Unit 11: Gases

Name: KEY

Learning Target
1. I CAN explain the Kinetic Molecular Theory and how it predicts ideal gas behavior
2. I CAN convert between different temperatures (C and K) and pressures (mmHg, torr, atm, psi, and kPa)
3. I CAN describe conditions at absolute zero
4. I CAN define pressure and describe what causes it on a molecular level
5. I CAN calculate a total pressure of a gas mixture.
6. I CAN recall the conditions that result in STP
7. I CAN describe the relationships between volume, pressure, and temperature with a constant number of moles.
8. I CAN use the Ideal Gas Law (PV=nRT) to solve for an unknown variable.
9. I CAN apply the Combined Gas Law to describe how changes in variables affect the pressure, volume, temperature, and moles of a gas.

Chemistry Important Dates!						
Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
May 8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	June 1	2	3	4

Notes on Kinetic Molecular Theory (KMT)

Include drawings of each state of matter. Make sure to write all Ideal Gas assumptions and examples.

Practice of Kinetic Molecular Theory—Complete the following chart:

State of Matter	Solid	Liquid	Gas
Energy	low KE	medium KE	high KE
Particle Movement	vibrations	slipping	fast, erratic
Particle Spacing	closely packed	medium spacing	far apart
Volume	defined	defined	undefined
Shape	defined	undefined	undefined

Notes on Standard Temperature and Conversions

What the Standard Temperature and Pressure are for gases? What is Absolute Zero? How do you convert from Celsius to Kelvin?

Practice with Temperature Calculations:

1. A person with hypothermia has a body temperature of 297 K. What is the body temperature in °C?

$K = °C + 273$

$297\,K - 273 = °C$

$°C = 24°C$

2. A person with hypothermia has a body temperature of 29.1 °C. What is the body temperature in K?

$K = °C + 273$

$K = 29.1°C + 273$

$K = 302.1\ K$

3. Standard Temperature and Pressure: 273 K and 1 atm

4. All temperatures in gas-related problems must be in units of Kelvin.

5. Absolute zero is Ø Kelvin. Describe the behavior of molecules at this temperature:

In theory, molecules no longer move. Even solids stop vibrating.

Notes on Pressure and Conversions

What is the definition of pressure? Include all units of pressure (names and abbreviations) and equivalences.

Practice with Pressure and Conversions. Show all work for the conversions!

1. What causes gases to have pressure?
   The gas molecules colliding with the sides of the container exerts a force over a given area. This force is pressure!

2. 1120 torr = 1120 mmHg

$$1120 \text{ torr} \times \frac{760 \text{ mmHg}}{760 \text{ torr}} = 1120 \text{ mmHg}$$

3. 4.3 atm = 440 kPa

$$4.3 \text{ atm} \times \frac{101.325 \text{ kPa}}{1 \text{ atm}} = 440 \text{ kPa}$$

4. 2.5 atm = 1900 mmHg

$$2.5 \text{ atm} \times \frac{760 \text{ mmHg}}{1 \text{ atm}} = 1900 \text{ mmHg}$$

5. Dalton's Law of Partial Pressures states that the total pressure of a gas mixture is the sum of all individual pressures of the gases in the mixture, if they are in equal parts. $P_{total} = P_{gas\ A} + P_{gas\ B} + P_{gas\ C} + \ldots\ldots$

   What is the total pressure (in atm) of a container that contains Helium gas at 750 torr, Oxygen gas at 120 mmHg, and Nitrogen gas at 3.2 atm?

$$P_{total} = P_{He} + P_{O_2} + P_{N_2}$$

$$P_{total} = \left(750 \text{ torr} \times \frac{1 \text{ atm}}{760 \text{ torr}}\right) + \left(120 \text{ mmHg} \times \frac{1 \text{ atm}}{760 \text{ mmHg}}\right) + 3.2 \text{ atm}$$

$$P_{total} = 4.4 \text{ atm}$$

Notes on Ideal Gas Law

Ideal Gas Law Practice. **SHOW ALL WORK.**

1. How many moles of oxygen will occupy a volume of 2.5 liters at 1.2 atm and 25°C?

$P = 1.2\,atm$
$V = 2.5\,L$
n
$T = 25°C$

$$n = \frac{PV}{RT} \qquad n = \frac{(1.2\,atm \times 2.5\,L)}{(0.0821 \frac{L \cdot atm}{mol \cdot K} \times 298\,K)}$$

$$\boxed{n = 0.12\,mol}$$

2. What volume will 2.0 moles of nitrogen occupy at 720 torr and 20. °C?

$P = 720\,torr$
V
$n = 2.0\,mol$
$T = 20°C$

$$V = \frac{nRT}{P} \qquad V = \frac{(2.0\,mol \times 0.0821 \frac{L \cdot atm}{mol \cdot K} \times 293K)}{(720\,torr \times \frac{1\,atm}{760\,torr})}$$

