CHEM 1411
Chapter 12 Homework Answers

1. A gas sample contained in a cylinder equipped with a moveable piston occupied 300. mL at a pressure of 2.00 atm. What would be the final pressure if the volume were increased to 500. mL at constant temperature?

$P_1V_1 = P_2V_2$

$(2.00 \text{ atm})(300. \text{ mL}) = P_2(500. \text{ mL})$

$$P_2 = \frac{(2.00 \text{ atm})(300. \text{ mL})}{500. \text{ mL}} = 1.20 \text{ atm}$$

2. A balloon that contains 1.50 L of air at 755 torr is taken under water to a depth that is at a pressure of 2265 torr. Calculate the new volume of the balloon. Assume constant temperature.

$$V_2 = \frac{P_1V_1}{P_2}$$

$$V_2 = \frac{(755 \text{ torr})(1.50 \text{ L})}{2265 \text{ torr}} = 0.500 \text{ L}$$

3. Several balloons are inflated with He to a volume of 0.75 L at 27 ^oC. One of the balloons was found several hours later; the temperature had dropped to 22 ^oC. What was the final volume of the balloon when found?

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \qquad V_2 = \frac{V_1T_2}{T_1}$$

$$V_2 = \frac{(0.75 \text{ L})(295 \text{ K})}{300. \text{ K}} = 0.74 \text{ L}$$

4. A gas occupies a volume of 333 mL at 19 ^oC. What is the temperature of the gas if the volume expands to 999 mL at constant pressure?

$$T_2 = \frac{V_2T_1}{V_1}$$

$$T_2 = \frac{(999 \text{ mL})(292 \text{ K})}{333 \text{ mL}}$$

$T_2 = 876 \text{ K} = 603\ ^oC$

5. Which of the following statements are true? Which are false? Why are each true or false? Assume constant pressure in each case.

(a) If a sample of gas is heated from 100. ^{o}C to 200. ^{o}C, the volume will double.
FALSE. The temperature must double, but on the Kelvin scale. In this case temperature rises from 373 K to 473 K.

(b) If a sample of gas is heated from 0 ^{o}C to 273 ^{o}C, the volume will double.
TRUE. The temperature on the Kelvin scale doubles from 273 K to 546 K.

(c) If a sample of gas is cooled from 1273 ^{o}C to 500. ^{o}C, the volume will decrease by a factor of two.
TRUE. The Kelvin temperature decreases from 1546 K to 773 K (773 K is half of 1546 K).

(d) If a sample of gas is cooled from 1000. ^{o}C to 200. ^{o}C, the volume will decrease by a factor of five.
FALSE. 1273 K/473 K = 2.7, not 5.

(e) If a sample of gas is heated from 473 ^{o}C to 1219 ^{o}C, the volume will increase by a factor of two.
TRUE. 1492 K (from 1219 ^{o}C) is double of 746 K (from 473 ^{o}C).

6. A sample of gas occupies 400. mL at STP. Under what pressure would this sample occupy 200. mL if the temperature is increased to 819 ^{o}C?

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \qquad \text{STP = 1 atm \& 273 K}$$

$$\frac{(1.00\text{ atm})(400.\text{ mL})}{273\text{ K}} = \frac{P_2(200.\text{ mL})}{1092\text{ K}}$$

$$P_2 = \frac{(1.00\text{ atm})(400.\text{ mL})(1092\text{ K})}{(273\text{ K})(200.\text{ mL})} = 8.00\text{ atm}$$

7. A 280. mL sample of neon exerts a pressure of 660. torr at 26 ^{o}C. At what temperature, in ^{o}C, would it exert a pressure of 940. torr in a volume of 440. mL?

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{(660.\text{ torr})(280.\text{ mL})}{299\text{ K}} = \frac{(940.\text{ torr})(440.\text{ mL})}{T_2}$$

$$(660.\text{ torr})(280.\text{ mL})T_2 = (940.\text{ torr})(440.\text{ mL})(299\text{ K})$$

$$T_2 = \frac{(940.\text{ torr})(440.\text{ mL})(299\text{ K})}{(660.\text{ torr})(280.\text{ mL})}$$

$$T_2 = 669\text{ K} = 396\ ^oC$$

8. A 247 mL sample of a gas exerts a pressure of 3.13 atm at 16 ^oC. What volume would it occupy at 100. ^oC and 1.00 atm?

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{(3.13\text{ atm})(247\text{ mL})}{289\text{ K}} = \frac{(1.00\text{ atm})V_2}{373\text{ K}}$$

$$V_2 = \frac{(3.13\text{ atm})(247\text{ mL})(373\text{ K})}{(289\text{ K})(1.00\text{ atm})} = 998\text{ mL}$$

9. Calculate the pressure needed to contain 2.44 mol of an ideal gas at 45 ^oC in a volume of 3.70 L.

$$P = \frac{nRT}{V}$$

$$P = \frac{(2.44\text{ mol})(0.0821\text{ L·atm/mol·K})(318\text{ K})}{3.70\text{ L}} = 17.2\text{ atm}$$

10. (a) How many molecules are in 1.00 L of gaseous oxygen if the pressure is 2.50 x 10^{-9} torr and the temperature is 1225 K? (b) How many grams of O_2 are in the container?

