Name: _KEY_

Chemistry 20
Stoichiometry Workbook

Review of Chemical Reactions

Write the balanced equations, including states, for the following chemical reactions. Give the reaction type for each reaction.

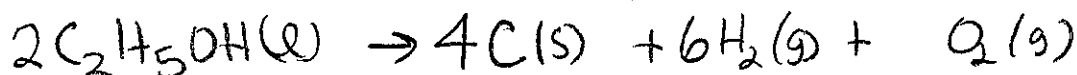1. Cyclopentane, $C_5H_{10}(\ell)$, reacts with oxygen to produce carbon dioxide and water vapour. Combustion

$$2\, C_5H_{10}(\ell) + 15O_2(g) \longrightarrow 10CO_2(g) + 10H_2O(g)$$

2. Copper(I) oxide forms from its elements. – formation

$$4\, Cu(s) + O_2(g) \longrightarrow 2Cu_2O(s)$$
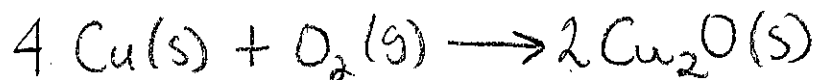
3. Phosphoric acid is neutralized by cesium hydroxide solution to produce cesium phosphate solution and liquid water. double replacement (DR) + neutralization
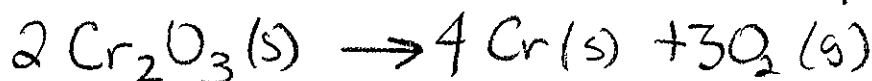
$$H_3PO_4(aq) + 3CsOH(aq) \longrightarrow 3HOH(\ell) + Cs_3PO_4(aq)$$
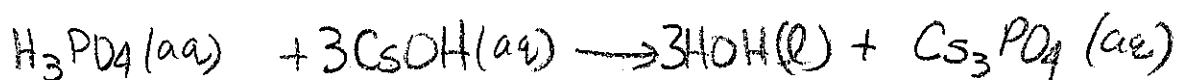
4. Ethanol breaks up into its elements. – decomposition

$$2C_2H_5OH(\ell) \rightarrow 4C(s) + 6H_2(g) + O_2(g)$$

5. Lead(II) acetate reacts with zinc metal to form zinc acetate solution and solid lead. – single replacement (S

$$Pb(CH_3COO)_2(aq) + Zn(s) \longrightarrow Zn(CH_3COO)_2(aq) + Pb(s)$$
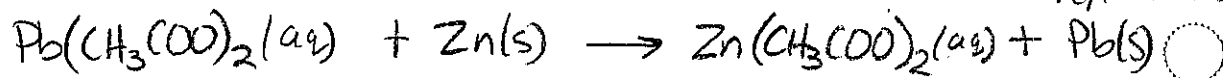
6. Chromium(III) oxide decomposes into its elements. – decomposition

$$2\, Cr_2O_3(s) \rightarrow 4\, Cr(s) + 3O_2(g)$$
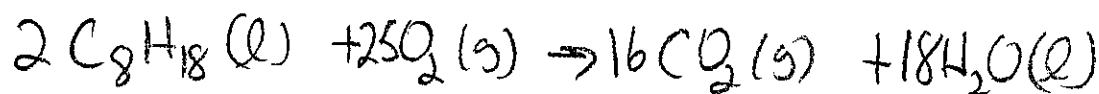
7. Calcium chlorate solution reacts with lithium sulfate and calcium sulfate solid forms in a lithium chlorate solution. (DR)

$$Ca(ClO_3)_2(aq) + Li_2SO_4(aq) \longrightarrow CaSO_4(s) + 2LiClO_3(aq)$$
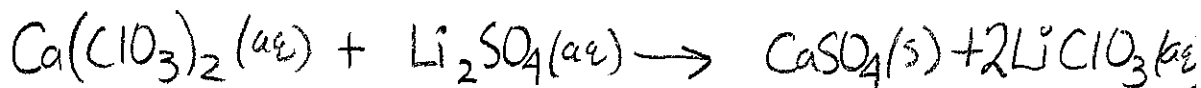
8. Dinitrogen tetraoxide gas forms from its elements. – formation

$$1\, N_2(g) + 2O_2(g) \longrightarrow 1\, N_2O_4(g)$$
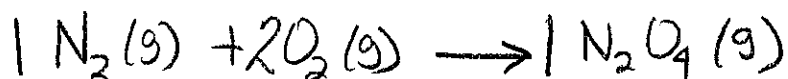
9. Octane $(C_8H_{18}(\ell))$ reacts with oxygen gas to produce carbon dioxide and liquid water in a bomb calorimeter. – combustion

$$2\, C_8H_{18}(\ell) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(\ell)$$

10. Aluminium nitrate solution reacts with magnesium metal to produce magnesium nitrate solution and aluminium metal.   SR

$$2\ Al(NO_3)_3(aq) + 3\ Mg(s) \rightarrow 3\ Mg(NO_3)_2(aq) + 2\ Al(s)$$
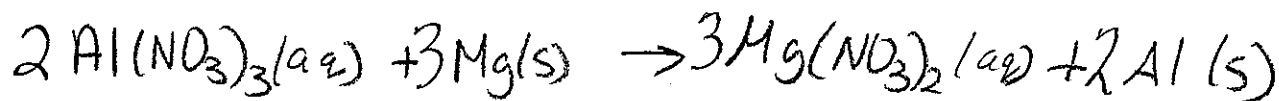
11. Nitrogen triiodide decomposes explosively into its elements. -decomposition

$$2\ NI_3(s) \rightarrow 1\ N_2(s) + 3\ I_2(s)$$
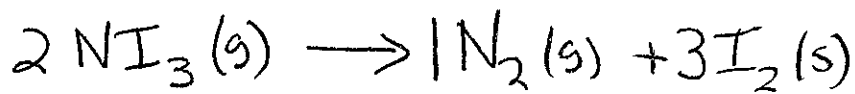
12. Solutions of calcium nitrate and potassium phosphate are mixed. DR

$$3\ Ca(NO_3)_2(aq) + 2\ K_3PO_4(aq) \rightarrow 6\ KNO_3(aq) + Ca_3(PO_4)_2(s)$$
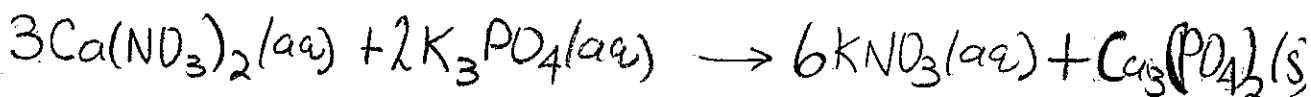
13. The main fuel used to propel rockets into outer space is liquid hydrogen combining with liquid oxygen to produce water vapour. formation

$$2\ H_2(l) + O_2(l) \rightarrow 2\ H_2O(g)$$
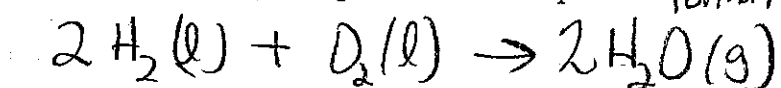
14. Steel wool (iron) will burn with a blinding flash in pure oxygen. The iron (III) compound is formed. - formation

$$3\ Fe(s) + O_2(g) \rightarrow Fe_3O_2(s)$$
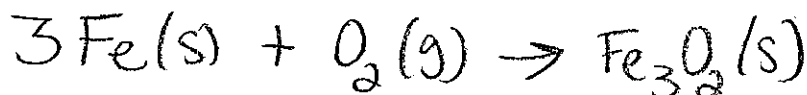
15. In the Haber process, nitrogen and hydrogen gas are reacted under high pressure and temperature conditions to produce ammonia gas. - formation

$$N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$$
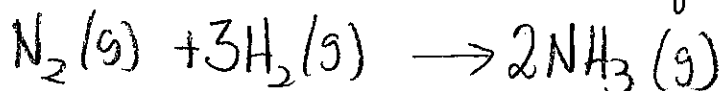
16. Iron reacts with silver nitrate. The iron (III) compound is formed. SR

$$Fe(s) + 3\ AgNO_3(aq) \rightarrow Fe(NO_3)_3(aq) + 3\ Ag(s)$$
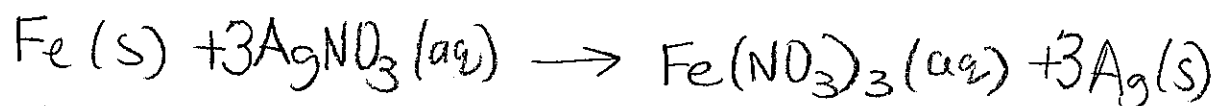
17. Phosphorus burns in air to produce solid diphosphorus pentaoxide. formation or combustion

$$P_4(s) + 5\ O_2(g) \rightarrow 2\ P_2O_5(s)$$
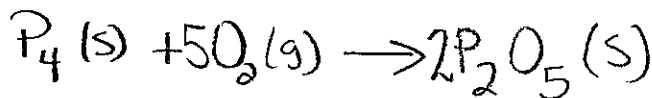
18. Propane ($C_3H_{8(g)}$) undergoes complete combustion. - combustion

