5.1 Organic compounds

Summary Notes

Crude oil is a naturally occurring liquid which consists mainly of hydrocarbons. Crude oil is separated into useful fractions in a process called fractional distillation. Fractional distillation sperate fractions according to their boiling points.
Eg: Gasoline fraction: as a fuel for cars, naphtha fraction: used to make chemicals

Hydrocarbons
Compounds containing carbon and hydrogen only.

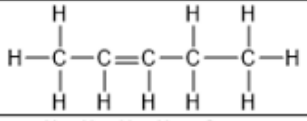
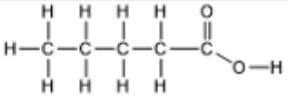
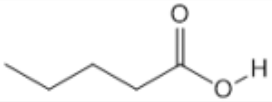
(i) **Saturated hydrocarbons:** contain carbon-carbon single bonds.
Eg: alkanes, cycloalkanes
(ii) **Unsaturated hydrocarbons:** contain carbon-carbon double bonds, triple bonds or both.
Eg: alkenes, alkynes
(iii) **Aromatic hydrocarbons**- a special type of cyclic compounds with alternating single and double bonds.
Eg: benzene

IUPAC Organic Nomenclature

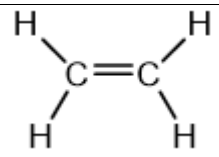
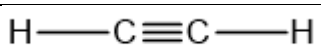
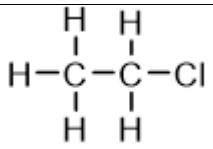
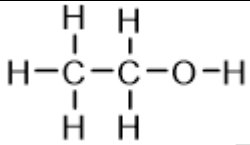
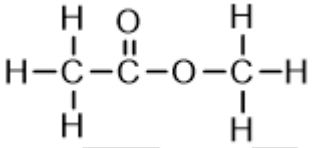
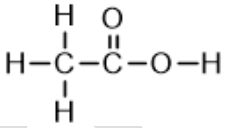
Number of C atoms	1	2	3	4	5	6	7	8
Prefix	meth	eth	prop	but	pent	hex	hept	oct

Homologous series
A group of compounds with similar chemical properties and same general formula and adjacent members differs from the each other by a by CH_2 group.

Ways to represent organic molecules

Name	Molecular formula	Structural formula	Semi structural (condensed) formula	Skeletal formula
Pent-2-ene	C_5H_{10}		$CH_3CH{=}CHCH_2CH_3$	
Pentanoic acid	$C_5H_{10}O_2$		$CH_3CH_2CH_2CH_2COOH$	

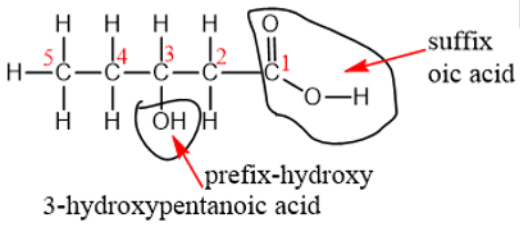
Functional groups

Homologous series	Name of the functional group	Structure of an example	Semi-structural formula for an example	Naming convention
Alkenes	Carbon-carbon double bond		$CH_2{=}CH_2$	Suffix-ene
Alkynes	Carbon-carbon triple bond		$CH{\equiv}CH$	Suffix-yne
Halo alkanes	halo		CH_3CH_2Cl	prefix-fluoro, chloro, bromo
Alcohols	Hydroxyl		CH_3CH_2OH	Suffix-ol prefix-hydroxy
Esters	Ester		CH_3COOCH_3	Suffixes – yl and oate
Carboxylic acids	carboxyl		CH_3COOH	Suffix-oic acid

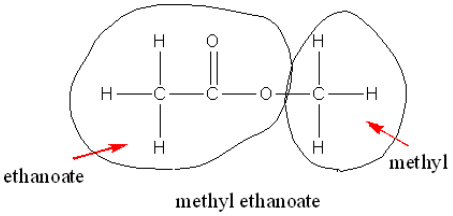
The priority order of functional groups

Carboxyl hydroxyl alkene alkyne halo

highest priority *lowest priority*



3-hydroxypentanoic acid



methyl ethanoate

Multiple Choice Questions

Question 1

Which of the following compounds can be found in crude oil?

