Chapter 10 — Gas Laws
Lecture Examples Answer Key

Ex 1 Some nitrogen gas is in a 2.00-L tank at a pressure of 3.00 atm. The tank is connected to a 5.00-L tank that is completely empty (evacuated), and a valve connects the two tanks., If the valve is opened, determine the total pressure in this two-tank system after the nitrogen stops flowing. No temperature change occurs in the process.

$P_1V_1 = P_2V_2$
$P_2 = P_1V_1/V_2$ = (3.00 atm)(2.00 L)/(7.00 L) = 0.857 atm

Ex 2 A certain mass of C_3H_6 reacts completely with an excess of ammonia and oxygen to give 38.2 L of C_3H_3N at 75°C and P = 1 atm. If the same mass of C_3H_6 reacts completely at 350°C and P = 1 atm, what volume of C_3H_3N can be collected at the higher temperature?

$$2\ C_3H_{6(g)} + 2\ NH_{3(g)} + 3\ O_{2(g)} \rightarrow 2\ C_3H_3N_{(g)} + 6\ H_2O_{(g)}$$

$V_1/T_1 = V_2/T_2$
$V_2 = V_1T_2/T_1$ = (38.2 L)(623K)/(348K) = 68.4 L

Ex 3 A gas is in a container with a movable piston under a pressure of 6.4 atm. The volume of the container is increased by a factor of 4.5 by moving the piston. The absolute temperature is simultaneously doubled. Calculate the pressure of the gas after these changes.

P_1 = 6.4 atm	**P_2 = ??**
V_1	**$V_2 = 4.5\ V_1$**
T_1	**$T_2 = 2\ T_1$**

$P_2 = P_1V_1T_2/V_2T_1$ = (6.4 atm)V_1(2T_1)/(4.5V_1)T_1 = 2.8 atm

Ex 4 At what temperature (in K) does 29.8 g of O_2 gas have a pressure of 2.00 atm in a 10.0-liter tank?

n = (29.8 g)(1 mol / 31.9988 g) = 0.9313 mol
T = PV/nR = (2.00 atm)(10.0 L) / (0.9313 mol)(0.08206 L·atm/mol·K) = 262K

Ex 5 Calculate the density of gaseous SF_6 at a temperature of 27°C and a pressure of 0.873 atm.

PV=nRT **density = d = m/V**
n/V = P/RT
m/V = P$\mathcal{M}$/RT = (0.873 atm)(146.0564 g/mol)/(0.08206 L·atm/mol·K)(300K) = 5.18 g / L

Ex 6 The empirical formula of a gaseous fluorocarbon is CF_2. If 1.55 g of this compound occupies 0.174 L at STP determine the molecular formula of this compound.

$\mathcal{M}$ = (m/V)RT/P = (1.55 g/0.174 L)(0.08206 L·atm/mol·K)(273K) / (1 atm)
= 199.56 g / mol

$\mathcal{M}_{CF2}$ = 50.0078 g / mol
199.56 / 50.0078 = 4

Molecular formula = C_4F_8

Ex 7 An important process for the production of acrylonitrile (C_3H_3N) is given by the following reaction:

$$2\ C_3H_{6(g)} + 2\ NH_{3(g)} + 3\ O_{2(g)} \rightarrow 2\ C_3H_3N_{(g)} + 6\ H_2O_{(g)}$$

A 150.0-L reactor is charged to the following partial pressures at 25°C:

P_{C3H6} = 4.93 atm, P_{NH3} = 7.90 atm, P_{O2} = 14.8 atm

What mass of acrylonitrile can be produced from this mixture?

n_{C3H6} = (4.93 atm)(150.0 L)/R(298K) = 30.24 mol C_3H_6
$n_{acrylonitrile}$ = (30.24 mol C_3H_6)(2 mol acrylonitrile / 2 mol C_3H_6) = 30.24 mol

n_{NH3} = (7.90 atm)(150.0L)/R(298K) = 48.46 mol NH_3
$n_{acrylonitrile}$ = (48.46 mol NH_3)(2 mol acrylonitrile / 2 mol NH_3) = 48.46 mol

n_{O2} = (14.8 atm)(150.0 L)/R(298K) = 90.78 mol O_2
$n_{acrylonitrile}$ = (90.78 mol O_2)(2 mol acrylonitrile / 3 mol O_2) = 60.52 mol

C_3H_6 is the limiting reactant

mass acrylonitrile = (30.24 mol)(42.0804 g / 1 mol) = 1.27 kg

Ex 8 A 0.326-g sample of XH_2 reacts with water according to the equation

$$XH_{2(s)} + 2\,H_2O_{(l)} \rightarrow X(OH)_{2(s)} + 2\,H_{2(g)}$$

The hydrogen evolved is found to have a volume when dry of 375 cm^3 at 21°C and 1.00 atm. What is the atomic mass of X?

