CHEMISTRY
LEVEL 4C
(CHM 415115)

ORGANIC CHEMISTRY

THEORY SUMMARY
&
REVISION QUESTIONS

INDEX:

CHEMISTRY (LEVEL 4C)
ORGANIC CHEMISTRY

(CRITERION 7)

INTRODUCTORY THEORY SUMMARY:

(FROM YEAR 11)

1. ORGANIC CHEMISTRY:

The term 'organic' chemistry has its origins in the fact that living systems are based on carbon compounds. However, our coverage of organic chemistry will encompass many compounds that are not associated with living things.
The principal issue is that the topic of organic chemistry is based on compounds of carbon. The other elements that are closely related to carbon in this branch of chemistry are hydrogen, oxygen, nitrogen, sulfur, halogens,.....
In year 12 we will specifically focus on 'families' of organic compounds like alcohols and carboxylic acids that have groups of atoms attached to chains or rings and these groups of atoms give them predictable properties.
These groups of attached atoms are described as "functional groups".
e.g. if an –OH group is attached to a carbon chain, the compound will be an alcohol. If there is a –COOH group attached to the end of a carbon chain, then the compound will be a carboxylic acid.

2. BONDING RULES:

The majority of organic compounds that we shall be investigating are ***covalent*** in their bonding. The number of covalent bonds formed by an atom is ususally determined by the number of unpaired valence electrons in the outer shell of the atom.
In organic chemistry it is vital to ensure that every carbon atom shown in a structure has 4 covalent bonds. Hydrogen forms 1 and oxygen forms 2 covalent bonds.
e.g.

ELEMENT	NUMBER OF VALENCE e–	NUMBER OF BONDS FORMED
CARBON	4	4
HYDROGEN	1	1
OXYGEN	6	2
SULFUR	6	2
HALOGENS	7	1

3. ORGANIC NOMENCLATURE ("IUPAC" PROCEDURE)

The systematic naming of organic compounds is done using the IUPAC method and it is based upon a few simple rules which you will find quite easy to learn and use.
Organic compounds have names which usually involve ***three*** parts:

(i) the beginning part of the name called the PREFIX
(ii) the main part called the STEM
(iii) the end of the name called the SUFFIX.

(i) THE STEM:

This tells us the number of carbon atoms that make up the longest continuous chain (or ring) forming the "backbone" of the molecule; ie.

C ATOMS:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
STEM:	meth	eth	prop	but	pent	hex	hept	oct	non	dec

(ii) THE SUFFIX:

The suffix is the name's "ending' and it tells us the type of carbon-carbon bonds present in the main carbon chain.

* If there are ***only*** C–C **SINGLE** bonds present, the suffix is **-ANE**

* If there are any C=C **DOUBLE** bonds present, the suffix is **-ENE**

* If there are any C≡C **TRIPLE** bonds present, the suffix is **-YNE**

(iii) THE PREFIX:

This gives information about the SIDE GROUPS attached to the main carbon chain or ring. You can assume that unless told otherwise the side groups are H atoms. Thus you only have to use a PREFIX when the side group is something other than hydrogen.

i.e.	**SIDE GROUP**	**PREFIX**
	-Br	BROMO
	-Cl	CHLORO
	-F	FLUORO
	-I	IODO
	$-CH_3$	METHYL
	$-CH_2CH_3$	ETHYL
	$-CH_2CH_2CH_3$	PROPYL
	RING	CYCLO

4. SYSTEMATIC NOMENCLATURE (PROCEDURES)

(i) Identify the longest carbon chain (or ring) and thus determine the STEM.

(ii) Number the carbon atoms making $\mathbf{C_1}$ nearest the end where multiple bonds or side groups occur.

(iii) The suffix will be ANE unless there there are C=C or C≡C present. In these cases locate the multiple bond using a carbon number.

e.g. " -3-ene" means that there is a double bond between carbons 3 and 4
" -2-yne" means that there is a triple bond between carbons 2 and 3

(iv) All side groups attached to the C chain (apart from H) are located alphabetically by the carbon number they are attached to. e.g. "2-chloro" means a Cl on carbon #2.

(v) If there are multiples of the same group use "di", "tri", "tetra",.... as prefixes.

(vi) If there are several identical groups attached to the same carbon, then the name will incorporate the use of repetitive location numbers.

e.g. if there are 2 fluorine atoms attached to carbon #5 we use "5,5-difluoro....."
if there are 3 fluorine atoms attached to carbon #1 we use "1,1,1-trifluoro....."

(vii) If there are several identical groups attached to different carbons, then the name will incorporate the use of multiple location numbers.

e.g. if there are bromine atoms attached to carbons #2, 3 and 5 we would use the prefix "2,3,5-tribromo....."

(viii) With cyclic compounds, the stem is determined by the number of carbons in the ring and any carbons attached to the ring are named as substituent(side) groups.

e.g. 5 carbon ring with just a $-CH_3$ attached is named as "methylcyclopentane"

(ix) A cyclic compound, with several substituent(side) groups has the side groups listed alphabetically and the numbering can be clockwise or anti-clockwise.

e.g. 6 carbon ring with just a $-CH_3$ attached and a chlorine attached on the adjacent carbon is named as "1-chloro-2-methylcyclohexane"

(x) With cyclic compounds incorporating a double bond, the stem is determined by the number of carbons in the ring and the suffix locates the multiple bond.

e.g. a 4 carbon ring with just a C=C is named as "cyclobutene" and carbons 1&2 are linked by this double bond.

(xi) With cyclic compounds incorporating a double bond, location numbers are based upon carbons 1&2 assumed linked by this double bond.

e.g. a 7 carbon ring with one C=C and two methyl groups attached to carbons one away from either side of the C=C will be named as "3,7-dimethylcyclohept-1-ene" or even "3,7-dimethylcycloheptene"

5. SATURATION & UNSATURATION:

(a) SATURATED organic compounds are ones that contain ONLY carbon/carbon single bonds. They will have a suffix "***ane***".

e.g. butane, 1,2-difluorohexane, ethylcyclopentane,.....

SATURATED organic compounds are able to undergo ***slow*** SUBSTITUTION reactions.

e.g.

$CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_3 + Br_2 \rightarrow CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_2Br + HBr$

(pentane) (1-bromopentane)

(b) UNSATURATED organic compounds are ones that contain at least one carbon/carbon multiple bond. They will have a suffix "***ene***" or "***yne***".

e.g. butene, 3,4-difluorohex-1-yne, 3-ethylcyclopentene,.....

UNSATURATED organic compounds are able to undergo ***rapid*** ADDITION reactions.

e.g.

$CH_2{=}CH\text{-}CH_2\text{-}CH_2\text{-}CH_3 + Br_2 \rightarrow CH_2(Br)\text{-}CH(Br)\text{-}CH_2\text{-}CH_2\text{-}CH_3$

(pent-1-ene) (1,2-dibromopentane)

6. TESTING FOR UNSATURATION:

Bromine in the elemental (uncombined) form is brown Br_2. When mixed with an unsaturated hyrocarbon (alkene or alkyne or cycloalkene) there is a very rapid ADDITION reaction as described above in 4. The new compound formed will be a "dibromo" compound and these are ***colourless***!

Thus: any organic compound that undergoes a rapid decolourising reaction with bromine is very likely to be unsaturated!

7. COMBUSTION OF HYDROCARBONS:

(a) COMPLETE COMBUSTION: When there is a plentiful supply of oxygen, the hydrocarbon will undergo complete combustion meaning that it burns and the only products are carbon dioxide and water, usually in the form of steam.

e.g.

$$C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(g)}$$

(b) INCOMPLETE COMBUSTION: When there is a limited supply of oxygen, the hydrocarbon will undergo incomplete combustion meaning that it burns and the products include some carbon or carbon monoxide as well as water, usually in the form of steam.

e.g.

$$C_3H_{8(g)} + 3O_{2(g)} \rightarrow 2CO_{(g)} + C_{(s)} + 4H_2O_{(g)}$$

or: $C_3H_{8(g)} + 7/2O_{2(g)} \rightarrow 3CO_{(g)} + 4H_2O_{(g)}$ etc.....

