EMPIRICAL FORMULA

16. (a) An unknown organic compound contains only carbon, hydrogen and oxygen. A 0.275g sample of the compound was combusted in excess oxygen to yield 0.403g of carbon dioxide and 0.165g of water. Determine the empirical formula of the compound. Given that a 1.50g sample of the same compound, when vapourised, occupied 498.5 mL at 295K and 123.0 kPa, determine the molecular formula of the compound.
($R = 8.314\ J\ K^{-1}\ mol^{-1}$) [10 marks]

(b) Had the organic compound turned blue litmus pink, draw its molecular structure and name it.

[2 marks]

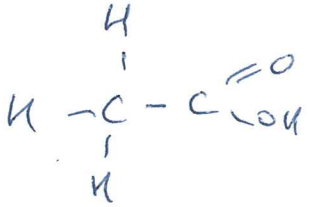
a) next page -

b) $M_r = 60$ with EF CH_2O

$12+2+16=30$

So MF = $C_2H_4O_2$

blue litmus → red



ethanoic acid

16) a)

$C_x H_y O_z \rightarrow CO_2 + H_2O$

0.275g 0.403g 0.165g

$n(C) = n(CO_2) = \frac{m}{M_r} = \frac{0.403}{44} = 0.00915$ mols (1)

$n(H) = n(H_2O) \times 2 = \frac{0.165}{18} = 0.0916$ mols

$\times 2 = 0.0183$ mols (1)

So mass of C $= 0.0915 \times 12 = 0.1098$g (1)

Mass of H $= 0.0183 \times 1 = 0.0183$g (1)

So mass of C & H $= 0.1098 + 0.0183 = 0.1281$g. (1)

$\therefore$ mass of O $= 0.275 - 0.1281$

$= 0.1469$g

$n(O) = \frac{m}{M_r} = \frac{0.1469}{16} = 0.00918$ mols (1)

(1)

So divide by least

	C	H	O
n	$\frac{0.00915}{0.00915}$	$\frac{0.0185}{0.00915}$	$\frac{0.00918}{0.00915}$
ratio	1	: 2	: 1

(1)

EF $= CH_2O$ (1)

$PV = nRT$

So $n = \frac{PV}{RT} = \frac{123 \times 0.4985}{8.314 \times 295} = 0.025$ mol. (1)

$n = \frac{m}{M_r}$ $0.025 = \frac{1.5g}{M_r}$

$M_r = 60.$

Q17. An unknown hydrocarbon containing carbon, hydrogen and chlorine was burnt in excess air and a 3.46 g sample was found to produce 4.80 g of carbon dioxide and 1.96 g of water. All the chlorine in this sample was converted to chloride ions and treated with excess silver nitrate solution, precipitating 7.81 g of silver chloride.

A second sample of the unknown was vaporised and 2.92 g occupied 0.515 L at STP.

Determine:

(a) The empirical formula (5 marks)
(b) The molecular formula (2 marks)
(c) Name and draw two possible structures for the compound. (2 marks)

(a)

$n(C) = n(CO_2) = 4.80/44.01 = \underline{0.109 \text{ moles}}$ ✓

$n(H) = 2 \times n(H_2O) = 2 \times 1.96/18.016 = \underline{0.217 \text{ moles}}$ ✓

$n(Cl) = n(AgCl) = 7.81/143.35 = \underline{0.0545 \text{ moles}}$ ✓

	C	H	Cl
n	0.109	0.217	0.0545
	2	4	1 ✓

EF = $\underline{C_2H_4Cl}$ ✓

(b)

EW = (12.01 x 2) + (1.008 x 4) + 35.45 = 63.50 ½ ✓

$n = v/22.71$ = 0.515 / 22.71 = 0.0227 moles ½ ✓

M = m / n = 2.92 / 0.0227 = 128.6 ½ ✓

128.6 / 63.50 = 2 ∴ MF = 2 x EF

= $C_4H_8Cl_2$ ½ ✓

(c) Possible structures include: 1,2-dichlorobutane, 1,3-dichlorobutane ✓✓
1,1-dichlorobutane, 2,2-dichlorobutane
2,3-dichlorobutane

End of Test

18. A herbicide which contains only carbon, hydrogen, nitrogen and chlorine, was analysed to determine its empirical formula. A combustion analysis of 0.6678 g of the compound produced 1.09 g of carbon dioxide and 0.390 g of water. (15 marks)

On treatment of 0.3320 g of the compound with silver nitrate 0.221 g of silver chloride was produced.

