Sample problem 1

CH_4 burns in O_2, producing CO_2 and $H_2O(g)$. A 1.22 L CH_4 cylinder, at 15°C, registers a pressure of 328 kPa.

a) What volume of O_2 at SATP will be required to react completely with all of the CH_4?

First: $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

PV = nRT P = 328 kPa, V = 1.22 L, T = 288 K

$$\frac{(328\text{ kPa})(1.22\text{ L})}{(8.31\text{ kPa•L/K•mol})(288\text{ K})} = n = 0.167\text{ mol}$$

$$\#\text{ mol } O_2 = 0.167\text{ mol } CH_4 \times \frac{2\text{ mol } O_2}{1\text{ mol } CH_4} = 0.334\text{ mol}$$

PV = nRT P= 100 kPa, n= 0.334 mol, T= 298 K

$$\frac{(0.334\text{ mol})(8.31\text{ kPa•L/K•mol})(298\text{ K})}{(100\text{ kPa})} = V = 8.28\text{ L}$$

or # L = 0.334 mol x 24.8 L/mol = 8.28 L

Sample problem 1 continued

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

b) How many grams of $H_2O(g)$ are produced?

$$\#\text{ g } H_2O = 0.334\text{ mol } O_2 \times \frac{2\text{ mol } H_2O}{2\text{ mol } O_2} \times \frac{18.02\text{ g } H_2O}{1\text{ mol } H_2O} = 6.02\text{ g } H_2O$$

c) What volume of CO_2 (at STP) is produced if only 2.15 g of the CH_4 was burned?

$$\#\text{ mol } CO_2 = 2.15\text{ g } CH_4 \times \frac{1\text{ mol } CH_4}{16.05\text{ g } CH_4} \times \frac{1\text{ mol } CO_2}{1\text{ mol } CH_4} = 0.134\text{ mol } CO_2$$

PV = nRT P = 101.3 kPa, n = 0.134 mol, T = 273 K

$$\frac{(0.134\text{ mol})(8.31\text{ kPa•L/K•mol})(273\text{ K})}{(101.3\text{ KPa})} = V = 3.00\text{ L } CO_2$$

or # L = 0.134 mol x 22.4 L/mol = 3.00 L

Sample problem 2

Ammonia (NH_3) gas can be synthesized from nitrogen gas + hydrogen gas. What volume of ammonia at 450 kPa and 80°C can be obtained from the complete reaction of 7.5 kg hydrogen?

First we need a balanced equation:

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

$$\#\text{ mol } NH_3 = 7500\text{ g } H_2 \times \frac{1\text{ mol } H_2}{2.02\text{ g } H_2} \times \frac{2\text{ mol } NH_3}{3\text{ mol } H_2} = 2475\text{ mol}$$

PV = nRT P = 450 kPa, n = 2475 mol, T = 353 K

$$\frac{(2475\text{ mol})(8.31)(353\text{ K})}{(450\text{ KPa})} = V = 16\,135\text{ L } NH_3$$

Sample problem 3

Hydrogen gas (and NaOH) is produced when sodium metal is added to water. What mass of Na is needed to produce 20.0 L of H_2 at STP?

First we need a balanced equation:

$2Na(s) + 2H_2O(l) \rightarrow H_2(g) + 2NaOH(aq)$

PV = nRT P= 101.3 kPa, V= 20.0 L, T= 273 K

$$\frac{(101.3\text{ kPa})(20.0\text{ L})}{(8.31\text{ kPa•L/K•mol})(273\text{ K})} = n = 0.893\text{ mol } H_2$$

or # mol = 20.0 L x 1 mol / 22.4 L = 0.893 mol

$$\#\text{ g Na} = 0.893\text{ mol } H_2 \times \frac{2\text{ mol Na}}{1\text{ mol } H_2} \times \frac{22.99\text{ g Na}}{1\text{ mol Na}} = 41.1\text{ g Na}$$

Answers

1. $3O_2(g) + 2CH_3OH(l) \rightarrow 2CO_2(g) + 4H_2O(g)$

L O_2=

$$15\text{ g } CH_3OH \times \frac{1\text{ mol } CH_3OH}{32.05\text{ g } CH_3OH} \times \frac{3\text{ mol } O_2}{2\text{ mol } CH_3OH} \times \frac{22.4\text{ L } O_2}{1\text{ mol } O_2} = 15.7\text{ L } O_2$$