8. ISOMERISM:

This occurs where there are compounds that have the same molecular formula but have different structural formulae.
These compounds are different compounds and may have quite different physical and chemical properties.
Consider the chemical formula C_5H_{10}. This gives rise to a number of different organic compounds, some of which are alkenes and others are cyclic alkanes.

e.g.

ALKENES C_5H_{10}	**CYCLOALKANES C_5H_{10}**
pent-1-ene	**cyclopentane**
pent-2-ene	**methylcyclobutane**
2-methylbut-1-ene	**1,1-dimethylcyclopropane**
2-methylbut-2-ene	**1,2-dimethylcyclopropane**
3-methylbut-1-ene	**ethylcyclopropane**

Q1. Give the structural formulae and names for all possible isomers having the chemical formula: (i) C_6H_{14} (ii) C_5H_8 (iii) C_4H_8

Q2. A student incorrectly names an organic compound 5,5-dibromo-2-ethylhexane.
(i) Write out the structural formula.
(ii) Give the ***correct*** systematic (IUPAC) name. (2,2-dibromo-5-methylheptane)
(iii) What is this compound's chemical formula? ($C_8H_{16}Br_2$)
(iv) What is this compound's empirical formula? (C_4H_8Br)

Q3. Give correct names for the following compounds that are all named incorrectly:
(i) 4-methylpentane (ii) 3,3-dimethylbutane
(iii) 2-ethylhexane (iv) 3-propyl-2-methylpentane

Q4. A pure hydrocarbon X is analysed and found to contain 85.7% by mass carbon and 14.3% by mass of hydrogen. Given that compound X has a relative molecular mass of 84.0 and that it undergoes a rapid decolourising reaction with bromine(Br_2), find:

- the empirical formula for compound X.
- the molecular formula for compound X.
- 3 possible structural formulae and names that could be X.

Q5. The gaseous hydrocarbon Z has an empirical formula of C_2H_5 and it has a gas density 29 times greater than hydrogen gas at the same temperature and pressure.
(i) What is the molecular formula for Z?
(ii) Give two possible structural formulae and IUPAC names that could be Z.

9. FUNCTIONAL GROUPS:

When specific groups of atoms are attached to the carbon chain or ring and this group gives the molecule special reactive properties, we describe the group as a "FUNCTIONAL" group.

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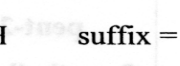
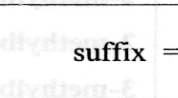
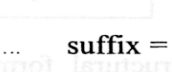
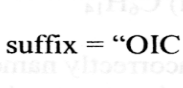
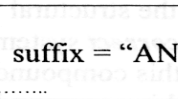
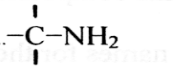
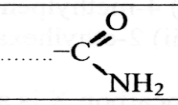
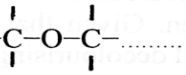
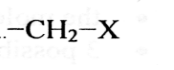
When specific groups of atoms are attached to the carbon chain or ring and this group gives the molecule special reactive properties, we describe the group as a "FUNCTIONAL" group.

In year 12 Chemistry you are expected to be familiar with about 9 different functional groups. These are:

FUNCTIONAL GROUPS	STRUCTURE OF FUNCTIONAL GROUP
ALCOHOLS $C_nH_{2n+2}O_1$	 suffix = "OL"
ALDEHYDES $C_nH_{2n}O_1$	 suffix = "AL"
KETONES $C_nH_{2n}O_1$	 suffix = "ONE"
CARBOXYLIC ACIDS $C_nH_{2n}O_2$	 suffix = "OIC ACID"
ESTERS $C_nH_{2n}O_2$	 suffix = "ANOATE"
AMINES	
AMIDES	
ETHERS	
ALKYL HALIDES	

If the functional group is attached to a chain that is derived from an **ALKANE**(C_nH_{2n+2}) some of the names are often given as:

ALCOHOLS = ALKANOLS	**ALDEHYDES = ALKANALS**
KETONES = ALKANONES	**CARBOXYLIC ACIDS = ALKANOIC ACIDS**

10. ALCOHOLS:

Alcohols are a family (or **HOMOLOGOUS SERIES**) of similar organic compounds identified by each having an "–OH" functional group attached to a carbon chain or ring. Our consideration of alcohols will be based almost exclusively on those derived from alkanes and thus these alcohols are also referred to as **ALKANOLS**.

GENERAL PROPERTIES:

(i) they are mostly water soluble liquids at SLC.
(ii) they have an alkane structure in which 1 H has been substituted by an –OH.
(iii) they have a general chemical formula of $C_nH_{2n+1}OH$ i.e. $C_nH_{2n+2}O$.
(iv) they give a neutral pH test.
(v) the IUPAC name is the alkane's name with the 'e' replaced by an "OL" suffix.
(vi) they react with sodium metal to release hydrogen gas; i.e.

$$C_nH_{2n+1}OH_{(l)} + Na(s) \rightarrow C_nH_{2n+1}O^-....Na^+ + \tfrac{1}{2}H_{2(g)}$$

NAMING:

CHEMICAL FORMULA	STRUCTURAL FORMULA	I.U.P.A.C. NAME
CH_4O	$CH_3–O–H$	methanol
C_2H_6O	$CH_3–CH_2–O–H$	ethanol
C_3H_8O	$CH_3–CH_2–CH_2–O–H$	propan-1-ol
C_3H_8O	$CH_3–\underset{\displaystyle OH}{\underset{\vert}{C}}H–CH_3$	propan-2-ol
$C_4H_{10}O$	$CH_3–CH_2–CH_2–CH_2–O–H$	butan-1-ol
$C_4H_{10}O$	$CH_3–\underset{\displaystyle OH}{\underset{\vert}{C}}H–CH_2–CH_3$	butan-2-ol
$C_4H_{10}O$	$CH_3–\underset{\displaystyle CH_3}{\underset{\vert}{C}}H–CH_2–O–H$	2-methylpropan-1-ol
$C_4H_{10}O$	$CH_3–\underset{\displaystyle CH_3}{\underset{\vert}{\overset{\displaystyle OH}{\overset{\vert}{C}}}}–CH_3$	2-methylpropan-2-ol
$C_5H_{12}O$	$CH_3–CH_2–CH_2–CH_2–CH_2–O–H$	pentan-1-ol etc....

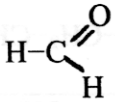
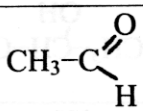
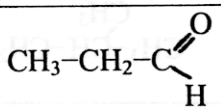
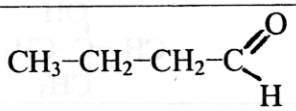
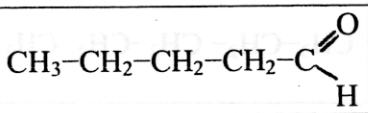
11. ALDEHYDES:

Aldehydes are a family (or **HOMOLOGOUS SERIES**) of similar organic compounds identified by each having an "–CHO" functional group attached to the **END** of a carbon chain. Our consideration of aldehydes will be almost exclusively based upon those derived from alkanes and thus, these aldehydes are also referred to as **ALKANALS**.

GENERAL PROPERTIES:

(i) they are mostly water soluble liquids at SLC.
(ii) they have an alkane structure in which a H atom at the **END** of the carbon chain has been substituted by a –CHO functional group. (This C=O group is called a "carbonyl" group)
(iii) they have a general chemical formula of $C_nH_{2n}O$.
(iv) they give a neutral pH test.
(v) the IUPAC name is the alkane's name with the final 'e' in the alkane's name replaced by the "AL" suffix.
(vi) they do not react with sodium metal.
(vii) aldehydes can be oxidised to form carboxylic acids.
(viii) aldehydes can be reduced to form primary alcohols (i.e. alcohols where the –OH functional group is on the ***end*** of the carbon chain).

NAMING OF ALDEHYDES:

CHEMICAL FORMULA	STRUCTURAL FORMULA	I.U.P.A.C. NAME
CH_2O		methanal
C_2H_4O		ethanal
C_3H_6O		propanal
C_4H_8O		butanal
$C_5H_{10}O$		pentanal etc……..

12. KETONES:

Ketones (pronounced "keytones") are a family (or **HOMOLOGOUS SERIES**) of similar organic compounds identified by each having a "C=O" carbonyl functional group attached to the **SIDE** of a carbon chain. Our consideration of ketones will be almost exclusively based upon those derived from alkanes and thus, these ketones are also referred to as **ALKANONES**.

