The Kinetic Molecular Theory and Gases **Name** KEY **Period**_____

1. Which of the following is not an assumption of the kinetic molecular theory of a gas?

   ✓ A. Gases are made up of tiny particles in constant, chaotic motion.

   ✓ B. Gas particles are very small compared to the average distance between the particles.

   ✓ C. Gas particles collide with the walls of their container in elastic collisions.

   * this is true → D. The average velocity of the gas particles is directly proportional to the absolute temperature. → $\mu_{rms} = \sqrt{\frac{3RT}{M}}$ ← molar mass in kg

   E. All of the above are correct.

BUT is not mentioned in the KMT! Tricky :)

2-4. Consider three 1 L flasks at STP. Flask A contains NH_3 gas, flask B contains NO_2 gas, and flask C contains N_2 gas.

If $V_1 = V_2 = V_3$, $T_1 = T_2 = T_3$, $P_1 = P_2 = P_3$, then $n_1 = n_2 = n_3$

2. Which contains the largest number of molecules?

   A. flask A

   B. flask B

   C. flask C

   → D. all are the same

   E. none

$PV = nRT$

$n = \frac{PV}{RT}$ → this is the same for all

3. In which flask are the molecules least polar and therefore most ideal in behavior?

Can't ask this yet!

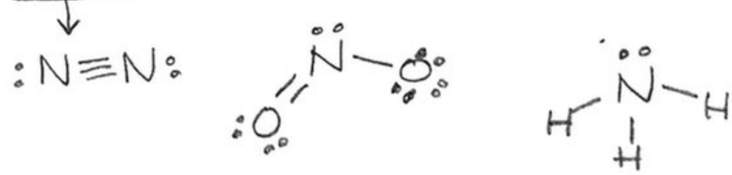
   A. flask A

   B. flask B

   → C. flask C

   D. all are the same

   E. none



4. In which flask do the molecules have the highest average kinetic energy?

   A. flask A

   B. flask B

   C. flask C

   → D. all are the same

   E. none

Same T means same KE

5. Which conditions of P, T, and *n*, respectively, are most ideal? → no attractions between particles

   A. high P, high T, high *n*

   B. low P, low T, low *n*

   C. high P, low T, high *n*

   D. low P, high T, high *n*

   → E. low P, high T, low *n* → • least Intermolecular attractions • negligible volume of gas particles

6. In which of the following is it impossible to predict whether the pressure of a gas will increase, decrease, or stay the same?

   A. A gas sample is heated. ↑T, ↑P

   → B. A gas sample is heated, and the volume is increased. → ↑T would ↑P, ↑V would ↓P

   C. A gas sample is cooled and some gas is withdrawn. (↓P, ↓P)

   D. Additional gas is added to a sample of gas. ↑P

   E. A gas sample is cooled, and the volume is increased. (↓P, ↓P)

7. Calculate the density of bromine at STP.

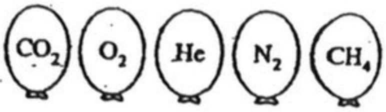
$D = \frac{M}{V} = \frac{\text{molar mass}}{\text{molar volume}} = \frac{159.80\,g}{22.4\,L} = 7.13\,g/L$

$D = \frac{MP}{RT} = \frac{(159.80)(1)}{(.08206)(273)} = 7.10\,g/L$

8. What volume will 150.0 g of NO_2 occupy at 750 mmHg and 30.0 C?

$PV = nRT$

$V = \frac{nRT}{P}$ → $V = \frac{\left(\frac{150.0\,g}{46.01\,g/mol}\right)\left(62.4\,\frac{mmHg \cdot L}{mol \cdot K}\right)(303\,K)}{750\,mmHg} = 82.2\,L$



$V_1 = V_2$, $P_1 = P_2$, $T_1 = T_2$ } so $n_1 = n_2$

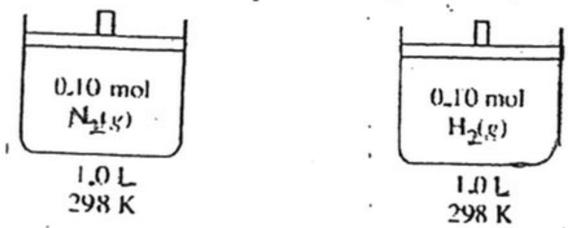
9. Represented above are five identical balloons, each filled to the same volume at 25 C and1.0 atm pressure with the pure gases indicated.