A. methane B. propane C. octane D. all A, B & C

Question 2

Which of the following statements about fractional distillation is **incorrect**?

A. fractional distillation separate compounds according to their boiling points

B. heavier fractions can be obtained from the bottom of the fractionating column

C. heavier fractions can be obtained from the top of the fractionating column

D. fraction with a greater boiling point can be obtained from the bottom of the column

Question 3

Which of the following lists of compounds shows only unsaturated hydrocarbons?

A. ethane, propene, butyne
B. ethene, ethyne, butene
B. benzene, hexane, hexane
D. pentene, pentyne, pentane

Question 4

Which of the following lists of compounds belongs to the same homologous series?

A. ethene, propene, butene
B. ethane, ethene, ethyne
C. ethane, propene, butyne
D. none of the above

Question 5

The third member of the alkene homologous series is,

A. propene B. propyne C. butene D. butyne

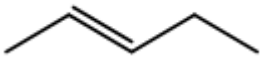
Question 6

The empirical, molecular and semistructural formula of propanoic acid is,

	Empirical formula	Molecular formula	Semistructural formula
A	CHO	$C_3H_6O_2$	CH_3CH_2COOH
B	CHO	$C_3H_8O_2$	CH_3CH_2COOH
C	$C_3H_6O_2$	$C_6H_{12}O_4$	$CH_3(CH_2)_4COOH$
D	$C_3H_6O_2$	$C_3H_6O_2$	CH_3CH_2COOH

Question 7

The systematic name and the semi-structural formula of the molecule shown is,



A. pentene and $CH_3CH=CHCH_2CH_3$
B. pent-2-ene and $CH_3CH_2CH_2CH_2CH_3$
C. pent-3-ene and $CH_3CH=CHCH_2CH_3$
D. pent-2-ene and $CH_3CH=CHCH_2CH_3$

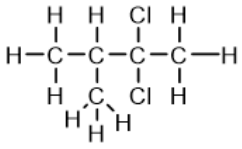
Question 8

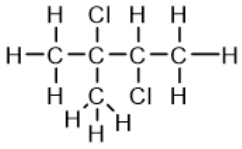
The molecular and semi-structural formula of 2-methylbutane is,

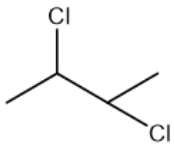
	Molecular formula	Semi-structural formula
A	C_4H_{10}	$CH_3CH(CH_3)CH_2CH_3$
B	C_5H_{12}	$CH_3CH(CH_3)CH_2CH_3$
C	C_5H_{12}	$CH_3(CH_2)_3CH_3$
D	C_4H_{10}	$CH_3(CH_2)_2CH_3$

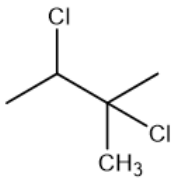
Question 9

The correct structural formula of 2,3-dichloro-2-methylbutane is,

A


B


C


D


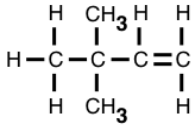
Question 10

Compounds from the same homologous series do **not** have,

A. same boiling points
B. similar chemical properties
C. same general formula
D. pattern to their boiling points

Question 11

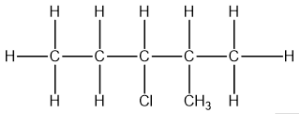
The compound shown below is,



A. hexene B. 2,2-dimethylbut-3-ene C. 3,3-dimethylbut-1-ene D. 2,2-dimethylbut-1-ene

Question 12

The compound shown below is,



A. 3-chloro-2-methylpentane
B. 3-chloro-2-methylpentene
C. 2-chloro-3-methylpentane
D. 3-chloro-3-methylpentane

Question 13

What is correct about structural isomers?

A. they have same molecular formula
B. they have the same semi-structural formula
B. they have same structural formula
D. none of A, B & C

Question 14

Number of structural isomers exist for C_4H_{10} is,

A. 1 B. 2 C. 3 D.4

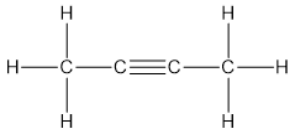
Question 15

Structural isomers of C_5H_{12} have,

A. similar chemical properties
B. similar physical properties
C. same boiling point
D. equal strength of dispersion forces between the chains

Question 16

The molecule shown below is,



A. bytyne B. but-1-yne C. but-2-yne D. but-3-yne

Question 17

Which of the following is true about the physical properties of alkanes?