$$\boxed{V = 51\,L}$$

3. What pressure will be exerted by 25 g of CO_2 at 25°C and a volume of 500.0 mL?

P
$V = 500.0\,mL$
$n = 25\,g\,CO_2$
$T = 25°C$

$$P = \frac{nRT}{V} \qquad P = \frac{\left[\left(25\,g\,CO_2 \times \frac{1\,mol\,CO_2}{44.01\,g\,CO_2}\right) \times 0.0821 \frac{L \cdot atm}{mol \cdot K} \times 298\,K\right]}{0.5000\,L}$$

$$\boxed{P = 28\,atm}$$

4. Find the number of grams of CO_2 that exert a pressure of 785 torr at a volume of 32.5 L and a temperature of 32 °C.

$P = 785\,torr$
$V = 32.5\,L$
n
$T = 32°C$

$$n = \frac{PV}{RT} \qquad n = \frac{\left[\left(785\,torr \times \frac{1\,atm}{760\,torr}\right) \times 32.5\,L\right]}{(0.0821 \frac{L \cdot atm}{mol \cdot K} \times 305\,K)}$$

$$n = 1.3\,mol\,CO_2$$

$$1.3\,mol\,CO_2 \times \frac{44.01\,g\,CO_2}{1\,mol\,CO_2} = \boxed{57.\,g\,CO_2}$$

Ideal Gas Law Practice

1. At what temperature will 5.00 g of Cl_2 exert a pressure of 900. Torr at a volume of 750. mL?

$T = \frac{PV}{nR}$ $\quad T = \frac{\left[\left(900\ torr \times \frac{1\ atm}{760\ torr}\right) \times 0.750\ L\right]}{\left[\left(5.00\ g\ Cl_2 \times \frac{1\ mol\ Cl_2}{70.90\ g\ Cl_2}\right) \times 0.0821\ \frac{L \cdot atm}{mol \cdot K}\right]}$ $\quad$ **T = 153 K**

2. How many moles of nitrogen gas will occupy a volume of 347 mL at 6680 torr and 27 °C?

$n = \frac{PV}{RT}$ $\quad n = \frac{\left[\left(6680\ torr \times \frac{1\ atm}{760\ torr}\right) \times 0.347\ L\right]}{\left(0.0821\ \frac{L \cdot atm}{mol \cdot K} \times 300\ K\right)}$ $\quad$ **n = 0.12 mol**

3. What volume will 454 grams (1 lb) of hydrogen gas occupy at 1.05 atm and 25 °C?

$V = \frac{nRT}{P}$ $\quad V = \frac{\left[\left(454\ g\ H_2 \times \frac{1\ mol\ H_2}{2.02\ g\ H_2}\right) \times 0.0821\ \frac{L \cdot atm}{mol \cdot K} \times 298\ K\right]}{1.05\ atm}$ $\quad$ **V = 5200 L**

4. If the density of a gas is 1.2 g/L at 745 torr and 20. °C, what is its molar mass?

$n = \frac{PV}{RT}$ $\quad n = \frac{\left[\left(745\ torr \times \frac{1\ atm}{760\ torr}\right) \times 1\ L\right]}{\left(0.0821\ \frac{L \cdot atm}{mol \cdot K} \times 293 K\right)}$ $\quad n = 0.0408\ mol$

$\text{Molar mass} = \frac{1.2\ g}{0.0408\ mol}$ $\quad$ **MM = 29 g/mol**

5. What is the density of NH_3 at 800. Torr and 25 °C? *(Hint: Density is measured in g/L)*

$n = \frac{PV}{RT}$ $\quad n = \frac{\left[\left(800.\ torr \times \frac{1\ atm}{760\ torr}\right) \times 1\ L\right]}{\left(0.0821\ \frac{L \cdot atm}{mol \cdot K} \times 298 K\right)}$ $\quad n = 0.043\ mol$

$0.043\ mol\ NH_3 \times \frac{17.04\ g\ NH_3}{1\ mol\ NH_3} = 0.7$

Density = 0.73 g/L

6. An elemental gas has a mass of 10.3 g. If the volume is 58.4 L and the pressure is 758 torr at a temperature of 2.5 °C, what is the gas?