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

19. Sulphur burns in air to produce sulphur dioxide gas. - formation or combustion

$$S_8(s) + 8\ O_2(g) \rightarrow 8\ SO_2(g)$$
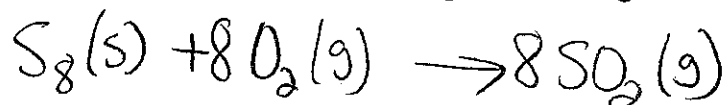
20. Chlorine gas is bubbled through an aluminum iodide solution. - SR -

$$3\ Cl_2(g) + 2\ AlI_3(aq) \rightarrow 2\ AlCl_3(aq) + 3\ I_2(s)$$
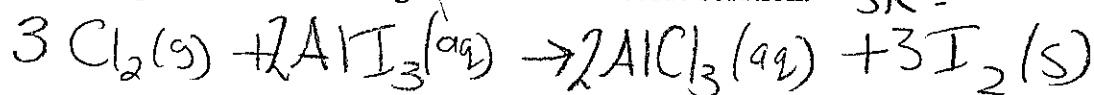
Mole to Mole Calculations

1. How many moles of gas is produced when 15.3 moles of calcium chloride decomposes?

$$CaCl_2 (s) \longrightarrow Ca(s) + Cl_2 (g)$$
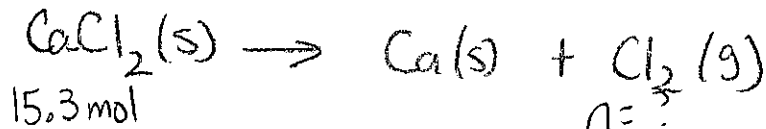
15.3 mol $\qquad\qquad\qquad\qquad n = ?$

1:1 ratio ∴ $\boxed{15.3 \ mol}$

2. How many moles of hydrogen are needed to react with 19.66 mol of oxygen.

$$2H_2 (g) + O_2 (g) \longrightarrow 2H_2O(g)$$

$n = ? \qquad 19.66 \ mol$

$$\frac{2 \ mol \ H_2}{1 \ mol \ O_2} = \frac{x \ mol \ H_2}{19.66 \ mol \ O_2} \qquad X = \boxed{39.32 \ mol}$$

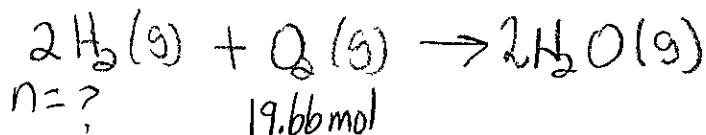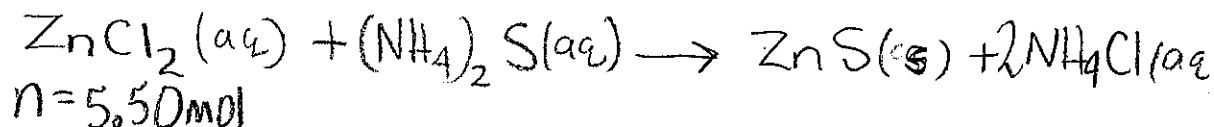3. If 5.50 moles of zinc chloride reacts with ammonium sulfide, how many moles of precipitate are formed?

$$ZnCl_2 (aq) + (NH_4)_2 S(aq) \longrightarrow ZnS(s) + 2NH_4Cl(aq)$$

$n = 5.50 \ mol$

1:1 ratio ∴ $\boxed{5.50 \ mol}$

4. Calcium oxide and diphosphorus pentoxide react to produce calcium phosphate. How many moles of calcium phosphate will be produced if 18.2 moles of calcium oxide are used?

$$3CaO(s) + P_2O_5 (s) \longrightarrow Ca_3(PO_4)_2 (s)$$
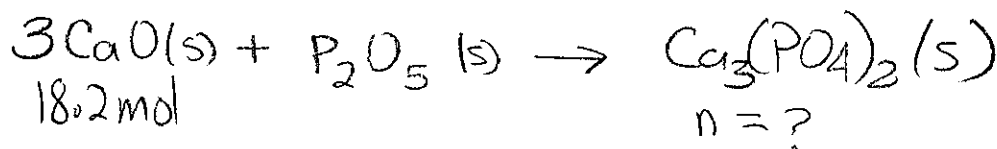
18.2 mol $\qquad\qquad\qquad\qquad n = ?$

$$\frac{3 \ mol \ CaO(s)}{1 \ mol \ Ca_3(PO_4)_2(s)} = \frac{18.2 \ mol}{x} \qquad X = \boxed{6.07 \ mol}$$

5. How many moles of gas are formed if 9.67 moles of aluminum chloride decomposes?

$$2AlCl_3 (s) \longrightarrow 2Al(s) + 3Cl_2 (g)$$
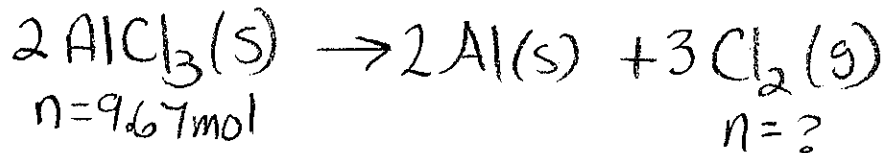
$n = 9.67 \ mol \qquad\qquad\qquad n = ?$

$$\frac{2 \ mol \ AlCl_3}{3 \ mol \ Cl_2} = \frac{9.67 \ mol}{x}$$

$$X = \boxed{14.5 \ mol}$$

Gravimetric Stoichiometry Calculations

1. Iron reacts with chlorine as follows:
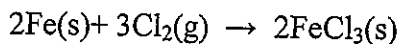
$$2Fe(s) + 3Cl_2(g) \rightarrow 2FeCl_3(s)$$
$$m = 0.520g \qquad m = ?$$

How many grams of iron(III) chloride would form if 0.520 g of chlorine reacted?

① moles of Cl_2

$$\frac{70.90g}{1 mol} = \frac{0.520g}{x}$$

$$x = 0.00733 mol$$

② mole ratio

$$\frac{3 mol\ Cl_2}{2 mol\ FeCl_3} = \frac{0.00733 mol\ Cl_2}{x mol\ FeCl_3}$$

$$x = 0.0146685 mol$$

③ mass $FeCl_3$

$$\frac{162.2g}{1 mol} = \frac{x g}{0.014\%}$$

$$\boxed{x = 2.38 g}$$

2. Ethane ($C2H6(g)$) reacts with oxygen in a hydrocarbon combustion reaction. How many grams of ethane need to burn to cause 10.6 g of water vapour to form?

$$2 C_2H_6(g) + 7O_2(g) \longrightarrow 4CO_2(g) + 6H_2O(g)$$
$$m = ? \qquad\qquad\qquad\qquad\qquad m = 10.6g$$
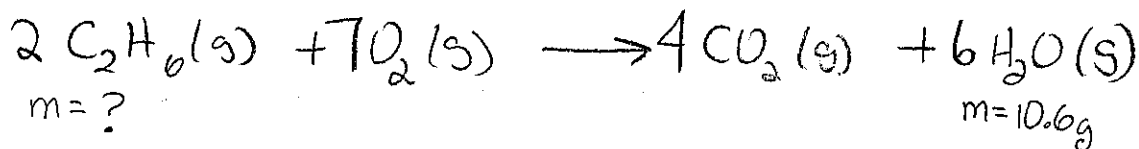
① moles of water

$$\frac{18.02g}{1 mol} = \frac{10.6g}{x mol}$$

$$x = 0.588235 mol$$

② mole ratio

$$\frac{2 mol\ C_2H_6}{6 mol\ H_2O} = \frac{x mol\ C_2H_6}{0.588235 mol}$$

$$x = 0.196078 mol$$

③ mass C_2H_6

$$\frac{26.04g}{1 mol} = \frac{x g}{0.196078}$$

$$\boxed{x = 5.11 g}$$

3. Xenon can be made to react with fluorine gas at about 400 °C. The product that forms is xenon tetrafluoride(g). How many grams of xenon tetrafluoride will form if 4.35 g of fluorine react?