A. Which balloon contains the greatest mass of gas? Explain. → CO_2. Each balloon contains same # of molecules. CO_2 is the heaviest of the molecules.

B. Compare the average kinetic energies of the gas molecules in the balloons. Explain. Same T, same KE

C. Which balloon contains the gas that would be expected to deviate most from the behavior of an ideal gas? Explain. CO_2. All of the particles are nonpolar. Since CO_2 has greatest molar mass, it has the strongest IMFs. (would not ask yet)

D. Twelve hours after being filled, all the balloons have decreased in size. Predict which balloon will be the smallest. Explain the reasoning. He will be smallest balloon as He is the smallest particle and will have the greatest rate of effusion.



10. Consider two containers of volume 1.0 L at 298 K, as shown above. One container holds 0.10 mole N_2 (g) and the other holds 0.10 mole H_2 (g). The average KE of the N_2 molecules is 6.2×10^{-21} J. Assume that the N_2 and the H_2 exhibit ideal behavior.

A. Is the pressure in the container holding the H_2 less than, greater than, or equal to the pressure in the container holding the N_2? Justify your answer. (equal) $PV = nRT$, $P = \frac{nRT}{V}$ → same for both gases

B. What is the average KE of the H_2 molecules? 6.2×10^{-21} J → Same T, same KE

C. The molecules of which gas, N_2 or H_2, have the greater average speed? Justify your answer. (H_2) $KE = \frac{1}{2}mv^2$ or $\mu_{rms} = \sqrt{\frac{3RT}{M}}$

D. What change could be made that would decrease the average KE of the N_2 molecules in the container? ↓T Kinetic energy is directly proportional to Kelvin temp. $KE = \frac{3}{2}RT$

E. If the volume of the container holding the H_2 was decreased to 0.50 L at 298 K, what would be the change in each of the following variables? In each case, justify your answer.

(i) The pressure within the container → ↓V, ↑P (Boyle's Law) → particles would collide with walls of container more often. (double P)

(ii) The average speed of the H_2 molecules

↓V, no effect on speed → velocity is related to Temp or KE → $KE = \frac{1}{2}mv^2$ → $\mu_{rms} = \sqrt{\frac{3RT}{M}}$

FRQs from College Board

1.) a) $\frac{24.5\text{ g } N_2}{1} \times \frac{1\text{ mol}}{28.02\text{ g}} = .874\text{ mol } N_2$

$\frac{28.0\text{ g } O_2}{1} \times \frac{1\text{ mol}}{32.00\text{ g}} = .875\text{ mol } O_2$

1.75 moles total

$V = 5.00\text{ L}$
$n = 3.50\text{ mol}$
$T = 298\text{ K}$

$$P = \frac{nRT}{V} = \frac{(1.75)(.08206)(298)}{5.00} = \boxed{8.56\text{ atm}}$$

b) i) $$X_{N_2} = \frac{\text{moles } N_2}{\text{moles total}} = \frac{.874}{1.75} = \boxed{.499}$$

no units!

ii) $$P_{N_2} = (P_T)(X_{N_2}) = (8.56)(.499) = \boxed{4.27\text{ atm}}$$

c) N_2 is smaller molecule than O_2 so would have a faster rate of effusion. The ratio of $\frac{\text{moles } N_2}{\text{moles } O_2}$ in the cylinder would **decrease.**

d) $2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)}$

e)

