L3- Learning Outcomes

11.1 Formulae, functional groups and terminology

I can:

- ❑ 8. Define structural isomers as compounds with the same molecular formula, but different structural formulae, including C_4H_{10} as $CH_3CH_2CH_2CH_3$ and $CH_3CH(CH_3)CH_3$ and C_4H_8 as $CH_3CH_2CH{=}CH_2$ and $CH_3CH{=}CHCH_3$

11.2 Naming organic compounds

I can:

- ❑ 1. Name and draw the displayed formulae of:

  (e) the products of the reactions stated in sections 11.4–11.7 (i.e. Carboxylic acids, Alcohols, Alkenes, and Alkanes).

11.4 Alkanes

3 State that in a substitution reaction one atom or group of atoms is replaced by another atom or group of atoms

4 Describe the substitution reaction of alkanes with chlorine as a photochemical reaction, with ultraviolet light providing the activation energy, E_a, and draw the structural or displayed formulae of the products, limited to monosubstitution

11.5 Alkenes

3 Describe the reasons for the cracking of larger alkane molecules

4 Describe the test to distinguish between saturated and unsaturated hydrocarbons by their reaction with aqueous bromine

5 State that in an addition reaction only one product is formed

6 Describe the properties of alkenes in terms of addition reactions with:

(a) bromine or aqueous bromine

(b) hydrogen in the presence of a nickel catalyst

(c) steam in the presence of an acid catalyst

and draw the structural or displayed formulae of the products

11.6 Alcohols

1 Describe the manufacture of ethanol by:

(a) fermentation of aqueous glucose at 25–35 °C in the presence of yeast and in the absence of oxygen

(b) catalytic addition of steam to ethene at 300 °C and 6000 kPa / 60 atm in the presence of an acid catalyst

11.7 Carboxylic acids

1 Describe the reaction of ethanoic acid with:

(a) metals

(b) bases

(c) carbonates

including names and formulae of the salts produced

2 Describe the formation of ethanoic acid by the oxidation of ethanol:

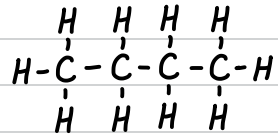
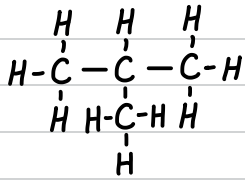
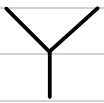
(a) with acidified aqueous potassium manganate(VII)

(b) by bacterial oxidation during vinegar production

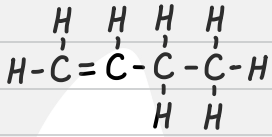
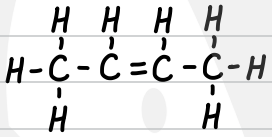
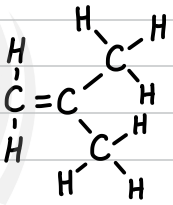
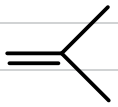
Structural Isomers

Structural isomer : compounds with the same molecular formula but different structural formula

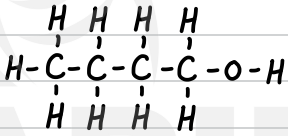
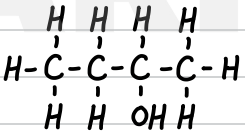
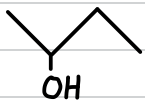
↳ alkanes

butane	C_4H_{10}		$CH_3CH_2CH_2CH_3$	
2-methylpropane	C_4H_{10}		$CH_3CH(CH_3)CH_3$	

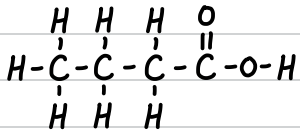
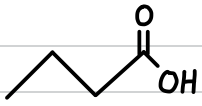
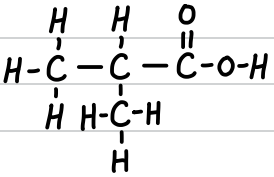
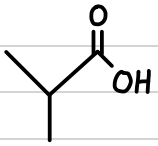
↳ alkenes

but-1-ene	C_4H_8		$CH_3CH_2CH=CH_2$	
but-2-ene	C_4H_8		$CH_3CH=CHCH_3$	
2-methylprop-1-ene	C_4H_8		$CH_3C=(CH_2)CH_3$	