(a) Determine the empirical formula of the compound.

[12 marks]

(b) 7.19 g of the compound was vapourised and was found to occupy 0.936 L at 150°C and 125.4 kPa. Determine the molecular formula of the compound.

[3 marks]

18. $n(CO_2) = \frac{m}{M} = \frac{1.09}{44} = 0.02477\ mol$

By %

$n(CO_2) = n(C) = 0.02477\ mol \times 12 =$

$m(C) = 0.29727\ g \ / 0.6678 = 44.5\%$

$n(H_2O) = \frac{0.39}{18} = 0.02166\ mol$

$n(H) = n(H_2O) \times 2 = 0.0433\ mol$

$m(H) = 0.0433\ g \ / 0.6678 = 6.49\%$

$n(AgCl) = \frac{0.221}{143.35} = 0.001542\ mol$

$n(AgCl) = n(Cl) = 0.001542\ mol \times 35.45$

$m(Cl) = 0.05465\ g \ / 0.332$

$\%\ Cl = 16.46\%$

$\%(N) = 100 - (44.5 + 6.49 + 16.46)$

$\%(N) = 32.55\%$

C	H	N	Cl
$\frac{44.5}{12}$	$\frac{6.49}{1}$	$\frac{32.55}{14}$	$\frac{16.46}{35.45}$
$\frac{3.70}{0.464}$	$\frac{6.49}{0.464}$	$\frac{2.32}{0.464}$	$\frac{0.464}{0.464}$
8	14	5	1

$C_8H_{14}N_5Cl$

18

$$C\ H\ N\ Cl \Rightarrow CO_2 + H_2O + AgCl$$

By ratio.

$$n(CO_2) = \frac{m}{Mr} = \frac{1.09}{44} = 0.0247727 \text{ mol}$$

$$n(CO_2) = n(C) = \frac{m}{Mr} = \frac{m}{12} = 0.297 \text{ g}.$$

$$n(H_2O) = \frac{m}{Mr} = \frac{0.39}{18} = 0.021666 \text{ mol}$$

$$n(H_2O) \times 2 = n(H) = 0.043333 = \frac{m}{1} = 0.0433 \text{ g}$$

Sample $0.13320 \text{ g} = \div 0.13320 \times 0.16678$

Result $0.1221 \text{ g} \div 0.13320 \times 0.16678 = 0.14445 \text{ g}$ AgCl.

$$n(Cl) = n(AgCl) = \frac{m}{Mr} \qquad n = \frac{0.14445}{143.35} = 0.0031 \text{ mol}.$$

$Mr\ AgCl = 143.35$

Or $Cl = \frac{35.45}{143.35} \times 0.14445 \text{ g}$

$m(Cl) = 0.0031 \times 35.45 = 0.1099 \text{ g} = 0.1099 \text{ g}.$

So $0.16678 - (C - H - Cl) = N.$

$0.16678 - (0.297 + 0.0433 + 0.1099)$

$0.16678 - 0.4502 = 0.2176 \text{ g}$ of N

$$n(N) = \frac{m}{Mr} \qquad 0.0155 \text{ mol} = \frac{0.2176}{14}$$

	C	H	N	Cl
Moles	0.02477	0.00433	0.00155	0.00031
	0.00031	0.00031	0.00031	0.00031
	8	14	5	1

$C_8 H_{14} N_5 Cl_1$

b)

$PV = nRT$ $\quad n = \frac{PV}{RT}$

$\frac{125.4 \times 0.936}{8.314 \times 423.15}$

$n = 0.033363$.