$$Xe(g) + 2F_2(g) \rightarrow XeF_4(g)$$
$$m = 4.35g \qquad\qquad x = ?$$
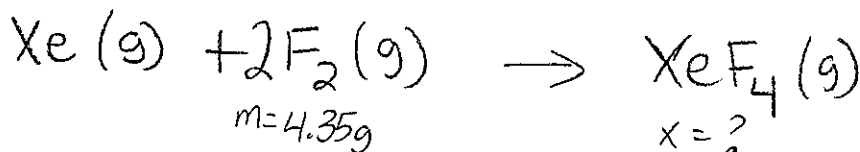
① mol $F_2(s)$

$$\frac{38.00g}{1 mol} = \frac{4.35g}{x mol}$$

$$x = 0.1144736 mol$$

② mole ratio

$$\frac{2 mol\ F_2(g)}{1 mol\ XeF_4 g} = \frac{0.1144736 mol\ F_2}{x}$$

$$x = 0.0572368 mol$$

③ mass XeF_4

$$\frac{207.29g}{1 mol} = \frac{x g}{0.05723}$$

$$\boxed{x = 11.86 g}$$

4. Calculate the mass of iron (III) oxide (rust) produced by the reaction of 250 g of iron with oxygen from the air.

$$4\ Fe_{(s)} + 3O_{2(g)} \longrightarrow 2\ Fe_2O_{3(s)}$$
$$m = 250g \qquad\qquad\qquad m = ?$$
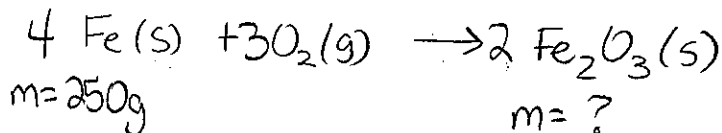
① moles Fe(s)

$$\frac{55.85g}{1\,mol} = \frac{250g}{X\,mol}$$

$$X = 4.47627\,mol$$

② mole ratio

$$\frac{4\,mol\,Fe}{2\,mol\,Fe_2O_3} = \frac{4.47627\,mol}{X\,mol}$$

$$X = 2.2381378\,mol\,Fe_2O_3$$

③ mass Fe$_2$O$_3$

$$\frac{159.70g}{1\,mol} = \frac{Xg}{2.23813}$$

$$X = \boxed{357g}$$

5. What mass of precipitate should form when 5.00 g of silver nitrate solution is reacted with excess sodium chloride solution?

$$AgNO_{3}(aq) + NaCl(aq) \longrightarrow AgCl(s) + NaNO_{3}(aq)$$
$$m = 5.00g \qquad\qquad\qquad m = ?$$
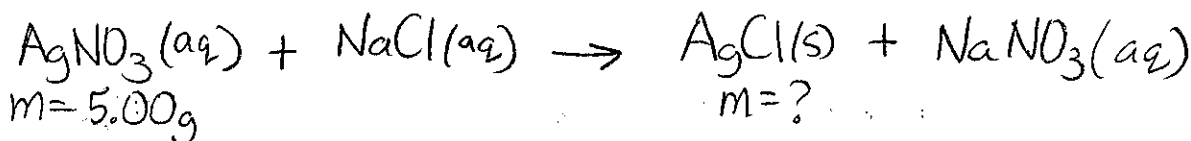
① moles of AgNO$_3$

$$\frac{169.88g}{1\,mol} = \frac{5g}{X}$$

$$X = 0.0294325\,mol$$

② mole ratio

$$1:1$$

③ mass AgCl

$$\frac{143.32g}{1\,mol} = \frac{Xg}{0.0294325\,mol}$$

$$\boxed{X = 4.22g}$$

6. Determine the mass of water vapour formed when 1.00 g of butane, C$_4$H$_{10}$(g), is burned in a lighter.

$$2\ C_4H_{10}(g) + 13O_{2}(g) \longrightarrow 8\ CO_2(g) + 10H_2O(g)$$
$$m = 1.00g \qquad\qquad\qquad m = ?$$
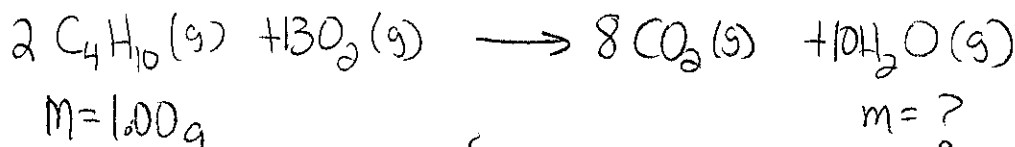
① mol C$_4$H$_{10}$(s)

$$\frac{58.14g}{1\,mol} = \frac{1.00g}{X\,mol}$$

$$X = 0.0171998\,mol$$

②

$$\frac{2\,mol\,C_4H_{10}}{10\,mol\,H_2O} = \frac{0.0171998\,mol}{X}$$

$$X = 0.085999\,mol$$

③ mass H$_2$O

$$\frac{18.02g}{1\,mol} = \frac{Xg}{0.085999}$$

$$\boxed{X = 1.55g}$$

Solution Stoichiometry Calculations

1. What volume of 0.125 mol/L NaOH(aq) is required to react completely with 15.0 mL of 0.100 mol/L $Al_2(SO_4)_3$(aq)?

$$6 NaOH(aq) + 1 Al_2(SO_4)_3 (aq) \rightarrow 2 Al(OH)_3 (s) + 3 Na_2SO_4 (aq)$$

V = ?
0.125 mol/L

V = 15 mL
C = 0.100 mol/L
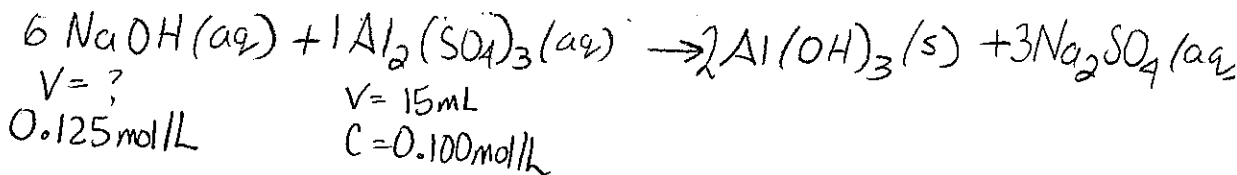
① moles of $Al_2(SO_4)_3$

$$\frac{0.100 mol}{1 L} = \frac{X mol}{0.0150 L}$$

X = 0.0015 mol

② mole ratio

$$\frac{6 mol NaOH}{1 mol Al_2(SO_4)_3} = \frac{X mol NaOH}{0.0015 mol}$$

X = 0.009 mol

③ volume of NaOH

$$\frac{0.125 mol}{1 L} = \frac{0.009 mol}{X}$$

X = 0.072 L or

$$\boxed{72.0 mL}$$

2. In a chemical analysis, a 10.0 mL sample of H_3PO_4(aq) was reacted with 18.2 mL of 0.259 mol/L NaOH(aq). Calculate the concentration of the phosphoric acid.

$$H_3PO_4 (aq) + 3 NaOH(aq) \rightarrow Na_3PO_4 (aq) + 3 HOH(\ell)$$

V = 10.0 mL
C = ?

V = 18.2 mL
C = 0.259 mol/L
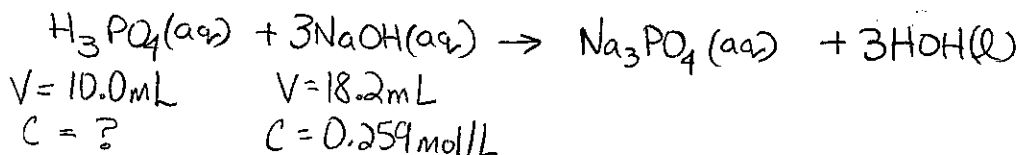
① moles NaOH

$$\frac{0.259 mol}{1 L} = \frac{X mol}{0.0182 L}$$

X = 0.0047138 mol

② mole ratio

$$\frac{1 mol H_3PO_4}{3 mol NaOH} = \frac{X mol H_3PO_4}{0.0047138}$$

X = 0.00157126 mol

③ Conc. H_3PO_4

$$\frac{0.0015712 mol}{0.010 L} = \frac{X M}{1 L}$$

$$\boxed{X = 0.157 M}$$

3. Silver nitrate and sodium chromate solutions react as follows:

$$2 AgNO_3(aq) + Na_2CrO_4(aq) \rightarrow Ag_2CrO_4(s) + 2 NaNO_3(aq)$$

V = 200 mL

m = ?
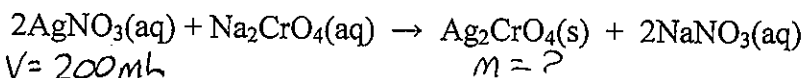
How many grams of precipitate will form if 200 mL of 0.500 mol/L silver nitrate react with sodium chromate?

