ANSWERS TO UNIT VII : CALCULATIONS INVOLVING REACTIONS (STOICHIOMETRY)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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.

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

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).

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

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

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.

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

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

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

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

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 − 8.0×10^1 = **39 g/mol** (= K)

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

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

18. The neutralization equation is: $HCl + NaOH \longrightarrow NaCl + H_2O$.

moles of NaOH $= 0.318\ \frac{mol}{L} \times 0.0250\ L = 7.95 \times 10^{-3}\ mol$ = moles HCl

volume of HCl $= \frac{n}{c} = \frac{0.00795\ mol}{0.250\ mol/L} = \mathbf{0.0318\ L\ (31.8\ mL)}$

19. (a) moles of $Cl^- = 0.0148\ \frac{mol}{L} \times 0.0154\ L = 2.279 \times 10^{-4}\ mol$

moles of $Hg^{2+} = 2.279 \times 10^{-4}\ mol\ Cl^- \times \frac{1\ mol\ Hg^{2+}}{2\ mol\ Cl^-} = 1.140 \times 10^{-4}\ mol$

= moles $HgCl_2$ (for second part of problem)

$[Hg^{2+}] = \frac{n}{V} = \frac{1.140 \times 10^{-4}\ mol}{0.0250\ L} = \mathbf{4.56 \times 10^{-3}\ M}$

(b) mass of $HgCl_2 = 1.140 \times 10^{-4}\ mol \times \frac{271.6\ g}{1\ mol} = \mathbf{0.0310\ g}$

20. (a) The neutralization reaction is: $Ca(OH)_2 + 2\ HCl \longrightarrow CaCl_2 + 2\ H_2O$.

moles of HCl $= 0.0156\ \frac{mol}{L} \times 0.0235\ L = 3.666 \times 10^{-4}\ mol$

moles of $Ca(OH)_2 = 3.666 \times 10^{-4}\ mol\ HCl \times \frac{1\ mol\ Ca(OH)_2}{2\ mol\ HCl} = 1.833 \times 10^{-4}\ mol$

$[Ca(OH)_2] = \frac{n}{V} = \frac{1.833 \times 10^{-4}\ mol}{0.0100\ L} = \mathbf{0.0183\ M}$

(b) mass of $Ca(OH)_2 = 0.01833\ \frac{mol}{L} \times 0.2500\ L \times \frac{74.1\ g}{1\ mol} = \mathbf{0.340\ g}$

21. (a) moles of $H_2O_2 = 1.24\ \frac{mol}{L} \times 0.00200\ L = 2.48 \times 10^{-3}\ mol$

moles of $MnO_4^- = 2.48 \times 10^{-3}\ H_2O_2 \times \frac{2\ mol\ MnO_4^-}{5\ mol\ H_2O_2} = 9.92 \times 10^{-4}\ mol$

volume of $MnO_4^- = \frac{n}{c} = \frac{9.92 \times 10^{-4}\ mol}{0.0496\ mol/L} = \mathbf{0.0200\ L\ (20.0\ mL)}$

(b) volume of $O_2 = 9.92 \times 10^{-4}\ mol\ MnO_4^- \times \frac{5\ mol\ O_2}{2\ mol\ MnO_4^-} \times \frac{22.4\ L\ O_2}{1\ mol\ O_2} = \mathbf{0.0556\ L}$

22. (a) moles of NaOH $= 0.853\ \frac{mol}{L} \times 0.0438\ L = 0.03736\ mol$

moles of $H_3PO_4 = 0.03736\ mol\ NaOH \times \frac{1\ mol\ H_3PO_4}{2\ mol\ NaOH} = 0.01868\ mol$

$[H_3PO_4] = \frac{n}{V} = \frac{0.01868\ mol}{0.00100\ L} = \mathbf{18.7\ M}$

(b) density $= 18.68\ \frac{mol}{L} \times \frac{98.0\ g}{1\ mol} = \mathbf{1.83 \times 10^3\ \frac{g}{L}}$

