

# Mastering Chemistry

- Book      3B
- Topic 8      Chemistry of Carbon  
                    Compounds



## Content

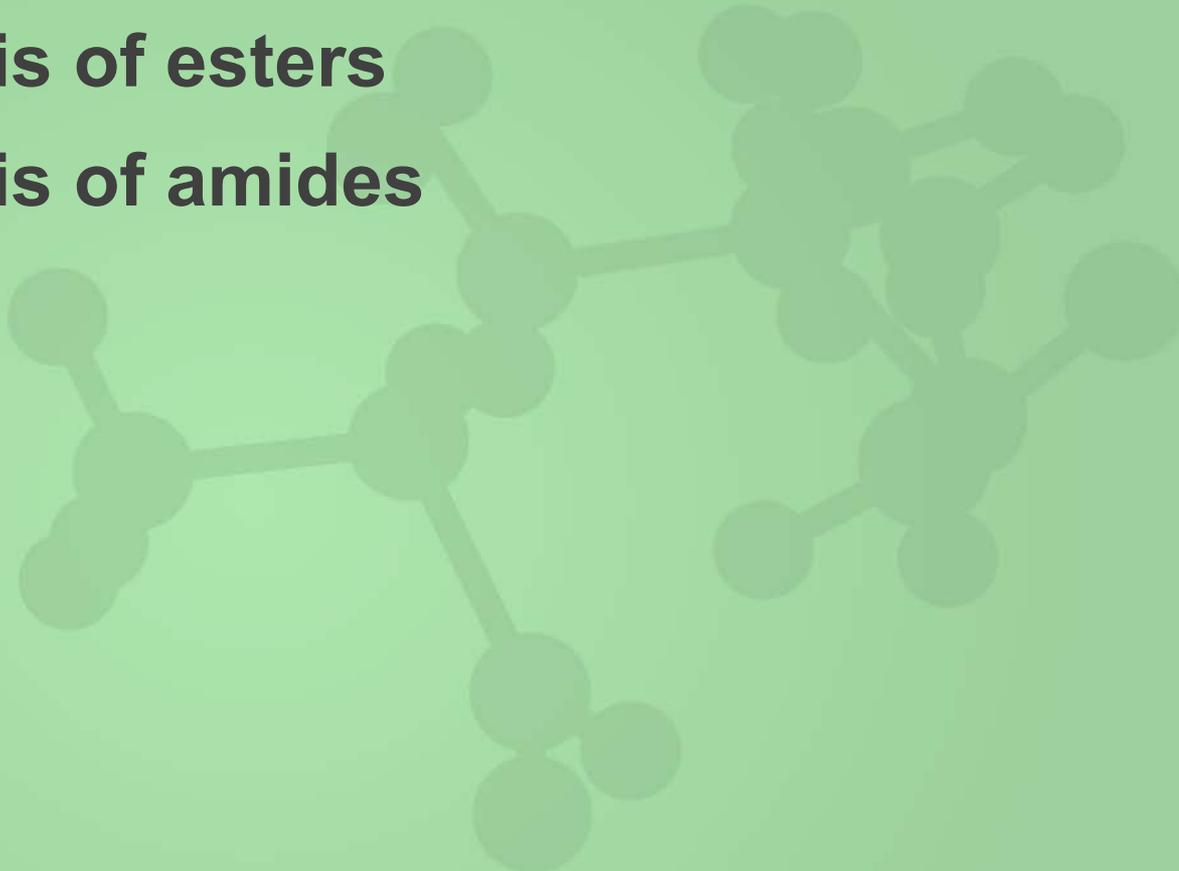
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## 31.1 Making new carbon compounds (p.91)

- ◆ There are more than seven million known carbon compounds. The majority of these have been synthesised in a laboratory. Many carbon compounds have important uses as drugs, pesticides, perfumes and dyes.
- ◆ The synthesis of carbon compounds requires functional groups to be converted into other functional groups.
- ◆ In order to plan a synthesis of carbon compound, you need to know the typical reactions of various functional groups and how one functional group is converted into another.



## 31.1 Making new carbon compounds (p.91)

You need to know the following two terms in your study:

- reagents — these are the chemicals involved in a reaction; and
- reaction conditions — these normally describe the temperature, pressure, solvent and the use of any catalyst in a reaction.



## 31.2 Reaction of alkanes with halogens (p.91)

- ◆ Alkanes react with halogens, either on heating or on exposure to ultraviolet radiation from the sun.
- ◆ These are **substitution reactions** (取代反應).



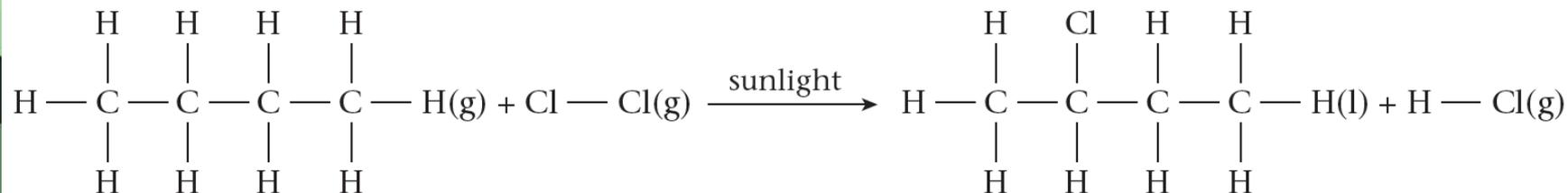
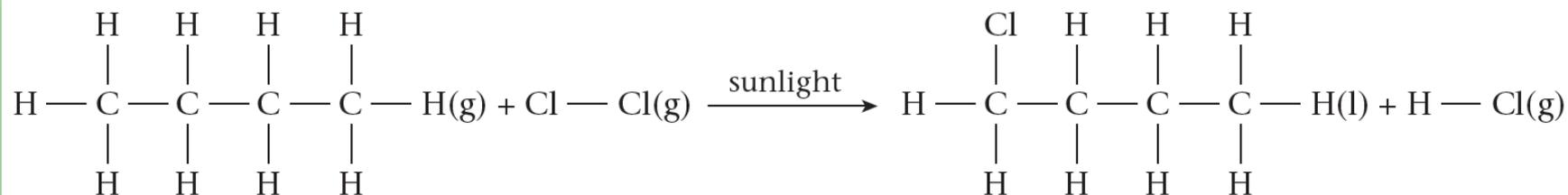
Important reactions in  
carbon chemistry [Ref.](#)



## 31.2 Reaction of alkanes with halogens (p.91)

**A substitution reaction is a reaction in which an atom or group of atoms in a molecule is replaced by another atom or group of atoms.**

- All alkanes react with halogens in a similar way. For example, butane reacts with chlorine in the presence of sunlight as shown below. There are two possible monosubstituted products and many multisubstituted products.





## 31.2 Reaction of alkanes with halogens (p.91)

### Practice 31.1

Consider the following conversion:

a) Name the type of reaction that takes place. **Substitution reaction**

b) Write the equation for the initial step of the reaction.  **$\text{Br}_2 \rightarrow 2\text{Br}\cdot$**

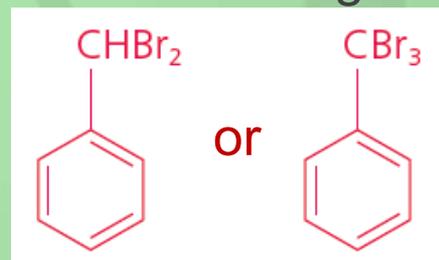
c) This reaction can occur at room temperature and pressure.

What further condition is needed for this reaction to take place?

**Ultraviolet light / heat / radical initiator**

d) The reaction can also produce dibromo and tribromo organic compounds.

i) Write the structural formula of ONE of these organic compounds.



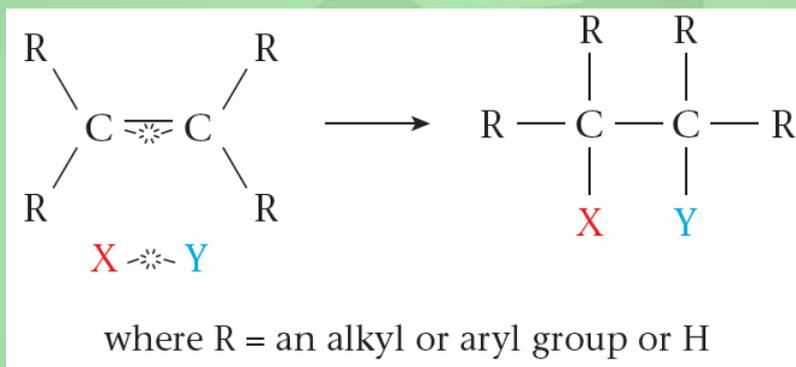
ii) Suggest a condition so that the reaction produces more of  $\text{C}_6\text{H}_5\text{CH}_2\text{Br}$  but less of other organic products.

**Use a large excess amount of  $\text{C}_6\text{H}_5\text{CH}_3$**



## 31.3 Addition reactions of alkenes (p.93)

- ◆ In an addition reaction, two or more molecules react to form a larger molecule.
- ◆ For alkenes, one of the two bonds in the carbon-carbon double bonds breaks and a small molecule is added across the two carbon atoms to make a saturated molecule.



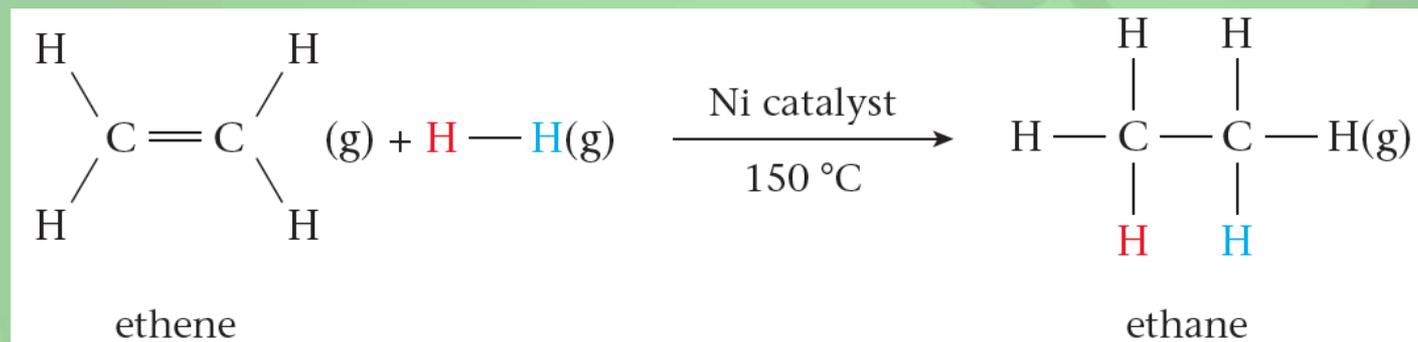
- ◆ Alkenes undergo various addition reactions, e.g. with  
- hydrogen; halogens; and hydrogen halides.



## 31.3 Addition reactions of alkenes (p.93)

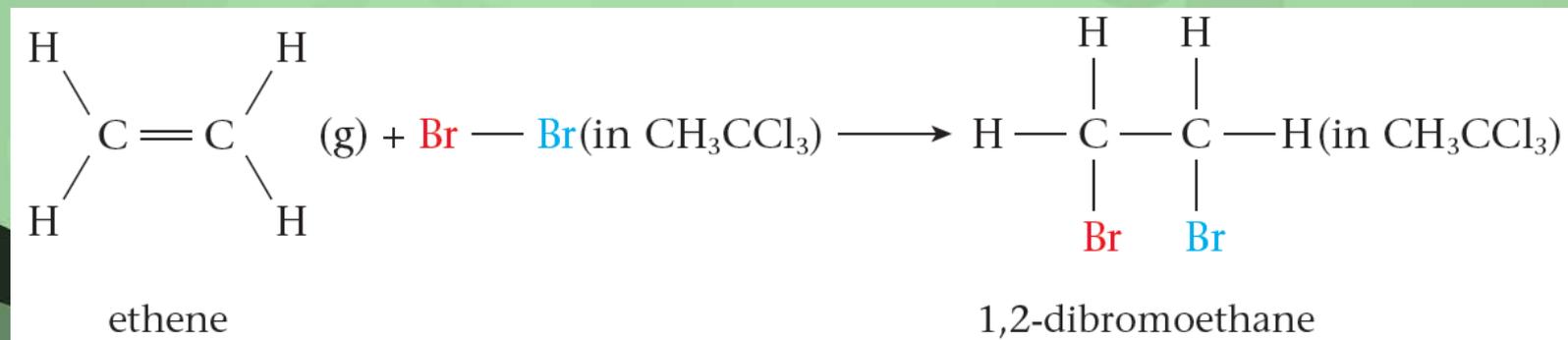
### Addition of hydrogen

#### ◆ Hydrogenation (氫化作用)



### Addition of halogens

#### ◆ Bromination (溴化作用)

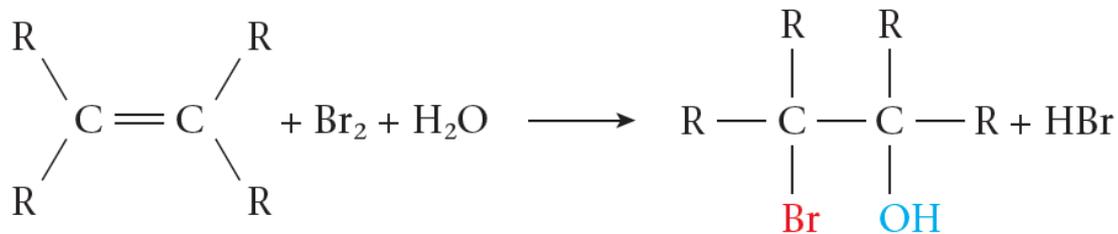




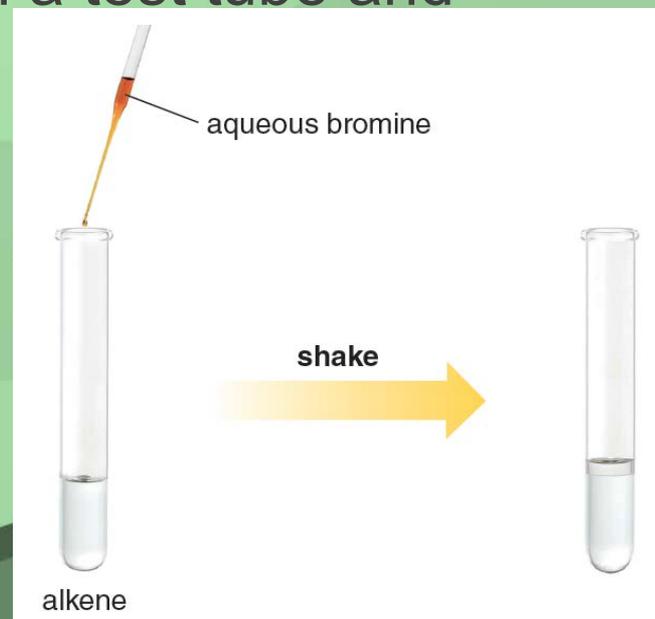
## 31.3 Addition reactions of alkenes (p.93)

### Test for unsaturation

- ◆ The reaction with bromine can be used to identify if there is a carbon-carbon double bond and the carbon compound is unsaturated.
- ◆ Add yellow-brown aqueous bromine (or bromine dissolved in an organic solvent) dropwise to an alkene in a test tube and shake.
- ◆ The aqueous bromine becomes colourless quickly.



where R = an alkyl or aryl group or H

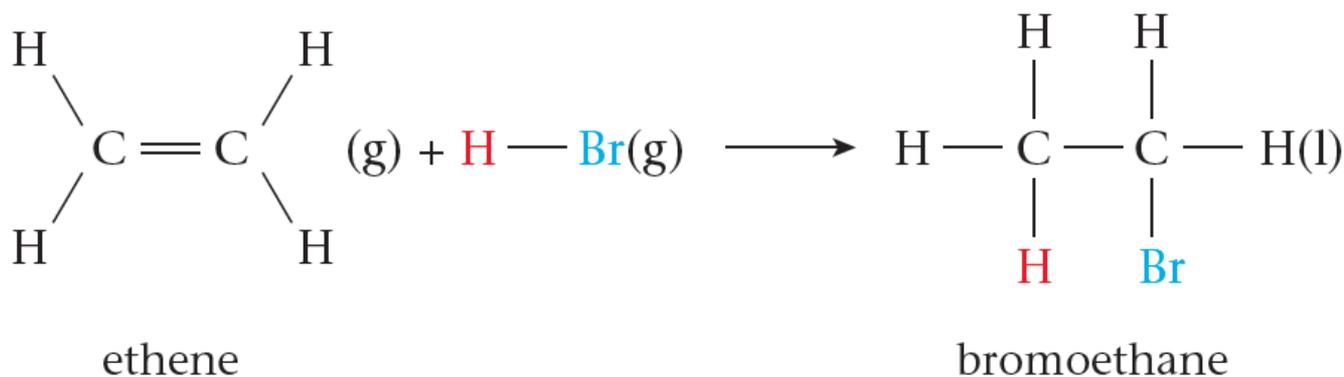




## 31.3 Addition reactions of alkenes (p.93)

### Addition of hydrogen halides

- Alkenes react with gaseous hydrogen halides at room temperature to form haloalkanes.
- Either mix a gaseous alkene with HX(g) or bubble the HX(g) into a liquid alkene. Alkenes also react with conc. HCl(aq) or conc. HBr(aq).

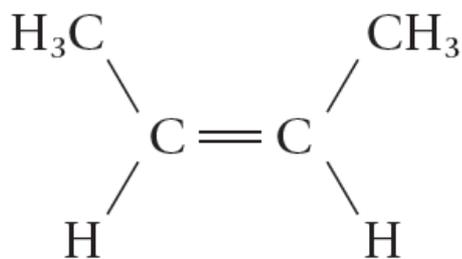




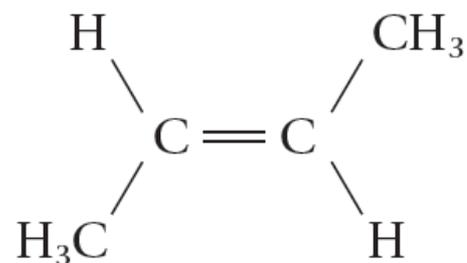
## 31.3 Addition reactions of alkenes (p.93)

### Addition of hydrogen halides to unsymmetrical alkenes

- ◆ But-1-ene and but-2-ene are isomers. But-2-ene exists as two stereoisomers, *cis*-but-2-ene and *trans*-but-2-ene.
- ◆ These stereoisomers are described as symmetrical alkenes as each carbon atom of the carbon-carbon double bond bears the same pair of groups. Each carbon atom of the carbon-carbon double bond has a hydrogen atom and a methyl group attached.



*cis*-but-2-ene

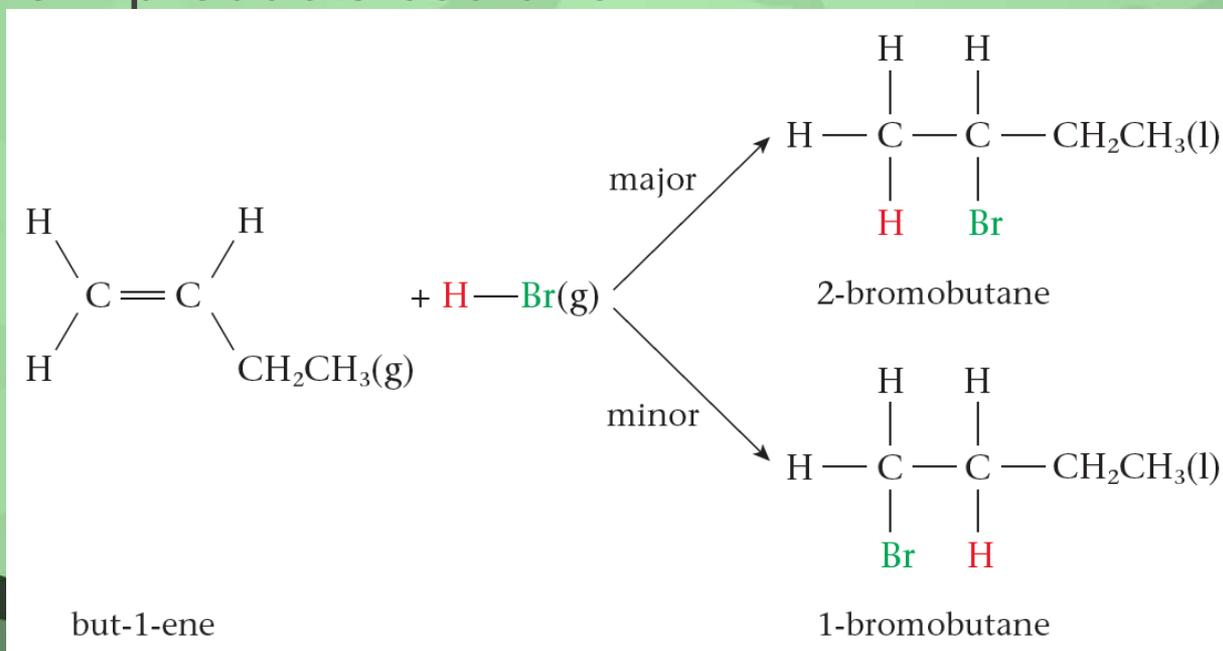


*trans*-but-2-ene



## 31.3 Addition reactions of alkenes (p.93)

- ◆ However, But-1-ene, however, is an unsymmetrical alkene. One carbon atom of the carbon-carbon double bond is bonded to two hydrogen atoms while the other is bonded to a hydrogen atom and an ethyl group.
- ◆ With the reaction between but-1-ene and hydrogen bromide, two different products could form:





## 31.3 Addition reactions of alkenes (p.93)

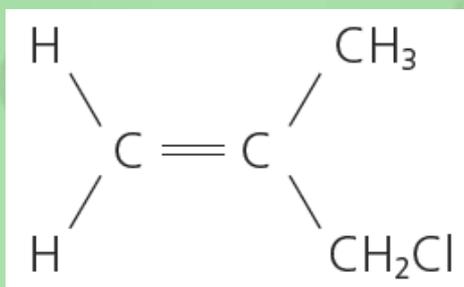
- ◆ Analysis of the products shows that much more 2-bromobutane than 1-bromobutane is produced.
- ◆ This suggests that the hydrogen atom from HBr adds mainly to the carbon atom of the carbon-carbon double bond which already has more hydrogen atoms attached to it. This is called **Markovnikov's rule** (馬科尼科夫規則).



## 31.3 Addition reactions of alkenes (p.93)

### Practice 31.2

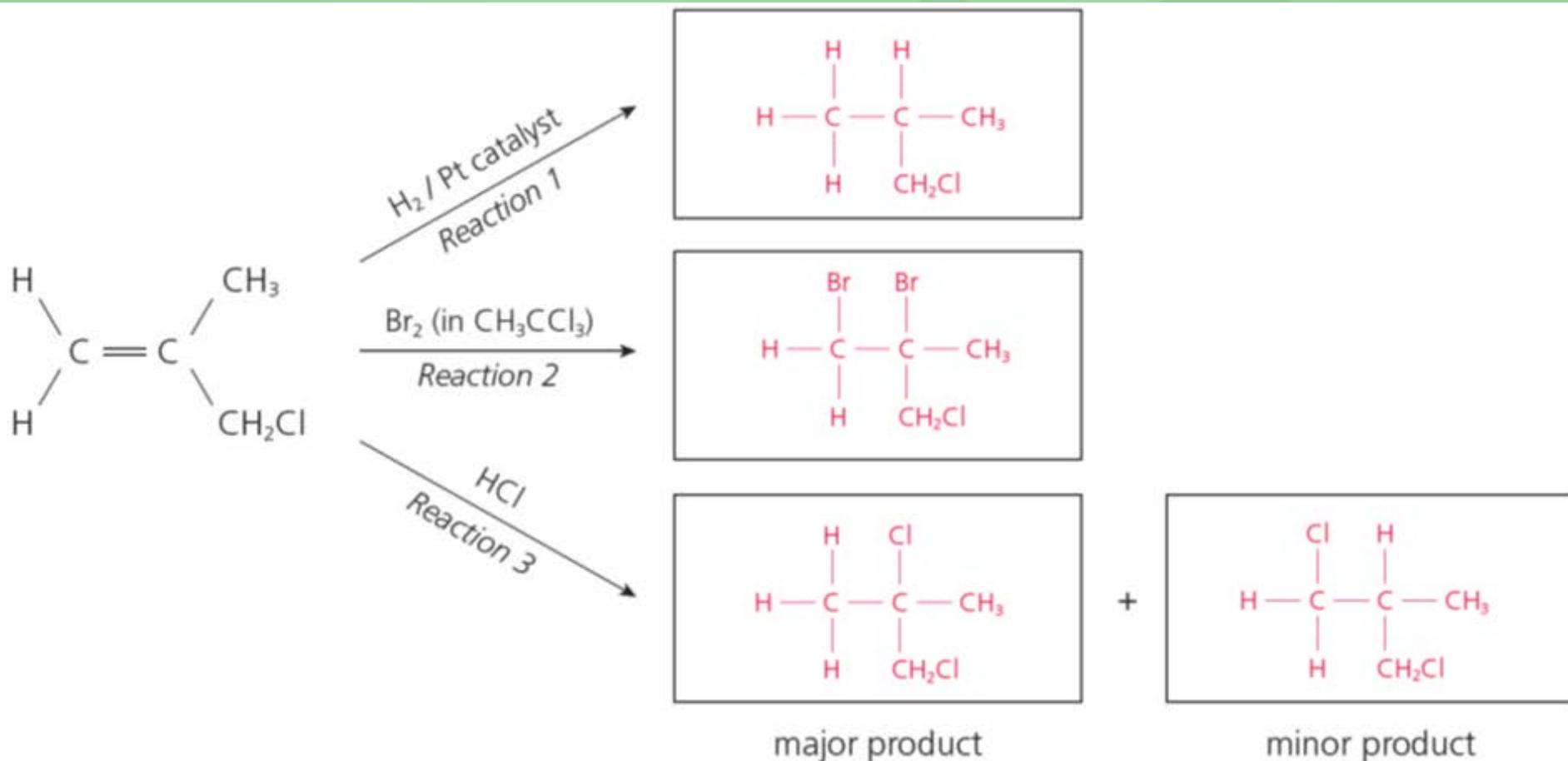
1 Methyl allyl chloride 'MAC' is a chemical used in the production of insecticides.



The flow chart below shows some reactions of MAC. Complete the flow chart.



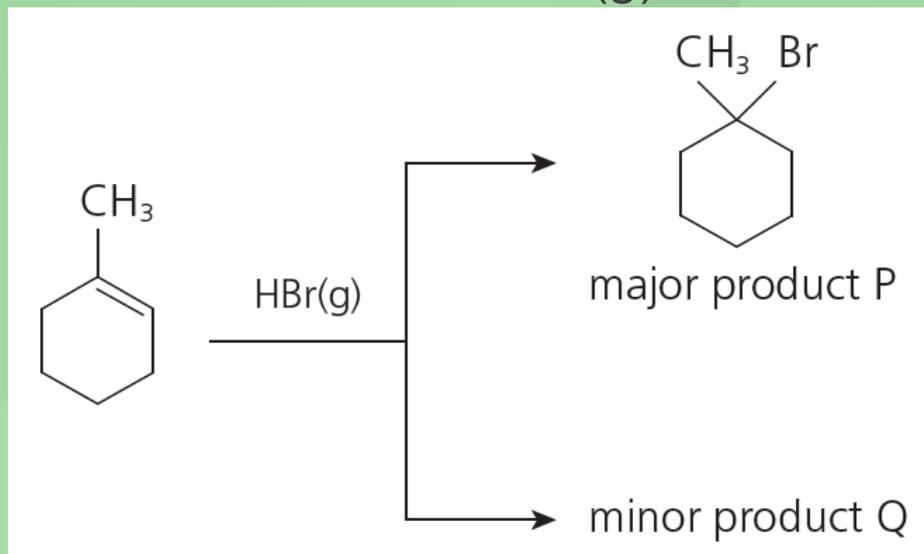
## 31.3 Addition reactions of alkenes (p.93)





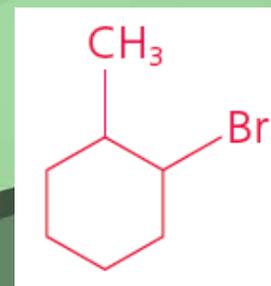
## 31.3 Addition reactions of alkenes (p.93)

2 The alkene shown below reacts with HBr(g).



- Name the type of reaction that takes place. **Addition reaction**
- Give the systematic name of the major product. **1-bromo-1-methylcyclohexane**
- Write the structural formula of the minor product.
- What kind of structural isomers are P and Q?

**Position isomerism**

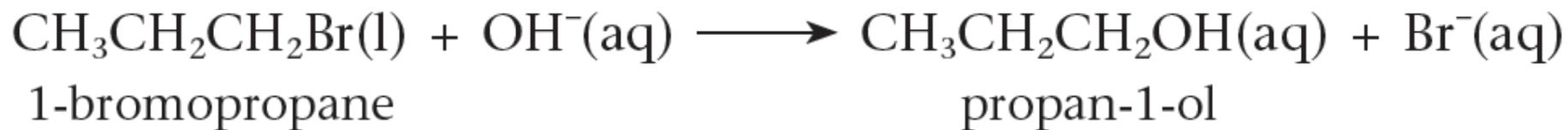
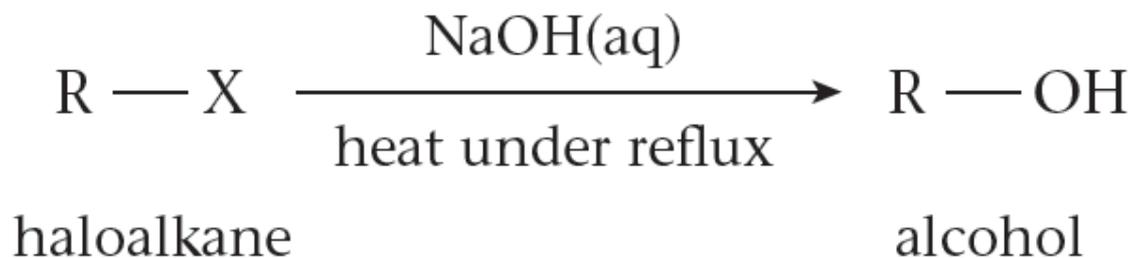




## 31.4 Substitution reactions of haloalkanes (p.98)

- ♦ Haloalkanes are saturated compounds (like alkanes), and as such they undergo substitution reactions.

♦ e.g.



- ♦ This reaction is also known as **hydrolysis (水解)** because it is essentially equivalent to breaking molecules apart using water.