(a) $n = \frac{PV}{RT}$ $\quad P = \frac{2.50 \times 10^{-9}\text{ torr}}{} \left| \frac{1\text{ atm}}{760\text{ torr}} \right| = 3.29 \times 10^{-12}\text{ atm}$

$$n = \frac{(3.29 \times 10^{-12}\text{ atm})(1.00\text{ L})}{(0.0821\text{ L·atm/mol·K})(1225\text{ K})} = 3.27 \times 10^{-14}\text{ mol } O_2$$

$$3.27 \times 10^{-14}\text{ mol} \left| \frac{6.02 \times 10^{23}\text{ molecules}}{1\text{ mole}} \right| = 1.97 \times 10^{10}\text{ molecules } O_2$$

(b) $3.27 \times 10^{-14}\text{ mol } O_2 \left| \frac{32.0\text{ g } O_2}{1\text{ mol } O_2} \right| = 1.05 \times 10^{-12}\text{ g } O_2$

11. Calculate the molar mass of a gaseous sample if 0.480 g of the gas occupies 367 mL at 365 torr and 45 ^{o}C.

$$MM = \frac{gRT}{PV} \qquad P = \frac{365 \text{ torr}}{} \left| \frac{1 \text{ atm}}{760 \text{ torr}} \right| = 0.480 \text{ atm}$$

$$V = \frac{367 \text{ mL}}{} \left| \frac{1 \text{ L}}{1000 \text{ mL}} \right| = 0.367 \text{ L}$$

$$MM = \frac{(0.480 \text{ g})(0.0821 \text{ L·atm/mol·K})(318 \text{ K})}{(0.480 \text{ atm})(0.367 \text{ L})} = 71.1 \text{ g/mol}$$

12. A cylinder was found in a storeroom. The label on the cylinder was gone, and the only thing anyone remembered is that the gas cylinder contained a noble gas. A 0.0140 g sample was found to occupy 4.13 mL at 23 ^{o}C and 745 torr. Identify the gas.

$$MM = \frac{gRT}{PV} \qquad P = \frac{745 \text{ torr}}{} \left| \frac{1 \text{ atm}}{760 \text{ torr}} \right| = 0.980 \text{ atm}$$

$$MM = \frac{(0.0140 \text{ g})(0.0821 \text{ L·atm/mol·K})(296 \text{ K})}{(0.980 \text{ atm})(4.13 \times 10^{-3} \text{ L})}$$

MM = 84.0 g/mol   The gas is Kr (krypton)

13. What is the mole fraction of each gas in a mixture having the partial pressure of 0.267 atm of He, 0.317 atm of Ar and 0.277 atm of Xe?

$$P_T = 0.267 \text{ atm} + 0.317 \text{ atm} + 0.277 \text{ atm} = 0.861 \text{ atm}$$

$$X_{He} = \frac{0.267 \text{ atm}}{0.861 \text{ atm}} = 0.310$$

$$X_{Ar} = \frac{0.317 \text{ atm}}{0.861 \text{ atm}} = 0.368$$

$$X_{Xe} = \frac{0.277 \text{ atm}}{0.861 \text{ atm}} = 0.322$$

14. A gaseous mixture contains 5.23 g of $CHCl_3$ and 1.66 g of CH_4. What pressure is exerted by the mixture inside a 50.0 mL metal container at 275 ^oC? What is the partial pressure of $CHCl_3$?

$$5.23\text{ g } CHCl_3 \left|\frac{1\text{ mol}}{119\text{ g}}\right| = 0.0439\text{ mol } CHCl_3 \qquad 1.66\text{ g } CH_4 \left|\frac{1\text{ mol}}{16.0\text{ g}}\right| = 0.104\text{ mol } CH_4$$

n_T = 0.0439 mol + 0.104 mol = 0.148 mol

$$P_T = \frac{n_T RT}{V} = \frac{(0.148\text{ mol})(0.0821\text{ L·atm/mol·K})(548\text{ K})}{0.0500\text{ L}} = 133\text{ atm}$$

$$P_{CHCl3} = \frac{n_{CHCl3}\,RT}{V} = \frac{(0.0439\text{ mol})(0.0821\text{ L·atm/mol·K})(548\text{ K})}{0.0500\text{ L}} = 39.5\text{ atm}$$

or, the following solution for partial pressure of $CHCl_3$ could have been used:

$$P_{CHCl3} = (X_{CHCl3})(P_T) \qquad X_{CHCl3} = \frac{P_{CHCl3}}{P_T} = \frac{0.0439\text{ mol}}{0.148\text{ mol}} = 0.297$$

$$P_{CHCl3} = (0.297)(133\text{ atm}) = 39.5\text{ atm}$$

15. A 4.00 L flask containing He at 6.00 atm is connected to a 3.00 L flask containing N_2 at 3.00 atm, and the gases are allowed to mix. (a) Find the partial pressures of each gas after they are allowed to mix. (b) Find the total pressure of the mixture. (c) What is the mole fraction of He?

