

Multiple Choice Questions

1. Hydrogen peroxide, H_2O_2 , in the presence of a catalyst decomposes into water and oxygen gas. How many liters of O_2 at STP are produced from the decomposition of 34.0 g of H_2O_2 ?
 - A) 1.00
 - B) 5.60
 - C) 11.2
 - D) 22.4
 - E) 44.8
2. A mixture of 6.02×10^{23} molecules $\text{NH}_3(\text{g})$ and 3.01×10^{23} molecules $\text{H}_2\text{O}(\text{g})$ has a total pressure of 6.00 atm. What is the partial pressure of NH_3 ?
 - A) 1.00 atm
 - B) 2.00 atm
 - C) 3.00 atm
 - D) 4.00 atm
 - E) 9.00 atm
3. What will happen to the volume of a bubble of air submerged in water under a lake at 10.0°C and 2.00 atm if it rises to the surface where the temperature is 20.0°C and the pressure is 1.00 atm?
 - A) The volume will increase by a factor of 4.00.
 - B) The volume will increase by a factor of 2.07.
 - C) The volume will increase by a factor of 2.00.
 - D) The volume will remain the same.
 - E) The volume will decrease by a factor of 1.93.
4. A gas has a density of 3.74 g L^{-1} at 0°C and a pressure of 1.00 atm. Which gas best fits these data?
 - A) H_2
 - B) He
 - C) N_2
 - D) Kr
 - E) Rn

5. Methanol, CH_3OH , burns in oxygen to form carbon dioxide and water. What volume of oxygen is required to burn 6.00 L of gaseous methanol measured at the same temperature and pressure?
- A) 4.00 L
 - B) 8.00 L
 - C) 9.00 L
 - D) 12.0 L
 - E) 24.0 L
6. Which increases when a gas is heated at constant volume?
- I. Pressure
 - II. Kinetic energy of molecules
 - III. Attractive forces between molecules
- A) I only
 - B) II only
 - C) III only
 - D) I and II only
 - E) II and III only
7. At room temperature and 1 atm pressure the molecules are farthest apart in:
- A) fluorine
 - B) bromine
 - C) iodine
 - D) mercury
 - E) water
8. What is the name of the process? $\text{H}_2\text{O}(\text{s}) \rightarrow \text{H}_2\text{O}(\text{g})$
- A) condensation
 - B) evaporation
 - C) fusion
 - D) sublimation
 - E) freezing

9. Which statement is true of a measured pressure of a sample of hydrogen gas collected over water at constant temperature?
- A) The measured pressure is greater than the pressure of dry hydrogen.
 - B) The measured pressure is less than the pressure of dry hydrogen.
 - C) The measured pressure is equal to the pressure of dry hydrogen.
 - D) The measured pressure varies inversely with the pressure of dry hydrogen.
 - E) The measured pressure is not related to the pressure of dry hydrogen.
10. A gas is most likely to behave as an ideal gas in which instance?
- A) At low temperature, because the particles have insufficient kinetic energy to overcome intermolecular attractions
 - B) When the molecules are highly polar, because intermolecular forces are more likely
 - C) At room temperature and pressure, because intermolecular interactions are minimized and the particles are relatively far apart
 - D) At high pressures, because the distance between molecules is likely to be small in relation to the size of the molecules
 - E) At high temperatures, because the molecules are always far apart

Free Response Questions

1. Equal masses (0.500 g each) of hydrogen and oxygen are placed in an evacuated 4.00 L flask at 25.0°C. The mixture is allowed to react to completion and the flask is returned to 25.0°C and allowed to come to equilibrium. The equilibrium vapor pressure of water at 25°C is 23.76 torr.
- a. Write and balance an equation for the reaction.
 - b. What is the total pressure inside the flask before the reaction begins?
 - c. What is the mass of water vapor in the flask at equilibrium?
 - d. How many grams of which reactant gas remains at equilibrium?
 - e. What is the total pressure inside the flask at equilibrium?
 - f. After the reaction, is there any liquid water present? If so, how many grams? If not, why not?
2. A 2.00 L flask at 27°C contains 3.00 grams each of Ar(g), SO₂(g), and He(g). Answer the following questions about the gases and in each case explain your reasoning.

- Which gas has particles with the highest average kinetic energy?
- Which gas has particles with the highest average velocity?
- Which gas has the highest partial pressure?
- Which gas will deviate the most from ideal behavior?
- Which substance will have the highest boiling point?
- What changes in temperature and pressure will increase the deviations of all the gases from ideal behavior?