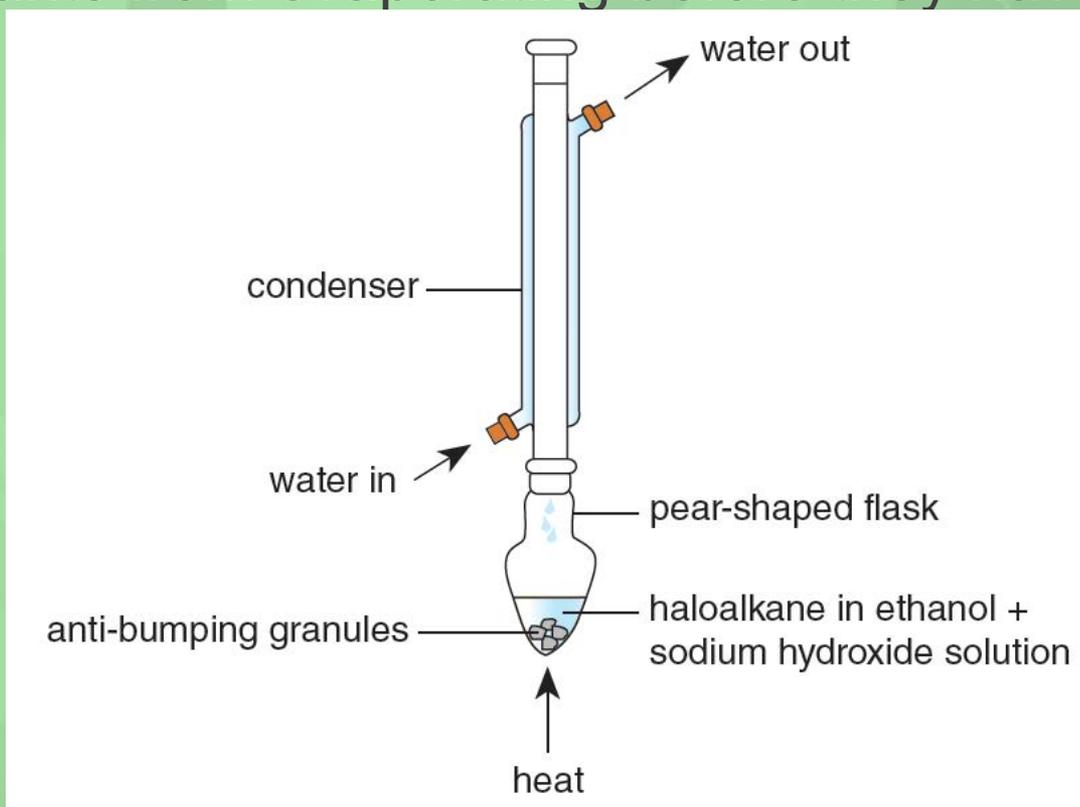
## 31.4 Substitution reactions of haloalkanes (p.98)

- ◆ Haloalkanes do not mix with water or aqueous solutions. For this reason, the reaction is carried out in the presence of ethanol, which can dissolve the haloalkane and also mix with the sodium hydroxide solution.
- ◆ This reaction occurs very slow at room temperature. To speed up the reaction, it is necessary to heat the mixture. The figure below shows the experimental set-up used for heating a haloalkane with sodium hydroxide solution under reflux.



## 31.4 Substitution reactions of haloalkanes (p.98)

- Use of a reflux condenser ensures that the volatile reactants are condensed back into the reaction mixture. This prevents the volatile reactants from evaporating before they have a chance to react.

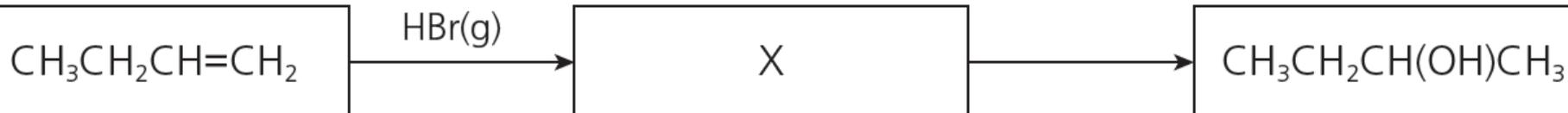




## 31.4 Substitution reactions of haloalkanes (p.98)

### Practice 31.3

A student proposed the following route for synthesising butan-2-ol from but-1-ene.



- a) i) Identify X.  $\text{CH}_3\text{CH}_2\text{CHBrCH}_3$   
ii) Name the type of reaction that takes place in the conversion of but-1-ene to X. **Addition reaction**
- b) i) Give the reagent and reaction condition needed in the conversion of X to butan-2-ol. **NaOH(aq), heat under reflux**  
ii) Name the type of reaction involved.  
**Substitution reaction / hydrolysis**



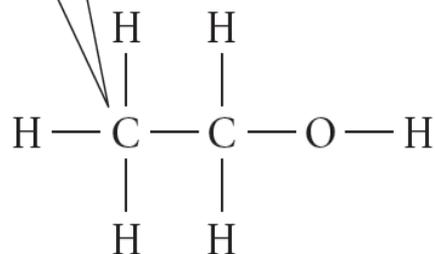
## 31.5 Reactions of alcohols (p.99)

- ◆ Alcohols occupy a central position in organic functional group chemistry —
  - they can be readily converted to aldehydes and carboxylic acids by oxidation, and can be formed from them by reduction;
  - they can be converted to and from haloalkanes by substitution.
- ◆ Alcohols are classified as **primary (1°, 一級)**, **secondary (2°, 二級)** and **tertiary (3°, 三級)** depending on the number of carbon atoms attached to the hydroxyl carbon, i.e. the carbon atom bearing the hydroxyl group (–OH).



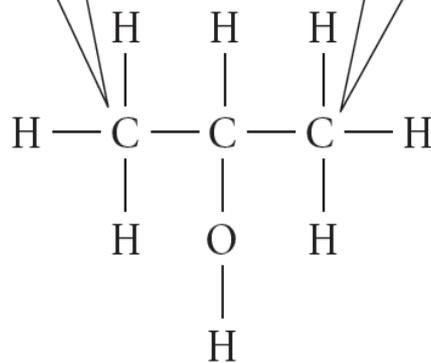
## 31.5 Reactions of alcohols (p.99)

one carbon atom attached to the hydroxyl carbon



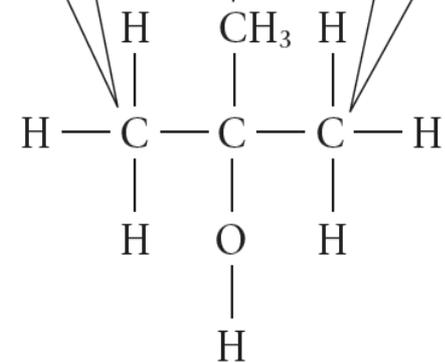
*Ethanol is a primary alcohol*

two carbon atoms attached to the hydroxyl carbon



*Propan-2-ol is a secondary alcohol*

three carbon atoms attached to the hydroxyl carbon



*Methylpropan-2-ol is a tertiary alcohol*

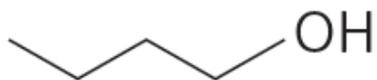


## 31.5 Reactions of alcohols (p.99)

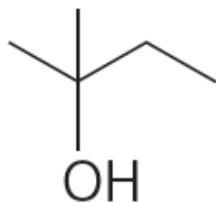
### Practice 31.4

Classify each of the following alcohols as primary, secondary and tertiary. Give the systematic name of each alcohol.

a)



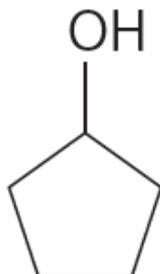
b)



c)



d)





## 31.5 Reactions of alcohols (p.99)

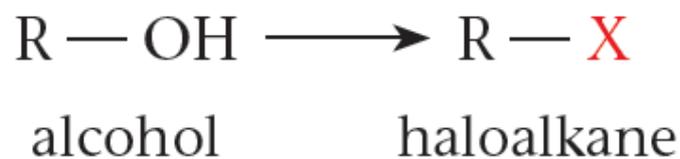
- ◆ You will study the following reactions of alcohols to form other carbon compounds:
  - substitution to form haloalkanes;
  - dehydration to form alkenes; and
  - oxidation to form aldehydes, ketones and carboxylic acids.



## 31.5 Reactions of alcohols (p.99)

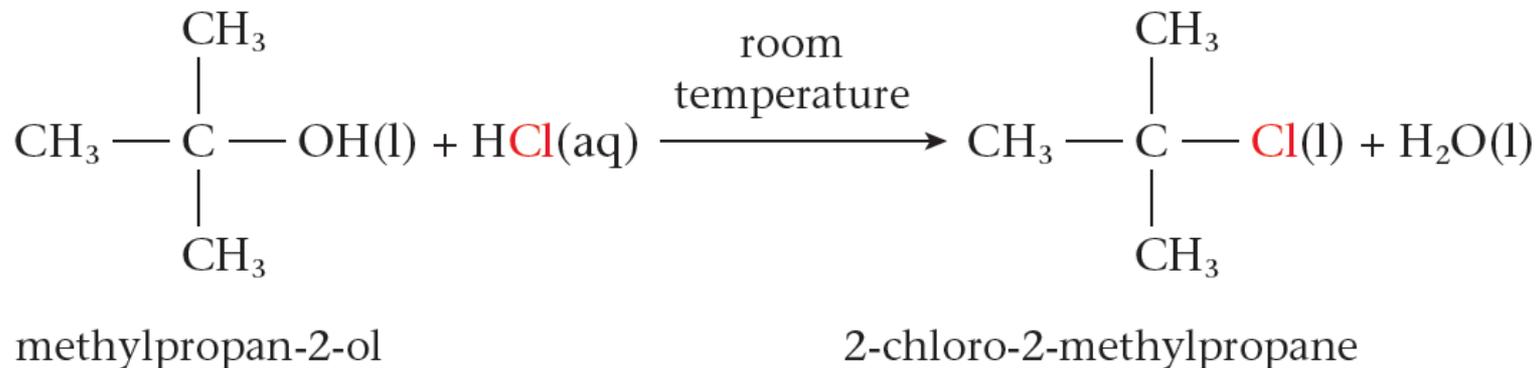
### Substitution to form haloalkanes

- The order of reactivity of alcohols in such substitution reactions is  $3^\circ > 2^\circ > 1^\circ$ .



### Reactions with HCl(aq) and HCl(g)

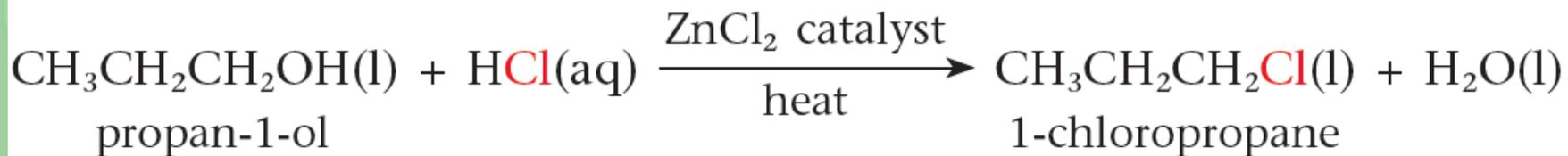
- Tertiary alcohols react rapidly with concentrated hydrochloric acid on shaking at room temperature.



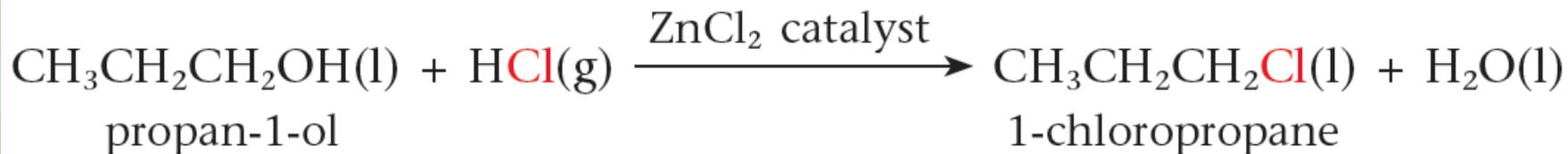


## 31.5 Reactions of alcohols (p.99)

- ◆ Secondary and primary alcohols also react with concentrated hydrochloric acid, but at a lower rate. Anhydrous zinc chloride needs to be added as a catalyst, and the mixture requires heating.



- ◆ A substitution reaction also occurs when dry hydrogen chloride gas is bubbled through an anhydrous alcohol in the presence of anhydrous zinc chloride catalyst.

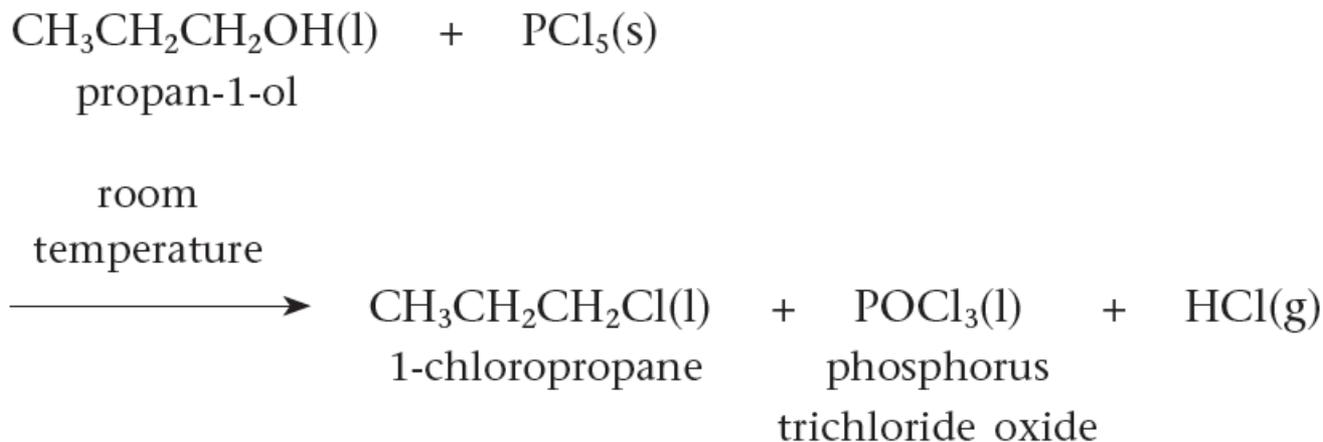




## 31.5 Reactions of alcohols (p.99)

### Reactions with $\text{PCl}_5(\text{s})$ and $\text{SOCl}_2(\text{l})$

- ◆ The reaction between an alcohol and phosphorus pentachloride is very vigorous at room temperature, so the reaction mixture does not need heating.

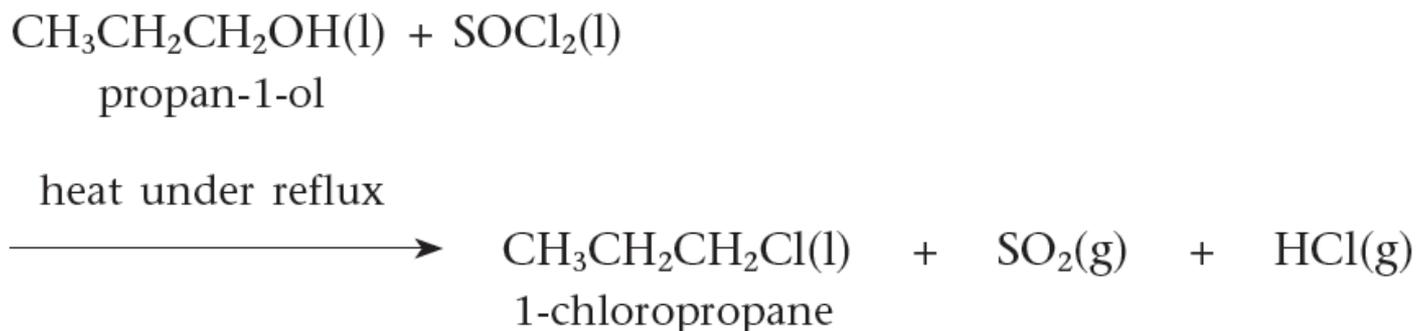


- ◆ The detection of the  $\text{HCl}(\text{g})$  released can be used as a test for the presence of a hydroxyl group. You can observe the 'steamy fumes' formed by the gas.



## 31.5 Reactions of alcohols (p.99)

- ◆ **Sulphur dichloride oxide**,  $\text{SOCl}_2$  (氧二氯化硫) can also be used to substitute a chlorine atom into an alcohol molecule.



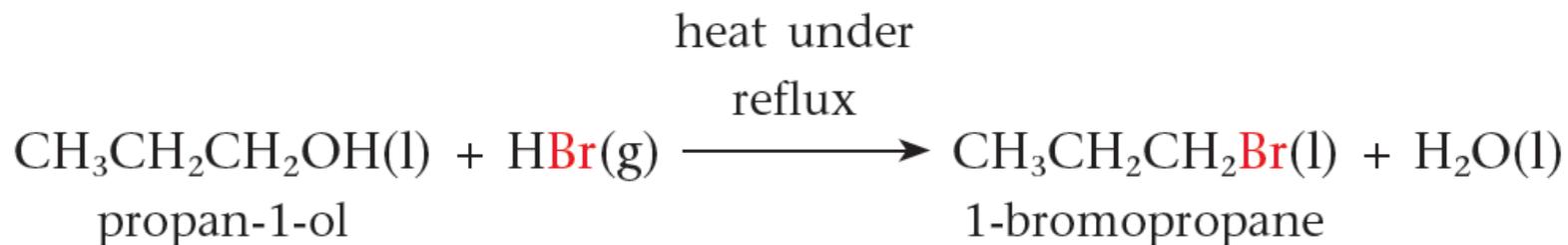
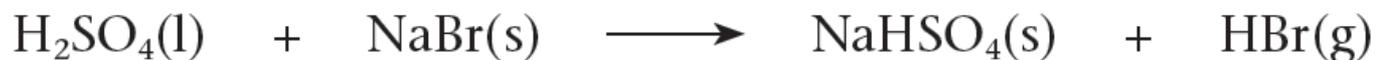
- ◆ Notice that in this reaction, the two other products ( $\text{SO}_2$  and  $\text{HCl}$ ) are both gases and they will escape from the reaction mixture, leaving the chloroalkane.



## 31.5 Reactions of alcohols (p.99)

### Reactions with HBr(g)

- ◆ An alcohol can be converted into a bromoalkane by heating under reflux with a mixture of sodium bromide and concentrated sulphuric acid.



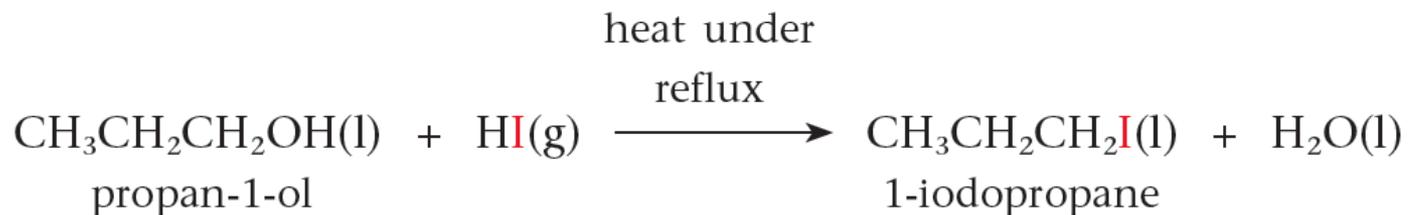
- ◆ The mixture is warmed to distil off the bromoalkane.



## 31.5 Reactions of alcohols (p.99)

### Reactions with HI(s)

- ◆ An alcohol can be converted into an iodoalkane by heating under reflux with a mixture of sodium iodide and concentrated phosphoric acid.
- ◆ Conc.  $\text{H}_3\text{PO}_4$ , instead of conc.  $\text{H}_2\text{SO}_4$ , is used because the latter reacts with HI to form  $\text{I}_2$  and produces hardly any HI.



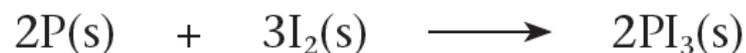
- ◆ The mixture is then warmed to distil off the iodoalkane.



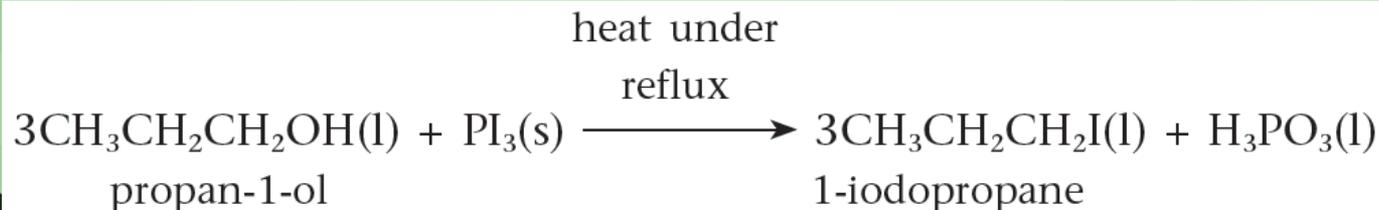
## 31.5 Reactions of alcohols (p.99)

### Reactions with red P(s) and Br<sub>2</sub>(l) or I<sub>2</sub>(l)

- An alcohol can be converted into a bromoalkane or an iodoalkane by heating under reflux with a mixture of red phosphorus and either bromine or iodine.

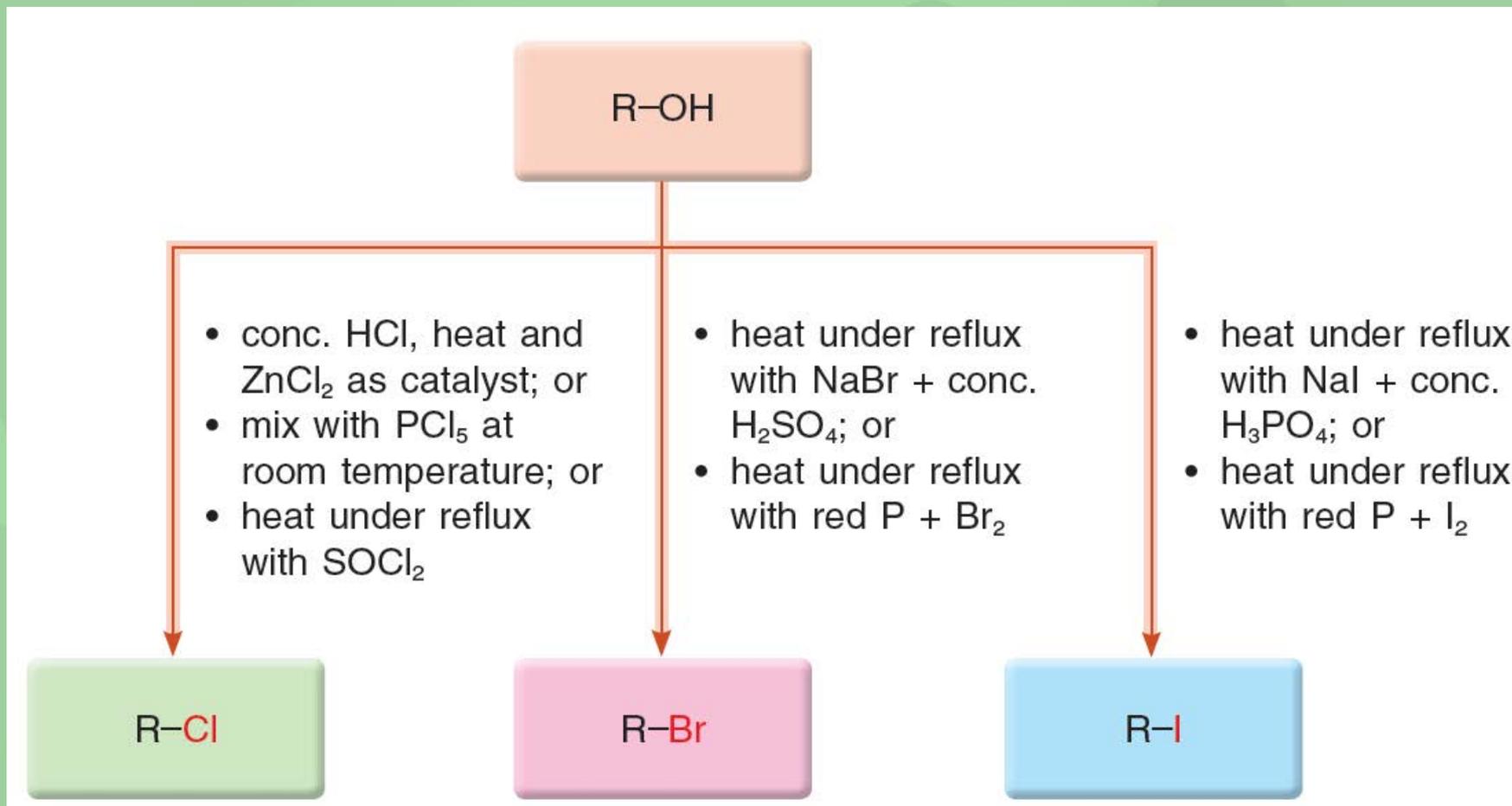


- The phosphorus trihalide, for example phosphorus triiodide, then reacts with the alcohol to give an iodoalkane which can be distilled off.





## 31.5 Reactions of alcohols (p.99)

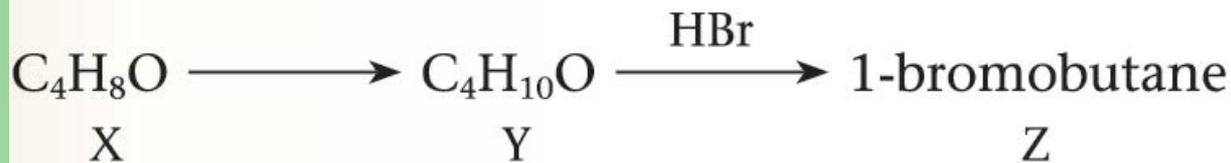




## 31.5 Reactions of alcohols (p.99)

### Q (Example 31.1)

Consider the following conversions:



- a) Write the structural formula of Z.
- b)
  - i) Deduce the structural formula of Y.
  - ii) Name the type of reaction for the conversion of Y to Z.
- c)
  - i) X exhibits cis-trans isomerism.  
Deduce the structural formulae of X.
  - ii) State the reagent and reaction condition(s) required for the conversion of X to Y.





## 31.5 Reactions of alcohols (p.99)

c) i) X has a C=C bond as there are two fewer hydrogen atoms in X as compared with Y.

As X exhibits cis-trans isomerism, there are two different atoms or groups of atoms on each carbon atom of the C=C bond.

Thus, the structural formula of X is



ii) Any one of the following:

- $\text{H}_2$  / Pt catalyst, heat
- $\text{H}_2$  / Ni catalyst, heat



## 31.5 Reactions of alcohols (p.99)

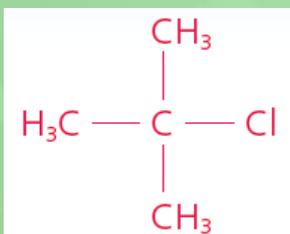
### Practice 31.5

1 For each of the following reactions,

- write the structural formula of the organic product;
- give the systematic name of the organic product.

a) Refluxing methylpropan-2-ol with a mixture of sodium chloride and concentrated sulphuric acid.

i)



ii) 2-chloro-2-methylpropane

b) Refluxing butan-1-ol with a mixture of red phosphorus and iodine.

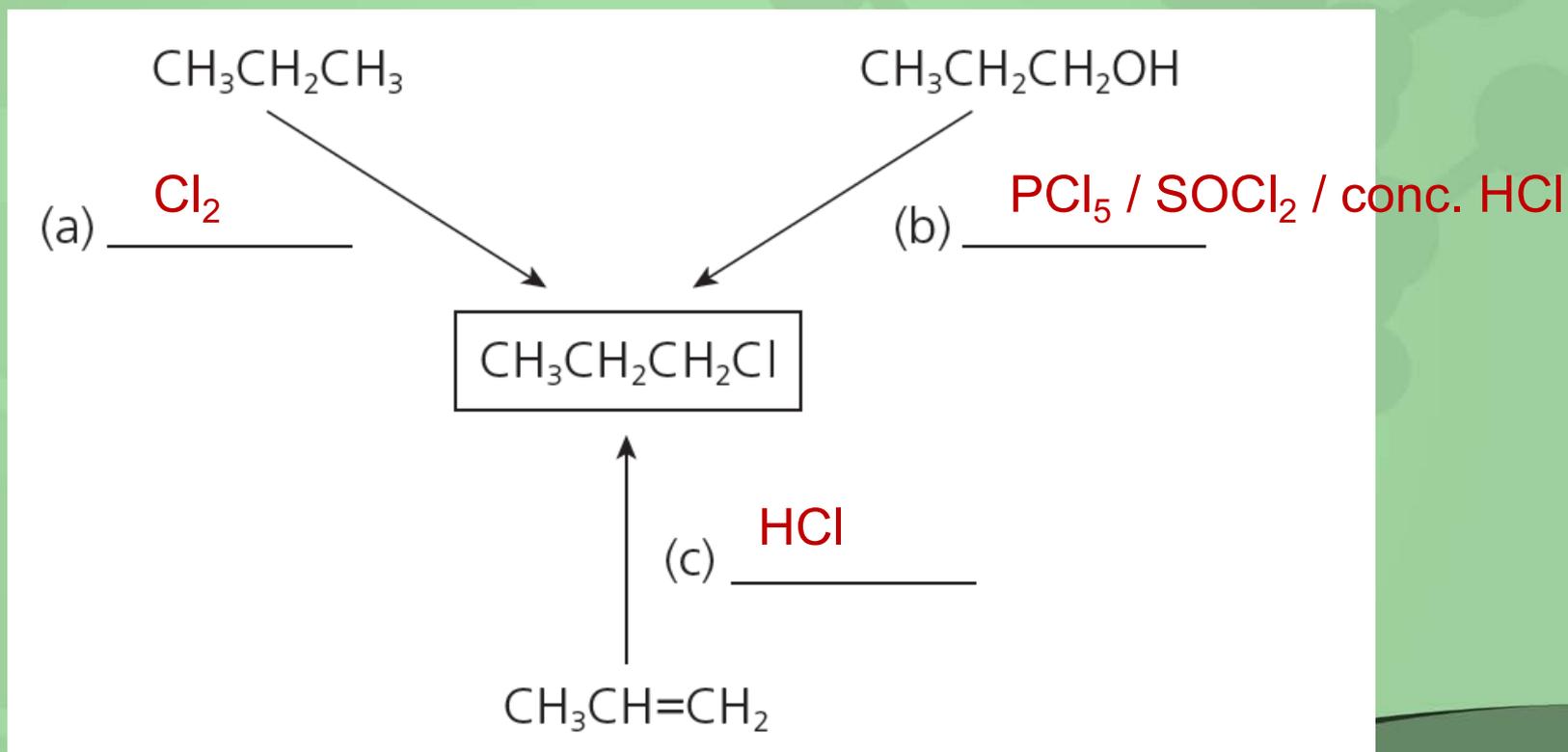
i)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{I}$

ii) 1-iodobutane



## 31.5 Reactions of alcohols (p.99)

- 2 1-chloropropane can be produced in various ways as shown below. State the reagent needed for each of these reactions.

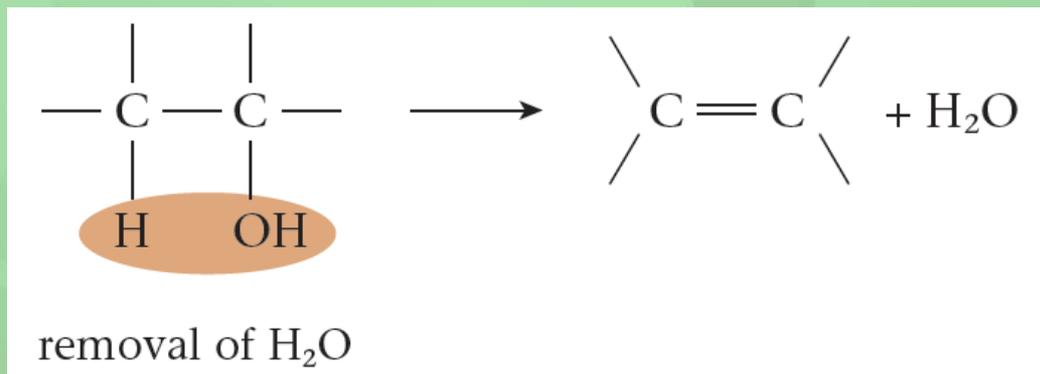




## 31.5 Reactions of alcohols (p.99)

### Dehydration to form alkenes

- ◆ **Dehydration (脱水作用)** is a reaction in which a water molecule is removed from a reactant molecule.
- ◆ When an alcohol is heated in the presence of a catalyst, water is lost to make an alkene. In the process, the  $\text{-OH}$  group and a hydrogen atom from an adjacent carbon atom are removed to form a water molecule, and a carbon-carbon double bond forms in the carbon chain.





