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.
($R = 8.314\ J\ K^{-1}\ mol^{-1}$) [4 marks]

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

[2 marks]

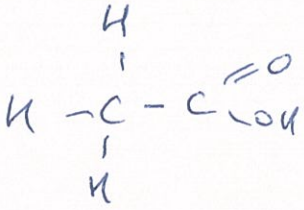
a) next page -

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

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

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

$\times 2 = 0.0183$ mols

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

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

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

∴ mass of O $= 0.275 - 0.1281$

$= 0.1469$g

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

So divide by smallest

	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

$n = \frac{m}{M_r}$ $0.025 = \frac{1.5g}{M_r}$ (1)

$M_r = 60.$

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

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

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

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

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

$n(H_2O) \times 2 = n(H) = 0.043333 = \frac{m}{1} = 0.04333\ g$

$0.3320\ g = \div 0.3320 \times 0.6678$

$0.221 \div 0.3320 \times 0.6678 = 0.4445\ g\ AgCl.$

$n(AgCl) = \frac{m}{Mr} \quad n = \frac{0.4445}{143.35} = 0.00311\ mols.$

$Mr\ AgCl = 143.35$

$Or\ Cl = \frac{35.45}{143.35} \times 0.4445\ g$

$= 0.1099\ g.$

So $0.6678 - (C - H - Cl) = N.$

$0.6678 - (0.297 + 0.04333 + 0.1099)$

$0.6678 - 0.4502 = 0.2176\ g\ of\ N$

$n(N) = \frac{m}{Mr} \quad 0.01555\ mols = \frac{0.2176}{14}$

	C	H	N	Cl
mol	0.02407	0.04322	0.01115	0.00031
	8	14	1	1

$C_8H_{14}NCl$

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 $\quad n = \frac{m}{M_r}$

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

$M_r = 215.5$

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

$= 215.45$

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?

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 3.27g

so $(3.27 \div 3.15) \times 5.21 = 5.15738g$

$Ca_3(PO_4)_2 = 5.15738g$

Mr 310 $= \frac{5.15738}{310} = 0.01798 mol$

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

$= 0.035596 mol$

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

$= 0.03559 \times 31$

$= 1.11147g$

so

$5.21 - (1.7236 + 0.3588 + 1.11147)$

$O = 2.01293g$

so 0.1258 mol $n = \frac{m}{Mr} \quad \frac{2.01293}{16} = 0.1258 mol$

C	H	P	O	EF $C_8H_{10}P_2O_7$
$\frac{0.1436}{0.035596}$	$\frac{0.3588}{0.035596}$	$\frac{0.035596}{0.035596}$	$\frac{0.1258}{0.035596}$	= 290
4	10	1	3.5	x2

% calc

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?

sample 1

$X + O_2 \longrightarrow CO_2 + H_2O$

5.21g 6.32g 3.23g

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

$\therefore n(C) = 0.1436$ (×12.0)

$m(C) = 1.725g$

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

$= 33.1\%$

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

$\therefore n(H) = 0.35857$ (×2)

$m(H) = 0.36144g$ (×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

$n(Ca_3(PO_4)_2) = \frac{3.37}{310.18} = 0.010865\ mol$

$n(PO_4) = 2 \times n(Ca_3(PO_4)_2) = 0.02173\ mol$

$n(P) = 0.02173$ (×30.97)

$m(P) = 0.67299g$

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

$= 21.36\%$

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

$= 38.6\%$

a) $C_8H_{20}P_2O_7$

	C	H	P	O
%	33.1	6.94	21.36	38.6
	÷12.01	÷1.008	÷30.97	÷16
mol	2.756	6.885	0.6897	2.4125 mol
	~~2.6175~~	~~2.6175~~	~~2~~	
	0.6897	0.6972	0.6897	0.6897
	3.99	9.98	1	3.49

∴ M.F = E.F.

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

1.279 g — 1.600 g — 0.770 g

$N = 0.1697$ g.

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: $m = 0.770$ g, $M = 18.0$ g.mol^{-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

$m(O) = m(\text{sample}) - (m(C) + m(H) + m(N))$

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

$= 0.587$ 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	0.0364/0.0121	0.0856/0.0121	0.0366/0.0121	0.0121/0.0121
ratio	3	7	3	1

EF $C_3H_7O_3N$ (1)

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

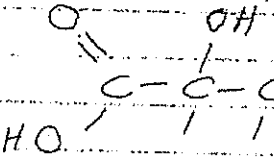
$= (12 \times 3) + (7) + (3 \times 16) + 14$

$= 105$ 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

(1.916 g) $X + Na_2CO_3 \rightarrow Fe$

$\downarrow OH^-$

NH_3 0.218L

@ STP

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

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

$m(NH_4) = 0.17559\ g$

$\%(NH_4) = \frac{0.1759}{1.916} \times 100$

$= 9.16\%$

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

$= 100 - 27.55 - 9.16 - 49.01$

$= 14.28\%$

	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 / 0.25568	0.510 mol / 0.25568	0.508 mol / 0.25568	1.529 mol / 0.25568
	1	1.99	1.99	5.98

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