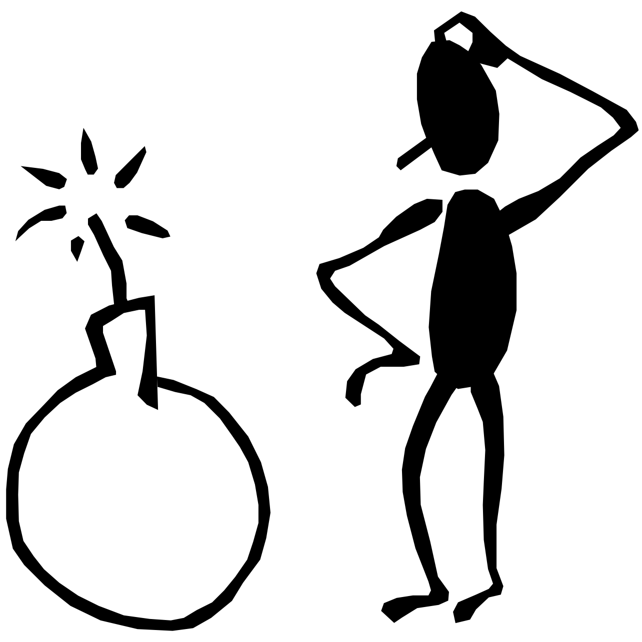
Name: KEY

Chemistry 20 Stoichiometry Worksheets



Worksheet 2.1: Mole to Mole Stoichiometry

Directions: Write balanced equations with states. Solve the problem. Assume water is available.

1. Liquid water decomposes into its elements. **How many moles of hydrogen gas** are produced if 0.500 mol of water is used?

   G R

   step 1) $2H_2O_{(l)} \rightarrow 2H_{2(g)} + O_{2(g)}$

   0.500 mol ?

   step 3) $\frac{0.500 \text{ mol of } H_2O_{(g)}}{} \times \frac{2 \text{ mol of } H_{2(g)}}{2 \text{ mol of } H_2O_{(g)}} = 0.500 \text{ mol of } H_2 \text{ (g)}$

2. Sulphur reacts with barium oxide. **How many moles of sulphur** are needed if 2.00 mol of barium oxide is used?

   R G

   1) $1\ S_8\ (s) + 8\ BaO\ (s) \rightarrow 4\ O_2(g) + 8\ BaS\ (s)$

   ? 2.00 mol

   3) $2.00 \text{ mol of } BaO_{(s)} \times \frac{1 \text{ mol of } S_{8(s)}}{8 \text{ mol of } BaO_{(s)}} = 0.250 \text{ mol of } S_{8(s)}$

3. Methane gas burns. **How many moles of oxygen** gas are needed to completely burn 3.00 mol of methane?

   G R

   1) $1\ CH_{4(g)} + 2\ O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$

   3.00 mol ?

   3) $3.00 \text{mol of } CH_{4(g)} \times \frac{2 \text{ mol of } O_{2(g)}}{1 \text{ mol of } CH_{4\ (g)}} = 6.00 \text{ moles of } O_{2(g)}$

4. Sodium and phosphorus react. **How many moles of phosphorus** are needed if 0.600 mol of sodium metal is used?

   G R

   1) $12Na_{(s)} + 1\ P_{4(s)} \rightarrow 4Na_3P_{(aq)}$

   0.600 mol ?

   3) $0.600 \text{ mol of } Na_{(s)} \times \frac{1 \text{ mole of } P_{4(s)}}{12 \text{ moles of } Na_{(s)}} = 0.0500 \text{ moles of } P_4(s)$

5. Magnesium phosphate reacts with lithium carbonate. **How many moles of lithium carbonate** are needed when 1.50 mol of magnesium phosphate is used?

   G R

   1) $1\ Mg_3(PO_4)_{2(s)} + 3Li_2CO_{3(aq)} \rightarrow 3MgCO_{3(s)} + 2Li_3PO_{4(aq)}$

   1.50 mol ?

   3) $1.50 \text{ mol of } Mg_3(PO_4)_{2(s)} \times \frac{3 \text{ mol of } Li_2CO_{3(aq)}}{1 \text{ mol of } Mg_3(PO_4)_{2(s)}} = 4.50 \text{ mol of } Li_2CO_{3(aq)}$

6. Sulphur dioxide decomposes. How many moles of sulphur dioxide are needed to produce 0.30 mol of sulphur?

R G

1) $8SO_{2(g)} \rightarrow 1\ S_{8(s)} + 8O_{2(g)}$

3) $\frac{0.30 \text{ mol of } S_{8(s)} \times 8 \text{ mol of } SO_{2(g)}}{1 \text{ mol of } S_{8(s)}}$ = 2.4 mol of Sulphur dioxide

7. Magnesium chloride reacts with sodium. How many moles of sodium are needed to react with 0.0250 mol of magnesium chloride?

G R

1) $1\ MgCl_{2(aq)} + 2Na_{(s)} \rightarrow Mg_{(s)} + 2NaCl_{(aq)}$

3) $\frac{0.0250 \text{ mol } MgCl_{2(aq)} \text{ of } \times 2 \text{ mol of } Na_{(s)}}{1 \text{ mol of } MgCl_{2(aq)}}$ = 0.0500 mol of $Na_{(s)}$ (5.00×10^{-2} mol)

8. Iron (II) phosphate reacts with tin (IV) nitride. How many moles of tin (IV) nitride are needed to produce 0.500 mol of iron (II) nitride?

R G

1) $2\ Fe_3(PO_4)_{2(s)} + 1\ Sn_3N_{2(s)} \rightarrow 2Fe_3N_{2(s)} + Sn_3(PO_4)_{4(s)}$

3) $\frac{0.500 \text{ mol of } Fe_3N_{2(s)} \times 1 \text{ mol of } Sn_3N_{2(s)}}{2 \text{ mol of } Fe_3N_{2(s)}}$ = 0.250 mol of tin (IV) phosphate

9. Gasoline ($C_8H_{18(l)}$) is burned. How many moles of carbon dioxide are produced when 3.00 mol of gasoline is reacted?

G R

2 25 16 18

1) $1\ C_8H_{18(s)} + 25/2\ O_{2(g)} \rightarrow 8CO_{2(g)} + 9H_2O_{(g)}$

3) $\frac{3.00 \text{ mol of } C_8H_{18(l)} \times 8\ (16) \text{ mol of } CO_{2(g)}}{1\ (2) \text{mol of } C_8H_{18(l)}}$ = 24.0 mol of carbon dioxide.

10. Chlorine reacts with potassium bromide. How many moles of chlorine would be needed to completely use up 25 mol of potassium bromide?

R G

1) $1\ Cl_{2(g)} + 2KBr_{(aq)} \rightarrow 2\ KBr_{(aq)} + Br_{2(l)}$

3) $\frac{25 \text{ mol of } KBr_{(aq)} \times 1 \text{ mol of } Cl_{2\ (g)}}{2 \text{ mol of } KBr_{(aq)}}$ = 13 mol of chlorine

Worksheet 2.2: Mole to Quantity Stoichiometry

Directions: Solve the following hypothetical stoichiometry problems. Assume water is available.

1. When 6.5 mol of solid potassium chlorate breaks into solid potassium chloride and oxygen gas, what mass of solid potassium chloride is produced?

   G R

   1) $2KClO_{3(s)} \rightarrow 2KCl_{(s)} + 3O_{2(g)}$

   6.5 mol ?

