26.(2014:18-c) The first three reactions will occur as they have a net positive reaction potential.

I	$I_2 + 2e^- \rightarrow 2I^-$	+0.54 V	
	$H_2S \rightarrow S + 2H^+ + 2e^-$	−0.17 V	Net reaction potential = +0.37 V
II	$Br_2 + 2e^- \rightarrow 2Br^-$	+1.08 V	
	$Fe^{2+} \rightarrow Fe^{3+} + e^-$	−0.77 V	Net reaction potential = +0.31 V
III	$A\ell \rightarrow A\ell^{3+} + 3e^-$	−1.68 V	
	$2H^+ + 2e^- \rightarrow H_2$	0.00 V	Net reaction potential = +1.68 V
IV	$Co \rightarrow Co^{2+} + 2e^-$	+0.28 V	
	$Cr^{3+} + 3e^- \rightarrow Cr$	−0.74 V	Net reaction potential = −0.46 V

The last reaction (IV) will not occur as it has a net negative cell potential. In other words, cobalt has a greater tendency to be reduced and chromium has a greater tendency to be oxidised. The answer is 'c'.

27.(2014 S2:12-b) Answer b: At the anode oxidation occurs. Oxidation is loss of electrons. The chloride ions lose electrons to form chlorine.

28.(2014 S2:14-b) Answer d: Hydrogen ON is +1 except in hydrides, oxygen ON is −2 except in peroxides. The sum of oxidation numbers is zero as the molecule has no charge. The ON of S is +6.

29.(2015:01-a) Answer 'a'. Using rules for assigning ON.

30.(2015:05-b) Answer 'b'. E° = +0.59.

31.(2015:08-a) Answer 'a'. No precipitate and no reaction.

32.(2015:10-c) Answer 'c'. Nickel and chromium are green but lead will not react.

33.(2015:17-b) Answer 'b'. 1.28 V.

34.(2016 SP:15-c) In this cell Mn will be oxidised and Ag^+ will be reduced.

E° values: Mn + 1.18

Ag^+ + 0.80

Total E° = +1.98. The answer is 'c'.

35.(2016 SP:16-c) A fuel cell is a REDOX cell utilising gases. So answer (i) is correct. Answer (ii) is correct. As the main product of hydrogen fuel cells is water vapour it is a low-emission technology. They cannot be recharged by reversing the flow of electricity. The answer is 'c'.

36.(2016:13-d) Calculation of oxidation numbers is specifically mentioned in the syllabus. The negative ON is awarded to the element closest to fluorine. So for nitrogen, Step 1: 0 → −3, Step 2: −3 → +2, Step 3: +2 → +4, Step 4: +4 → +5 a change of 1. The answer is d.

37.(2016:14-a) Students might see chromate and dichromate and assume it is a redox reaction in part a. It is in fact acid/base. In all other cases the ON of chromium changes. The answer is a.

38.(2016:15-c) This question can be solved using the data sheet. Reducing agents get oxidised so we need to look at equations where the species is losing electrons. Check the E° values of the reactions using the loss of electrons form. The answer is c.

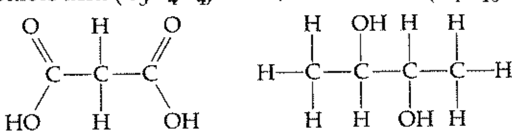
39.(2016:16-c) This question can be solved using the data sheet. Find the E° values of each of the half-equations. Add them and find which total is negative – i.e. it is NOT spontaneous. The answer is c.

40.(2016:17-a) The element C reduced both A^{2+} and B^{2+}. Thus it is the most powerful reducing agent. A reduced B^{2+} so the answer is a.

Chapter 4: Organic Chemistry

1.(2009:25-c) The molecular formulae of each of these compounds are: ethanal (C_2H_4O); propylmethanoate ($C_4H_8O_2$); ethanol (C_2H_5OH) and butanoic acid ($C_4H_8O_2$). The corresponding empirical formulae are C_2H_4O, C_2H_4O, C_2H_5OH and C_2H_4O. The odd one with a different empirical formula is ethanol (C_2H_5OH). The answer is 'c'.

2.(2009:26-d) Analysis of the structure provided shows that it is formed by condensation polymerisation of a -dioic acid and a -diol condensing out a water molecule during the union of the two different monomers. These two monomers are 1,3-propanedioic acid ($C_3H_4O_4$) and 2,3-butanediol ($C_4H_{10}O_2$) as shown below. The answer is 'd'.



3.(2009:27-d) $CH_3CH_2CH_2CH_3$ molecules are held together by dispersion forces only. CH_3CH_2CHO molecules are held together by dipole-dipole forces and dispersion forces. $CH_3CH_2CH_2OH$ molecules are held together by hydrogen bonds and dispersion forces. $CH_3CH_2CH_2CH_2OH$ molecules are held together by hydrogen bonds and stronger dispersion forces due to its relatively greater molecular mass. There is an increasing trend in boiling points from the first one to the last one *as listed above*. The answer is 'd'.

4.(2009:28-a) This is an addition reaction that occurs as follows:

$CH_3CHCHCH_3 + Br_2 \rightarrow CH_3CHBrHBrCH_3$ (2,3-dibromobutane). The answer is 'a'.

5.(2009:29-d) For *cis-trans* isomerism to be present, the compound must have a double-bond between any two of the carbon atoms somewhere in the middle of the chain. Identical atoms must be bonded to the carbon atoms on either side of the double bond. $CH_3CH{=}CHCH_2CH_3$ is the only one given here that fits these conditions. The answer is 'd'.

6.(2010:21-a) An ester is formed when an alcohol and a carboxylic acid react in the presence of concentrated sulfuric acid. Only the alcohol ($CH_3(CH_2)_4OH$) and carboxylic acid ($CH_3(CH_2)_3COOH$) can do this: $CH_3(CH_2)_3COOH$ + $HO(CH_2)_2CH_3 \rightarrow CH_3(CH_2)_3COO\ (CH_2)_4CH_3 + H_2O$. The answer is 'a'.

7.(2010:22-c) An amino acid unit should contain an amine ($-NH_2$) group and a carboxylic acid group ($-COOH$). Hence both the alternatives, 'a' and 'c', are amino acids. However, the prefix 'alpha' is used to show that the 'NH_2' and 'COOH' are attached to the same carbon atom that is at the end of the carbon chain. The answer is 'c'.

8.(2010:23-c) When $CH_3CHCHCH_3$ (but-2-ene) reacts with $HC\ell(g)$ an addition product $CH_3CHC\ell CH_2CH_3$ (2-chlorobutane) is produced. The answer is 'c'.

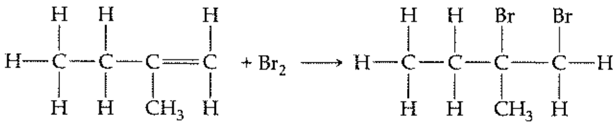
9.(2010:24-b) When $CH_3CHCHCH_3$ (but-2-ene) reacts with $C\ell_2(g)$, a different addition product, $CH_3CHC\ell CHC\ell CH_3$ (2,3-dichlorobutane) is produced. The answer is 'b'.

10.(2011:08-d) Here is an analysis of the four structural formulae given.
Compound I is an ester. The 'COO' functional group can be recognised.
Compound II is a carboxylic acid. The 'COOH' functional group can be recognised.
Compound III is a ketone. The 'CO' functional group can be recognised.
Compound IV is an aldehyde (alkanal). The 'CHO' functional group at the end can be recognised.
Therefore, the correct order is provided in alternative 'd'.