C = 0.500 mol/L

① moles $AgNO_3$

$$\frac{0.500 mol}{1 L} = \frac{X mol}{0.200 mL}$$

X = 0.100 mol

② mole ratio

$$\frac{2 mol AgNO_3}{1 mol Ag_2CrO_4(s)} = \frac{0.100 mol AgNO_3}{X mol Ag_2CrO_4}$$

X = 0.05 mol Ag_2CrO_4

③ mass Ag_2CrO_4

$$\frac{331.74 g}{1 mol} = \frac{X g}{0.05}$$

$$\boxed{X = 16.6 g}$$

Jill Agnew

4. What volume of 0.320 mol/L sulfuric acid reacts with 47.3 mL of 0.224 mol/L sodium hydroxide?

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2HOH(l) \bigcirc$$

V = ?   V = 47.3 mL

C = 0.320 mol/L   C = 0.224 mol/L
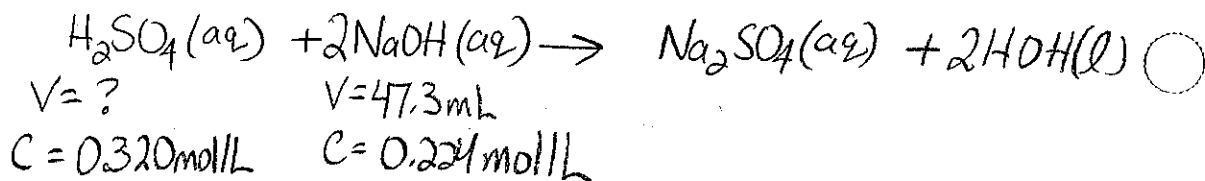
① moles of NaOH

$$\frac{0.224 \, mol}{1 L} = \frac{x \, mol}{0.0473 L}$$

$$x = 0.0105952 \, mol$$

② mole ratio

$$\frac{1 \, mol \, H_2SO_4}{2 \, mol \, NaOH} = \frac{x \, mol \, H_2SO_4}{0.0105952 \, mol}$$

$$x = 0.0052976 \, mol \, H_2SO_4$$

③ volume H₂SO₄

$$\frac{0.320 \, mol}{1L} = \frac{0.005}{x}$$

$$x = 0.01655\ldots$$

[16.6 mL]

5. A student adds 5.77 g of zinc to 100 mL of HCl(aq). What would the concentration of zinc chloride be in the 100 mL solution when all the zinc had reacted?

$$2HCl(aq) + Zn(s) \longrightarrow ZnCl_2(aq) + H_2(g)$$

m = 5.77 g   V = 100 mL

C = ?

① moles of Zn(s)

$$\frac{66.41 \, g}{1 \, mol} = \frac{5.77 \, g}{x \, mol}$$
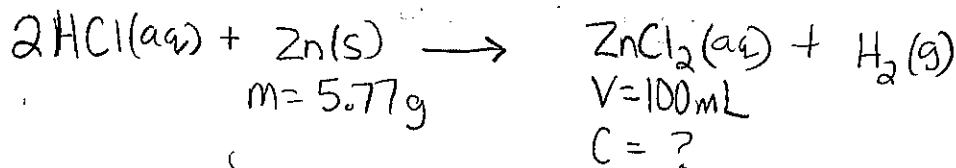
$$0.08688 \, mol$$

② mole ratio

$$\frac{1}{1}$$

③ conc. ZnCl₂(aq)

$$\frac{0.08688 \, mol}{0.1 L} = \frac{x \, mol}{1L} \bigcirc$$

$$\boxed{x = 0.869 \, mol/L}$$

6. The concentration of magnesium ions from magnesium chloride in sea water was analyzed and found to be 50.0 mmol/L. What volume of 0.200 mol/L sodium hydroxide solution would be needed in an industrial process to precipitate all of the magnesium ions from 1.00 ML of sea water?

$$MgCl_2(aq) + 2NaOH(aq) \rightarrow Mg(OH)_2(s) + 2NaCl(aq)$$

C = 50×10⁻³ mol/L   V = ?

V = 1.00×10⁶ L   C = 0.200 mol/L
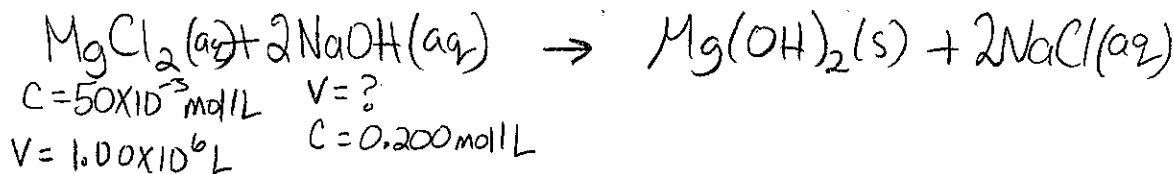
① moles MgCl₂

$$\frac{50×10^{-3} \, mol}{1L} = \frac{x \, mol}{1.00×10^6 L} \quad x = 50000 \, mol$$

$$MgCl_2(aq) \rightarrow Mg^{2+}(aq) + 2Cl^{-}(aq)$$

50×10⁻³ mol/L   50×10⁻³ mol/L

② mole ratio

$$\frac{1 \, mol \, MgCl_2}{2 \, mol \, NaOH} = \frac{50000 \, mol}{x \, mol}$$

$$x = 100000 \, mol$$

③ Volume NaOH

$$\frac{0.200 \, mol}{1L} = \frac{100000 \, mol}{x \cdot 1}$$

of 5.00×10⁵

[0.500 ML] of

$$x = [500 KL]$$

Jill Agnew

Law of Combining Volumes Calculations

Solve these questions assuming that the conditions of temperature and pressure of both reactants and products are the same.

1. Write the reaction for the formation of water vapour from hydrogen and oxygen gas.

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

(a) How many moles of hydrogen react with 3.4 mol of oxygen gas?

$$\frac{2\ mol\ H_2}{1\ mol\ O_2} = \frac{x\ mol\ H_2}{3.4\ mol} \qquad x = \boxed{6.8\ mol}$$
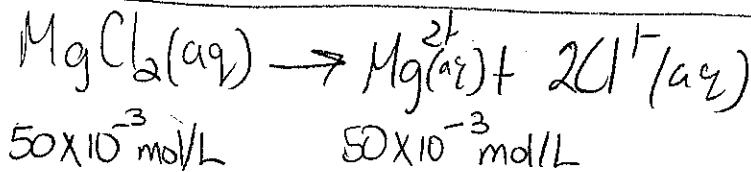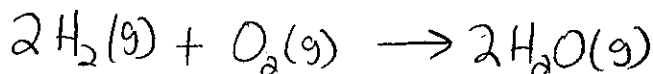
(b) How many litres of water vapour would form if 9.4 L of oxygen react?