$n = \frac{PV}{RT}$ $\quad n = \frac{\left[\left(758\ torr \times \frac{1\ atm}{760\ torr}\right) \times 58.4 L\right]}{\left(0.0821\ \frac{L \cdot atm}{mol \cdot K} \times 275.5 K\right)}$ $\quad n = 2.58\ mol$

$\text{Molar mass} = \frac{10.3\ g}{2.58\ mol}$ $\quad MM = 4.00\ g/mol$ $\quad$ **Helium**

The Tanker Scenario

BEFORE	AFTER
P =	P =
V=	V=
n =	n =
T=	T=

Combined Gas Law Practice. Complete the following table. Show all of your work!

	P_1	V_1	n_1	T_1	P_2	V_2	n_2	T_2
①	600. mmHg	0.84 L	2.2 mol	22 °C	760 mmHg	1.8 L	6.4 mol	2.5°C
②	1.2 atm	750 mL	1.0 mol	0.0 °C	2.0 atm	500. mL	1.0 mol	25 °C
③	1.5 atm	3.0 L	1.0 mol	20.°C	2.5 atm	1.9L	1.0 mol	30. °C

① $\frac{P_1V_1}{P_2V_2} = \frac{n_1R_1T_1}{n_2R_2T_2}$ $V_1 = \frac{P_2V_2n_1R_1T_1}{P_1n_2R_2T_2}$ $V_1 = \frac{(1\text{atm} \times 1.8\text{L} \times 2.2\text{mol} \times 295\text{K})}{(0.789\text{ atm} \times 6.4\text{mol} \times 275.5\text{K})}$

② $\frac{P_1V_1}{P_2V_2} = \frac{n_1R_1T_1}{n_2R_2T_2}$ $P_1 = \frac{P_2V_2n_1R_1T_1}{V_1n_2R_2T_2}$ $P_1 = \frac{(2.0\text{ atm} \times 0.500\text{L} \times 273\text{K})}{(0.75\text{L} \times 298\text{K})}$

③ $\frac{P_1V_1}{P_2V_2} = \frac{n_1R_1T_1}{n_2R_2T_2}$ $V_2 = \frac{P_1V_1n_2R_2T_2}{P_2n_1R_1T_1}$ $V_2 = \frac{(1.5\text{atm} \times 3.0\text{L} \times 303\text{K})}{(2.5\text{atm} \times 293\text{K})}$

Pressure and Volume Relationship ***Assume all scenarios are at a constant temperature with a constant amount of moles.**

1. A sample of oxygen gas occupies a volume of 250. mL at 740. Torr pressure. What volume will it occupy at 800. Torr pressure?

$\frac{P_1V_1}{P_2V_2} = \frac{n_1R_1T_1}{n_2R_2T_2}$ $\frac{P_1V_1}{P_2} = V_2$ $\frac{(0.974\,atm \times 0.250L)}{1.05\,atm} = V_2$ **$V_2 = 0.232L$**

2. A 2.0 Liter container of nitrogen had a pressure of 3.2 atm. What volume would be necessary to decrease the pressure to 1.0 atm?

$\frac{P_1V_1}{P_2} = V_2$ $\frac{(3.2\,atm \times 2.0L)}{1.0\,atm} = V_2$ **$V_2 = 6.4L$**

3. A sample of hydrogen at 1.5 atm had its pressure decreased to 0.50 atm producing a new volume of 750 mL. What was its original volume?

$V_1 = \frac{P_2V_2}{P_1}$ $\frac{(0.50\,atm \times 0.75\,L)}{1.5\,atm} = V_1$ **$V_1 = 0.25\,L$**

Temperature and Volume Relationship ***Assume all scenarios are at a constant pressure with a constant amount of moles.**

4. A sample of nitrogen occupies a volume of 250 mL at 25 °C. What volume will it occupy at 95°C?

$\frac{P_1V_1}{P_2V_2} = \frac{n_1R_1T_1}{n_2R_2T_2}$ $V_2 = \frac{V_1T_2}{T_1}$ $\frac{(0.25\,L \times 468K)}{298K} = V_2$ **$V_2 = 0.39\,L$**

5. Oxygen gas is at a temperature of 40. °C when it occupies a volume of 2.3 liters. To what temperature should it be raised to occupy a volume of 6.5 L?

$T_2 = \frac{V_2T_1}{V_1}$ $\frac{(6.5L \times 313K)}{2.3L} = T_2$ **$T_2 = 880K$**

6. Chlorine gas occupies a volume of 25 mL at 300. K. What volume will it occupy at 600. K?

$V_2 = \frac{V_1T_2}{T_1}$ $\frac{(0.025\,L \times 600K)}{300.K} = V_2$ **$V_2 = 0.050L$**

7. In order to decrease the pressure, 400.0 L of gas at 35 atm is moved to a new container. What is the volume of the new container if the pressure becomes 905 mmHg?