11.(2011:09-d) propan-1-ol ($CH_3CH_2CH_2OH$) is a primary alcohol. On mild oxidation, it can become propanal (CH_3CH_2CHO).
The half-reaction is $CH_3CH_2CH_2OH \rightarrow CH_3CH_2CHO + 2\ H^+ + 2\ e^-$
On strong oxidation, it can become propanoic acid (CH_3CH_2COOH).
The half-reaction is $CH_3CH_2CH_2OH + H_2O \rightarrow CH_3CH_2COOH + 4\ H^+ + 4\ e^-$
The answer is 'd'.

12.(2012:22-c) A *cis/trans* isomer results from the presence of a double bond and is also called a *cis/trans* isomer which exists only in alkenes. An examination of the four given alternatives indicates that structures 'i' and 'iv' are *cis/trans* isomers. The answer is 'c'.

13.(2012:24-a) The reaction of bromine with compound iii (2-methylbut-1-ene), is an addition reaction. The bromine atoms bond with the carbon atoms on either side of the double bond to form 1,2-dibromo-2-methylbutane. The structural equation is presented below. The answer is 'a'.



2-methylbut-1-ene — 1, 2-dibromo-2-methylbutane

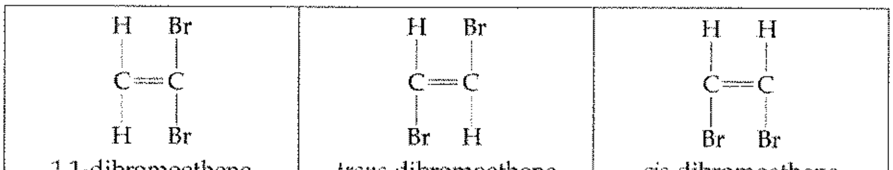
14.(2013:22-d) The functional groups are
I) Aldehyde (-CHO) II) ketone (R-CO-R) III) carboxylic acid (-COOH) IV) ester (RCOOR) The answer is 'd'.

15.(2013:23-b) Compound II is a ketone (pentan-2-one). Ketones are produced by the oxidation of secondary alcohols. The 'CO' functional group is located as the second carbon atom in the ketone. This ketone is formed by the removal of the two hydrogen atoms from this carbon atom in the alcohol chain. Therefore, the secondary alcohol should be $CH_3CH_2CH_2CHOHCH_3$ which gives the ketone, $CH_3CH_2CH_2COCH_3$. The answer is 'b'.

16.(2013:24-c) A carboxylic acid would react with an alcohol in the presence of an acid which would obviously form an ester. Therefore, the compound is III, $CH_3CH_2CH_2CH_2COOH$. The answer is 'c'.

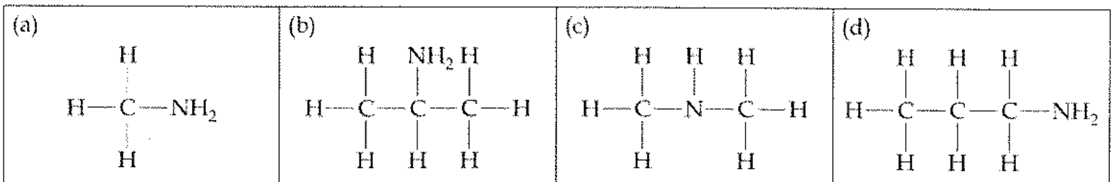
17.(2013:25-d) The compound is *cis*-pent-2-ene. It additively combines with iodine decolourising it to form 2,3-dibromopentane. As a non-polar substance it will dissolve in non-polar hexane. Following the addition, it can react with chlorine to form a substituted product. Therefore, all statements are true. The answer is 'd'.

18.(2014:21-b) The compound $C_2H_2Br_2$ has three isomers. The answer is 'b'.



1,1-dibromoethene — *trans*-dibromoethene — *cis*-dibromoethene

19.(2014:22-c) An amine is an alkyl derivative of ammonia (NH_3).

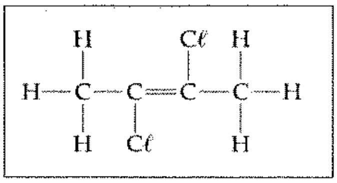


(a) Aminomethane — (b) 2-aminopropane — (c) Dimethylamine — (d) 1-aminopropane

The answer is: 'c'.

20.(2014:23-b) The reaction that produces $C_4H_8Br_2$ is, $C_4H_8 + Br_2 \rightarrow C_4H_8Br_2$.
This is bromination – an addition reaction of butene.
The hydrogenation reaction for butene produces butane. $C_4H_8 + H_2 \rightarrow C_4H_{10}$.
Therefore, X = C_4H_8, and Y = C_4H_{10}. The answer is 'b'.

21.(2014:24-a) The redrawn structure of the compound is shown below showing the linearity of the carbon chain.



The IUPAC name of the compound is 2,3-dichloro-*trans*-but-2-ene. The answer is 'a'.

22.(2015:14-a) Answer 'a'. Hydrogen bonding causes more solubility in water than dispersion forces.

23.(2015:22-b) Answer 'b'. Dispersion forces < hydrogen bonding < hydrogen bonding and dipole bonding.

24.(2015:23-d) Answer 'd'. Double bonds engage in addition polymerisation.

25.(2015:24-d) Answer 'd'. Addition is always across the double bond.

26.(2015:25-b) Answer 'b'. III cannot accept or donate H bonds.

27.(2016 SP:17-c) Secondary alcohols can be oxidised to form ketones. $CH_3CH(OH)CH_3$ is a secondary alcohol. The answer is 'c'.

28.(2016 SP:20-c) Barium sulfate is insoluble. Number (iv) can donate hydrogen bonds and accept them in two places so will be very soluble. Number (ii) can accept and donate hydrogen bonds so will be quite soluble. The answer is 'c'.

29.(2016 SP:23-a) To form a polymer we need a link to be formed between monomers. Substance (a) has carboxylic acid groups and could form ester linkages. So with (iv) this could form a polymer. (ii) and (iii) cannot form linkages. The answer is 'a'.

30.(2016 SP:24-a) The primary structure of a protein shows its functional groups. Function is dependent on functional groups. The answer is 'a'.

31.(2016:18-b) The –CH = O group is an aldehyde. Aldehydes always appear at the end of a chain. The base substance is therefore butanal. The answer is b.

32.(2016:19-d) The reactions are addition to an alkene, oxidation of an aldehyde, esterification, and neutralisation acid with a carbonate. The answer is d.

33.(2016:20-c) To make a polymer either an alkene is needed or the necessary groups to form a polyester or a polyamide. Addition is possible with I and III, while a polyester can form with II, III and V. The answer is c.

34.(2016:21-d) An α amino acid has a central α carbon a COOH, one side group (or an H) and an NH_2. In 'a' there is no central C, 'b' has two central carbons, 'c' has two groups. The answer is d.

Chapter 5: Synthesis

1.(2016 SP:22-b) To form an ester an alcohol and a carboxylic acid are required. The ethene can form ethanol in the presence of water, and the ethanol can be oxidised to form ethanoic acid. These two substances can react to form ethyl ethanoate. The answer is 'b'.

2.(2016:05-b) This is an equation mentioned in syllabus and should be known. NaOH produces soap while methanol produces the transesterification reaction making biodiesel. The answer is b.

3.(2016:22-a) Hardness is a measure of calcium and magnesium salts. This is measured by volume of soap reacted. Other salts (chlorides etc.) will respond to silver ions or raise the boiling point but they have nothing to do with hardness. Only soap solution is indicative of hardness. The answer is a.

4.(2016:23-b) Reaction X is a REDOX reaction with catalyst but this is not one of the answers offered. The best answer is b.

5.(2016:24-c) This is a known reaction from the syllabus. The answer is c.

6.(2016:25-a) This is a known reaction from the syllabus. The answer is a.