   UNIT ANALYSIS OR LINEAR METHOD

   n = 6.5mol x 2 mol of $KCl_{(s)}$ / 2 mol of $KClO_{(s)}$ x 74.55 g of $KCl_{(s)}$ / 1 mol of $KCl_{(s)}$ = 484 g = 4.8×10^2g of $KCl_{(s)}$

   STEP BY STEP METHOD

   2) no conversion

   3) mol ratio: $n_R = n_G \times R/G$

   6.5 ~~mol of $KClO_{3(s)}$~~ x 2mol of $KCl_{(s)}$ /2 ~~mol of $KClO_{3(s)}$~~ = 6.5 moles of $KCl_{(s)}$

   4) m=nM m=74.55 g/~~mol~~ x 6.5 ~~mol~~ = 484g = 4.8×10^2 g of $KCl_{(s)}$

2. When 5.00 mol of methane burns, what volume of carbon dioxide at STP, will be produced?

   G R

   1) $1\ CH_{4(g)} + 2\ O_{2(g)} \rightarrow 1\ CO_{2(g)} + 2H_2O_{(g)}$

   UNIT ANALYSIS OR LINEAR METHOD:

   5.00 mol of CH_4 x 1 mol of CO_2 / 1 mol of CH_4 x 22.4 L of CO_2 / 1 mol of CO_2 = 112 L of CO_2

   STEP BY STEP METHOD: 2) no conversion

   3) $n_R = n_G \times R/G$ = 5.00 mol of CH_4 x 1mol of CO_2 /1mol of CH_4 = 5.00 mol of CO_2

   4) v = nV v = 5.00 mol of CO_2 x 22.4L/mol = 112 L of CO_2

3. How many particles of hydrochloric acid is needed to neutralize 2.50 mol of calcium hydroxide?

   R G

   1) $2HCl_{(aq)} + 1Ca(OH)_{2(s)} \rightarrow 2H_2O_{(g)} + CaCl_{2(aq)}$

   ? 2.5 mol

   UNIT ANALYSIS OR **LINEAR METHOD:**

   n= 2.5 mol of $Ca(OH)_{2(s)}$ x 2 mol of $HCl_{(aq)}$ / 1 mol of $Ca(OH)_{2(s)}$ x 6.02 x 10 23 particles of $HCl_{(aq)}$ / 1 mol of $HCl_{(aq)}$ = 3.01 E 24 particles

   STEP BY STEP:

   2) no conversion

   3) **$n_R = n_G \times R/G$ = 2.5 mol of $Ca(OH)_{2(s)}$ x 2 mol of $HCl_{(aq)}$ / 1 mol of $Ca(OH)_{2(s)}$**

   n=5.0 mol

   ***4) p*=nxP *p*= 6.02×10^{23} x5.0 mol = 3.01 E 24 or 3.01×10^{24} particles of $HCl_{(aq)}$**

4. When 5.25 mol of butane ($C_4H_{10(l)}$) burns, what volume of water vapour will be produced at SATP?

   G R

   1) $1\ C_4H_{10}(l) + 6.5O_2(g) \rightarrow 4CO_2(g) + 5H_2O(g)$

   UNIT ANALYSIS OR LINEAR METHOD:

   5.25 mol of $C_4H_{10(l)}$ x 5 mol of $H_2O_{(g)}$ / 1 mol of $C_4H_{10(l)}$ x 24.8 L of $H_2O_{(g)}$ / 1 mol of $H_2O_{(g)}$ = 651 L of H2O

   STEP BY STEP METHOD: 2) no conversion

   3) $n_R = n_G \times R/G$ = 5.25 mol of $C_4H_{10(l)}$ x 5mol of $H_2O_{(g)}$/1mol of $C_4H_{10(l)}$= 16.25 mol of $H_2O_{(g)}$

   4) v = nV v = 16.25 mol of H_2O x 24.8L/mol = 651 L of water

5. When excess silver reacts with 3.45 mol of zinc phosphate, what mass of silver phosphate would be produced?

G R

1) $6Ag_{(s)} + 1Zn_3(PO_4)_{2(s)} \rightarrow 2Ag_3(PO_4)_{(s)} + 3Zn_{(s)}$

3.45 mol ?

UNIT ANALYSIS OR LINEAR METHOD:

$3.45 \text{ mol of } Zn_3(PO_4)_2 \times \frac{2 \text{ mol of } 2Ag_3PO_4}{1 \text{ mol of } Zn_3(PO_4)_2} \times \frac{418.58 \text{ g of } Ag_3PO_4}{1 \text{ mol of } Ag_3PO_4} = 2888 \text{ g} = 2.89 \text{ kg}$

STEP BY STEP METHOD: **2) no conversion**

3) $n_R = n_G \times R/G = 3.45 \text{ mol of } Zn_3(PO_4)_2 \times \frac{2 \text{ mol of } 2Ag_3PO_4}{1 \text{ mol of } Zn_3(PO_4)_2} = 6.90 \text{ mol}$

4) m=Mn = (418.58 g/mol)(6.90 mol) = 2888 g = 2.89×10^3g or 2.89 kg

6. When 3.00 mol of iron (II) hydroxide reacts with cobalt (II) phosphate, what mass of cobalt (II) phosphate is needed? G R

1) $3\ Fe(OH)_{2(aq)} + Co_3(PO_4)_{2(aq)} \rightarrow 3\ Co(OH)_{2(s)} + Fe_3(PO_4)_{2(aq)}$

3.00 mol ?

UNIT ANALYSIS OR LINEAR METHOD:

$3.00 \text{ mol of } Fe(OH)_{2(aq)} \times \frac{3 \text{ mol of } Co(OH)_{2(s)}}{3 \text{ mol of } Fe(OH)_{2(aq)}} \times \frac{552.55 \text{ g of } Co_3(PO_4)_{2(s)}}{1 \text{ mol of } Co3(PO4)_{2(s)}}$ = 278.85 = 279 g of $Co(OH)_2$

STEP BY STEP METHOD:

2) no conversion

3) $n_R = n_G \times R/G = 3.00 \text{ mol of } Fe(OH)_{2(aq)} \times \frac{3 \text{ mol of } Co(OH)_{2(s)}}{3 \text{ mol of } Fe(OH)_{2(aq)}} = 3.00 \text{ mol of } Co(OH)_{2(s)}$

4) m=Mn =(92.95 g/mol)(3.00 mol) = 278.85 = 279 g of $Co(OH)_2$

7. In a neutralization reaction, 4.56 mol of sodium hydroxide neutralizes the sulphuric acid. What mass of water is produced? G R

1) $2NaOH_{(aq)} + H_2SO_{4(aq)} \rightarrow 2H_2O_{(g)} + Na_2SO_{4(aq)}$

4.56 mol ?

UNIT ANALYSIS OR LINEAR METHOD:

$4.56 \text{ mol of } NaOH_{(aq)} \times \frac{2 \text{ mol of } H_2O_{(g)}}{2 \text{ mol of } NaOH_{(aq)}} \times \frac{18.02 \text{ g of } H_2O_{(g)}}{1 \text{ mol of } H_2O_{(g)}} = 8.22\times10^1$ g of water

STEP BY STEP METHOD:

2) no conversion

3) $n_R = n_G \times R/G = 4.56 \text{ mol of NaOH} \times \frac{2 \text{ mol of } H_2O}{2 \text{ mol of NaOH}} = 4.56 \text{ mol of } H_2O$

4) m=Mn =(18.02 g/mol)(4.56 mol) = 8.22×10^1 g of water

8. Hydrogen and 2.5 mol of nitrogen react to form ammonia. How many moles of ammonia will be produced at STP? SATP? G R

1) $3\ H_{2(g)} + 1\ N_{2(g)} \rightarrow 2\ NH_{3(g)}$

UNIT ANALYSIS OR LINEAR METHOD **STP** **SATP**

$2.5 \text{ mol of } N_{2(g)} \times \frac{2 \text{ mol of } NH_{3(g)}}{1 \text{ mol of } N_{2(g)}} \times \frac{22.4L\ (24.8\ L) \text{ of } NH_{3(g)}}{1 \text{ mol of } NH_{3(g)}}$ = (112)1.1E2 L of $N_{2(g)}$; (124)1.2E2 L of $N_{2(g)}$

STEP BY STEP METHOD:

2) no conversion

3) $n_R = n_G \times R/G = 2.5 \text{ mol of } N_2 \times \frac{2 \text{ mol of } H_2O}{1 \text{ mol of NaOH}} = 5.00 \text{ mol of } N_2$

4) v=nV =(5.00mol)(22.4L/mol)=1.1E2 L of N_2 STP; v=nV=(5.00mol)(24.8L/mol) = 1.2E2L of N_2 SATP

Worksheet 2.3: Quantity to Mole Stoichiometry

Directions: Solve the following hypothetical stoichiometry problems. Assume water is available.

1. How many moles of iron (III) oxide is produced when 5.6 g of iron burns with oxygen gas?

G R

1) $2\ Fe_{(s)} + 3/2\ O_{2(g)} \rightarrow 1Fe_2O_{3(s)}$

5.6 g ?

