Chemistry 1000 – In Class Gas Law Problems - SOLUTIONS

1. What volume does 0.64 mol of oxygen occupy at STP?
0.64 mol × 22.41 L/1 mol = 14 L

2. Calculate the temperature of 1.82 mol of a gas contained in a vessel of 5.43 L on which it exerts a pressure of 9.42 atm.
p = 9.42 atm ×*101325 Pa/ 1atm = 954000 Pa*
$V = 5.62L \times 0.001\ m^3/1L = 0.00562\ m^3$
$T = pV/nR = 954000Pa \times 0.00562\ m^3/(1.82\ mol \times 8.3145\ J\ K^{-1}\ mol^{-1})$
$= 354\ Pa\ m^3\ K\ J^{-1} = 354\ (kg\ m^{-1}\ s^{-2})\ m^3\ K\ (kg^{-1}\ m^{-2}\ s^2)$
$= 354\ K = 81\ °C$

3. A gas has a volume of 0.78 L when measured at 20.1 °C and 1.00 atm. What is the volume of the gas at 36.5 °C at 1.00 atm pressure?
p and n = const.
$V_1/T_1 = V_2/T_2$
$V_2 = V_1/T_1 \times T_2 = (0.78\ L/20.1\ °C) \times 36.5\ °C = 1.4\ L$

4. The density of air at 0 °C and a pressure of 101325 Pa is 0.001293 g cm^{-3}. What is the apparent molar mass of air, assuming it behaves like an ideal gas.
T = 273 K
$\rho = 0.001293\ g\ cm^{-3} \times 1000000\ cm^3/\ 1\ m^3 = 1293\ g\ m^3$ *[we are not converting g into the SI unit kg, since we need the unit g/mol for the molar mass]*
$M = \rho RT/p = 1293\ g\ m^{-3} \times 8.3145\ J\ K^{-1}\ mol^{-1} \times 273\ K/101325\ Pa$
$= 29.0\ g\ m^{-3}\ J\ mol^{-1}\ Pa^{-1} = 29.0\ g\ m^{-3}\ (kg^1\ m^2\ s^{-2})\ mol^{-1}\ (kg^{-1}\ m\ s^2)$
$= 29.0\ g/mol$

5. A 2.1 L vessel contains 4.65 g of a gas at 1.00 atm and 27.0 °C. Calculate the density and the molar mass of the gas.
$T = (27.0 + 273.15)\ K = 300.2\ K$
$p = 1\ atm \times 101325\ Pa/\ 1atm = 101325\ Pa$
$V = 2.1\ L = 2100\ cm^3 = 0.0021\ m^3$
$\rho = 4.65\ g/2100\ cm^3 = 0.00221\ g\ cm^{-3} = 2210\ g\ m^{-3}$
$M = \rho RT/p = 2210\ g\ m^{-3} \times 8.3145\ J\ K^{-1}\ mol^{-1} \times 300.2\ K/101325\ Pa$
$= 54.4\ g\ m^{-3}\ J\ mol^{-1}\ Pa^{-1} = 54.4\ g\ m^{-3}\ (kg^1\ m^2\ s^{-2})\ mol^{-1}\ (kg^{-1}\ m\ s^2)$
$= 54.4\ g/mol$

6. An anesthetic contains 64.9 %C, 13.5 %H, and 21.6%O. One liter of the gas at 120 °C and 750 mmHg weighs 2.30 g. What is the molecular formula of the gas?
64.9 g C – 5.40 mol C
13.5 g H – 13.4 mol H
21.6 g O – 1.35 mol O
$C:H:O \approx 4:10:1$
Empirical formula: $C_4H_{10}O$

$M(C_4H_{10}O)$ = 74.123 g/mol

T = (120 + 273)K = 393 K
p = 750 Torr ×101325 Pa/ 760 Torr = 100000 Pa
$V = 1L = 0.001\ m^3$

$$M = m\ RT/pV = 2.30\ g \times 8.3145\ J\ K^{-1}\ mol^{-1} \times 393\ K/(100000\ Pa \times 0.001\ m^3)$$
$$= 75.2\ g\ J\ mol^{-1}\ Pa^{-1}\ m^{-3} = 75.2\ g\ (kg^1\ m^2\ s^{-2})\ mol^{-1}\ (kg^{-1}\ m\ s^2)\ m^{-3}$$
$$= 75.2\ g/mol$$

molecular formula: $C_4H_{10}O$

7. Calculate the volume of $O_{2(g)}$ (in L) at STP required for the complete combustion of 2.64 L of acetylene ($C_2H_{2(g)}$) at STP.

$$2\ C_2H_2 + 5\ O_2 \rightarrow 2\ H_2O + 4\ CO_2$$

mol O_2 = mol C_2H_2× 5 mol O_2/2 mol C_2H_2
Since the number of moles and the volume are propotional when p and T = const., we can substitute mol by volume in the above equation.
$V(O_2)$ = L O_2 = L C_2H_2× 5 L O_2/2L C_2H_2 = 2.64 L C_2H_2× 5 L O_2/2L C_2H_2 = 6.60 L O_2

8. Calculate the volume of $CO_{2(g)}$ produced at STP that could be obtained by allowing 45.0 g of $CaCO_{3(s)}$ to react with hydrochloric acid.

$$CaCO_3 + 2\ HCl \rightarrow CaCl_2 + H_2O + CO_2$$

$M(CaCO_3)$ =100.087 g mol^{-1}
$n(CaCO_3)$ =45.0 g/(100.087 g mol^{-1}) = 0.450 mol
$n(CO_2)$ =0.450 mol $CaCO_3$ consumed× 1 mol CO_2 formed/1 mol $CaCO_3$ consumed
= 0.450 mol CO_2 formed
At STP 1 mol: 22.41 L
At STP: $V(CO_2)$ = 0.450 mol ×22.41 L/mol = 10.1 L

1 mol of an ideal gas occupies a volume of 22.41 L (0.02241 m^3) at 0 °C (273.15 K) and 1 atm of pressure (101325 Pa).

$pV = nRT$ $\qquad$ $n = m/MW$ $\qquad$ $\rho = m/V$

$R = 8.3145\ J\ K^{-1}\ mol^{-1}$