TOPIC 1 PROBLEM SET – QUANTITATIVE CHEMISTRY

Many of these questions involve concepts you should be familiar with from MYP chemistry. They progress from simple to more challenging. After completing 1 – 58, a selection of prior exam questions follows. It is important that you develop a feel for what prior exam questions are like, as being familiar with exam questions will be quite helpful when you take your IB chemistry exam.

1. Practice your fluency in inorganic nomenclature with these charts.

formula	# and type of atoms and A_r of each atom	Formula mass (M_r)
$Ba_3(PO_4)_2$	3Ba 2P 8O	601.93
$Fe(NO_3)_3$	1Fe 3N 9O	241.88
$(NH_4)_2SO_4$	2N 8H 1S, 4O	132.10

Ionic Compounds:

cations	anions	formula	name	Formula mass (M_r)
Al^{3+}	S^{2-}	Al_2S_3	Aluminum Sulfide	149.96
K^{1+}	O^{2-}	K_2O	Potassium oxide	94.20
Ca^{2+}	NO_3^-	$Ca(NO_3)_2$	calcium nitrate	164.10
Zn^{2+}	CO_3^{2-}	$ZnCO_3$	Zinc (II) carbonate	125.40
Cu^{2+}	F^{1-}	CuF_2	Copper (II) fluoride	101.55

Molecular (Covalent) Compounds:

Name	Formula	Formula mass (M_r)
Sulfur trioxide	SO_3	80.00
diphosphorus pentaoxide	P_2O_5	141.94
Carbon tetrachloride	CCl_3	118.36
Trinitrogen hexasulfide	N_3S_6	234.03
nitrogen dioxide	NO_2	46.01

2. Give the name for the following ions:

a) NH_4^+ ammonium ion
b) SO_4^{2-} sulfate ion
c) CrO_4^{2-} chromate ion
d) NO_3^- nitrate ion
e) OH^- hydroxide ion
f) $Cr_2O_7^{2-}$ dichromate ion
g) CO_3^{2-} carbonate ion
h) HCO_3^- bicarbonate ion (hydrogen carbonate)
i) PO_4^{3-} phosphate ion
j) CH_3COO^- acetate ion

3.

3. How many moles are there in 4.2 g aluminum chloride? $AlCl_3 = 133.33$

$\frac{4.2g}{} \Big| \frac{1 mol}{133.3g} = 0.0315 mol\ AlCl_3$

4. How many moles are there in 42.5 g copper (II) fluoride? $CuF_2 = 101.54$

$\frac{42.5g}{} \Big| \frac{1 mol}{101.54} = 0.419 mol\ CuF_2$

5. What is the mass of 2.25 moles zinc (II) phosphate? $Zn_3(PO_4)_2 = 386.17$

$\frac{2.25 mol}{} \Big| \frac{386.17g}{1 mol} = 868.9 g\ Zn_3(PO_4)_2$

6. How many moles are there in 27.5 g aluminum nitrate? $AlN = 40.99$

$\frac{27.5g}{} \Big| \frac{1 mol}{40.99g} = 0.671 mol\ AlN$

7. How many molecules of sulfur dioxide are there in 1.25 g of sulfur dioxide? $SO_2 = 64.06$

$\frac{1.25g}{} \Big| \frac{1 mol}{64.06} \Big| \frac{6.02 \times 10^{23} molecules}{1 mol} = 1.17 \times 10^{22} molecules\ SO_2$

8. What is the mass of 3.29 x 10^{25} molecules of water? H_2O

$\frac{3.29 \times 10^{25} molecules}{} \Big| \frac{1 mol}{6.02 \times 10^{23} molecules} \Big| \frac{18.02g}{1 mol} = 984.8 g\ H_2O$

9. How many moles of hydrogen are there in 64.9 g water?

$\frac{64.9g}{} \Big| \frac{1 mol\ H_2O}{18.02g} \Big| \frac{2 mol\ H}{1 mol\ H_2O} = 7.20 mol\ H$

10. What mass of zinc is in 14.4 g zinc (II) fluoride? $ZnF_2 = 103.4$

$\frac{14.4g}{} \Big| \frac{1 mol\ ZnF_2}{103.4g} \Big| \frac{1 mol\ Zn}{1 mol\ ZnF_2} = 0.139 mol\ Zn$

