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Chemistry
Teach Yourself Series
Topic 8: Carbon chemistry

A: Level 14, 474 Flinders Street Melbourne VIC 3000
T: 1300 134 518 **W:** tssm.com.au **E:** info@tssm.com.au

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Organic chemistry

Australia has a mining industry that is mainly interested in rocks and the metals they contain. Another major source of substances, however, is living things. Plants and animals are chemical factories, continually building up supplies of complex and useful molecules. Most of these substances are based on the atom carbon. The chemistry of living things is referred to as organic chemistry.

Carbon

As it appears in Unit 1

Carbon is unusual in the number of **allotropes** that it has. (Allotropes are different forms of the same element)

- Diamond: Every carbon has a tetrahedral arrangement. Giant array, high melting point, very hard.
- Graphite: Layered structure with delocalized electrons. Conductive, soft, lubricant.
- Charcoal: No set structure at all. Black soot.
- Buckyballs and nanotubes: Graphite wound into tubes or into a sphere. High melting point, high technology.

Carbon also has more compounds than any other element. This is because it

- has four outer shell electrons, allowing it to bond with up to four other elements
- can bond to a range of other elements – i.e. hydrogen, oxygen, nitrogen and chlorine.
- can form single, double and triple bonds
- can bond to itself to form long chains

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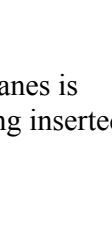
Hydrocarbons

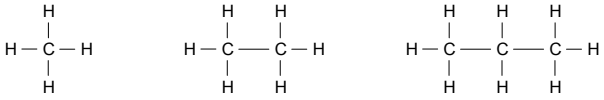
As it appears in Units 1 and 3

Alkanes: hydrocarbons with all carbon to carbon **single** bonds.

Each member of the alkanes is formed from $-CH_2-$ being inserted into the chain



the alkanes are an example of a homologous series



methane	ethane	propane
CH_4	C_2H_6	C_3H_8
natural gas		LPG

general formula $\mathbf{C_nH_{2n+2}}$ i.e. octane = C8 and 8x2+2 H = 18 H => C_8H_{18}

Most alkanes are fuels i.e. LPG, petrol, kerosene and diesel. They are fuels because their combustion with air releases large amounts of energy.

$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$

5464 kJ of energy is released when each 1 mole of octane burns

molecule and prefix	**number of carbons & formula**
methane	1C CH_4
ethane	2C C_2H_6
propane	3C C_3H_8
butane	4C C_4H_{10}
pentane	5C C_5H_{12}
hexane	6C C_6H_{14}
heptane	7C C_7H_{16}
octane	8C C_8H_{18}
nonane	9C C_9H_{20}
decane	10C $C_{10}H_{22}$

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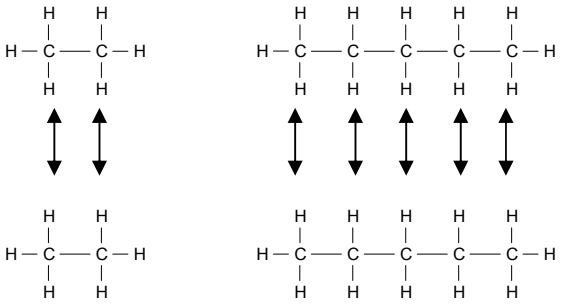
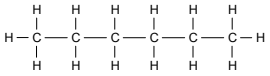
As the molecule gets longer

- the boiling point increases
- the flammability decreases
- the viscosity increases
- the solubility because

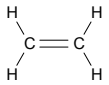
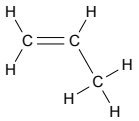
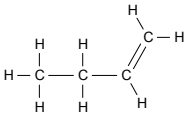
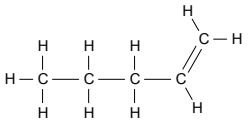


each bond is not stronger in pentane but there are more of them

Drawing molecules - hexane

empirical formula	molecular formula	semi-structural formula	structural formula
C_3H_7	C_6H_{14}	$CH_3CH_2CH_2CH_2CH_2CH_3$	