Chapter 6: Science Enquiry Skills

1.(2012:13-c) $NaHCO_3$ powder is used as conc sulfuric acid reacts violently with water. Solutions cannot be used. It neutralises the acid according to the reaction, $NaHCO_3(s) + H_2SO_4(aq) \rightarrow Na^+(aq) + HSO_4^-(aq) + CO_2(g) + H_2O(\ell)$. The answer is 'c'

2.(2016 SP:11-b) Systematic error is caused by equipment and cannot be reduced by repeating an experiment. A pipette offers more sig figs and will lower random error. Answer is 'b'.

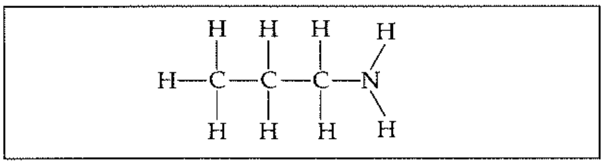
3.(2016:6-d) A systematic error can be identified by data that is precise (many values close together) but wrong. The answer is d.

The electrolytic refining of copper involves the dissolution of an impure blister copper sample (used as the anode) in a copper sulfate solution, and the subsequent deposition of copper ions as solid on the pure copper electrode used as the cathode.
A potential difference is applied across the electrodes giving a positive change to the anode and a negative charge to the cathode.
This induces an otherwise non-spontaneous redox reaction in which the copper is oxidised and reduced.
Oxidation equation: $Cu \rightarrow Cu^{2+} + 2e^-$
Reduction equation: $Cu^{2+} + 2e^- \rightarrow Cu$
The electrons flow from the ionised blister copper via the eternal circuit to the copper cathode.
The dissolved copper ions will then flow towards the negatively charged cathode due to electrostatic attraction, where they are deposited as metallic solid.
Impurities in the original blister copper sample are either dissolved preferentially in solution and stay there (such as zinc or magnesium) or alternatively drop down and form a mud (gold and silver do this) as copper is preferentially oxidised and they do not react.
The voltage is chosen so not to oxidise gold or reduce zinc etc.

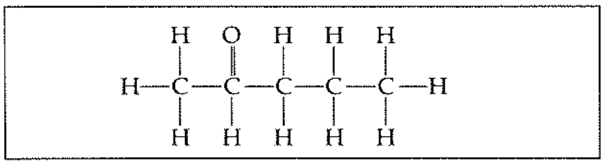
Chapter 10: Organic Chemistry

1.(2009:04) The structure for vitamin C indicates multiple OH links which can provide stronger hydrogen bonding with water, which is also held together with hydrogen bonds. Vitamin A, on the other hand, has a long carbon chain with a non-polar end and a single OH link at the other end to act as a polar end. This makes it less soluble in water compared to vitamin C as it bonds using dispersion forces. The non-polar vitamin A molecules are predominantly held together by dispersion forces and has a lower solubility in water.

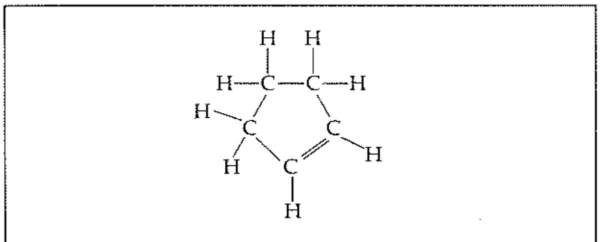
2.(2009:10) a) An amine containing 9 hydrogen atoms Name: propan-1-amine



b) The product of oxidation of pentan-2-ol Name: pentan-2-one



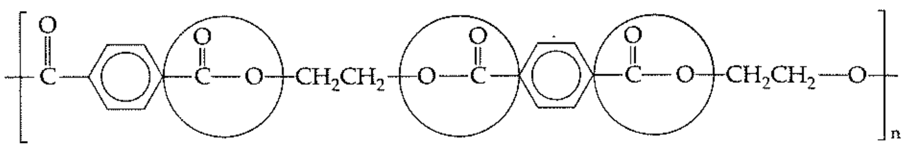
c) A compound X has the molecular formula C_5H_8. When X is warmed with excess hydrogen in the presence of powdered nickel, it forms a compound with the molecular formula C_5H_{10}. Give the structure and the name of the compound X.



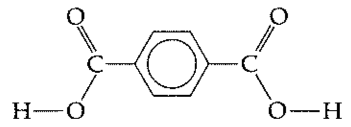
Cyclopentene

3.(2009:11)
A: Alcohol
B: Ketone
C: Alkene

4.(2010:31) a) All ester linkages are shown by a circle.



b) Two monomers:
Monomer A (1,4-dicarboxylbenzene)



1,4-dicarboxylbenzene

Monomer B (ethane-1,2-diol)

$HO—CH_2CH_2—OH$

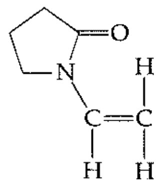
ethane-1,2-diol

5.(2011:30)

Substances to be distinguished		Description of chemical test	Observation with Substance 1	Observation with Substance 2
Substance 1	Substance 2			
1. Butan-2-ol	2. 2-methylpropan-2-ol	Add acidified $KMnO_4$ solution or, acidified $K_2Cr_2O_7$ solution to each.	The purple $KMnO_4$ is decolourised. The orange $K_2Cr_2O_7$ turns green.	There is no observable colour change for either test.
1. Methanol	2. Methanal	Add a few drops of acidified ethanoic acid to each, or, add a piece of sodium metal to each.	With the acid, a substance of fruity odour is produced. With sodium a vigorous evolution of a colourless, odourless gas occurs.	No observable change occurs with either ethanoic acid or with the sodium metal.

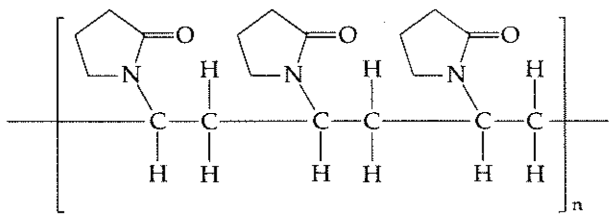
6.(2011:31) a) Three units in the polymer formed by the monomer, 'Polyvinylpyrrolidone'.
The monomer:

Monomer



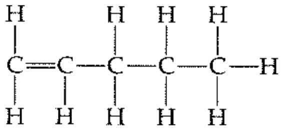
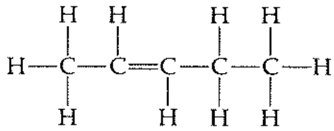
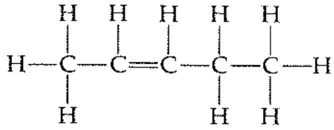
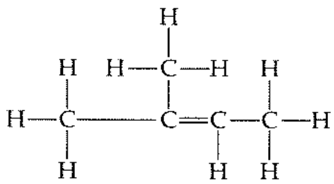
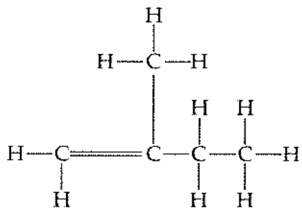
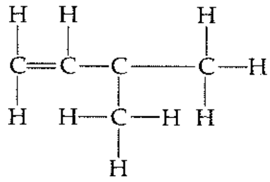
The polymer:

A polymer chain of 3 monomer units

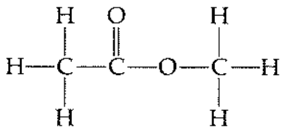
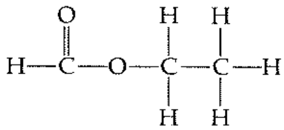


b) The type of polymerisation reaction that occurs to form this polymer is **addition** polymerisation.