## 31.5 Reactions of alcohols (p.99)

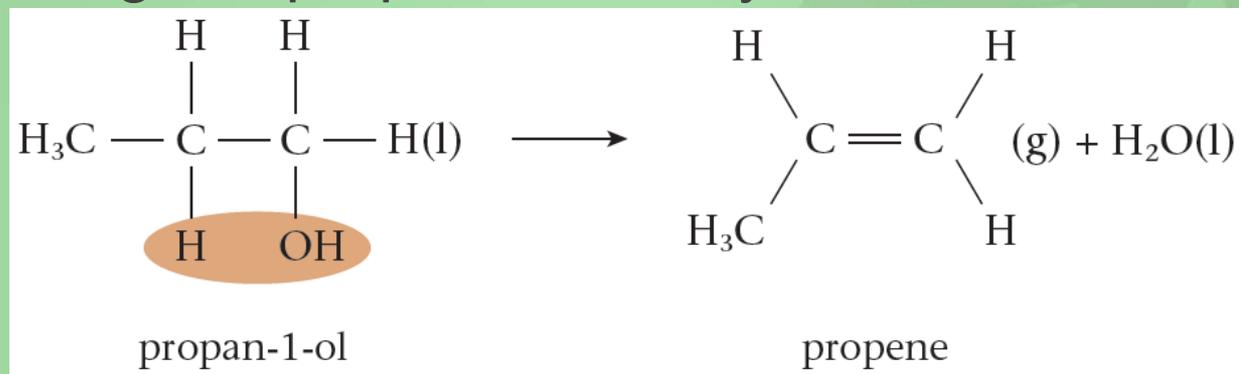
- ◆ Dehydration is a type of **elimination reaction** (消去反應). An elimination reaction is one where a small molecule is removed (eliminated) from a reactant molecule.
- ◆ The relative ease of the dehydration of different alcohols follows the order:  $3^\circ > 2^\circ > 1^\circ$ .
- ◆ Hence the experimental conditions required for dehydration depend on the classes of alcohol involved.



## 31.5 Reactions of alcohols (p.99)

### Dehydration of primary alcohols

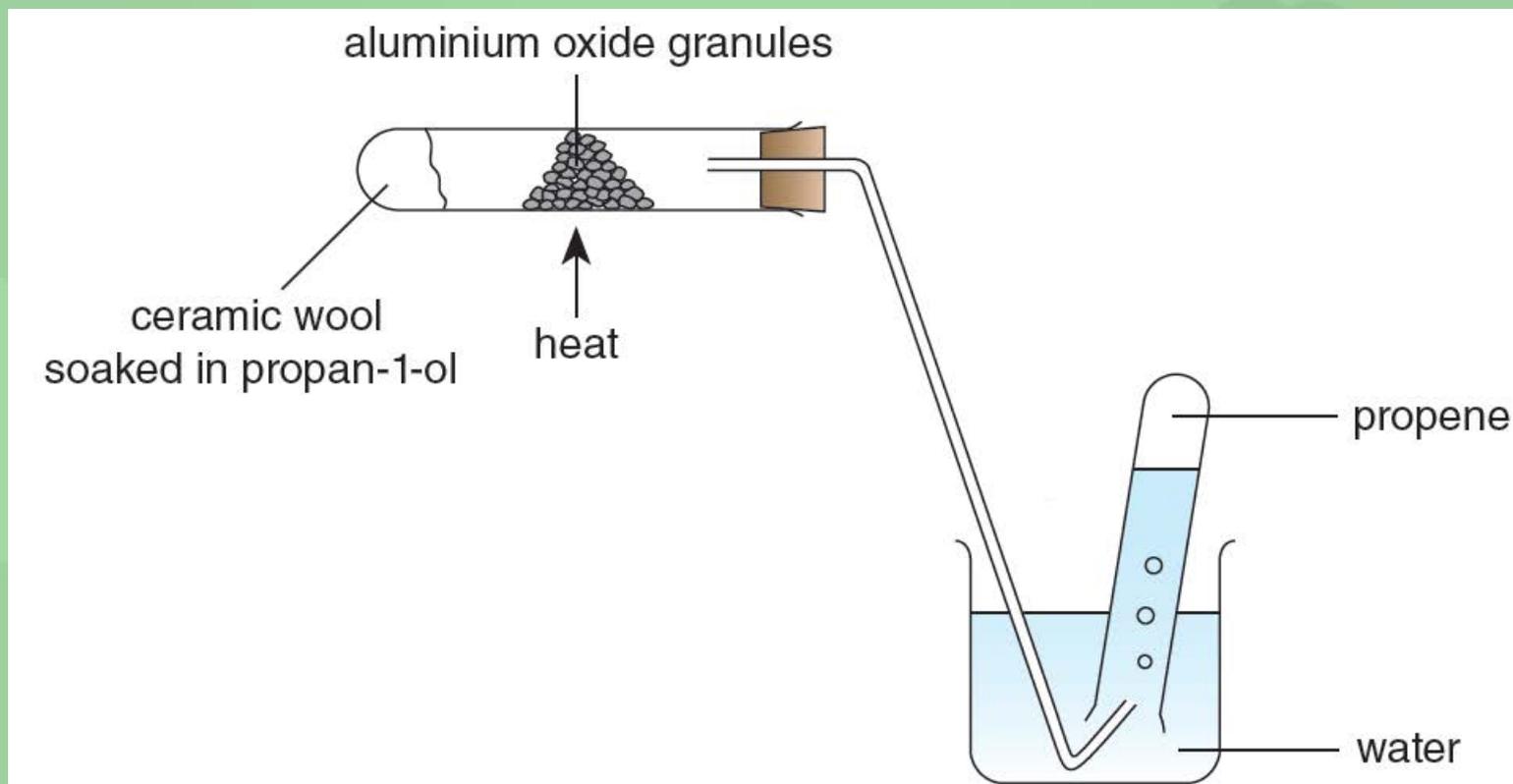
- Primary alcohols are the most difficult to dehydrate. Propan-1-ol gives propene on dehydration.



- There are two ways of carrying out this dehydration:
  - pass the propan-1-ol over a catalyst of aluminium oxide at 300 °C;
  - heat propan-1-ol with an acid catalyst, such as concentrated sulphuric acid, at 180 °C.

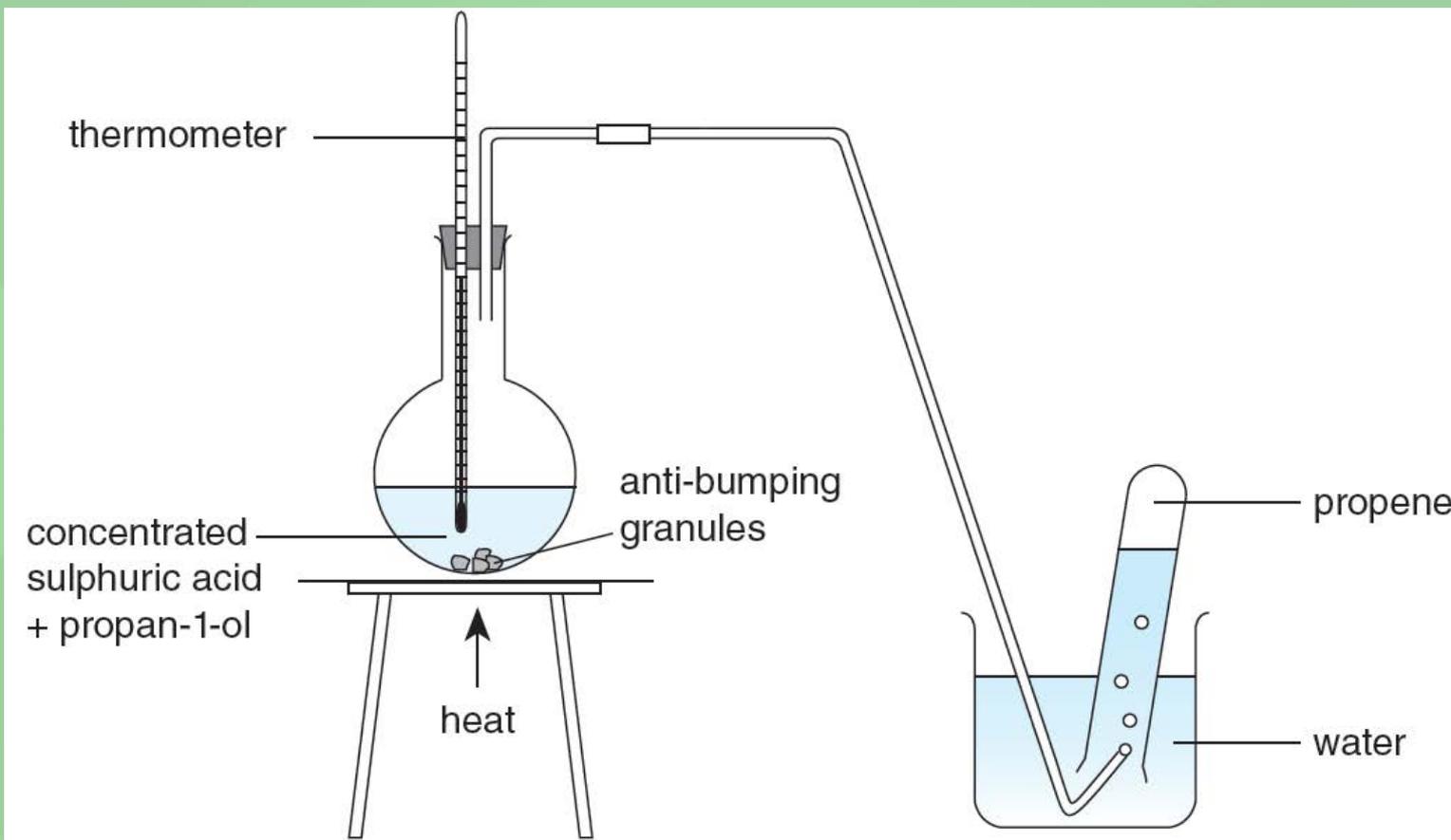


## 31.5 Reactions of alcohols (p.99)





# 31.5 Reactions of alcohols (p.99)

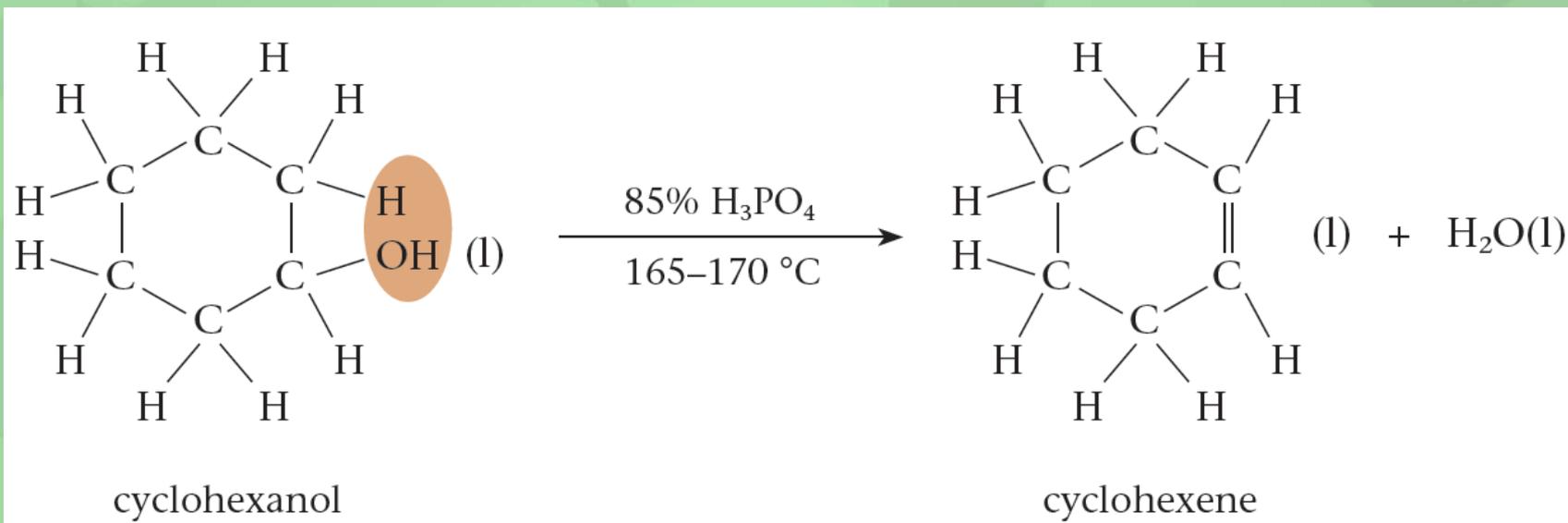




## 31.5 Reactions of alcohols (p.99)

### Dehydration of secondary alcohols

- Secondary alcohols usually dehydrate under milder conditions. Cyclohexanol, for example, dehydrates in 85% phosphoric acid at 165–170 °C.

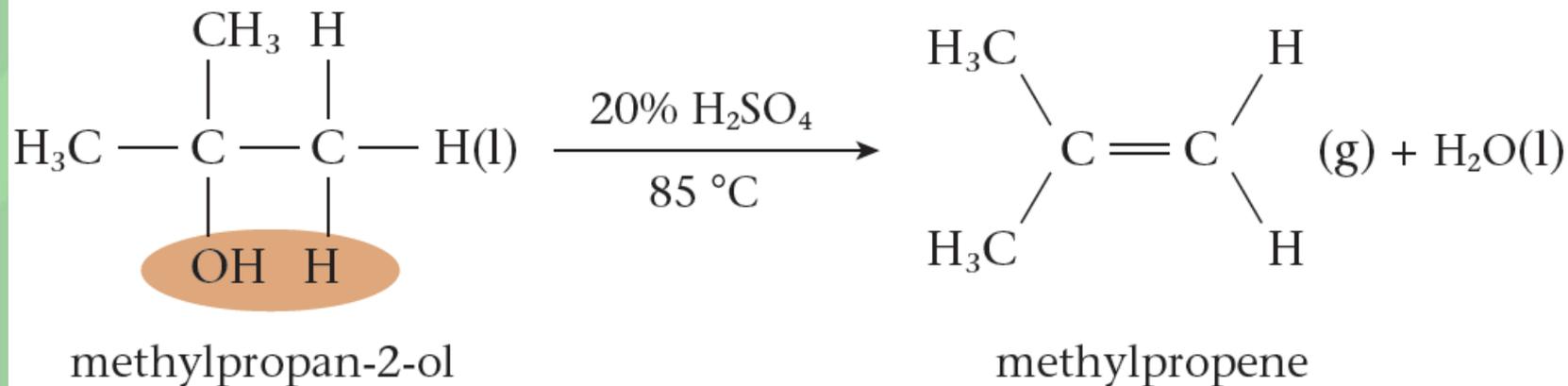




## 31.5 Reactions of alcohols (p.99)

### Dehydration of tertiary alcohols

- ♦ Tertiary alcohols are usually so easily dehydrated that extremely mild conditions can be used. For example, methylpropan-2-ol dehydrates in 20% sulphuric acid at 85 °C.

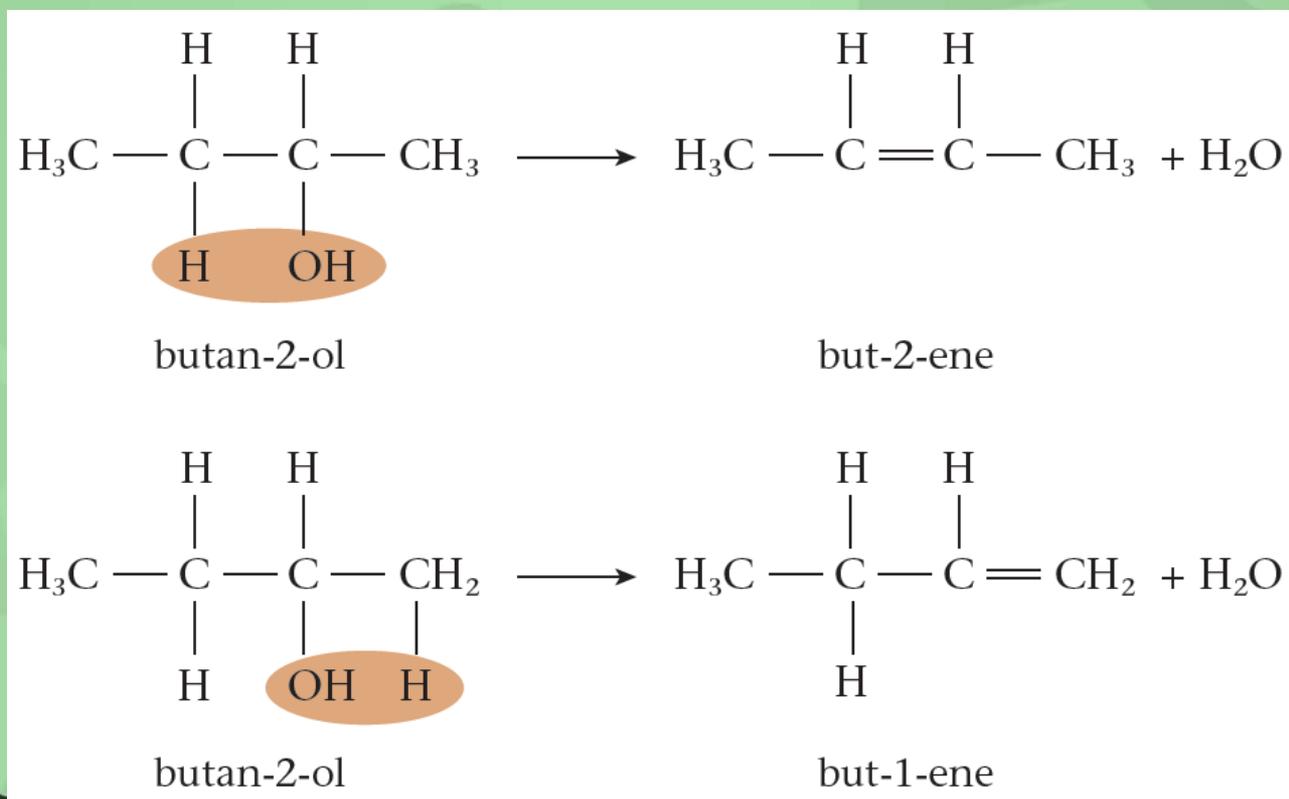




## 31.5 Reactions of alcohols (p.99)

### Major dehydration product of butan-2-ol

- Dehydration of an alcohol may produce more than one alkene. For butan-2-ol, water can be lost in two ways:





## 31.5 Reactions of alcohols (p.99)

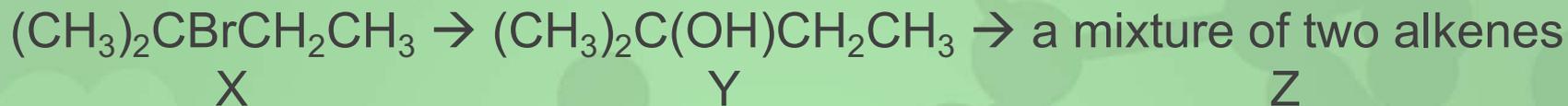
- ◆ Remember that but-2-ene actually exists as a pair of *cis-trans* isomers. It is therefore correct to state that there are three products— but-1-ene and the two isomeric forms of but-2-ene (i.e. *cis*-but-2-ene and *trans*-but-2-ene).
- ◆ But-2-ene has two alkyl groups attached to the carbon atoms of the carbon-carbon double bond while but-1-ene has only one. But-2-ene is the alkene bearing more alkyl groups and the major dehydration product.



## 31.5 Reactions of alcohols (p.99)

### Q (Example 31.2)

Consider the following conversions:



a) For each of the following conversions:



i) name the type of reaction involved; and

ii) give the reagent and reaction condition(s) required.

b) i) Write the structural formulae of the two alkenes in Z. Give their systematic names.

ii) Suggest whether the two alkenes can exhibit cis-trans isomerism. Explain.



## 31.5 Reactions of alcohols (p.99)

A

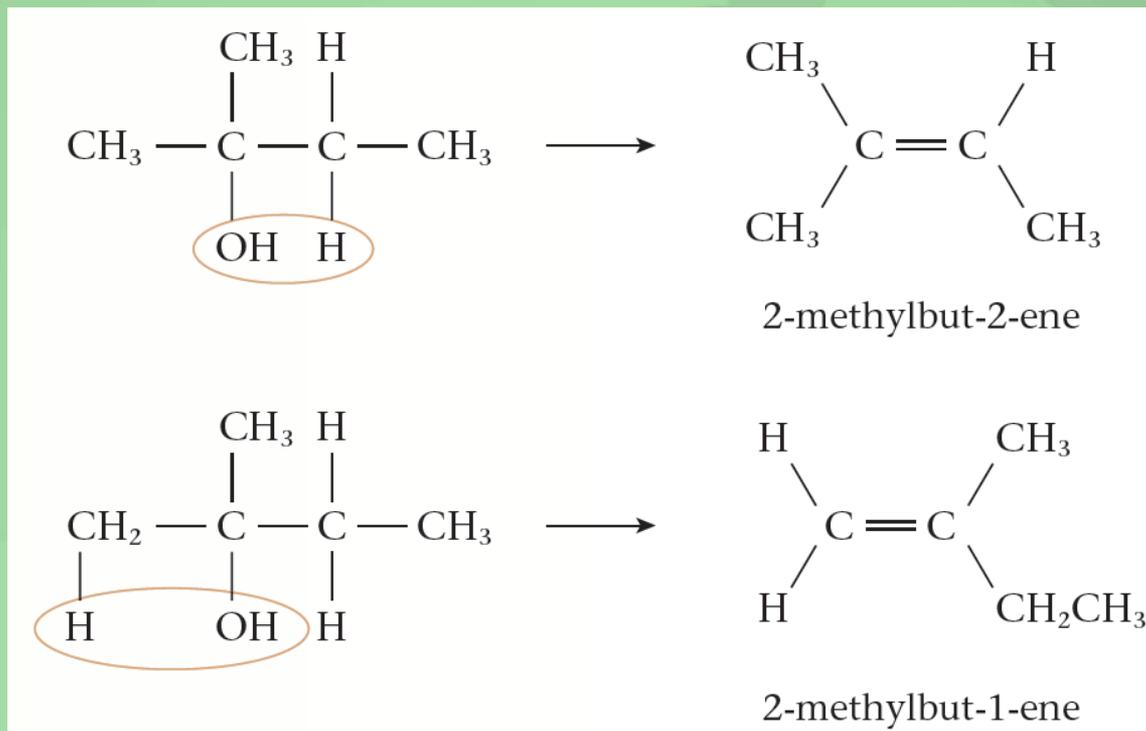
a)

Conversion	Type of reaction involved	Reagent and reaction condition(s) required
$X \longrightarrow Y$	substitution (or hydrolysis)	NaOH(aq); heat under reflux
$Y \longrightarrow Z$	dehydration (or elimination)	Any one of the following: <ul style="list-style-type: none"><li>concentrated <math>H_2SO_4</math> or <math>H_3PO_4</math> as catalyst, heat</li><li>aluminium oxide as catalyst, heat</li></ul>



## 31.5 Reactions of alcohols (p.99)

b) i) Water can be lost from Y in two ways:



ii) These alkenes do not exhibit *cis-trans* isomerism. In each alkene, one of the carbon atoms of the C=C bond bears identical atoms or groups.



## 31.5 Reactions of alcohols (p.99)

### Practice 31.6

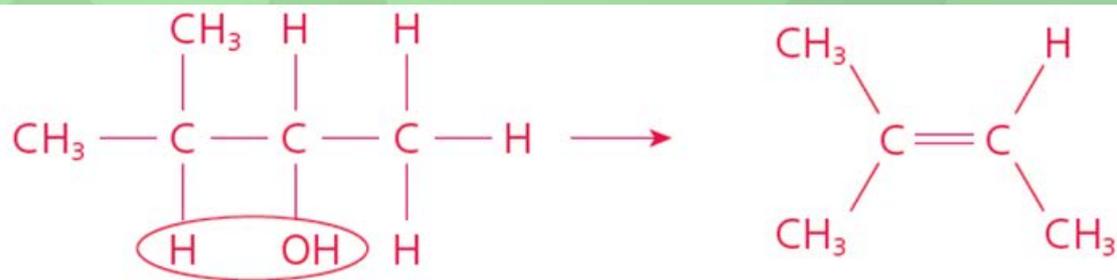
Alcohol A  $(\text{CH}_3)_2\text{CHCH}(\text{OH})\text{CH}_3$  undergoes a reaction to give two isomeric alkenes X and Y.

a) Name the type of reaction that takes place. **Dehydration**

b) Give the reagent and the reaction conditions required.

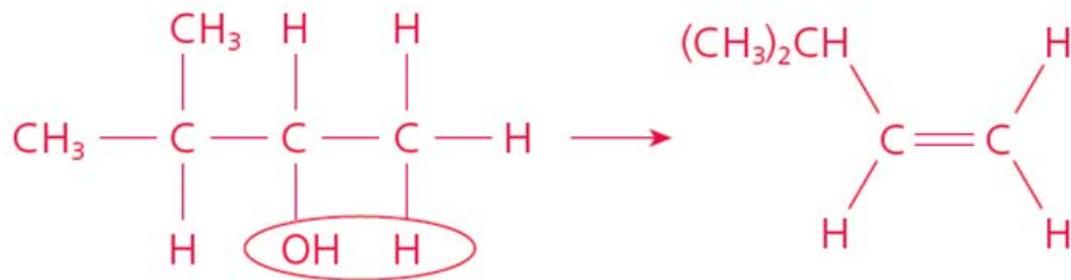
**Heat,  $\text{Al}_2\text{O}_3$  or conc.  $\text{H}_2\text{SO}_4$  as catalyst**

c) i) Write the structural formulae of the two isomeric alkenes X and Y.



ii) What kind of structural isomers are X and Y?

**Position isomerism**

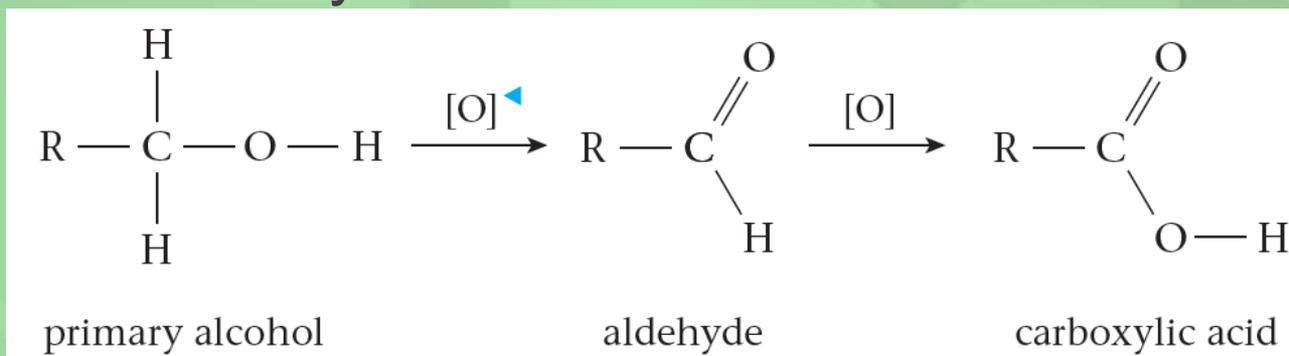




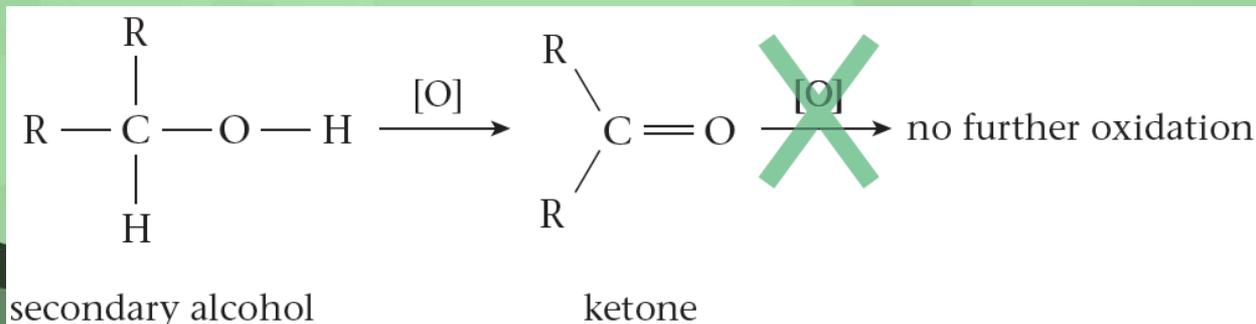
## 31.5 Reactions of alcohols (p.99)

### Oxidation of alcohols

- Primary alcohols are easily oxidised in the presence of oxidising agents to produce aldehydes, which can be further oxidised to carboxylic acids.



- Secondary alcohols can be oxidised to ketones, which do not undergo further oxidation.





## 31.5 Reactions of alcohols (p.99)

- ◆ Tertiary alcohols are not easily oxidised as they do not have any hydrogen atom directly attached to the hydroxyl carbon.
- ◆ A number of oxidising agents can be used, such as acidified potassium dichromate solution and acidified or alkaline potassium permanganate solution.