Additional Practice in Chemistry the Central Science

For more practice answering questions in preparation for the Advanced Placement examination try these problems in Chapter 10 of Chemistry the Central Science.

Additional Exercises: 10.95, 10.98, 10.99, 10.101, 10.107.

Integrative Exercises: 10.112, 10.113, 10.119, 10.121, 10.122.

Multiple Choice Answers and Explanations

- C. The balanced equation is: $\text{H}_2\text{O}_2 \rightarrow \text{H}_2\text{O} + \frac{1}{2} \text{O}_2$. One mole of hydrogen peroxide produces one half mole of oxygen gas. One mole of H_2O_2 is 34.0 g because the molar mass of hydrogen peroxide is 34.0 g/mol. If one mole of gas at STP occupies 22.4 liters then one-half mole has a volume of 11.4 L.
- D. Because there are twice as many molecules of ammonia than of water, there are twice as many moles of ammonia. The mole fraction of ammonia is $\frac{2}{3}$. The partial pressure of ammonia is given by:

$$P_{\text{NH}_3} = X_{\text{NH}_3} \times P_{\text{T}} = \frac{2}{3} \times 6.00 \text{ atm} = 4.00 \text{ atm}.$$
- B. Halving the pressure doubles the volume. However, doubling the Celsius temperatures does not double the volume because the volume is proportional to the absolute temperature, not the Celsius temperature. The absolute temperature increase is modest increasing the volume by the factor $(20 + 273)/(10 + 273)$, which is a little more than one. The pressure decrease and the temperature increase couple to give a volume increase of just over a factor of 2, which makes 2.07 the most likely correct answer.
- D. Even without a calculator the product of $(3.74 \text{ g/L})(22.4 \text{ L/mol})$ can be estimated to be about 80 g/mol ($4 \times 20 = 80$). The molar mass of krypton from the periodic table is 83.8 g/mol while the closest other noble gases are argon (39.9 g/mol) and xenon (131 g/mol).

5. C. The balanced equation is: $2\text{CH}_3\text{OH}(g) + 3\text{O}_2(g) \rightarrow 2\text{CO}_2(g) + 4\text{H}_2\text{O}(g)$. The coefficients for gases that balance an equation are ratios of liters as well as moles at constant temperature and pressure. If two liters of methanol requires 3 liters of oxygen, then six liters of methanol requires nine liters of oxygen.
- $$\times \text{L O}_2 = 6 \text{ L CH}_3\text{OH} (3 \text{ L O}_2 / 2 \text{ L CH}_3\text{OH}) = 9.00 \text{ L}$$
6. D. Heating causes the temperature to increase, and temperature is a measure of kinetic energy. The faster moving molecules strike the walls of the container more frequently and with greater force, increasing the pressure. Intermolecular forces are a function of the structures of the molecules present and not of the temperature or pressure.
7. A. Kinetic molecular theory says that liquids and solids are in close contact with each other because of the attractive forces between molecules. Gases have little or no attractive forces and the molecules are far apart. This question is really asking, "Which of the following is a gas?" Fluorine, at room temperature and 1 atmosphere, is the only gas on the list.
8. D. Sublimation is the process by which a solid changes directly to a gas.
9. A. Whenever a gas is collected over water, the gas is contaminated with water vapor. The measured pressure is equal to the pressure of the dry gas plus the partial pressure of water vapor at a given temperature: $P_{\text{total}} = P_{\text{H}_2} + P_{\text{H}_2\text{O}}$. The pressure of the hydrogen sample is greater than the pressure of the dry gas.
10. C. Gases behave ideally at low pressures because the molecular volumes are small compared to the volume of the container and at high temperature because the kinetic energy overcomes the intermolecular forces, making them insignificant. Most gases behave as ideal gases at room temperature and pressure.

Free Response Answers



b. $\text{mol H}_2 = 0.500 \text{ g} / 2.00 \text{ g/mol} = 0.250 \text{ mol H}_2$

