ANSWERS TO UNIT VII : CALCULATIONS INVOLVING REACTIONS (STOICHIOMETRY)

1. (a) $\text{\# of } O_2 \text{ molecules} = 6 \text{ molecules } C_2H_6 \times \frac{7 \text{ molecules } O_2}{2 \text{ molecules } C_2H_6} = \textbf{21 molecules}$

   (b) $\text{\# of } H_2O \text{ molecules} = 12 \text{ molecules } C_2H_6 \times \frac{6 \text{ molecules } H_2O}{2 \text{ molecules } C_2H_6} = \textbf{36 molecules}$

   (c) $\text{\# of moles of } O_2 = 18 \text{ mol } CO_2 \times \frac{7 \text{ mol } O_2}{4 \text{ mol } CO_2} = \textbf{31.5 mol}$

   (d) $\text{\# of moles of } CO_2 = 13 \text{ mol } C_2H_6 \times \frac{4 \text{ mol } CO_2}{2 \text{ mol } C_2H_6} = \textbf{26 mol}$

2. (a) $\text{\# of molecules } Fe_3O_4 = 12 \text{ atoms Fe} \times \frac{1 \text{ molecule } Fe_3O_4}{3 \text{ atoms Fe}} = \textbf{4 molecules}$

   (b) $\text{\# of moles of Fe} = 16 \text{ mol } H_2 \times \frac{3 \text{ mol Fe}}{4 \text{ mol } H_2} = \textbf{12 mol}$

   (c) $\text{\# of molecules } H_2 = 40 \text{ molecules } Fe_3O_4 \times \frac{4 \text{ molecules } H_2}{1 \text{ molecule } Fe_3O_4} = \textbf{160 molecules}$

   (d) $\text{\# of moles of } H_2O = 14.5 \text{ mol Fe} \times \frac{4 \text{ mol } H_2O}{3 \text{ mol Fe}} = \textbf{19.3 mol}$

3. $\text{\# of moles of } H_2O = 9.6 \text{ mol } O_2 \times \frac{2 \text{ mol } H_2O}{1 \text{ mol } O_2} = \textbf{19 mol}$

4. (a) $\text{\# of moles of } I_4F_2 = 5.40 \text{ mol } F_2 \times \frac{1 \text{ mol } I_4F_2}{6 \text{ mol } F_2} = \textbf{0.900 mol}$

   (b) $\text{\# of moles of } F_2 = 4.50 \text{ mol } IF_5 \times \frac{6 \text{ mol } F_2}{2 \text{ mol } IF_5} = \textbf{13.5 mol}$

   (c) $\text{\# of moles of } I_2 = 7.60 \text{ mol } F_2 \times \frac{3 \text{ mol } I_2}{6 \text{ mol } F_2} = \textbf{3.80 mol}$

5. Since 2 mol of reactants make a total of 3 mol of products, then O_2 represents $^1/_5$ of the total moles involved. Therefore:

   $$\text{\# of moles of } O_2 = \frac{0.125 \text{ mol}}{5} = \textbf{0.025 mol}$$

   Alternately: $\text{\# of moles of } O_2 = 0.125 \text{ mol molecules} \times \frac{1 \text{ mol } O_2}{5 \text{ mol molecules}} = \textbf{0.025 mol}$

6. (a) $\text{mass of NO} = 2.00 \text{ mol } NH_3 \times \frac{4 \text{ mol NO}}{4 \text{ mol } NH_3} \times \frac{30.0 \text{ g NO}}{1 \text{ mol NO}} = \textbf{60.0 g}$

   (b) $\text{mass of } H_2O = 4.00 \text{ mol } O_2 \times \frac{6 \text{ mol } H_2O}{5 \text{ mol } O_2} \times \frac{18.0 \text{ g } H_2O}{1 \text{ mol } H_2O} = \textbf{86.4 g}$