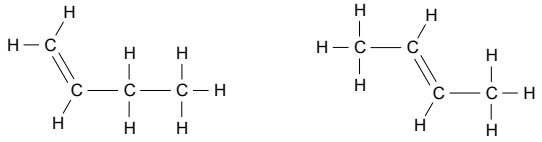
Alkenes: One carbon-carbon double bond. General formula $\mathbf{C_nH_{2n}}$

member	Formula	structure
ethene	C_2H_4	
1-propene	C_3H_6	
1-butene	C_4H_8	
1-pentene	C_5H_{10}	

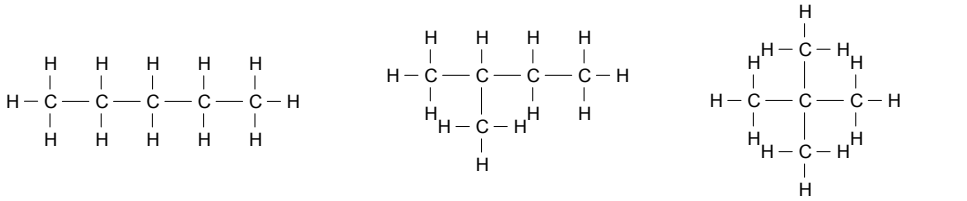
Isomers: Molecules with the **same molecular formula but different structures**.

Isomers of butene

1-butene and 2-butene



Isomers of pentane: Pentane has 3 isomers, all drawn below.

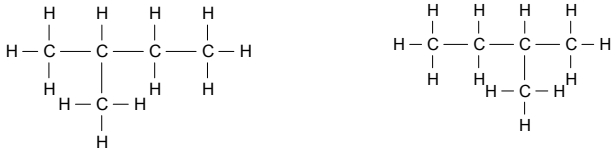


pentane

2-methylbutane
methyl group on 2nd carbon of butane

2,2-dimethylpropane
two methyl groups on the 2nd carbon

The isomers are named according to the longest chain of carbons in the molecule.
The longest chain in the 3rd molecule has 3 carbon atoms => propane



These two molecules are not isomers – they are both 2-methylbutane

Review Questions

1. Give a molecular formula and a structural diagram for each of the following moleules

a. propane b. heptane c. nonane

d. 1-butene e. 2-pentene f. 3-hexene

2. How will the properties of propane compare to those of decane?

_____

_____

3. Write a balanced equation for the combustion of hexane

_____

4. Give the empirical formula, molecular formula, semi-structural formula and structural formula of 2-hexene

_____

5. Butane has an isomer – draw and name the isomer.

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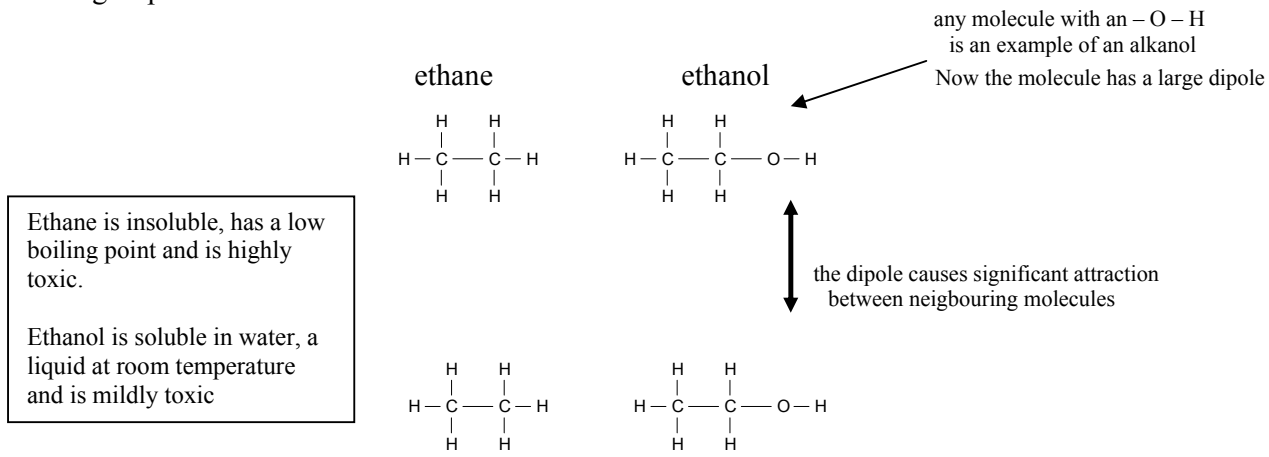
Functional Groups