7.19g. So $n = \frac{m}{Mr}$

$0.033363 = \frac{7.19}{Mr}$

$Mr = 215.5$.

$E_f = (8 \times 12) + (14 \times 1) + (5 \times 14) + 35.45$.

$= 215.45$.

So $M_f = E_f$

4. [12 marks] *(2008:05)*

An old drum of pesticide has been found on a farm. The label has fallen off and for safe disposal its contents need to be analysed.

Elemental analysis shows the presence of carbon, hydrogen, phosphorus and oxygen. A 5.21 g sample of the pesticide produces 6.32 g of carbon dioxide and 3.23 g of water when combusted completely in excess oxygen.

A second, 3.15 g, sample of the pesticide is treated with excess nitric acid to convert all of the phosphorus to phosphate ions. The resulting solution is treated with excess calcium nitrate solution to produce 3.37 g of calcium phosphate.

(a) Determine the empirical formula of the pesticide.

(b) Mass spectral analysis shows the molar mass of the pesticide to be 290.18 g mol^{-1}. What is the pesticide's molecular formula?

ratio

4) $CHPO \rightarrow CO_2 + H_2O$

5.21g 6.32g 3.23g

$n(C) = n(CO_2) = \frac{6.32}{44} = 0.1436$ mol

1.7236g = x12

$n(H) = n(H_2O) \times 2 = \frac{3.23}{18} = 0.3588$ mol

0.3588g = x1

Second Sample. product 3.37g

so $(3.37 \div 3.15) \times 5.21 = 5.5738$g.

$Ca_3(PO_4)_2 = 5.5738$g

Mr 310 $= \frac{5.5738}{310} = 0.01798$ mol

$n(Ca_3(PO_4)_2 \times 2 = n(PO_4^{3-})$

$= 0.03596$ mol

$n(PO_4^{3-}) = n(P)$

$= 0.03596 \times 31$

$= 1.1147$g

so

$5.21 - (1.7236 + 0.3588 + 1.1147)$

$O = 2.0129$g

so no. of mol $n = \frac{m}{Mr}$ $\frac{2.0129}{16} = 0.1258$ mol

C	H	P	O
$\frac{0.1436}{0.03596}$	$\frac{0.3588}{0.03596}$	$\frac{0.03596}{0.03596}$	$\frac{0.1258}{0.03596}$
4	10	1	3.5

EF $C_8H_{20}P_2O_7$

$= 290$

x2

% calc

4. [12 marks] (2008:05)

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(a) Determine the empirical formula of the pesticide.

(b) Mass spectral analysis shows the molar mass of the pesticide to be 290.18 g mol^{-1}. What is the pesticide's molecular formula?

sample 1

$X + O_2 \longrightarrow CO_2 + H_2O$

5.21g 6.32g 3.23g

$n(CO_2) = \frac{6.32}{44.01} = 0.1436\ mol$

$\therefore n(C) = 0.1436 \times 12.0$

$m(C) = 1.725g$

$\% (C) = 1.725/5.21g \times 100$

$= 33.1\%$

$n(H_2O) = \frac{3.23}{18.016} = 0.1793\ mol$

$\therefore n(H) = 0.35857 \times 2$

$m(H) = 0.36144g \times 1.008$

$\% (H) = \frac{0.36144}{5.21} \times 100$

$= 6.94\%$

sample 2

$X \xrightarrow{HNO_3} PO_4^{3-} \xrightarrow{Ca} Ca_3(PO_4)_2$

3.15g

$n(Ca_3(PO_4)_2) = \frac{3.37}{310.18}$

$= 0.010865\ mol$

$n(PO_4) = 2 \times n(Ca_3(PO_4)_2)$

$= 0.02173\ mol$

$n(P) = 0.02173$

$m(P) = 0.6729g \times 30.97$

$\% (P) = \frac{0.6729}{3.15} \times 100$

$= 21.36\%$

$\therefore \% (O) = 100 - 33.1 - 6.94 - 21.36$

$= 38.6\%$

a) $C_8H_{20}P_2O_7$

	C	H	P	O
%	33.1	6.94	21.36	38.6
	$\div 12.01$	$\div 1.008$	$\div 30.97$	$\div 16$
mol	2.756	6.885	0.6897	2.4125 mol
	0.6897	0.6897	0.6897	0.6897
	3.99	9.98	1	3.49

b) M.F = E.F.