GENERAL PROPERTIES:

(i) they are mostly liquids at SLC.
(ii) they have an alkane structure with a C=O carbonyl group attached to the **SIDE** of the carbon chain.
(iii) they have a general chemical formula of $C_nH_{2n}O$ ($\therefore$ isomeric with aldehydes).
(iv) they give a neutral pH test.
(v) the IUPAC name is the alkane's name with the final 'e' in the alkane's name replaced by the "ONE" suffix (pronounced "own")
(vi) they do not react with sodium metal.
(vii) ketones can't be oxidised; unless combustion is occurring.
(viii) ketones can be reduced to form secondary alcohols (i.e. alcohols where the –OH functional group is on the ***side*** of the carbon chain).
(ix) Because the C=O cannot be on the end of the carbon chain, the first member of this family has to be one where there are **3** carbons in the chain!

NAMING OF KETONES

CHEMICAL FORMULA	STRUCTURAL FORMULA	I.U.P.A.C. NAME
C_3H_6O	$CH_3-\overset{\overset{O}{\|\|}}{C}-CH_3$	propanone (acetone)
C_4H_8O	$CH_3-\overset{\overset{O}{\|\|}}{C}-CH_2-CH_3$	butanone
$C_5H_{10}O$	$CH_3-\overset{\overset{O}{\|\|}}{C}-CH_2-CH_2-CH_3$	pentan-2-one
$C_5H_{10}O$	$CH_3-CH_2-\overset{\overset{O}{\|\|}}{C}-CH_2-CH_3$	pentan-3-one
$C_6H_{12}O$	$CH_3-\overset{\overset{O}{\|\|}}{C}-CH_2-CH_2-CH_2-CH_3$	hexan-2-one
$C_6H_{12}O$	$CH_3-CH_2-\overset{\overset{O}{\|\|}}{C}-CH_2-CH_2-CH_3$	hexan-3-one etc……..

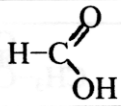
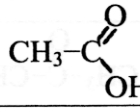
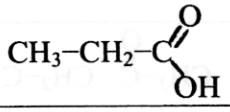
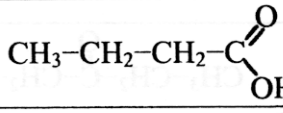
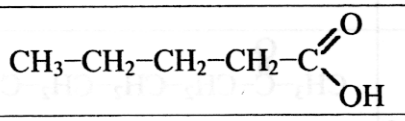
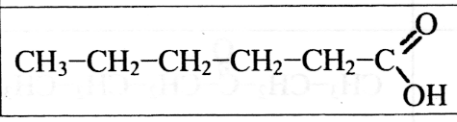
13. CARBOXYLIC ACIDS:

Carboxylic acids are a family (or **HOMOLOGOUS SERIES**) of similar organic compounds identified by each having an "–COOH" functional group attached to the **END** of a carbon chain. Our consideration of carboxylic acids will be almost exclusively based upon those derived from alkanes and thus, these acids are also referred to as **ALKANOIC ACIDS**.

GENERAL PROPERTIES:

(i) they are mostly water soluble liquids at SLC.
(ii) they have an alkane structure in which the **END** carbon atom is attached to both a =O and an –OH, giving a single functional group –COOH.
(iii) they have a general chemical formula of $C_nH_{2n}O_2$.
(iv) their aqueous solutions give an acidic pH test.
(v) the IUPAC name is the alkane's name with the final 'e' in the alkane's name replaced by the "OIC ACID" suffix.
(vi) they do react with sodium metal forming sodium alkanoates + hydrogen gas.
(vii) carboxylic acids can't be oxidised; unless combustion is occurring.
(viii) carboxylic acids can be reduced to form aldehydes and then further reduced to form primary alcohols.

NAMING OF CARBOXYLIC ACIDS:

CHEMICAL FORMULA	STRUCTURAL FORMULA	I.U.P.A.C. NAME
CH_2O_2		methanoic acid
$C_2H_4O_2$		ethanoic acid
$C_3H_6O_2$		propanoic acid
$C_4H_8O_2$		butanoic acid
$C_5H_{10}O_2$		pentanoic acid
$C_6H_{12}O_2$		hexanoic acid etc……..

14. OXIDATION OF ALCOHOLS:

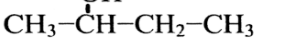
(a) The oxidation of alcohols usually involves one of two following processes or a combination of the two; i.e.

(i)	the ***addition*** of an ***oxygen*** atom to a molecule
(ii)	the ***removal*** of ***hydrogen*** atoms from a molecule.

When considering the oxidation of alcohols, the outcome is dependent upon the ***type*** of alcohol undergoing the reaction. The **THREE** types of alcohol concerning us are:

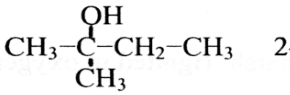
1. PRIMARY ALCOHOLS:
These are alcohols where the –OH functional group is on the ***END*** of the carbon chain.
e.g. propan-1-ol $CH_3{-}CH_2{-}CH_2{-}O{-}H$.

2. SECONDARY ALCOHOLS:
These are alcohols where the –OH functional group is on the ***SIDE*** of the carbon chain.
e.g.



butan-2-ol.

3. TERTIARY ALCOHOLS:
These are alcohols where the –OH functional group is on the ***SIDE*** of the carbon chain directly opposite a side attached carbon chain.
e.g.



2-methylbutan-2-ol

(b) **OXIDISING AGENTS USED:**
In our chemistry course there are 4 commonly encountered oxidising agents:

(i) acidified potassium dichromate = strong oxidiser:
$Cr_2O_7^{2-}{}_{(aq)} + 14H^+{}_{(aq)} + 6e^- \rightarrow 2Cr^{3+}{}_{(aq)} + 7H_2O_{(l)}$

(ii) acidified potassium permanganate = very strong oxidiser:
$MnO_4^-{}_{(aq)} + 8H^+{}_{(aq)} + 5e^- \rightarrow Mn^{2+}{}_{(aq)} + 4H_2O_{(l)}$

(iii) acidified hydrogen peroxide = very strong oxidiser:
$H_2O_{2(aq)} + 2H^+{}_{(aq)} + 2e^- \rightarrow 2H_2O_{(l)}$

(iv) combustion in oxygen = 'harsh' oxidiser (*):
$O_{2\,(g)} + 4H^+{}_{(aq)} + 4e^- \rightarrow 2H_2O_{(l)}$

Note that in (i) and (ii) the potassium ions are ***spectator*** ions and the acidified nature of the oxidiser is indicated by the presence of aqueous hydrogen ions ($H^+{}_{(aq)}$) or hydronium ions ($H_3O^+{}_{(aq)}$). Sulfuric acid ($H_2SO_{4(aq)}$) is normally used as the acidifying agent.
* (iv) combustion in oxygen from the air was studied in the year 11 Physical Sciences course.

(c) OXIDATION SEQUENCES:

The products of oxidation of an alcohol are principally determined by knowing whether it is a primary, secondary or tertiary alcohol. {NOTE: R, R_1, R_2, R_3…..represent organic chains}

(i) PRIMARY ALCOHOLS:

These oxidise firstly to form an aldehyde, then oxidise further to form a carboxylic acid and then, if oxidised harshly (ignited in oxygen) they burn to form CO_2 & H_2O.

PRIMARY ALCOHOL → ALDEHYDE → CARBOXYLIC ACID [→ CO_2 & H_2O]

i.e. $R-CH_2-OH \rightarrow R-C(=O)-H \rightarrow R-C(=O)-OH$

alkanol alkanal alkanoic acid

(ii) SECONDARY ALCOHOLS:

These oxidise to form a ketone and then, if oxidised harshly (ignited in oxygen) they burn to form carbon dioxide and water. i.e.

SECONDARY ALCOHOL → KETONE [→ CO_2 & H_2O]

i.e. $R_1-CH(OH)-R_2 \rightarrow R_1-C(=O)-R_2$

alkanol alkanone

(ii) TERTIARY ALCOHOLS:

These **DO NOT** undergo oxidation unless it is 'harsh' (ignited in oxygen) and then they burn to form carbon dioxide and water. i.e.