Remember this only works → when comparing gases

$$\frac{1\ L\ O_2}{2\ L\ H_2O} = \frac{9.4\ L\ O_2}{x\ L\ H_2O} \qquad x = 18.8 \rightarrow \boxed{19\ L}$$

2. Write the balanced equation for the combustion of propane ($C_3H_8(g)$).

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$
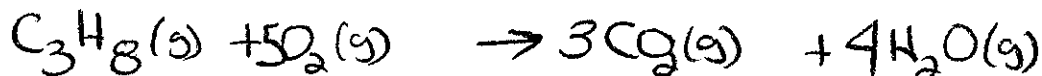
(c) How many litres of propane must react in order to make 2.36 L of water vapour?

$$\frac{1\ L\ C_3H_8}{4\ L\ H_2O} = \frac{x\ L\ C_3H_8}{2.36\ L\ H_2O} \qquad \boxed{x = 0.585\ L}$$

(d) How many moles of oxygen must react to produce 35.8 mol of carbon dioxide?

$$\frac{5\ mol\ O_2}{3\ mol\ CO_2} = \frac{x\ mol\ O_2}{35.8\ mol\ CO_2} \qquad x = \boxed{59.7\ mol}$$

(e) The total volume of products that form if 9.53 L of propane reacted with oxygen would be _____ L.

$$\frac{1\ L\ C_3H_8}{3\ L\ CO_2} = \frac{9.53\ L\ C_3H_8}{x\ CO_2} \qquad x = 28.59\ CO_2(g)$$

$$\frac{1\ L\ C_3H_8}{4\ L\ H_2O} = \frac{9.53\ L}{x\ H_2O}$$

$$x = 38.12\ H_2O$$

$$x = 28.59 + 38.1$$

$$\boxed{66.7\ L}$$

3. Write the reaction between sulfur and oxygen to produce sulfur trioxide gas.

$$S_8(s) + 12O_2(g) \rightarrow 8SO_3(g)$$
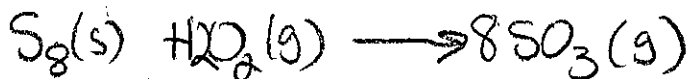
(a) How many litres of sulfur trioxide would form from the reaction of 0.65 L of oxygen?

$$\frac{12\ L\ O_2}{8\ L\ SO_3} = \frac{0.65\ L\ O_2}{x} \qquad \boxed{x = 0.43\ L}$$

(b) How many moles of oxygen need to react to form 1.56 mol of sulfur trioxide?

$$\frac{12\ mol\ O_2}{8\ mol\ SO_3} = \frac{x\ mol\ O_2}{1.56\ mol\ SO_3} \qquad \boxed{x = 2.34\ mol}$$

Gas Stoichiometry Calculations

1. The first recorded observation of hydrogen gas was made by the famous alchemist Paraclesus when he added iron to sulphuric acid. Calculate the volume of hydrogen gas at 20°C and 98 kPa produced by added 10 g of iron to excess sulphuric acid.

$$3 H_2SO_4(aq) + 2Fe(s) \rightarrow Fe_2(SO_4)_3(aq) + 3H_2(g)$$

$$m = 10g \qquad T = 293K$$
$$P = 98 KPa$$
$$V = ?$$

① mol Fe

$$\frac{55.85g}{1 \, mol} = \frac{10g}{X \, mol}$$

$$X = 0.17905 \, mol$$

② mole ratio

$$\frac{2 \, mol \, Fe}{3 \, mol \, H_2} = \frac{0.17905 \, mol}{X \, mol}$$
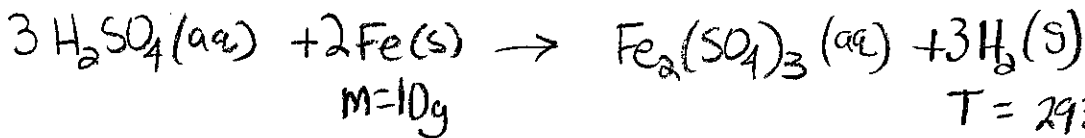
$$X = 0.26857 \, mol$$

③ $PV = nRT$

$$(98) V = (0.26857)(8.314)(293)$$

$$\boxed{V = 6.7 L}$$

2. What mass of sulphur must be burned in the presence of oxygen to produce 112 L of sulphur dioxide at STP?

$$S_8(s) + 8 O_2(g) \rightarrow 8 SO_2(g)$$

$$m = ? \qquad V = 112 L$$
$$V = 22.4 \, L/mol$$

① moles $SO_2(g)$

$$n = \frac{v}{V} = \frac{112 L}{22.4 \, L/mol}$$
$$= 5 \, mol$$

② mole ratio

$$\frac{1 \, mol \, S_8}{8 \, mol \, SO_2} = \frac{X \, mol \, S_8}{5 \, mol \, SO_2}$$

$$X = 0.625 \, mol$$

③ mass $S_8(s)$

$$\frac{256.56g}{1 \, mol} = \frac{X \, g}{0.625}$$

$$\boxed{X = 160g}$$

3. How many grams of sodium metal will form as 10.5 L of nitrogen form at 25.0 °C and 132.0 kPa? The production of a gas to fill an airbag rapidly is accomplished by the following reaction:

$$2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$$
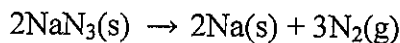
$$m = ? \quad V = 10.5 L$$
$$T = 298 K$$
$$P = 132.0 kPa$$

① moles $N_2(g)$

$$PV = nRT$$

$$(132.0)(10.5) = n(8.314)(298)$$

$$n = 0.5594 \, mol$$

② mole ratio

$$\frac{2 \, mol \, Na}{3 \, mol \, N_2} = \frac{X \, mol \, Na}{0.5594 \, mol}$$

$$X = 0.372945 \, mol$$

③ mass $Na(s)$

$$\frac{22.99g}{1 \, mol} = \frac{X \, g}{0.372}$$

$$\boxed{X = 8.57g}$$

4. Carbon dioxide gas can be removed from the air by bubbling it through LiOH(aq) solution. How many grams of lithium carbonate would form if 25.0 L of $CO_2(g)$ were absorbed at 28.3 °C and 95.0 kPa? The reaction is as follows:

$$2LiOH(aq) + CO_2(g) \rightarrow Li_2CO_3(aq) + H_2O(\ell)$$

$$V = 25.0 L \qquad m = \text{?}$$
$$T = 301.3 K$$
$$P = 95.0 \, kPa$$

① mols CO_2

$$PV = nRT$$
$$(95.0)(25) = n(8.314)(301.3)$$
$$n = 0.948 \, mol$$

② mole ratio

$$1 \mathbin{:}\! 1$$

③

$$\frac{73.89 g}{1 mol} = \frac{X g}{0.948 \, mol}$$

$$\boxed{X = 70.1 \, g}$$

5. A piece of zinc is dropped into a large volume of nitric acid, and 37.0 L of hydrogen gas form as a result. If the hydrogen was collected at 20.0 °C and 85.0 kPa, what mass of zinc reacted?

$$2 HNO_3(aq) + Zn(s) \longrightarrow Zn(NO_3)_2(aq) + H_2(g)$$
$$\qquad\qquad\qquad m = \text{?}$$
$$V = 37.0 L$$
$$T = 293 K$$
$$P = 85.0 \, kPa$$

① moles of $H_2(g)$
$$PV = nRT$$
$$(85)(37) = n(8.314)(293)$$
$$n = 1.291049 \, mol$$

② mole ratio
$$1 \mathbin{:}\! 1$$

③ mass $Zn(s)$

$$\frac{65.41 g}{1 mol} = \frac{X g}{1.291}$$

$$\boxed{X = 84.4 g}$$

6. Coal, pure carbon, can undergo incomplete combustion in the absence of a plentiful supply of air to produce deadly carbon monoxide gas. What volume of carbon monoxide is produced at SATP by the incomplete combustion of 150 kg of coal?
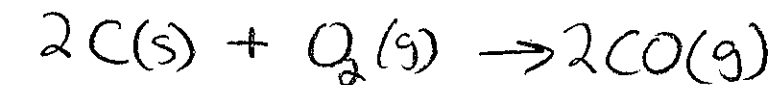
$$2 C(s) + O_2(g) \rightarrow 2 CO(g)$$
$$m = 150 kg \qquad\qquad V = \text{?}$$
$$V = 24.8 \, \text{⁴}/mol$$

① moles C

$$\frac{12.01 g}{1 mol} = \frac{150\,000 \, g}{X \, mol}$$

$$X = 12489.59 \, mol$$

② mole ratio
$$1 \mathbin{:}\! 1$$

③ $v = CO(g)$

$$n = \frac{v}{V}$$

$$12489.59 = \frac{v}{24.8}$$

$$\boxed{v = 309741 \, L}$$

Limited and Excess Reagents

1. 1.24 g of manganese(II) iodide reacts with 25.0 g of fluorine gas. What mass of manganese(III) fluoride is expected? Manganese(III) fluoride is formed in the following reaction:

$$2MnI_2(s) + 13F_2(g) \rightarrow 2MnF_3(s) + 4IF_5(\ell)$$

$m = 1.24g \qquad m = 25.0g \qquad m = ?$
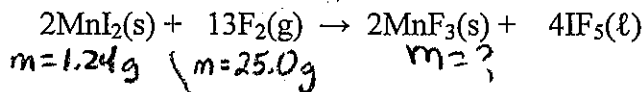
$$\frac{308.74g}{1mol} = \frac{1.24g}{x}$$