11. How many atoms of bromine are there in 0.155 g magnesium bromide? $MgBr_2 = 184.11$

$\frac{0.155g}{} \Big| \frac{1 mol\ MgBr_2}{184.11g} \Big| \frac{2 mol\ Br}{1 mol\ MgBr_2} \Big| \frac{6.02 \times 10^{23} atoms\ Br}{1 mol\ Br} = 1.01 \times 10^{21} atoms\ Br$

12. How many atoms are there in 12 g of K_2O? $= 94.20$

$\frac{12g}{} \Big| \frac{1 mol\ K_2O}{94.20g} \Big| \frac{6.02 \times 10^{23} molecules}{1 mol\ K_2O} \Big| \frac{3 atoms\ in\ K_2O}{1 molecule\ K_2O} = 2.3 \times 10^{23} atoms\ K_2O$

13. Ionic compounds form solid crystals that are held together by the attractive force between positive cations and negative anions. A hydrated ionic compound contains small amounts of water distributed throughout the crystal. A hydrated ionic compound has a unique formula, in which the number of moles of water is denoted after the formula of the compound. For example, in calcium chloride dihydrate, there are two moles of water to every one mole of calcium chloride, and the formula is written: $CaCl_2 \cdot 2H_2O$.

A hydrated copper (II) sulfate crystal is dehydrated by heating above a flame. Hydrated copper (II) sulfate has a characteristic light blue color, while dehydrated copper (II) sulfate is gray/white.

Consider the data

Object	Mass (± 0.1 g)
evaporating dish	47.4 g
evaporating dish and $CuSO_4$ * X H_2O	~~52.5 g~~ 52.5 g
mass of dish and $CuSO_4$ remaining after heating	50.9 g

Calculate the formula of the hydrate. $CuSO_4 = 50.9 - 47.4 = 3.5 g\ CuSO_4$

$H_2O = 52.5 - 50.9 = 1.6 g\ H_2O$

$CuSO_4 = \frac{3.5g}{} \Big| \frac{1 mol}{159.61g} = \frac{0.0219\ CuSO_4\ mol}{0.0219} = 1$ $\quad CuSO_4 \cdot 4H_2O$

$H_2O = \frac{1.6g}{} \Big| \frac{1 mol}{18.02g} = \frac{0.08879 mol\ H_2O}{0.0219} = 4$

For each of the following (14 – 22):

a) classify the reaction

b) write chemical equation (include state symbols: s, l, g, aq)

c) balance the equation

14. liquid ethyl alcohol (CH_3CH_2OH) burns in the presence of oxygen

$CH_3CH_2OH_{(l)} + 3O_{2(g)} \longrightarrow 2CO_2 + 3H_2O$ Comb.

15. sodium reacts with aqueous aluminum carbonate

$6Na_{(s)} + Al_2(CO_3)_{3(aq)} \longrightarrow 3Na_2CO_{3(aq)} + 2Al_{(s)}$ Single D.

16. zinc reacts with oxygen

$2Zn_{(s)} + O_{2(g)} \longrightarrow 2ZnO_{(s)}$ synth

17. aqueous sodium sulfide reacts with aqueous barium nitrate

$Na_2S_{(aq)} + Ba(NO_3)_{2(aq)} \longrightarrow BaS_{(aq)} + 2NaNO_{3(aq)}$ DD

18. copper (II) carbonate reacts to form copper (II) oxide and a gas

$CuCO_{3(s)} \longrightarrow CuO_{(s)} + CO_{2(g)}$ decomp.

19. potassium reacts with iodine

$K_{(s)} + I_{2(s)} \longrightarrow 2KI_{(s)}$ synth

20. ethane (C_2H_6) burns in air

$2C_2H_{6(g)} + 7O_{2(g)} \longrightarrow 4CO_{2(g)} + 6H_2O_{(l)}$ comb.

21. barium reacts with aqueous zinc (II) chloride

$Ba_{(s)} + ZnCl_{2(aq)} \longrightarrow BaCl_{2(aq)} + Zn_{(s)}$ Sing D.