As it appears in Unit 1 and Unit 3

When elements other than carbon and hydrogen are present, some standard arrangements can result. These functional groups can dominate the behaviour of a molecule.

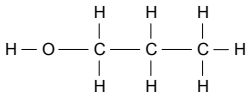


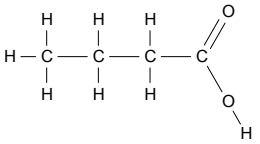
Functional group	Structure	Example
alkanol or alcohol	– C – O – H -CH_2 – OH	ethanol
haloalkane	– C – Cl -CH_2 – Cl or Br or F or I	chloroethane
carboxylic acid	– C(=O) – O – H -CO – OH	ethanoic acid
amine	– C – NH_2 -CH_2 – NH_2	ethanamine
amide	– C(=O) – N(H) – -CO – NH -	
ester	– C(=O) – O – C(H) – -CO – O- CH_2	methyl ethanoate

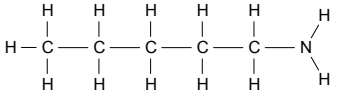
Examples

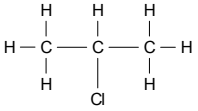
Draw structural diagram of each of the following

a. 1-propanol b. butanoic acid c. 1-pentanamine d. 2-chloropropane



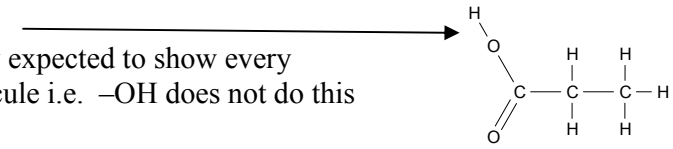






CARE: Show all bonds

In exams, you are usually expected to show every bond present in the molecule i.e. –OH does not do this

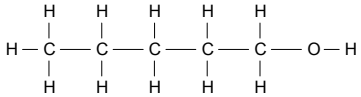


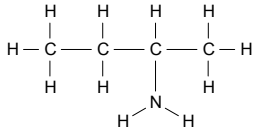
Review Questions

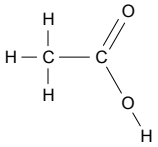
6. Draw structural diagrams of the following

a. pentanoic acid b. 2-butanol c. 1-butanamine d. 1-chloropentane

7. Name the following







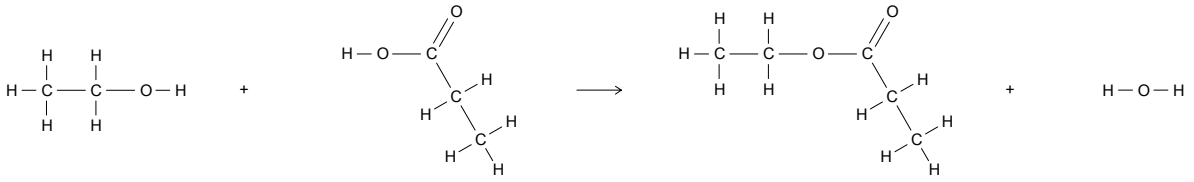
8. How will the properties of butane and butanoic likely differ?