$\frac{P_1V_1}{P_2V_2} = \frac{n_1R_1T_1}{n_2R_2T_2}$ $V_2 = \frac{P_1V_1}{P_2}$ $\frac{(35atm \times 400.0L)}{1.19atm} = V_2$ **$V_2 = 12{,}000L$**

8. A scientist collects 400.0 mL of gas at 20.0 °C and 1atm. What is the volume of the gas at STP? How many moles of gas are in the container at STP? (remember: 1 mole=22.4L at STP)

$\frac{P_1V_1}{P_2V_2} = \frac{n_1R_1T_1}{n_2R_2T_2}$ $V_2 = \frac{P_1V_1T_2}{T_1P_2}$ $\frac{(1\,atm \times 0.4000L \times 273K)}{(293K \times 1atm)}$ **$V_2 = 0.37L$**

$0.37L \times \frac{1\,mol}{22.4L} =$ **$n = 0.017mol$**

Gases Practice Test

1. Convert 3.6×10^2 atm to torr.

2. A balloon has a volume of 1.20 L at 24.0°C. The balloon is heated to 48.0°C. Calculate the new volume of the balloon.

3. A sample of helium gas occupies 2.65 L at 1.20 atm. What pressure would this sample of gas exert in a 1.50L container at the same temperature?

4. A gas has a volume of 5.0 L at a certain pressure. How must the pressure be changed to double the volume of the gas at constant temperature?

a. The pressure must be doubled.
b. The pressure must be halved.
c. The pressure must be quadrupled.
d. There is not enough information to decide.
e. none of these

5. A helium balloon has a volume of 2.30 L at 23.5°C and a pressure of 1.00 atm at sea level. The balloon is released and floats upward. At a certain height the atmospheric pressure is 0.810 atm and the temperature is 12.0°C. Calculate the volume of the balloon.

a. 2.73 L b. 2.84 L c. 1.45 L d. 2.21 L e. none of these

6. A 6.5 L sample of nitrogen at 25°C and 1.5 atm is allowed to expand to 13.0 L. The temperature remains constant. What is the final pressure?

a. 0.063 atm b. 0.12 atm c. 0.75 atm d. 3.0 atm e. 0.38 atm

7. You transfer a sample of a gas at 17°C from a volume of 5.67 L and 1.10 atm to a container at 37°C that has a pressure of 1.10 atm. What is the new volume of the gas?

8. Gaseous chlorine is held in two separate containers at identical temperature and pressure. The volume of container 1 is 1.30 L, and it contains 6.70 mol of the gas. The volume of container 2 is 2.20 L. How many moles of the gas are in container 2?

a. 11.3 mol b. 19.2 mol c. 0.427 mol d. 3.96 mol e. none of these

9. If temperature and pressure are held constant, the volume and number of moles of a gas are

a. independent of each other
b. directly proportional
c. inversely proportional
d. equal

10. A sample of an ideal gas containing 0.954 mol is collected at 742 torr pressure and 31°C. Calculate the volume.

11. A gas originally occupying 10.1 L at 0.925 atm and 25°C is changed to 12.2 L at 625 torr. What is the new temperature?

12. Which of the following statements is true of 19.0 g of $F_{2(g)}$ at STP?

a. It contains 6.02×10^{23} molecules.
b. It contains the same number of molecules as 1/2 mol of $O_{2(g)}$ at STP.
c. It occupies a volume of 22.4 L.
d. It only exists in the form of ions.
e. none of the above

13. A 4.37-g sample of a certain diatomic gas occupies a volume of 3.00 L at 1.00 atm and a temperature of 45°C. Identify this gas.

a. F_2 b. N_2 c. H_2 d. O_2 e. Cl_2

14. A 25.0-L sample of gas at STP is heated to 55°C at 605 torr. What is the new volume?

15. What volume will 28.0 g of N_2 occupy at STP?

a. 5.60 L b. 11.2 L c. 22.4 L d. 44.8 L e. none of these

16. A vessel with an internal volume of 10.0 L contains 2.80 g of nitrogen gas, 0.403 g of hydrogen gas, and 79.9 g of argon gas. At 25°C, what is the pressure (in atm) inside the vessel?

a. 0.471 atm b. 6.43 atm c. 3.20 atm d. 5.62 atm e. 2.38 atm

17. What would happen to the average kinetic energy of the molecules of a gas sample if the temperature of the sample increased from 20°C to 40°C?

a. It would double.
b. It would increase.
c. It would decrease.
d. It would become half its value.
e. Two of these

Answers:

1) 270,000 torr
2)1.3L
3)2.12atm
4)b
5)a
6)c
7)6.06 L
8)a
9)b
10)24.4L
11)319.9K
12)b
13)a
14)38 L
15)c
16)d
17)b