22. aqueous sodium carbonate reacts with aqueous zinc (II) fluoride

$Na_2CO_{3(aq)} + ZnF_{2(aq)} \longrightarrow ZnCO_{3(s)} + 2NaF_{(aq)}$

23. lead (II) oxide decomposes

$2PbO_{(s)} \longrightarrow 2Pb_{(s)} + O_{2(g)}$ decomp.

For each of the following (24 – 27), determine the empirical formula from the percentage composition or mass data given. An empirical formula displays the **lowest whole number mole ratio of elements in a compound**. A molecular formula **shows this same ratio, only it isn't always in the most simplified form** (for example, glucose has a molecular formula of $C_6H_{12}O_6$, but when simplified, its empirical formula is CH_2O).

24. A ~~3.00~~ 4.00 gram sample of an unknown compound that contains 1.71 g carbon and 2.29 g oxygen

$C: \frac{1.71g}{} \left| \frac{1 mol}{12.01g} \right. = \frac{0.1424}{0.1424} = 1$

$O: \frac{2.29g}{} \left| \frac{1 mol}{15.99g} \right. = \frac{0.1432}{0.1424} = 0.99$

$\boxed{CO}$

25. A 7.95 gram sample of an unknown compound that contains 2.03 g magnesium and 5.92 g chlorine

$Mg: \frac{2.03g}{} \left| \frac{1 mol}{24.31g} \right. = \frac{0.0835}{0.0835}$ $\boxed{MgCl_2}$ $Cl: \frac{5.92g}{} \left| \frac{1 mol}{35.45g} \right. = \frac{0.167}{0.0835}$

26. An unknown sample that contains 31.9 % potassium, 29.0 % chlorine, and 39.1 % oxygen, by mass.

$K: \frac{31.9g}{} \left| \frac{1 mol}{39.10g} \right. = \frac{0.8159}{0.816}$ $\boxed{KClO_3}$ $Cl: \frac{29.0g}{} \left| \frac{1 mol}{35.45g} \right. = \frac{0.818}{0.816}$ $O: \frac{39.1g}{} \left| \frac{1 mol}{15.99g} \right. = \frac{2.45}{0.816}$

27. Deduce the empirical formula of a compound that contains 25.9 % nitrogen and 74.1% oxygen, by mass.

$N: \frac{25.9g}{} \left| \frac{1 mol}{14.01g} \right. = \frac{1.849}{1.849} = 1 \times 2$

$\boxed{N_2O_5}$

$O: \frac{74.1g}{} \left| \frac{1 mol}{15.99g} \right. = \frac{4.634}{1.849} = 2.5 \times 2$

28. A compound is 80% carbon and 20% hydrogen, by mass.

a) What is the empirical formula?

C: 80g | 1mol / 12.01g = 6.66 / 6.66 = 1   H: 20g | 1mol / 1.01g = 19.8 / 6.66 = 2.97 CH_3

b) If the molar mass is about 30, what is the molecular formula?

CH_3 = 15.04g/mol   30 / 15.04 ≈ 2 $\boxed{C_2H_6}$

29. Determine the empirical and molecular formulas of a compound with a molecular weight of 42 that contains 85.9% C and 14.1% H.

C: 85.9g | 1mol / 12.01g = 7.152 / 7.152 = 1   H: 14.1g | 1mol / 1.01g = 13.96 / 7.152 = 1.95 CH_2 42 / 14.03 = 3 $\boxed{C_3H_6}$

30. A compound is analyzed and found to contain: 4.80g carbon, 0.80g hydrogen, 3.20g oxygen and 2.80g nitrogen. What is the empirical formula? If the molar mass is about 174, what is the molecular formula?

C: 4.80g | 1mol / 12.01g = 0.3997 / 0.2000   O: 3.20g | 1mol / 15.99g = 0.2001 / 0.2000 C_2H_4NO = 58.06

H: 0.80g | 1mol / 1.01g = 0.792 / 0.2000   N: 2.80g | 1mol / 14.01g = 0.2000 / 0.2000   174 / 58.06 = 3 $\boxed{C_6H_{12}O_3N_3}$

31. A sample of a hydrocarbon burns completely in oxygen to form 13.2g carbon dioxide and 5.4g water. What is the empirical formula?