UNIT ANALYSIS OR LINEAR METHOD

$\dfrac{5.6\text{ g of }Fe_{(s)}}{} \times \dfrac{1\text{ mol of }Fe_{(s)}}{55.85\text{ g of }Fe_{(s)}} \times \dfrac{1\text{ mol of }Fe_2O_{3(s)}}{2\text{ mol of }Fe_{(s)}} = 0.050\text{ mol of }Fe_2O_{3(s)}$

STEP BY STEP METHOD:

2) n=m/M = 5.6g / 55.85 g/mol = 0.10 mol

3) $n_R = n_G \times R/G = 0.10\text{mol of }Fe_{(s)} \times \dfrac{1\text{ mol of }Fe_2O_{3(s)}}{2\text{ mol of }Fe_{(s)}}$ **n= 0.050 mol of** $Fe_2O_{3(s)}$

2. When 4.00 x 10^{23} particles of methanol is burned, how many moles of water vapour are produced?

G R

1) $1\ CH_3OH_{(l)} + 3/2\ O_{2(g)} \rightarrow 1\ CO_{2(g)} + 2\ H_2O_{(g)}$

UNIT ANALYSIS OR LINEAR METHOD

$4.00\times10^{23}\text{ part of }CH_3OH_{(l)} \times \dfrac{1\text{ mol of }CH_3OH_{(l)}}{6.02E23\text{ part of }CH_3OH_{(l)}} \times \dfrac{2\text{ mol of }H_2O_{(g)}}{1\text{ mol of }CH_3OH_{(l)}} = 1.3289\ldots\text{mol} = 1.33\text{ mol of }H_2O_{(l)}$

STEP BY STEP:

2) n=p/P = **4.00×10^{23} part of $CH_3OH_{(l)}$/6.02E23 part of $CH_3OH_{(l)}$ per mol = 0.66445…mol of $CH_3OH_{(l)}$**

3) $n_r = n_g \times R/G = 0.66445\ldots\text{ mol of }CH_3OH_{(l)} \times \dfrac{2\text{ mol of }H_2O_{(g)}}{1\text{ mol of }CH_3OH_{(l)}} = 1.3289\ldots\text{mol} = 1.33\text{ mol of }H_2O_{(l)}$

3. If 122.6 g of solid potassium chlorate is heated, the crystals melt and decompose into solid potassium chloride and oxygen gas. How many moles of potassium chloride are formed?

G R

1) $2\ KClO_{3(s)} \rightarrow 2\ KCl_{(s)} + 3\ O_{2(g)}$

122.6 g ?

K = 39.10 x1 = 39.10
Cl = 35.45x1 = 35.45
O = 16.00x3 = 48.00
TOTAL 125.55g/mol

UNIT ANALYSIS OR LINEAR METHOD

$122.6\text{ g of }KClO_{3(s)} \times \dfrac{1\text{ mol of }KClO_{3(s)}}{122.55\text{ g of }KClO_{3(s)}} \times \dfrac{2\text{ mol of }KCl_{(s}}{2\text{ mol of }KClO_{3(s)}} = 1.000\text{ mol of }KCl_{(s)}$

STEP BY STEP METHOD

2) n=m/M =122.6 g / 122.55 g/mol =1.000 mol of $KClO_{3(s)}$

3) $n_R = n_G \times R/G = 1.000\text{ mol of }KClO_{3(s)} \times \dfrac{2\text{ mol of }KCl_{(s)}}{2\text{ mol of }KClO_{3(s)}} = 1.000\text{ mol of }KCl_{(s)}$

4. Black iron (III) oxide solid can be converted into water and iron metal when the iron (III) oxide is reacted with hydrogen gas. If 125 g of iron (III) oxide is reacted, how many moles of water are formed?

G R

1) $1\ Fe_2O_{3(s)} + 3\ H_{2(g)} \rightarrow 2\ Fe_{(s)} + 3\ H_2O_{(g)}$

125 g ?

Fe = 55.85x2 =111.70
O = 16.00 x3 = 48.00
TOTAL 159.70g/mol

UNIT ANALYSIS OR LINEAR METHOD

$125\text{ g of }Fe_2O_{3(s)} \times \dfrac{1\text{ mol of }Fe_2O_{3(s)}}{159.70\text{ g of }Fe_2O_{3(s)}} \times \dfrac{3\text{ mol of }H_2O_{(g)}}{1\text{ mol of }Fe_2O_{3(s)}} = 2.34815\ldots\text{ mol} = 2.35\text{ mol of }H_2O_{(g)}$

STEP BY STEP METHOD:

2) n=m/M = 125g / 159.70 g/mol = 0.7827175… mol of $Fe_2O_{3(s)}$

3) $n_R = n_G \times R/G = 0.7827175\ldots\text{mol of }Fe_2O_{3(s)} \times \dfrac{1\text{ mole of }H_2O_{(g)}}{2\text{ moles of }Fe_2O_{3(s)}} = 2.34815\ldots\text{ mol} = 2.35\text{ mol of }H_2O_{(g)}$

5. How many moles of zinc can react with hydrochloric acid to form 44.8 L of hydrogen gas at STP?

R G

1) $1\ Zn_{(s)} + 2\ HCl_{(aq)} \rightarrow 1\ H_{2(g)} + ZnCl_{2(aq)}$

? 44.8 L

UNIT ANALYSIS OR LINEAR METHOD:

$$44.8\text{ L of }H_2 \times \frac{1\text{ mol of }H_2}{22.4\text{ L of }H_2} \times \frac{1\text{ mol of Zn}}{1\text{ mol of }H_2} = 2.00\text{ mol of Zn}$$

STEP BY STEP METHOD:

2) n=v/V = 44.8 L / 22.4 L/mol =2.00 mol of H2

3) $n_R = n_G \times R/G = \frac{2.00\text{ mol of }H_2 \times 1\text{ mol of Zn}}{1\text{ mol of }H_2} = 2.00\text{ mol of Zn}$

6. Solutions of copper (II) sulphate and potassium phosphate are mixed. If 8.5 g of copper (II) phosphate form, how many moles of copper (II) sulphate react?

Cu = 63.55x3=190.65
P = 30.97x2=61.94
O = 16.00x8=128.00
TOTAL = 380.59g/mol

R G

1) **$3\ CuSO_{4(aq)} + 2\ K_3PO_{4(aq)} \rightarrow 3\ K_2SO_{4(aq)} + 1\ Cu_3(PO_4)_{2(s)}$**

? mol 8.5 g

2) n=m/M = 8.5 g of $Cu_3(PO_4)_{2(s)}$ / 380.59g/mol of $Cu_3(PO_4)_{2(s)}$ = 0.02233…mol of $Cu_3(PO_4)_{2(s)}$

3) $n_R = n_G \times R/G = \frac{0.500\text{ mol of }Fe_3N_{2(s)} \times 1\text{ mol of }Sn_3N_{2(s)}}{2\text{ mol of }Fe_3N_{2(s)}} = 0.250\text{ mol of tin (IV) phosphate}$

LINEAR: $$8.5\text{ g of }Cu_3(PO_4)_{2(s)} \times \frac{1\text{mol of }Cu_3(PO_4)_{2(s)}}{380.59\text{g/mol of }Cu_3(PO_4)_{2(s)}} \times \frac{1\text{ mol of }Sn_3N_{2(s)}}{2\text{ mol of }Fe_3N_{2(s)}} = 0.250\text{ mol of tin (IV) phosphate}$$

7. In the manufacturing of nitric acid, nitrogen dioxide gas reacts with water to from nitric acid and nitrogen monoxide gas. How many moles of nitrogen dioxide gas reacts if 120.6 L of nitrogen monoxide gas is formed at SATP?

R G

1) **$3\ NO_{2(g)} + H_2O_{(l)} \rightarrow 2\ HNO_{3(aq)} + 1\ NO_{(g)}$**

? 120.6 L

UNIT ANALYSIS OR LINEAR METHOD:

$$120.6\text{ L of }NO_{2(g)} \times \frac{1\text{ mol of }NO_{2(g)}}{24.8\text{ L of }NO_{2(g)}} \times \frac{3\text{ mol of }NO_{(g)}}{1\text{ mol of }NO_{2(g)}} = 14.59\text{ moles of }NO_{(g)}$$

STEP BY STEP METHOD:

2) n=v/V = 120.6 L / 24.8 mol/L = 4.863 mol of $NO_{2(g)}$

3) $n_R = n_G \times R/G = \frac{4.863\text{ mol of }NO_{2(g)} \times 3\text{ mol of }NO_{(g)}}{1\text{ mol of }NO_{2(g)}} = 14.59\text{ moles of }NO_{(g)}$

8. The thermite reaction is used in welding iron and steel. Aluminium and iron (III) oxide are ignited at high temperatures to produce aluminium oxide and iron. If 15.0 g of aluminium is used in this reaction, how many moles of aluminium oxide will be produced?