   (c) $\text{volume of } NH_3 = 3.00 \text{ mol } O_2 \times \frac{4 \text{ mol } NH_3}{5 \text{ mol } O_2} \times \frac{22.4 \text{ L } NH_3}{1 \text{ mol } NH_3} = \textbf{53.8 L}$

   (d) $\text{volume of } NH_3 = 0.750 \text{ mol } H_2O \times \frac{4 \text{ mol } NH_3}{6 \text{ mol } H_2O} \times \frac{22.4 \text{ L } NH_3}{1 \text{ mol } NH_3} = \textbf{11.2 L}$

7. (a) mass of CO_2 = $100.0\text{ g }C_5H_{12} \times \frac{1\text{ mol }C_5H_{12}}{72.0\text{ g }C_5H_{12}} \times \frac{5\text{ mol }CO_2}{1\text{ mol }C_5H_{12}} \times \frac{44.0\text{ g }CO_2}{1\text{ mol }CO_2}$ = **306 g**

(b) mass of O_2 = $60.0\text{ g }H_2O \times \frac{1\text{ mol }H_2O}{18.0\text{ g }H_2O} \times \frac{8\text{ mol }O_2}{6\text{ mol }H_2O} \times \frac{32.0\text{ g }O_2}{1\text{ mol }O_2}$ = **142 g**

(c) mass of C_5H_{12} = $90.0\text{ L }CO_2 \times \frac{1\text{ mol }CO_2}{22.4\text{ L }CO_2} \times \frac{1\text{ mol }C_5H_{12}}{5\text{ mol }CO_2} \times \frac{72.0\text{ g }C_5H_{12}}{1\text{ mol }C_5H_{12}}$ = **57.9 g**

(d) volume of O_2 = $70.0\text{ g }CO_2 \times \frac{1\text{ mol }CO_2}{44.0\text{ g }CO_2} \times \frac{8\text{ mol }O_2}{5\text{ mol }CO_2} \times \frac{22.4\text{ L }O_2}{1\text{ mol }O_2}$ = **57.0 L**

(e) volume of O_2 = $48.0\text{ L }CO_2 \times \frac{1\text{ mol }CO_2}{22.4\text{ L }CO_2} \times \frac{8\text{ mol }O_2}{5\text{ mol }CO_2} \times \frac{22.4\text{ L }O_2}{1\text{ mol }O_2}$ = **76.8 L**

(f) mass of H_2O = $106\text{ L }CO_2 \times \frac{1\text{ mol }CO_2}{22.4\text{ L }CO_2} \times \frac{6\text{ mol }H_2O}{5\text{ mol }CO_2} \times \frac{18.0\text{ g }H_2O}{1\text{ mol }H_2O}$ = **102 g**

8. (a) volume of O_2 = $100.0\text{ g PbO} \times \frac{1\text{ mol PbO}}{223.2\text{ g PbO}} \times \frac{27\text{ mol }O_2}{2\text{ mol PbO}} \times \frac{22.4\text{ L }O_2}{1\text{ mol }O_2}$ = **135 L**

(b) # of molecules of CO_2 = $1.00 \times 10^{-6}\text{ g Pb}(C_2H_5)_4 \times \frac{1\text{ mol Pb}(C_2H_5)_4}{323.2\text{ g Pb}(C_2H_5)_4} \times \frac{16\text{ mol }CO_2}{2\text{ mol Pb}(C_2H_5)_4}$

$\times \frac{6.02 \times 10^{23}\text{ molecules }CO_2}{1\text{ mol }CO_2}$ = **1.49 x 10^{16} molecules**

(c) # of molecules of H_2O = $135\text{ molecules }O_2 \times \frac{20\text{ molecules }H_2O}{27\text{ molecules }O_2}$ = **100 molecules**