C: 13.2g CO_2 | 1mol / 44.00g | 1molC / 1molCO_2 = 0.30molC / 0.30 = 1 $\boxed{CH_2}$

H: 5.4gH_2O | 1mol / 18.02g | 2molH / 1molH_2O = 0.599molH / 0.30 = 2

For 32 - 37:

◊ Write correct formulas for products and reactants.

◊ Write the equation

◊ Balance the equation

◊ Perform the conversion, using the following T-chart template as a guide if you like:

mass given	mol given	unknown from equation	formula **mass** unknown
	Formula mass given	given from equation	mol unknown

32. How many grams of oxygen react with excess hydrogen to form 13.5 g water? $O_2 + 2H_2 \longrightarrow 2H_2O$

13.5gH_2O | 1molH_2O / 18.02g | 1molO_2 / 2molH_2O | 32.00gO_2 / 1molO_2 = $\boxed{11.99g O_2}$

33. How many grams of silver are formed as 125 g zinc reacts with excess aqueous silver nitrate?

$Zn + 2AgNO_3 \longrightarrow Zn(NO_3)_2 + 2Ag$

125g Zn | 1mol / 65.41g | 2mol Ag / 1mol Zn | 107.87gAg / 1mol Ag = $\boxed{412.3g Ag}$

34. What mass of aqueous lithium carbonate reacts with excess calcium nitrate to form 87 g of aqueous calcium carbonate?   = $\boxed{72.8g LiCO_3}$

$Ca(NO_3)_2 + 2LiCO_3 \longrightarrow Ca(CO_3)_2 + 2LiNO_3$ 87g $Ca(CO_3)_2$ | 1mol / 160.04g | 2mol$LiCO_3$ / 1mol$Ca(CO_3)_2$ | 66.92g$LiCO_3$ / 1mol $LiCO_3$

35. How many grams of oxygen form as 50.0 g of Hg_2O decomposes?

$2Hg_2O \longrightarrow 4Hg + O_2$

50.0gHg_2O | 1molHg_2O / 417.17g | 1molO_2 / 2molHg_2O | 32.0gO_2 / 1molO_2 = $\boxed{1.92g O_2}$

$4K + O_2 \longrightarrow 2K_2O$

36. How many grams of potassium oxide form as 15.0g potassium burns in the presence of oxygen?

$\frac{15.0g\,K}{} \Big| \frac{1\,mol\,K}{39.10g} \Big| \frac{2\,mol\,K_2O}{4\,mol\,K} \Big| \frac{94.2g\,K_2O}{1\,mol\,K_2O} = \boxed{18.07g\,K_2O}$

37. Calculate the amount (in grams) of potassium and the amount (in grams) of silver (I) oxide required to produce 4.6 grams of silver. $Ag_2O + 2K \longrightarrow K_2O + 2Ag$

$Ag_2O: \frac{4.6g\,Ag}{} \Big| \frac{1\,mol\,Ag}{107.9g\,Ag} \Big| \frac{1\,mol\,Ag_2O}{2\,mol\,Ag} \Big| \frac{231.8g\,Ag_2O}{1\,mol\,Ag_2O} = \boxed{4.94g\,Ag_2O}$

$K: \frac{4.6g\,Ag}{} \Big| \frac{1\,mol\,Ag}{107.9g\,Ag} \Big| \frac{2\,mol\,K}{2\,mol\,Ag} \Big| \frac{39.1g\,K}{1\,mol\,K} = \boxed{1.67g\,K}$

38. 45.0 g of potassium carbonate react with 45.0 g silver nitrate. The products of the reaction are silver carbonate and potassium nitrate. $K_2CO_3 + 2AgNO_3 \longrightarrow Ag_2CO_3 + 2KNO_3$

a) What is the theoretical yield of silver (I) carbonate (i.e. what is the maximum mass of silver (I) carbonate that can be produced)?