n_{H2} = (1.00 atm)(0.375 L)/R(294K) = 0.01554 mol

n_{XH2} = (0.01554 mol H2)(1 mol XH_2 / 2 mol H_2) = 0.00777 mol XH_2

molar mass XH_2 = 0.326 g / 0.00777 mol = 41.96 g / mol

molar mass of X = 41.96 g / mol – 2(1.0079 g / mol) = 39.94 g / mol

Ex 9 Acetylene (C_2H_2) can be made by allowing calcium carbide to react with water.

$$CaC_{2(s)} + 2\,H_2O_{(l)} \rightarrow C_2H_{2(g)} + Ca(OH)_{2(aq)}$$

You place 2.65 g of CaC_2 in excess water and collect the acetylene over water.

(a) Calculate the theoretical yield of acetylene (in grams).

mol CaC_2 = (2.65 g)(1 mol / 64.10 g) = 0.04134 mol CaC_2
mol C_2H_2 = (0.04134 mol)(1 mol C_2H_2 / 1 mol CaC_2) = 0.04134 mol C_2H_2
mass C_2H_2 = (0.04134 mol)(26.0378 g / 1 mol) = 1.08 g Theoretical yield

(b) After reaction, the volume of the acetylene and water vapor is 795 mL at 25.0°C and a pressure of 0.967 atm. Calculate the percent yield of acetylene. The vapor pressure of water at 25.0°C is 0.0313 atm.

P_{C2H2} = 0.967 atm – 0.0313 atm = 0.9357 atm

n_{C2H2} = PV/RT = (0.9357 atm)(0.795 L)/R(298K) = 0.03042 mol
m = (0.03042 mol)(26.0378 g / 1 mol) = 0.792 g Actual yield

% yield = (0.792 g / 1.08 g) × 100% = 73.3%

Ex 10 The partial pressure of $O_{2(g)}$ in a mixture of $O_{2(g)}$ and $H_{2(g)}$ is 2.54 atm. The total pressure of the mixture is 3.92 atm. Determine the partial pressure of H_2(g), and the mole fraction of each gas in the mixture.

P_{H2} = 3.92 atm – 2.54 atm = 1.38 atm

$X_{H2} = P_{H2} / P_{tot}$ = 1.38 atm / 3.92 atm = 0.352

$X_{O2} = P_{O2} / P_{tot}$ = 2.54 atm / 3.92 atm = 0.648

Ex 11 A gas mixture at room temperature contains 4.3 mol of H_2 and 8.2 mol of N_2.

(a) Compute the mole fraction of N_2 in the mixture.

$X_{N2} = n_{N2} / n_{tot} = 8.2$ mol / (4.3 mol + 8.2 mol) = 0.66

(b) The mixture is then heated, and the N_2 starts to react with the H_2 to give NH_3:

$$N_{2(g)} + 3\,H_{2\,(g)} \rightarrow 2\,NH_{3(g)}$$

The reaction is stopped when 2.8 mol of NH_3 is present. Determine the mole fraction of N_2 in this new mixture.

mol N_2 used = (2.8 mol NH_3)(1 mol N_2 / 2 mol NH_3) = 1.4 mol N_2 used
mol N_2 left over = 8.2 mol – 1.4 mol = 6.8 mol N_2 left

mol H_2 used = (2.8 mol NH_3)(3 mol H_2 / 2 mol NH_3) = 4.2 mol H_2 used
mol H_2 left over = 4.3 mol – 4.2 mol = 0.1 mol H_2 left

Total mol of gas = 2.8 mol + 6.8 mol + 0.1 mol = 9.7 mol

$X_{N2} = n_{N2} / n_{tot} = 6.8$ mol / 9.7 mol = 0.70

Ex 12 Hydrogen gas is produced when zinc reacts with sulfuric acid:

$$Zn_{(s)} + H_2SO_{4(aq)} \rightarrow ZnSO_{4(aq)} + H_{2(g)}$$

If 159 mL of wet H_2 is collected over water at 24°C and a barometric pressure of 738 torr, how many grams of Zn have been consumed?

($P_{H2O,\ 24^\circ C}$) = 22.38 torr.

$P_{H2} = 738$ torr – 22.38 torr = 715.62 torr = 0.942 atm
$n_{H2} = PV/RT = (0.942$ atm)(0.159 L)/R(297K) = 0.006146 mol H_2
mass Zn = (0.006146 mol H_2)(1 mol Zn/ 1 mol H_2)(65.39 g / 1 mol Zn) = 0.402 g Zn