(d) volume of O_2 = $1.00 \times 10^{15}\text{ molec Pb}(C_2H_5)_4 \times \frac{1\text{ mol Pb}(C_2H_5)_4}{6.02 \times 10^{23}\text{ molec Pb}(C_2H_5)_4} \times \frac{27\text{ mol }O_2}{2\text{ mol Pb}(C_2H_5)_4}$

$\times \frac{22.4\text{ L }O_2}{1\text{ mol }O_2} \times \frac{1\text{ mL}}{10^{-3}\text{ L}}$ = **5.02 x 10^{-4} mL**

9. (a) mass of H_2O = $0.150\text{ g }CH_3NO_2 \times \frac{1\text{ mol }CH_3NO_2}{61.0\text{ g }CH_3NO_2} \times \frac{6\text{ mol }H_2O}{4\text{ mol }CH_3NO_2} \times \frac{18.0\text{ g }H_2O}{1\text{ mol }H_2O}$ = **0.0664 g**

(b) First, note that 4 mol of CH_3NO_2 produce 4 mol $CO_2(g)$ and 2 mol $N_2(g)$; that is, 6 mol of gas.

volume of gas = $0.316\text{ g }CH_3NO_2 \times \frac{1\text{ mol }CH_3NO_2}{61.0\text{ g }CH_3NO_2} \times \frac{6\text{ mol gas}}{4\text{ mol }CH_3NO_2} \times \frac{22.4\text{ L gas}}{1\text{ mol gas}}$ = **0.174 L**

(c) volume of O_2 = $0.250\text{ g }CO_2 \times \frac{1\text{ mol }CO_2}{44.0\text{ g }CO_2} \times \frac{3\text{ mol }O_2}{4\text{ mol }CO_2} \times \frac{22.4\text{ L }O_2}{1\text{ mol }O_2}$ = **0.0955 L**

(d) mass of H_2O = $0.410\text{ g }CO_2 \times \frac{1\text{ mol }CO_2}{44.0\text{ g }CO_2} \times \frac{6\text{ mol }H_2O}{4\text{ mol }CO_2} \times \frac{18.0\text{ g }H_2O}{1\text{ mol }H_2O}$ = **0.252 g**

10. mass of $SiCl_4$ = $1.00\text{ g Si} \times \frac{1\text{ mol Si}}{28.1\text{ g Si}} \times \frac{1\text{ mol }SiCl_4}{1\text{ mol Si}} \times \frac{170.1\text{ g }SiCl_4}{1\text{ mol }SiCl_4}$ = **6.05 g**

mass of H_2 = $1.00\text{ g Si} \times \frac{1\text{ mol Si}}{28.1\text{ g Si}} \times \frac{2\text{ mol }H_2}{1\text{ mol Si}} \times \frac{2.0\text{ g }H_2}{1\text{ mol }H_2}$ = **0.14 g**

11. volume of $NH_3 = 1.25 \times 10^4$ kg $N_2H_4 \times \frac{10^3\ g\ N_2H_4}{1\ kg\ N_2H_4} \times \frac{1\ mol\ N_2H_4}{32.0\ g\ N_2H_4} \times \frac{2\ mol\ NH_3}{1\ mol\ N_2H_4} \times \frac{22.4\ L\ NH_3}{1\ mol\ NH_3}$

$= \mathbf{1.75 \times 10^7\ L}$

12. mass of $H_2SO_4 = 25.0\ mL \times 1.84\ \frac{g}{mL} = 46.0\ g$

mass of $P_4O_{10} = 46.0\ g\ H_2SO_4 \times \frac{1\ mol\ H_2SO_4}{98.1\ g\ H_2SO_4} \times \frac{1\ mol\ P_4O_{10}}{6\ mol\ H_2SO_4} \times \frac{284.0\ g\ P_4O_{10}}{1\ mol\ P_4O_{10}} = \mathbf{22.2\ g}$

volume of $SO_3 = 46.0\ g\ H_2SO_4 \times \frac{1\ mol\ H_2SO_4}{98.1\ g\ H_2SO_4} \times \frac{6\ mol\ SO_3}{6\ mol\ H_2SO_4} \times \frac{22.4\ L\ SO_3}{1\ mol\ SO_3} = \mathbf{10.5\ L}$