7.(2011:32) a) Five straight chain isomers and their names, with the molecular formula, 'C_5H_{10}'

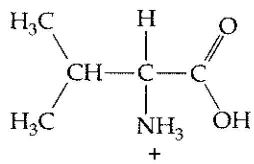
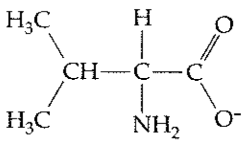
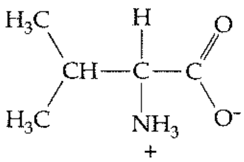
pent-1-ene 	*trans*-pent-2-ene 	*cis*-pent-2-ene 
2-methylbut-2-ene 	2-methylbut-1-ene 	3-methylbut-1-ene 

b) i) and ii) Structural formula for an organic compound which is an ester with a molar mass of 74 g mol^{-1}

Methyl ethanoate 	Ethyl methanoate 

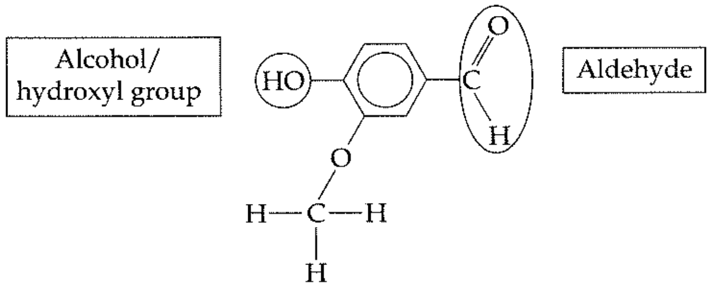
iii) The IUPAC name for a carboxylic acid that has the same molecular formula as the ester above: **Propanoic acid**

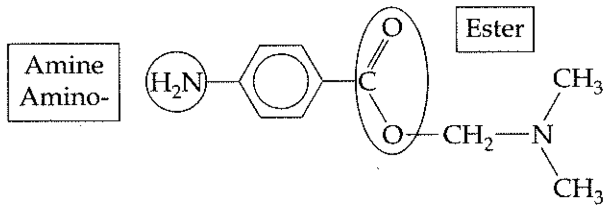
8.(2011:33) The approximate pH ranges of the amino acid 'valine' under different pH conditions.

Valine structure	pH range
	Acidic: (pH<7)
	Basic (pH>7)
	Neutral (ph=7)

9.(2012:27) Butanoic acid ($CH_3CH_2CH_2COOH$) has the highest boiling point. This is due to hydrogen bonding between molecules, dipole-dipole interaction forces as well as strong dispersion forces.
Butan-1-ol ($CH_3CH_2CH_2CH_2OH$) has a lower boiling point than butanoic acid because it has hydrogen bonding and dispersion forces only.
Butanal ($CH_3CH_2CH_2CHO$) has the lowest boiling point of the three. There are no hydrogen bonding sites in the molecule. It has dipole-dipole forces and dispersion forces only.
As the molar masses are not very much different, they do not significantly contribute to any difference in the boiling points among the three compounds.

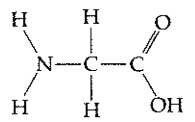
10.(2012:31)





11.(2013:34) a) Chemical formula of glycine is $C_2H_5NO_2$, also written as a condensed structure, NH_2CH_2COOH. Its structural formula is given below:

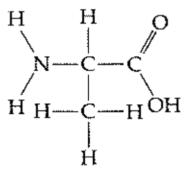
Chemical formula of Glycine, NH_2CH_2COOH



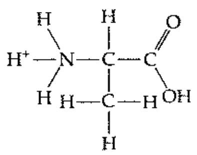
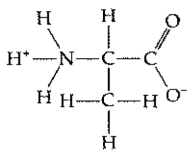
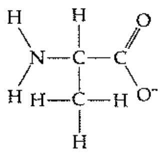
or, H_2NCH_2COOH

b) The structural formula for α – amino acid, alanine is given below.

Structural formula of Alanine, H_2NCHCH_3COOH



The structure for alanine in acidic, neutral and basic conditions.

Acidic species	Neutral species	Basic species
	 Zwitterion	

12.(2014:33) a) Equations for the oxidation of methanoic acid by acidified MnO_4^- solution.

Oxidation half equation	$CH_3OH(aq) + H_2O(\ell) \rightarrow HCOOH(\ell) + 4\ H^+(aq) + 4\ e^-$
Reduction half equation	$MnO_4^-(aq) + 8\ H^+(aq) + 5\ e^- \rightarrow Mn^{2+}(aq) + 4\ H_2O(\ell)$
Final redox equation	$4\ MnO_4^-(aq) + 12\ H^+(aq) + 5\ CH_3OH(\ell) \rightarrow 5\ HCOOH(\ell) + 4\ Mn^{2+}(aq) + 11\ H_2O(\ell)$

b) Balanced reaction between methanol and ethanoic acid in the presence of sulfuric acid to produce a fruity-smelling compound.

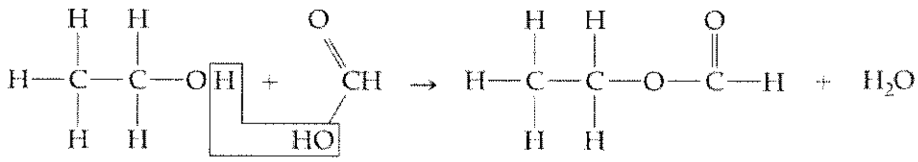
$$HCOOH(\ell) + CH_3CH_2OH(\ell) \rightarrow HCOOCH_2CH_3(aq) + H_2O(\ell)$$

$$CH_2O_2 + C_2H_6O \rightarrow HCOOC_2H_5 + H_2O$$

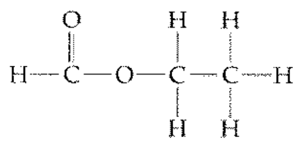
or

$$HCOOH + CH_3CH_2OH \rightarrow HCOOCH_2CH_3 + H_2O$$

or

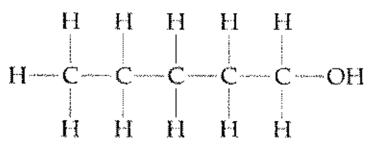
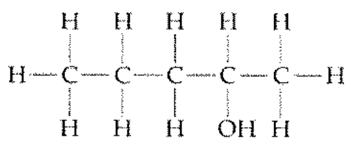
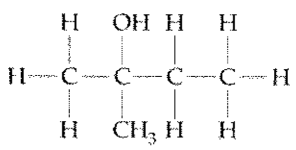


c) The structural formula for the fruity-smelling compound

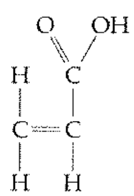


Ethyl methanoate

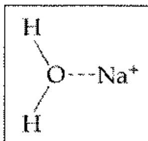
13.(2014:34)

	Primary alcohol Pentan-1-ol There are several other examples available
	Secondary alcohols Pentan-2-ol There are several other examples available
	Tertiary alcohol 2-methylbutan-2-ol

14.(2014:35) a)

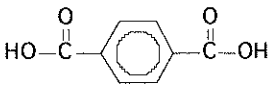
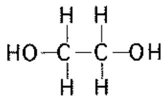


b) i) Name of the interactions occurring between water molecules and sodium ions Ion-dipole interactions.



ii) Reason why the polymer absorbs so much of water.

- Ion-dipole interaction between the '–COOH' group and water molecules forms hydrogen bonds.
- Because there is a large number of carboxylic acid groups in the polymer, a large number of water molecules can bond with the polymer. This accounts for the polymer's capacity to absorb large quantities of water.