G R

Step 1) $2\ Al_{(s)} + Fe_2O_{3(s)} \rightarrow 1\ Al_2O_{3(s)} + 2\ Fe_{(s)}$

15.0g ? mol

Step 2) n=m/M = 15.0g of Al(s)/26.98g/mol = 0.55596…mol of Al(s)

Step 3) $n_R = n_G \times R/G$ **= 0.55596…mol of Al(s) x 1 mol of $Al_2O_{3(s)}$ /2 mol of Al(s) = 0.27798… = 0.278mol of $Al_2O_{3(s)}$**

LINEAR: $$15.0\text{g of Al(s)} \times \frac{1\text{ mol of Al(s)}}{26.98\text{g of Al(s)}} \times \frac{1\text{ mol of }Al_2O_{3(s)}}{2\text{ mol of Al(s)}} = 0.27798\ldots\text{ mol} = 0.278\text{mol of }Al_2O_{3(s)}$$

Worksheet 2.4: Quantity to Quantity Stoichiometry

Directions: Solve the following hypothetical stoichiometry problems. Assume water is available.

1. How many particles of aluminium oxide must be decomposed to produce 80.0 g of oxygen gas at STP?

   R G

   1) 2 $Al_2O_{3\,(s)}$ → 4 $Al_{(s)}$ + 3 $O_{2(g)}$

   UNIT ANALYSIS OR LINEAR METHOD:

   $\frac{80.0\text{ g of }O_{2(g)}}{} \times \frac{1\text{ mol of }O_{2(g)}}{32.00\text{ g of }O_{2(g)}} \times \frac{2\text{ mol of }Al_2O_{3(s)}}{3\text{ mol of }O_{2(g)}} \times \frac{6.02E23\text{ particles of }Al_2O_{3(s)}}{1\text{ mol of }Al_2O_{3(s)}}$ = 1.00E24 part of $Al_2O_{3(s)}$

   STEP BY STEP:

   2) n = m/M = 80.0g /32.00 g/mol = 2.5 mol of O_2

   3) $n_R = n_G \times R/G$ = 2.5 mol of O_2 x $\frac{2\text{ mol of }Al_2O_3}{3\text{ mol of }O_2}$ = 1.66666... mol of $Al_2O_{3(s)}$

   4) p = n P = 1.6666...mol x 6.02 E 23 particles/mol = 1.00 E 24 or 1.00 x 10^{24} particles of $Al_2O_{3(s)}$

2. Natural gas is mainly made up of methane. What mass of methane must be burned to produce 56.0 L of carbon dioxide at STP?

   R G

   1) 1 CH_4 (g) + 2 O_2(g) → 1 CO_2 (g) + 2 H_2O (g)

LINEAR: $\frac{56.0\text{ L of }CO_2}{} \times \frac{1\text{ mol of }CO_2}{22.4\text{ L of }CO_2} \times \frac{1\text{ mol of }CH_4}{1\text{ mol of }CO_2} \times \frac{16.05\text{ g of }CH_4}{1\text{ mol of }CH_4}$ = 40.1 g of $CH_{4(g)}$

STEP BY STEP:

   2) n=v/V = **56.0 L of CO_2/ 22.4 L of CO_2 = 2.5 mol of CO_2**

   3) $n_R = n_G \times R/G$ = 2.5 mol of CO_2 x 1 mol of CH_4/1 mol of CO_2 = 2.5 mol of CO2

   4) m = nM = 2.5 mol of CO_2 x 16.05g/mol of CO_2 = 40.1 g of $CH_{4(g)}$

3. Aluminium metal is refined from bauxite ore. In the refining process, aluminium oxide decomposes to aluminium and oxygen gas. What mass of aluminium can be produced from **2.04 kg** of aluminium oxide?

   G R

   1) 2 Al_2O_3 (s) → 4 Al (s) + 3 O_2(g)

LINEAR: $\frac{2040\text{ g of }Al_2O_3}{} \times \frac{1\text{ mol of }Al_2O_3}{101.96\text{ g of }Al_2O_3} \times \frac{4\text{ mol of Al}}{2\text{ mol of }Al_2O_3} \times \frac{26.98\text{ g of Al}}{1\text{ mol of Al}}$ = 1079.6 g = 1.08 kg of Al

STEP BY STEP:

   2) **n =m/M = 2040 g of Al_2O_3/ 101.96g/mol of Al_2O_3 = 20.0078… mol of Al_2O_3**

   3) **$n_R = n_G \times R/G$ = 20.0078…mol of Al_2O_3 x 4 mol of Al/2 mol of Al_2O_3 = 40.0156… mol of Al(s)**

   4) **m = nM = 40.0156… mol of Al(s) x 26.98 g/mol of Al = 1079.6 g = 1.08 kg of Al**

4. Sodium hydrogen carbonate can be used to neutralize acids. If sodium hydrogen carbonate reacts with hydrochloric acid, what volume of carbon dioxide gas at STP can be produced by 16.8 g of sodium hydrogen carbonate? NOTE: Sodium chloride and water vapour is also produced.

   G R

   1) 1 $NaHCO_3$ (aq) + 1 HCl(aq) → 1 CO_2 (g) + 1 NaCl (aq) + 1 H_2O(l)

LINEAR: $\frac{16.8\text{ g of }NaHCO_3}{} \times \frac{1\text{ mol of }NaHCO_3}{84.01\text{ of }NaHCO_3} \times \frac{1\text{ mol of }CO_2}{1\text{ mol of }NaHCO_3} \times \frac{22.4\text{ L of }CO_2}{1\text{ mol of }CO_2}$ = 4.48 L of $CO_{2(g)}$

STEP BY STEP:

   2) n=m/M = **16.8 g of $NaHCO_3$/ 84.01 g/mol of $NaHCO_3$ = 0.19997…mol of $NaHCO_3$**

   3) **$n_R = n_G \times R/G$ =0.19997…mol of $NaHCO_3$x1mol of CO_2/1mol of $NaHCO_3$ = 0.19997…mol of $NaHCO_3$**

   4) **v = nV =0.19997…mol of $NaHCO_3$ x 22.4 L of CO_2 = 4.48 L of $CO_{2(g)}$**

5. Photography film is coated with silver chloride, which is produced when silver nitrate reacts with sodium chloride. What mass of silver chloride can be made from 11.7 g of sodium chloride?

G **R**

1) 1 NaCl (aq) + 1 $AgNO_3$ (aq) → 1 AgCl (aq) + 1 $NaNO_3$(aq)

LINEAR: 11.7 g of NaCl x 1 mol of NaCl / 58.44g of NaCl x 1 mol of AgCl / 1 mol of NaCl x 143.32 g of AgCl / 1 mol of AgCl = 28.7 g of AgCl

STEP BY STEP:

2) n = m/M = **11.7 g/58.44g/mol = 0.200205…mol of NaCl**

3) **$n_R = n_G$ x R/G = 0.200205…mol of NaCl x 1 mol of AgCl / 1 mol of NaCl = 0.200205…mol of AgCl**

4) m = nM = 0.200205…mol of AgCl x 143.32g/mol = 28.693…g = 28.7g of AgCl

6. Ammonia reacts with hydrochloric acid to produce ammonium chloride. What volume of ammonia at SATP is needed to produce 36.1 g of ammonium chloride?

