a mixture that contains five gases with partial pressure of 54.3 kPa, 53.2 kPa, 35.9 kPa, 45.3 kPa, and 48.5 kPa.

   * $P_{Total} = P_1 + P_2 + P_3 + P_4 + P_5 \rightarrow P_{Total} = (54.3\ kPa) + (53.2\ kPa) + (35.9\ kPa) + (45.3\ kPa) + (48.5\ kPa) = 237.2\ kPa$

   $P_{Total} = 237.2\ kPa \rightarrow \frac{237.2\ kPa}{1} \times \frac{1\ atm}{101.3\ kPa} \rightarrow \boxed{P_{Total} = 2.34\ atm}$

4. What is the partial pressure of oxygen **(in mm Hg)** in a mixture of helium and oxygen if the total pressure is 543 mm Hg and the partial pressure of helium is 309 kPa?

   $\frac{309\ kPa}{1} \times \frac{1\ atm}{101.3\ kPa} \times \frac{760\ mmHg}{1\ atm} = 2318\ mmHg$

   * $P_{Total} = P_{He} + P_{O_2} \rightarrow P_{O_2} = P_{Total} - P_{He} \rightarrow P_{O_2} = (543\ mmHg) - (2318\ mmHg) \rightarrow \boxed{P_{O_2} = -1.78 \times 10^3\ mmHg}$

Intermolecular (Interparticle) Forces:

1. For the following substances, identify the type of substance as either ***ionic, polar covalent, non-polar covalent, metallic, or network ~~covalent~~ Solid.***
2. Determine the intermolecular (interparticle) force for each type of substance: ***H-bonding (H-B), dipole-dipole (D-D), ion-dipole (I-D), London Dispersion Force (LDF), Networks (NC), or Metallic (M).***
3. Rank the relative melting point for each substance from ***highest (1)*** to ***lowest (6).***
4. Rank the relative boiling point for each substance from ***highest (1)*** to ***lowest (6).***
5. Determine the conductivity for each substance: Choose from ***High, NONE, In Solution/Molten Liquid***
6. Determine the solubility for each substance: Choose from ***YES, NO, or Slight***

	Substance	Type of Substance	Strongest Interparticle Force	Relative Melting Point	Relative Boiling Point	Conductivity	Solubility
1)	PCl_5	NPC	LDF	5	5	None	No
2)	H_2O	PC	H-B	4	4	None	Slightly
3)	Fe_2O_3	Ionic	I-D	2	2	In Soln	Yes
4)	BF_3	NPC	LDF	6	6	None	Slightly
5)	C (diamond)	Network Solid	NC	1	1	In Soln	Yes
6)	Al	Metallic	M	3	3	High	No

Phase Changes & Phase Diagrams:

1. A phase change from a solid to a liquid is called melting.
2. The process by which a liquid changes to a gas is called vaporization.
3. Process by which a solid changes directly to a gas without becoming a liquid is called sublimation.

4. Temperature at which a liquid changes into a solid is called the freezing point.

5. Process by which a gas becomes a liquid is called Condensation.

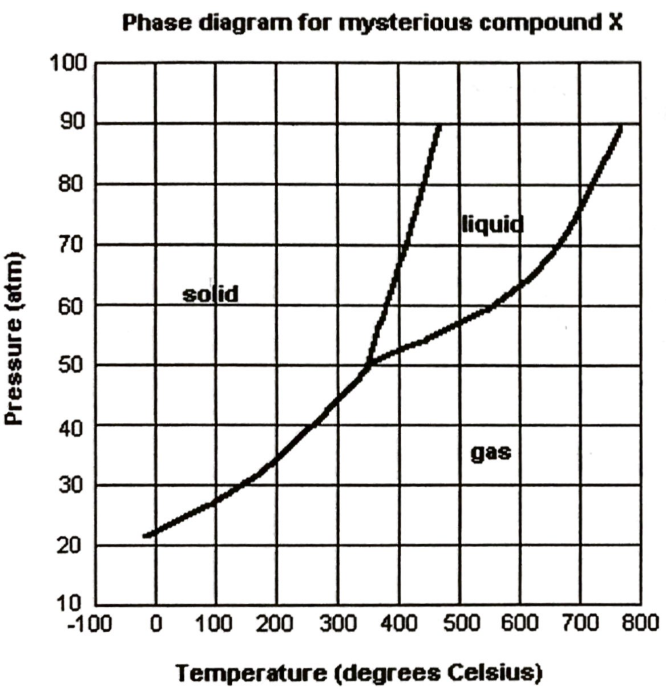
6. Process by which substance changes from gas to solid without first becoming a liquid is deposition.