TERTIARY ALCOHOL [→ CO_2 & H_2O]

i.e. $R_1-C(OH)(R_3)-R_2 \rightarrow$ NO REACTION

alkanol

NOTES:

(i) To oxidise a primary alcohol right through the two steps to the carboxylic acid, requires the more powerful oxidising agent; H^+/MnO_4^-.

(ii) To oxidise a primary alcohol through to the aldehyde, requires the slightly less powerful oxidising agent; $H^+/Cr_2O_7^{2-}$.

(iii) To oxidise a secondary alcohol through to the ketone, either oxidising agent; $H^+/Cr_2O_7^{2-}$ or H^+/MnO_4^- will do.

(iv) Tertiary alcohols do not undergo oxidation unless it is harsh; i.e. the tertiary alcohol is ignited in air and undergoes 'combustion'.

(v) Each of the above 'oxidation' steps can be reversed by using a suitable reducing agent such as nascent hydrogen ($H_{2(g)}$)

(D) TYPICAL EXAM QUESTIONS ON OXIDATION OF ALCOHOLS

Q1. Write and balance the chemical equation for the oxidation of butan-1-ol using excess acidified potassium permanganate solution.

ANSWER:

As there is ***excess*** of the ***powerful oxidiser***, the oxidation will occur through the 2 steps and the primary alcohol will thus be oxidised through to the corresponding carboxylic acid. i.e.

$$\underset{(C_4H_{10}O)}{CH_3{-}CH_2{-}CH_2{-}CH_2{-}O{-}H} \rightarrow \underset{(C_4H_8O_2)}{CH_3{-}CH_2{-}CH_2{-}C(=O){-}O{-}H}$$

The half equations are thus:

$$C_4H_{10}O + H_2O \rightarrow C_4H_8O_2 + 4H^+ + 4e^- \quad \text{(oxidation)}$$
$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O \quad \text{(reduction)}$$

Giving the net equation:

$$5C_4H_{10}O_{(aq)} + 4MnO_4^-{}_{(aq)} + 12H^+{}_{(aq)} \rightarrow 5C_4H_8O_{2(aq)} + 4Mn^{2+}{}_{(aq)} + 11H_2O_{(l)}$$

Note that the 'spectator' potassium ions are not included in the net equation.
Do a quick check of charge balance left and right to ensure that your balancing is correct.
Do not attempt to use structural fromulae when writing redox equations like this; molecular formulae will suffice.

Q2. Write and balance the chemical equation for the oxidation of propan-2-ol using excess acidified potassium dichromate solution.

ANSWER:

The oxidation of this secondary alcohol will thus produce the ketone.

$$\underset{(C_3H_8O = \text{propan-2-ol})}{CH_3{-}CH(OH){-}CH_3} \rightarrow \underset{(C_3H_6O = \text{propanone})}{CH_3{-}C(=O){-}CH_3}$$

The half equations are thus:

$$C_3H_8O \rightarrow C_3H_6O + 2H^+ + 2e^- \quad \text{(oxidation)}$$
$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O \quad \text{(reduction)}$$

Giving the net equation:

$$3C_3H_8O_{(aq)} + Cr_2O_7^{2-}{}_{(aq)} + 8H^+{}_{(aq)} \rightarrow 3C_3H_6O_{(aq)} + 2Cr^{3+}{}_{(aq)} + 7H_2O_{(l)}$$

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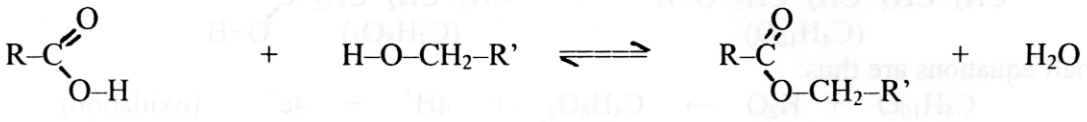
15. ESTERS:

Esters are a family (or **HOMOLOGOUS SERIES**) of similar organic compounds identified by each having a "–COOC–" functional group within a carbon chain. Our consideration of esters will be almost exclusively based upon those derived from alkanes and thus, these compounds are also referred to as **ALKYL ALKANOATES**. They are chemically formed in a reaction called "**ESTERIFICATION**". The chemical reaction involves an equilibrium.

i.e. CARBOXYLIC ACID + ALCOHOL $\rightleftharpoons$ ESTER + WATER



GENERAL PROPERTIES OF ESTERS:

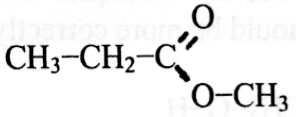
(i) they are mostly liquids at SLC and have low solubility in water.
(ii) they have an alkane structure with a "–COOC–" functional group within a carbon chain.
(iii) they have a general chemical formula of $C_nH_{2n}O_2$ which means that esters are isomeric with carboxylic acids.
(iv) their aqueous solutions give a neutral pH test.
(v) they usually have a sweet or fruity odour and are very often the active compounds in the perfumes of flowers.
(vi) the IUPAC name is alkyl alkanoate where "alkyl" is derived from the parent alcohol and "alkanoate" is derived from the parent carboxylic acid.
(vii) they do not react with sodium metal.
(viii) esters can't be oxidised; unless combustion is occurring.
(ix) esters can be hydrolysed (reacted with water) to form the parent alcohol and carboxylic acid. (This involves reversing the equilibrium reaction shown above)
(x) The formation of esters is a fairly slow chemical reaction but using concentrated H_2SO_4 catalyses the reaction making it much faster.

Some examples of esters:

Butyl butanoate = pineapple odour
Octyl methanoate = orange odour
Pentyl methanoate = banana odour
Ethyl methanoate = peach-kernel odour
Ethyl butanoate = strawberry odour
Methyl salicylate = liniment odour

NAMING ESTERS:

The key to naming any ester is to firstly identify the parent alcohol and parent acid.

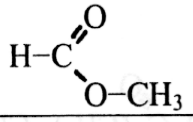
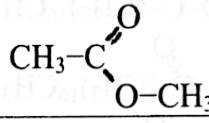
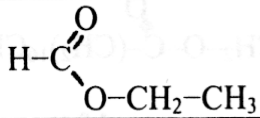
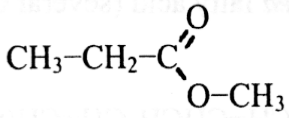
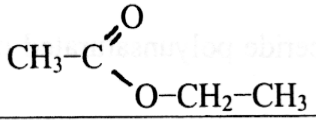
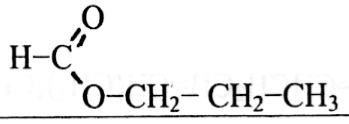
e.g. Consider the ester structure shown: 

(i) The C=O bond was originally associated with the parent carboxylic acid which had 3 carbons in its chain and was thus propanoic acid. All esters of propanoic acid are called "**propanoates**".

(ii) The O–C bond was originally associated with the parent alcohol which had only 1 carbon in its chain and was thus methanol. All esters of methanol are called "**methyl**" esters.

(iii) Now combining the information from (i) and (ii) above, we determine that the ester must be: **methyl propanoate**.

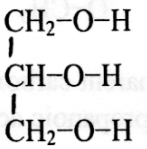
NAMING OF SOME ESTERS:

CHEMICAL FORMULA	STRUCTURAL FORMULA	I.U.P.A.C. NAME
$C_2H_4O_2$		methyl methanoate
$C_3H_6O_2$		methyl ethanoate
$C_3H_6O_2$		ethyl methanoate
$C_4H_8O_2$		methyl propanoate
$C_4H_8O_2$		ethyl ethanoate
$C_4H_8O_2$		propyl methanoate

FATS AND OILS (naturally occurring esters)

Animal fats and vegetable oils are examples of naturally occurring esters derived from the alcohol **GLYCEROL** which should be more correctly referred to as propan-1,2,3-triol.

i.e. GLYCEROL is:



Fats and oils are the esters formed when this alcohol (glycerol) undergoes esterification with a long carbon chain carboxylic acid called a **FATTY ACID.**

(i) If the fatty acid is a ***saturated*** fatty acid (only single C–C bonds in the chain) such as:

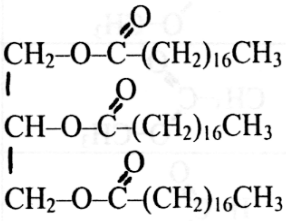
STEARIC ACID:

$$CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2COOH$$

i.e. $CH_3(CH_2)_{16}COOH$

then the ester will be a "**triglyceride saturated fat**" and will be typically associated with animal growth.

e.g.