Question 38 **(17 marks)**

Caffeine is an organic molecule found in tea, coffee and energy drinks. It is a stimulant that also can be taken in tablet form. Pure caffeine is a white odourless powder that tastes bitter and contains carbon, hydrogen, nitrogen and oxygen.

A 2.55 g sample of caffeine was combusted to produce 4.623 g of carbon dioxide and 1.18 g of water. A second, 3.33 g sample of caffeine was treated to convert all of the nitrogen to 1.17 g of ammonia.

(a) Determine the empirical formula of caffeine. (13 marks)

See next page

Empirical formula

A third, 1.05 g sample of caffeine was converted to the gaseous phase. Measurement showed that 100.0 mL of the gas exerted 370 kPa pressure at a temperature of 550 °C.

(b) Calculate the molar mass of caffeine. (2 marks)

(c) From your answers to part (a) and part (b), determine the molecular formula of caffeine, showing clearly how this was determined. (2 marks)

Question 38 **(17 marks)**

(a) Determine the empirical formula of caffeine. (13 marks)

Description		Marks
$n(CO_2)$	= 4.623 / 44.01 = 0.10504 = n(C)	1
m(C)	= 12.01 x 0.10504 = 1.2616	1
%(C)	= 1.2616 / 2.55 x 100 = 49.475 %	1
$n(H_2O)$	= 1.18 / 18.016 = 0.065497	1
n(H)	= 2 $n(H_2O)$ = 2 x 0.065497 = 0.13099	1
m(H)	= 1.008 x 0.13099 = 0.13204	1
%(H)	= (0.13204 / 2.55) x 100 = 5.1781 %	1
$n(N) = n(NH_3)$	= 1.17 / 17.034 = 0.068686	1
m(N)	= 14.01 x 0.068686 = 0.96229	1
%(N)	= (0.96229 / 3.33) x 100 = 28.898	1
%(O)	= 100 – (49.475 + 5.1781 + 28.898) = 16.449 %	1

	C	H	N	O	
n	49.475/12.01 = 4.119	5.1781/1.008 = 5.137	28.898/14.01 = 2.063	16.449/16.00 = 1.028	1
ratio	4.12/1.03 = 3.999 ~ 4	5.14/1.03 = 4.987 ~ 5	2.063/1.03 = 2.003 ~ 2	1.028/1.03 = 0.998 ~ 1	
Empirical Formula $C_4H_5N_2O$					1
				Total	**13**

Note:
Not every step needs to be set out as above but it must be clear how the answer was obtained - all ratios, conversions and calculations are demonstrated.

38

ratio

$n(CO_2) = \frac{4.623}{44} = 0.1050$ mol

$n(CO_2) = n(C)$

$\frac{m}{M}$ $\times 12$

$m(C) = 1.261$ g.

$n(H_2O) = \frac{1.18}{18} = 0.0655$ mol

$n(H) = \times 2 = 0.1311$ mol

$= 0.1311$ g.

ratio

$n(NH_3) = \frac{0.8959}{17} = 0.0527$ mol

$\frac{1.17\text{g}}{3.77} \times 2.55 = 0.8959$ g

$n(NH_3) = n(N)$

$n = 0.0527 = \frac{m}{M} \times 14$

mass nitrogen $= 0.7378$ g.