R **G**

1) 1 NH_3 (g) + 1 HCl(aq) → 1 NH_4Cl(aq)

LINEAR: 36.1 g of NH_4Cl x 1 mol of NH_4Cl / 53.50 g of NH_4Cl x 1 mol of NH_3 / 1 mol of NH_4Cl x 24.8 L of NH_3 / 1 mol of NH_3 = 16.7 L of NH_3

STEP BY STEP:

2) n = m/M = 36.1g / 53.50g/mol = 0.674766…mol of NH4Cl

3) **$n_R = n_G$ x R/G = 0.674766…mol of NH4Cl x 1 mol of NH3 / 1 mol of NH4Cl = 0.674766… mol of NH3**

4) v = n V = 0.674766… mol of NH3 x 24.8L/mol = 16.734… L **= 16.7 L of NH_3**

7. If sulphuric acid reacts with 29.4 g of potassium hydroxide, what mass of potassium sulphate is produced?

G **R**

1) 2 H_2SO_4 (aq) + 2 KOH(aq) → 1 K_2SO_4(aq) + 2 HOH(l)

LINEAR: 29.4 g of KOH x 1 mol of KOH / 56.11 g of KOH x 1 mol of K_2SO_4 / 2 mol of KOH x 174.27 g of K_2SO_4 / 1 mol of K_2SO_4 = 45.7 g of K_2SO_4

STEP BY STEP:

2) n = m/M = 29.4g / 56.11g/mol =

3) **$n_R = n_G$ x R/G =**

4) m = nM

8. If sodium iodide reacts with lead (II) nitrate, what mass of lead (II) nitrate will be required to produce 150 g of precipitate?

R **G**

1) 2 NaI (aq) + 1 $Pb(NO_3)_2$(aq) → 1 PbI_2 (s) + 2 $NaNO_3$(aq)

LINEAR: 150 g of PbI_2 x 1 mol of PbI_2 / 461 g of PbI_2 x 1 mol of $Pb(NO_3)_2$ / 1 mol of PbI_2 x 331.22 g of $Pb(NO_3)_2$ / 1 mol of $Pb(NO_3)_2$ = 108 g of $Pb(NO_3)_2$

STEP BY STEP:

2) n = m/M =

3) **$n_R = n_G$ x R/G =**

4) m = nM

Worksheet 2.5: Limiting & Excess Reagents

Directions: For each of the following, write a balanced equation and determine the limiting reagent & the excess reagent (if they are present).

1. 5.0 mol of gasoline ($C_8H_{18(l)}$) burns 47.0 mol of oxygen at STP. How many **moles of carbon dioxide are present at STP**? B) How many moles of excess remains?

G=E G=L R

(2) (25) (16) (18)

Step 1) $1\ C_8H_{18(l)} + 12.5\ O_{2(g)} \rightarrow 8\ CO_{2(g)} + 9H_2O_{(g)}$

Step 3) $5.0 \text{ mol of } C_8H_{18} \times \frac{8 \text{ mol of } CO_2}{1 \text{ mol of } C_8H_{18(l)}} = 40 \text{ mol of } CO_{2(g)}$ **(C_8H_{18} is EXCESS)**

$47.0 \text{ mol} \times \frac{8 \text{ mol of } CO_{2(g)}}{12.5 \text{ mol of } O_{2(g)}} = 30.08 \text{ mol of } CO_{2(g)}$ **(LIMITING)=30.1 mol of $CO_{2(g)}$**

b) E=R L=G

$1\ C_8H_{18(l)} + 12.5\ O_{2(g)} \rightarrow 8\ CO_{2(g)} + 9H_2O_{(g)}$

$47.0 \text{ mol of } O_2 \times \frac{1 \text{ mol of } C_8H_{18}}{12.5 \text{ mol of } O_2} = 3.76 \text{ mol of } C_8H_{18}$ **used**

Remains = Original Excess (Step 2) – Used Excess (Step 3)

= 5.0 mol – 3.76 mol = 1.24 mol = 1.2 mol left over (2 sig digs)

2. 18.0 g of hydrogen is added to 6.0 g of oxygen. How **many grams of water** are formed? How much excess reagent is left over in grams?

G1 G2 R

Step 1) $1\ O_{2(g)} + 2\ H_{2(g)} \rightarrow 2\ H_2O_{(g)}$

Step 2) n=m/M = 18.0g/2.02g/mol of H2 = 8.9…mol of water

n = m/M = 6.0g/32.0g/mol = 0.1875 mol of oxygen

Step 3) $8.9\ldots \text{ mol of } H_2 \times \frac{2\text{mol of water}}{2\text{mol of } H_2} = 8.9\ldots$ **mol of water (H_2 is EXCESS)**

$0.1875\text{mol of } O_2 \times \frac{2\text{mol of water}}{1\text{mol of } O_2} = 0.375$ **mol of water (O_2 is LIMITING)**

Step 4) 0.375 mol x 18.02g/mol = 6.8 g of water is produced

L=G E=R

b) $1\ O_{2(g)} + 2\ H_{2(g)} \rightarrow 2\ H_2O_{(g)}$

Step 2) n = m/M = 6.0g/32.0g/mol = 0.1875 mol of oxygen

Step 3) $0.1875 \text{ mol of } O_2 \times \frac{2\text{mol of } H_2}{1\text{mol of } O_2} = 0.375 \text{ mol of } H_2$ **used**

Remaining = Original moles of Excess – Used moles of Excess

= 8.9…mol of water – 0.375… mol = 8.545…mol remaining

Step 4) m=nM = 8.545…mol x 2.02g/mol = 17.2… = 17 g

3. 22.4 mL of methane reacts with 22.4 mL of oxygen at SATP. How many moles of water are made?

G G R

Step 1) $1\ CH_{4(g)} + 2\ O_{2(g)} \rightarrow CO_{2(g)} + 2\ H_2O_{(g)}$

Step 2) n = v/V = 0.0224/24.8 = 9.03…E-4 mol | n = v/V = 0.0224/24.8 =9.03…E -4 mol

Step 3) $9.03\ldots\text{E-4} \times \frac{2\text{mol } H_2O_{(g)}}{1\text{mol } CH_{4(g)}}$ **= 1.806..E-3 mol (EXCESS)** | $9.03\ldots\text{E-4 mol of } O_2 \times \frac{2\text{mol } H_2O_{(g)}}{2\text{mol } O_{2(g)}}$ **= 9.03E-4 mol of water (O_2 is LIMITING)**

B) E = R G

$1\ CH_{4(g)} + 2\ O_{2(g)} \rightarrow CO_{2(g)} + 2\ H_2O_{(g}$

$9.03\ldots\text{E -4 mol of } O_2 \times \frac{1 \text{ mol of } CH_4}{2 \text{ mol of } O_2} = 4.516..\text{E-4 mol of } CH_4$ **used**

EXCESS LEFT OVER = ORIGINAL(STEP 2) – USED (STEP 3 the 3rd time)

EXCESS LEFT OVER = 9.03…E-4 mol - 4.516..E-4 mol of CH_4 = 4.52 E-4 mol are left over

4. 26 g of magnesium react with 1.00 mol of hydrochloric acid.

a) What **volume of Hydrogen gas** is made at **STP**?

		G1 R used		G2	R
Step 1)		**1 $Mg_{(s)}$**	**+**	**2 $HCl_{(aq)}$ →**	**1 $H_{2(g)}$ + $MgCl_{2(aq)}$**
Step 2)	**n = m/M**	**= 26/24.31g/mol** **= 1.069…mol**		**1.00 mol**	
Step 3)		**1.069…mol x 1mol $H_{2(g)}$ / 1mol $Mg_{(s)}$** **=1.0695…mol (EXCESS)**		**1.00 mol x1 mol $H_{2(g)}$ / 2 mol $HCl_{(aq)}$** **= 0.500 mol (HCl is LIMITing)**	

Step 4) v = nV **0.500 mol of $H_{2(g)}$ x 22.4L/mol = 11.2 L of $H_{2(g)}$**

b) How much excess reagent is left over?

	G E=R used		L=G	
Step 1)	**1 $Mg_{(s)}$**	**+**	**2 $HCl_{(aq)}$ →**	**1 $H_{2(g)}$ + $MgCl_{2(aq)}$**
Step 2)			**1.00 mol**	

Step 3) **1.00 mol of $HCl_{(aq)}$ x1 mol $Mg_{(s)}$ / 2 mol $HCl_{(aq)}$ = 0.500 mol of $Mg_{(s)}$ is used**

Step 4) Excess = Original moles of Excess – used moles of Excess

= 1.069…mol – 0.500mol = 0.570 mol of $Mg_{(s)}$ left

m= n M = 0.5695… mol of Mg x 24.31g/mol = 13.8 g of $Mg_{(s)}$ left over

5. 3.02 x 10^{23} formula units of sodium react with 12 L of chlorine gas at STP. How much excess reagent is left over if the limiting is all used up?