(A TYPICAL ANIMAL FAT)

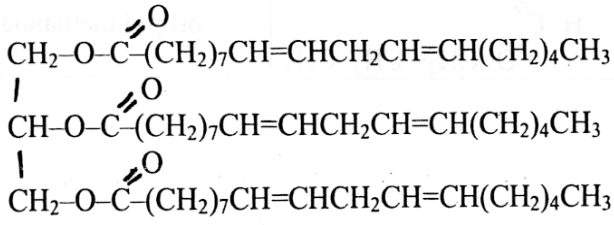
(ii) If the fatty acid is a ***polyunsaturated*** fatty acid (several C=C bonds in the chain) such as:

LINOLEIC ACID:

$$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$$

then the ester will be a "triglyceride polyunsaturated oil" and will be typically associated with plant growth.

e.g.



(A TYPICAL VEGETABLE OIL)

QUESTIONS ON ESTERS:
Note that where answers require structures, these have been given in simplified form.

Q1. A pure organic compound has the chemical formula $C_2H_4O_2$ and gives a neutral pH test. The compound has a fruity odour and does not react with sodium metal.
What are the likely structure and name of this compound? **(methyl methanoate)**

Q2. What is the IUPAC name for the compound formed when ethanol is reacted with pentanoic acid? **(ethyl pentanoate)**

Q3. A pure organic compound has the ***empirical*** formula $C_2H_4O_1$. The compound has a fruity odour, does not react with sodium metal and has a $M_r = 88.0$
When hydrolysed, the compound decomposes and one of the products is propanol.
(i) What is the compound's molecular formula? **($C_4H_8O_2$)**
(ii) What is the compound's systematic name? **(propyl methanoate)**
(iii) What is the compound's structure? **($HCOOCH_2CH_2CH_3$)**

Q4. Compounds X and Y both have the chemical formula $C_3H_6O_2$. An aqueous solution of compound X gives a pH of 3.4 whereas an aqueous solution of compound Y gives a pH of 7.0.
(i) What is the likely name and structure for compound X? **(CH_3CH_2COOH) (propanoic acid)**
(ii) What are two possible names and structures for compound Y?
(methyl ethanoate CH_3COOCH_3 and ethyl methanoate $HCOOCH_2CH_3$)

Q5. The ester $C_8H_{16}O_2$ is hydrolysed in the presence of a catalyst to produce the two organic compounds A and B. Compound B can be oxidised using excess H^+/MnO_4^- to produce compound A. Identify compounds A and B and hence the original ester.
(A = butanoic acid, B = butan-1-ol and the ester was butyl butanoate)

Q6. An ester contains 31.4% oxygen by mass. What is its molecular formula?
(HINT: let the ester be $C_nH_{2n}O_2$ and hence its M_r will be $(12n + 2n + 32) = (14n + 32)$
($C_5H_{10}O_2$)

Q7. Give the names of at least 4 isomeric esters having the chemical formula $C_5H_{10}O_2$.
(methyl butanoate, ethyl propanoate, propyl ethanoate, butyl methanoate, …..)

Q8. A pure ester X is analysed gravimetrically by burning 1.76 g of the ester in air. The products of the complete combustion were 3.52 g of carbon dioxide and 1.44 g of water. Find the empirical formula and hence the chemical formula for the ester X.
(empirical $C_2H_4O_1$) (molecular $C_4H_8O_2$)

Q9. Using structural formulae, write balanced equations for the esterification reaction occurring between (i) ethanol and hexanoic acid (ii) hexan-1-ol and ethanoic acid. Systematically name the ester formed in each case.

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16. AROMATIC COMPOUNDS (e.g. BENZENE)

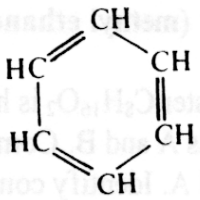
Aromatic compounds are unusual organic compounds as they have covalent bonding between carbon atoms that is neither true single(C–C) nor true double(C=C) bonding.
For our discussion on aromatic compounds we will focus on the compound *benzene* which is a typical example of this unexpected bonding state.

BENZENE:

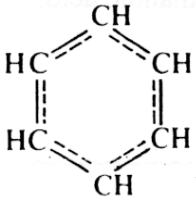
- a colourless, volatile, flammable liquid
- empirical formula C_1H_1
- M_r of benzene = 78.0
- molecular formula C_6H_6
- all carbon/carbon bond lengths are the same
- spectral details indicate that it has a flat ring structure
- it does not undergo a rapid addition reaction with Br_2; thus no C=C bonds present

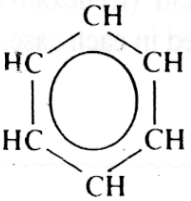
STRUCTURE:

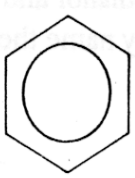
(i) Originally, chemists suggested that the benzene ring involved alternating single and double bonds such as is shown to the right.
This structure had to be rejected because it would indicate that benzene was an unsaturated compound and should undergo many addition reactions but it doesn't unless severe conditions are used.



(ii) The present day view is that the benzene molecule is a hexagonal ring with the bonds between adjacent carbon atoms being intermediate between single and double bonds.
i.e. not true single or double bonds but 1½ bonds!
There are six single bonds between the carbon atoms with 6 delocalised electrons around the ring.
The structure can be represented by any of the following in which the dotted line or circle is used to represent the delocalised electrons.
The third representation is used most frequently even though the H atoms aren't even shown!