$45.0g\,K_2CO_3 \times \frac{1\,mol}{138.21g} = 0.32559\,mol\,K_2CO_3$

$45.0g\,AgNO_3 \times \frac{1\,mol}{169.87g} = 0.2649\,mol\,AgNO_3 \times \frac{1\,mol\,Ag_2CO_3}{2\,mol\,AgNO_3} = 0.1325\,mol\,Ag_2CO_3$

$0.1325\,mol\,Ag_2CO_3 \times \frac{275.75g}{1\,mol} = 36.52g\,Ag_2CO_3$

b) What is the limiting reactant?

$AgNO_3$

c) What is the reactant present in excess? K_2CO_3

d) Determine the percentage yield if only 30.0 grams of silver (I) carbonate are produced experimentally.

$30.0g\,Ag_2CO_3$ actual
$36.52g\,Ag_2CO_3$ theory

$\frac{30.0g}{36.52g} \times 100 = 82.2\%$

39. 15.0 g of potassium reacts with 5.0 g sulfur.

$2K + S \longrightarrow K_2S$

a) What is the theoretical yield of potassium sulfide (i.e. what is the maximum mass of potassium sulfide that can be produced)?

$\frac{15.0g\,K}{} \Big| \frac{1\,mol\,K}{39.1g\,K} \Big| \frac{1\,mol\,K_2S}{2\,mol\,K} \Big| \frac{94.19g\,K_2S}{1\,mol\,K_2S} = 18.1g\,K_2S$

$\frac{5.0g\,S}{} \Big| \frac{1\,mol\,S}{32.0g\,S} \Big| \frac{1\,mol\,K_2S}{1\,mol\,S} \Big| \frac{94.19g\,K_2S}{1\,mol\,K_2S} = \boxed{14.72g\,K_2S}$

b) What is the limiting reactant?

Sulfur

c) What is the reactant present in excess?

Potassium

d) Determine the percentage yield if only 10.9 grams of potassium sulfide are produced experimentally. (actual)

$\frac{10.9g}{14.72g} \times 100 = 74.1\%$ yield

40. What is the maximum mass of iron (III) oxide produced when 10.0 grams of iron are allowed to completely oxidize?

$4Fe_{(s)} + 3O_{2(g)} \rightarrow 2Fe_2O_{3(s)}$

$\frac{10.0\,g\,Fe}{} \Big| \frac{1\,mol\,Fe}{55.85\,g} \Big| \frac{2\,mol\,Fe_2O_3}{4\,mol\,Fe} \Big| \frac{159.7\,g\,Fe_2O_3}{1\,mol\,Fe_2O_3} = \boxed{14.3\,g\,Fe_2O_3}$

41. What volume of carbon dioxide is released when 10 dm^3 of carbon monoxide are combined with 10 dm^3 of oxygen?

$2CO_{(g)} + O_{2(g)} \rightarrow 2CO_{2(g)}$

$\frac{10\,dm^3\,O_2}{} \Big| \frac{1\,mol\,O_2}{22.7\,dm^3} \Big| \frac{2\,mol\,CO_2}{1\,mol\,O_2} \Big| \frac{22.7\,dm^3\,CO_2}{1\,mol\,CO_2} = 20\,dm^3\,CO_2$

$\frac{10\,dm^3\,CO}{} \Big| \frac{1\,mol\,CO}{22.7\,dm^3} \Big| \frac{2\,mol\,CO_2}{2\,mol\,CO} \Big| \frac{22.7\,dm^3\,CO_2}{1\,mol\,CO_2} = \boxed{10\,dm^3\,CO_2}$

$n = \frac{m}{M}$

42. 1.00 moles of NaCl are dissolved in 500 ml of solution. What is the concentration in mol dm^{-3}?

$\frac{1.00\,mol}{0.500\,dm^3} = \boxed{2\,mol\,dm^{-3}\,NaCl}$ $\quad \frac{500\,mL}{} \Big| \frac{1\,dm^3}{1000\,mL} = 0.500\,dm^3$

43. 3.5 moles of KF are dissolved in 2.0 L of solution. What is the concentration in mol dm^{-3}?