_____

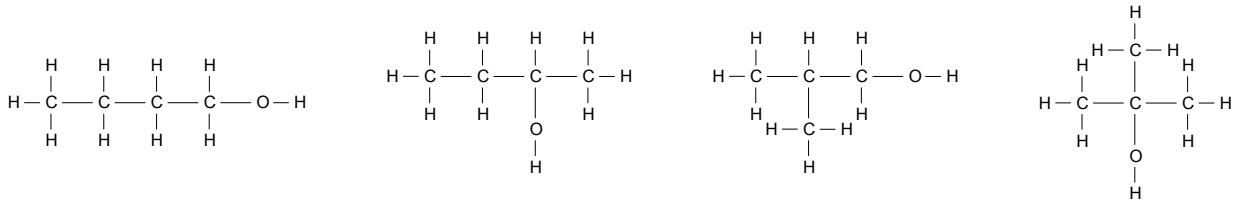
_____

Esters
Esters = alkanol + carboxylic acid. The name of the alkanol comes first.

Example
ethylpropanoate = ethanol + propanoic acid



Isomers
Draw all isomers of C_4H_9OH

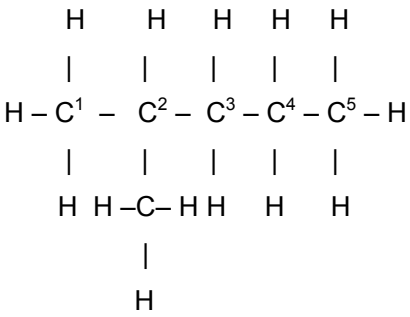


IUPAC (International Union of Pure and Applied Chemistry)

As it appears in Unit 3

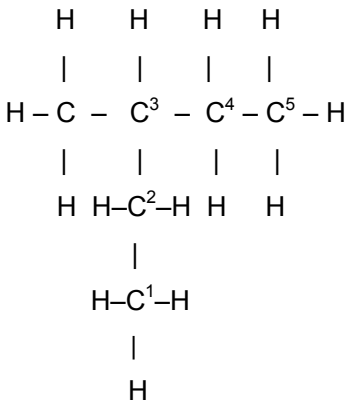
Nomenclature has been accepted as a way of providing uniform names for organic compounds.

Identify the parent hydrocarbon chain. This is the **longest continuous chain** of carbon atoms.



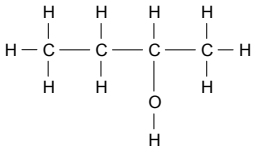
2-methylpentane

(5 carbons in a row, methyl group on 2nd)



3-methylpentane (not 2-ethylbutane)

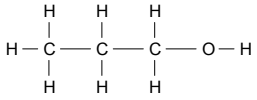
Identify the functional groups present
Start from the end of the molecule that leads to the functional group having the lowest number.



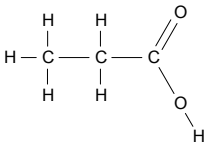
This is 2-butanol, not 3-butanol

If the **functional group can only exist at the end of a molecule**, do not use a number i.e.

1-propanol



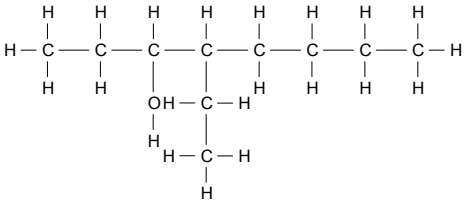
propanoic acid



The alcohol group can have another position but the carboxyl group cannot

Side chains are listed in **alphabetical order**, ignoring prefixes like di- i.e. ethyl comes before dimethyl

4-ethyl-3-hydroxyoctane



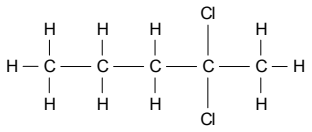
Review Questions

9. Draw all isomers of C_4H_9Cl

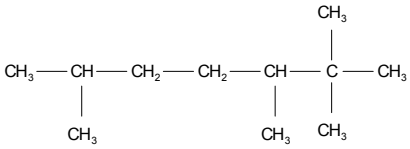
10. Draw structural diagrams of the following
a. propylethanoate b. methylpropanoate

11. Provide correct names for the following

a.



b.