A. they are insoluble in water
B. their boiling points increase with the number of carbon atoms
C. their viscosity increases with the number of carbon atoms
D. all A, B & C

Question 18

The most volatile hydrocarbon is,

A. propane B. butane C. pentane D. octane

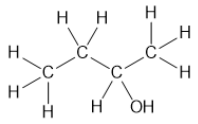
Question 19

Number of alcohol isomers exist for the formula, $C_4H_{10}O$ is,

A. 2 B. 3 C. 4 D.5

Question 20

The molecule shown below is,



A. methylpropan-2-ol B. butanol C. butanoic acid D. butan-2-ol

Question 21

Which of the following statements is **incorrect** about the physical properties of alcohols?

A. they have higher boiling points than those of alkanes with similar molar mass

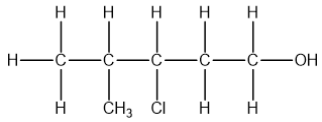
B. boiling points of alcohols increase with the number of carbon atoms

C. smaller alcohols are soluble in water

D. they have higher boiling points than those of carboxylic acids with a similar molar mass

Question 22

The compound shown below is,



A. 3-chloro-4-methylpentan-1-ol B. 3-chloro-2-methylpentan-5-ol

C. 3-chloro-4-methylpentanoic acid D. 3-chloro-2-methylpentan-1-ol

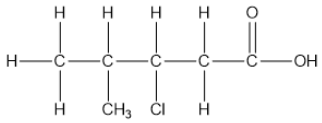
Question 23

The semi-structural formula of propanoic acid is,

A. $C_3H_6O_2$ B. CH_3CH_2COOH C. CH_3COOH D. C_3H_8O

Question 24

Molecule shown below is,



A. 3-chloro-4-methylpentanoic acid B. 3-chloro-2-methylpentanoic acid

C. 3-chloro-4-methyl-1-pentanoic acid D. 3-chloro-2-methyl-5-pentanoic acid

Question 25

Which of the following statements is **incorrect** about carboxylic acids?

A. they have higher boiling points than those of alcohols with similar molar mass

B. boiling points of carboxylic acids increase with the number of carbon atoms

C. smaller carboxylic acids are insoluble in water

D. they can make hydrogen bonds between themselves.

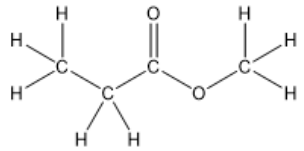
Question 26

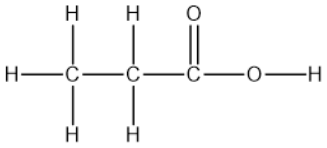
Name of the molecule shown by the semi-structural formula, $HCOOCH_3$ is,

A. ethanoic acid B. methyl ethanoate C. methyl methanoate D. methanoic acid

Question 27

Structural formula of methyl propanoate is,

A. 

B. 

C. $CH_3CH_2COOCH_3$

D. $CH_3COOCH_2CH_2CH_3$

Question 28

How many ester isomers exist for $C_3H_6O_2$?

A. 1 B. 2 C. 3 D.4

Question 29

Which of the following compounds have the highest boiling point?

A. ethane B. ethanol C. ethene D. chloroethane

Question 30

Which of the following compounds have the lowest boiling point?

A. pentane B. 2-methylbutane C. 2,2-dimethylpropane

D. they all have the same boiling point as the number of atoms they have are the same

Question 31

Which of the following compounds have the highest boiling point?

A. ethanol B. ethanoic acid C. ethane

D. they all have the same boiling point as they all have two carbon atoms

Question 32

which of the following compounds have the highest solubility in water?