2. $2NaCl(l) \rightarrow 2Na(l) + Cl_2(g)$

$$\#\text{ mol } Cl_2 = 105\text{ g Na} \times \frac{1\text{ mol Na}}{22.99\text{ g Na}} \times \frac{1\text{ mol } Cl_2}{2\text{ mol Na}} = 2.284\text{ mol } Cl_2$$

PV = nRT P = 100 kPa, n = 2.284 mol, T = 1073 K

$$\frac{(2.284\text{ mol})(8.31)(1073\text{ K})}{(100\text{ KPa})} = V = 204\text{ L } Cl_2$$

3. $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

$$\#\text{ g } C_3H_8 = 20\text{ L } O_2 \times \frac{1\text{ mol } O_2}{24.8\text{ L } O_2} \times \frac{1\text{ mol } C_3H_8}{5\text{ mol } O_2} \times \frac{44.11\text{ g } C_3H_8}{1\text{ mol } C_3H_8} = 7.1\text{ g } C_3H_8$$

4. $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

PV = nRT $n = \frac{(1317\text{ kPa})(5.0\text{ L})}{(8.31)(283\text{ K})} = 2.8\text{ mol } C_3H_8$

$$\#\text{ mol } O_2 = 2.8\text{ mol } C_3H_8 \times \frac{5\text{ mol } O_2}{1\text{ mol } C_3H_8} = 14\text{ mol } O_2$$

PV = nRT P = 103 kPa, n = 14 mol, T = 283 K

$$\frac{(14\text{ mol})(8.31)(283\text{ K})}{(103\text{ KPa})} = V = 320\text{ L } O_2$$

5. # mol $C_3H_5(NO_3)_3$=

$$100\text{ g } C_3H_5(NO_3)_3 \times \frac{1\text{ mol } C_3H_5(NO_3)_3}{227.11\text{ g } C_3H_5(NO_3)_3} = 0.4403\text{ mol}$$

$$\#\text{ L } CO_2 = 0.4403\text{ mol } C_3H_5(NO_3)_3 \times \frac{12\text{ mol } CO_2}{4\text{ mol } C_3H_5(NO_3)_3} \times \frac{22.4\text{ L}}{1\text{ mol}} = 29.6\text{ L } CO_2$$

$$\#\text{ L } N_2 = 0.4403\text{ mol } C_3H_5(NO_3)_3 \times \frac{6\text{ mol } N_2}{4\text{ mol } C_3H_5(NO_3)_3} \times \frac{22.4\text{ L}}{1\text{ mol}} = 14.8\text{ L } N_2$$

$$\#\text{ L } H_2O = 0.4403\text{ mol } C_3H_5(NO_3)_3 \times \frac{10\text{ mol } H_2O}{4\text{ mol } C_3H_5(NO_3)_3} \times \frac{22.4\text{ L}}{1\text{ mol}} = 24.7\text{ L } H_2O$$

$$\#\text{ L } O_2 = 0.4403\text{ mol } C_3H_5(NO_3)_3 \times \frac{1\text{ mol } O_2}{4\text{ mol } C_3H_5(NO_3)_3} \times \frac{22.4\text{ L}}{1\text{ mol}} = 2.47\text{ L } O_2$$

5. # mol $C_3H_5(NO_3)_3$=

$$200\text{ g } C_3H_5(NO_3)_3 \times \frac{1\text{ mol } C_3H_5(NO_3)_3}{227.11\text{ g } C_3H_5(NO_3)_3} = 0.8806\text{ mol}$$

mol all gases=

$$0.8806\text{ mol } C_3H_5(NO_3)_3 \times \frac{29\text{ mol gases}}{4\text{ mol } C_3H_5(NO_3)_3} = 6.385\text{ mol all gases}$$

PV = nRT V = 50 L, n = 6.385 mol, T = 493 K

$$\frac{(6.385\text{ mol})(8.31)(493\text{ K})}{(50\text{ L})} = P = 523\text{ kPa}$$