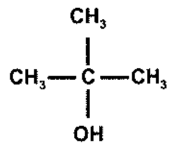
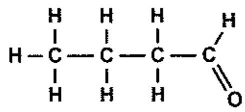
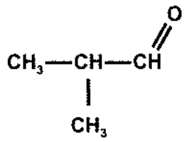
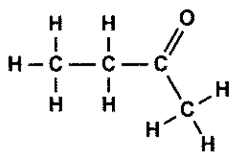
15.(2015:32) a)  and 

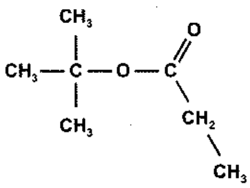
b) Water

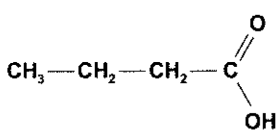
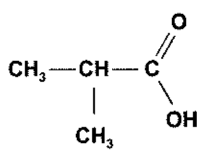
c) Increasing the length of the polymer chain increases the dispersion forces of the polymers. The number of =O dipoles increases so the number of dipole attractions along the length of the polymer chains increases.

- This increases the magnitude of its interactions with neighbouring chains making the polymer more rigid
- More energy is required to overcome the attraction of the chains of the polymer from each other thereby raising the melting point

16.(2015:34) a)

Unknown organic compound	Functional group	Structural formula or name of the organic compound
1	alcohol	methylpropan-2-ol 
2	aldehyde	butanal or methylpropanal  
3	ketone	Butanone 

b) i) 

ii) either of  

17.(2015:39) a) The $-NH_2$ group and the $-COOH$ group must be attached to the same (α) carbon atom

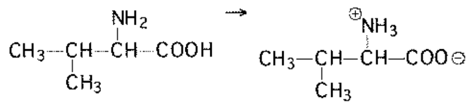
b) From the given formula, the empirical formula is $C_3NH_7O_2$

Empirical formula mass ($C_3NH_7O_2$) = 89.094

$n_{(alanine)} = PV/RT = (50.0 \times 2.86) / (8.314 \times 823.15) = 0.020895$ mol

$M_{(alanine)} = m/n = 1.86 / 0.02089 = 89.02$ g mol^{-1}

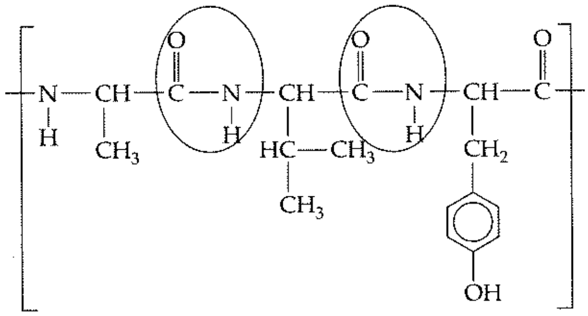
The empirical formula mass is the same as the calculated molecular formula mass c)



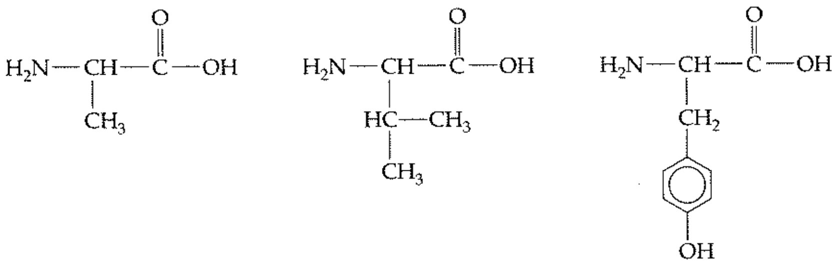
This transfer produces a zwitterion. It has a positive and a negative ionic charge. It has no overall electrical charge. This strong ionic attraction between ions forms a crystalline lattice in the solid state. The di-amine and di-carboxylic acid bond using weaker hydrogen bonding. These ionic attractions require more energy to break and so the zwitterions have high melting points.

18.(2016 SP:28b) To dissolve well the bonds between solutes must be broken as do the bonds between solvents. Acetylsalicylic acid and water have only dispersion forces and interact poorly so it is a weak acid, and only partly ionises in water. Acetic acid (CH_3COOH) forms hydrogen bonds with water and so dissolves well.

19.(2016 SP:31) a)



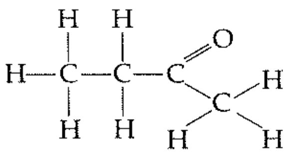
b)



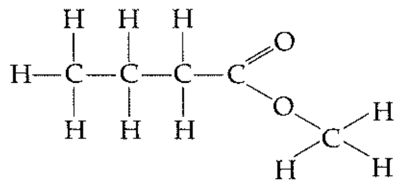
c)

Type of interaction	Functional groups
hydrogen bonding	carbonyl and amide groups

20.(2016 SP:33) a)

Observations	the solution turns from orange to green
Structural formula of organic product	
Name of organic product	butanone

b) Butanoic acid reacts with methanol in the presence of H_2SO_4 solution.

Observations	a fruity smell develops (and a new layer forms above the reactants)
Structural formula of organic product (show all atoms)	
Name of organic product	methylbutanoate

21.(2016 SP:36) a)

Label	Type of interaction
A	dispersion forces
B	ionic bond
C	covalent bond or disulfide bond
D	hydrogen bond

b) The 'tertiary structure' is the overall 3-dimensional shape

22.(2016:27) a)

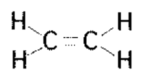
i)
- three colourless liquids mix
- an immiscible layer appears on the surface
- a fruity smell produced

ii)
- Note the acid is inxs – this means there will be no $MgCO_3$ left over
- a white solid is added to colourless liquid
- a colourless odourless gas is produced
- the white powder dissolves and a clear and colourless solution is formed

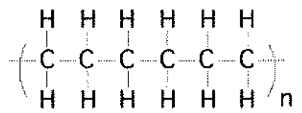
iii)
- Note the alcohol is inxs which means all the MnO_4^- will react
- a purple liquid is mixed with a colourless liquid
- the purple colour fades to very pale pink
- a new paint smell can be detected

b)
- Pentanoic acid
- $Cr_2O_7^{2-} + 3\ C_5H_{10}O + 8\ H^+ \rightarrow 2\ Cr^{3+} + 3\ C_5H_{10}O_2 + 4\ H_2O$

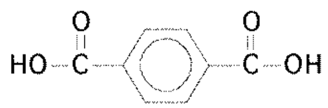
23.(2016:29) a) As it is an addition polymer it must have a double bond. The simplest and easiest answer is ethene and polyethene but you could use PVC, styrene, propene, Teflon etc.
Example.

Ethene	

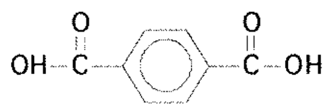
b) Note that the polymer has bonds on each end.

Polyethene	

c) This answer is taken from the syllabus. Note you need to say what it is used for and why.
If you used polyethene you could say cling-wrap, or take-away containers BECAUSE it is strong, transparent, flexible and cheap.

d)  

Note these structures below would be wrong if we wrote them. Can you see why?