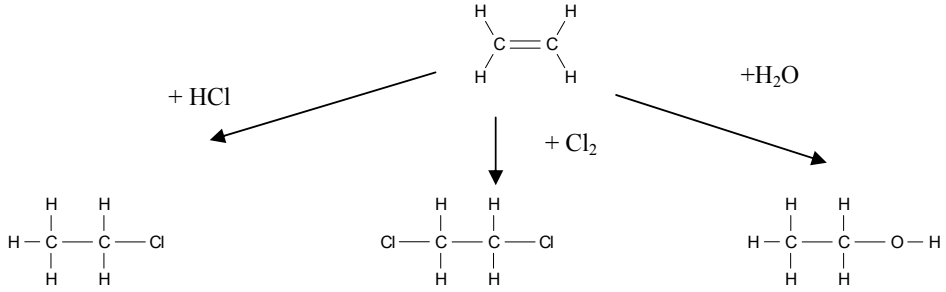


Organic pathways

As it appears in Unit 3

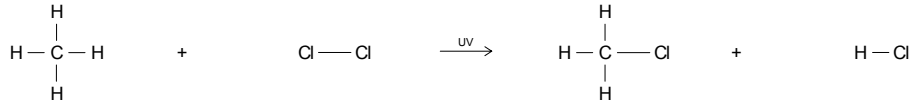
Many useful molecules do not exist in nature. **Reaction pathways** are needed to construct these molecules.

Alkene reactions
Alkenes can undergo many different **addition** reactions.
Addition: Reactions where a **double bond** is used in the reaction and only one product is formed.



chloroethane 1,2-dichloroethane ethanol

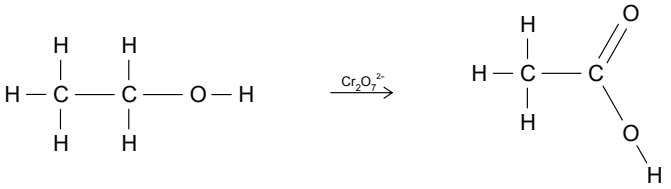
Alkane reactions
Alkanes can undergo **substitution** reactions.
Substitution: One functional group takes the place of another on an alkane molecule.



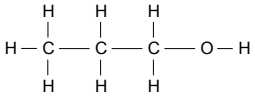
A chlorine atom is substituted onto the methane molecule, also forming hydrochloric acid.

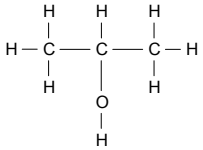
The **substitution** process can **continue** to form more chloroalkanes.
Substitution of other functional groups can also occur.

Oxidation
Ethanol can be oxidized to ethanoic acid



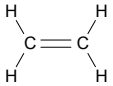
Note: 1-propanol can be oxidized to propanoic acid but 2-propanol cannot

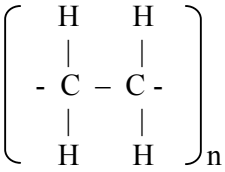




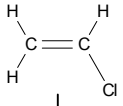
Polymerisation

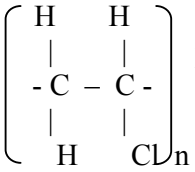
Alkenes can react with themselves many times to form polymers. This is addition polymerization.





polyethene





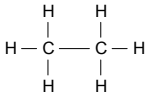
polyvinylchloride

PVC

In a polymer, ther might be thousands of monomers joined together.

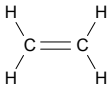
Bromine test

Bromine is **brown**. It **reacts with unsaturated molecules** but not saturated molecules. Therefore, if bromine is added to a compound and the brown colour disappears, the compound must have contained double or triple bonds.