23. (a) moles of $Cr_2O_7^{2-} = 0.125\ \frac{mol}{L} \times 0.0176\ L = 2.20 \times 10^{-3}\ mol$

moles of $Fe^{2+} = 2.20 \times 10^{-3}\ mol\ Cr_2O_7^{2-} \times \frac{6\ mol\ Fe^{2+}}{1\ mol\ Cr_2O_7^{2-}} = 0.0132\ mol$

$[Fe^{2+}] = \frac{n}{V} = \frac{0.0132\ mol}{0.0250\ L} = \mathbf{0.528\ M}$

(b) mass of Fe = mass of $Fe^{2+} = 0.01320\ mol \times \frac{55.8\ g}{1\ mol} = \mathbf{0.737\ g}$

24. (a) $[NH_4NO_3] = \frac{15.5\ g}{0.5000\ L} \times \frac{1\ mol}{80.0\ g} = 0.3875\ M$

moles of $NH_4NO_3 = 0.3875\ \frac{mol}{L} \times 0.0100\ L = 3.875 \times 10^{-3}\ mol$ = moles NaOH

$[NaOH] = \frac{n}{V} = \frac{3.875 \times 10^{-3}\ mol}{0.0250\ L} = \mathbf{0.155\ M}$

(b) volume of $NH_3 = 3.875 \times 10^{-3}\ mol\ NaOH \times \frac{1\ mol\ NH_3}{1\ mol\ NaOH} \times \frac{22.4\ L\ NH_3}{1\ mol\ NH_3} = \mathbf{0.0868\ L}$

25. (a) moles of $Ba(OH)_2$ (at start) $= 0.0538\ \frac{mol}{L} \times 0.0250\ L = \mathbf{1.345 \times 10^{-3}\ mol}$

(b) moles of HCl $= 0.104\ \frac{mol}{L} \times 0.0230\ L = 2.392 \times 10^{-3}\ mol$

moles of $Ba(OH)_2$ (remaining) $= 2.392 \times 10^{-3}\ mol\ HCl \times \frac{1\ mol\ Ba(OH)_2}{2\ mol\ HCl} = \mathbf{1.196 \times 10^{-3}\ mol}$

(c) moles of $Ba(OH)_2$ (reacted) = moles $Ba(OH)_2$ (at start) – moles $Ba(OH)_2$ (remaining)
$= 1.345 \times 10^{-3} - 1.196 \times 10^{-3} = \mathbf{1.49 \times 10^{-4}\ mol}$

(d) moles of $CO_2 = 1.49 \times 10^{-4}\ mol\ Ba(OH)_2 \times \frac{1\ mol\ CO_2}{1\ mol\ Ba(OH)_2} = \mathbf{1.49 \times 10^{-4}\ mol}$

(e) volume of $CO_2 = 1.49 \times 10^{-4}\ mol \times \frac{22.4\ L}{1\ mol} = 3.34 \times 10^{-3}\ L$

% CO_2 in air $= \frac{3.34 \times 10^{-3}\ L}{10.0\ L} \times 100\% = \mathbf{0.0334\%}$

26. mass of CS_2 (based on C) $= 17.5\ g\ C \times \frac{1\ mol\ C}{12.0\ g\ C} \times \frac{1\ mol\ CS_2}{5\ mol\ C} \times \frac{76.2\ g\ CS_2}{1\ mol\ CS_2} = 22.2\ g$

mass of CS_2 (based on SO_2) $= 39.5\ g\ SO_2 \times \frac{1\ mol\ SO_2}{64.1\ g\ SO_2} \times \frac{1\ mol\ CS_2}{2\ mol\ SO_2} \times \frac{76.2\ g\ CS_2}{1\ mol\ CS_2} = 23.5\ g$

Since C produces the least amount of CS_2, then the mass of CS_2 produced is **22.2 g.** The SO_2 is present in excess, so the mass of SO_2 used can be calculated arbitrarily based on the mass of C.