$\frac{3.5\,mol}{2.0\,dm^3} = \boxed{1.75\,mol\,dm^{-3}\,KF}$

44. 133.0 g of NaCl are dissolved in 1.00 L of solution. What is the concentration in mol dm^{-3}?

$\frac{133.0\,g}{} \Big| \frac{1\,mol\,NaCl}{58.45\,g\,NaCl} = \frac{2.28\,mol\,NaCl}{1.00\,dm^3} \longrightarrow \boxed{2.28\,mol\,dm^{-3}\,NaCl}$

45. How many moles of sodium carbonate are dissolved in 500 ml of 0.055 mol dm^{-3} solution? $\hookrightarrow 0.500\,dm^3$

$\frac{0.500\,dm^3}{} \Big| \frac{0.055\,mol}{1\,dm^3} = \boxed{0.0275\,mol\,Na_2CO_3}$

46. What is the concentration in mol dm^{-3} of 38 g lead (II) iodide dissolved in 500 ml of solution? PbI_2 $\hookrightarrow 0.500\,dm^3$

$\frac{38\,g\,PbI_2}{} \Big| \frac{1\,mol}{461.2\,g\,PbI_2} = 0.0824\,mol\,PbI_2$

$\frac{0.0824\,mol}{0.500\,dm^3} = \boxed{0.165\,mol\,dm^{-3}\,PbI_2}$

47. How many grams of NaCl are there in 500 ml of a 1.3 mol dm^{-3} solution NaCl?

$\frac{0.500\,dm^3}{} \Big| \frac{1.3\,mol}{1\,dm^3} \Big| \frac{58.45\,g\,NaCl}{1\,mol} = \boxed{38.0\,g\,NaCl}$

48. What mass of copper[redacted]de will react with 500 mL of 2 mol dm^{-3} magnesium chloride? $Cu + MgCl_2 \rightarrow CuCl_2 + Mg$

$\frac{0.500\,dm^3}{} \Big| \frac{2\,mol\,MgCl_2}{1\,dm^3} = 1.0\,mol\,MgCl_2 \Big| \frac{1\,mol\,Cu}{1\,mol\,MgCl_2} \Big| \frac{63.55\,g\,Cu}{1\,mol\,Cu} = \boxed{63.55\,g\,Cu}$

49. Methanol, CH_3OH, can be prepared according the equation: $CO + 2\,H_2 \rightarrow CH_3OH$

When 175 g of carbon monoxide is mixed with 36.5 g hydrogen gas and allowed to react, 112 g of product forms. Determine a) theoretical yield b) percent yield c) limiting reactant (CO is limiting)

$\frac{175\,g\,CO}{} \Big| \frac{1\,mol\,CO}{28.01\,g} \Big| \frac{1\,mol\,CH_3OH}{1\,mol\,CO} \Big| \frac{32.05\,g\,CH_3OH}{1\,mol\,CH_3OH} = 200.2\,g\,CH_3OH$ = theoretical yield

$\frac{36.5\,g\,H_2}{} \Big| \frac{1\,mol\,H_2}{2.02\,g\,H_2} \Big| \frac{1\,mol\,CH_3OH}{2\,mol\,H_2} \Big| \frac{32.05\,g\,CH_3OH}{1\,mol\,CH_3OH} = 289.6\,g\,CH_3OH$

% yield $= \frac{112\,g}{200.2\,g} \times 100 = 55.9\%$ yield

$0.150 dm^3 \mid \frac{1.5 mol}{1 dm^3} \mid \frac{208.2 g BaCl_2}{1 mol} = 46.85 g BaCl_2$ or $0.225 mol BaCl_2$

50. 150 mL of 1.5 mol dm^{-3} $BaCl_2$ and 30.0g Na_2SO_4 are placed in a beaker to react. $BaCl_2 + Na_2SO_4 \longrightarrow BaSO_4 + 2NaCl$

a) How many grams of $BaSO_4$ form? $0.225 mol \mid \frac{1 mol BaSO_4}{1 mol BaCl_2} \mid \frac{233.4 g BaSO_4}{1 mol BaSO_4} = 52.52 g BaSO_4$

b) Which reactant is the limiting reactant?

c) Which reactant is present in excess?