A. ethane B. ethanol C. chloroethane D. ethene

Question 33

The reaction of ethane with chlorine in the presence of UV light produces

A. chloroethane B. chloroethene

C. chloroethane and hydrogen chloride gas D. chloroethene and hydrogen chloride gas

Question 34

The product of the reaction below is,

$CH_3CH=CHCH_3 + Br_2 \rightarrow$

A. $CH_2BrCH_2CH_2CH_3$ B. $CH_2BrCH_2CH_2CH_2Br$ C. $CH_3CBr_2CH_2CH_3$ D. $CH_3CHBrCHBrCH_3$

Question 35

The type of reaction given in question 34 is,

A. substitution reaction B. addition reaction C. oxidation reaction D. hydrolysis reaction

Question 36

An organic compound has 54.5% carbon, 9.1% hydrogen and 36.4 % of oxygen. The empirical formula is,

A. C_2H_4O B. C_3H_4O C. C_2H_6O D. $C_2H_4O_2$

Question 37

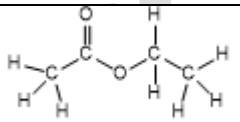
A 0.2800 g sample of an organic compound containing carbon, hydrogen and oxygen undergoes complete combustion to produce 0.536 g of CO_2 and 0.329 g of H_2O. The empirical formula of this compound is,

A. C_2H_6O B. $C_2H_8O_2$ C. C_3H_6O D. $C_2H_5O_2$

Short Answer Questions

Question 1

a. Complete the table below.

Name	Molecular formula	Structural formula	Semi-structural formula
2,3-dimethylpentan-3-ol			
			
			$CH_3CH=CHCH_2Cl$

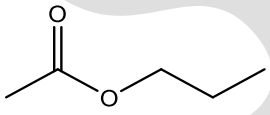
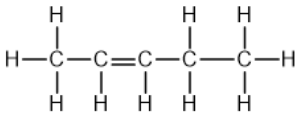
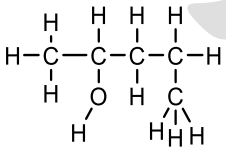
b. To which homologous series the following compounds belongs?

i. chlorobutane ii. propan-2-ol iii. 2-aminobenzoic acid

iv. CH_3COOH v. CH_3CH_2OH vi. $CH_3COOCH_2CH_3$

Question 2

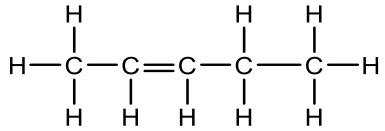
a. Give systematic names of the following compounds.

i.		ii.	
iii.		iv.	$CH_3COOC_4H_9$
v.	CH_2ClCH_2COOH	vi.	$CH_3CH_2CH_2OH$

b. Give names of all the possible isomers of the third members of the following homologous series.

i. alkyne ii. alcohol iii. alkene iv. carboxylic acids

Question 3



a. What are the molecular formula and semi-structural formula of the above compound?
b. Draw a straight chain isomer of the above compound.
c. Name the isomer you did in part b.
d. Name two other isomers of the above compound.

Question 4

Propanoic acid, butan-1-ol, 1-chlorobutane and pentane belong to four different homologous series.
i. Give semi-structural formulas of them.
ii. List the above compounds in order of increasing boiling points? Give reasons for your answer.
iii. Which two compounds from above show the greatest solubility in water? Give reasons for your answer.
iv. Which of the above compounds are highly soluble in hexane?

b. Butane and methylpropane are structural isomers. The boiling point of butane is -5 ^{o}C while boiling point of methylpropane is -12 ^{o}C. Explain the difference in their boiling points?

Question 5

a. Complete the following reactions
i. $C_3H_8 + Cl_2 \rightarrow$ ---------- + ----------
ii. ---------- + HCl $\rightarrow$ C_2H_5Cl
iii. $C_4H_8 + H_2 \rightarrow$ ----------
iv. $C_4H_8 + Br_2 \rightarrow$ ----------
v. $CH_3COOH + C_2H_5OH \rightarrow$ ---------- + ----------

b. Classify the reactions in part a, as substitution, addition and condensation
c. What are the necessary conditions and reagents to carry out reactions in part a, i, iii and v?

Question 6

Give the semi-structural formula of the following compounds.