mass of SO_2 used $= 17.5\ g\ C \times \frac{1\ mol\ C}{12.0\ g\ C} \times \frac{2\ mol\ SO_2}{5\ mol\ C} \times \frac{64.1\ g\ SO_2}{1\ mol\ SO_2} = 37.4\ g$

mass of SO_2 in excess $= 39.5 - 37.4 = \mathbf{2.1\ g}$

27. $$\text{mass of NO (based on Cu)} = 87.0\text{ g Cu} \times \frac{1\text{ mol Cu}}{63.5\text{ g Cu}} \times \frac{2\text{ mol NO}}{3\text{ mol Cu}} \times \frac{30.0\text{ g NO}}{1\text{ mol NO}} = 27.4\text{ g}$$

$$\text{mass of NO (based on HNO}_3) = 225\text{ g HNO}_3 \times \frac{1\text{ mol HNO}_3}{63.0\text{ g HNO}_3} \times \frac{2\text{ mol NO}}{8\text{ mol HNO}_3} \times \frac{30.0\text{ g NO}}{1\text{ mol NO}} = 26.8\text{ g}$$

Since HNO_3 produces the least amount of NO, then the mass of NO produced is **26.8 g.**
Now find the mass of Cu in excess, based on the amount of HNO_3 used.

$$\text{mass of Cu used} = 225\text{ g HNO}_3 \times \frac{1\text{ mol HNO}_3}{63.0\text{ g HNO}_3} \times \frac{3\text{ mol Cu}}{8\text{ mol HNO}_3} \times \frac{63.5\text{ g Cu}}{1\text{ mol Cu}} = 85.0\text{ g}$$

mass of Cu in excess = 87.0 − 85.0 = **2.0 g**

28. $$\text{mass of P}_4\text{ [based on Ca}_3\text{(PO}_4)_2] = 41.5\text{ g Ca}_3\text{(PO}_4)_2 \times \frac{1\text{ mol Ca}_3\text{(PO}_4)_2}{310.3\text{ g Ca}_3\text{(PO}_4)_2} \times \frac{1\text{ mol P}_4}{2\text{ mol Ca}_3\text{(PO}_4)_2} \times \frac{124.0\text{ g P}_4}{1\text{ mol P}_4} = 8.29\text{ g}$$

$$\text{mass of P}_4\text{ (based on SiO}_2) = 26.5\text{ g SiO}_2 \times \frac{1\text{ mol SiO}_2}{60.1\text{ g SiO}_2} \times \frac{1\text{ mol P}_4}{6\text{ mol SiO}_2} \times \frac{124.0\text{ g P}_4}{1\text{ mol P}_4} = 9.11\text{ g}$$

$$\text{mass of P}_4\text{ (based on C)} = 7.80\text{ g C} \times \frac{1\text{ mol C}}{12.0\text{ g C}} \times \frac{1\text{ mol P}_4}{10\text{ mol C}} \times \frac{124.0\text{ g P}_4}{1\text{ mol P}_4} = 8.06\text{ g}$$

Since C produces the least amount of P_4, then the mass of P_4 produced is **8.06 g.**
Next, calculate the masses of both $Ca_3(PO_4)_2$ and SiO_2 used by the C:

$$\text{mass of Ca}_3\text{(PO}_4)_2\text{ used} = 7.80\text{ g C} \times \frac{1\text{ mol C}}{12.0\text{ g C}} \times \frac{2\text{ mol Ca}_3\text{(PO}_4)_2}{10\text{ mol C}} \times \frac{310.3\text{ g Ca}_3\text{(PO}_4)_2}{1\text{ mol Ca}_3\text{(PO}_4)_2} = 40.3\text{ g}$$

mass of $Ca_3(PO_4)_2$ in excess = 41.5 − 40.3 = **1.2 g**

$$\text{mass of SiO}_2\text{ used} = 7.80\text{ g C} \times \frac{1\text{ mol C}}{12.0\text{ g C}} \times \frac{6\text{ mol SiO}_2}{10\text{ mol C}} \times \frac{60.1\text{ g SiO}_2}{1\text{ mol SiO}_2} = 23.4\text{ g}$$