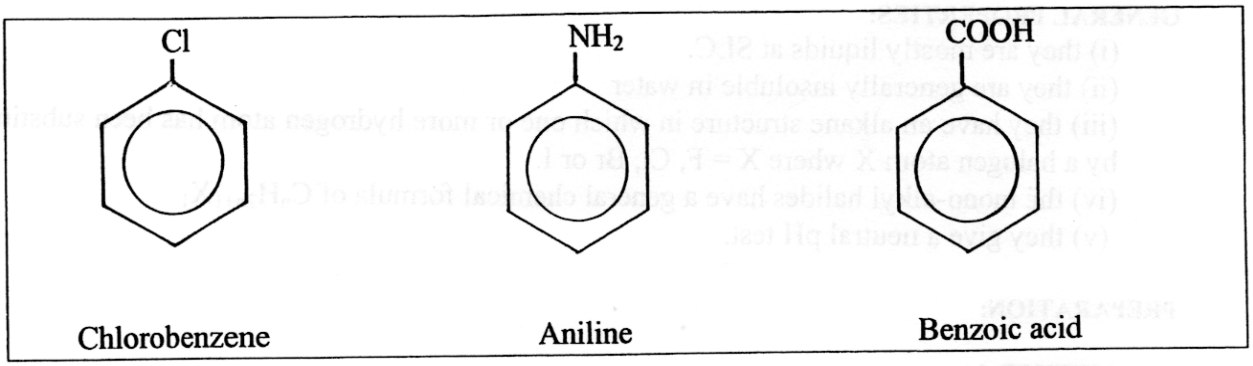


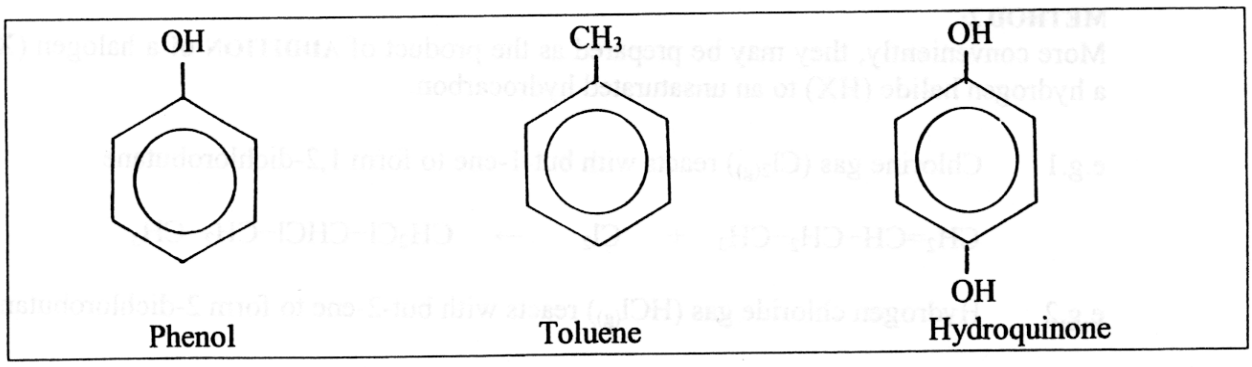


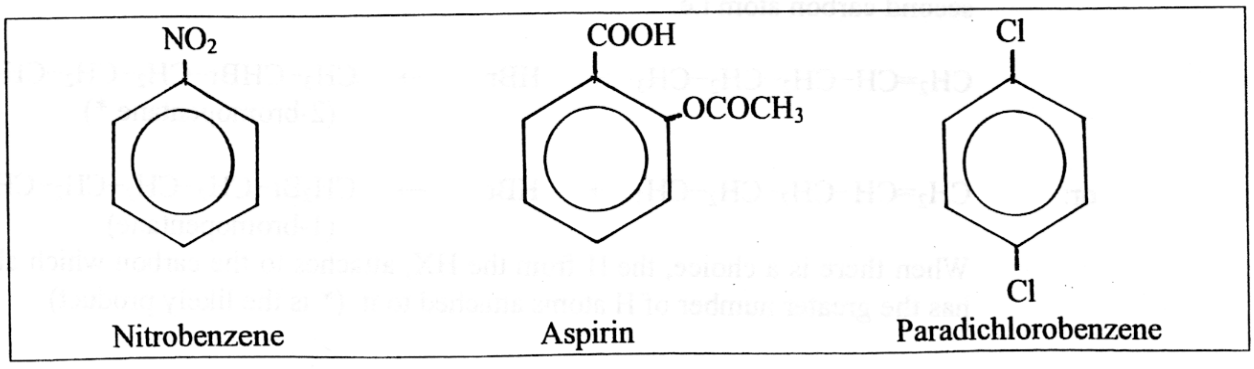


REACTIONS OF BENZENE:

The vast majority of benzene's reactions involve **SUBSTITUTION** reactions where one or more
of the six hydrogen atoms attached to the ring are replaced by other atoms or groups of atoms.
Some of the possible products of benzene substitution reactions are shown below.







17. ALKYL HALIDES:

Alkyl halides are a family (or **HOMOLOGOUS SERIES**) of similar organic compounds identified by each having one or more halogen atom (F, Cl, Br or I) attached to a carbon chain.
They are sometimes referred to as **HALOALKANES**.

GENERAL PROPERTIES:

(i) they are mostly liquids at SLC.
(ii) they are generally insoluble in water
(iii) they have an alkane structure in which one or more hydrogen atom has been substituted by a halogen atom X where X = F, Cl, Br or I.
(iv) the mono-alkyl halides have a general chemical formula of $C_nH_{2n+1}X_1$
(v) they give a neutral pH test.

PREPARATION:

METHOD 1:
They may be prepared as one of the products of a slow **SUBSTITUTION** reaction between a saturated hydrocarbon and a halogen (X_2) in the presence of U.V. light.

e.g. $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$

METHOD 2:
More conveniently, they may be prepared as the product of **ADDITION** of a halogen (X_2) or a hydrogen halide (HX) to an unsaturated hydrocarbon.

e.g.1 Chlorine gas ($Cl_{2(g)}$) reacts with but-1-ene to form 1,2-dichlorobutane

$CH_2{=}CH{-}CH_2{-}CH_3 + Cl_2 \rightarrow CH_2Cl{-}CHCl{-}CH_2{-}CH_3$

e.g.2 Hydrogen chloride gas ($HCl_{(g)}$) reacts with but-2-ene to form 2-dichlorobutane.

$CH_3{-}CH{=}CH{-}CH_3 + HCl \rightarrow CH_3{-}CHCl{-}CH_2{-}CH_3$

e.g.3 When hydrogen bromide gas ($HBr_{(g)}$) reacts with an alkene like pent-1-ene there are two possible products depending upon whether the Br attaches to the first or second carbon atom i.e.

$CH_2{=}CH{-}CH_2{-}CH_2{-}CH_3 + HBr \rightarrow CH_3{-}CHBr{-}CH_2{-}CH_2{-}CH_3$
(2-bromopentane *)

or: $CH_2{=}CH{-}CH_2{-}CH_2{-}CH_3 + HBr \rightarrow CH_2Br{-}CH_2{-}CH_2{-}CH_2{-}CH_3$
(1-bromopentane)

When there is a choice, the H from the HX, attaches to the carbon which already has the greater number of H atoms attached to it. (* is the likely product)

REACTIONS OF ALKYL HALIDES:

There are only 3 possible reactions of alkyl halides that you have to be familiar with for this chemistry course.

1. **alkyl halides react with AQUEOUS sodium hydroxide to form an alcohol. In these reactions, the halogen atom is SUBSTITUTED by an OH group. This procedure may be used to prepare primary, secondary or tertiary alcohols.**

   e.g.

   $$CH_3-\overset{H}{\underset{Cl}{C}}-CH_2-CH_3 + NaOH_{(aq)} \rightarrow CH_3-\overset{H}{\underset{OH}{C}}-CH_2-CH_3 + NaCl_{(aq)}$$

   (2-chlorobutane) **(butan-2-ol)**

2. **alkyl halides react with sodium hydroxide in ethanol to form an alkene. This called an ELIMINATION reaction.**

   e.g.

   $$CH_3-\overset{Cl}{CH}-CH_3 + NaOH_{(eth)} \rightarrow CH_2{=}CH-CH_3 + NaCl + H_2O$$

   (2-chloropropane) **(propene)**

3. **alkyl halides react with ammonia to form an amine.**

   e.g.

   $$CH_3-CH_2-CH_2Cl + NH_3 \rightarrow CH_3-CH_2-CH_2NH_2 + HCl$$

QUESTIONS ON ALKYL HALIDES:

Q1. Using structural formulae and systematic names, write the chemical equations for the following reactions:

(i) ethene reacts with fluorine. (ii) propene reacts with chlorine.

(iii) but-1-ene reacts with iodine. (iv) propyne reacts with ***excess*** fluorine.

(v) hex-3-ene reacts with HF. (v) methane reacts with I_2.

(vi) hex-1-ene reacts with hydrogen iodide. (show two possible products)

Q2. How would you prepare:

(i) 2,3-dibromopentane?

(ii) (ii) 2-fluoropropane?

Q3. Ethane gas (CH_3-CH_3) reacts extremely slowly with chlorine gas ($Cl_{2(g)}$) at room temperature and pressure.

(i) What type of reaction is this?

In the presence of U.V. light, this reaction is considerably faster.

(ii) Explain why the U.V. light makes this reaction faster.

If excess chlorine is reacted with ethane in the presence of U.V. light, there are 5 possible alkyl halide products.

(iii) Give the structures and IUPAC names for the five possible alkyl halides formed.

Q4. Starting with but-1-ene, how could you firstly synthesise (make)

(i) 2-chlorobutane and then synthesis (ii) butan-2-ol?