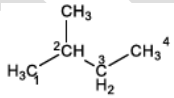
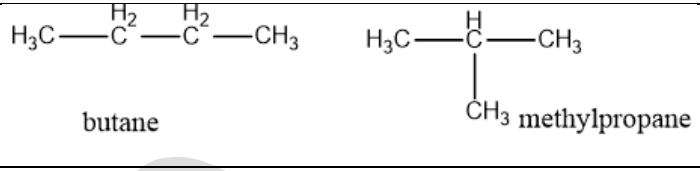
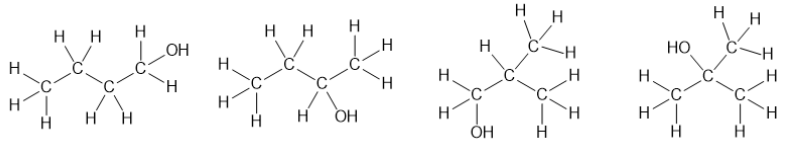
a. 2-chloropentane	b. pentan-3-ol	c. butanoic acid	d. ethyl propanoate
e. pent-2-ene	f. but-1-ene	g. hexane	h. methyl methanoate

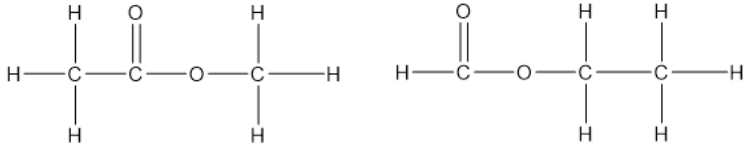
Question 7

a. An organic compound has 66.6% carbon, 11.2% hydrogen and 22.2% oxygen.
i. What is the empirical formula of this compound?
ii. If the molar mass of this compound is 144 g/mol, what is its molecular formula?

b. A 0.350 g sample of an organic compound containing carbon, hydrogen and oxygen undergoes complete combustion to produce 0.513 g of CO_2 and 0.210 g of H_2O.
i. What is the mass of carbon present in this compound?
ii. What is the mass of hydrogen present in this compound?
iii. What is the mass of oxygen present in this compound?
iv. What is the empirical formula of this compound?

Answers for Multiple Choice Questions

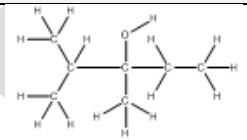
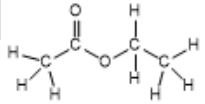
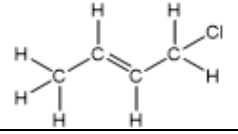
1	D	Crude oil is a naturally occurring liquid which consists mainly of hydrocarbons.
2	C	Different fractions of the crude oil vapour condensed back to liquid at different places in the column depending on their boiling points. The lighter fractions are collected at the top of the column while heavier fractions (greater boiling point) are collected at the bottom of the column.
3	B	Unsaturated hydrocarbons are alkenes, and alkynes and their names end up with the suffixes 'ene' and 'yne' respectively.
4	A	Compounds from the same homologous series have a same general formula, and member differs by the previous by a CH_2 group. They all end up with the same suffix; eth**ene**, prop**ene**, but**ene.**
5	C	The first member of the alkene homologous series is ethene. So, the third member is butene.
6	D	Propanoic acid is a carboxylic acid with three carbon atoms (including the COOH carbon). So, the semi-structural formula is CH_3CH_2COOH. Molecular formula is $C_3H_6O_2$. When you simplify the molecular formula, you get the empirical formula. In this case molecular and the empirical formulas are the same as you cannot simplify the molecular formula.
7	D	Each point in this skeletal formula is a carbon atom. There are 5 carbon atoms, and the double bond is starting at the second carbon atom. Always count from the side to give the lowest possible number to the functional group, in this case the double bond.
8	B	In the semi-structural formula, substituents are shown in brackets. The molecular formula must include all the atoms present. 
9	B	A and B display structural formulas while C and D are skeletal formulas. Chlorine atoms need to be on second and third carbon atoms.
10	A	The boiling points are increasing with the number of carbon atoms.
11	C	Always count from the side to give the lowest possible number to the functional group, in this case, the double bond.
12	A	Count from the side to give the lowest possible numbers to the substituents. Write the names of the substituents in the alphabetical order.
13	A	Structural isomers have the same molecular formula but different semi-structural and structural formula.
14	B	 butane methylpropane
15	A	Isomers of C_5H_{12} have similar chemical properties, but their physical properties such as boiling points are different. Straight chain molecules can pack more closely to one another. The dispersion forces between the molecules are more effective and therefore, require more energy to overcome them.
16	C	The triple bond is starting at the second carbon atom.
17	D	Alkanes are nonpolar molecules, and they are insoluble in polar water. Forces between them are weak dispersion forces, which increase in strength as the size of the molecule increases. Greater the strength of dispersion forces, more energy is required for them to boil. Therefore, boiling points increases with the number of carbon atoms. Longer molecules to become 'tangled' together easily and also make more dispersion forces than the short chain molecules. Therefore, viscosity increases with the number of carbon atoms.
18	A	Volatility is the tendency of a compound to escape into the gas phase. Smaller molecules with less dispersion forces are more volatile than bigger molecules.
19	C	
20	D	The OH group on the second carbon atom so it is 2-ol.
21	D	Hydrogen bonds present between alcohol molecules are stronger than dispersion forces presence between alkanes. So, alcohols have greater boiling points than alkanes of the similar molar masses. However, carboxylic acids can make more hydrogen bonds than alcohols and carboxylic acids, therefore, show greater boiling points. Boiling points of alcohols increase with the number of carbon atoms as bigger molecules can make more dispersion forces. They are soluble in water as they can make hydrogen bonding with water molecules. However, the solubility decreases with increasing the size of the non-polar carbon chain.
22	A	Count from the side to give the lowest number to the carbon atom containing the OH group and write the substituents in the alphabetical order.
23	B	Propanoic acid is a carboxylic acid with 3 carbon atoms. Carboxyl functional group is written as COOH in the semi-structural formula.
24	A	Count from the carboxyl carbon side. Carboxyl group always appear at the end of the chain, and we do not give a number to that.
25	C	Carboxylic acids can make more hydrogen bonds than alcohols and therefore, they show greater boiling points. Boiling points of alcohols increase with the number of carbon atoms as bigger molecules can make more dispersion forces. Carboxylic