mass of SiO_2 in excess = 26.5 − 23.4 = **3.1 g**

29. $$\text{mass of Br}_2\text{ (based on K}_2\text{Cr}_2\text{O}_7) = 25.0\text{ g K}_2\text{Cr}_2\text{O}_7 \times \frac{1\text{ mol K}_2\text{Cr}_2\text{O}_7}{294.2\text{ g K}_2\text{Cr}_2\text{O}_7} \times \frac{3\text{ mol Br}_2}{1\text{ mol K}_2\text{Cr}_2\text{O}_7} \times \frac{159.8\text{ g Br}_2}{1\text{ mol Br}_2} = 40.7\text{ g}$$

$$\text{mass of Br}_2\text{ (based on KBr)} = 55.0\text{ g KBr} \times \frac{1\text{ mol KBr}}{119.0\text{ g KBr}} \times \frac{3\text{ mol Br}_2}{6\text{ mol KBr}} \times \frac{159.8\text{ g Br}_2}{1\text{ mol Br}_2} = 36.9\text{ g}$$

$$\text{mass of Br}_2\text{ (based on H}_2\text{SO}_4) = 60.0\text{ g H}_2\text{SO}_4 \times \frac{1\text{ mol H}_2\text{SO}_4}{98.1\text{ g H}_2\text{SO}_4} \times \frac{3\text{ mol Br}_2}{7\text{ mol H}_2\text{SO}_4} \times \frac{159.8\text{ g Br}_2}{1\text{ mol Br}_2} = 41.9\text{ g}$$

KBr is the limiting reactant (it produces the least amount of Br_2). $K_2Cr_2O_7$ and H_2SO_4 are in excess.
Calculate the mass of $K_2Cr_2O_7$ and H_2SO_4 present in excess, arbitrarily based on the mass of KBr.

$$\text{mass of K}_2\text{Cr}_2\text{O}_7\text{ used} = 55.0\text{ g KBr} \times \frac{1\text{ mol KBr}}{119.0\text{ g KBr}} \times \frac{1\text{ mol K}_2\text{Cr}_2\text{O}_7}{6\text{ mol KBr}} \times \frac{294.2\text{ g K}_2\text{Cr}_2\text{O}_7}{1\text{ mol K}_2\text{Cr}_2\text{O}_7} = 22.7\text{ g}$$

mass of $K_2Cr_2O_7$ in excess = 25.0 − 22.7 = **2.3 g**

$$\text{mass of H}_2\text{SO}_4\text{ used} = 55.0\text{ g KBr} \times \frac{1\text{ mol KBr}}{119.0\text{ g KBr}} \times \frac{7\text{ mol H}_2\text{SO}_4}{6\text{ mol KBr}} \times \frac{98.1\text{ g H}_2\text{SO}_4}{1\text{ mol H}_2\text{SO}_4} = 52.9\text{ g}$$

mass of H_2SO_4 in excess = 60.0 − 52.9 = **7.1 g**

30. volume of CO_2 (based on C_5H_{12}) $= 0.0250\ L\ C_5H_{12} \times \frac{626.0\ g\ C_5H_{12}}{1\ L\ C_5H_{12}} \times \frac{1\ mol\ C_5H_{12}}{72.0\ g\ C_5H_{12}} \times \frac{5\ mol\ CO_2}{1\ mol\ C_5H_{12}}$

$\times \frac{22.4\ L\ CO_2}{1\ mol\ CO_2} = 24.3\ L$

volume of CO_2 (based on O_2) $= 40.0\ L\ O_2 \times \frac{1\ mol\ O_2}{22.4\ L\ O_2} \times \frac{5\ mol\ CO_2}{8\ mol\ O_2} \times \frac{22.4\ L\ CO_2}{1\ mol\ CO_2} = 25.0\ L$

Hence, the C_5H_{12} is the limiting reactant and **24.3 L** of $CO_2(g)$ will be produced.