**Comparing the properties of alcohols with different carbon chain length**



## 31.5 Reactions of alcohols (p.99)

### Oxidising a primary alcohol to an aldehyde

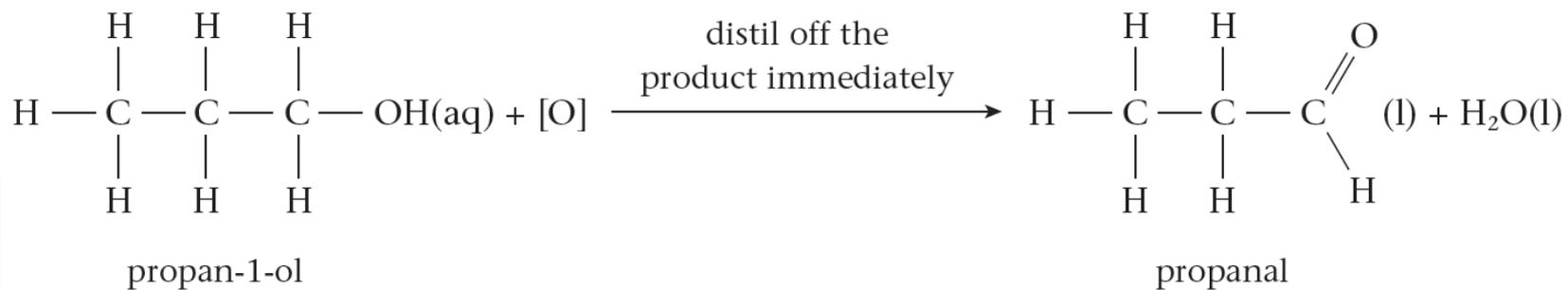
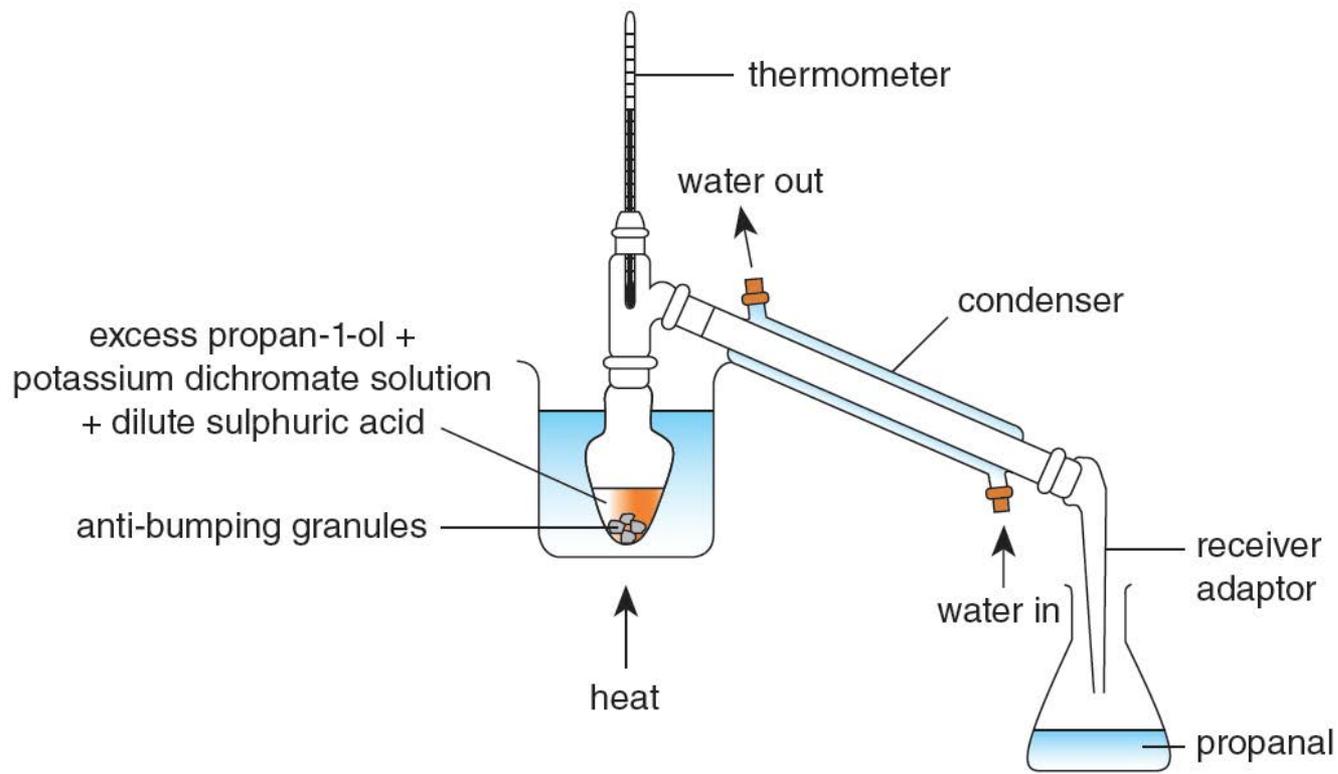
- ◆ To produce an aldehyde, the primary alcohol must be in excess and the product distilled off immediately. This is to ensure that the oxidation is only partial to form the aldehyde and not the carboxylic acid.
- ◆ To oxidise propan-1-ol to propanal, excess propan-1-ol is heated gently with acidified potassium dichromate solution in the set-up shown. Propanal (boiling point  $49\text{ }^{\circ}\text{C}$ ) vaporises as soon as it is formed and is distilled off.



Oxidising ethanol to ethanoic acid and testing the ethanoic acid produced [Ref.](#)



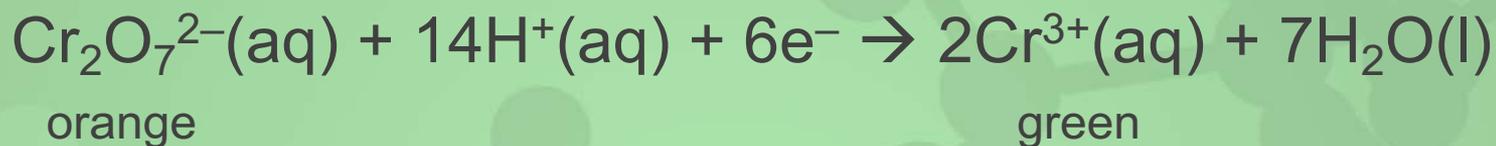
## 31.5 Reactions of alcohols (p.99)





## 31.5 Reactions of alcohols (p.99)

- ◆ The dichromate ions are reduced to chromium(III) ions. The half equation for the reduction is



Hence the colour of the reaction mixture changes from orange to green.

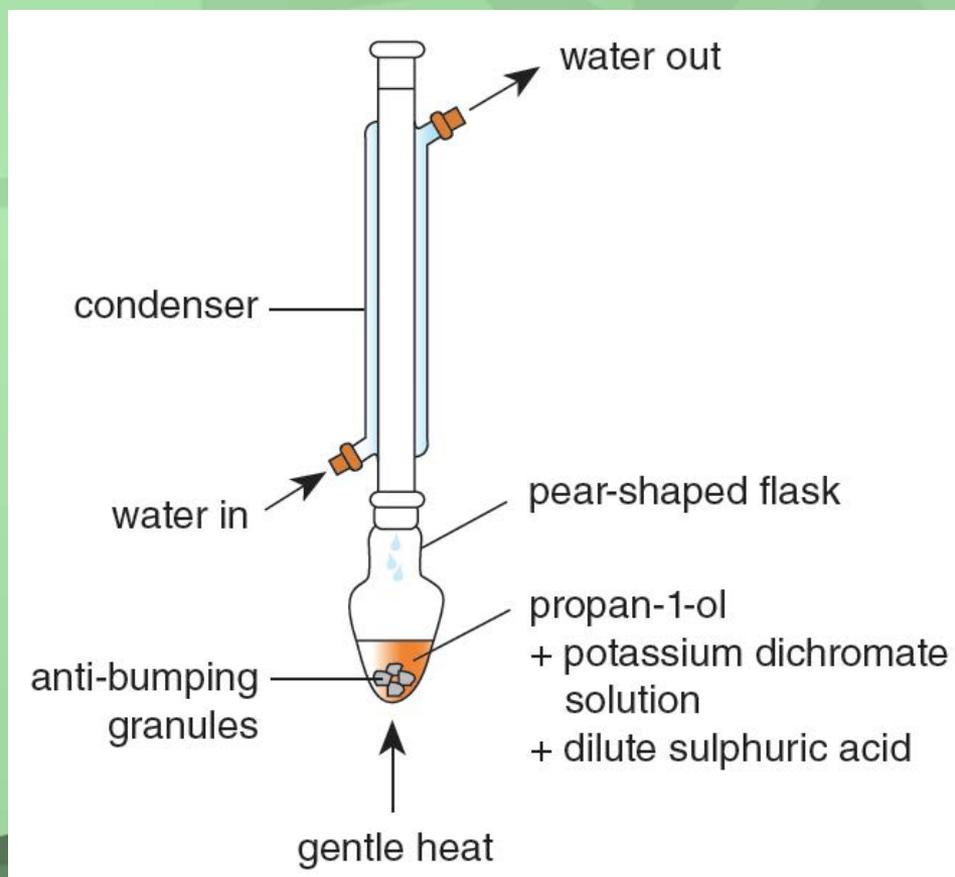


## 31.5 Reactions of alcohols (p.99)

### Oxidising a primary alcohol to a carboxylic acid

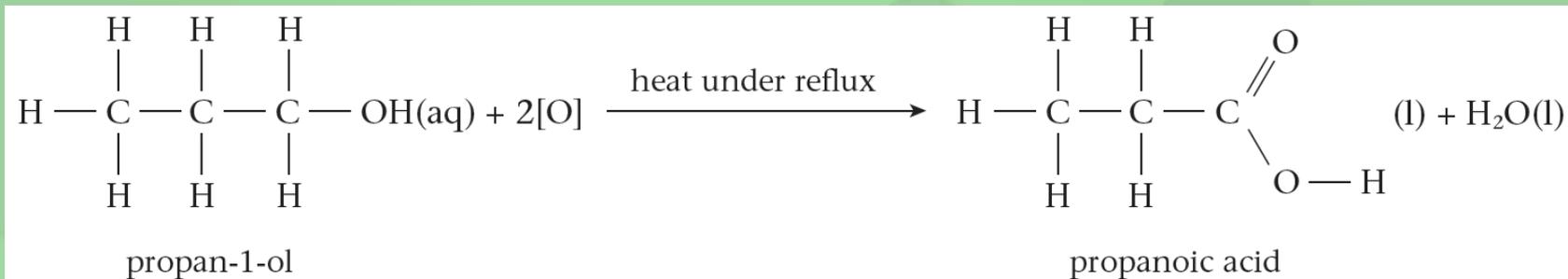
◆ If a primary alcohol is heated strongly under reflux with an excess of acidified potassium dichromate solution, a carboxylic acid is formed.

- Use of an excess of acidified potassium dichromate solution ensures that all of the alcohol is oxidised.
- Heating under reflux ensures that any aldehyde formed initially in the reaction also undergoes oxidation to the carboxylic acid.





## 31.5 Reactions of alcohols (p.99)



- ◆ After the reaction has finished, the propanoic acid is distilled off from the reaction mixture, using simple distillation apparatus.
- ◆ Acidified potassium permanganate solution is an oxidising agent which is too powerful to stop at the aldehyde stage; it oxidises primary alcohols to acids and secondary alcohols to ketones.



## 31.5 Reactions of alcohols (p.99)

- ◆ Ethanol can be oxidised to ethanoic acid by warming with acidified potassium permanganate solution. The colour change shown occurs because permanganate ions are reduced to manganese(II) ions in the process.

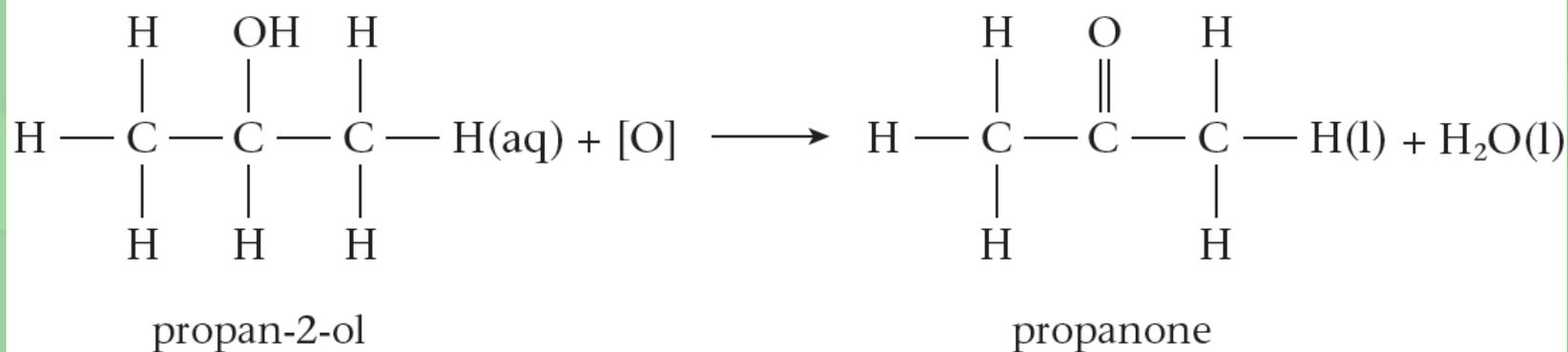




## 31.5 Reactions of alcohols (p.99)

### Oxidising a secondary alcohol to a ketone

- Secondary alcohols are oxidised to ketones by heating under reflux, in the presence of an oxidising agent, such as acidified potassium dichromate solution.





## 31.5 Reactions of alcohols (p.99)

### Oxidising tertiary alcohols

- ◆ Tertiary alcohols, such as methylpropan-2-ol, are very resistant to oxidation and are not oxidised by acidified potassium dichromate solution. Thus, you do not see a colour change when acidified potassium dichromate solution is heated with a tertiary alcohol.



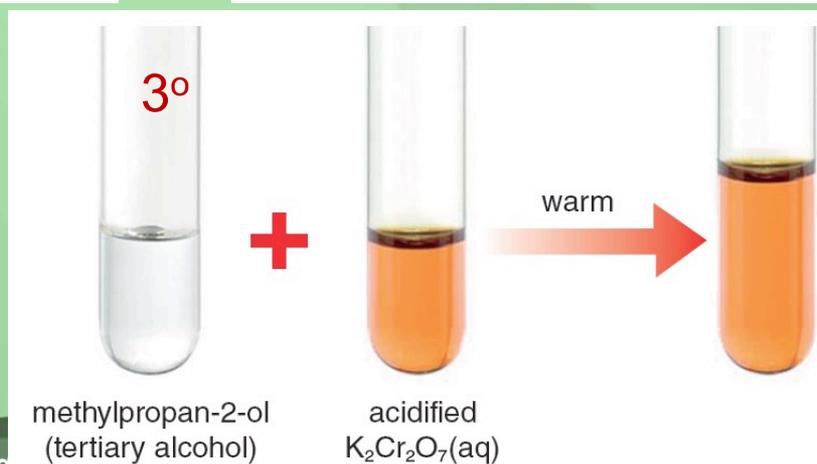
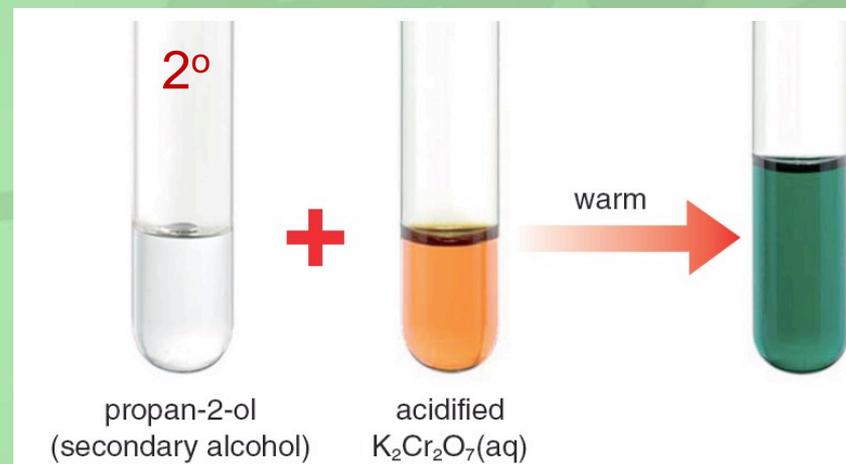
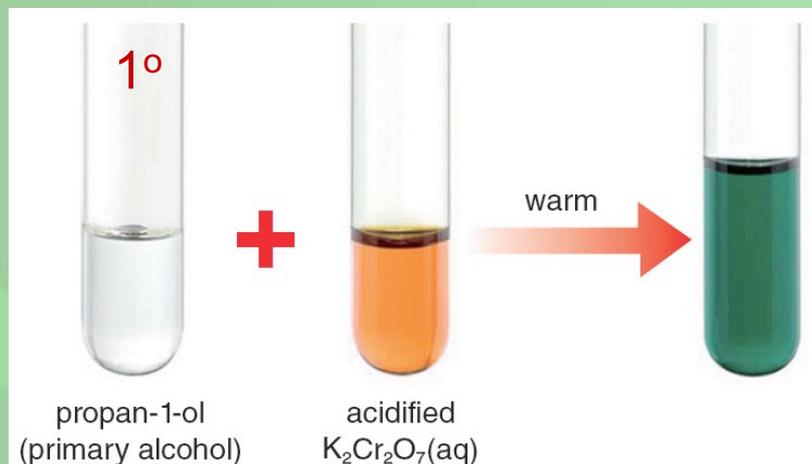
## 31.5 Reactions of alcohols (p.99)

Class of alcohol	Condition(s) of oxidation with acidified $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$	Product	Observable change of reaction mixture
Primary	gentle heating; distilling off the product once formed (alcohol in excess)	aldehyde	colour changes from orange to green
	stronger heating under reflux (oxidising agent in excess)	carboxylic acid	colour changes from orange to green
Secondary	heat under reflux	ketone	colour changes from orange to green
Tertiary	no reaction	–	remains orange



## 31.5 Reactions of alcohols (p.99)

- Hence you can find out whether an alcohol under test is a tertiary alcohol by warming it with acidified potassium dichromate solution and observe if any colour change occurs.



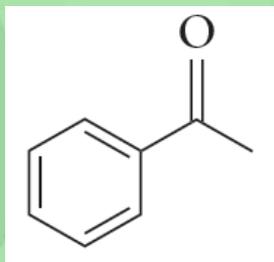


## 31.5 Reactions of alcohols (p.99)

### Q (Example 31.3)

Compounds P and Q are two isomers. They have the same melting point and same solubility in methanol.

Oxidation of P and Q separately produces compound X with the structure shown below.



- To which homologous series does X belong?  
What deductions can be made about P and Q from this?
- What kind of isomers are P and Q?
- Suggest a chemical test to show how P and X can be distinguished.



## 31.5 Reactions of alcohols (p.99)

A

a) X is a ketone.

P and Q are secondary alcohols.

b) P and Q are enantiomers.

c) Any one of the following:

- Warm each compound with acidified  $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$ .

P turns the dichromate solution from orange to green.

There is no observable change for X.

- Warm each compound with acidified  $\text{KMnO}_4(\text{aq})$ .

P turns the permanganate solution from purple to colourless.

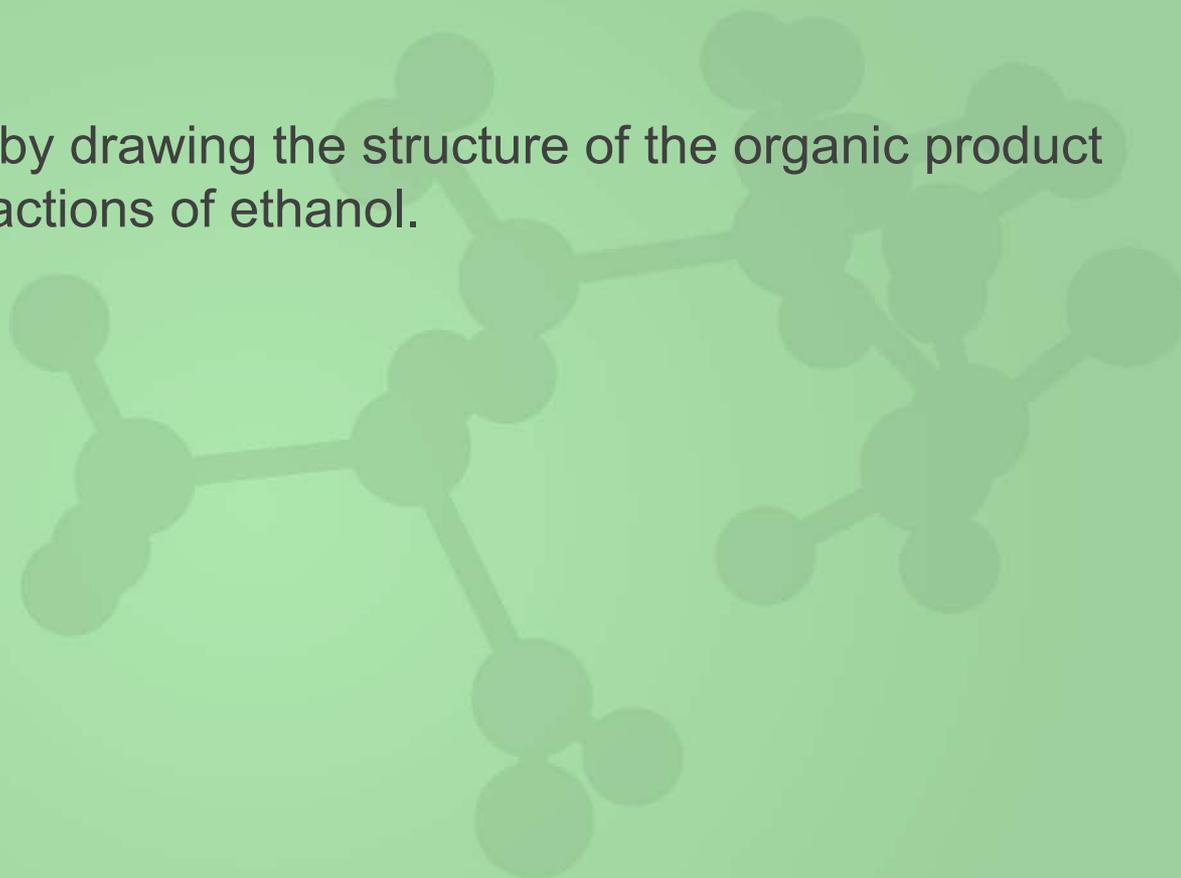
There is no observable change for X.



## 31.5 Reactions of alcohols (p.99)

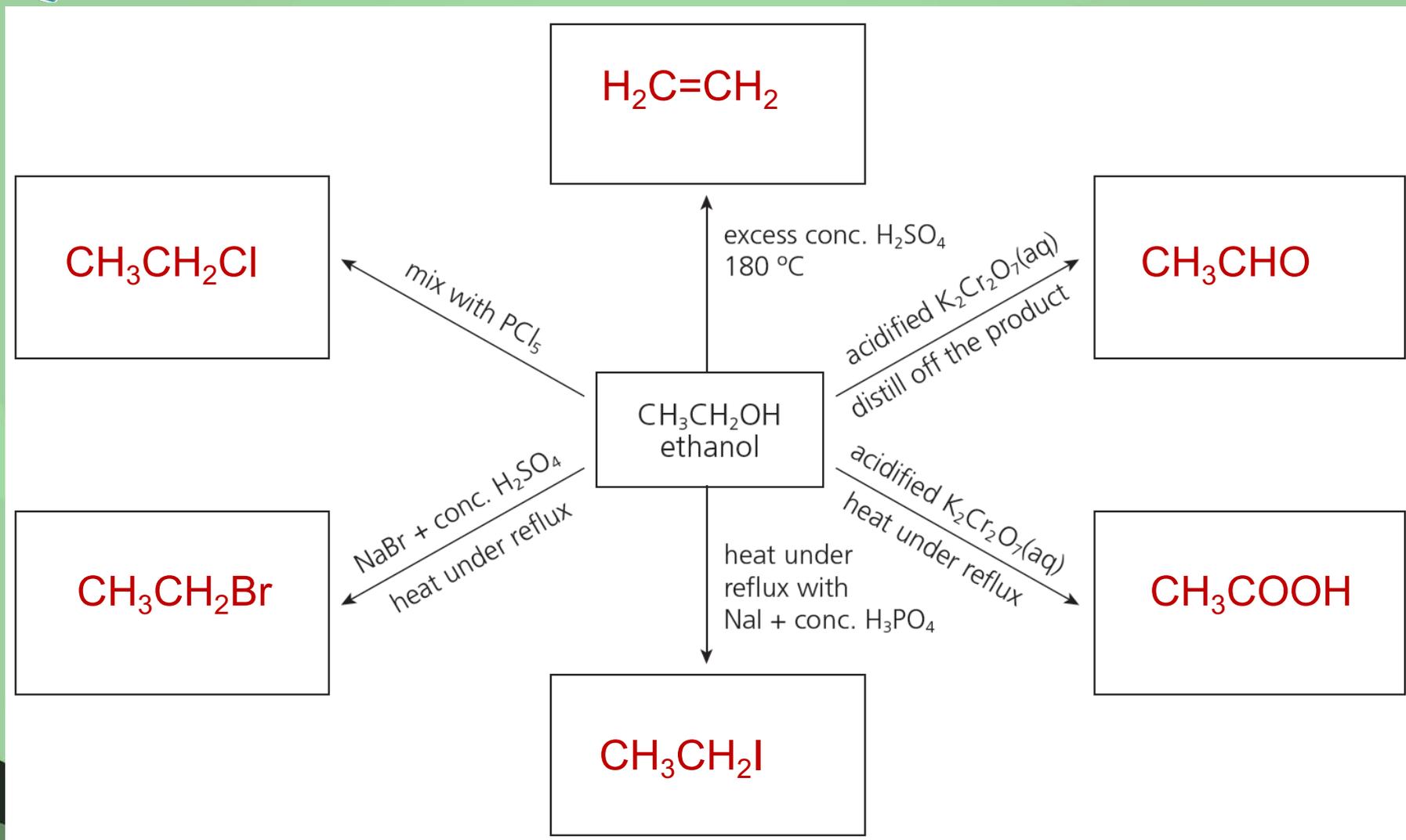
### Practice 31.7

1 Complete the flow chart by drawing the structure of the organic product formed in each of the reactions of ethanol.





## 31.5 Reactions of alcohols (p.99)

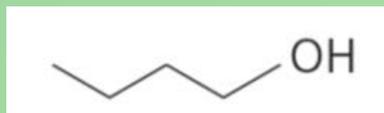




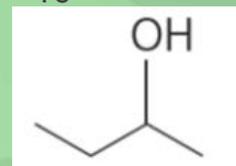
## 31.5 Reactions of alcohols (p.99)

2 Four isomers, each with the molecular formula  $C_4H_{10}O$ , are shown below:

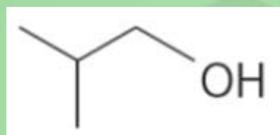
isomer W:



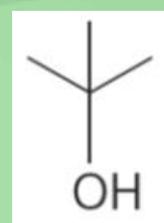
isomer X:



isomer Y:



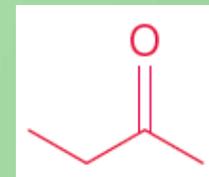
isomer Z:



a) One of the isomers can react with acidified  $K_2Cr_2O_7(aq)$  to form a ketone.

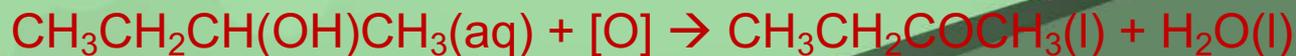
i) Identify the isomer. **Isomer X**

ii) Write the skeletal formula of the ketone formed.



iii) Write the chemical equation for the reaction of the isomer with acidified  $K_2Cr_2O_7(aq)$ .

Use [O] to represent acidified  $K_2Cr_2O_7(aq)$ .





## 31.5 Reactions of alcohols (p.99)

b) Two of the isomers can react with acidified  $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$  to form aldehydes.

i) Identify the two isomers. **Isomers W and Y**

ii) Briefly suggest a practical measure to maximise the yield of the aldehydes. Justify your answer.

**Distil off the aldehydes as they form.**

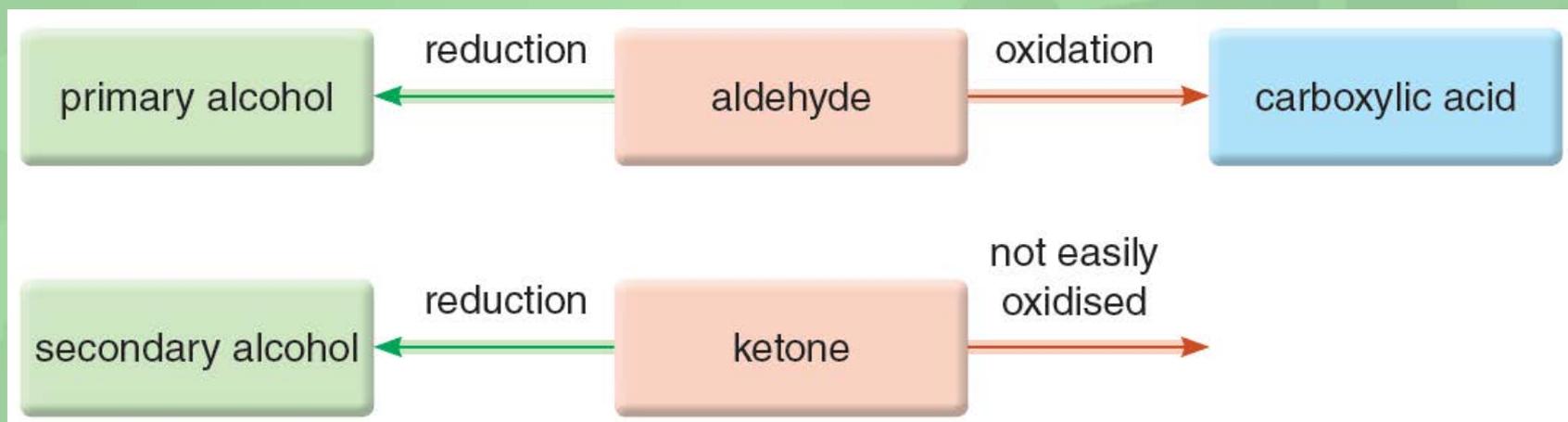
**Use excess alcohol.**

**To prevent further oxidation. / To prevent the formation of carboxylic acid.**



## 31.6 Reactions of aldehydes and ketones (p.119)

- Aldehydes can be reduced and oxidised, but ketones can only be reduced.



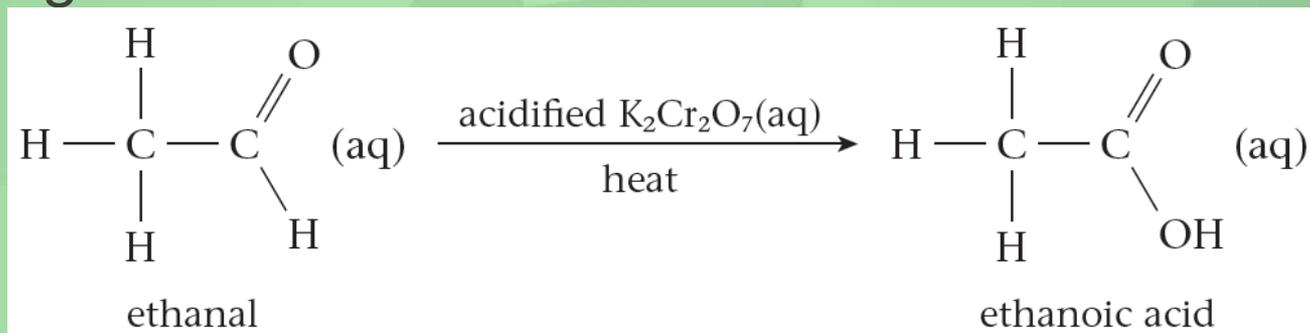
Studying the properties of  
propanal and propanone



## 31.6 Reactions of aldehydes and ketones (p.119)

### Oxidation of aldehydes

- Aldehydes are easily oxidised by acidified potassium dichromate solution. The reaction takes place on gentle warming, and the colour of the reaction mixture changes from orange to green.



- Ketones are not oxidised by acidified potassium dichromate solution. You can use this difference to distinguish between aldehydes and ketones.



## 31.6 Reactions of aldehydes and ketones (p.119)

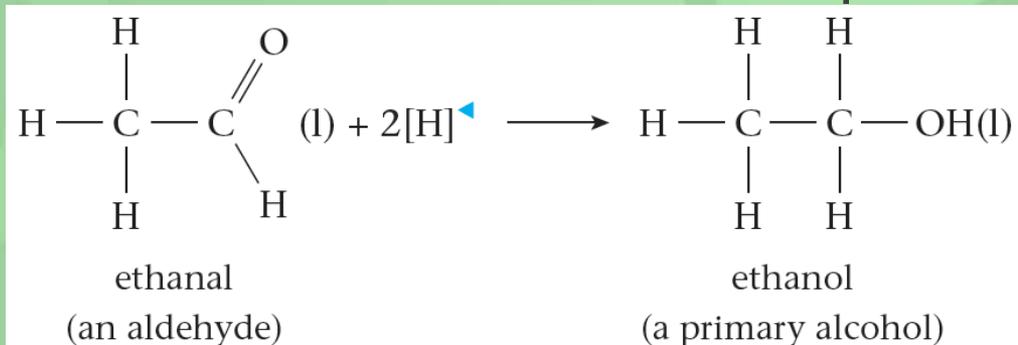
### Reduction of aldehydes and ketones

- ◆ Aldehydes and ketones can be reduced to alcohols. Common reducing agents include:
  - **sodium borohydride ( $\text{NaBH}_4$ )** (硼氫化鈉) in aqueous solution; and
  - **lithium aluminium hydride ( $\text{LiAlH}_4$ )** (氫化鋁鋰) in dry diethyl ether, followed by the addition of a dilute acid.
- ◆ Lithium aluminium hydride is a stronger reducing agent and can be used to reduce aldehydes, ketones and carboxylic acids, but sodium borohydride is only strong enough to reduce aldehydes and ketones.