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18. AMINES:

Amines are a family (or **HOMOLOGOUS SERIES**) of similar organic compounds identified by each having a nitrogen atom attached to a carbon chain or ring.
They are derived from ammonia (NH_3) where one or more of the hydrogen atoms has been replaced by a alkyl(carbon chain) or aryl (carbon ring) group .
The amines are classified as primary, secondary or tertiary depending upon whether one, two or three H atoms in ammonia have been substituted by an alkyl or aryl group(R)

e.g. $R-NH_2$ (primary) $R-NH-R'$ (secondary) $R-\overset{\displaystyle R'}{\underset{|}{N}}-R''$ (tertiary)

For this course you need only be familiar with some of the simplest amines where R is either a methyl group or an ethyl group or a phenyl(benzene ring) group

NAMING AMINES:
The name is given by stating the name of the alkyl or aryl group attached to the nitrogen followed by the group term "amine" all as one word.

e.g. CH_3-NH_2 would be called methylamine
$CH_3-CH_2-NH_2$ would be called ethylamine
$(CH_3)_2NH$ would be called dimethylamine
$(CH_3)_3N$ would be called trimethylamine


$-NH_2$ would be called phenylamine or 'aniline'

GENERAL PROPERTIES:
(i) they are mostly gases or liquids at SLC.
(ii) they are reasonably soluble in water.
(iii) their aqueous solutions give an alkaline pH test (pH > 7)
(iv) they are weak bases as shown by their dissociation constants.
e.g.

$$CH_3NH_2 + H_2O \rightleftharpoons CH_3NH_3^+ + OH^-$$

$$K_B = \frac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2]} = 4.2 \times 10^{-4}$$

PREPARATION:
(i) Reaction of an alkyl halide with ammonia.
e.g.

$$CH_3CH_2Cl + 2NH_3 \rightarrow CH_3CH_2NH_2 + NH_4Cl$$

(ii) Reaction of an alkyl cyanide with hydrogen.
e.g.

$$CH_3CH_2CN + 2H_2 \rightarrow CH_3CH_2CH_2NH_2$$

19. HYDROGEN BONDING

When hydrogen atoms are bonded to a highly electronegative element such as oxygen, fluorine or nitrogen, the covalent bond formed does not involve an ***equal*** sharing of the electron pair.

The electrons are drawn nearer the electronegative element (O, F or N) making the bond a **POLAR COVALENT BOND**.

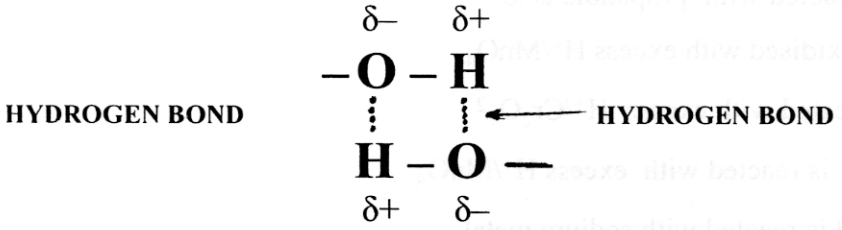
This means that the bond has a distinctively positive end ($\delta+$) and a distinctively negative end ($\delta-$). (This means that the bond has a slight IONIC character)

In the organic chemistry unit studied this year we are particularly interested in the effect that the polar covalent O–H bond has on the properties of alcohols and carboxylic acids.
e.g. consider the O–H bond.

O: H results in the polarity **$\overleftarrow{-O-H}$** or **$\overset{\delta-}{-O}-\overset{\delta+}{H}$**

UNEQUAL SHARING

This means that molecules which include O–H groups (especially alcohols and carboxylic acids) will have significant intermolecular attractive forces between them due to the opposite poles of the bond attracting each other.



These attractive forces are called **HYDROGEN BONDS (shown above as ".....")**

NOTES:

(i) Hydrogen bonds are much stronger than van der Waal's forces and result in molecules such as alcohols having strong intermolecular attractive forces. These stronger intermolecular forces ("hydrogen bonds") result in alcohols and carboxylic acids having higher melting points and boiling points than other similar sized molecules not possessing the O–H groups.

HYDROGEN BONDING (continued)

(ii) H–bonding also explains the water solubility of organic compounds possessing O–H groups. This is because water also has O–H groups which attract the O–H groups on the alcohol or carboxylic acid. Remember the water molecule is H–O–H

e.g. CH_3Cl is insoluble in water but CH_3OH is soluble in water.
$CH_3COOC_3H_7$ is insoluble in water but CH_3COOH is soluble in water.

(iii) The larger the organic molecule the ***less*** the solubility in water.

e.g. CH_3COOH is soluble in water but $C_{10}H_{21}COOH$ is insoluble in water.
As the carbon chain increases in length (e.g. from ethanoic acid to decanoic acid) the effects of hydrogen bonding between O–H groups become less significant due to a greater proportion of the molecule being well separated from the O–H group.

20. REVISION QUESTIONS

Q1. Give the structural formula and systematic name(s) for the organic product(s) formed (if any) when each of the following reactions occurs. **No equations are expected**.

(i) butan-1-ol is reacted with propanoic acid

(ii) methanol is oxidised with excess H^+/MnO_4^-

(iii) pentanal is treated with excess $H^+/Cr_2O_7^{2-}$

(iv) ethanoic acid is reacted with excess H^+/MnO_4^-

(v) propanoic acid is reacted with sodium metal

(vi) hexanoic acid is reduced with excess reducing agent (H^+/Zn)

(vii) ethyl methanoate is hydrolysed in the presence of a catalyst.

Q2. The pure organic compound X (molecular formula $C_5H_{12}O$) undergoes a reaction with sodium metal releasing a flammable gas. Compound X has an **unbranched** carbon chain.

(i) When X is reacted with excess acidified potassium permanganate, compound Y (molecular formula $C_5H_{10}O_2$) is the only organic product.

(ii) When X is reacted with acidified potassium dichromate, compound Z (molecular formula $C_5H_{10}O$) is the organic product.

Deduce the structures and names for X, Y and Z. Give your reasons.

Q3. (i) Write and balance the equation for the oxidation of pentanal using acidified potassium dichromate solution. In your equation use molecular formulae and do not show spectator ions.
(ii) Would the products have been different if acidified potassium permanganate had been used as the oxidising agent? Explain.

Q4. The pure liquid organic compound **X** is analysed and the results are summarised below:

(i) **X** is a monofunctional, saturated compound having a fruity odour.

(ii) **X** has the molecular formula $C_6H_{12}O_2$

(iii) **X** does not react with sodium metal.

(iv) When **X** is hydrolysed with a suitable catalyst, **W** and **Z** are the two organic products.

(v) **W** can be oxidised with excess oxidant to produce **Z**.

Use this information to find
(a) the structural formula for **X** (give the correct name)

(b) the structural formula for **W** (give the correct name)

(c) the structural formula for **Z** (give the correct name)

Q5. Suggest a suitable **laboratory test** that coud be used to distinguish between:
(no equations need be given) **NB**. "smell" is not an appropriate test!
(a) ethanol and ethanal
(b) 2-methylpropan-1-ol and 2-methylpropan-2-ol
(c) methyl butanoate and butanoic acid
(d) methylamine and methanal
(e) propan-1-ol and propan-2-ol
(f) butan-2-ol and butanone
(g) cyclohexene and benzene
(h) propanone and propanal.

Q6. Explain the difference between the terms ‘polyunsaturated triglyceride oil’ and ‘saturated triglyceride fat’ in terms of how they are:
(i) formed
(ii) how they might be distinguished in terms of differing chemical reactivity.

Q7. Using an alkene as one of the reactants, how would you prepare:
(i) 1,2-dichloropentane?
(ii) 2,3-difluoroheptane?
(iii) 2-iodoethane?

Q8. Butane gas (C_4H_{10}) reacts extremely slowly with chlorine gas ($Cl_{2(g)}$) at room temperature and pressure.

(i) What type of reaction is this?

In the presence of U.V. light, this reaction is considerably faster.

(ii) Explain why the U.V. light makes this reaction considerably faster.

(iii) Give the structures and IUPAC names for a possible alkyl halide formed.

Q9. Starting with ethene, how could you synthesise (make)

(i) chloroethane

(ii) ethanol using the chloroethane?

(iii) ethanamine using the chloroethane?

Q10. The pure organic compound X (molecular formula $C_4H_{10}O$) undergoes a reaction with sodium metal releasing a flammable gas. Compound X has an **unbranched** carbon chain.

(i) When X is reacted with excess acidified potassium permanganate, compound Y (molecular formula $C_4H_8O_2$) is the only organic product.

(ii) When X is reacted with acidified potassium dichromate, compound Z (molecular formula C_4H_8O) is the product.

(a) Give the structures and names for X, Y and Z.