7. What does a ***phase diagram*** describe →
Graph of pressure vs temperature showing which phase a substance can exist in under different conditions of pressure and temperature.

8. What is the ***triple point*** →
Represents pressure and temperature at which all three phases of a substance can coexist at equilibrium.

9. What is the ***critical point*** →
Pressure and temperature at which a liquid and gas are indistinguishable from one another. Beyond this point, the substance is called a supercritical fluid (Ex: CO_2 & H_2O)

For each of the questions below, refer to the phase diagram for mysterious compound "X".



10. If you had a bottle containing compound "X " in your closet under STP, what phase would it most likely be in? Explain.
Gas → @ STP, compound "X" is well below the sublimation/condensation interface.

11. At what temperature and pressure will all three phases coexist?
350°C @ ~51 atm (Triple Point)

12. If I have a bottle of compound "X" at a pressure of 45 atm and temperature of 100° C, what will happen if I raise the temperature to 400° C? ***(Specify phase change.)*** It will sublimate

13. If compound "X" is non-toxic, would you be able to drink it in the liquid form? Why or why not?
No; It would be way too hot; Lowest melting point temperature is 350°C.

14. If I have a bottle of compound X at a pressure of 70 atm and temperature of 750° C, what will happen if I lower the temperature to 600° C? ***(Specify phase change.)***
It will condense

hapter 14: Gas Laws (5)/Avogadro's Law/Gas Stoichiometry/Real Vs Ideal Gases

1. Gases behave differently based on conditions of pressure, volume, temperature, and the amount (moles) of a gas.

Boyle's Law Practice:

2. What is the formula for Boyle's Law? $P_1V_1 = P_2V_2$

3. Boyle's Law states that volume of a given amount of gas is inversely proportional with applied pressure.

4. What variable is kept constant in Boyle's Law? → Temperature

5. Air trapped in a cylinder fitted with a piston occupies 157.4 mL at 1.53 atm pressure. What is the new volume of air when the pressure is increased to 2.01 atm by applying force to the piston?

$$V_2 = \frac{P_1V_1}{P_2} \rightarrow V_2 = \frac{(1.53\text{ atm})(157.4\text{ mL})}{(2.01\text{ atm})} \rightarrow \boxed{V_2 = 120.\text{ mL}}$$

6. A balloon was inflated to a volume of 5.0 liters at a pressure of 0.90 atm. It rises to an altitude where its volume becomes 25.0 liters. What will be the new pressure?

$$P_2 = \frac{P_1V_1}{V_2} \rightarrow P_2 = \frac{(0.90\text{ atm})(5.0\text{ L})}{(25.0\text{ mL})} \rightarrow \boxed{P_2 = 0.18\text{ atm}}$$

7. A SCUBA diver inflates a balloon to 10.0 liters at the surface of the water, with air pressure of 1.0 atm, and takes it on a dive. At a depth of 100.0 feet the pressure increases to 4.0 atm. What was the new volume of the balloon?

$$V_2 = \frac{P_1V_1}{P_2} \rightarrow V_2 = \frac{(1.0\text{ atm})(10.0\text{ L})}{(4.0\text{ atm})} \rightarrow \boxed{V_2 = 2.5\text{ L}}$$

Charles's Law Practice:

1. What is the formula for Charles's Law? $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

2. Charles's Law states that the volume of a gas is directly proportional to the temperature.

3. What variable is kept constant in Charles's Law? → Pressure

4. What unit must be used for temperature in Charles's Law? → Kelvin (K)

5. The temperature inside my refrigerator is about 7°C. If I place a balloon in my fridge that initially has a temperature of 27°C and a volume of 0.95 liters, what will be the volume of the balloon when it is fully cooled by my refrigerator?

$$V_2 = \frac{V_1T_2}{T_1} \rightarrow V_2 = \frac{(0.95\text{ L})(280\text{ K})}{(300\text{ K})} \rightarrow \boxed{V_2 = 0.89\text{ L}}$$

6. When 50.0 liters of oxygen at 20.0°C is compressed to 5.00 liters, what is the new temperature to maintain constant pressure?

$$T_2 = \frac{V_2T_1}{V_1} \rightarrow T_2 = \frac{(5.00\text{ L})(293\text{ K})}{(50.0\text{ L})} \rightarrow \boxed{T_2 = 29.3\text{ K}}$$