Sample $2.55 - (1.261 + 0.1311 + 0.7378$

$O = 0.4201$ g

$= \frac{m}{M}$ $\frac{0.4201}{16}$ 0.02625 mol

C	H	N	O
$\frac{0.1050}{0.02625}$	$\frac{0.1311}{0.02625}$	$\frac{0.0527}{0.02625}$	$\frac{0.02625}{0.02625}$

4 5 2 1

EF $C_4H_5N_2O$

b) $PV = nRT$

$370 \times 1.1 = n \times 8.31 \times 823.15$

$n = 0.005 \text{ mols}$

$\frac{1.05}{MW} = 0.0054 \text{ mols}$

$MW = 194 \text{ g mol}^{-1}$

$EF = 97 \qquad MF/EF = 2$

So molecular formula $= C_8H_{10}N_4O_2$

c) So $\frac{MF}{EF} \qquad \frac{194.1}{97.1} = 2 \times EF$

$2 \times C_4H_5N_2O$

$= C_8H_{10}N_4O_2$

Section Three: Extended answer **40% (94 Marks)**

This section contains **six** questions. You must answer **all** questions. Write your answers in the spaces provided.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the appropriate number of significant figures.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 70 minutes.

Question 35 **(16 marks)**

A chemical, commonly called iopromide (IOP), is used to enhance the images produced by a medical procedure called a CT scan. It contains carbon, hydrogen, iodine, nitrogen and oxygen, $C_vH_wI_xN_yO_z$.

Use the following information to determine the molecular formula of IOP.

- The molar mass of IOP is 791.102 g mol^{-1}.
- A 5.62 g sample of IOP contained 0.2986 g of nitrogen, N.
- A 3.54 g sample of IOP is fully combusted to produce;
  - 1.72 L of carbon dioxide gas, $CO_2(g)$, at 125 °C and 155.3 kPa.
  - 0.967 g of water vapour, $H_2O(g)$.
- All of the iodine contained in a 2.523 g sample of IOP is converted to iodide, I^-. This sample is then dissolved in water and excess lead(II) nitrate solution, $Pb(NO_3)_2(aq)$, is added to precipitate the iodine as lead(II) iodide, $PbI_2(s)$. This produced 2.21 g of lead(II) iodide.

See next page

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  0.967 g of water vapour, $H_2O(g)$.
- All of the iodine contained in a 2.523 g sample of IOP is converted to iodide, I^-. This sample is then dissolved in water and excess lead(II) nitrate solution, $Pb(NO_3)_2(aq)$, is added to precipitate the iodine as lead(II) iodide, $PbI_2(s)$. This produced 2.21 g of lead(II) iodide.

Description	Marks
Carbon	
$V(CO_2)$ = 1.72 L T = 125 + 273.15 = 398.15 K P = 155.3 kPa	
PV = nRT 155.3 x 1.72 = n x 8.314 x 398.15	1
n(C) = $n(CO_2)$ = 0.08069 mol m(C) = 0.08069 x 12.01 = 0.9691 g	1
Percentage of C by mass in IOP = 0.9691/3.54 x 100 = 27.37 %	1
Hydrogen	
$m(H_2O)$ = 0.967 g $n(H_2O)$ = 0.967/18.016 = 0.05367 mol	1
n(H) = 2 x 0.053674511 = 0.1073 mol m(H) = 0.107349023 x 1.008 = 0.1082 g	1
Percentage of H by mass in IOP = 0.1082/3.54 x 100 = 3.05 %	1
Nitrogen	
Percentage of N by mass in IOP = 0.2986/5.62 x 100 = 5.313 %	1
Iodine	
$m(PbI_2)$ = 2.21 g $M(PbI_2)$ = 461 $g\ mol^{-1}$	1
$n(PbI_2)$ = 2.21 /461 = 4.793926247 x 10^{-3} mol n(I) = 2 x 4.793 x 10^{-3} = 0.009587 mol m(I) = 0.009587 x 126.9 = 1.216 g	1
Percentage of I by mass in IOP = 1.216 / 2.523 x 100 = 48.22 %	1
Oxygen (add all % to work out % oxygen)	
% oxygen = 100 – (27.37 % C + 3.056 % H + 5.313 % N + 48.22 % I)	1
= 100 - 83.97 = 16.03 %	1

Question 35 (continued)