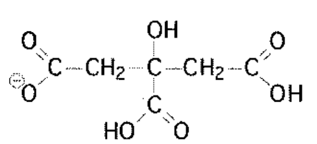
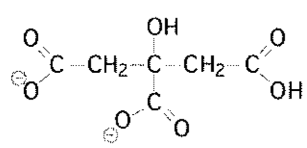
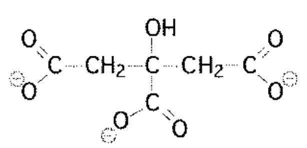
e) ß-pleated sheets

24.(2016:33) a) $C_6H_8O_7(aq) + 3\ NaOH(s) \rightarrow Na_3C_6H_5O_7(aq) + 3\ H_2O(\ell)$

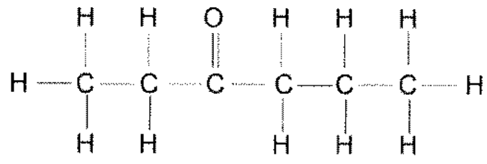
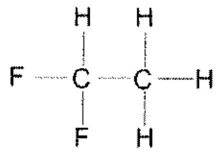
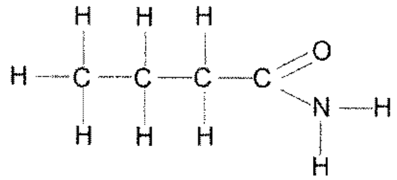
or

$C_6H_8O_7(aq) + 3\ NaOH(s) \rightarrow 3\ Na^+ + C_6H_5O_7^{3-}(aq) + 3\ H_2O(\ell)$

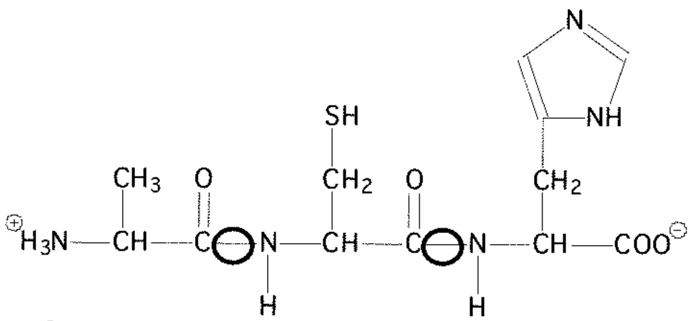
b)

		
Note the alcohol group is not considered acidic in this situation		

25.(2016:35)

Organic compound	Full structural formula	All intermolecular forces
hexan-3-one		dispersion dipole-dipole
1,1-difluoroethane		dispersion dipole-dipole
butanamide		dispersion hydrogen bonding dipole-dipole

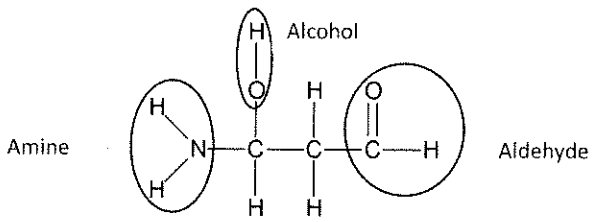
26.(2016:36) a) i)



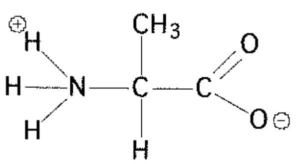
ii) Alanine, Cysteine, Histidine

b) This question requires you to understand amino acids can polymerise in any order. The answer must be different from the example given AlCysHis so Ala-His-Cys or His-Ala-Cys or any other combination is fine.

c)



d)



Any isomer is acceptable including the zwitterion. Be careful not to draw alanine of the isomer from part c)

27.(2016:37) To boil a molecular substance such as these three examples we must overcome the total secondary forces between the molecules.

Pentane, pentanal and pentanoic acid all exhibit dispersion forces due to the presence of electrons. As they contain the same number of carbon atoms the dispersion forces will be about equal.

Both pentanal and pentanoic acid have a carbonyl group that has a polar C=O bond. This gives these molecules dipole-dipole forces beween them. Thus they have a higher boiling point than pentane. (note pentanal can accept hydrogen bonds from water but in this question there isn't any so its irrelevant)

Only pentanoic acid has an -O-H configuration that allows the molecules to hydrogen bond to each other. Thus as it has dispersion forces, dipole-dipole bonds and hydrogen bonds it has the highest boiling point.

Please note that the desk you are writing on probably has a plastic top made of long carbon chains held together by dispersion forces. It is very strong. It is not correct to say substances with hydrogen bonds have higher boiling points than substances with dispersion forces so pentanoic acid has a higher BP. It is the sum of all three that counts.

c) Calculation of the average titre of NaOH solution:

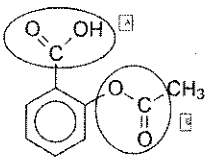
Final volume (mL)	25.30	23.55	22.40	22.25
Initial volume (mL)	3.50	2.70	1.50	1.30
Titre (mL)	21.80	20.85	20.90	20.95

Discarding the first titre of 21.80 mL, the average titre of NaOH = **20.90 mL**

d) Determining the percentage composition of citric acid by mass.
Volume of the cleaner liquid taken = 10.0 mL
Volume of the stock solution made by dilution = 100.0 mL
Volume of the aliquot used for titration = 20.0 mL
Citric acid is a triprotic acid. This means that one mole of citric acid requires 3 mols of NaOH for complete neutralisation.
n (NaOH) = (c × v) = (0.0916 mol L^{-1} × 0.02090 L) = 1.91444 × 10^{-3} mol
Therefore n (citric acid in 20.0 ml dilute) = (1.91444 × 10^{-3} ÷ 3) = 6.3815 × 10^{-4} mol
Therefore, 100.0 mL dilute stock solution contains
= [(6.3815 × 10^{-4} ÷ 20) × 100] = 3.19073 × 10^{-3} mol of citric acid.
Therefore, the mass of citric acid in 10.0 mL of the original solution = (n × M) = 3.19073 × 10^{-3} × 192.184) = 0.6130 g
Therefore, the mass of citric acid in the original undiluted solution is 0.6130 g.
Since the mass of the 10.0 mL of the original solution is 10.4 g,
% by mass of citric acid in the cleaner = [(0.6130 ÷ 10.4) × 100] = **5.89%**

e) Since citric acid is a weak acid and NaOH is a strong base, the equivalence point occurs on the basic side of the pH scale which is between 8 and 10. The hydrolysis of citrate ion will produce OH^- ions according to the equation, $C_6H_5O_7^{3-}(aq) + 3\,H_2O(\ell) \rightarrow C_6H_8O_7(aq) + 3\,OH^-(aq)$. The most suitable indicator from the given list is 'thymol blue' (pH = 8.00 to 9.6).

6.(2015:36) a) i)



ii) Group A: carboxylic acid, Group B: ester
b) i) At the equivalence point the Na^+ and $C\ell^-$ ions are neutral. The carboxylate ions react with water to form the carboxylic acid and hydroxide ions

$RCOO^-(aq) + H_2O(\ell) \rightarrow RCOOH(aq) + OH^-(aq)$

The basic solution means that it is necessary to use an indicator that changes colour higher than 7.
ii) $n(H^+)$ = cv = 0.125 × 0.01789 = 2.236 × 10^{-3} mol
$n(OH^-)_{excess}$ in 20 mL = $n(H^+)$ = 2.236 × 10^{-3} mol
$n(OH^-)_{excess}$ in 100 mL = 2.236 x 10^{-3} x 5 = 1.118 × 10^{-2} mol
$n(OH^-)_{initially}$ in 100 mL = cv = 0.204 × 0.1 = 0.0204 mol
$n(OH^-)_{reacting\ with\ aspirin}$ = 0.0204 – 0.01118 = 0.00921 or 9.21 × 10^{-3}mol
iii) $n_{(aspirin)}$ = ∫ $n(OH^-)$ = ∫ × 0.00921 = 0.00461 mol
$m_{(aspirin)}$ = 0.00461 × 180.154 = 0.8304 g
$m_{(aspirin)}$ in 1 tablet = 0.8304 ÷ 3 = 0.2768 g
% aspirin in 1 tablet = 0.2768/0.3 × 100 = 92.3%
c)

	Description	
Washing procedure	**Effect on the volume of hydrochloric acid used**	**Effect on the % of aspirin calculated**
The conical flask was washed with distilled water	No effect	No effect
The burette was washed with distilled water	Increase	decrease

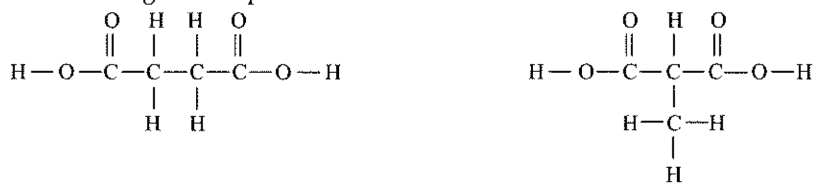
Chapter 14A: Calculations: Organic

1.(2009:03) a) Calculating the empirical formula:
mass of the sample = 9.76 g; mass of carbon dioxide = 17.9 g; mass of water = 4.88 g.
m (C) = [17.9 × (12.01 ÷ 44.01)] = 4.88 g.
m (H) = [4.88 × (2.016 ÷ 18.016)] = 0.546 g.
Therefore m (O) = [9.76 – (4.88 + 0.546)] = 4.33 g.