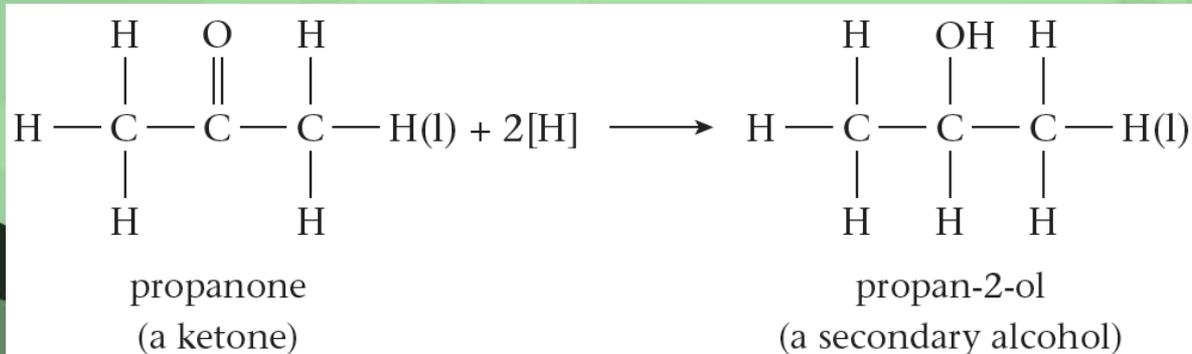


## 31.6 Reactions of aldehydes and ketones (p.119)

- The preferred reagent for the reduction of aldehydes and ketones is sodium borohydride. Although lithium aluminium hydride will carry out the reduction more efficiently, it is both more hazardous and more expensive.



**Reducing vanillin to vanillyl alcohol**

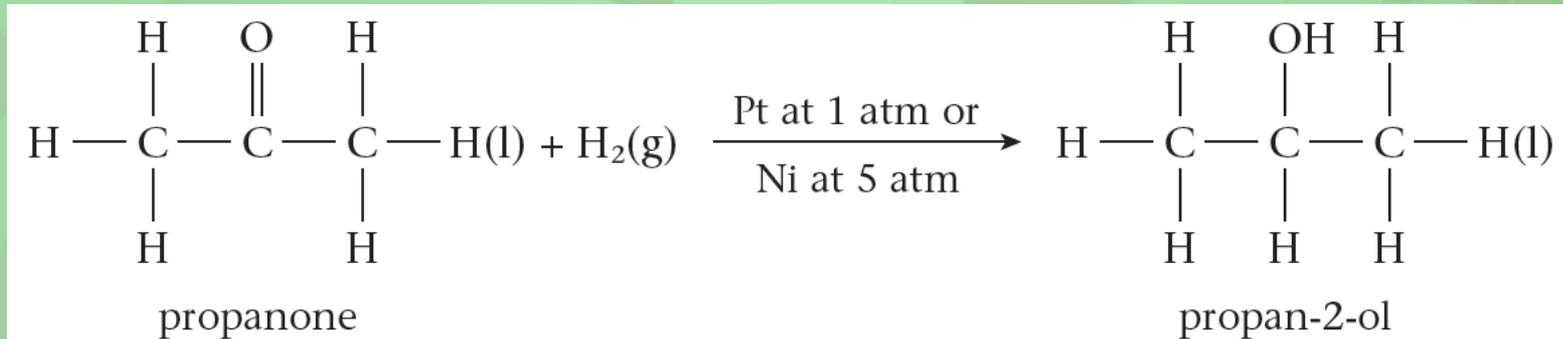




## 31.6 Reactions of aldehydes and ketones (p.119)

### Catalytic hydrogenation

- Like alkenes, carbonyl compounds can be reduced by hydrogen gas over a nickel or platinum catalyst.

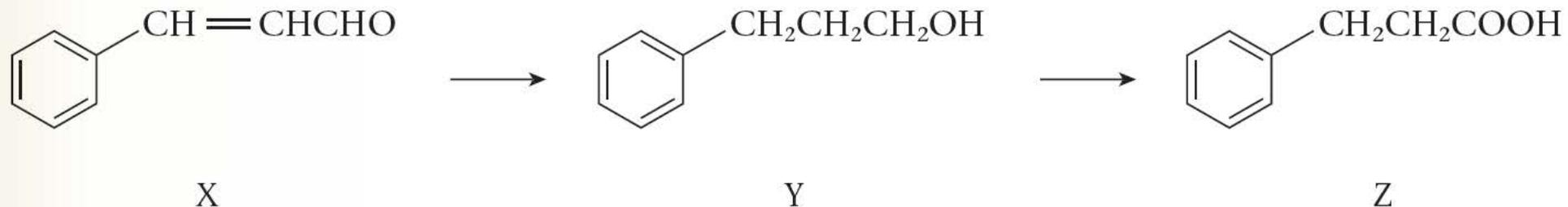




## 31.6 Reactions of aldehydes and ketones (p.119)

### Q (Example 31.4)

Consider the following conversions:



For each of the following conversions,

- $X \rightarrow Y$
- $Y \rightarrow X$

- name the type of reaction involved; and
- give the reagent and reaction condition(s) required.



## 31.6 Reactions of aldehydes and ketones (p.119)

A

Conversion	Type of reaction involved	Reagent and reaction condition(s) required
$X \longrightarrow Y$	reduction	$H_2(g)$ Pt or Ni as catalyst
$Y \longrightarrow Z$	oxidation	heat under reflux with acidified $K_2Cr_2O_7(aq)$ or acidified $KMnO_4(aq)$

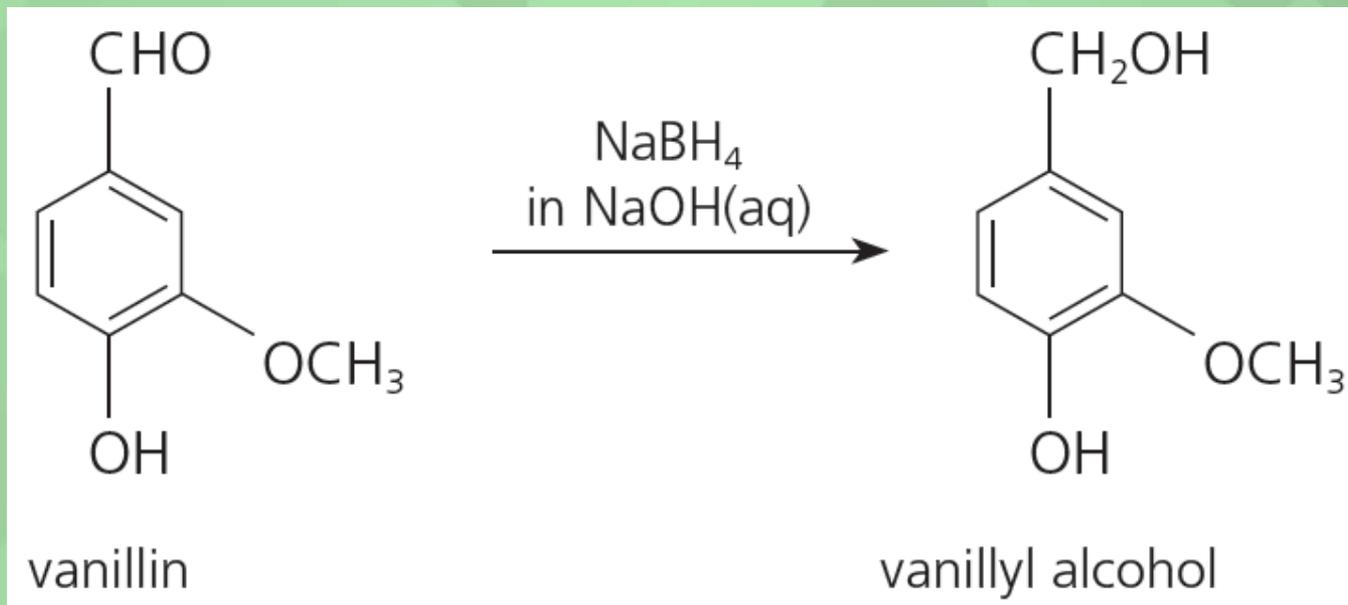
▶ Both  $LiAlH_4$  and  $NaBH_4$  do NOT affect carbon-carbon double bonds. Hence they convert an unsaturated aldehyde into an unsaturated alcohol.



## 31.6 Reactions of aldehydes and ketones (p.119)

### Practice 31.8

1 A student carried out an experiment to study the reduction of vanillin to vanillyl alcohol using sodium borohydride.





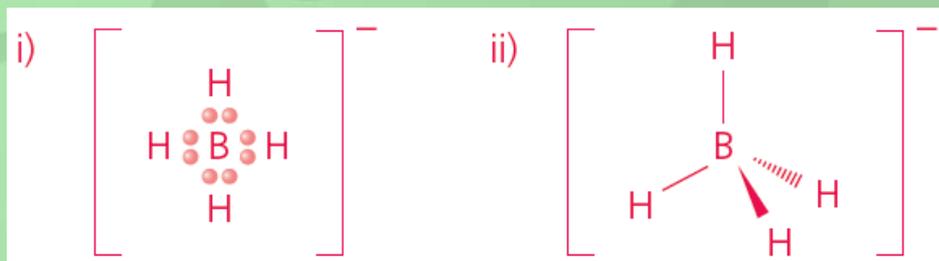
## 31.6 Reactions of aldehydes and ketones (p.119)

- Step 1* Place a sample of vanillin solid in a conical flask. Add 2 cm<sup>3</sup> of ethanol into the flask.
- Step 2* Stir to dissolve the vanillin solid completely. Cool the mixture in an ice-cold water bath.
- Step 3* Slowly add NaBH<sub>4</sub> dissolved in NaOH(aq) dropwise to the vanillin solution with continuous stirring and cooling.
- Step 4* Remove the flask from the ice-cold water bath and stir the reaction mixture at room temperature for 10 minutes.
- Step 5* Cool the reaction mixture again with an ice-water bath. With stirring, add HCl(aq) dropwise to the reaction mixture until no more gas (which is H<sub>2</sub>) evolves from the mixture.  
(HCl is added to react with the excess NaBH<sub>4</sub> and NaOH.)
- Step 6* Cool the mixture with continuous stirring to allow the product to precipitate from the reaction mixture.



## 31.6 Reactions of aldehydes and ketones (p.119)

- a) Point out the structural difference between vanillin and vanillyl alcohol.  
**Vanillin contains a carbonyl group while vanillyl alcohol contains a hydroxyl group.**
- b) The chemical formula of the borohydride ion is  $\text{BH}_4^-$ .
- Draw the electron diagram for the ion.
  - Suggest the shape of the ion.



- c) Why was the vanillin solution cooled continuously in *Step 3*?  
**The reaction was exothermic.**
- d) Suggest how the student could obtain dry vanillyl alcohol after *Step 6*.  
**Collect the product by filtration.**  
**Wash the product with ice-cold water.**  
**Transfer the product to a piece of filter paper to air dry.**

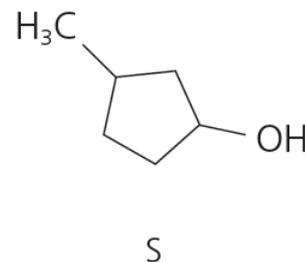
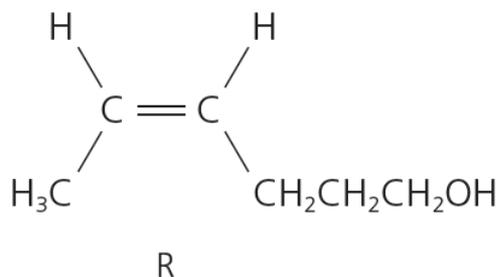
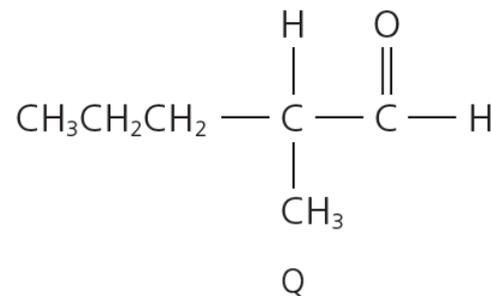
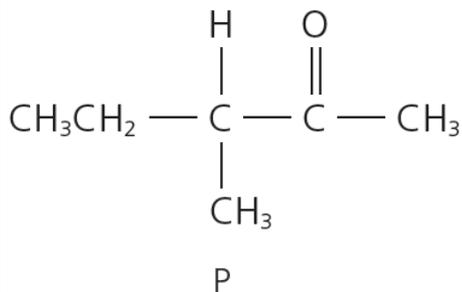


## 31.6 Reactions of aldehydes and ketones (p.119)

2 The following four isomers (P, Q, R and S) were investigated using test tube reactions.

Suggest a chemical test to distinguish each of the following pairs of isomers. Your answer should include the reagent(s) used and the observation(s) expected.

- a) P and Q  
b) R and S





## 31.6 Reactions of aldehydes and ketones (p.119)

a) Any one of the following:

- Warm each isomer with acidified  $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$ .  
Q turns the dichromate solution from orange to green.  
There is no observable change for P.
- Warm each isomer with acidified  $\text{KMnO}_4(\text{aq})$ .  
Q turns the permanganate solution from purple to colourless.  
There is no observable change for P.

b) Any one of the following:

- Add  $\text{Br}_2(\text{aq})$  to each isomer separately and shake.  
The yellow-brown  $\text{Br}_2(\text{aq})$  turns colourless quickly when added to isomer R.  
There is no observable change for isomer S.
- Add cold acidified dilute  $\text{KMnO}_4(\text{aq})$  to each isomer separately and shake.  
The purple  $\text{KMnO}_4(\text{aq})$  turns colourless quickly when added to isomer R.  
There is no observable change for isomer S.



## 31.7 Reactions of carboxylic acids (p.123)

- ◆ You will study the following reactions of carboxylic acids:
  - reaction with alkalis and hydrogencarbonates to form salts;
  - reaction with alcohols to form esters;
  - reduction to form alcohols; and
  - amide formation.

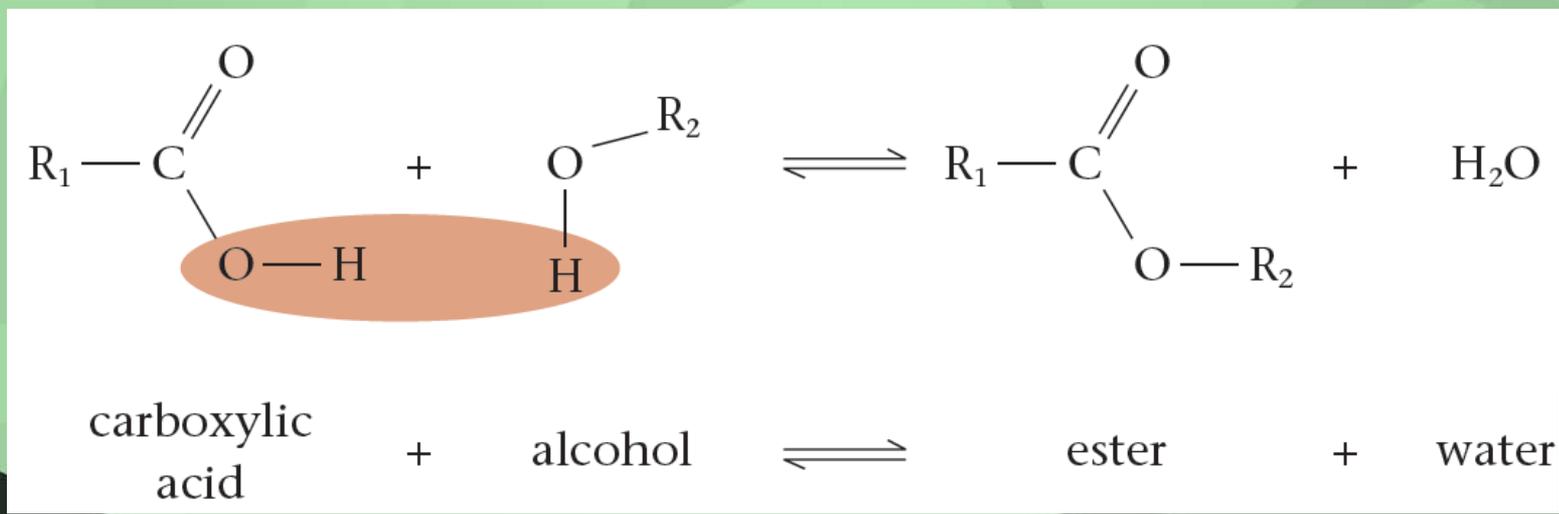




## 31.7 Reactions of carboxylic acids (p.123)

### Esterification

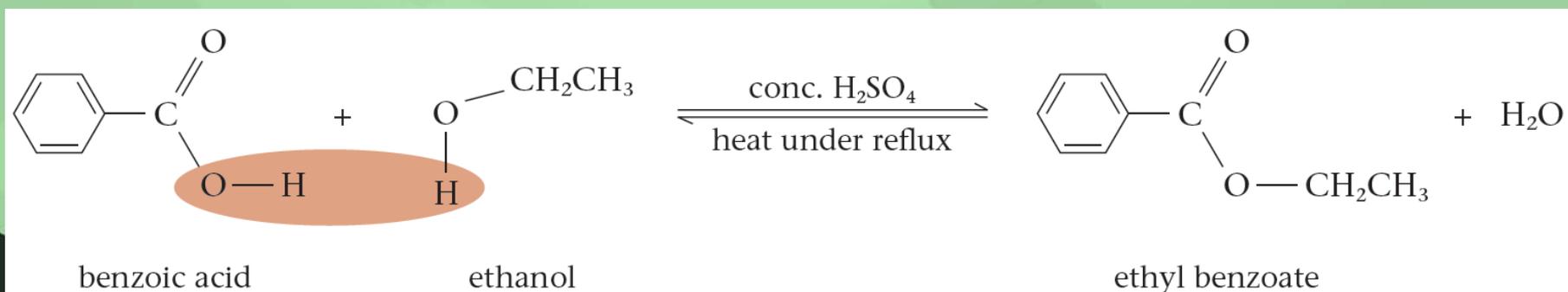
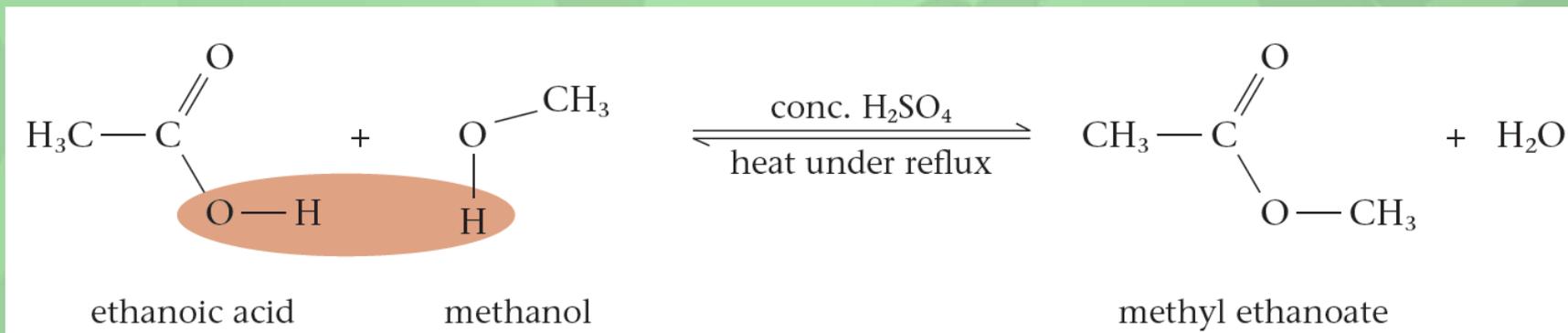
- A carboxylic acid can react with an alcohol to form an ester. This type of reaction is known as **esterification** (酯化作用). It is a reversible reaction which is usually carried out in the presence of a concentrated acid catalyst, such as concentrated sulphuric acid.





## 31.7 Reactions of carboxylic acids (p.123)

- Esterification can be classified as a **condensation reaction** (縮合反應)—a reaction in which two or more molecules join together to form a larger molecule with the elimination of a small molecule, such as water.





## 31.7 Reactions of carboxylic acids (p.123)

- ◆ The ' $\rightleftharpoons$ ' symbol means the reaction is reversible, i.e. both reactants and products are present. The ester would have to be separated from the mixture by distillation and then purified.



**Preparing ethyl benzoate with microscale apparatus**



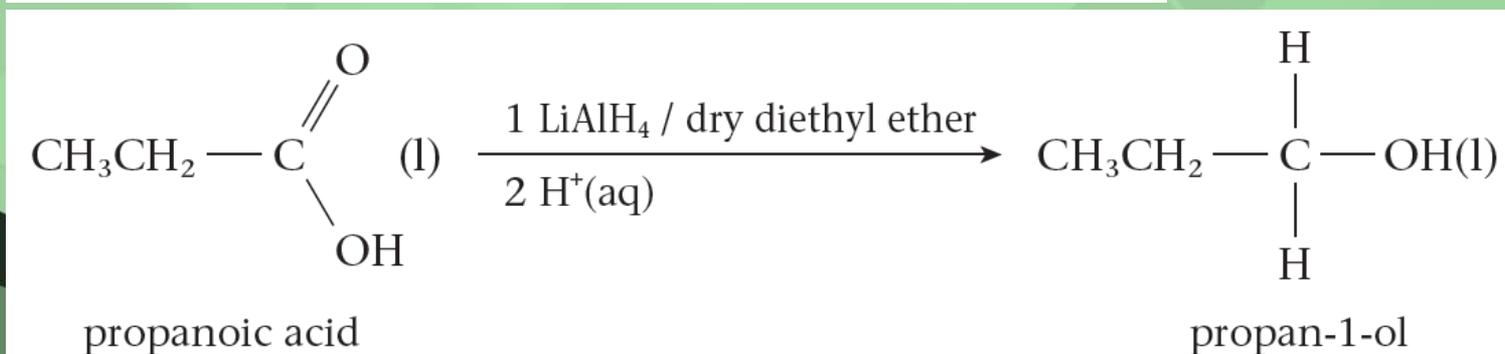
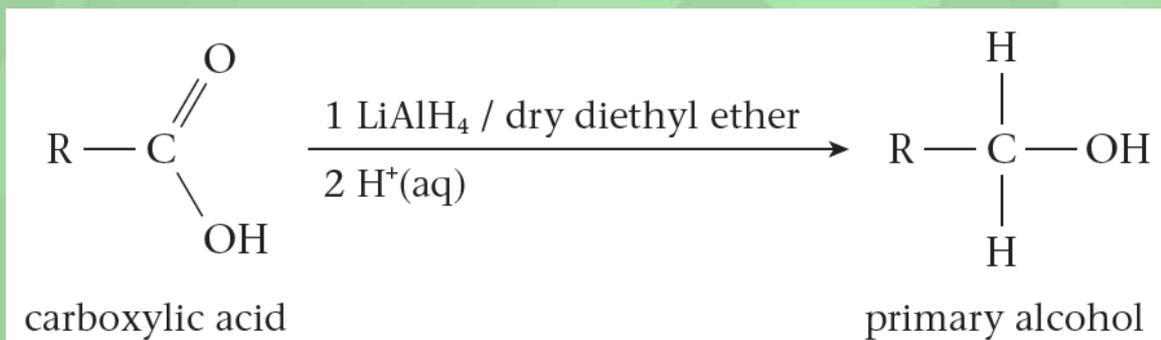
**Preparing benzyl ethanoate by reacting benzyl alcohol with ethanoic acid**



## 31.7 Reactions of carboxylic acids (p.123)

### Reduction of carboxylic acids

- The reduction of a carboxylic acid happens in two stages — first to form an aldehyde and then a primary alcohol.  $\text{LiAlH}_4$  reacts rapidly with the aldehyde formed. It is impossible to stop at the halfway stage.



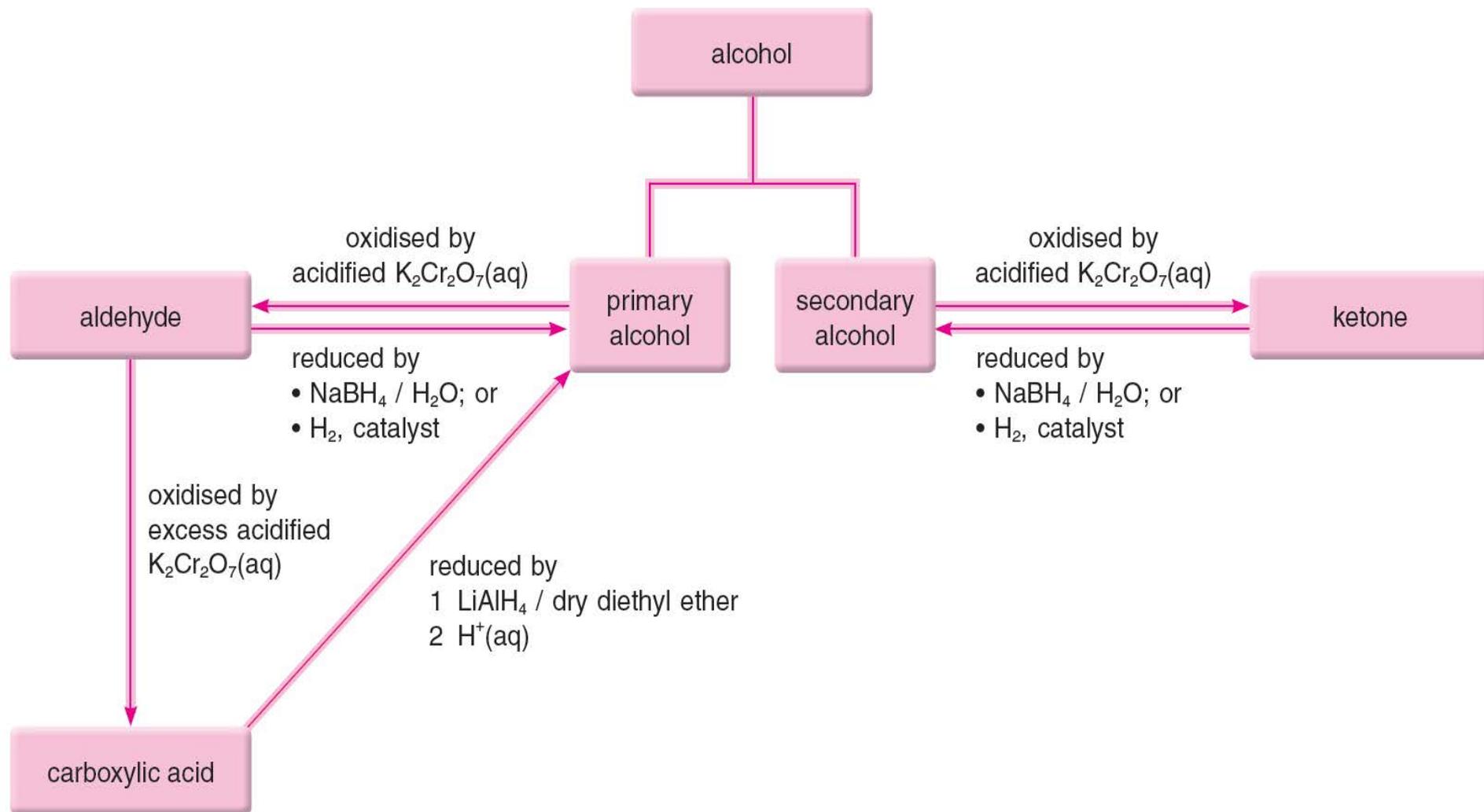


## 31.7 Reactions of carboxylic acids (p.123)

- ◆ The reduction of carboxylic acids requires the powerful reducing agent, lithium aluminium hydride. Neither sodium borohydride nor hydrogen are strong enough to reduce carboxylic acids.
- ◆ The figure below summarises the oxidation and reduction reactions involving alcohols, aldehydes, ketones and carboxylic acids discussed so far.



## 31.7 Reactions of carboxylic acids (p.123)

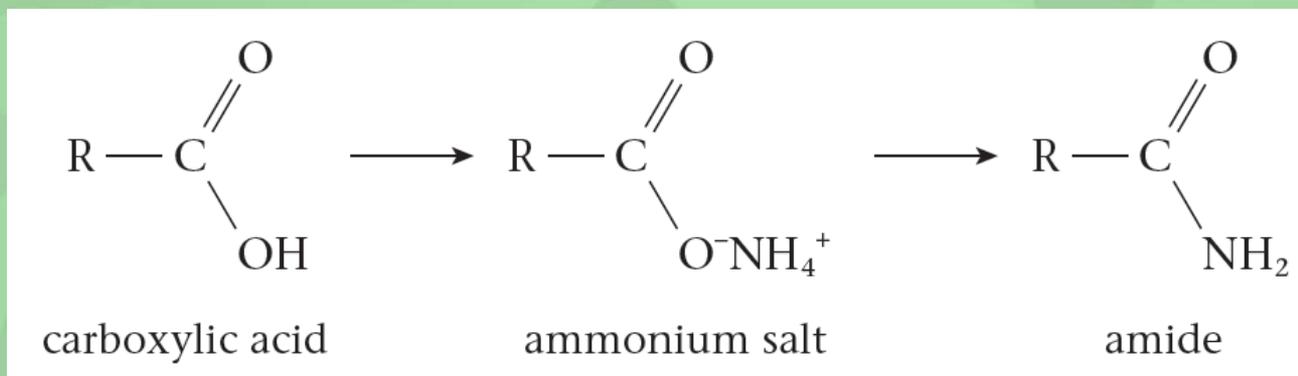




## 31.7 Reactions of carboxylic acids (p.123)

### Amides from carboxylic acids

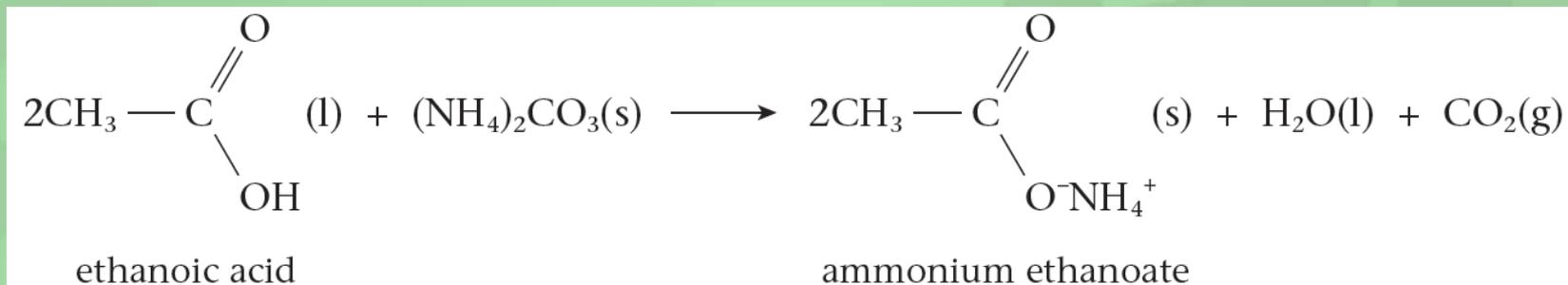
- ◆ Convert the carboxylic acid into an ammonium salt which then produces an amide on heating.