13. mass of $Cl = 1.5 \times 10^{15}\ L\ O_3 \times \frac{1\ mol\ O_3}{22.4\ L\ O_3} \times \frac{1\ mol\ Cl}{1.0 \times 10^5\ mol\ O_3} \times \frac{35.5\ g\ Cl}{1\ mol\ Cl} = \mathbf{2.4 \times 10^{10}\ g}$

14. We know that 0.150 mol of R_4 reacts with 143.8 g of Q_2, but the reaction ($R_4 + 6\ Q_2 \longrightarrow 4\ RQ_3$) shows 1 mol of R_4 reacting with 6 mol of Q_2. The amount of Q_2 formed by 0.150 mol of R_4 is

moles of $Q_2 = 0.150\ mol\ R_4 \times \frac{6\ mol\ Q_2}{1\ mol\ R_4} = 0.900\ mol.$

But, if 0.15 mol of R_4 reacts with 0.900 mol of Q_2 and with 143.8 g of Q_2, then

$0.900\ mol\ Q_2 = 143.8\ g\ Q_2$, so that: $1\ mol\ Q_2 = 159.8\ g$.

Hence, the molar mass of Q is 159.8 g / 2 = **79.9 g**. (A check of the periodic chart shows that Q is "Br".)

15. First find how many MOLES of atoms are in 100.0 g of Ne.

moles of Ne $= 100.0\ g \times \frac{1\ mol\ Ne}{20.2\ g\ Ne} = 4.95\ mol$

moles of atoms from decomposing HgO = 4.95 mol / 3 = 1.65 mol.

Now, 2 HgO molecules decompose to form 4 atoms of products (2 Hg atoms and 2 O atoms).

moles of HgO needed $= 1.65$ moles products $\times \frac{2\ mol\ HgO}{4\ mol\ products} = 0.825\ mol$

and: mass of HgO $= 0.825\ mol \times \frac{216.6\ g}{1\ mol} = \mathbf{179\ g}$

16. Balance the equation: $2\ XZO_3 \longrightarrow 3\ O_2 + 2\ XZ$. Using the mass of O_2, find the moles of XZ produced.

moles of XZ $= 2.208\ g\ O_2 \times \frac{1\ mol\ O_2}{32.0\ g\ O_2} \times \frac{2\ mol\ XZ}{3\ mol\ O_2} = 0.0460\ mol$

Now: molar mass of XZ $= \frac{5.474\ g}{0.0460\ mol} = 119\ g/mol$

Balance the double replacement equation: $XZ + AgNO_3 \longrightarrow AgZ + XNO_3$. The double replacement implies that 1 mol XZ produces 1 mol AgZ (or that 0.0460 mol XZ produces 0.0460 mol AgZ). Hence: 0.0460 mol AgZ = 8.639 g (from problem statement) and

molar mass of AgZ $= \frac{8.639\ g}{0.0460\ mol} = 188\ g/mol$

Since the molar mass of Ag is 107.9, then molar mass of Z = 188 − 107.9 = $\mathbf{8.0 \times 10^1}$ **g/mol** (= Br)

and: molar mass X = molar mass XZ − molar mass Z = $119 - 8.0 \times 10^1 =$ **39 g/mol** (= K)

17. Moles of NaOH $= 50.0\ L\ H_2 \times \frac{1\ mol\ H_2}{22.4\ L\ H_2} \times \frac{2\ mol\ NaOH}{3\ mol\ H_2} = 1.488\ mol$

volume of NaOH $= \frac{n}{c} = \frac{1.488\ mol}{3.00\ mol/L} = \mathbf{0.496\ L}$