		G_1 = L		G_2 = E	R
Step 1)		**2 $Na_{(s)}$**	**+**	**1 $Cl_{2(g)}$**	**→ 2 $NaCl_{(aq)}$**
Step 2)	**n = p/P**	**= 3.02E23FU/6.02E23 FU/mol** **= 0.5016… mol of $Na_{(s)}$**		**n = v/V = 12L/22.4L/mol** **= 0.535714… mol of $Cl_{2(g)}$**	
Step 3)		**0.5016… x 2 mol $NaCl_{(aq)}$ / 2 mol $Na_{(s)}$** **=0.502 mol of NaCl (Na LIMIT)**		**0.5357.. mol x 2 mol $NaCl_{(aq)}$ / 1 mol $Cl_{2(g)}$** **= 1.0714… mol of NaCl (Cl2 Exce)**	

	G =L		G_2 R	
Step 1)	**2 $Na_{(s)}$**	**+**	**1 $Cl_{2(g)}$ →**	**2 $NaCl_{(aq)}$**
Step 2)	**0.5016… mol of $Na_{(s)}$**			

Step 3) **0.5016…mol of $Na_{(s)}$ x 1 mol $Cl_{2(g)}$ / 2 mol $Na_{(s)}$ = 0.2508.. mol of $Cl_{2(g)}$ used**

Step 4) Excess = original moles of Excess – used moles of Excess

= 0.535714… mol of $Cl_{2(g)}$ – 0.2508.. mol = 0.28 mol of $Cl_{2(g)}$ left

6. Describe a limiting reagent and an excess reagent.

- **A limiting reagent is a reactant that controls how much product you have (it is the first reagent to be used up.**
- **An excess reagent is a reactant that is left over (it is not all used up)**

Worksheet 2.6: Percent yield and Percent error

Directions: For each of the following write a balanced equation and determine the theoretical yield, actual yield, percent yield & the percent error.

1. 8.0 mol of sulphur dioxide decomposes and actually **produces** 7.0 mol of oxygen gas.

G R = TY

Step 1) **8 $SO_{2(g)}$ → $S_{8(s)}$ + 8 $O_{2(g)}$**

8.0 mol **7.0 *mol* = AY; TY = ?**

Step 3) **8.0 mol $SO_{2(g)}$ x 8 mol of $O_{2(g)}$ = 8.0 *mol* of $O_{2(g)}$ is the TY**

8 mol of $SO_{2(g)}$

Step 5) % yield = AY/TY x100 7.0 *mol*/ 8.0 *mol* x 100 = 88 %

% error = \ (TY – AY) \ = 12.5 = 13 % (100 – 87.5 = 13%)

TY

2. 26.0 g of aluminum reacts with a solution of calcium nitrate and produces 3.00 moles of calcium. **G** **R = TY = ?**

Step 1) **2 $Al_{(s)}$ + 3 $Ca(NO_3)_{2(aq)}$ → 3 $Ca_{(s)}$ + 2 $Al(NO_3)_{3(aq)}$**

Step 2) **26.0g/26.98g/mol** **3.00 *mol* = AY**

= 0.964… mol

Step 3) **0.964… mol x 3 mol of $Ca_{(s)}$ = 1.44… *mol* of $Ca_{(s)}$ = TY**

2 mol of $Al_{(s)}$

Step 5) % yield = AY/TY x 100 3.00 mol / 1.44… mol x 100 = 208% because of of the solution (not evaporated)

% error = (TY - AY)/TY x 100 = +108%

1. 6.50 mol of potassium chlorate solid is heated and breaks down into potassium chloride solid and 223 L of oxygen gas at SATP.

G **R (TY) = ?**

Step 1) **2 $KClO_{3(s)}$ → 2$KCl_{(s)}$ + 3 $O_{2(g)}$**

Step 2) **6.50 mol** **223L = AY**

(n=v/V= 223L/24.8L/mol =8.99… mol)

Step 3) **6.50 mol $KClO_3$ x 3 mol of O_2 = 9.75… mol of O_2 = TY**

2mol of $KClO_3$

Step 4) v = nV = 9.75 x 24.8 = 241.8 L = TY (Not necessary if you changed AY to moles)

Step 5) % yield AY/TY x 100 = 223L/241.8 L x 100% = 92.2% (%yield =8.99…/9.75 x 100%)

% error = (TY-AY)/TY x 100% = (241.8L – 223L)/241.8L = 7.78%

4. 33.6 L of methane burns and produces 2.00 mol of carbon dioxide gas at STP.

G R

Step 1) balance 1 $CH_{4(g)}$ + 2 $O_{2(g)}$ → 1 $CO_{2(g)}$ + 2 $H_2O_{(g)}$

Step 2) n = v/V = 33.6 /22.4 = 1.5 mol **2.00 mol = AY**

Step 3) mole ratio **1.5 mol of CH_4 x 1 mol of $CO_{2(g)}$ = 1.5 mol of CO_2 = TY**

1 mol of $CH_{4(g)}$

Step 5) % yield = AY/TY x 100 = 2.00 mol/1.5 mol x 100 = 133 %

% error = 33.3% (answer becomes positive)

5. Sulphuric acid reacts with 29.4 g of potassium hydroxide and produces 40.5 g of potassium sulphate

G R

Step 1) **$H_2SO_{4\ (aq)}$ + 2 $KOH_{(aq)}$ → 2 $HOH_{(l)}$ + 1 $K_2SO_{4\ (aq)}$**

Step 2) **n = m/M** **= 29.4g/56.11g/mol** **40.5g/174.27= AY**

= 0.5239… mol of KOH **= 0.23239… mol = AY**

Step 3) **0.5239…mol KOH x1mol of $K_2SO_{4\ (aq)}$=0.26195… mol TY**

2mol of $KOH_{(aq)}$

Step 4) Both AY and TY are in moles. (m=0.26195x174.27= 45.65…g)

Step 5) %yield = AY/TY = 0.23239…mol/0.26195…mol x 100 = 88.7 %

(40.5g / 45.65…g = 88.7%)

% error = (AY–TY)/TYx100 =(0.26195-0.23239)/ 0.26195x100= 11.3%

6. Describe percent yield and percent error.

Percent yield: a ratio between AY and TY as a percent; how much you produce compared to what you should produce.

Percent error: an indication of error (human, instrumental & experimental).

Worksheet 2.7: Limiting Reagents and Percent Yield

1. Methane gas burns at STP.

   a. If 0.500 mol of methane is burned in 2.50 mol of oxygen, what is the limiting reagent? **G1**   **G2**   **R**

Step 1) **1** $CH_{4(g)}$ **+** **2** $O_{2(g)}$ → $CO_{2(g)}$ **+ 2** $H_2O_{(g)}$

Step 2) **0.500 mol**   **2.50 mol**

Step 3) **0.500mol of CH_4 x 2mol of $H_2O_{(g)}$ / 1 mol of $CH_{4(g)}$**   **2.50 mol of O2 x 2mol of $H_2O_{(g)}$ / 2mol of $O_{2(g)}$**

= 1.00 mol of water ← TY   **2.50 mol of water**

CH_4 is limiting   **O_2 is excess**

   b. What is the theoretical yield, in moles, of water?

1.00 mol of water is the theoretical yield (use the limiting side

2. Sodium and chlorine are mixed together.

   a. What is the limiting reagent if there is 10.0 g of sodium and 20.0 g of chlorine?

G1   G2   **R**

1) 2 **$Na_{(s)}$ +** 1 **$Cl_{2(g)}$ →** 2 **$NaCl_{(aq)}$**

2) **n=m/M = 10.0g/22.99g/mol**   **n=20.0g/70.90g/mol**

= 0.4349717…mol   **= 0.282087447…mol**

3) **x 2 mol of $NaCl_{(aq)}$/2mol of $Na_{(s)}$**   **x 2 mol of $NaCl_{(aq)}$/1 mol of $Cl_{2(g)}$**

= 0.4349…mol of $NaCl_{(aq)}$ (smaller)   **= 0.56417…mol of $NaCl_{(aq)}$**

$Na_{(s)}$ is LIMITING   **$Cl_{2(g)}$ is EXCESS**

UNIT ANALYSIS OR LINEAR METHOD:

10.0g x 1 mol of $Na_{(s)}$ / 22.99 g x 2 mol of $NaCl_{(aq)}$ / 2 mol of $Na_{(s)}$ x 58.44 g of $NaCl_{(aq)}$ / 1 mol of $NaCl_{(aq)}$ = 25.419… g of NaCl LIMIT

20.0g x 1 mol of Cl_2 / 70.90 g x 2 mol of $NaCl_{(aq)}$ / 1 mol of $Cl_{2(s)}$ x 58.44 g of $NaCl_{(aq)}$ / 1 mol of $NaCl_{(aq)}$ = 32.970… g of NaCl EXCESS

   b. How many grams of the product are produced?