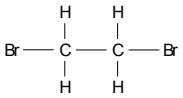


+ Br – Br → no reaction

Saturated → no colour change



+ Br – Br →



brown colourless

Unsaturated goes colourless

Review Questions

12. Draw the product of the reaction between 2-butene and bromine

13. Draw each of the steps required to form butanoic acid from butene

14. Explain how you might use a chemical reaction to distinguish between
a. butane and butene

_____

b. 1-propanol and 2-propanol

_____

15. Outline how you might form butanoic acid from butane.

16. Draw both products that can form when HCl gas reacts with propene

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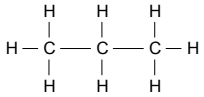
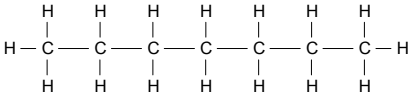
Solutions to Review Questions

1.

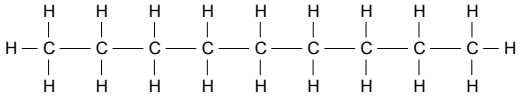
a.



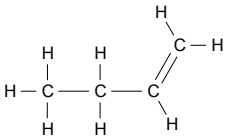
b.



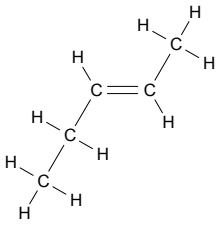
c



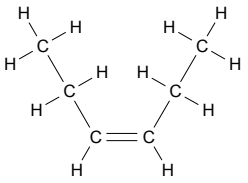
d.



e.



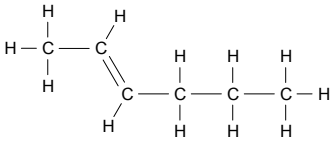
f.



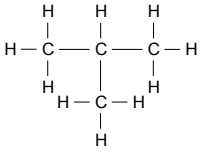
2. Propane will be more volatile and flammable. It will have a lower boiling point. It will be low viscosity as a liquid.

3. $2C_6H_{14}(l) + 19O_2(g) \rightarrow 12CO_2(g) + 14H_2O(g)$

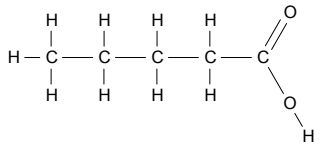
4. CH_2 C_6H_{12} $CH_3CHCHCH_2CH_2CH_3$

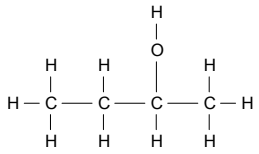


5. methylpropane

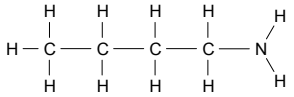


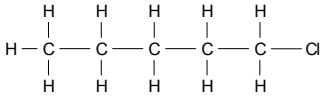
6. a. b.



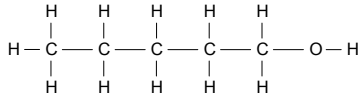


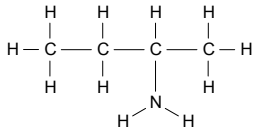
c. **d.**

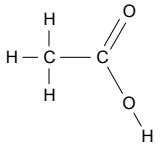




7. 1-pentanol or pentan-1-ol 2-aminobutane or 2-butanamine ethanoic acid

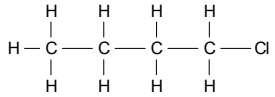


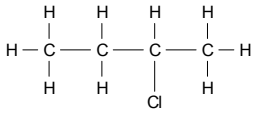


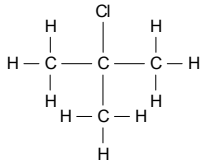


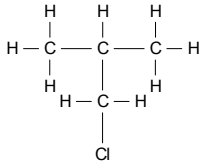
8. Butane will have a low boiling point and be a flammable fuel. Butanoic acid will have a higher boiling point. It is less flammable and less toxic.

9.