7. A 50.0 mL soap bubble is blown in a 27.0°C room. It drifts out an open window and lands in a snow bank at 3.0°C. What is its new volume?

$$V_2 = \frac{V_1T_2}{T_1} \rightarrow V_2 = \frac{(50.0\text{ mL})(276\text{ K})}{(300\text{ K})} \rightarrow \boxed{V_2 = 46.0\text{ mL}}$$

Gay-Lussac's Law Practice:

1. What is the formula for Gay-Lussac's Law? $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

2. Gay-Lussac's Law states that the pressure of a gas is directly proportional to the temperature.

3. What variable is kept constant in Gay-Lussac's Law? → Volume

4. What unit must be used for temperature in Gay-Lussac's Law? → Kelvin (K)

5. The pressure in an automobile tire is 1.38 atm at 25.0°C. What will be the pressure if the temperature warms up to 41.0°C?

$$P_2 = \frac{P_1 T_2}{T_1} \rightarrow P_2 = \frac{(1.38\ \text{atm})(314\ \text{K})}{(298\ \text{K})} \rightarrow \boxed{P_2 = 1.45\ \text{atm}}$$

6. A rigid plastic container holds 1.00 L methane gas at 670 torr pressure when the temperature is 25.0°C. How much more pressure will the gas exert if the temperature is raised to 48.5°C?

$$P_2 = \frac{P_1 T_2}{T_1} \rightarrow P_2 = \frac{(670\ \text{Torr})(321.5\ \text{K})}{(298\ \text{K})} \rightarrow \boxed{P_2 = 720\ \text{Torr}}$$

7. A sample of gas at 3.00 x 10^3 mmHg inside a steel tank is cooled from 500.0°C to 5.00°C. What is the final pressure of the gas in the steel tank

$$P_2 = \frac{P_1 T_2}{T_1} \rightarrow P_2 = \frac{(3.00 \times 10^3\ \text{mmHg})(278\ \text{K})}{(773\ \text{K})} \rightarrow \boxed{P_2 = 1.08 \times 10^3\ \text{mmHg}}$$

Combined Gas Law Practice:

1. What is the formula for Combined Gas Law? $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

2. Combined Gas Law states the relationship among what **three** variables? Pressure, Volume, Temperature

3. What unit must be used for temperature in Combined Gas Law? → Kelvin (K)

4. A helium-filled balloon at sea level has a volume of 3.2 L at 1.32 atm and 39°C. If it is released and rises to an elevation at which the pressure is 1.01 atm and the temperature is 31°C, what will be the new volume of the balloon?

$$V_2 = \frac{P_1 V_1 T_2}{P_2 T_1} \rightarrow V_2 = \frac{(1.32\ \text{atm})(3.2\ \text{L})(304\ \text{K})}{(1.01\ \text{atm})(312\ \text{K})} \rightarrow \boxed{V_2 = 4.1\ \text{L}}$$

5. An unopened, cold 2.30 L bottle of soda contains 48.0 mL of gas confined at a pressure of 1.38 atm at a temperature of 5.6°C. If the bottle is dropped into a lake and sinks to a depth at which the pressure is 1.65 atm and the temperature is 2.39°C, what will be the volume of gas in the bottle?

$$V_2 = \frac{P_1 V_1 T_2}{P_2 T_1} \rightarrow V_2 = \frac{(1.38\ \text{atm})(48.0\ \text{mL})(275.39\ \text{K})}{(1.65\ \text{atm})(278.6\ \text{K})} \rightarrow \boxed{V_2 = 39.7\ \text{mL}}$$

6. A gas sample occupies 3.25 liters at 24.5°C and 1825 mmHg. Determine the temperature at which the gas will occupy a volume of 4.25 liters at 1750 mmHg.

$$T_2 = \frac{P_2 V_2 T_1}{P_1 V_1} \rightarrow T_2 = \frac{(1750\ \text{mmHg})(4.25\ \text{L})(297.5\ \text{K})}{(1825\ \text{mmHg})(3.25\ \text{L})} \rightarrow \boxed{T_2 = 373\ \text{K}}$$

Ideal Gas Law Practice:

1. What is the formula for Ideal Gas Law? $PV = nRT$

2. In the Ideal Gas Law, pressure can be expressed in what **three** units? → atm / mmHg / kPa

3. The units for volume in the Ideal Gas Law must be Liters (L).

4. The units for temperature in the Ideal Gas Law must be Kelvin (K).

5. What does ***"n"*** represent in the formula? The ***"R"***? → "n" = moles / "R" = Ideal Gas Constant

6. List the numerical values of "R" and its units that are used depending on which unit is used for pressure.

   a. atm = $0.0821 \frac{L \cdot atm}{mol \cdot K}$

   b. kPa = $8.314 \frac{L \cdot kPa}{mol \cdot K}$

   c. mmHg = $62.4 \frac{L \cdot mmHg}{mol \cdot K}$

7. Calculate the volume that a 0.463 mol sample of a gas will occupy at 285 K and a pressure of 0.990 atm.

$$V = \frac{nRT}{P} \rightarrow V = \frac{(0.463\ mol)(0.0821 \frac{L \cdot atm}{mol \cdot K})(285\ K)}{(0.990\ atm)} \rightarrow \boxed{V = 10.9\ L}$$

8. What is the pressure in atm of a 0.188 mol sample of helium gas at a temperature of 26.0°C if its volume is 0.701 L?

$$P = \frac{nRT}{V} \rightarrow P = \frac{(0.188\ mol)(0.0821 \frac{L \cdot atm}{mol \cdot K})(299\ K)}{(0.701\ L)} \rightarrow \boxed{P = 6.58\ atm}$$

9. At what temperature would 2.10 moles of N_2 gas have a pressure of 1.25 atm and in a 25.0 L tank?

$$T = \frac{PV}{nR} \rightarrow T = \frac{(1.25\ atm)(25.0\ L)}{(2.10\ mol)(0.0821 \frac{L \cdot atm}{mol \cdot K})} \rightarrow \boxed{T = 181\ K}$$

Gas Stoichiometry:

(Non-STP) 1. Ammonium sulfate, an important fertilizer, can be prepared by the reaction of ammonia gas and sulfuric acid to produce ammonium sulfate. Calculate the volume of ammonia (in Liters) needed at 20.0°C and 25.0 atm to react with 150. kg of sulfuric acid (H_2SO_4). $2\ NH_{3(g)} + 1\ H_2SO_4 \rightarrow 1\ (NH_4)_2SO_4$

① $\frac{150\ kg\ H_2SO_4}{1} \times \frac{1000\ g\ H_2SO_4}{1\ kg\ H_2SO_4} \times \frac{1\ mol\ H_2SO_4}{98.076\ g\ H_2SO_4} \times \frac{2\ mol\ NH_3}{1\ mol\ H_2SO_4} = 3058.9\ mol\ NH_3$

② $V = \frac{nRT}{P} \rightarrow V = \frac{(3.058\ mol)(0.0821 \frac{L \cdot atm}{mol \cdot K})(293\ K)}{(25.0\ atm)} \rightarrow \boxed{V = 2940\ L\ NH_3}$

(Non-STP) 2. Fritz Haber, a German scientist, discovered a way to synthesize ammonia gas (NH_3) by combining hydrogen and nitrogen gases at extremely high temperatures and pressures. If 10.0 kg of nitrogen combines with hydrogen at 550.°C and 250. atm, what volume (L) of ammonia gas is produced? $3\ H_{2(g)} + 1\ N_{2(g)} \rightarrow 2\ NH_{3(g)}$

① $\frac{10.0\ kg\ N_2}{1} \times \frac{1000\ g\ N_2}{1\ kg\ N_2} \times \frac{1\ mol\ N_2}{28.02\ g\ N_2} \times \frac{2\ mol\ NH_3}{1\ mol\ N_2} = 713.8\ mol\ NH_3$

② $V = \frac{nRT}{P} \rightarrow V = \frac{(713.8\ mol\ NH_3)(0.0821 \frac{L \cdot atm}{mol \cdot K})(823\ K)}{(250.\ atm)} \rightarrow \boxed{V = 193\ L\ NH_3}$

(STP) 3. Assume that 8.50 L of iodine gas (I_2) are produced, along with the production of potassium chloride, at STP, from the reaction of aqueous potassium iodide and chlorine gas, how many moles of iodine gas are produced?

$2\ KI + 1\ Cl_{2(g)} \rightarrow 2\ KCl + 1\ I_{2(g)}$

$\frac{8.50\ L\ I_2}{1} \times \frac{1\ mol\ I_2}{22.4\ L\ I_2} \rightarrow \boxed{0.379\ mol\ I_2}$