	C	H	O
Mass ratio (g)	4.88	0.546	4.38
Mole ratio	4.88 ÷ 12.01	0.546 ÷ 1.008	4.33 ÷ 16.00
	0.406	0.542	0.271
Simple ratio	0.406 ÷ 0.271	0.542 ÷ 0.271	0.271 ÷ 0.271
Simple ratio	1.5	2.00	1.00
Empirical ratio	3	4	2

Therefore the empirical formula is **$C_3H_4O_2$**

b) Calculating the molar mass of the dicarboxylic acid monomer:
n (NaOH) = c × v = 0.487 × 0.0153 = 7.451 × 10^{-3} mol
n (acid) in 0.050 L =($\frac{1}{2}$ × 7.451 × 10^{-3} mol) = 3.725 × 10^{-3} mol
n (acid) in 0.250 L = [3.725 × 10^{-3} × (0.250 ÷ 0.050)] = 1.863 × 10^{-2} mol
Therefore the molar mass of the acid = (m ÷ n) = (2.20 ÷ 1.863 × 10^{-2}) = **118.1 g mol^{-1}**
c) A possible structure for the dicarboxylic acid:
The monomer has four oxygen atoms as it has two 'COOH' groups in it. Taking away the mass of the four oxygen atoms from the molar mass of 118, the residual mass is (118 – 64) 54 which is shared by 4 carbon atoms and 6 hydrogen atoms. This gives a molecular formula of $C_4H_6O_4$.
The following are two possible structures:



2.(2010:40)

m (sample sweetener) = 1.021 g; m (CO_2) = 1.715 g, m (H_2O) = 0.2521 g; m (NO_2) = 0.2558 g; m (SO_2) = 0.3568 g

m (C) = [1.715 × (12.01 ÷ 44.01)] = 0.4680 g
Therefore, n (C) = (0.4680 ÷ 12.01) = *0.03897*

m (H) = [0.2521 × (2.016 ÷ 18.016)] = 0.02821 g
Therefore, n (H) = (0.02821 ÷ 1.008) = *0.02799*

m (N) = [0.2558 × (14.01 ÷ 46.01)] = 0.07789 g
Therefore, n (N) = (0.07789 ÷ 14.01) = *0.00556*

m (S) = [(0.3568 × (32.06 ÷ 64.06)] = 0.17857 g
Therefore, n (S) = (0.17857 ÷ 32.06) = *0.00557*

Therefore, m (O) = [1.021 – (0.4680 + 0.02821 + 0.07789 + 0.17857)] = 0.2683 g
n (O) = (0.2683 ÷ 16.0) = *0.01677*

	C	H	N	S	O
Mole ratio	0.03897	0.02799	0.00556	0.00557	0.01677
Dividing each by the smallest mole of 0.00556					
Simple ratio	6.959	4.998	1.000	1.002	3.016
	7	5	1	1	3

Therefore, the empirical formula is **$C_7H_5NSO_3$**

3.(2011:36) This is an empirical-molecular formula calculation in which gas volume calculation steps are involved. The compound contains carbon, hydrogen, oxygen and fluorine.

m (sample) = 1.6328 g.
The volume of CO_2 produced at 50°C and 101.3 kPa = 0.866 L.
Since, PV = nRT, n = (PV ÷ RT),
n = [(101.3 × 0.866) ÷ (8.315 × 323)] = 0.03266 mol
Therefore, n (C) = **0.03266 mol** and, m (C) = n × M = 0.03266 × 12.01 = **0.3923 g**

m (H_2O) = 0.220 g; n (H_2O) = (0.220 ÷ 18.016) = 0.0122 mol
Therefore, n (H) = 2 × 0.0122 = **0.02442 mol** and, m (H) = 0.02442 × 1.008 = **0.02462 g**

n (HF) = 0.0571 mol
Therefore, n (F) = **0.0571 mol** and, m (F) = 0.0571 × 19.00 = **1.0849 g**

m (O) = [1.638 –(0.3923 + 0.02462 + 1.0849)] = **0.131 g**
Therefore, n (O) = (0.131 ÷ 16.0) = **0.008188 mol**

	C	H	O	F
Mass ratio	0.3923	0.02462	0.131	1.0849
Mole ratio	0.03266	0.0244	0.008188	0.0571
Simple ratio	÷ 0.008188	÷ 0.008188	÷ 0.008188	÷ 0.008188
	3.989	2.98	1	6.97
Whole No. ratio	4	3	1	7

Empirical Formula = $\mathbf{C_4H_3OF_7}$

Alternative Method using the percentage composition

% C = [(0.0923 ÷ 1.6328) × 100] = 24.03%; Mol ratio = (24.03 ÷ 12.01) = 2.00
% H = [(0.02462 ÷ 1.632) × 100] = 1.51%; Mol ratio = (1.51 ÷ 1.008) = 1.50
% O = [(0.131 ÷ 1.632) × 100] = 8.03%; Mol ratio = (8.03 ÷ 16.00) = 0.50
% F = [(1.0849 ÷ 1.632) × 100] = 66.48%; Mol ratio = (66.48 ÷ 19.00) = 3.5

Fractional mole ratio of the elements in the compound: C = 2.00, H = 1.50; O = 0.50 and F = 3.5
Multiplying this ratio throughout by 2, in order to get whole numbers,
we get the empirical formula: $\mathbf{C_4H_3OF_7}$

4.(2012:39)

a) The compound contains carbon, hydrogen and oxygen only.
m (sample) = 0.5096 g
n (H_2O) = 0.4160 g
n (H_2O) = 0.4160 ÷ 18.016 = 0.0231 mol
n (H) = 2 × 0.0231 = 0.0462 mol
m (H) = n × M = 0.0462 × 1.008 = 0.04655 g

V (CO_2 – 100°C & 102.8 kPa) = 0.7007 L
Using the equation, PV = nRT
n = (PV ÷ RT) = [(102.8 × 0.7007) ÷ (8.314 × 373.15)] = 0.02322 mol of CO_2
Therefore, n (C) = n (CO_2) = 0.02322 mol
Therefore, m (C) = n × M = 0.02322 × 12.01 = 0.2789 g

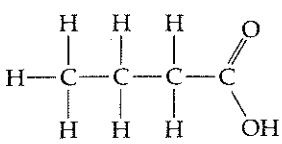
Therefore, m (O) = [0.5096 g – (0.04655 g + 0.2789 g)] = 0.1842 g
Therefore, n (O) = (m ÷ M) = (0.1842 ÷ 16) = 0.01151 mol

	C	H	O
Mass ratio	0.2789 g	0.04655 g	0.1842 g
Mole ratio	0.2789 ÷ 12.01	0.04655 ÷ 1.008	0.01842 ÷ 16
	0.02322	0.04618	0.01151
Dividing by the smallest mole of 0.01151,			
Simple ratio	0.02322 ÷ 0.01151	0.04618 ÷ 0.01151	0.01151 ÷ 0.01151
	2.017	4.012	1
Rounded mole ratio	2	4	1
Empirical Formula:	$\mathbf{C_2H_4O}$	(Empirical Mass = 44.052 g)	

b) Determining the molecular mass.
m (second sample) = 0.4832 g
This sample at 261°C, has a pressure of 241 kPa in a 100.0 mL container.
Using the relationship, PV = nRT, and, n = PV ÷ RT,
n = [(241 × 0.100) ÷ (8.314 × 534.15)] = 5.4268×10^{-3} mol
Since, 5.4268×10^{-3} mol has a mass of 0.4832 g
One mole has a mass = [(1 × 0.4832) ÷ (5.4268×10^{-3})] = 89.04 g mol^{-1}.
The ratio of molecular mass ÷ empirical mass = (89.04 ÷ 44.052) = Nearly 2.
Therefore, the **molecular formula** = 2 × C_2H_4O = $\mathbf{C_4H_8O_2}$

c) Since a fruity smell is characteristic of an ester and the ester is the product of an alcohol and a carboxylic acid, this compound is most likely to be butanoic acid with the following Lewis structure.