$2NO$	O_2	$2NO_2$
.176	.176	0
−.176	−.088	+.176
0	.088	.176

.088 + .176 → .264 moles total

$$P = \frac{nRT}{V} = \frac{(.264)(.08206)(298)}{5.00} = \boxed{1.29\text{ atm}}$$

2.) a) $V = 8.20\,L$

$T = 400\,K$

$n_{H_2} = 2.50\,mol$ } 3.00

$n_{O_2} = .500\,mol$ }

$$P = \frac{nRT}{V} = \frac{(3.00)(.08206)(400)}{8.20}$$

$P_{H_2+O_2} = 12.0\,atm$

$P_T = 12.0 + 2.00 = \boxed{14.00\ atm}$

12.0 ↓ P of H_2 & N_2; 2.00 ↓ P of Ar

b) $$n = \frac{PV}{RT} = \frac{(14.00)(8.20)}{(.08206)(400)} = 3.50 \text{ moles total}$$

$$\chi_{H_2} = \frac{2.50}{3.50} = \boxed{.714}$$

c) $$\frac{2.50 \text{ moles } H_2}{1} \times \frac{2.02\,g\ H_2}{1\ mol\ H_2} = 5.05\,g\ H_2$$

$$\frac{.500 \text{ moles } O_2}{1} \times \frac{32.00\,g\ O_2}{1\ mol\ O_2} = 16.0\,g\ O_2$$

$$\frac{.500 \text{ moles Ar}}{1} \times \frac{39.95\,g\ Ar}{1\ mol\ Ar} = 20.0\,g\ Ar$$

41.05 g total

$$D = \frac{M}{V} = \frac{41.05\,g}{8.20\,L} = \boxed{5.01\ g/L}$$

d) $$2H_2 + O_2 \rightarrow 2H_2O$$

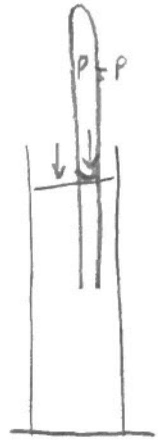
$2H_2$	O_2	$2H_2O$
2.50	.500	0
−1.00	−.500	+1.00
1.50	0	1.00

$$\chi_{H_2} = \frac{1.50}{3.50} = .429$$

$$\chi_{H_2O} = \frac{1.00}{3.50} = .286$$

$$\chi_{Ar} = \frac{.500}{3.50} = .143$$

$\overset{+1}{H_2}\overset{-1}{O_2}$ (KEY)



$$\overset{-1}{2\,H_2O_2(aq)} \rightarrow \overset{-2}{2\,H_2O(l)} + \overset{0}{O_2(g)}$$

3. The mass of an aqueous solution of H_2O_2 is 6.951 g. The H_2O_2 in the solution decomposes completely according to the reaction represented above. The $O_2(g)$ produced is collected in an inverted graduated tube over water at 23.4°C and has a volume of 182.4 mL when the water levels inside and outside of the tube are the same. The atmospheric pressure in the lab is 762.6 torr, and the equilibrium vapor pressure of water at 23.4°C is 21.6 torr.

(1) (a) Calculate the partial pressure, in torr, of $O_2(g)$ in the gas-collection tube.

$P_T = P_{O_2} + P_{H_2O}$

$P_{O_2} = 762.6\text{ torr} - 21.6\text{ torr}$

$= 741.0\text{ torr}$

(2) (b) Calculate the number of moles of $O_2(g)$ produced in the reaction.

(2) (c) Calculate the mass, in grams, of H_2O_2 that decomposed.

(1) (d) Calculate the percent of H_2O_2, by mass, in the original 6.951 g aqueous sample.

(2) (e) Write the oxidation number of the oxygen atoms in H_2O_2 and the oxidation number of the oxygen atoms in O_2 in the appropriate cells in the table below.

Substance	Oxidation Number of Oxygen Atoms
H_2O_2	−1
O_2	0

(d) $\frac{.498\text{ g }O_2}{6.951\text{ g soln}} \times 100$ $= 7.16\%$

(2) (f) Write the balanced oxidation half-reaction for the reaction.