4) **m = nM_{NaCl} = 0.4349717…mol of $NaCl_{(aq)}$ x 58.44g/mol = 25.4 g of $NaCl_{(aq)}$**

3. In the synthesis of sulphuric acid, one step involves the mixing of sulphur dioxide with oxygen to produce sulphur trioxide. If 175 L of sulphur dioxide was mixed with 85 L of oxygen at SATP, how **many litres of sulphur trioxide** is produced?

G1 = E   **G2 = L**   **R**

STEP 1) **2 $SO_{2(g)}$ +** **1 $O_{2(g)}$ →** **2 $SO_{3(g)}$**

175 L   **85L**   **?**

STEP 2) **n = v/V = 175L/24.8L/mol**   **n = 85L/24.8L/mol**

n = 7.0564…mol $SO_{2(g)}$ **n = 3.4274…mol of $O_{2(g)}$**

STEP 3) **x 2 mol $SO_{3(g)}$ / 2 mol $SO_{2(g)}$ = 7.0564… mol**   **x 2 mol $SO_{3(g)}$ / 1 mol of $O_{2(g)}$ =6.8548…mol of $SO_{3(g)}$ (LIMITING)**

STEP 4) v=nV = 6.8548…mol of $SO_{3(g)}$ x 24.8 = 170 L of $SO_{3(g)}$

UNIT ANALYSIS OR LINEAR METHOD:

For **$SO_{2(g)}$: 175L x 1 mol of $SO_{2(g)}$ / 24.8 L of $SO_{2(g)}$ x 2 mol of $SO_{3(g)}$ / 2 mol of $SO_{2(g)}$ x 24.8 L of $SO_{3(g)}$ / 1 mol of $SO_{3(g)}$ = 174.99 … L of $SO_{3(g)}$**

For **$O_{2(g)}$: 85L x 1 mol of $O_{2(g)}$ / 24.8 L of $O_{2(g)}$ x 2 mol of $SO_{3(g)}$ / 1 mol of $O_{2(g)}$ x 24.8 L of $SO_{3(g)}$ / 1 mol of $SO_{3(g)}$ = 170 L of $SO_{3(g)}$**

4. Adipic acid ($C_6H_{10}O_{4(s)}$), a raw material for nylon, is made by the oxidation (reacting with oxygen) of cyclohexane ($C_6H_{12(s)}$). Water is a by-product.

a. How many **moles of oxygen gas** would be needed to make 40.0 mol of adipic acid?

		R		G
STEP 1) $C_6H_{12(s)}$	+	**2.5** $O_{2(g)}$	→	**1** $C_6H_{10}O_{4(s)}$ + $H_2O(l)$
STEP 2) Already in moles		**?**		**40.0mol = n_g**

STEP 3) **40.0 mol** $C_6H_{10}O_{4(s)}$ **of x 2.5 mol $O_{2(g)}$ / 1 mol $C_6H_{10}O_{4(s)}$ = 100 mol of $O_{2(g)}$**

STEP 4) Not needed

UNIT ANALYSIS OR LINEAR METHOD:

For **$SO_{2(g)}$**: **40.0 mol of** $C_6H_{10}O_{4(s)}$ **x 2.5 mol of $O_{2(g)}$ / 1 mol of** $C_6H_{10}O_{4(s)}$ **= 100 mol of $O_{2(g)}$**

b. If 2.00 mol of oxygen is reacted with 164 g of cyclohexane, what is the theoretical **yeild of adipic acid** in grams?

		G1 = L		R
STEP 1) (G2) 1 $C_6H_{12(s)}$	+	**2.5** $O_{2(g)}$	→	**1** $C_6H_{10}O_{4(s)}$ + $H_2O(l)$
STEP 2) n=m/M=164g/84.18g/mol **n=1.9482… mol of** $C_6H_{12(s)}$		**2.00 mol**		**?**

STEP 3) **1.9482… mol x 1 mol** $C_6H_{10}O_{4(s)}$ **/ 1 mol** $C_6H_{12(s)}$ **= 1.9482… mol of** $C_6H_{10}O_{4(s)}$

2.00 mol x 1 mol of $C_6H_{10}O_{4(s)}$ **/ 2.5 mo of $O_{2(g)}$ = 0.8 mol of $C_6H_{10}O_{4(s)}$** (O_2 is LIMITING)

STEP 4) 0.8 mol of $C_6H_{10}O_{4(s)}$ x 146.16 g/mol = 116.928 g =117 g of $C_6H_{10}O_{4(s)}$=TY(3 sig dig)

UNIT ANALYSIS OR LINEAR METHOD:

For **$O_{2(g)}$**: **2 mol of** $O_{2(g)}$**x1 mol / 2.5 mol** $O_{2(g)}$ **x146.16g of** $C_6H_{10}O_{4(s)}$ / 1 mol of $C_6H_{10}O_{4(s)}$ **=** 117 g of $C_6H_{10}O_{4(s)}$ (3 sig dig)

For $C_6H_{12(s)}$: **164gx1mol x 1 mol / 84.18g 1 mol** **x146.16g of** $C_6H_{10}O_{4(s)}$ / 1 mol of $C_6H_{10}O_{4(s)}$ **=** 285 g of $C_6H_{10}O_{4(s)}$ (3 sig dig)

c. If 85 g of acid was produced in b) what is the percent yield? (Use rounded answer from b)

%yield = AY/TY x 100% = 85 g / 117 g of $C_6H_{10}O_{4(s)}$ x 100% = **72.6% yield**

5. A chemist, new to the behaviour of chlorine toward hydrocarbon compounds, tried to make dichloromethane ($CH_2Cl_{2(g)}$), by mixing 5500 mL of chloromethane ($CH_3Cl_{(g)}$) and 5500 mL of chlorine at STP. Hydrogen chloride gas was a by product. After the reaction was complete, some chloromethane remained unchanged and 12.8 g of dichloromethane was obtained.

a. Which reactant is excess?

	G1 = E		G2 = L		R (TY)		
STEP 1)	**1 $CH_3Cl_{(g)}$**	**+**	**1.5 $Cl_{2(g)}$**	**→**	**1 $CH_2Cl_{2(g)}$**	**+**	**$HCl_{(g)}$**
	5500 mL		**5500 mL**		**12.8 g = AY**		
STEP 2) n= v/V	**= 5.5L/22.4L/mol**		**5.5L/22.4L/mol**				
	=0.2455…mol		**=0.2455…mol**				
STEP 3)	**x 1mol/1mol=0.2455…mol**		**x 1 mol/1.5 mol = 0.1636…mol (Cl2 is limiting)**				

b. How much dichlormethane can theoretically be produced?

STEP 4) **m = nM = 0.1636…mol x 84.93 g/mol = 13.89… g = 13.9 g = TY**

c. What is the percent yield?

%yield = AY/TY x 100% = 12.8 g / 13.9 g x 100% = 92.086…% = 92.1%

d. What is the percent error?

%error = (TY-AY)/TY x 100% = (13.9 – 12.8)/13.9 x 100% = 7.91 %

Worksheet 2.8: Stoichiometry Review

1. A 34.5 g sample of sodium hydroxide solution is reacted with excess phosphoric acid. What is the **mass of sodium phosphate** that will form?