↳ alcohols

butan-1-ol	C_4H_9OH		$CH_3CH_2CH_2CH_2OH$	
butan-2-ol	C_4H_9OH		$CH_3CH_2CHOHCH_3$	

↳ carboxylic acids

butanoic acid	C_3H_7COOH		$CH_3CH_2CH_2COOH$	
butanoic acid	C_3H_7COOH		$CH_3CH(CH_3)COOH$	

Reactions involving alkanes and alkenes

substitution reaction : reaction where one atom or group of atoms is replaced by another atom or group of atoms

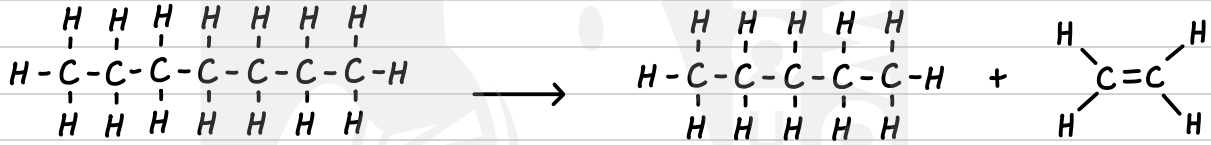
↳ alkanes undergo a substitution reaction with chlorine to produce chloroalkanes and hydrogen chloride. Reaction requires ultraviolet light to provide the necessary activation energy (E_a)

※ **photochemical reaction** · reactions that are initiated when light energy is absorbed by reactants

ex: 

ethane — chlorine — chloroethane — hydrogen chloride

cracking : process of breaking long hydrocarbons into smaller, simpler molecules typically requires the addition of heat or a catalyst

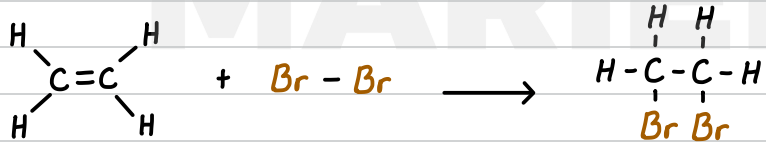
ex: 

heptane — pentane — ethene

uses: shorter alkanes can be used as fuels
alkenes can be used to produce polyethylene i.e. plastic

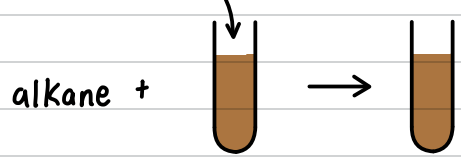
Addition reaction : reaction where two or more molecules combine to form one product

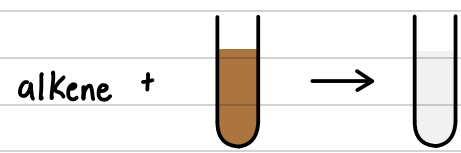
↳ alkene reactions with bromine

ex: 

ethene — bromine — dibromoethane

※ saturation test: using bromine water (aqueous bromine) to test for the prescence of alkenes