(a) Since a new volume is obtained (7.00 L), we will use Boyle's Law to obtain new pressures.

$$\text{He: } P_2 = \frac{(6.00\text{ atm})(4.00\text{ L})}{7.00\text{ L}} = 3.43\text{ atm} \qquad N_2\text{: } P_2 = \frac{(3.00\text{ atm})(3.00\text{ L})}{7.00\text{ L}} = 1.28\text{ atm}$$

(b) P_T = 3.43 atm + 1.28 atm = 4.71 atm

(c) $$X_{He} = \frac{P_{He}}{P_T} = \frac{3.43\text{ atm}}{4.71\text{ atm}} = 0.728$$

16. Individual samples of O_2, N_2, and He are present in three-2.25 L vessels. Each exerts a pressure of 1.50 atm. (a) If all three are forced into the same 1.00 L container, without change in temperature, what will be the resulting pressure? (b) What is the partial pressure of O_2 in the mixture?

$$P_2 = \frac{P_1V_1}{V_2} = \frac{(1.50\text{ atm})(2.25\text{ L})}{1.00\text{ L}} = 3.38\text{ atm is the partial pressure of each gas, including } O_2$$

$$P_T = 3(3.38\text{ atm}) = 10.1\text{ atm}$$

17. A sample of oxygen (O_2) of mass 30.0 g is confined in a vessel at 0 ^oC and 1000. torr. Then, 8.00 g of hydrogen (H_2) is pumped into the vessel at constant temperature. What will be the final pressure in the vessel?

$$30.0\text{ g }O_2 \times \frac{1\text{ mol }O_2}{32.0\text{ g }O_2} = 0.938\text{ mol }O_2 \qquad 8.00\text{ g }H_2 \times \frac{1\text{ mol }H_2}{2.02\text{ g }H_2} = 3.96\text{ mol }H_2$$

$$P_{O2} = X_O\ P_T$$

$$P_T = \frac{P_{O2}}{X_{O2}} \qquad X_{O2} = \frac{0.938\text{ mol}}{(0.938\text{ mol} + 3.96\text{ mol})} = 0.192$$

$$P_T = \frac{1000.\text{ torr}}{0.192} = 5.21 \times 10^3\text{ torr}$$

18. During a collision, air bags are inflated by gas formed from the reaction:

$$2\ NaN_{3\,(s)} \longrightarrow 2\ Na_{(s)} + 3\ N_{2\,(g)}$$

What mass of NaN_3 would be needed to inflate a 30.0 L bag to a pressure of 1.40 atm at 25 ^oC?

$$n = \frac{PV}{RT}$$

$$n = \frac{(1.40\text{ atm})(30.0\text{L})}{(0.0821\text{ L·atm/mol·K})(298\text{ K})} = 1.72\text{ mol }N_2$$

$$1.72\text{ mol }N_2 \times \frac{2\text{ mol }NaN_3}{3\text{ mol }N_2} \times \frac{65.0\text{ g }NaN_3}{1\text{ mol }NaN_3} = 74.5\text{ g }NaN_3$$

19. Calculate the volume of methane, CH_4, measured at 300. K and 815 torr, that can be produced by the bacterial breakdown of 1.00 kg of simple sugar.

$$C_6H_{12}O_{6\,(s)} \longrightarrow 3\,CH_{4\,(g)} + 3\,CO_{2\,(g)}$$

$$\frac{1.00 \times 10^3 \text{ g } C_6H_{12}O_6}{} \left| \frac{1 \text{ mol } C_6H_{12}O_6}{180.\text{ g } C_6H_{12}O_6} \right| \frac{3 \text{ mol } CH_4}{1 \text{ mol } C_6H_{12}O_6} \right| = 16.7 \text{ mol } CH_4$$

$$P = \frac{815 \text{ torr}}{} \left| \frac{1 \text{ atm}}{760 \text{ torr}} \right| = 1.07 \text{ atm}$$

$$V = \frac{nRT}{P} = \frac{(16.7 \text{ mol})(0.0821 \text{ L·atm/mol·K})(300.\text{ K})}{1.07 \text{ atm}} = 384 \text{ L}$$

20. What mass of KNO_3 would decompose to produce 21.1 L of O_2 at STP?

$$2\,KNO_{3\,(s)} \longrightarrow 2\,KNO_{2\,(s)} + O_{2\,(g)}$$

$$n = \frac{PV}{RT} = \frac{(1.00 \text{ atm})(21.1 \text{ L})}{(0.0821 \text{ L·atm/mol·K})(273 \text{ K})} = 0.941 \text{ mol } O_2$$

$$\frac{0.941 \text{ mol } O_2}{} \left| \frac{2 \text{ mol } KNO_3}{1 \text{ mol } O_2} \right| \frac{101 \text{ g } KNO_3}{1 \text{ mol } KNO_3} \right| = 190.\text{ g } KNO_3$$