$x = 0.004016\,mol$

HAVE

LIMITING

$$\frac{38g}{1mol} = \frac{25.0g}{x\,mol}$$

0.65789 HAVE

EXCESS

$$\frac{2\,mol\,MnI_2}{13\,mol\,F_2} = \frac{0.004016\,mol}{x\,mol}$$

$x = 0.026\,mol\,F_2\,needed$

① $0.004016\,mol\,MnI_2$

② mole ratio
2:2
1:1

③ mass MnF_3

$$\frac{111.94g}{1mol} = \frac{x}{0.00}$$

$x = 0.449$

$\boxed{x = 0.450g}$

2. A quantity of sodium sulphide with a mass of 8.76 g is added to 350 mL of 0.250 mol/L lead(II) nitrate solution. Which reactant is limiting and what mass of precipitate is formed?

$$Na_2S(aq) + Pb(NO_3)_2(aq) \longrightarrow 2NaNO_3(aq) + PbS(s)$$

$m = 8.76g \qquad\qquad V = 0.350L \qquad\qquad m = ?$
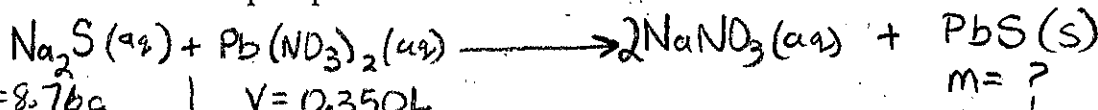
$$\frac{78.05g}{1mol} = \frac{8.76g}{x\,mol} \qquad C = 0.250\,mol/L$$

$x = 0.1122\,mol$

$$\frac{0.250\,mol}{1L} = \frac{x\,mol}{0.350L}$$

$x = 0.0875\,mol$

EXCESS

LIMITING

1:1 ratio ∴ the smaller one is limiting

① moles limiting reactant = $0.0875\,mol$

② 1:1 mole ratio

③ mass $PbS(s)$

$$\frac{239.27g}{1mol} = \frac{x\,g}{0.0875\,mol}$$

$\boxed{x = 20.9g}$

3. A 25.0 mL volume of 0.400 mol/L lead(II) nitrate is mixed with 300 mL of 0.220 mol/L potassium iodide. What is the maximum mass of precipitate that can form?

LIMITING

$$Pb(NO_3)_2(aq) + 2KI(aq) \longrightarrow 2KNO_3(aq) + PbI_2(s)$$
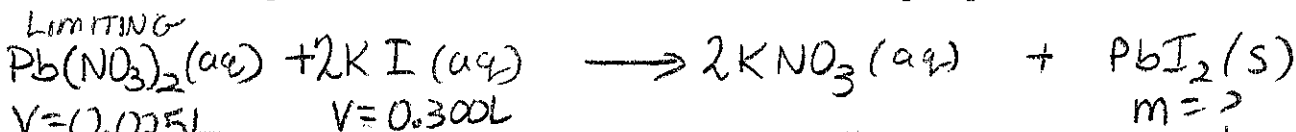
$V = 0.025L \qquad\qquad V = 0.300L \qquad\qquad m = ?$

$C = 0.400\,mol/L \qquad C = 0.220\,mol/L$

$n = 0.01\,mol \qquad\qquad n = 0.066\,mol$

EXCESS

Determine limiting

$$\frac{1\,mol\,Pb(NO_3)_2}{2\,mol\,KI} = \frac{0.01\,mol}{x\,mol\,of\,KI}$$

$x = \boxed{0.02\,mol\,required}$ of KI

have $0.066\,mol\,KI$ ∴ it is excess

① moles limiting $0.01\,mol$

② mole ratio 1:1

③ moles PbI_2

$$\frac{461g}{1mol} = \frac{x\,g}{0.01\,mol}$$

$\boxed{x = 4.61g}$

4. What mass of liquid water is expected when 2.00 L of hydrogen gas reacts with 2.00 L of oxygen gas, both at 22 °C and 102.5 kPa?

$$\underset{\text{LIMITING}}{2H_2\,(g)} \quad + \quad \underset{\text{EXCESS}}{O_2\,(g)} \quad \longrightarrow \quad 2H_2O\,(l)$$

2.00 L   2.00 L

$PV = nRT$ same numbers

$102.5\,(2) = n(8.314)(295)$

$n = 0.08358\,mol$
    HAVE

$\dfrac{2\,mol\,H_2}{1\,mol\,O_2} = \dfrac{0.08358\,mol\,H_2}{x\,mol\,O_2}$

$x = 0.04179\,mol\,O_2$ required have more than ref excess

① moles limiting
    0.08358 mol
② mole ratio 1:1
③ mass of $H_2O(l)$

$\dfrac{18.02\,g}{1\,mol} = \dfrac{x\,g}{0.08358\,mol}$

$\boxed{x = 1.5\,g}$
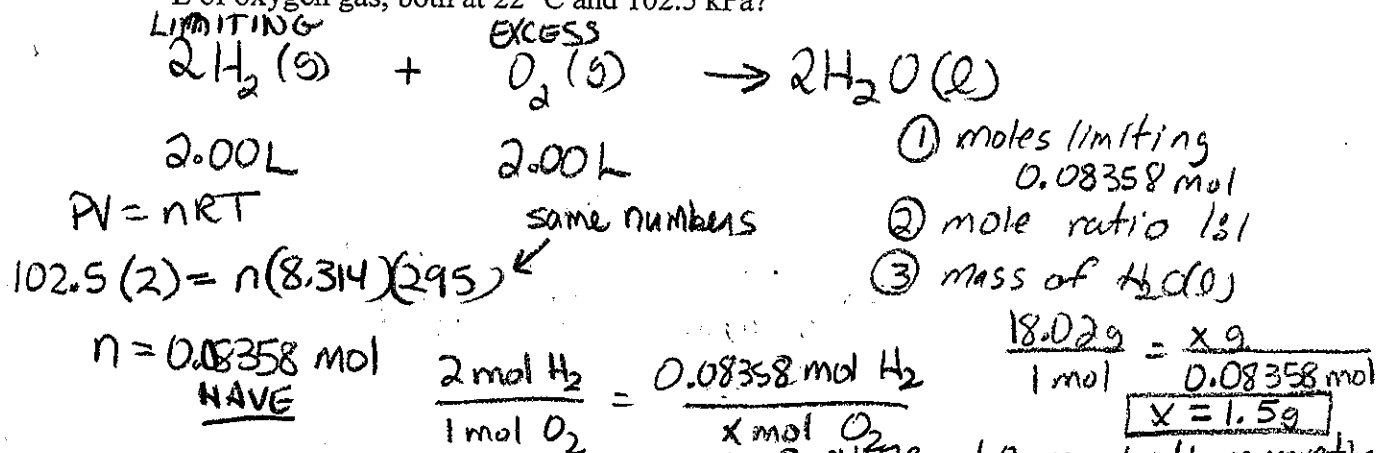
5. When ammonia gas reacts with oxygen gas, the products are nitrogen dioxide gas and water vapour. A 1.30 kg mass of ammonia is present in 4.21 kg of oxygen gas. What mass of nitrogen dioxide is expected?

$$\underset{\text{EXCESS}}{4NH_3\,(g)} + \underset{\text{LIMITING}}{7O_2\,(g)} \longrightarrow 4NO_2\,(g) + 6H_2O\,(g)$$

m=1.30Kg | m=4.21Kg   m=?