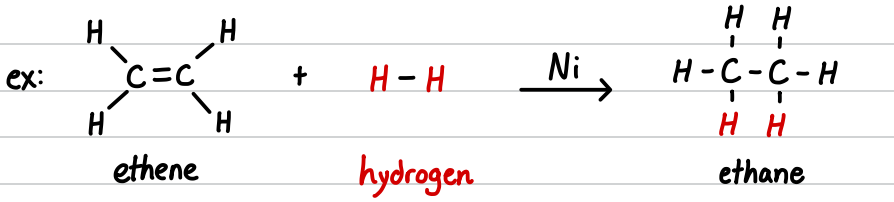


Reactions involving alkenes

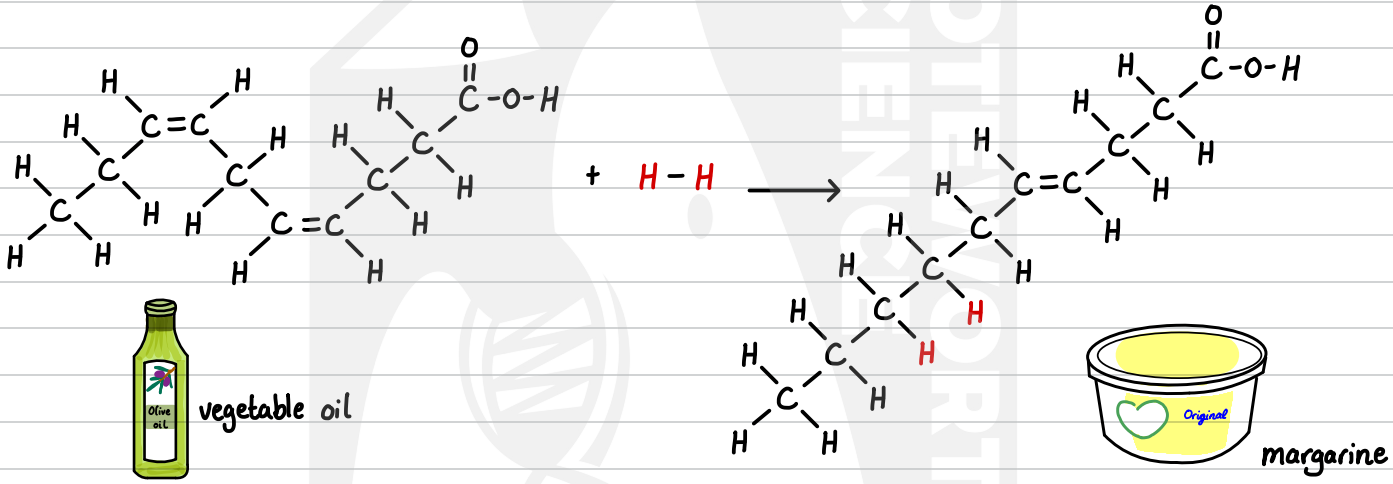
↳ alkene reactions with hydrogen

hydrogenation : reaction between alkene and hydrogen in the presence of a catalyst (ex: nickle) and high temperatures (ex: 200 °C)

↳ substance which increases rate of reaction without undergoing permanent change by lowering activation energy

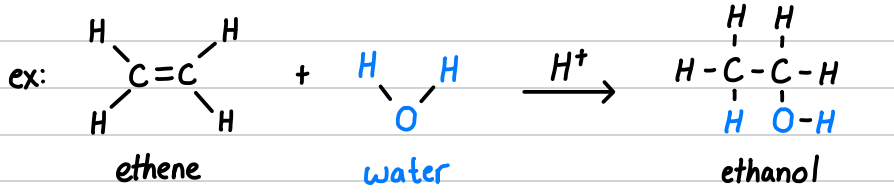


※ partial hydrogenation of unsaturated fats (found in oils) leads to trans fats which raise melting point causing them to be solid at room temperature ex: margarine



↳ alkene reactions with water (steam)

hydration : reaction where substance combines with water.
when alkenes are heated (300 °C) in presence of steam (water), an acid catalyst, and high pressure (60 atm), an addition reaction occurs: breaking the double bond and water, forming an alcohol

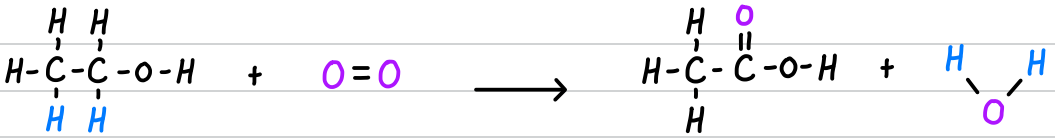


Reactions involving alcohols

↳ oxidation of alcohol into carboxylic acid

bacterial oxidation : reaction with oxygen by bacteria such as Acetobacter forming a carboxylic acid

ex:

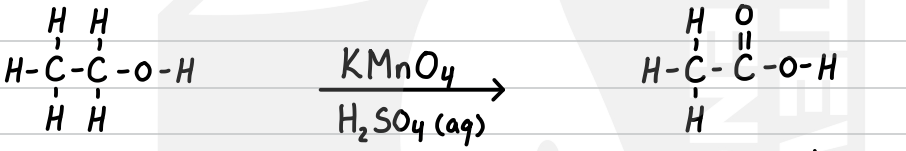


ethanol + oxygen → ethanoic acid + water

(acetic acid / vinegar acid)

oxidation with catalyst : alcohol can be oxidized in the presence of a strong oxidizing agent such as acidified potassium manganate (VII) solution

ex:



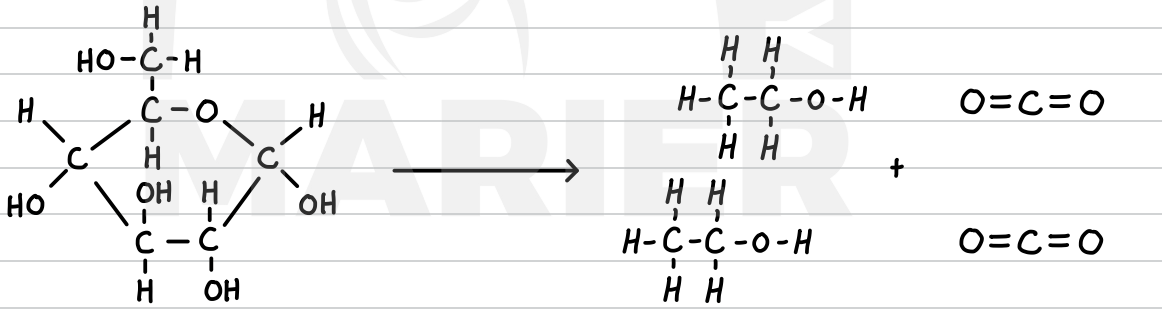
ethanol → ethanoic acid

(acetic acid / vinegar acid)

↳ alcohol production by fermentation

alcohol fermentation : metabolic process where sugar, such as glucose is converted to alcohol and carbon dioxide. Occurs in yeast, plants, and bacteria

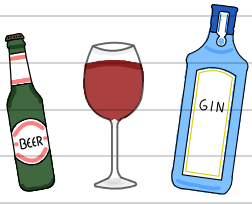
ex:



$C_6H_{12}O_6$ → $2\ C_2H_5OH$ + $2\ CO_2$

glucose → ethanol + carbon dioxide

uses: production of alcoholic beverages



baking of bread

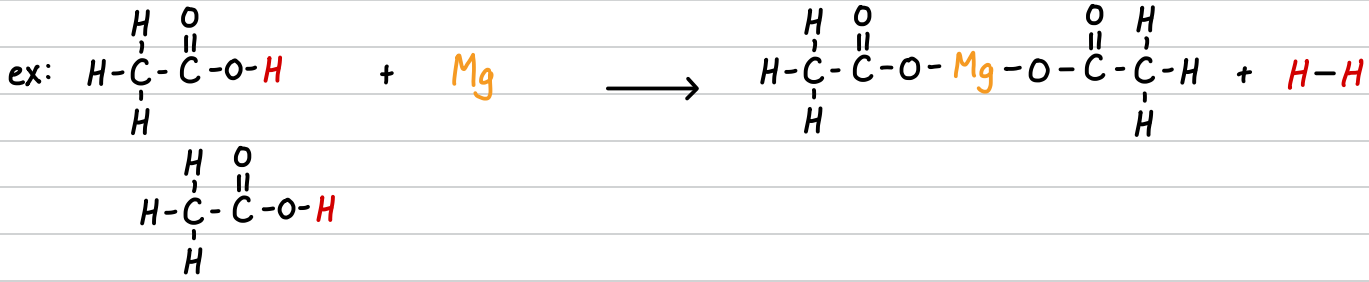
production of biofuel

Reactions involving carboxylic acids

↳ carboxylic acid reactions with metals

generally: acid + metal ⟶ salt + hydrogen gas

ex:



$$2\ CH_3COOH_{(aq)} + Mg_{(s)} \longrightarrow (CH_3COO)_2Mg_{(aq)} + H_{2(g)}$$

ethanoic acid + magnesium ⟶ magnesium ethanoate + hydrogen

※ hydrogen test: the presence of hydrogen gas can be tested by exposing a gas to a burning splint
if H_2 is present a 'POP' sound will occur