## 31.7 Reactions of carboxylic acids (p.123)

- For example, ammonium ethanoate is made by adding ammonium carbonate (or aqueous ammonia) to an excess of ethanoic acid.



- Upon heating,  $\text{CH}_3\text{COONH}_4(\text{s})$  tends to split into  $\text{NH}_3(\text{g})$  and  $\text{CH}_3\text{COOH}$ .

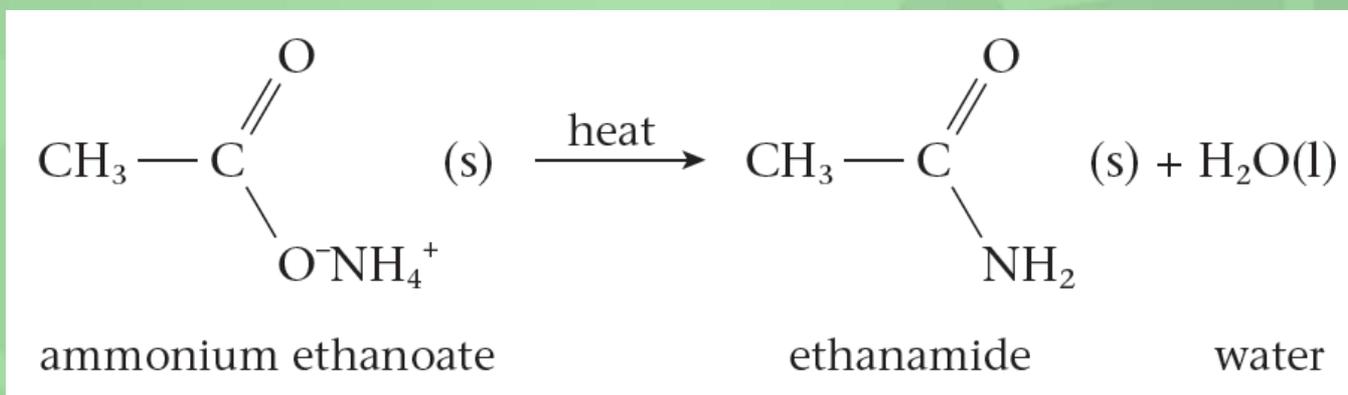


Excess ethanoic acid helps to prevent this from happening by moving the position of equilibrium to the left



## 31.7 Reactions of carboxylic acids (p.123)

- ◆ When the reaction is complete, heat the mixture under reflux. The ammonium salt dehydrates to produce ethanamide.



- ◆ The mixture is distilled at about 170 °C to remove excess ethanoic acid and water — leaving almost pure ethanamide in the reaction flask.



Identifying unknown carbon compounds



## 31.7 Reactions of carboxylic acids (p.123)

### Q (Example 31.5)

The following experiment was carried out to prepare an ester.

*Step 1* Place 10 drops of glacial ethanoic acid in a microscale test tube.

*Step 2* Add 10 drops of isoamyl alcohol, followed by 5 drops of concentrated sulphuric acid.

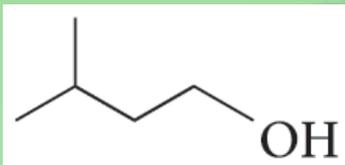
*Step 3* Place the test tube in a hot water bath. Allow the reactants to react for 10 minutes.

*Step 4* Pour the liquid contents of the tube into a beaker half-full of sodium carbonate solution.



## 31.7 Reactions of carboxylic acids (p.123)

a) The structure of isoamyl alcohol is shown below:



- Give the systematic name of isoamyl alcohol.
  - Draw the structure of the ester prepared.
- b) State TWO observable changes when the liquid contents of the tube is poured into the sodium carbonate solution.

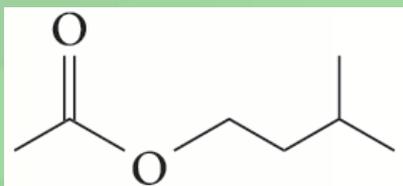


## 31.7 Reactions of carboxylic acids (p.123)

A

a) i) 3-methylbutan-1-ol

ii)



b) Any two of the following:

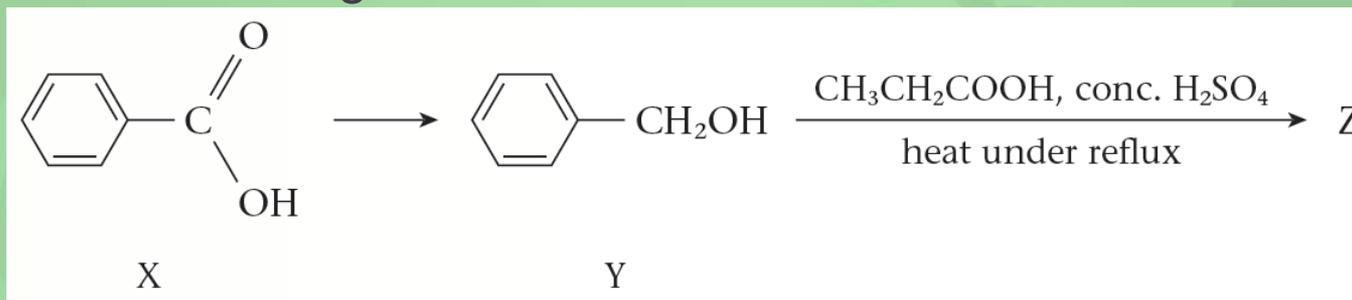
- Effervescence occurs.
- An insoluble layer floats on the aqueous layer. (The ester is only slightly soluble in water.)
- A fruity sweet smell is detected.



## 31.7 Reactions of carboxylic acids (p.123)

### Q (Example 31.6)

Consider the following conversion:



- a) For the conversion from X to Y,
- name the type of reaction that takes place;
  - give the reagent(s) and reaction condition(s) required.
- b) i) Write the structural formula of Z.  
ii) Name the type of reaction that takes place.



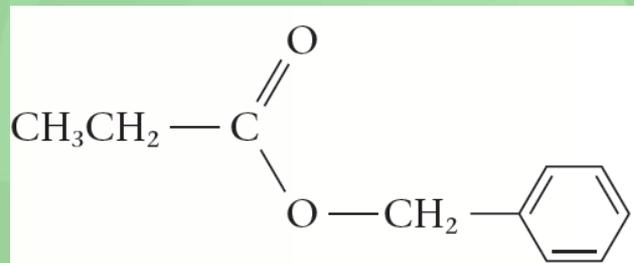
## 31.7 Reactions of carboxylic acids (p.123)

A

a) i) Reduction

ii) 1  $\text{LiAlH}_4$  / dry diethyl ether  
2  $\text{H}^+(\text{aq})$

b) i)



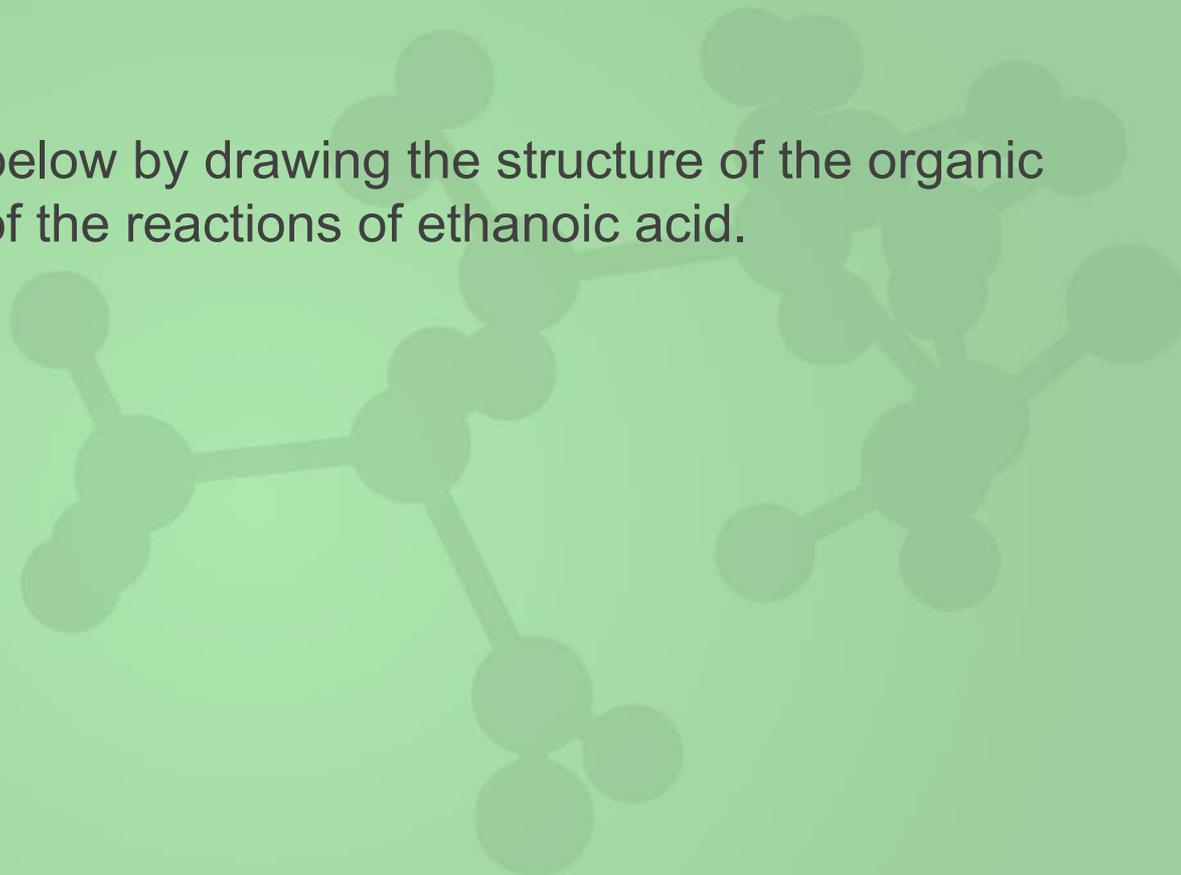
ii) Esterification



## 31.7 Reactions of carboxylic acids (p.123)

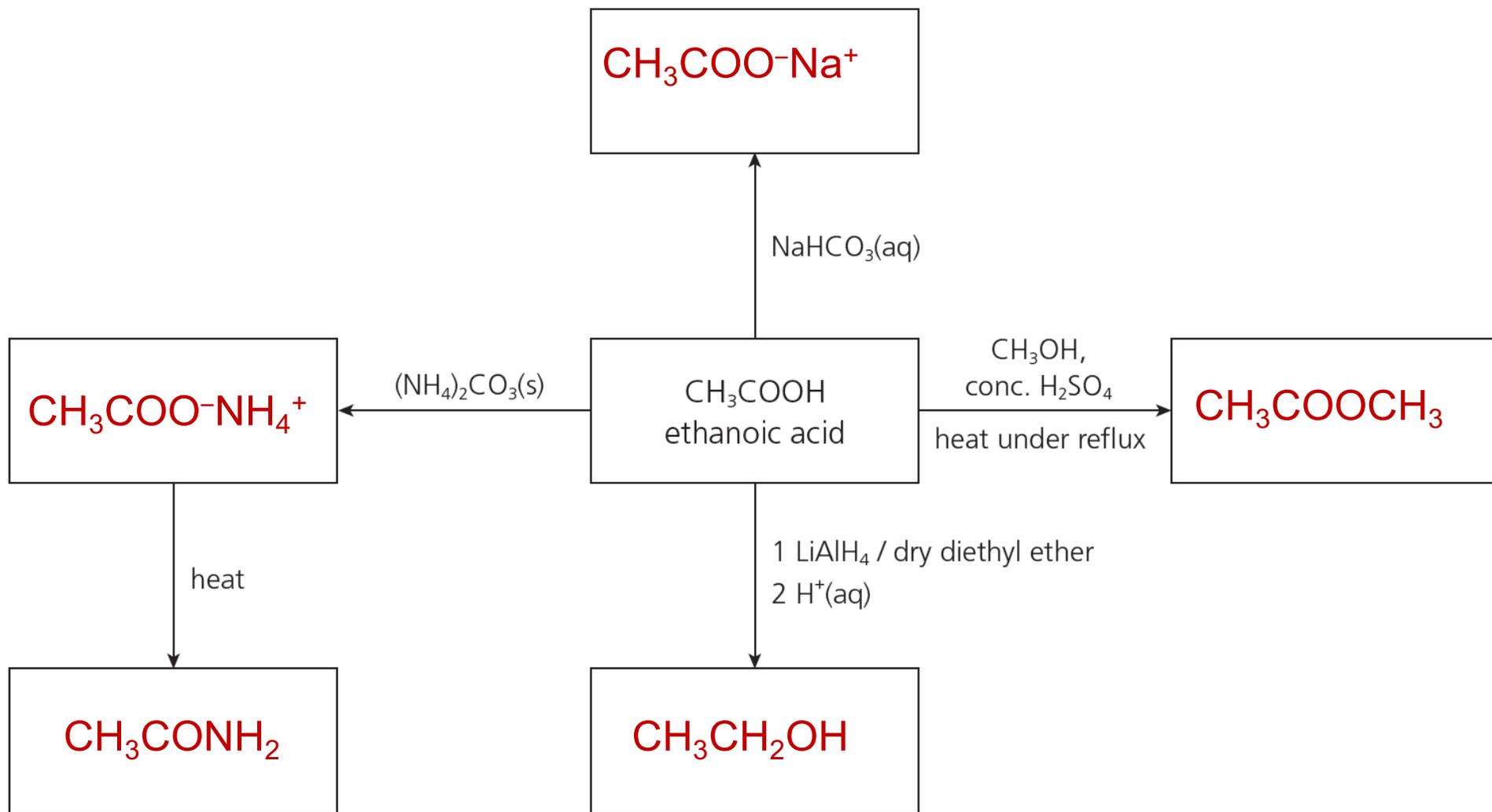
### Practice 31.9

1 Complete the flowchart below by drawing the structure of the organic product formed in each of the reactions of ethanoic acid.





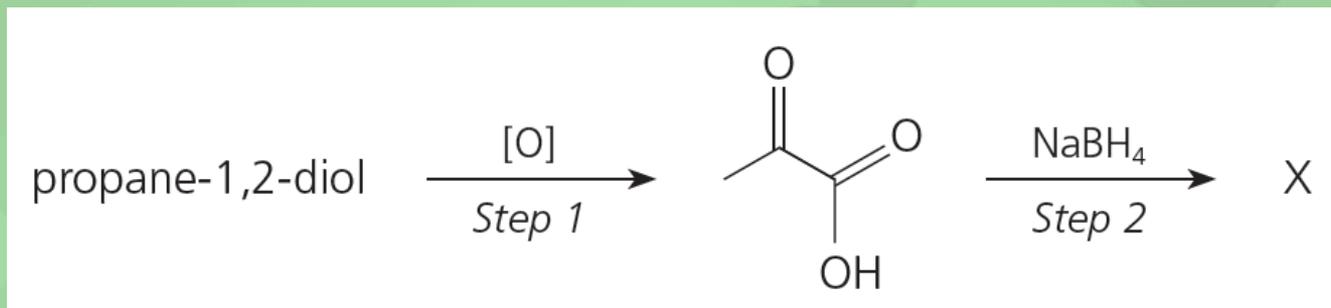
## 31.7 Reactions of carboxylic acids (p.123)





## 31.7 Reactions of carboxylic acids (p.123)

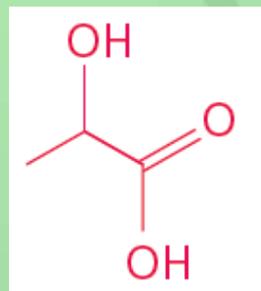
2 A student makes compound X from propane-1,2-diol as shown below:



a) State a suitable oxidising agent for *Step 1*.

**Acidified  $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$**

b) Write the structural formula of X.



c) Name the type of reaction that takes place in *Step 2*.

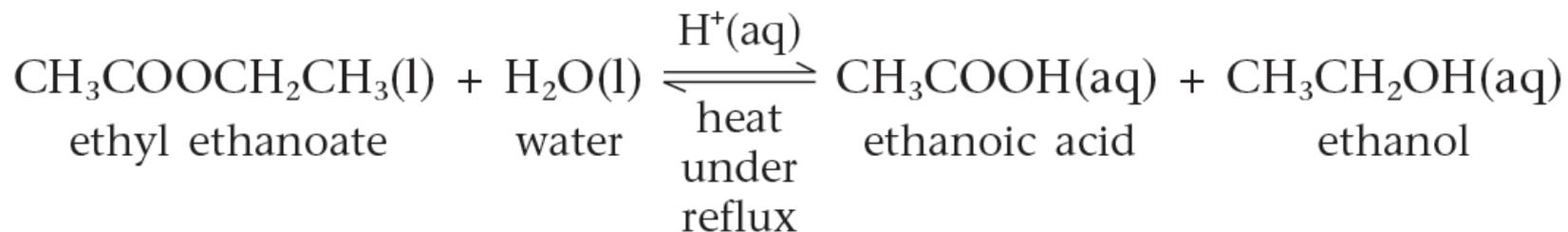
**Reduction**



## 31.8 Hydrolysis of esters (p.131)

- ◆ The reverse of esterification corresponds to the breakdown of an ester by water, i.e. hydrolysis. The hydrolysis of an ester needs heat and can be catalysed by either a dilute mineral acid (such as dilute sulphuric acid) or a dilute sodium hydroxide solution.

### Acid hydrolysis

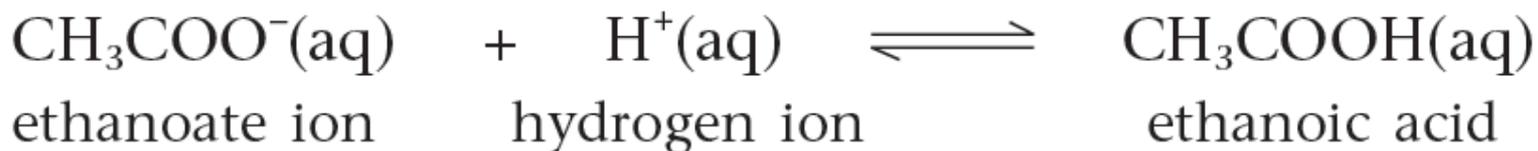






## 31.8 Hydrolysis of esters (p.131)

- ◆ To liberate the ethanoic acid from its salt, add excess dilute mineral acid (such as dilute hydrochloric acid or dilute sulphuric acid) to the salt.

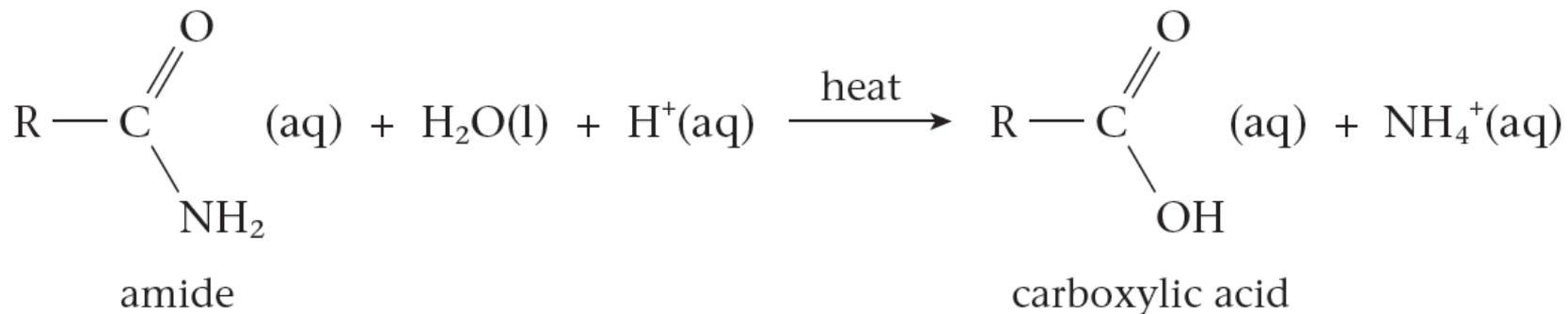




## 31.9 Hydrolysis of amides (p.132)

### Acid hydrolysis

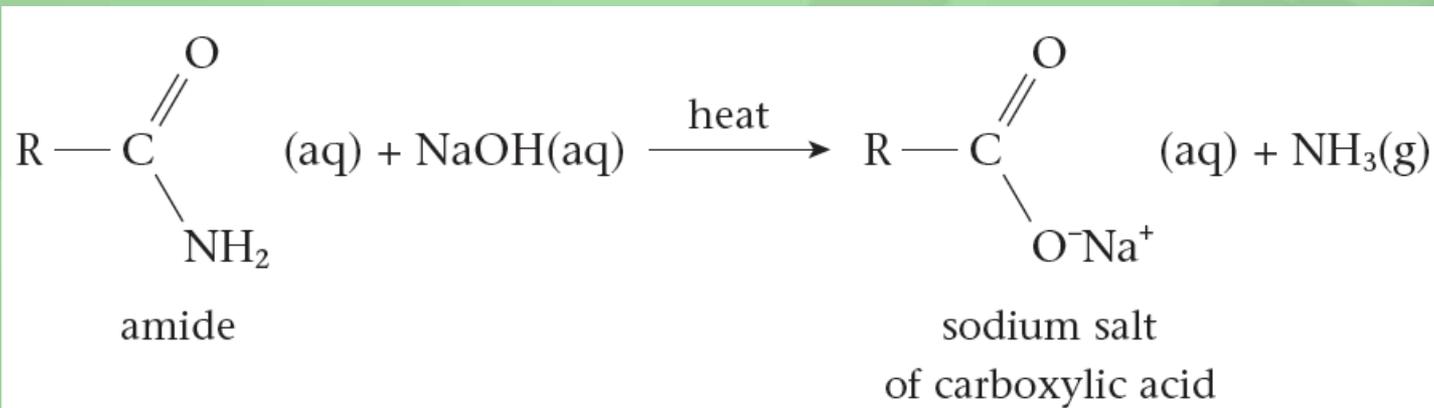
- ◆ As well as acting as a catalyst, the hydrogen ion of the acid also forms ammonium ion with the ammonia produced in the process.





## 31.9 Hydrolysis of amides (p.132)

### Alkaline hydrolysis



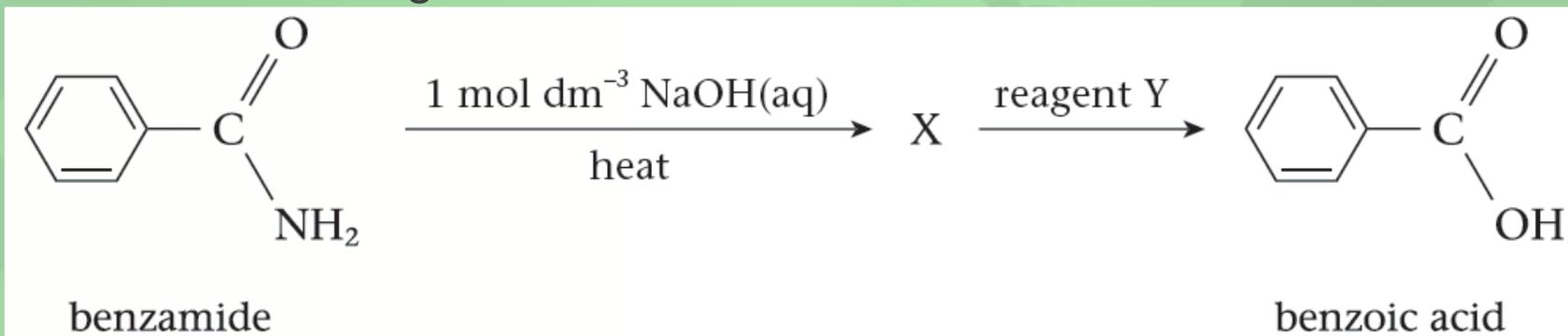
- ◆ Ammonia gas is given off and escapes. You are left with a solution containing the sodium salt. You can liberate the free acid from its salt by adding excess mineral acid (such as dilute hydrochloric acid).



## 31.9 Hydrolysis of amides (p.132)

### Q (Example 31.7)

Consider the following conversion:



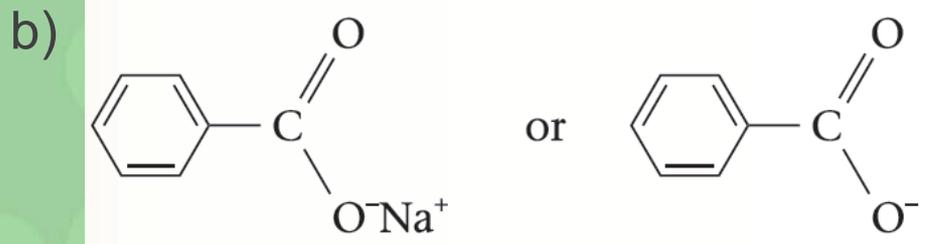
- Name the type of reaction that takes place in the conversion of benzamide to X.
- Write the structural formula of X.
- Suggest what Y would be.
- Suggest why X is more soluble than benzoic acid in water.



## 31.9 Hydrolysis of amides (p.132)

A

a) Alkaline hydrolysis



c) HCl(aq) / H<sub>2</sub>SO<sub>4</sub>(aq)

d) X is an ionic compound which has stronger interactions with water. Molecules of benzoic acid are very large and cannot form hydrogen bonds with water molecules easily.



## 31.9 Hydrolysis of amides (p.132)

### Practice 31.10

Complete the following equations by inserting the structures of the missing reactants or products, or by writing the reaction conditions above the arrow.

$\text{H}^+(\text{aq})$ , heat under reflux



heat under reflux



?  $\text{HCl}(\text{aq})$ , heat



heat





## 31.9 Hydrolysis of amides (p.132)

2 State THREE ways in which the acid hydrolysis of an ester differs from the alkaline hydrolysis of an ester.

In acid hydrolysis,

- the acid is a catalyst;
- the reaction is reversible / does not go to completion;
- the carboxylic acid (not its salt) is produced.

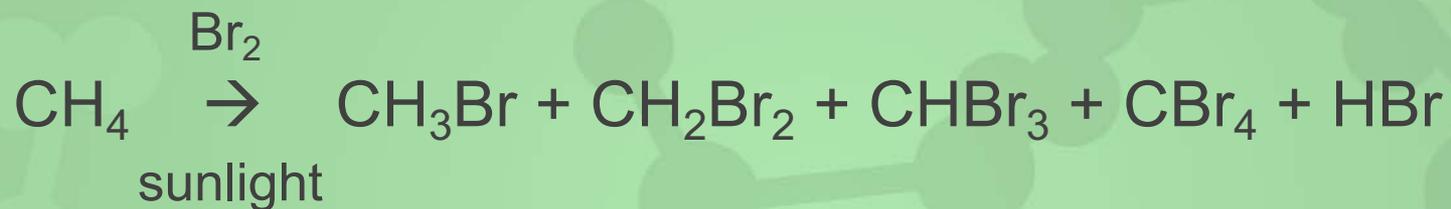


## Key terms (p.135)

substitution reaction	取代反應	sulphur dichloride oxide	氧二氯化硫
hydrogenation	氫化作用	dehydration	脫水作用
bromination	溴化作用	elimination reaction	消去反應
Markovnikov's rule	馬科尼科夫規則	sodium borohydride	硼氫化鈉
hydrolysis	水解	lithium aluminium hydride	氫化鋁鋰
primary	一級	diethyl ether	二乙醚
secondary	二級	esterification	酯化作用
tertiary	三級	condensation reaction	縮合作用

 Summary (p.136)

- 1 Substitution reactions of alkanes with halogens  
Example:





## Summary (p.136)

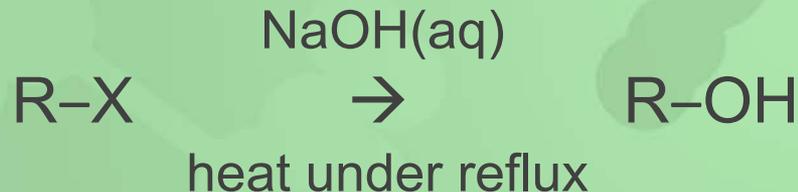
2 The table below summarises the addition reactions of alkenes.

Addition reaction of alkene		Reagent(s) and / or reaction condition(s)
Addition of hydrogen	$\text{RCH}=\text{CH}_2 \longrightarrow \text{RCH}_2\text{CH}_3$	$\text{H}_2(\text{g})$ , Pt catalyst or Ni catalyst at $150\text{ }^\circ\text{C}$
Addition of halogens	$\text{RCH}=\text{CH}_2 \longrightarrow \text{RCHClCH}_2\text{Cl}$	$\text{Cl}_2(\text{g})$
	$\text{RCH}=\text{CH}_2 \longrightarrow \text{RCHBrCH}_2\text{Br}$	$\text{Br}_2$ (in $\text{CH}_3\text{CCl}_3$ )
Addition of hydrogen halides	$\text{RCH}=\text{CH}_2 \longrightarrow \text{RCHClCH}_3$ major product + $\text{RCH}_2\text{CH}_2\text{Cl}$ minor product	$\text{HCl}(\text{g})$

 Summary (p.136)

3 When a molecule HX adds to an unsymmetric alkene, the hydrogen atom attaches mainly to the carbon atom that already carries the greater number of hydrogen atoms.