$\frac{30.0 g Na_2SO_4}{} \mid \frac{1 mol}{142.0 g} \mid \frac{1 mol BaSO_4}{1 mol Na_2SO_4} \mid \frac{233.4 g BaSO_4}{1 mol BaSO_4} = \boxed{49.3 g BaSO_4}$

Na_2SO_4 $\quad$ $BaCl_2$

d) If 20 g of $BaSO_4$ is isolated, what is the percent yield?

$\frac{20 g}{49.3 g} \times 100 = 40.6\%$ yield

$0.042 mol Ca(NO_3)_2 \mid \frac{1 mol Al_2(SO_4)_3}{3 mol} \mid \frac{342.15 g}{1 mol} = 4.79 g Al_2(SO_4)_3$

$11.29 g - 4.79 g = 6.5 g Al_2(SO_4)_3$ in excess

51. 12 mL of 3.5 mol dm^{-3} calcium nitrate and 27.5 ml of 1.2 mol dm^{-3} aluminum sulfate are placed in a beaker to react.

$3Ca(NO_3)_2 + Al_2(SO_4)_3 \longrightarrow 3CaSO_4 + 2Al(NO_3)_3$

a) What is the theoretical yield of $CaSO_4$? $\boxed{5.72 g CaSO_4}$

b) Which reactant is the limiting reactant? $\boxed{Ca(NO_3)_2}$

c) Which reactant is present in excess? How much will remain unreacted? $\boxed{6.5 g Al_2(SO_4)_3}$

$0.012 dm^3 \mid \frac{3.5 mol}{1 dm^3} = 0.042 mol Ca(NO_3)_2$ $\qquad$ $0.0275 dm^3 \mid \frac{1.2 mol}{1 dm^3} = 0.033 mol Al_2(SO_4)_3$

$0.042 mol Ca(NO_3)_2 \mid \frac{3 mol CaSO_4}{3 mol Ca(NO_3)_2} = 0.042 mol CaSO_4$ $\qquad$ $0.033 mol Al_2(SO_4)_3 \mid \frac{3 mol CaSO_4}{2 mol Al_2(SO_4)_3} = 0.0495 mol CaSO_4$

$0.042 mol \mid \frac{136.14 g CaSO_4}{1 mol CaSO_4} = 5.718 g CaSO_4$ $\qquad$ $0.033 mol Al_2(SO_4)_3 \mid \frac{342.15 g}{1 mol} = 11.29 g Al_2(SO_4)_3$ total

52. A mixture of $MgSO_4$ and $MgSO_4 \cdot 7H_2O$ with a mass of 11.08 g is heated until the water is removed. The total mass of the anhydrous $MgSO_4$ after heating is 7.25g. Determine the percentage of the hydrate in the original mixture.

$11.08 g - 7.25 g = 3.83 g H_2O$ $\qquad$ $\frac{7.48 g}{11.08 g} = \boxed{67.5\% \text{ hydrate}}$

$3.83 g H_2O \mid \frac{1 mol H_2O}{18.02 g H_2O} \mid \frac{1 mol MgSO_4}{7 mol H_2O} \mid \frac{120.31 g MgSO_4}{1 mol MgSO_4} = 3.65 g MgSO_4 + 3.83 g H_2O = 7.48 g$ hydrate

53. If 12.56 g of a solid dibasic acid reacts completely with 24.4 cm^3 of 1.8 mol dm^{-3} NaOH, what is the molar mass of the acid, in g/mol? $H_2A + 2NaOH \longrightarrow Na_2A + 2H_2O$

$24.4 cm^3 = (0.0244 dm^3)(1.8 mol dm^{-3}) = 0.0439 mol NaOH \mid \frac{1 mol H_2A}{2 mol NaOH} = 0.02196 mol H_2A$

$\frac{12.56 g}{0.02196 mol} = \boxed{571.95 g/mol}$

54. Menthol is a compound that contains only carbon, hydrogen and oxygen. When a 0.0956g sample of menthol burns in air, 0.269 g CO_2 and 0.110 g H_2O are formed. What is the empirical formula of menthol?