(b) Write a balanced chemical equation for the reaction in which X is converted into Y. (use molecular formulae in the equation)

Q11. A monofunctional carboxylic acid (contains only one functional group) has the molecular formula $C_8H_8O_2$. The compound does not undergo a rapid decolourising reaction with bromine. What are three possible **structural formulae** for this acid? (names are not required)

(HINT: the carboxylic acid is an aromatic compound)

Q12. The organic compound $C_4H_8O_2$ does not have appreciable solubility in water. Is the compound likely to be a carboxylic acid? Explain in terms of hydrogen bonding.

Q13. Which of the following pairs is likely to be more soluble in water:

(i) decan-1-ol or decanal?

(ii) decan-1-ol or butan-1-ol?

(iii) decanoic acid or butanoic acid?

Carefully explain your answers in terms of structure and intermolecular forces.

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NAME.....

ORGANIC - FUNCTIONAL GROUPS
END OF UNIT TEST

TOTAL = 34 marks

Q1. Give the structural formula and systematic name(s) for the organic product(s) formed (if any) when each of the following reactions occurs. **No equations are expected**.

(i) ethanol is reacted with sodium metal

(ii) pentan-3-ol is oxidised with excess H^+/MnO_4^-

(iii) propanal is treated with excess $H^+/Cr_2O_7^{2-}$

(iv) ethanoic acid is reacted with hexan-1-ol

(v) pentanoic acid is reacted with sodium metal

(vi) butanone is reduced with excess reducing agent (H^+/Zn)

(12 marks)

Q2. Three different organic compounds A, B and C are isomeric having the same molecular formula $C_4H_{10}O_1$. Their properties are as follows:

(i) They all react with sodium metal to release a flammable gas.
(ii) B doesn't undergo any reaction with acidified $K_2Cr_2O_7$ but A and C do.
(iii) A reacts with excess acidified $KMnO_4$ to form a compound $C_4H_8O_1$
(iv) C reacts with excess acidified $KMnO_4$ to form a compound $C_4H_8O_2$

Give possible structural formulae and systematic names that could correspond to compounds A, B and C.
Give reasons for your choices. (6 marks)

COMPOUND	STRUCTURE	NAME	REASONS
A			
B			
C			

Q3. Write and balance the equation for the oxidation of methanol using excess acidified potassium permanganate solution. In your equation use molecular formulae and do not show spectator ions. Identify the product by giving its IUPAC name.

(4 marks)

Q4. A 5.00 g sample of the pure compound **X** undergoes complete combustion in air producing 11.38 g of CO_2 and 4.66 g of H_2O.

Compound X has a molar mass between 100 and 120 and resists oxidation. X does not react with sodium metal. When X is hydrolysed with a suitable catalyst, one of the products is butan-1-ol.

(i) Find the empirical formula and molecular formula for X.

(ii) Give the structural formula for X and its systematic name.

(8 marks)

Q5. Suggest a suitable **laboratory test** that coud be used to distinguish between: (no equations need be given) **NB**. "smell" is not an appropriate test!

(4 marks)

(a) hexanol and hexanal

(b) butanone and butanal

(c) ethylpropanoate and propanoic acid

(d) butan-1-ol and butan-2-ol

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END OF UNIT TEST - ANSWERS

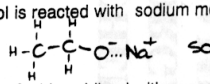
NAME ANSWERS

ORGANIC FUNCTIONAL GROUPS TEST

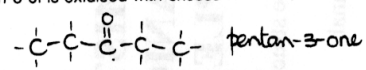
TOTAL = 34 marks

1. Give the structural formula and systematic name(s) for the organic product(s) formed (if any) when each of the following reactions occurs. **No equations are expected.**

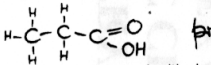
(i) ethanol is reacted with sodium metal



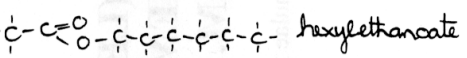
(ii) pentan-3-ol is oxidised with excess H^+/MnO_4^{1-}



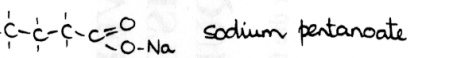
(iii) propanal is treated with excess $H^+/Cr_2O_7^{2-}$



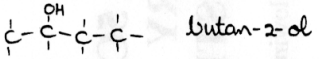
(iv) ethanoic acid is reacted with hexan-1-ol



(v) pentanoic acid is reacted with sodium metal



(vi) butanone is reduced with excess reducing agent (H+/Zn)

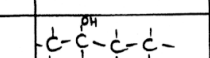
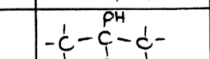
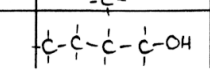


(12 marks)

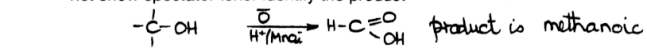
2. Three different organic compounds A, B and C are isomeric having the same molecular formula $C_4H_{10}O_1$. Their properties are as follows:

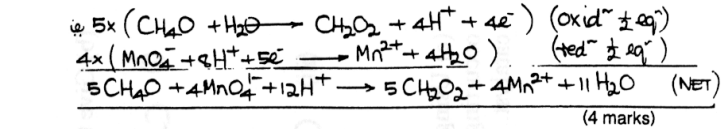
(i) They all react with sodium metal to release a flammable gas.
(ii) B doesn't undergo any reaction with acidified $K_2Cr_2O_7$ but A and C do.
(iii) A reacts with excess acidified $KMnO_4$ to form a compound $C_4H_8O_1$
(iv) C reacts with excess acidified $KMnO_4$ to form a compound $C_4H_8O_2$

Give possible structural formulae and systematic names that could correspond to compounds A, B and C.
Give reasons for your choices. (6 marks)

COMPOUND	STRUCTURE	NAME	REASONS all are alcohols
A		butan-2-ol	oxidised to give a ketone $C_4H_8O_1$
B		2-methylpropan-2-ol	resists oxidation
C		butan-1-ol	oxidises to give carboxylic acid $C_4H_8O_2$

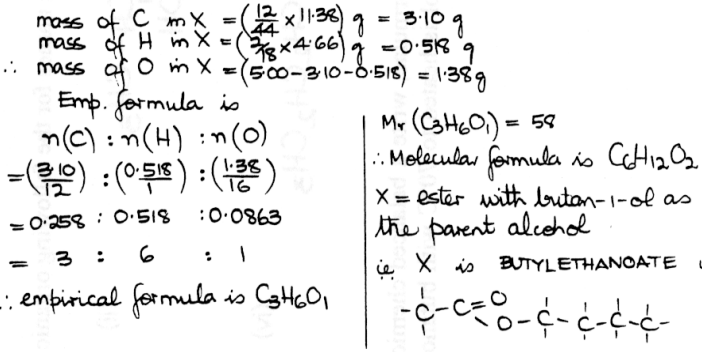
3. Write and balance the equation for the oxidation of methanol using excess acidified potassium permanganate solution. In your equation use molecular formulae and do not show spectator ions. Identify the product





(4 marks)

4. A 5.00 g sample of the pure compound **X** undergoes complete combustion in air producing 11.38 g of CO_2 and 4.66 g of H_2O.
Compound X has a molar mass between 100 and 120 and resists oxidation. X does not react with sodium metal. When X is hydrolysed with a suitable catalyst, one of the products is butan-1-ol.
(i) Find the emprical formula and molecular formula for X.
(ii) Give the structural formula for X and its systematic name.



(8 marks)

5. Suggest a suitable **laboratory test** that could be used to distinguish between: (no equations need be given) **NB.** "smell" is not an appropriate test! (4 marks)

(a) hexanol and hexanal

React with Na metal: Hexanol will release H_2 gas, hexanal doesn't.

(b) butanone and butanal

Oxidise with H^+/MnO_4^{1-}. Butanal is oxidised, butanone is not.

(c) ethylpropanoate and propanoic acid

pH test: propanoic acid (aq) gives ACID test (pH < 7)

(d) butan-1-ol and butan-2-ol

butan-1-ol will be oxidised to produce an acidic product (pH test)
but butan-2-ol is oxidised to produce a neutral ketone.

CHEMISTRY (LEVEL 3C)

ORGANIC CHEMISTRY

IDENTIFICATION OF (SOME*) FUNCTIONAL GROUPS:

* ALCOHOLS
C. ACIDS
ESTERS
ALDEHYDES
KETONES