31. moles of HCl $= 0.100\ \frac{mol}{L} \times 0.0500\ L = 5.00 \times 10^{-3}\ mol$

moles of NaCl (based on HCl) $= 5.00 \times 10^{-3}\ mol\ HCl \times \frac{1\ mol\ NaCl}{1\ mol\ HCl} = 5.00 \times 10^{-3}\ mol$

moles of NaOH $= 0.200\ \frac{mol}{L} \times 0.0300\ L = 6.00 \times 10^{-3}\ mol$

moles of NaCl (based on NaOH) $= 6.00 \times 10^{-3}\ mol\ NaOH \times \frac{1\ mol\ NaCl}{1\ mol\ NaOH} = 6.00 \times 10^{-3}\ mol$

Since the NaOH can produce more NaCl, the **NaOH** is in excess.

32. mass of $BaBr_2$ [based on $Ba(OH)_2$] $= 0.250\ g\ Ba(OH)_2 \times \frac{1\ mol\ Ba(OH)_2}{171.3\ g\ Ba(OH)_2} \times \frac{1\ mol\ BaBr_2}{1\ mol\ Ba(OH)_2}$

$\times \frac{297.1\ g\ BaBr_2}{1\ mol\ BaBr_2} = 0.434\ g$

moles of HBr $= 0.125\ \frac{mol}{L} \times 0.0150\ L = 1.875 \times 10^{-3}\ mol$

mass of $BaBr_2$ (based on HBr) $= 1.875 \times 10^{-3}\ mol\ HBr \times \frac{1\ mol\ BaBr_2}{2\ mol\ HBr} \times \frac{297.1\ g\ BaBr_2}{1\ mol\ BaBr_2} = 0.279\ g$

Since HBr is the limiting reactant, **0.279 g** of $BaBr_2$ can be formed.

33. (a) First assume the $FeCO_3$ is 100 % pure.

mass of $Fe_2O_3 = 15.0\ g\ FeCO_3 \times \frac{1\ mol\ FeCO_3}{115.8\ g\ FeCO_3} \times \frac{2\ mol\ Fe_2O_3}{4\ mol\ FeCO_3} \times \frac{159.6\ g\ Fe_2O_3}{1\ mol\ Fe_2O_3} = 10.3\ g$

Since the $FeCO_3$ is only 42.0 % pure there will be less than 10.3 g.
mass of pure $FeCO_3 = 0.420 \times 10.3\ g =$ **4.34 g**

(b) First calculate the mass of pure $FeCO_3$ required to produce 37.0 g of Fe_2O_3.

mass of $FeCO_3 = 37.0\ g\ Fe_2O_3 \times \frac{1\ mol\ Fe_2O_3}{159.6\ g\ Fe_2O_3} \times \frac{4\ mol\ FeCO_3}{2\ mol\ Fe_2O_3} \times \frac{115.8\ g\ FeCO_3}{1\ mol\ FeCO_3} = 53.69\ g$

Then: $\%\ purity = \frac{mass\ of\ pure\ FeCO_3}{mass\ of\ impure\ FeCO_3} \times 100\% = \frac{53.69\ g}{55.0\ g} \times 100\% =$ **97.6%**

(c) First calculate the mass of Fe_2O_3 EXPECTED from the reaction.

mass of $Fe_2O_3 = 35.0\ g\ FeCO_3 \times \frac{1\ mol\ FeCO_3}{115.8\ g\ FeCO_3} \times \frac{2\ mol\ Fe_2O_3}{4\ mol\ FeCO_3} \times \frac{159.6\ g\ Fe_2O_3}{1\ mol\ Fe_2O_3} = 24.12\ g$

Now: $\%\ yield = \frac{mass\ obtained}{mass\ expected} \times 100\% = \frac{22.5\ g}{24.12\ g} \times 100\% =$ **93.3%**