		acids are soluble in water as they can make hydrogen bonds with water molecules. However, the solubility decreases with increasing the size of the non-polar carbon chain.
26	C	Esters have COO functional group. The group joined to the O atom is CH_3, so it is methyl. Other side with C=O, has one carbon atom so methanoate.
27	A	The structural formula must show all the bonds. The group joined to the O atom is CH_3, so it is methyl. Other side with C=O, has three carbon atoms so propanoate.
28	B	
29	B	Hydrogen bonds present between ethanol molecules are stronger than dispersion forces (in ethane and ethene) and dipole-dipole interactions (in chloroethane). More energy is needed to overcome these strong forces.
30	C	There are dispersion forces occurring between chains of Pentane, 2-methylbutane and 2,2-dimethylpropane. The strength of dispersion forces between unbranched pentane molecules are stronger than that of highly branched 2,2-dimethylpropane. Weaker the strength of dispersion forces less energy is needed to overcome them.
31	B	Molecules of ethanoic acid can make more hydrogen bonds than ethanol. There are weak dispersion forces between ethane molecules.
32	B	Ethanol can form hydrogen bonds with water.
33	C	$C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$.
34	D	Two bromine atoms will add up to the carbon atoms bearing the double bond.
35	B	Breaking of double bond and adding up atoms or groups of atoms to the carbon atoms bearing the double bond is known as an addition reaction.
36	A	n(C)=54.5/12 = 4.54 mol, n(H)=9.1/1 = 9.1 mol, n(O)=36.4/16 = 2.275 mol n (C: H: O) = 2:4:1
37	A	$n(CO_2)$= 0.536/44 = 0.0122 mol, n(C)= 0.0122 mol, m(C)=0.0122 x 12 = 0.146 g $n(H_2O)$= 0.329/18 = 0.0183 mol, n(H)= 0.0183 x2 = 0.0366 mol, m(H)=0.0366 x 1 = 0.0366 g, m(O) = 0.2800 – (0.146+0.0366) = 0.0974 g, n(O)= 0.0974/16 = 0.0061 mol, n (C: H: O) = 0.0122: 0.0366: 0.0061 = 2:6:1

Answers for Short Answer Questions

Question 1

a.