$H_2O_2 \rightarrow O_2 + 2H^+ + 2e^-$

(b) $PV = nRT$

$n = \frac{PV}{RT} = \frac{(741.0)(.1824\text{ L})}{(62.4)(296)} = .001732 = .00732\text{ moles }O_2$

(c) $\frac{.00732\text{ moles }O_2}{1} \cdot \frac{2\text{ moles }H_2O_2}{1\text{ mole }O_2} \cdot \frac{34.02\text{ g }H_2O_2}{1\text{ mole }H_2O_2} = .498\text{ g }H_2O_2$

STOP

If you finish before time is called, you may check your work on this part only.
Do not turn to the other part of the test until you are told to do so.

Question 3 (10 points)

$$2\,H_2O_2(aq) \rightarrow 2\,H_2O(l) + O_2(g)$$

The mass of an aqueous solution of H_2O_2 is 6.951 g. The H_2O_2 in the solution decomposes completely according to the reaction represented above. The $O_2(g)$ produced is collected in an inverted graduated tube over water at 23.4°C and has a volume of 182.4 mL when the water levels inside and outside of the tube are the same. The atmospheric pressure in the lab is 762.6 torr, and the equilibrium vapor pressure of water at 23.4°C is 21.6 torr.

(a) Calculate the partial pressure, in torr, of $O_2(g)$ in the gas-collection tube.

$P_{atm} = P_{O_2} + P_{H_2O} \Rightarrow P_{O_2} = P_{atm} - P_{H_2O}$ $P_{O_2} = 762.6\text{ torr} - 21.6\text{ torr} = \mathbf{741.0\text{ torr}}$	One point is earned for the correct answer.

(b) Calculate the number of moles of $O_2(g)$ produced in the reaction.

$PV = nRT \Rightarrow n = \frac{PV}{RT}$ $P = 741.0\text{ torr} \times \frac{1\text{ atm}}{760\text{ torr}} = 0.9750\text{ atm}$ $T = 273.15 + 23.4°C = 296.6\text{ K}$ $V = 182.4\text{ mL} \times \frac{1\text{ L}}{1{,}000\text{ mL}} = 0.1824\text{ L}$ $n_{O_2} = \frac{PV}{RT} = \frac{(0.9750\text{ atm})(0.1824\text{ L})}{(0.0821\text{ L atm mol}^{-1}\text{ K}^{-1})(296.6\text{ K})} = \mathbf{7.304 \times 10^{-3}\text{ mol}}$	One point is earned for the correct substitutions. One point is earned for the correct answer.

(c) Calculate the mass, in grams, of H_2O_2 that decomposed.

$(7.304 \times 10^{-3}\text{ mol } O_2) \times \frac{2\text{ mol } H_2O_2}{1\text{ mol } O_2} \times \frac{34.0\text{ g } H_2O_2}{1\text{ mol } H_2O_2} = \mathbf{0.497\text{ g } H_2O_2}$	One point is earned for the conversion of mol O_2 to mol H_2O_2. One point is earned for the correct mass.

(d) Calculate the percent of H_2O_2, by mass, in the original 6.951 g aqueous sample.

$\frac{0.497\text{ g } H_2O_2}{6.951\text{ g sample}} \times 100 = \mathbf{7.15\%}$	One point is earned for the correct answer.

Question 3 (continued)

(e) Write the oxidation number of the oxygen atoms in H_2O_2 and the oxidation number of the oxygen atoms in O_2 in the appropriate cells in the table below.

Substance	Oxidation Number of Oxygen Atoms
H_2O_2	
O_2	

In H_2O_2, the oxidation number of O is **−1**. In O_2, the oxidation number of O is **0**.	Two points are earned for the correct oxidation numbers (1 point each).

(f) Write the balanced oxidation half-reaction for the reaction.

$H_2O_2(aq) \rightarrow O_2(g) + 2\ H^+(aq) + 2\ e^-$	One point is earned for the correct reactant and products. One point is earned for correct balancing.