$\dfrac{17.04\,g}{1\,mol} = \dfrac{1300\,g}{x\,mol}$ | $\dfrac{32\,g}{1\,mol} = \dfrac{4210\,g}{x\,mol}$

$x = 76.29\,mol$ | $x = 131.56\,mol$

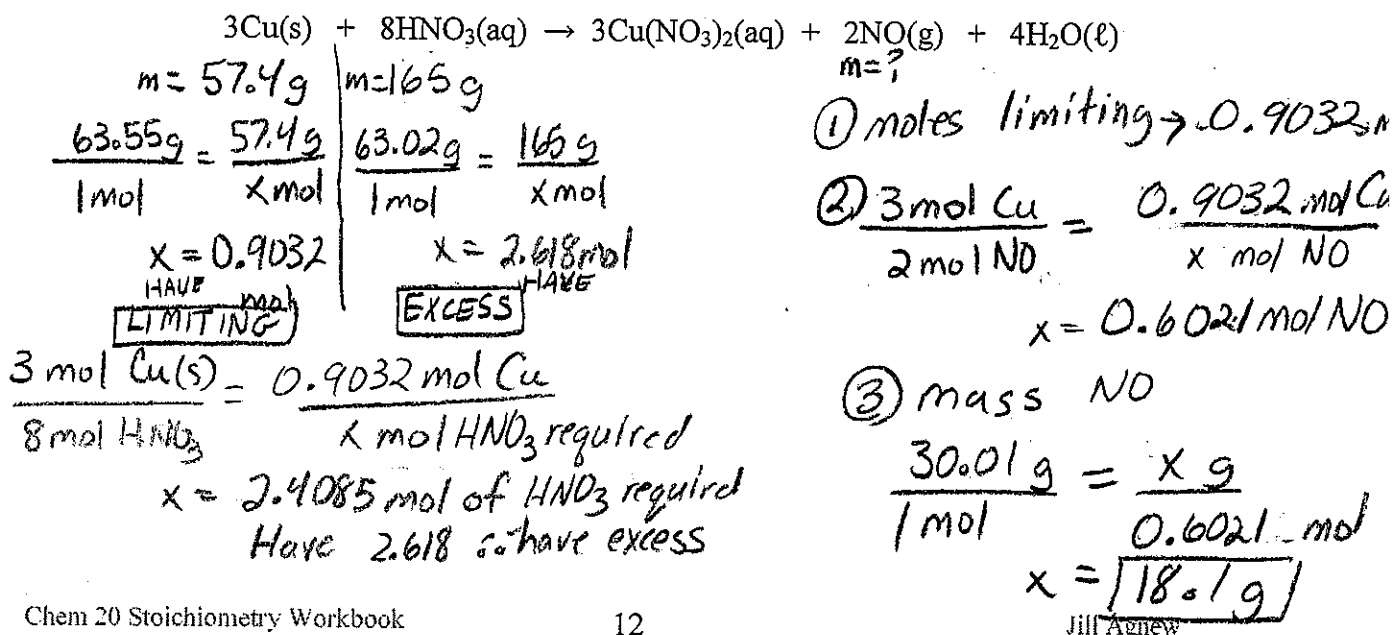$\dfrac{4\,mol\,NH_3}{7\,mol\,O_2} = \dfrac{76.29\,mol\,NH_3}{x}$

$x =$

$x = 133.5075\,mol$

required → only have 131.56% it is limiting

① moles limiting reactant 131.56 mol
② mole ratio

$\dfrac{7\,mol\,O_2}{4\,mol\,NO_2} = \dfrac{131.56\,mol\,O_2}{x = mol}$

$x = 75.177\,mol$

③ $\dfrac{46.01\,g}{1\,mol} = \dfrac{x\,g}{75.177\,mol}$ $x = 3458.89$

$\boxed{3.46Kg}$
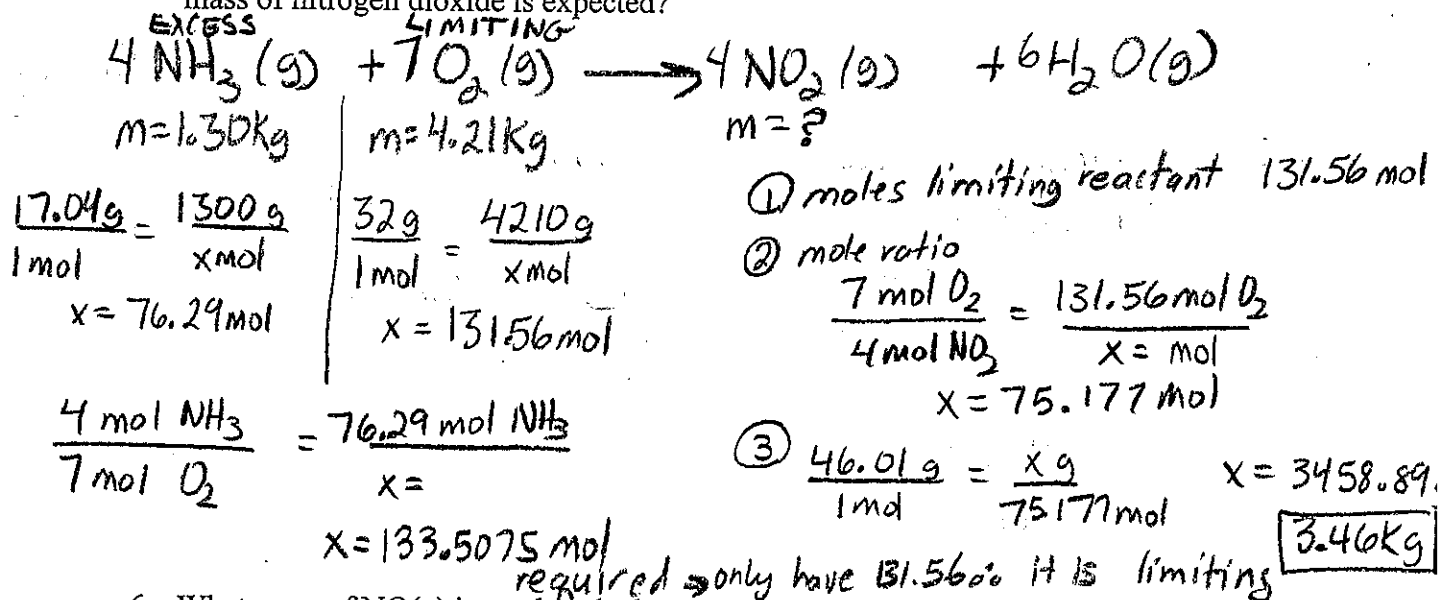
6. What mass of NO(g) is produced when 57.4 g of Cu reacts with 165 g of HNO₃? Copper metal reacts with nitric acid according to the following reaction:

$$3Cu(s) + 8HNO_3(aq) \rightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$$

m= 57.4g | m=165 g   m=?

$\dfrac{63.55\,g}{1\,mol} = \dfrac{57.4\,g}{x\,mol}$ | $\dfrac{63.02\,g}{1\,mol} = \dfrac{165\,g}{x\,mol}$

$x = 0.9032$ | $x = 2.618\,mol$

HAVE $\boxed{\text{LIMITING}}$ | $\boxed{\text{EXCESS}}$ HAVE

$\dfrac{3\,mol\,Cu(s)}{8\,mol\,HNO_3} = \dfrac{0.9032\,mol\,Cu}{x\,mol\,HNO_3\ required}$

$x = 2.4085\,mol$ of HNO_3 required
Have 2.618 ∴ have excess

① moles limiting → 0.9032 M
② $\dfrac{3\,mol\,Cu}{2\,mol\,NO} = \dfrac{0.9032\,mol\,Cu}{x\,mol\,NO}$

$x = 0.6021\,mol\,NO$

③ mass NO

$\dfrac{30.01\,g}{1\,mol} = \dfrac{x\,g}{0.6021\,mol}$

$x = \boxed{18.1\,g}$

Predicted and Experimental Yield

1. When 7.5×10^1 g of nitrogen gas reacts with sufficient hydrogen gas, the theoretical yield of ammonia is 9.10g. If 1.72 g of ammonia is obtained by experiment, what is the percentage yield of the reaction?

$$\% \text{ yield} = \frac{\text{actual (experiment)}}{\text{theoretical}} \times 100$$

$$= \frac{1.72g}{9.10g} \times 100 = 18.9\%$$

2. 20.0 g of bromic acid, $HBrO_3$, is reacted with excess HBr.

$$HBrO_3(aq) + 5HBr(aq) \rightarrow 3H_2O(\ell) + 3Br_2(aq)$$
$$m=20g \qquad\qquad\qquad\qquad\qquad m=?$$
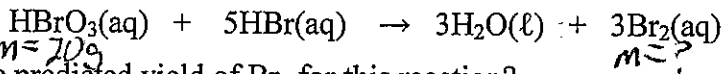
a. What is the predicted yield of Br_2 for this reaction?

b. If 47.3 g of Br_2 is produced, what is the percentage yield of Br_2?

a)

① moles $HBrO_3$

$$\frac{128.91g}{1mol} = \frac{20g}{X mol}$$

$$X = 0.155 mol$$

② mole ratio

$$\frac{1 mol\ HBrO_3}{3 mol\ Br_2} = \frac{0.155 mol}{x mol\ Br_2}$$

$$X = 0.46544 mol\ Br_2$$

③ mass Br_2 $\frac{159.8g}{1mol} = \frac{X g}{0.46544 mol}$ $X = \boxed{74.4g}$

b)

$$\% \text{ yield} = \frac{\text{actual}}{\text{theoretical}} \times 100$$

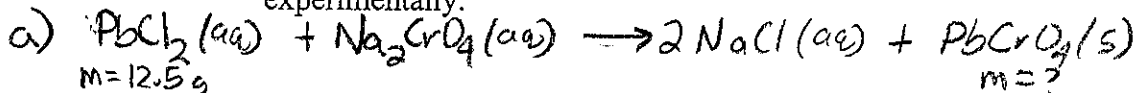$$= \frac{47.3g}{74.4g} \times 100 = \boxed{63.6\%}$$