4 Substitution reactions of haloalkanes





## Summary (p.136)

5 Substitution reactions of alcohols with halides  
 Order of reactivity of alcohols is  $3^\circ > 2^\circ > 1^\circ$ .

Reaction of alcohol with		Reagent(s) and reaction condition(s)
Chloride	$\text{ROH} \longrightarrow \text{RCl}$	<ul style="list-style-type: none"> <li>• conc. HCl, heat and <math>\text{ZnCl}_2</math> as catalyst; or</li> <li>• mix with <math>\text{PCl}_5</math> at room temperature; or</li> <li>• heat under reflux with <math>\text{SOCl}_2</math></li> </ul>
Bromide	$\text{ROH} \longrightarrow \text{RBr}$	<ul style="list-style-type: none"> <li>• heat under reflux with <math>\text{NaBr} + \text{conc. H}_2\text{SO}_4</math>; or</li> <li>• heat under reflux with red P + <math>\text{Br}_2</math></li> </ul>
Iodide	$\text{ROH} \longrightarrow \text{RI}$	<ul style="list-style-type: none"> <li>• heat under reflux with <math>\text{NaI} + \text{conc. H}_3\text{PO}_4</math>; or</li> <li>• heat under reflux with red P + <math>\text{I}_2</math></li> </ul>



# Summary (p.136)

6 The table below summarises the dehydration and oxidation of alcohols.

	Reaction of alcohol	Reagent(s) and / or reaction condition(s)
<p>Dehydration Ease of dehydration: <math>3^\circ &gt; 2^\circ &gt; 1^\circ</math> alcohol</p>	$\begin{array}{c} \text{OH} \\   \\ \text{RCH}_2\text{CHCH}_3 \end{array} \longrightarrow$ $\begin{array}{c} \text{R} \quad \text{H} \\ \diagdown \quad / \\ \text{C} = \text{C} \\ / \quad \diagdown \\ \text{H} \quad \text{CH}_3 \end{array} \quad \text{and} \quad \begin{array}{c} \text{R} \quad \text{CH}_3 \\ \diagdown \quad / \\ \text{C} = \text{C} \\ / \quad \diagdown \\ \text{H} \quad \text{H} \end{array}$ <p>major products</p> <p style="text-align: center;">+</p> $\begin{array}{c} \text{RCH}_2 \quad \text{H} \\ \diagdown \quad / \\ \text{C} = \text{C} \\ / \quad \diagdown \\ \text{H} \quad \text{H} \end{array}$ <p>minor product</p> <p>normally the alkene bearing more alkyl groups is the major product</p>	<ul style="list-style-type: none"> <li>• conc. <math>\text{H}_2\text{SO}_4</math> catalyst, heat; or</li> <li>• <math>\text{Al}_2\text{O}_3</math> catalyst, heat</li> </ul>



# Summary (p.136)

Oxidation	<p>1° alcohol</p> $\text{RCH}_2\text{OH} \longrightarrow \text{RCHO}$ $\text{RCH}_2\text{OH} \longrightarrow \text{RCOOH}$	<ul style="list-style-type: none"> <li>acidified <math>\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})</math>, gentle heat, distil off the aldehyde</li> <li>acidified <math>\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})</math>, heat under reflux to form carboxylic acid</li> </ul>
	<p>2° alcohol</p> $\begin{array}{c} \text{OH} \\   \\ \text{RCHCH}_3 \end{array} \longrightarrow \text{RCOCH}_3$	<p>acidified <math>\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})</math>, heat under reflux</p>



## Summary (p.136)

7 The table below summarises the oxidation and reduction of aldehydes and ketones.

Oxidation / reduction of carbonyl compound		Reagent(s) and / or reaction condition(s)
Oxidation of aldehydes	$\text{RCHO} \longrightarrow \text{RCOOH}$	acidified $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$ , heat
Reduction of aldehydes and ketones	$\text{RCHO} \longrightarrow \text{RCH}_2\text{OH}$ <p style="text-align: center;">1° alcohol</p> $\text{RCOR}' \longrightarrow \begin{array}{c} \text{OH} \\   \\ \text{RCHR}' \end{array}$ <p style="text-align: center;">2° alcohol</p>	<ul style="list-style-type: none"> <li>• <math>\text{NaBH}_4 / \text{H}_2\text{O}</math>; or</li> <li>• 1 <math>\text{LiAlH}_4 / \text{dry diethyl ether}</math></li> <li>• 2 <math>\text{H}^+(\text{aq})</math>; or</li> <li>• <math>\text{H}_2(\text{g})</math>, Ni catalyst, 5 atm</li> </ul>



## Summary (p.136)

8 The table below summarises the reactions of carboxylic acids.

Reaction of carboxylic acid		Reagent(s) and / or reaction condition(s)
With alkalis	$\text{RCOOH} \longrightarrow \text{RCOO}^-\text{Na}^+$	$\text{NaOH(aq)}$
With hydrogencarbonate	$\text{RCOOH} \longrightarrow \text{RCOO}^-\text{Na}^+$	$\text{NaHCO}_3\text{(aq)}$
Esterification	$\text{RCOOH} + \text{R}'\text{OH} \rightleftharpoons \text{RCOOR}' + \text{H}_2\text{O}$	conc. $\text{H}_2\text{SO}_4$ catalyst, heat
Reduction	$\text{RCOOH} \longrightarrow \text{RCH}_2\text{OH}$	1 $\text{LiAlH}_4$ / dry diethyl ether 2 $\text{H}^+\text{(aq)}$
Amide synthesis	$\text{RCOOH} \longrightarrow \text{RCOO}^-\text{NH}_4^+$ $\downarrow \text{heat}$ $\text{RCONH}_2$	$(\text{NH}_3)_2\text{CO}_3\text{(s)}$ or $\text{NH}_3\text{(aq)}$



# Summary (p.136)

9 The table below summarises the hydrolysis of esters and amides.

Hydrolysis		
Ester	using an acid	$\text{RCOOR}' + \text{H}_2\text{O} \xrightleftharpoons[\text{heat under reflux}]{\text{acid}} \text{RCOOH} + \text{ROH}$
	using an alkali	$\text{RCOOR}' + \text{NaOH} \xrightarrow{\text{heat under reflux}} \text{RCOO}^-\text{Na}^+ + \text{ROH}$ $\downarrow \text{H}^+(\text{aq})$ $\text{RCOOH}$
Amide	using an acid	$\text{RCONH}_2 + \text{H}_2\text{O} + \text{H}^+ \xrightarrow{\text{heat}} \text{RCOOH} + \text{NH}_4^+$
	using an alkali	$\text{RCONH}_2 + \text{NaOH} \xrightarrow{\text{heat}} \text{RCOO}^-\text{Na}^+ + \text{NH}_3$ $\downarrow \text{H}^+(\text{aq})$ $\text{RCOOH}$



## Summary (p.136)

10 The table below summarises the results of some tests for alcohols, aldehydes, ketones and carboxylic acids.

Test Compound	Add water and test the pH of the solution	Warm with acidified potassium dichromate solution	Warm with ethanoic acid (with conc. sulphuric acid as a catalyst)	Warm with ethanol (with conc. sulphuric acid as a catalyst)	Mix with sodium hydrogen-carbonate solution
Primary alcohol	neutral	orange dichromate solution turns green	a sweet-smelling ester formed	no observable change	no observable change
Secondary alcohol		no observable change			
Tertiary alcohol		orange dichromate solution turns green	no observable change		
Aldehyde		no observable change			
Ketone	pH below 7	no observable change	a sweet-smelling ester formed	colourless CO <sub>2</sub> gas evolves	



## Unit Exercise (p.140)

**Note: Questions are rated according to ascending level of difficulty (from 1 to 5):**



question targeted at level 3 and above;



question targeted at level 4 and above;



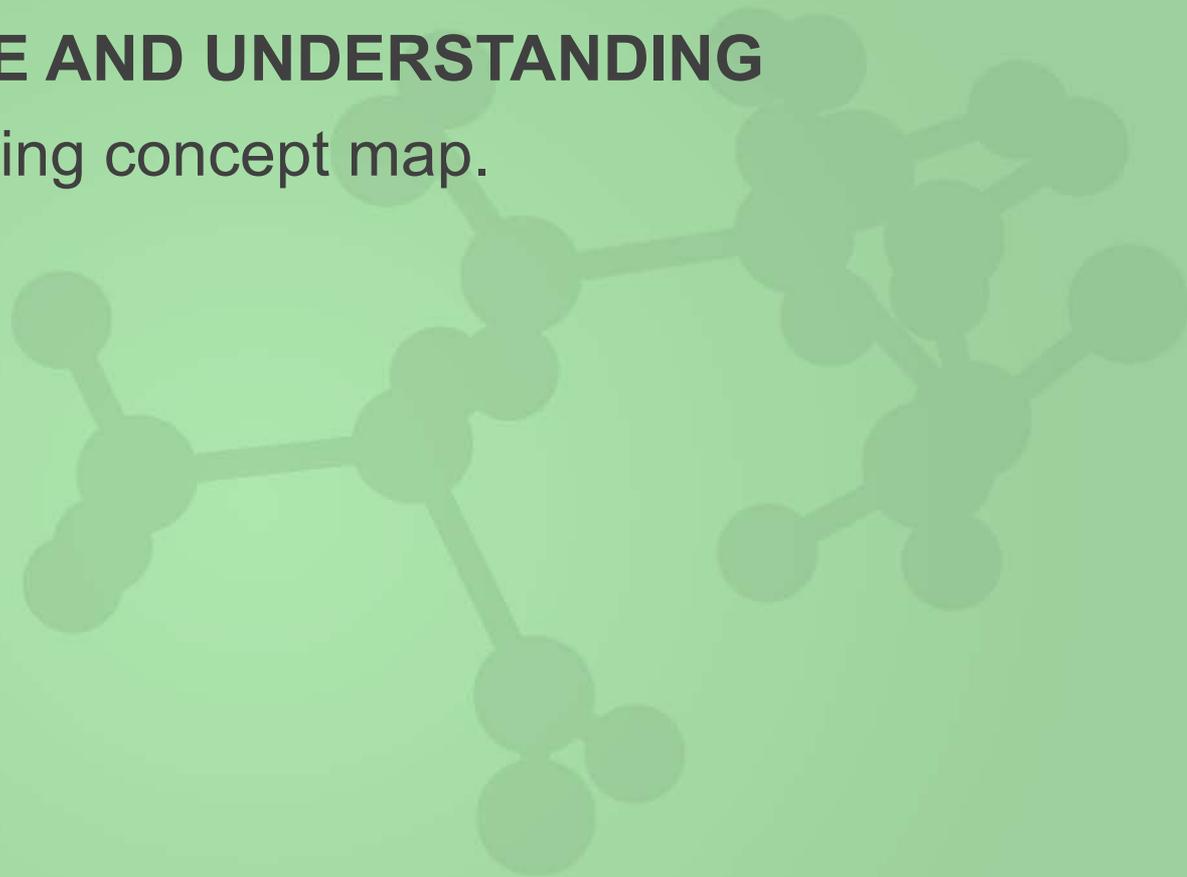
question targeted at level 5.

' \* ' indicates 1 mark is given for effective communication.

## Unit Exercise (p.140)

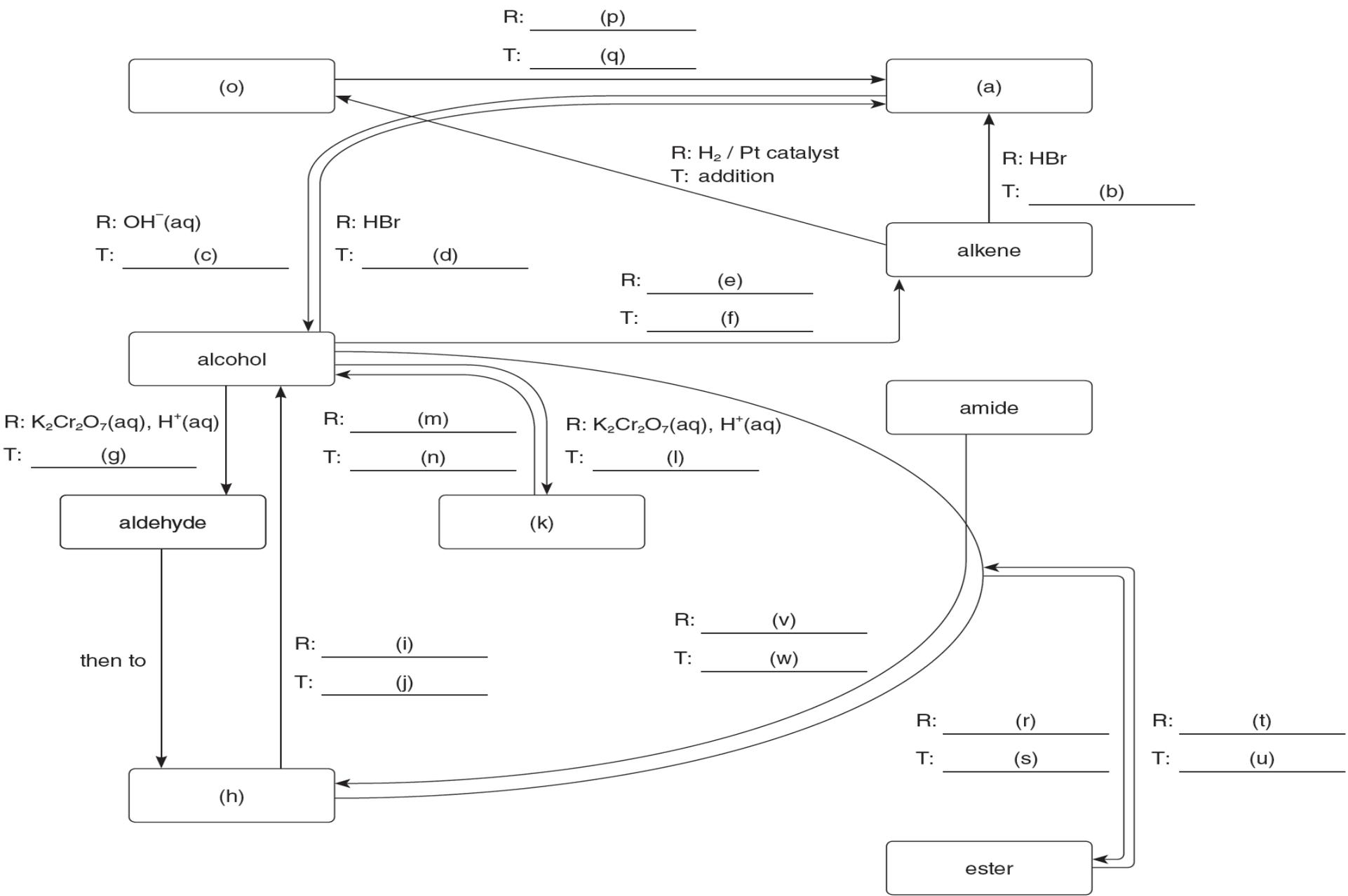
### **PART I** KNOWLEDGE AND UNDERSTANDING

1 Complete the following concept map.



key:  
 R Reagent  
 T Reaction type

typical reactions

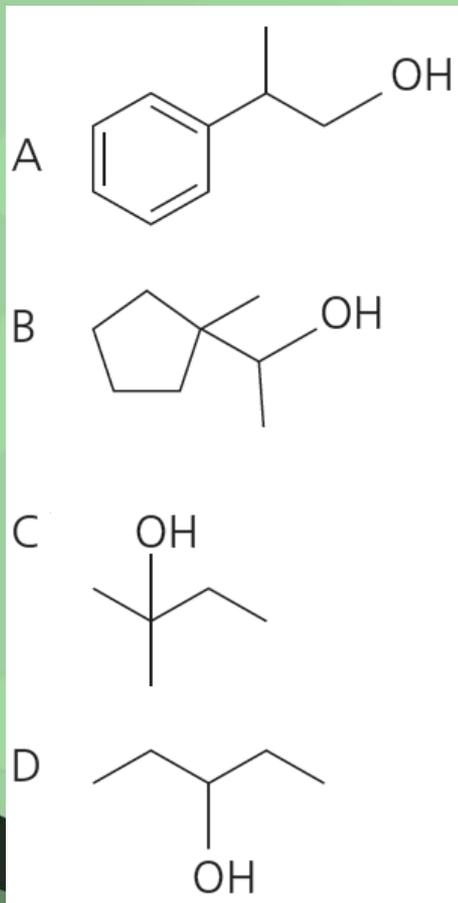


 Unit Exercise (p.140)

- a) haloalkane
- b) addition
- c) hydrolysis
- d) substitution
- e) heating with excess conc.  
 $\text{H}_2\text{SO}_4$
- f) dehydration / elimination
- g) oxidation
- h) carboxylic acid
- i) 1  $\text{LiAlH}_4$  / dry diethyl ether  
2  $\text{H}^+(\text{aq})$
- j) reduction
- k) ketone
- l) oxidation
- m)  $\text{NaBH}_4$  /  $\text{H}_2\text{O}$
- n) reduction
- o) alkane
- p)  $\text{Br}_2$ , sunlight
- q) substitution reaction
- r) heat, concentrated  
sulphuric acid as catalyst
- s) esterification
- t) heat under reflux, dilute  
sulphuric acid
- u) hydrolysis
- v) heat, moderately  
concentrated sulphuric  
acid or hydrochloric acid
- w) hydrolysis

 Unit Exercise (p.140)**PART II MULTIPLE CHOICE QUESTIONS**

2 Which of the following alcohols is a tertiary alcohol?

**Answer: C**



## Unit Exercise (p.140)

3 Which one of the following will NOT react with ethanol to form 1-chloroethane?

A  $\text{Cl}_2$  in sunlight at  $100\text{ }^\circ\text{C}$

B  $\text{NaCl}$  and concentrated sulphuric acid

C  $\text{PCl}_5$

D  $\text{SOCl}_2$  at room temperature

*(CEA Advanced Subsidiary GCE, Unit 2, Module 2, Jun. 2016, 8)*

**Answer: A**



## Unit Exercise (p.140)

4 Which of the following statements concerning but-1-ene and butan-1-ol is **INCORRECT**? 

- A Both of them can decolourise acidified  $\text{KMnO}_4(\text{aq})$ .
- B Butan-1-ol can react with  $\text{PBr}_3(\text{l})$  while but-1-ene cannot.
- C Both of them can react with  $\text{H}_2(\text{g})$  in the presence of platinum.
- D But-1-ene can be obtained from heating butan-1-ol with  $\text{Al}_2\text{O}_3(\text{s})$ .

*(HKDSE, Paper 1A, 2016, 28)*

**Answer: C**



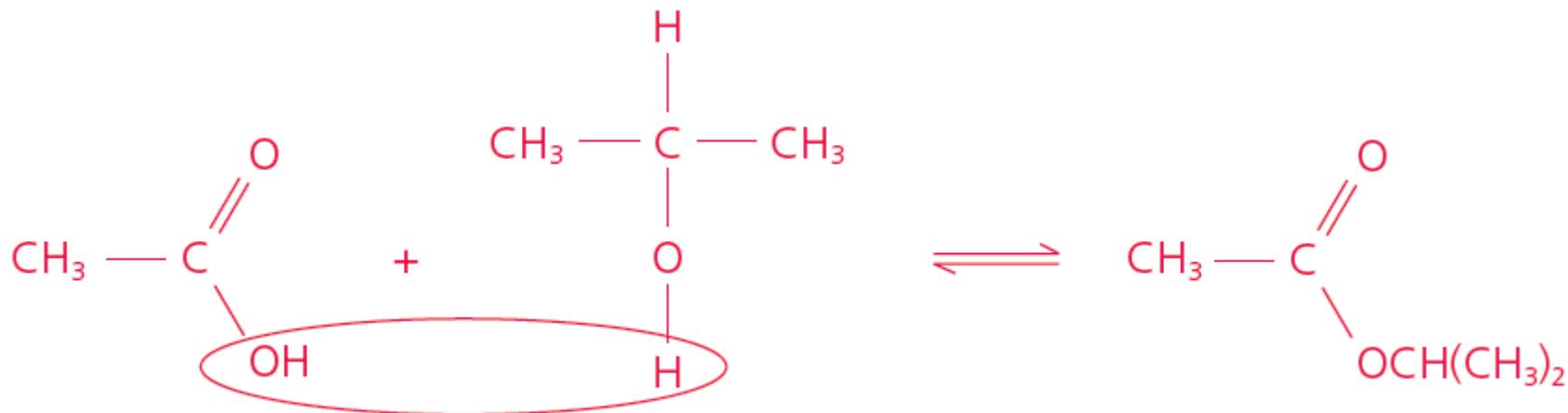
## Unit Exercise (p.140)

5 Which of the following alcohols could be used to produce  $\text{CH}_3\text{COOCH}(\text{CH}_3)_2$ ?



- A Ethanol
- B Methylpropan-2-ol
- C Propan-1-ol
- D Propan-2-ol

Answer: D



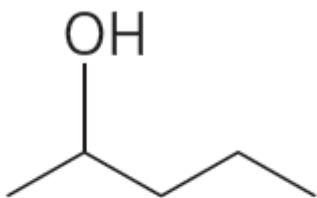


## Unit Exercise (p.140)

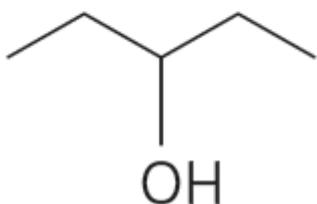


6 Which of the following isomeric alcohols, with molecular formula  $C_5H_{12}O$ , can be oxidised to a carboxylic acid with five carbon atoms?

A



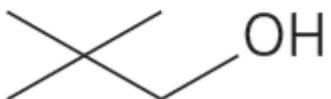
B



C



D



**Answer: D**

**Explanation:**

Options A and B — These secondary alcohols can be oxidised to ketones.

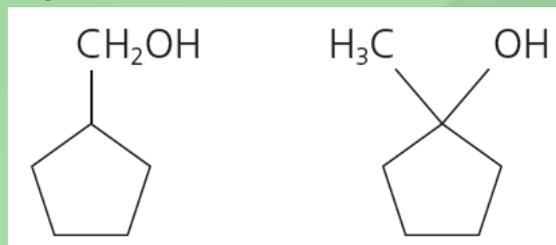
Option C — This tertiary alcohol CANNOT be oxidised.

Option D — This primary alcohol gives an aldehyde and then a carboxylic acid upon oxidation.



## Unit Exercise (p.140)

7 Consider the two compounds shown below.



**Answer: C**

Which of the following reagents gives a different observation with the two compounds?

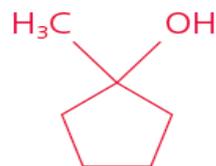
- A Hot  $\text{SOCl}_2(\text{l})$
- B  $\text{PCl}_5(\text{s})$  at room temperature
- C Hot acidified  $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$
- D  $\text{NaOH}(\text{aq})$



is a primary alcohol while is a tertiary alcohol.

When each alcohol is mixed with hot acidified

$\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$ , only  produces a colour change from orange to green.



gives no observable change.

 Unit Exercise (p.140)

8 Butan-2-ol can be formed in each of the following reactions:



I Reducing compound X with  $\text{NaBH}_4$

II Heating compound Y with  $\text{NaOH(aq)}$

Which of the following combinations about the compounds X and Y is correct?

	<u>X</u>	<u>Y</u>
A	butanal	1-chlorobutane
B	butanal	2-chlorobutane
C	butanone	1-chlorobutane
D	butanone	2-chlorobutane

Answer: D

Explanation:

Reduction of butanone (a ketone) gives butan-2-ol (a secondary alcohol).

2-chlorobutane undergoes hydrolysis to give butan-2-ol when heated with  $\text{NaOH(aq)}$ .

 Unit Exercise (p.140)

9 Which alcohol could NOT be produced by the reduction of an aldehyde or a ketone?

- A 2-methylbutan-1-ol
- B 2-methylbutan-2-ol
- C 3-methylbutan-1-ol
- D 3-methylbutan-2-ol

*(AQA Advanced Level, 7405/3, Specimen v0.5, 2015, 29)*

**Answer: B**

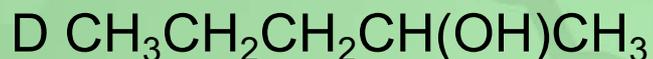
**Explanation:**

Reduction of an aldehyde produces a primary alcohol while the reduction of a ketone produces a secondary alcohol.

2-methylbutan-2-ol is a tertiary alcohol. Hence it could NOT be produced by the reduction of an aldehyde or a ketone.

 Unit Exercise (p.140)

Directions: Questions 10 and 11 refer to the four carbon compounds shown below.



10 Which carbon compound is formed by the oxidation of a secondary alcohol? **Answer: C**

**Explanation:**

The oxidation of a secondary alcohol forms a ketone.

11 Which carbon compound forms a primary alcohol upon reduction by  $\text{NaBH}_4$ ? **Answer: A**

**Explanation:**

The reduction of an aldehyde by  $\text{NaBH}_4$  gives a primary alcohol.

 Unit Exercise (p.140)

12 Which of the following compounds would NOT produce a colour change when heated with acidified  $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$ ?

- A Propan-1-ol
- B Propan-2-ol
- C Propanal
- D Propanone

**Explanation:**

Propanone CANNOT be oxidised when heated with acidified  $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$ .

**Answer: D**



## Unit Exercise (p.140)

13 Which of the following compounds can be formed when butan-2-ol is dehydrated?



A (1) and (2) only

B (1) and (3) only

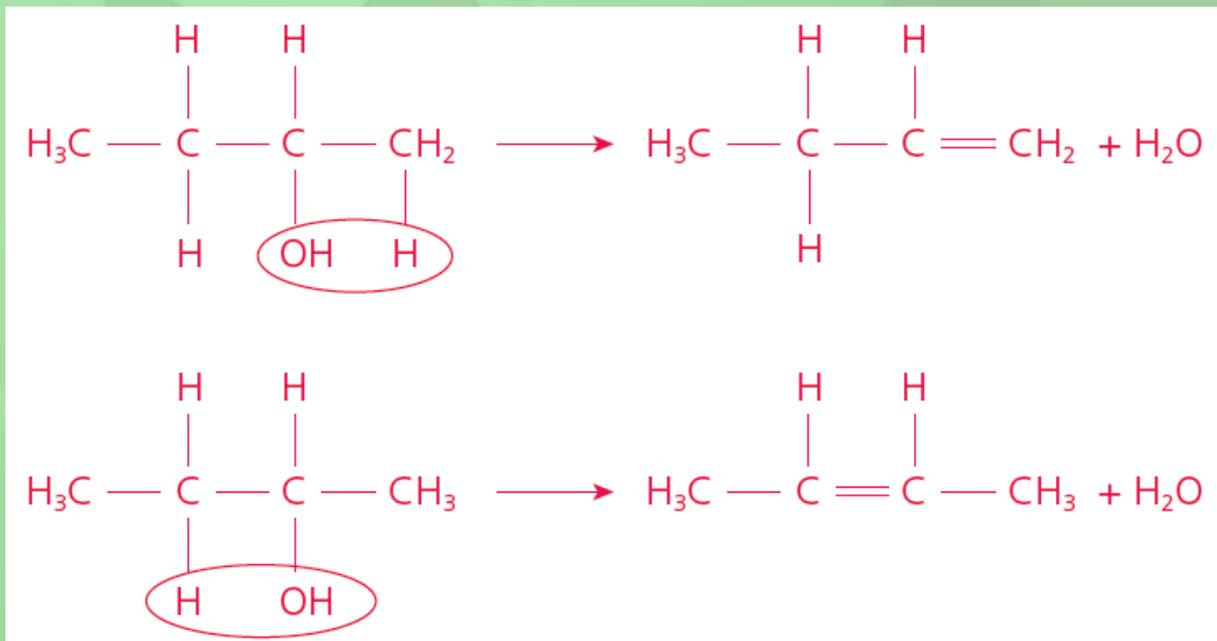
C (2) and (3) only

D (1), (2) and (3)

**Answer: B**

**Explanation:**

For butan-2-ol, water can be lost in two ways:





## Unit Exercise (p.140)

14 Which of the following statements about  $\text{CH}_3\text{CH}=\text{CHCH}_2\text{CHO}$  are correct?

- (1) It turns acidified  $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$  green upon warming.
- (2) It has stereoisomers.
- (3) It reacts with a carboxylic acid to form an ester.

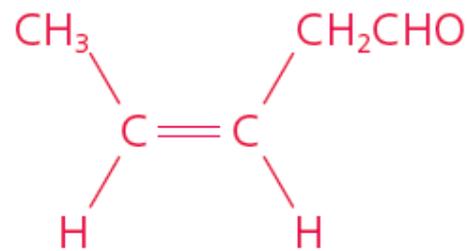
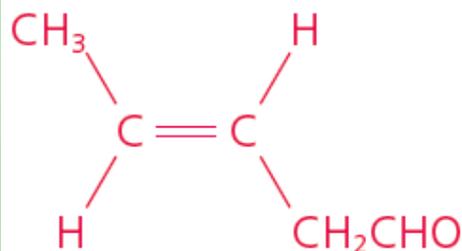
**Answer: A**

- A (1) and (2) only
- B (1) and (3) only
- C (2) and (3) only
- D (1), (2) and (3)

**Explanation:**

(1)  $\text{CH}_3\text{CH}=\text{CHCH}_2\text{CHO}$  is an aldehyde. It can be oxidised by acidified  $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$ .

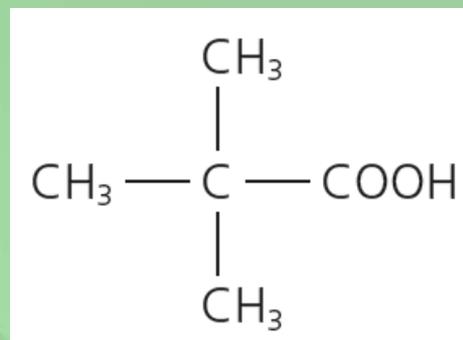
(2)  $\text{CH}_3\text{CH}=\text{CHCH}_2\text{CHO}$  has stereoisomers.





## Unit Exercise (p.140)

15 The structure of a compound is shown below:



Which of the following statements about this compound are correct?

- (1) It can form a salt with aqueous ammonia.
- (2) It can be reduced to a ketone by using  $\text{NaBH}_4$ .
- (3) It is an isomer of ethyl propanoate.

**Answer: B**

- A (1) and (2) only  
B (1) and (3) only  
C (2) and (3) only  
D (1), (2) and (3)

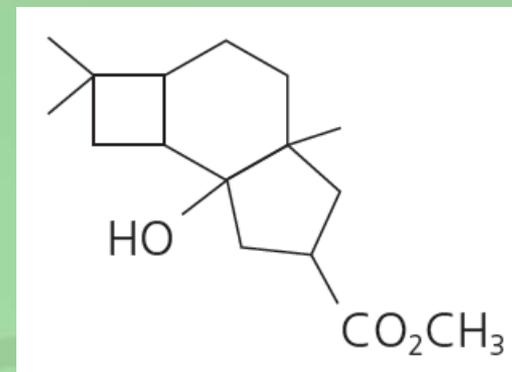
**Explanation:**

- (1) The compound is a carboxylic acid. It undergoes neutralisation with aqueous ammonia to form a salt.
- (2)  $\text{NaBH}_4$  is NOT strong enough to reduce carboxylic acids.  $\text{LiAlH}_4$  is a stronger reducing agent and can be used to reduce carboxylic acids.
- (3) The compound and ethyl propanoate are functional group isomers.



## Unit Exercise (p.140)

16 An organic compound has the following structure:



Which of the following statements concerning this compound are correct?

- (1) It has an ester group.
- (2) It contains at least one chiral centre.
- (3) It reacts with acidified sodium dichromate solution to form a ketone.

**Answer: A**

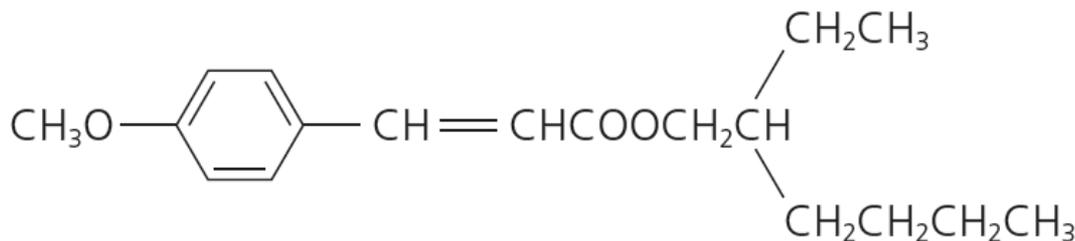
- A (1) and (2) only
- B (1) and (3) only
- C (2) and (3) only
- D (1), (2) and (3)

*(HKDSE, Paper 1A, 2018, 35)*



## Unit Exercise (p.140)

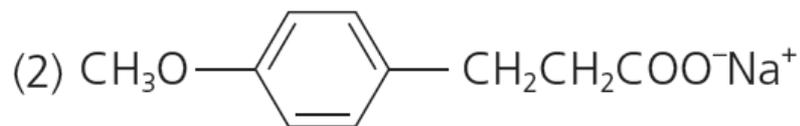
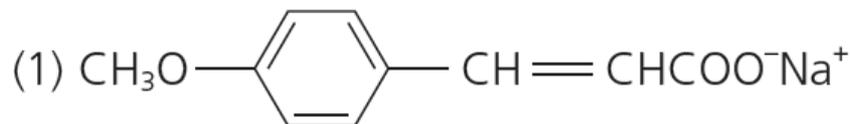
17 A sun protection cream contains the following compound as its active ingredient:



The compound is heated under reflux with sodium hydroxide solution. Which of the following compounds will form?