	C	H	N	I	O	
%	27.37	3.056	5.313	48.22	16.03	
Moles	2.279	3.032	0.3792	0.3800	1.002	1
Mole ratio	6.0107	7.996	1	1	2.64	1
	x 3	x 3	x 3	x 3	x 3 = 7.92	1
	18	24	3	3	8	
this gives the formula as $C_{18}H_{24}I_3N_3O_8$						
the empirical formula mass (791.102 g mol^{-1}) is identical to the molar mass given so this is also the molecular formula mass (791.102 g mol^{-1}) molecular formula is $C_{18}H_{24}I_3N_3O_8$						1
					Total	**16**

Alternative marking key for Question 35 (for proportion method)	
Description	**Marks**
Carbon in 3.54g	
PV = nRT 155.3 x 1.72 = n x 8.314 x 398.15	1
n(C) = n(CO_2) = 0.08069 mol m(C) = 0.080694356 x 12.01 = 0.9691 g	1 1
Hydrogen in 3.54g	
m(H_2O) = 0.967 g n(H_2O) = 0.967/18.016 = 0.05367 mol	1
n(H) = 2 x 0.053674511 = 0.10735 mol m(H) = 0.107349023 x 1.008 = 0.1082 g	1 1
Nitrogen in 3.54g	
Mass N in 3.54g = 0.2986/5.62 x 3.54 = 0.1881 g	1
Iodine in 3.54g	
m(PbI_2) = 2.21 g M(PbI_2) = 461 g mol^{-1}	1
n(PbI_2) = 2.21 /461 = 4.793926247 x 10^{-3} mol n(I) = 2 x 4.793926247 x 10^{-3} = 9.588 x 10^{-3} mol m(I) = 9.588 x 10^{-3} x 126.9 = 1.217 g	1
Mass I in 3.54g = 1.217 / 2.523 x 3.54 = 1.707 g	1
Oxygen (add all mass to work out mass of oxygen)	
m oxygen = 3.54 – (m C + m H + m N + m I)	1
= 3.54 – 2.972 = 0.5675 g	1

	C	H	N	I	O	
mass	0.9691 g	0.1082 g	0.1881 g	1.7071 g	0.5675 g	
Moles	0.0807	0.1073	0.0134	0.01345	0.0355	1
Mole ratio	6	8.01	1	1	2.65	1
	x 3	x 3	x 3	x 3	x 3 = 7.92	1
	18	24	3	3	8	
this gives the formula as $C_{18}H_{24}I_3N_3O_8$						
the empirical formula mass (791.102 g mol^{-1}) is identical to the molar mass given so this is also the molecular formula mass (791.102 g mol^{-1}) molecular formula is $C_{18}H_{24}I_3N_3O_8$						1
					Total	**16**

6. (a) Elementary analysis of a compound indicated that it contained only carbon, hydrogen, nitrogen and oxygen. A 1.279g sample was burned completely in oxygen such that all the carbon was converted to carbon dioxide and the hydrogen to water. This resulted in 1.600g of carbon dioxide and 0.770g of water. A separate 1.279g sample was shown by analysis to contain 0.1697g of nitrogen. Calculate the empirical formula of the compound.

(b) Given that the molecular mass of the compound was found to be 105g.mol^{-1}, determine the molecular formula.

(c) Given that the compound is a primary amine, reacts rapidly with sodium metal yielding an alkanoate and can be neutralized with NaOH, draw a possible structure.

[8 marks]

6. $C_xH_yO_zN_w + O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O + wNO_2$

1.279g   1.600g   0.770g

$N = 0.1697g.$

CO_2

$m = 1.60\,g$

$M = 44.0\,g.mol^{-1}$

$n = m/M$

$= 1.600/44.0$

$= 3.64 \times 10^{-2}\,mol.$

$n(C) = n(CO_2)$

$= 3.64 \times 10^{-2}\,mol.$

$m(C) = n \times M$

$= 3.64 \times 10^{-2} \times 12.$

$= 0.4364\,g.$ (1)

H_2O

$m = 0.770g$

$M = 18.0\,gmol^{-1}$

$n = m/M$

$= 0.770/18.0$

$= 4.28 \times 10^{-2}\,mol$

$n(H) = 2 \times n(H_2O)$

$= 8.56 \times 10^{-2}\,mol.$

$m(H) = n \times M$

$= 0.0855 \times 1.008$

$= 0.08624\,g.$ (1)