3. In order to produce a lead(II) chromate precipitate, lead(II) chloride reacts with sodium chromate in solution. A 12.5 g mass of lead(II) chloride is mixed into solution, and is allowed to react with excess sodium chromate.

a. What is the predicted yield of lead(II) chromate?

b. Calculate the percentage yield if 13.8 g of lead(II) chromate is produced experimentally.

b) $\frac{12.5}{14.5} \times 100$

$= 86.2\%$

a) $PbCl_2(aq) + Na_2CrO_4(aq) \rightarrow 2NaCl(aq) + PbCrO_4(s)$
$m=12.5g \qquad\qquad\qquad\qquad\qquad\qquad m=?$

① moles $PbCl_2$

$$\frac{278.1g}{1mol} = \frac{12.5g}{X mol} \qquad X = 0.0449 mol$$

② mole ratio 1:1

③ mass $PbCrO_4(s)$

$$\frac{323.2g}{1mol} = \frac{Xg}{0.0449 mol} \qquad \boxed{X=14.5}$$

4. When calcium carbonate reacts with hydrogen chloride, the products are calcium chloride, carbon dioxide and water. If this reaction occurs with 81.5% yield, what mass of carbon dioxide will be collected if 15.7 g of calcium carbonate is added to sufficient hydrogen chloride?

$$CaCO_3(aq) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(\ell)$$
$$m=15.7g \qquad\qquad\qquad\qquad\qquad\qquad m=?$$

① moles $CaCO_3$

$$\frac{100.09g}{1mol} = \frac{15.7g}{X mol}$$

$$X = 0.15685 mol$$

② mole ratio 1:1

③ mass CO_2

$$\frac{44.01g}{1mol} = \frac{Xg}{0.15685 mol}$$

$$X = 6.90g - \text{Theoretical}$$
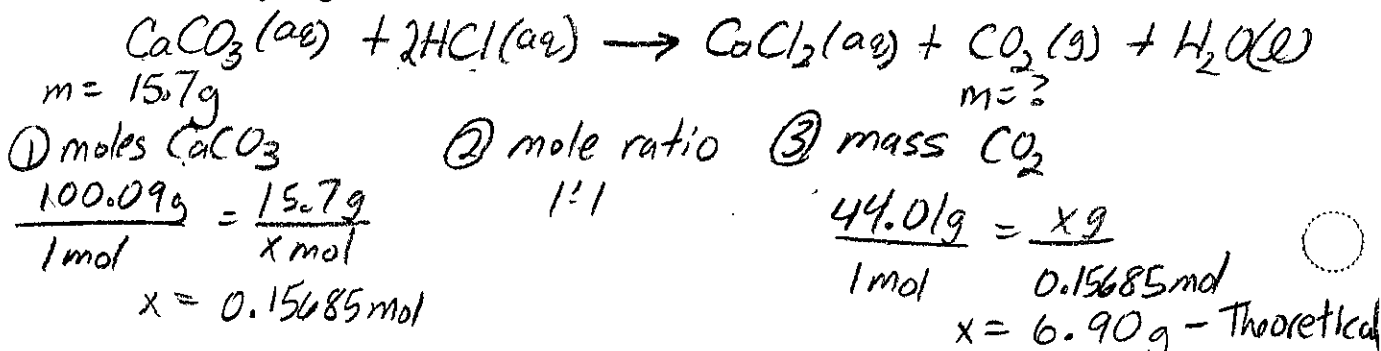
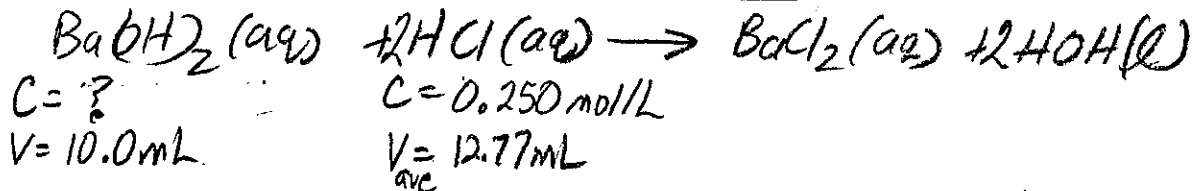$81.5 = \frac{\text{actual}}{6.90} \times 100 \qquad 0.815 = \frac{\text{actual}}{6.90} \qquad \boxed{\text{actual} = 5.62g}$

Titrations

1. A student conducts three trials to determine the concentration of barium hydroxide. The titrant used is a 0.250 mol/L hydrochloric acid solution. Each sample of barium hydroxide is 10.00 mL. Calculate the concentration of the barium hydroxide.

Trial #	1	2	3
Final volume HCl(aq) (mL)	24.56	37.32	~~50.00~~
Initial volume HCl(aq) (mL)	11.78	24.56	~~37.32~~
Volume of HCl(aq) (mL)	12.78	12.76	~~12.68~~

$$\frac{12.78 + 12.76}{2} = 12.77$$

$$Ba(OH)_2(aq) + 2HCl(aq) \rightarrow BaCl_2(aq) + 2HOH(l)$$

$C = ?$ $C = 0.250 \, mol/L$

$V = 10.0 \, mL$ $V_{ave} = 12.77 \, mL$

① $\dfrac{0.250 \, mol}{1 \, L} = \dfrac{x \, mol}{0.01277 \, L}$

$X = 0.0031925 \, mol$

② mole ratio

$\dfrac{1 \, mol \, Ba(OH)_2}{2 \, mol \, HCl} = \dfrac{x \, mol}{0.00319z}$

$x = 0.0015962s$

③ Conc $Ba(OH)_2$ $\dfrac{0.0015962s \, mol}{0.010 \, L} = \boxed{0.160 \, mol/L}$

2. A solution contains an unknown concentration of H_3PO_4(aq). You take 10.0 mL of this acid and titrate it with a 0.750 mol/L solution of NaOH(aq). Calculate the concentration of the phosphoric acid using the following data.

Trial #	1	2	3	4	5	6
Final volume NaOH(aq) (mL)	~~16.05~~	29.92	~~44.01~~	~~14.93~~	28.64	42.33
Initial volume NaOH(aq) (mL)	~~0.00~~	16.05	~~29.92~~	~~0.72~~	14.93	28.64
Volume of NaOH(aq) (mL)	~~16.05~~	13.87	~~14.09~~	~~14.21~~	13.71	13.69

✻ Average the three closest trials

$$\frac{13.87 + 13.71 + 13.69}{3} = 13.757 \, mL$$

$$H_3PO_4(aq) + 3NaOH(aq) \rightarrow Na_3PO_4(aq) + 3HOH(l)$$

$V = 10 \, mL$ $V = 13.757 \, mL$
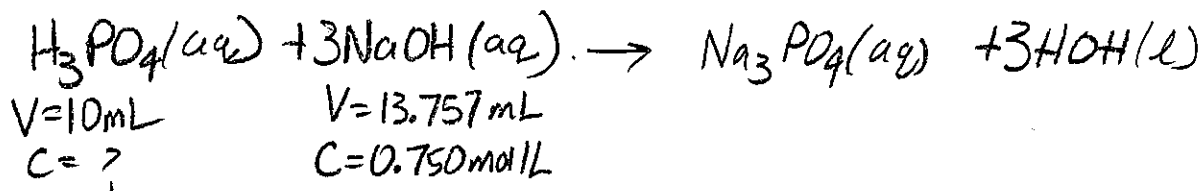
$C = ?$ $C = 0.750 \, mol/L$

① moles NaOH

$\dfrac{0.750 \, mol}{1 \, L} = \dfrac{x \, mol}{0.013757 \, L}$ $X = 0.0103 \, mol$

② mole ratio

$\dfrac{1 \, mol \, H_3PO_4}{3 \, mol \, NaOH} = \dfrac{x \, mol}{0.0103 \, m}$

$X = 0.003439 \, mo$

③ Conc H_3PO_4 $\dfrac{0.003439 \, mol}{0.010 \, L} = 0.344 \, mol/L$ H_3PO_4

Jill Agnew