↳ carboxylic acid reactions with bases

generally: acid + base ⟶ salt + water

ex:

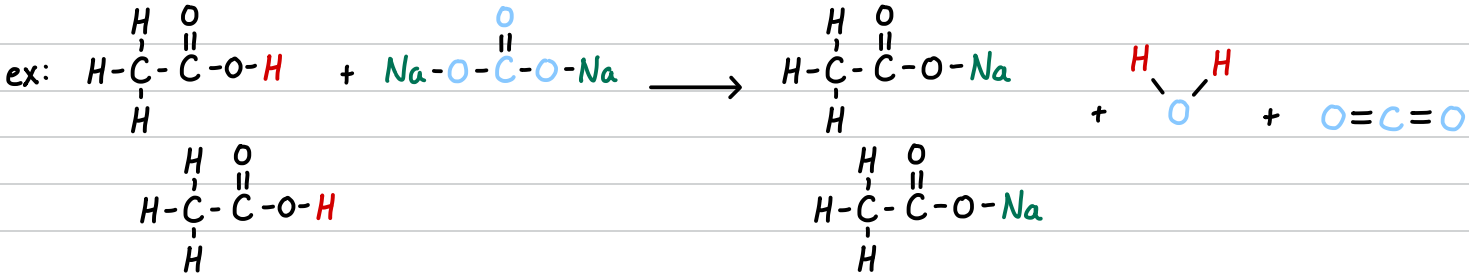
$$CH_3COOH_{(aq)} + NaOH_{(aq)} \longrightarrow (CH_3COO)Na_{(aq)} + H_2O_{(l)}$$

ethanoic acid + sodium hydroxide ⟶ sodium ethanoate + water

↳ carboxylic acid reactions with carbonates

generally: acid + metal carbonate ⟶ salt + water + carbon dioxide

ex:



$$2\ CH_3COOH_{(aq)} + Na_2CO_{3(s)} \longrightarrow 2\ (CH_3COO)Na_{(aq)} + H_2O_{(l)} + CO_{2(g)}$$

ethanoic acid + sodium carbonate ⟶ sodium ethanoate + water + carbon dioxide

Practice questions

① What is the minimum number of carbons for structural isomers for the following (explain your answer)

a) alkanes
b) alkenes
c) alcohols
d) carboxylic acids

② How many structural isomers exist for alkanes of 5, 6, 7, 8, 9 carbons? Is there a pattern?

③ Complete the following chemical reactions by providing the word and balanced chemical equations.

example C_2H_6 (ethane) + Cl_2 (chlorine) $\xrightarrow{light}$ C_2H_5Cl (chloroethane) + HCl (hydrogen chloride)

a) methane + chlorine $\xrightarrow{light}$

b) $\xrightarrow{light}$ C_3H_7Cl + HCl

c) $\longrightarrow$ dibromobutane

d) C_3H_6 + Br_2 $\longrightarrow$

e) but-1-ene + hydrogen $\xrightarrow{Ni}$

f) + H_2 $\xrightarrow{Ni}$ C_3H_8

g) $\xrightarrow{H^+}$ propan-1-ol

h) but-2-ene + water $\xrightarrow{H^+}$

i) $\longrightarrow$ C_2H_5COOH + H_2O

j) pentan-1-ol + oxygen $\longrightarrow$

③ Cont.

k) $HCOOH$ + Na ⟶

l) butanoic acid + calcium ⟶

m) ⟶ C_4H_9COOK + H_2O

n) methanoic acid + sodium hydroxide ⟶

o) ⟶ potassium propanoate + water + carbon dioxide

p) C_4H_9COOH + $CaCO_3$ ⟶

④ Describe the difference between a substitution and addition reaction. Include examples

⑤ In a chemical reaction, a catalyst can be used. A student describes a catalyst as a substance added to increase energy and thus increase rate of reaction. Explain whether they are correct or not.