8

$m(O) = m(sample) - (m(C) + m(H) + m(N))$

$= 1.279 - (0.4364 + 0.08624 + 0.1697)$

$= 0.587\,g.$

$n(O) = M/M$

$= 0.587 \div 16$

$= 0.0366\,mol.$ (1)

$n(N) = m/M$

$= 0.1697/14$

$= 0.0121\,mol$ (1)

	C	H	O	N
mol	0.0364	0.0856	0.0366	0.0121
÷ by smallest	$\frac{0.0364}{0.0121}$	$\frac{0.0856}{0.0121}$	$\frac{0.0366}{0.0121}$	$\frac{0.0121}{0.0121}$
ratio	3 :	7 :	3 :	1
EF	$C_3H_7O_3N$			

(1)

b) $EFW = (3 \times C) + (7 \times H) + (3 \times O) + (1 \times N)$

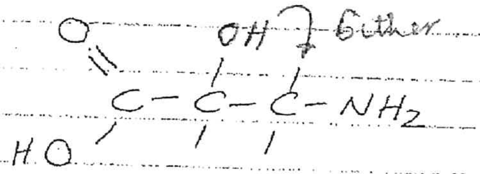
$= (12 \times 3) + (7) + (3 \times 16) + 14.$

$= 105\,g.mol^{-1}$ (1)

$MF = \frac{MFW}{EFW} \times EF$

$= \frac{105}{105} \times C_3H_7O_3N$

$= C_3H_7O_3N$ (1)

c) 

(1)

1. A pure substance is known to contain the following - iron II ions, sulfate ions, ammonium ions and waters of crystallisation. It has the formula; $Fe_w(NH_4)_x(SO_4)_y . zH_2O$

A 2.018 g sample was heated to remove all of the water. The resulting mass was 1.462g.

A second sample of 1.916 g was dissolved in water, then treated with sodium carbonate to remove the iron II ions through filtration. Concentrated sodium hydroxide was then added, and the solution heated to produce ammonia gas with volume of 0.218L at STP.

Addition of barium chloride solution gave a dry mass of barium sulfate of 2.281 g.

What is the ratio of ions and water in this compound? i.e. Find the value of w,x,y,z to determine the empirical formula of the compound

[13 marks]

Sample 1

$m(H_2O) = 2.018 - 1.462\ g$

$= 0.556\ g$

$\%(H_2O) = \frac{0.556}{2.018} \times 100$

$= 27.55\%$

$BaCl_2$

$2.281\ g$ of $BaSO_4$

$n(BaSO_4) = \frac{2.281}{233.36}$

$= 0.00977\ mol$

$n(SO_4^{2-}) = 0.00977\ mol$

$m(SO_4) = 0.9389\ g$ $\times 96.06$

$\% = \frac{0.9389}{1.916} \times 100$

$= 49.01\%$

Sample 2

$(1.916g)$ X + Na_2CO_3 → Fe

OH → NH_3 0.218L

@ STP

$n(NH_3) = \frac{V}{22.4} = \frac{0.218}{22.4} = 0.00973\ mol$

$n(NH_4) = n(NH_3) = 0.00973$ $\times 18.042$

$\therefore m(NH_4) = 0.17559\ g$

$\%(NH_4) = \frac{0.17559}{1.916} \times 100$

$= 9.16\%$

$\%(Fe) = 100 - \%(H_2O) - \%(NH_4) - \%(SO_4^{2-})$

$= 100 - 27.55 - 9.16 - 49.01$

$= 14.28\%$

	Fe	SO_4^{2-}	NH_4^+	$+H_2O$
%	14.28%	49.01%	9.16%	27.55%
	÷ 55.85	÷ 96.06	÷ 18.042	÷ 18.016
mol	0.25568 mol	0.510 mol	0.508 mol	1.529 mol
	0.25568	0.25568	0.25568	0.25568
	1	1.99	1.99	5.98

$Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$