$0.269 g CO_2 \mid \frac{1 mol CO_2}{44 g CO_2} \mid \frac{1 mol C}{1 mol CO_2} = \frac{0.00611 mol C}{(6.188 \times 10^{-4})}$ $\qquad$ $0.00611 mol C \mid \frac{12.01 g C}{1 mol C} = 0.0733 g$

$0.110 g H_2O \mid \frac{1 mol H_2O}{18.02 g H_2O} \mid \frac{2 mol H}{1 mol H_2O} = \frac{0.0123 mol H}{(6.188 \times 10^{-4})}$ $\qquad$ $0.0123 mol H \mid \frac{1.01 g H}{1 mol H} = 0.0123 g H$

$+ \quad 0.0857 g$

17

$0.0956 g - 0.0857 g = 0.0099 g O$

$0.0099 g O \mid \frac{1 mol O}{16.00 g O} = \frac{6.188 \times 10^{-4} mol O}{6.188 \times 10^{-4}}$ $\qquad$ $\boxed{C_{10}H_{20}O}$

$0.007321g$

55. 7.321 mg of an organic compound containing carbon, hydrogen, and oxygen was analyzed by combustion. The amount of carbon dioxide produced was 17.873 mg and the amount of water produced was 7.316 mg. Determine the empirical formula of the compound.

$C: 17.873mg \left| \frac{1g}{1000mg} \right| \frac{1mol\ CO_2}{44.0g\ CO_2} \left| \frac{1mol\ C}{1mol\ CO_2} \right. = 4.06\times10^{-4}mol\ C \ (1.01\times10^{-4}) \rightarrow \frac{4.06\times10^{-4}mol}{} \left| \frac{12.01g}{1mol} \right. = 0.00488g\ C$

$H: 7.316mg \left| \frac{1g}{1000mg} \right| \frac{1mol\ H_2O}{18.01g\ H_2O} \left| \frac{2mol\ H}{1mol\ H_2O} \right. = 8.12\times10^{-4}mol\ H \ (1.01\times10^{-4}) \rightarrow \frac{8.12\times10^{-4}}{} \left| \frac{1.01g}{1mol} \right. = 8.20\times10^{-4}g\ H$

$0.007321g - (0.00488g\ C + 8.20\times10^{-4}g\ H) = 0.001621g\ O \left| \frac{1mol\ O}{16.00g\ O} \right. = 1.01\times10^{-4}mol\ O \ (1.01\times10^{-4})$

$\boxed{C_4H_8O}$

56. 0.1101 gram of an organic compound containing carbon, hydrogen, and oxygen was analyzed by combustion. The amount of carbon dioxide produced was 0.2503 gram and the amount of water produced was 0.1025 gram. A determination of the molar mass of the compound indicated a value of approximately 115 grams/mol. Determine the empirical formula and the molecular formula of the compound.

$C: 0.2503g\ CO_2 \left| \frac{1mol\ CO_2}{44.0g\ CO_2} \right| \frac{1mol\ C}{1mol\ CO_2} = 0.005689mol\ C \rightarrow \frac{0.005689mol\ C}{} \left| \frac{12.01g\ C}{1mol\ C} \right. = 0.06832g\ C$

$H: 0.1025g\ H_2O \left| \frac{1mol\ H_2O}{18.02g\ H_2O} \right| \frac{2mol\ H}{1mol\ H_2O} = 0.01138mol\ H \rightarrow \frac{0.01138mol\ H}{} \left| \frac{1.01g\ H}{1mol\ H} \right. = 0.01149g\ H$

$0.1101g - (0.06832g\ C + 0.01149g\ H) = 0.0303g\ O$

$0.0303g\ O \left| \frac{1mol\ O}{16.0g\ O} \right. = \frac{0.001893mol\ O}{0.001893} = 1$

$C: \frac{0.005689mol\ C}{0.001893} = 3$

$H: \frac{0.01138mol\ H}{0.001893} = 6$

$\boxed{C_3H_6O = E.F.}$

$\hookrightarrow$ mass = 58.06g/mol

$\frac{115g\,mol^{-1}}{58.06g\,mol^{-1}} = 1.98$

$E.F. \times 2 = M.F.$

$\boxed{M.F. = C_6H_{12}O_2}$