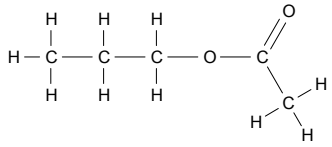


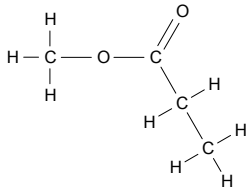






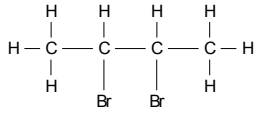
10. a. propylethanoate b. methylpropanoate



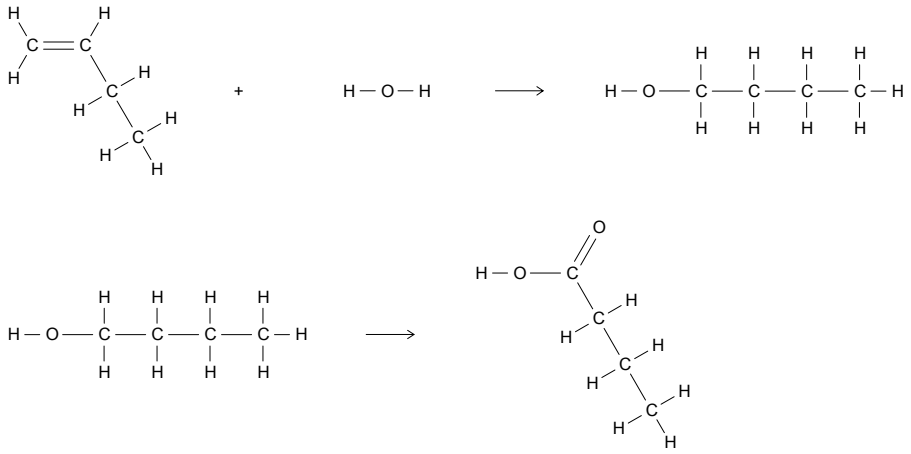


11. a. 2,2-dimethylpentane b. 2,2,3,6-tetramethylheptane

12.



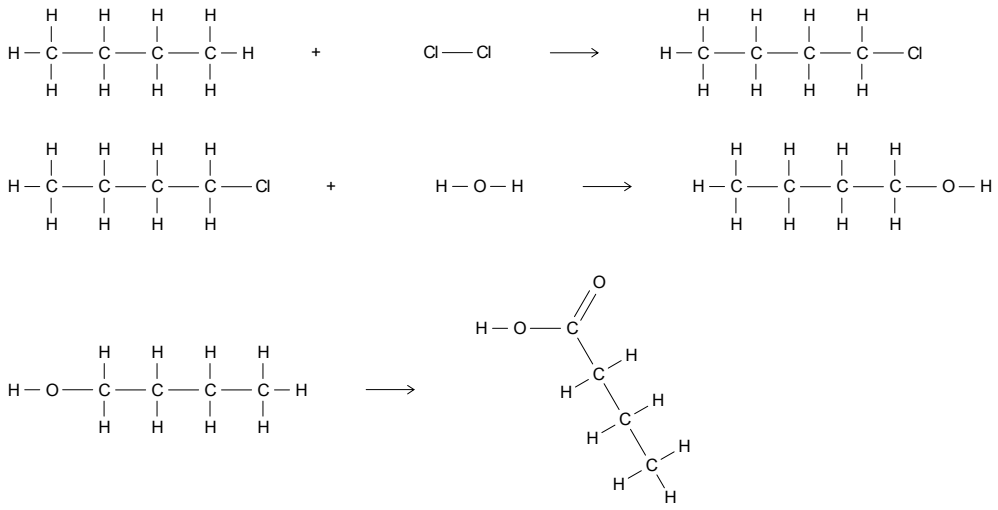
13. Butene → butanol → butanoic acid



14. a. a bromine test would work. Bromine will remain brown in an alkane but go colourless in alkene

b. 1-propanol can be oxidized to propanoic acid as it is a primary alkanol but 2-propanol cannot

15. butane. → chlorobutane → butanol → butanoic acid



16.