Name	Molecular formula	Structural formula	Semistructural formula
2,3-dimethylpentan-3-ol	$C_7H_{16}O$		$(CH_3)_2CHC(CH_3)(OH)CH_2CH_3$
Ethyl ethanoate	$C_4H_8O_2$		$CH_3COOCH_2CH_3$
1-chlorobut-2-ene	C_4H_7Cl		$CH_3CH=CHCH_2Cl$

b. i. haloalkanes ii. alcohol iii. carboxylic acids
iv. carboxylic acids v. alcohol vi. ester

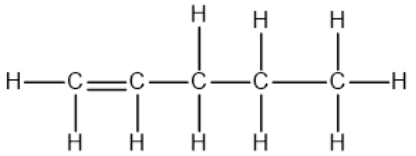
Question 2

a. i. propyl ethanoate ii. pent-2-ene iii. Pentan-2-ol iv. butyl ethanoate
v. 3-chloropropanoic acid vi. Propan-1-ol

b. i. but-1-yne and but-2-yne ii. propan-1-ol, propan-2-ol
iii. but-1-ene, but-2-ene and methylpropene iv. Propanoic acid

Question 3

a. C_5H_{10}, $CH_3CH=CHCH_2CH_3$

b. 

c. pent-1-ene

d. 2-methylbut-1-ene, 3-methylbut-1-ene, 2-methylbut-2-ene

Question 4

a. i. CH_3CH_2COOH, $CH_3CH_2CH_2CH_2OH$, $CH_3CH_2CH_2CH_2Cl$, $CH_3CH_2CH_2CH_2CH_3$

ii. Pentane < 1-chlorobutane < butan-1-ol < propanoic acid.

Pentane is a nonpolar molecule and there are dispersion forces between chains of pentane. Dispersion forces are the weakest of the intermolecular interactions. Therefore, less energy is needed to break the forces between pentane. There are dipole-dipole interactions between chains of 1-chlorobutane and hydrogen bonds between chains of propanoic acid and butan-1-ol. Hydrogen bonds are stronger than dipole-dipole interactions. Propanoic acid can make more hydrogen bonds than butan-1-ol. This makes the boiling point of propanoic acid greater than butan-1-ol.

iii. Propanoic aid and butan-1-ol. They can make hydrogen bonds with water.

iv. Pentane. It is a nonpolar molecule and soluble in nonpolar solvents like hexane.

b. Even though they both have the same number of atoms, butane is a straight chain molecule, and methylpropane is a branched molecule. Straight chain molecules can pack closer together and make stronger dispersion forces than branched molecules. Stronger the forces between molecules more energy is needed to overcome them. So, the boiling point of butane is greater than methylpropane.

Question 5

a. i. $C_3H_8 + Cl_2 \rightarrow \mathbf{C_3H_7Cl} + \mathbf{HCl}$

ii. $\mathbf{C_2H_4} + HCl \rightarrow C_2H_5Cl$

iii. $C_4H_8 + H_2 \rightarrow \mathbf{C_4H_{10}}$

iv. $C_4H_8 + Br_2 \rightarrow \mathbf{C_4H_8Br_2}$

v. $CH_3COOH + C_2H_5OH \rightarrow \mathbf{CH_3COOC_2H_5} + \mathbf{H_2O}$

b. i. substitution ii. addition iii. addition iv. addition v. condensation

c. i. UV light or diffuse sunlight iii. Ni catalyst v. concentrated sulfuric acid and heat

Question 6

a. $CH_3CH(Cl)CH_2CH_2CH_3$ b. $CH_3CH_2CH(OH)CH_2CH_3$ c. $CH_3CH_2CH_2COOH$

d. $CH_3CH_2COOCH_2CH_3$ e. $CH_3CH{=}CHCH_2CH_3$ f. $CH_2{=}CHCH_2CH_3$

g. $CH_3(CH_2)_4CH_3$ h. $HCOOCH_3$

Question 7

a. i. $\mathbf{C_4H_8O}$

C	H	O
66.6/12=5.55	11.2/1=11.2	22.2/16= 1.388
5.55/1.388 = 4	11.2/1.388= 8	1.388/1.388 = 1

ii. M (C_4H_8O) = 72, 144/72= 2 Molecular formula is $\mathbf{C_8H_{16}O_2}$

b. i. $n(CO_2)$= 0.513/44 = 0.0117 mol, n(C)= 0.0117 mol, m(C)=0.0117 x 12 = **0.140 g**

ii. $n(H_2O)$= 0.210/18 = 0.0117 mol, n(H)= 0.0117 x2 = 0.0233 mol, m(H)=0.0233 x 1 = **0.0233 g**

iii. m(O) = 0.350 – (0.140+0.0233) = **0.187 g**

iv. n(O)= 0.187/16 = 0.0117 mol n (C: H: O) = 0.0117: 0.0233: 0.0117 = 1:2:1, $\mathbf{CH_2O}$