Structure of butanoic acid

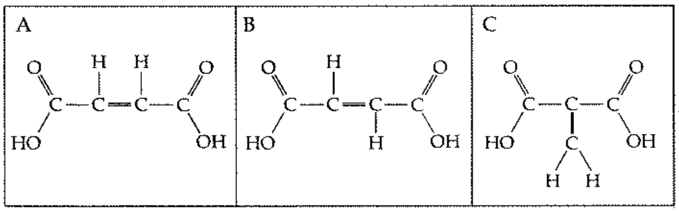


d) Additional chemical tests for butanoic acid:
i) Reaction with metallic carbonates such as $CaCO_3$ would produce a colourless, odourless gas and the test tube (if the reaction is carried out in a test tube) will get warm.
$CaCO_3(s) + CH_3CH_2CH_2COOH(\ell) \rightarrow Ca(CH_3CH_2CH_2COO)_2(aq) + CO_2(g) + H_2O(\ell)$
Other minor tests for consideration:
ii) Litmus test: acids turn litmus red. This confirms that the compound is an acid.
A large amount of heat is produced when butanoic acid is mixed with water.

5.(2013:35) a) Empirical formula = CHO
Empirical mass = 12.01 + 1.008 + 16.00 = 29.018
Molecular mass = 116 g mol^{-1}
Molecular mass to empirical mass ratio = 116 ÷ 29.018 = 3.9975 ≈ 4
Molecular formula = Empirical formula × 4 = CHO × 4 = **$C_4H_4O_4$**
b)

Test	Observation	Possible functional group
Water solubility	788 g L^{-1}	R–COOH = carboxylic acid or, R–OH = alcohol
Add to bromine water	Bromine water decolourises rapidly	Can be a double bond or a triple bond.

c) m (sample of the white solid) = 2.32 g
n (H^+) ions in the above sample = 0.0400 mol
n (in 2.32 g sample) = (2.32 ÷ 116) = 0.0200 mol
Therefore, the ratio of the moles of the compound to the moles of hydrogen = 0.0200 ÷ 0.0400
= 1:2
Therefore, the substance is a diprotic acid
Three possible structures are shown below:



6.(2014:39) This is a straightforward empirical-molecular formula calculation.
a) The organic compound contains C, H, O and Br. The mass of the sample is 1.50 g.
m (CO_2) produced on combustion = 1.58 g
n (CO_2) produced = (1.58 ÷ 44.01) = 0.03590 mol
Therefore, n (C) = n (CO_2) = 0.03590 mol
Therefore, m (C) = 0.03590 × 12.01 = 0.4312 g. Therefore, carbon is **28.7%** of the compound.

m (H_2O) produced on combustion = 0.563 g.
n (H_2O) produced = (0.563 ÷ 18.016) = 0.03125 mol
Therefore n (H) produced = 2 × 0.03125 = 0.0625 mol
Therefore, m (H) produced = 0.0625 × 1.008 = 0.0630 g. Therefore, hydrogen is **4.2%** of the compound.

Another sample of mass 1.75 g results in 1.97 g of AgBr.
Therefore, the original mass, 1.50 g sample would have produced, [(1.50 × 1.97) ÷ 1.75] = 1.6886 g of AgBr.
Therefore, n (Br) = n (AgBr) = 1.6886 ÷ (107.9 + 79.90) = 0.008991 mol.
Therefore, m (Br) produced = 0.008991 × 79.90 = 0.7184 g. Therefore, bromine is **47.9%** of the compound.

Therefore, the mass of oxygen in the compound is = [1.50 – (0.4313 + 0.0630 + 0.7184)] = 0.2874 g. Oxygen is **19.2%** of the compound.
n (O) = (0.2874 ÷ 16.0) = 0.01796 mol.

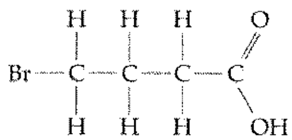
Calculation of the empirical formula

	28.7%	4.2%	19.2%	47.4%
Elements present	C	H	O	Br
Mass ratio (g)	0.04312	0.0630	0.2874	0.7184
Mole ratio	0.03590	0.0625	0.01796	0.008991
Simple ratio	3.993	6.951	1.998	1
Whole No. ratio	4	7	2	1

Therefore, the empirical formula is **$C_4H_7O_2Br$**

b) The empirical mass of the compound is = 48.04 + 7.056 + 32.0 + 79.9 = 167.0
Using the relationship, PV = nRT and [n = (PV ÷ RT)], the number of moles of the compound of mass 1.95 g is calculated as follows:
n = {(95.0 × 0.387) ÷ [8.314 × (273 + 105)]} = [36.765 ÷ (8.314 × 378)] = 0.01170 mol
Since 0.01170 mol of the compound has a mass of 1.95 g
1.00 mol of the compound (the molecular mass) is = (1.95 ÷ 0.01170) = 166.7 g mol^{-1}
As the empirical mass (167.0 g) and the molar mass (166.7 g) are equal within the limits of the experimental error, the molecular formula is the same as the empirical formula.
The molecular formula of the compound is = **$C_4H_7O_2Br$**.

c) A possible structure for the formula is given below.

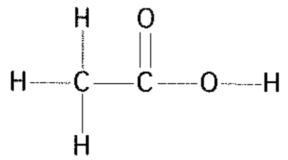
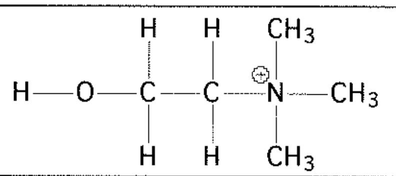


4-bromobutanoic acid

This compound could be 4-bromobutanoic acid. Other position isomers involving the –Br functional groups are also possible.

7.(2016:38) a) Enzymes are proteins which act as biological catalysts. They are more efficient than inorganic catalysts.

b)

Ethanoic acid	Choline
	

c)

CHNO	+	O_2	→	CO_2	+	H_2O	+	NO_2
4.270 g				9.020 g		5.169 g		1.886 g
				n = 9.020/44.01 = 0.2050 mol m = 0.2050 × 12.01 = 2.461 g		n = 5.169/18.016 = 0.2869 mol of H But there are 2 × H m = 0.2869 × 2 × 1.008 = 0.5784 g		n = 1.886/46.01 = 0.0410 mol m = 0.0410 × 14.01 = 0.5743 g

Mass of oxygen = total mass – mass of C – mass of H – mass of N
= 4.270 – 2.4614 – 0.5784 – 0.5743 = 0.6559 g

Ratio of mol =

	C	H	O	N
n	0.20495	0.57382	0.04099	0.04099
÷ n(O)	5	14	1	1

Therefore the empirical formula is $C_5H_{14}ON$

d) The acetylcholine produced 4.270 g of a compound with the molecular formula $C_5H_{14}NO$. This compound matches the structure of choline, so it is evident that the enzyme is active as it has produced the product of the equation rather than the reactant.