$\text{mol O}_2 = 0.500 \text{ g} / 32.0 \text{ g/mol} = 0.0156 \text{ mol O}_2$

$P_{\text{total}} = n_{\text{total}} RT / V =$

$(0.250 + 0.0156 \text{ mol})(0.0821 \text{ L atm/mol K})(25 + 273 \text{ K}) /$

$(4.00 \text{ L}) = 1.62 \text{ atm}$

$$c. n = PV/RT = (23.76 \text{ torr}/760 \text{ torr/atm})(4.00\text{L}) / (0.0821 \text{ L atm/mol K})(298 \text{ K}) = 0.00511 \text{ mol H}_2\text{O vapor}$$

$$0.00511 \text{ mol} \times 18.0 \text{ g/mol} = 0.0920 \text{ g H}_2\text{O vapor.}$$

d. O_2 is limiting because 0.250 mol of hydrogen would require 0.125 mol of oxygen to react and there are only 0.0156 mol of oxygen. Twice as many moles of hydrogen react:

$$2 \times 0.0156 \text{ mol} = 0.0312 \text{ mol H}_2 \text{ react.}$$

$$0.250 - 0.0312 \text{ mol} = 0.219 \text{ mol H}_2 \text{ remain}$$

$$0.219 \text{ mol} \times 2.00 \text{ g/mol} = 0.438 \text{ g H}_2 \text{ remain}$$

$$e. P_{\text{H}_2} = (n_{\text{H}_2})RT/V = (0.219 \text{ mol})(0.0821 \text{ L atm/mol K})(298 \text{ K})/4.00\text{L} = 1.34 \text{ atm}$$

$$P_t = P_{\text{H}_2\text{O}} + P_{\text{H}_2} (23.76 \text{ torr}/760 \text{ torr/atm}) + 1.34 \text{ atm} = 1.37 \text{ atm}$$

f. Yes, liquid water remains in the flask.

0.0312 moles of hydrogen will produce 0.0312 moles water. There are only 0.00511 moles of water vapor present so the rest is liquid.

$$0.0312 \text{ mol} - 0.00511 \text{ mol} = 0.0261 \text{ mol water is liquid}$$

$$0.0261 \text{ mol} \times 18.0 \text{ g/mol} = 0.470 \text{ g liquid water.}$$

2. a. All three gases have the same average kinetic energy because the temperature is the same for each and temperature is a measure of average kinetic energy.
- b. The helium atoms will have the highest average velocity because they are the smallest. At the same temperature, the rms velocity of a gas is inversely proportional to the square root of the molar mass.
- c. Helium has the highest partial pressure because partial pressure is proportional to the number of moles of gas present and the number of moles increases with decreasing molar mass.
- d. Sulfur dioxide will display the greatest deviation from ideal behavior because SO_2 molecules are the largest and most complex of the three different kinds of gas particles. It is also polar and will have the highest attractive forces.
- e. Sulfur dioxide will have the highest boiling point because its polarity provides higher attractive forces.
- f. Decreasing the temperature and increasing the pressure will increase deviations from ideal behavior for all gases.

Gases

Worksheet B

- A. Circle the true statement(s). If the statement is false, rewrite it to make it true.
- When 2.0 L of hydrogen gas are combined with 2.0 L of oxygen gas at 25°C and 1.0 atm,
$$2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{g})$$
4.0 L of steam are obtained.
 - A gas at 25°C in a 10.0 L sealed stainless steel tank has a pressure of 1.00 atm. When the temperature in the tank is doubled to 50°C,
 - the volume of the tank doubles.
 - the pressure in the tank doubles.
 - the number of moles of gas doubles.
 - the kinetic energy of the molecules increases.
 - the velocity of the molecules stays the same.
 - A tank has a total pressure of 1.00 atm. It contains 25.0 g of oxygen and 25.0 g of sulfur dioxide. The partial pressure of oxygen in the tank is 0.500 atm.
- B. What is the density of CO₂ (g) at 745 mm Hg and 32°C?
- C. A gas has a density of 1.10 g/L at 27°C and 0.750 atm. What is its molar mass?
- D. Fifteen mL of HCl is added to aluminum metal producing 125 mL of hydrogen gas at 25°C and 1.00 atm. What is the molarity of the HCl added?
- E. Consider two bulbs connected by a valve. Bulb A has a volume of 200.0 mL and contains nitrogen gas at a pressure of 0.500 atm. Bulb B has a volume of 1.00 L and contains CO gas at a pressure of 1.00 atm. What is the pressure in the two tanks when the valve is opened? The volume of the connecting tube and valve is negligible. Nitrogen does not react with carbon monoxide.

CHALLENGE PROBLEM: What would the pressure in both tanks be if nitrogen were replaced by oxygen in bulb A under the same conditions?

(*Hint:* $2\text{CO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g})$)

ANSWERS

Worksheet B

A. 1. FALSE - 2.0 L of steam

2. a. FALSE - ~~to~~ remains the same

b. FALSE - increases but does not double.

c. FALSE - remains the same

d. TRUE

e. FALSE - increases

3. FALSE - 0.666 atm

B. 1.72 g/L

C. 36.1 g/mole

D. 0.681 M

E. 0.917 atm

Challenge: 0.833 atm