G R

1) 3 $NaOH_{(s)}$ + $H_3PO_{4(aq)}$ → $3HOH_{(l)}$ + 1 $Na_3PO_{4(aq)}$

UNIT ANALYSIS OR LINEAR METHOD:

(2) (3) (4)

34.5g x 1 mol of NaOH / 40.00g x 1mol of Na_3PO_4 / 3 mol of NaOH x 163.94 g of Na_3PO_4 / 1 mol of Na_3PO_4 =47.1 g of sodium phosphate

2. A 75.0 g sample of lithium carbonate reacts with 120 g of aluminium nitrate. What mass of precipitate will form?

G1=E=R G2 = LR R

1) 3 $Li_2CO_{3(aq)}$ + 2 $Al(NO_3)_{3(aq)}$ → 6 $LiNO_{3(aq)}$ + 1 $Al_2(CO_3)_3$ (s)

? g

2) 75.0 g/73.89 = 1.0150… mol

3) 1.015.. x 1 mol / 3mol (Excess) = 0.33… mol

120g/213.01=0.56333...mol

0.563... x 1 mol of / 2 mol = 0.28…mol (LIMITING)

4) 0.28…mol of $Al_2(CO_3)_{3(s)}$ x 233.99g/mol= 65.9 g of $Al_2(CO_3)_{3(s)}$

UNIT ANALYSIS or LINE METHOD

75.0 g x 1 mol / 73.80 g x 1 mol of $Al_2(CO_3)_3$ / 3 mol of $Li_2CO_{3(aq)}$ x 233.99 g of $Al_2(CO_3)_{3(s)}$ / 1 mol of $Al_2(CO_3)_{3(s)}$ =79.2 g

120 g x 1mol $Al(NO_3)_{3(aq)}$ / 213.01 g x 1mol of $Al_2(CO_3)_3$ / 2 mol of $Al(NO_3)_{3(aq)}$ x 233.99 g of $Al_2(CO_3)_{3(s)}$ / 1 mol of $Al_2(CO_3)_{3(s)}$ = 65.9 g (LIMITED)

b) HOW MUCH EXCESS LEFT OVER

~~G~~ R EXCESS G = LR

3 Li_2CO_3(aq) + 2 $Al(NO_3)_3$ (aq) → 6 $LiNO_3$ (aq) + 1 $Al_2(CO_3)_3$ (s)

120g/213.01 = 0.563333...mol

=0.56333...mol x 3 mol of / 2 mol of $Al(NO_3)_3$ Li_2CO_3 x 73.89 g/mol of Li_2CO_3 = 62.4… g of Li_2CO_3 used

ORIGINAL - USED

75.0g -62.4…g = 12.6 g of EXCESS LEFT OVER

3. A 45.0 g sample of ethanol burns in the presence of 105 L of oxygen gas. (assume STP). What is the percent yield if **50.0 g of carbon dioxide** is formed?

G1=L G2=E R

1) 1 $C_2H_5OH_{(l)}$ + 3 $O_{2(g)}$ → 2 $CO_{2(g)}$ + 3 $H_2O_{(g)}$

45.0g 105 L 50.0g/44.01g = 1.13…mol

(2) (3) (4)

45.0g x 1 mol of C_2H_5OH / 46.08g x 2 mol of $CO_{2(g)}$ / 1 mol of C_2H_5OH =1.953…mol x 44.01 g of $CO_{2(g)}$ / 1 mol of $CO_{2(g)}$ = 85.97..g of CO2 ethanol limiting

105L x 1 mol of O2 / 22.4 L x 2 mol of $CO_{2(g)}$ / 3 mol of O2 = 4.6…mol 44.01 g of $CO_{2(g)}$ / 1mol of $CO_{2(g)}$ = 137.5 of CO2 oxygen excess

%yield = AY/TY x 100% = 50.0g/85.97.. x 100% = 58.16…% = 58.2 %

%yield = AY/TY x 100% = 1.136mol/1.953.. x 100% = 58.16…% = 58.2 %

EXCESS LEFT OVER:

1) 1 $C_2H_5OH_{(l)}$ + 3 $O_{2(g)}$ → 2 $CO_{2(g)}$ + 3 $H_2O_{(g)}$

45.0g x 1 mol of C_2H_5OH / 46.08g x 3 mol of $O_{2(g)}$ / 1 mol of C_2H_5OH =2.929…mol x 22.4 L of $O_{2(g)}$ / 1 mol of $O_{2(g)}$ = 65.625L of O2 used

Excess of O2 = Original O2 – Used O2 = 105L – 65.625L = 39.4L of O2 left over

2. When 5.6 x 10^{24} particles of magnesium sulfide reacts with potassium hydroxide, then 500 g of precipitate forms. What is the percent error?

Mg =24.31
Ox2=32.00
Hx2= 2.02
58.33

G1 R

1) 1 $MgS_{(s)}$ + 2 $KOH_{(aq)}$ → 1 $K_2S_{(aq)}$ + 1 $Mg(OH)_{2(s)}$

5.6 E 24 particles 500g = AY

(2) (3) (4)

5.6E24parts x 1 mol of MgS / 6.02E23parts x 1mol of $Mg(OH)_{2(g)}$ / 1 mol of C_2H_5OH x 58.33 g $Mg(OH)_{2(s)}$ / 1 mol of $Mg(OH)_{2(g)}$ = .. of $Mg(OH)_2$(AY)

%error = (TY-AY)/TY x 100% = 500g/85.97.. x 100 = 58.15…% = 58.2 %

5. When 36.9 L of chlorine gas (SATP) reacts with 36.8 g of magnesium oxide, 38.9 g of magnesium chloride formed. What mass of magnesium chloride did you expect?(TY)

G1 G2 R

1) 2 $Cl_{2(g)}$ + 2 $MgO_{(s)}$ → 1 $O_{2(g)}$ + 2 $MgCl_{2(s)}$

36.9L 36.8g 38.9 g = AY

(2) (3) (4)

36.9L x 1 mol of Cl_2 / 24.8L x 2 mol of $MgCl_{2(s)}$ / 2 mol of Cl_2 x 95.21 g of $MgCl_{2(g)}$ / 1 mol of $MgCl_{2(s)}$ =70.831.. g of $MgCl_2$
Cl_2 is excess

36.8g x 1 mol of MgO / 40.31 g x 2mol of $MgCl_{2(s)}$ / 2 mol of MgO x 95.21 g of $MgCl_{2(g)}$ / 1mol of $MgCl_{2(g)}$ = 86.919…g=86.9g of $MgCl_2$(TY)
MgO excess

EXCESS LEFT OVER:

~~G1~~= E=R G2 = LR

1) 2 $Cl_{2(g)}$ + 2 $MgO_{(s)}$ → 1 $O_{2(g)}$ + 1 $MgCl_{2(s)}$

36.9L x 1 mol of Cl_2 / 24.8L x 2 mol of MgO / 2 mol of Cl_2 x 24.8 L of $Cl_{2(g)}$ / 1mol of $Cl_{2(g)}$ =22.64…L of Cl_2 used

Excess of Cl2 = Original – Used = 36.9L – 22.64…L= 14.3 L of Cl_2 left over.

6. When 24.5 g of iron(II) chloride reacts with 35.0 g of zinc, 7.2 g of iron was formed. What is the percent yield and percent error is this experiment?

G1=L ~~G2=E~~R used R

1 $FeCl_{2(aq)}$ + 1 $Zn_{(s)}$ → 1 $Fe_{(s)}$ + $ZnCl_{2(aq)}$

7.2 g = AY

(2) (3) (4)

G1: 24.5g x 1 mol of $FeCl_2$ / 126.75g x 1 mol of Fe / 1 mol of $FeCl_2$ x 55.85g of Fe / 1 mol of Fe = 10.79546… g of Fe (TY)
$FeCl_2$ is limiting

G2: 35.0g x 1 mol of Zn / 65.41g x 1 mol of Fe / 1 mol of Zn x 55.85g of Fe / 1mol of Fe = 29.8.. g of Fe
Zn is excess

%yield = AY/TY x 100% = 7.2g/10.795…g x 100% = 66.7%
%error = (TY-AY)/TY x 100% = (10.7…g - 7.2g)10.7…g x100% = 33.3%
EXCESS LEFT OVER:

1 $FeCl_{2(aq)}$ + 1 $Zn_{(s)}$ → 1 $Fe_{(s)}$ + $ZnCl_{2(aq)}$

24.5g x 1 mol of $FeCl_2$ / 126.75g x 1 mol of Zn / 1 mol of $FeCl_2$ x 65.41g of Zn / 1 mol of Zn = 12.64… g of Zn used

Excess Zn = Original – Used
Excess Zn = 35.0 g – 12.64…g = 22.4 g left over