**Answer: A**

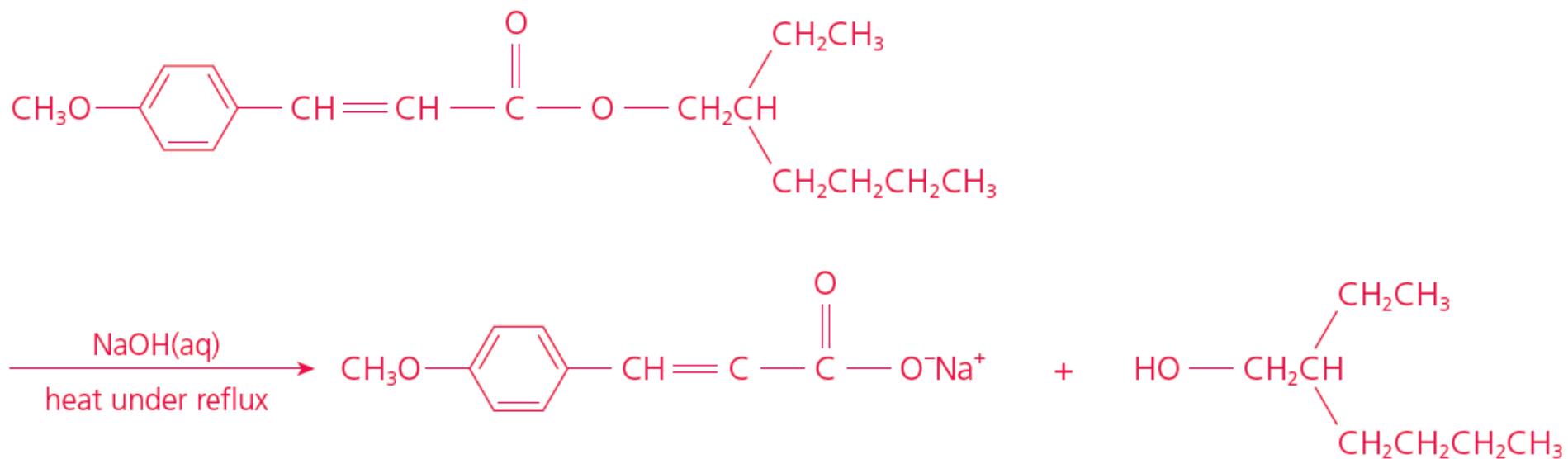
- A (1) only  
 B (2) only  
 C (1) and (3) only  
 D (2) and (3) only





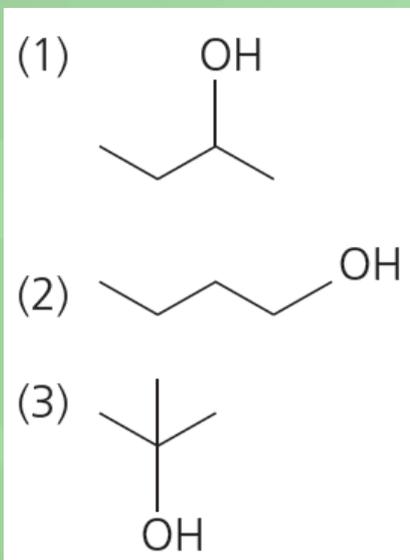
## Unit Exercise (p.140)

Explanation:



 Unit Exercise (p.140)

18 Which of the following compounds can react with acidified potassium dichromate solution to form a ketone?



Answer: A

- A (1) only  
B (2) only  
C (1) and (3) only  
D (2) and (3) only

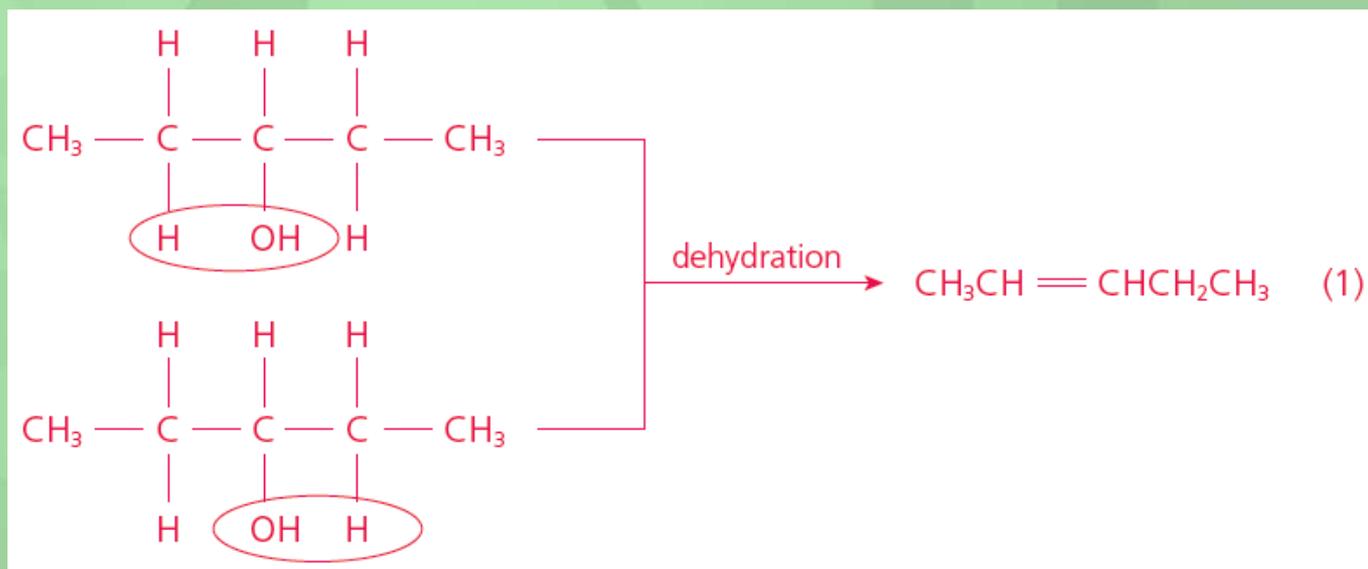
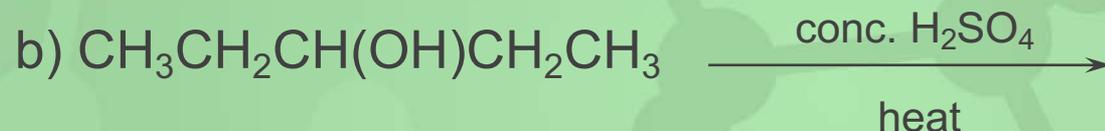
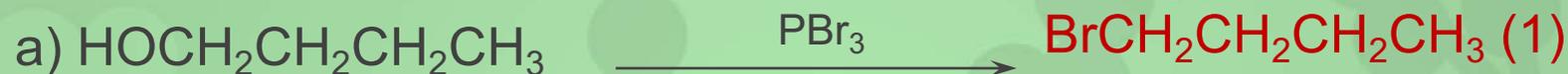
(HKDSE, Paper 1A, 2015, 32)



## Unit Exercise (p.140)

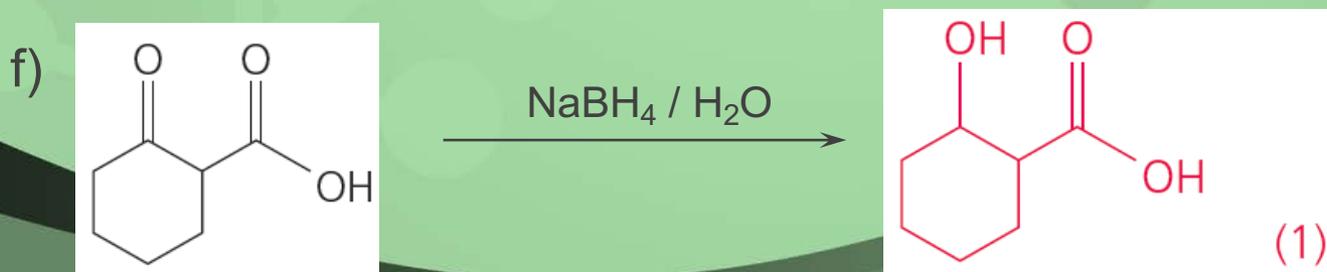
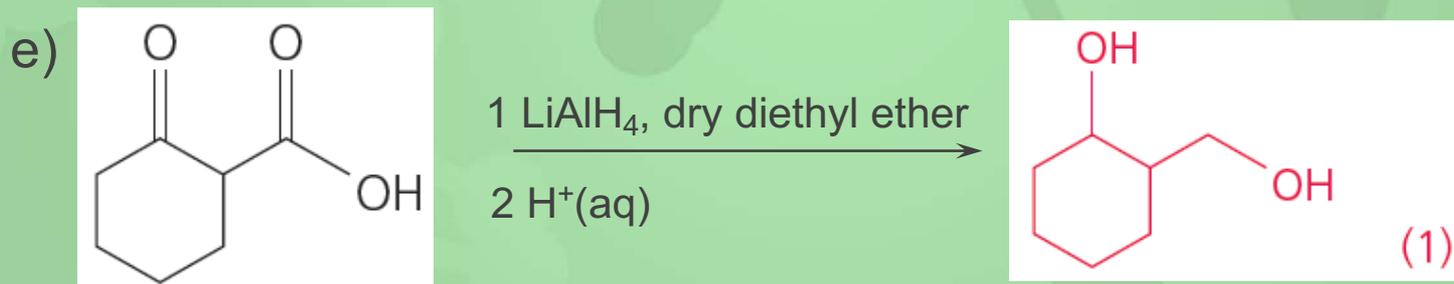
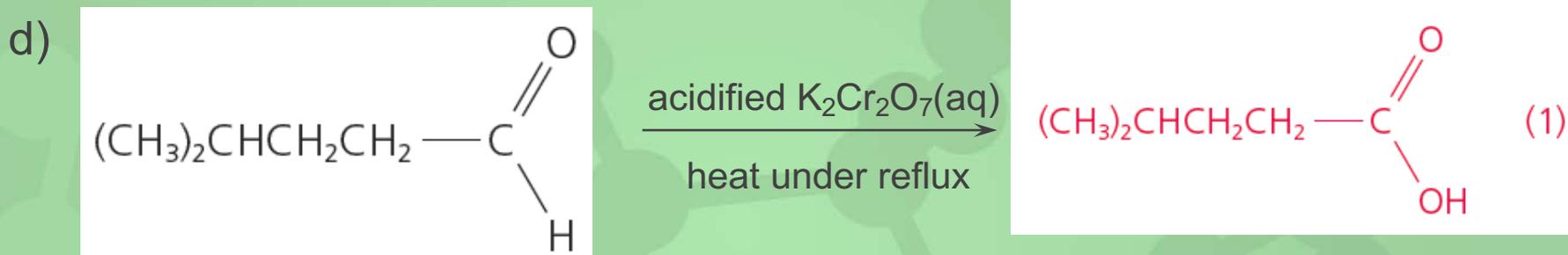
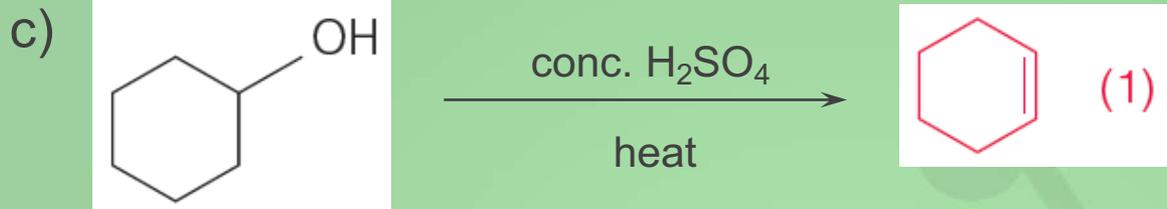
## PART III STRUCTURED QUESTIONS

19 Give the structural formula(e) of the major product(s) in each of the following reactions.



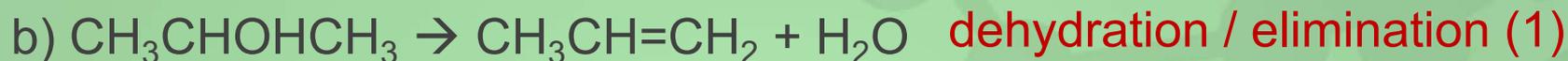


## Unit Exercise (p.140)



 Unit Exercise (p.140)

20 State the type of reaction shown in each of following reactions:

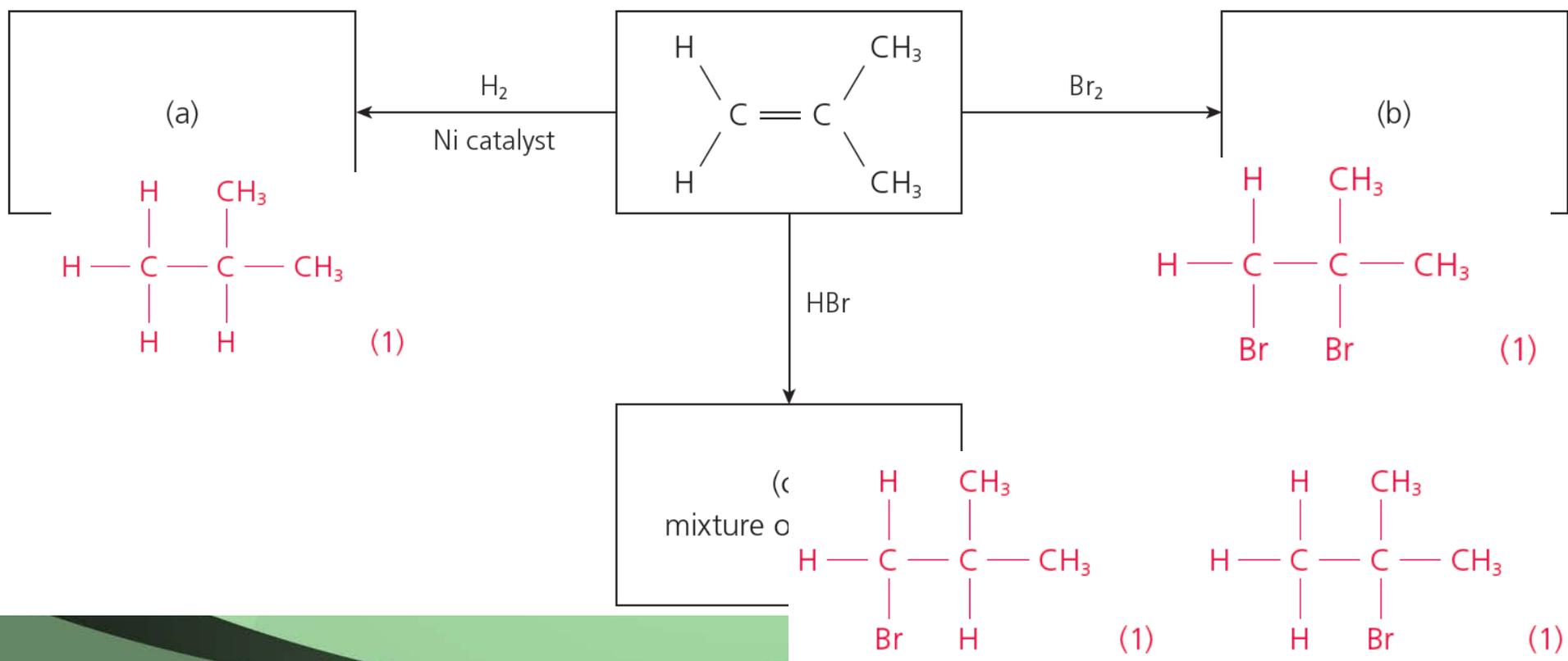




## Unit Exercise (p.140)

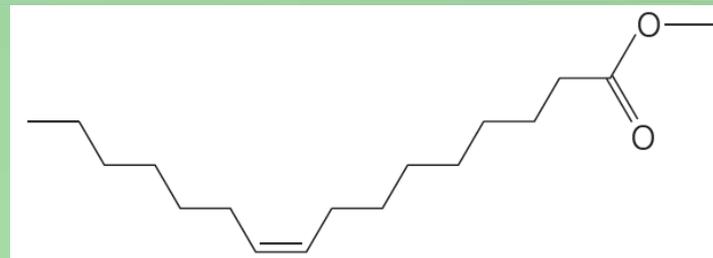
21 Alkenes are unsaturated hydrocarbons used in the industrial production of many organic compounds.

Complete the flow chart to show the structural formula(e) of organic product(s) formed in each addition reaction of methylpropene.





## Unit Exercise (p.140)



22 Compound I is found in biodiesel.

 It has the skeletal formula shown.

a) Name the TWO functional groups that are present in a molecule of I.

**carbon-carbon double bond (1)                      ester group (1)**

b) Why is compound I unsaturated? **It has a C=C bond. (1)**

c) A sample of compound I is shaken with aqueous bromine.

What colour change would you see? **From yellow-brown to colourless (1)**

d) Compound J is a stereoisomer of compound I.

i) What is meant by the term 'stereoisomers'?

**Stereoisomers are isomers whose atoms are bonded together in the same way but are arranged differently in space. (1)**

ii) Draw or describe how the structure of J differs from that of I.



iii) The student noticed that compound I burnt with a yellow flame and produced black smoke. Suggest an explanation for these observations.

*(OCR Advanced Subsidiary GCE, Chem A, F322, Jun. 2013, 3(a)–(d)(ii),(v))*

**Incomplete combustion occurs. (1)**

**Carbon is formed.**

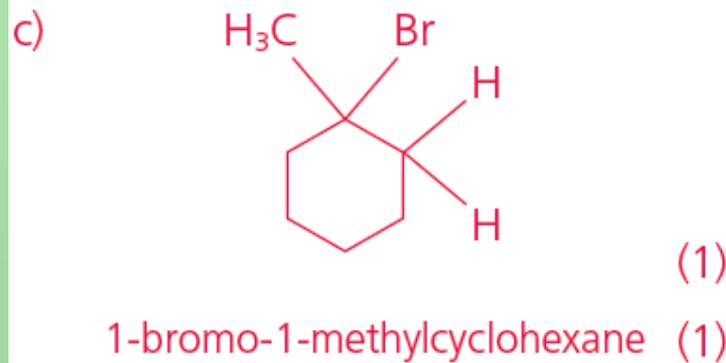
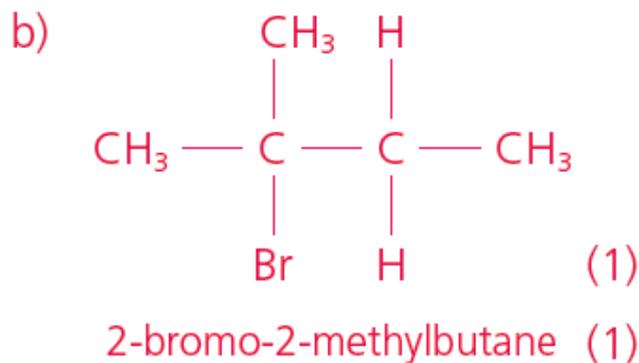
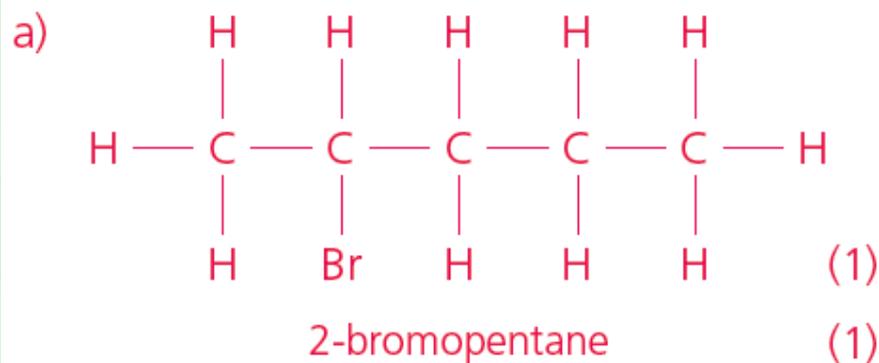
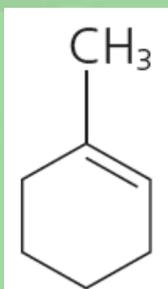


## Unit Exercise (p.140)

23 Write the structural formula and the name of the major product of the reaction of each of the following compounds with hydrogen bromide.



c)



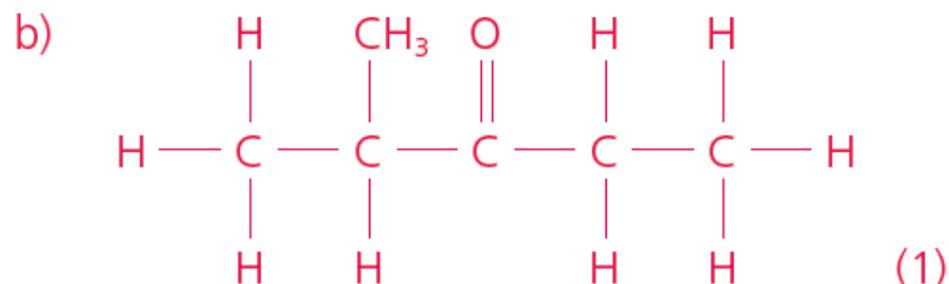
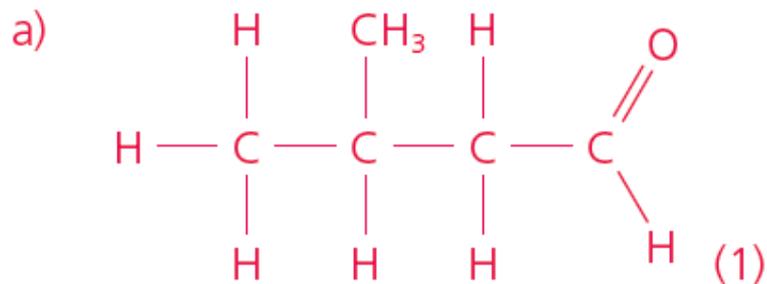


## Unit Exercise (p.140)

24 Write the structural formula of the organic product when each of the following alcohols is heated with acidified  $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$  with the set-up for distillation:

a) 3-methylbutan-1-ol

b) 2-methylpentan-3-ol





## Unit Exercise (p.140)

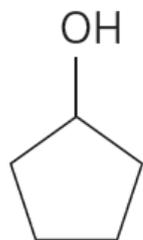
25 Alcohol X reacts with three different reagents.



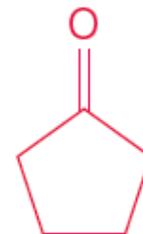
Complete the flow chart to show the organic product(s) formed in each of the reactions.



## Unit Exercise (p.140)

acidified  $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$ 

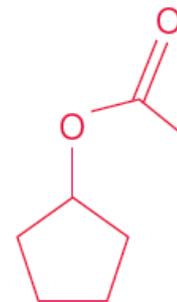
heat



(1)

 $\text{CH}_3\text{COOH}$  and an acid catalyst

heat



(1)

an acid catalyst

heat



(1)



## Unit Exercise (p.140)

26 Allyl bromide is the traditional name for the compound shown below.



- a) Give the systematic name of this compound. **3-bromopropene (1)**
- b) Allyl bromide can be converted to acraldehyde in a two-step reaction.



- i) State the names of reagents X and Y.  
**reagent X — NaOH(aq) (1)**  
**reagent Y — acidified K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>(aq) (1)**
- ii) Give the systematic name of acraldehyde.  
**pro-2-enal (1)**





## Unit Exercise (p.140)

d) Describe the chemical tests you would use to identify cyclohexene and cyclohexanol.

Your answer should include:

- names of the chemicals used to carry out the tests;
- conditions if appropriate;
- observations for each test.

(A test involving phosphorus pentachloride is NOT acceptable.)

### Cyclohexene

Add  $\text{Br}_2(\text{aq})$  to cyclohexene and shake. (1)

The yellow-brown  $\text{Br}_2(\text{aq})$  turns colourless quickly. (1)

### Cyclohexanol

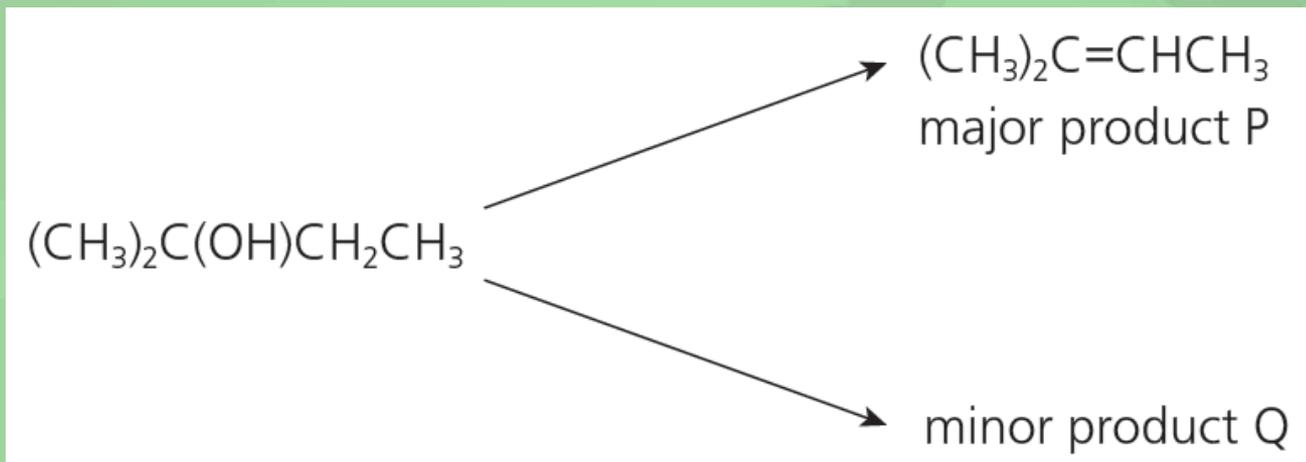
Warm with acidified  $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$ . (1)

The orange dichromate solution turns green. (1)



## Unit Exercise (p.140)

28 Alcohol X undergoes dehydration to give two alkenes.



a) Suggest what the dehydrating agent might be.

**Aluminium oxide / concentrated sulphuric acid (1)**

b) Write the structural formula of the minor product Q.



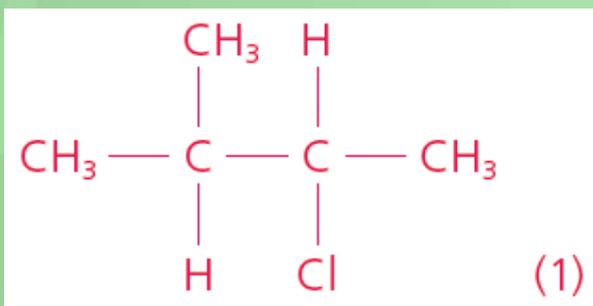
 Unit Exercise (p.140)

c) Products P and Q are isomers. What kind of isomers are P and Q?

**Structural isomers (1)**

d) The major product P can react with HCl to form an optically active chloroalkane.

Write the structural formula of this chloroalkane.





## Unit Exercise (p.140)

29 Butan-1-ol can be oxidised to form compounds X and Y.

 Compound X is obtained by distilling it off as it forms during the oxidation.

Compound Y is formed when the oxidation takes place under reflux.

a) Identify the functional groups in X and Y.

**X contains a carbonyl group. (1)**

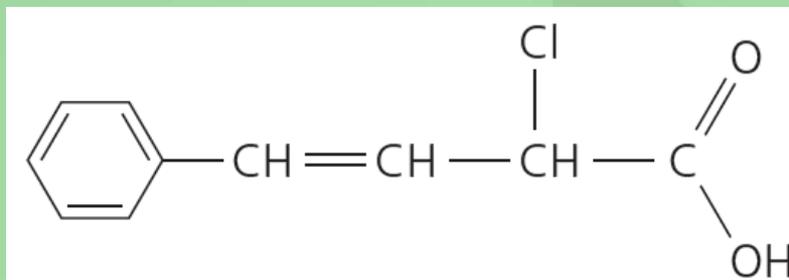
**Y contains a carboxyl group. (1)**

b) Explain, with reference to intermolecular forces, why it is possible to obtain compound X but NOT Y from the reaction mixture by distilling off X as soon as it forms.

**Y can form hydrogen bonds, which are stronger than the van der Waals' forces in X. (1)**

 Unit Exercise (p.140)

30 The structural formula of compound X is shown below:  
State and explain what you would observe when X reacts with



a) sodium carbonate solution;

Effervescence occurs due to the presence of the  $\text{-COOH}$  group. (1)

b) aqueous bromine.

The yellow-brown  $\text{Br}_2(\text{aq})$  turns colourless quickly due to the presence of the carbon-carbon double bond. (1)

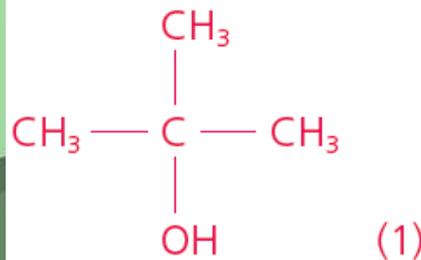


## Unit Exercise (p.140)



31 Carbon compound X is a colourless liquid. It contains four carbon atoms and one functional group. A series of tests were carried out on compound X.

- a) A dry sample of X reacted with phosphorus pentachloride, producing steamy fumes. What deduction can be made from the result of this test alone? **X contains a hydroxyl group. (1)**
- b) No reaction was observed when X was added to sodium carbonate solution,  $\text{Na}_2\text{CO}_3(\text{aq})$ . What further deduction can be made from the result of this test? **X is not a carboxylic acid. (1)**
- c) There was no observable changes when X was warmed with acidified potassium dichromate solution,  $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$ . What further deduction can be made from the result of this test? **X is a 3° alcohol. (1)**
- d) Use your answers from (a)–(c), and the fact that each molecule of X contains four carbon atoms, to deduce the structural formula of X.

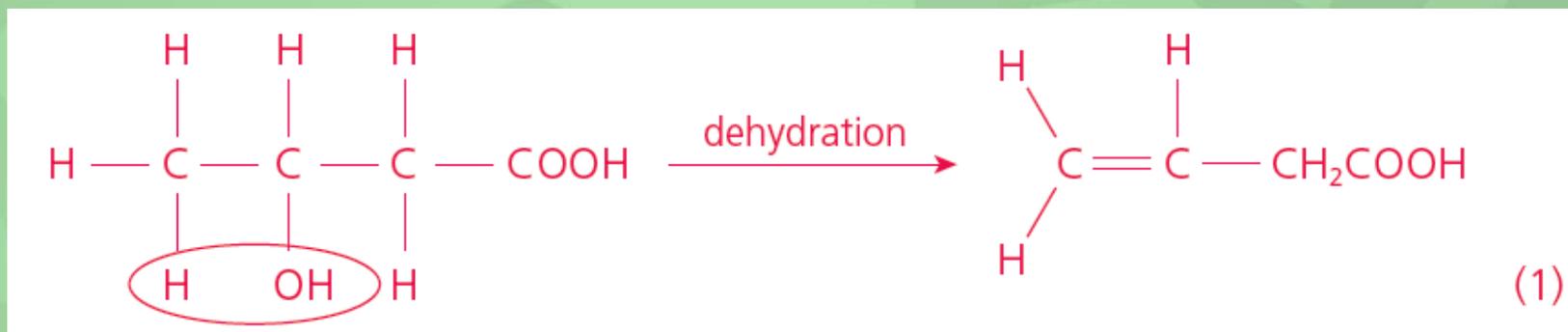






## Unit Exercise (p.140)

- Name the type of reaction that takes place.  
**dehydration / elimination (1)**
- Write the structural formula of product Q, which is a structural isomer of product P.



- Explain why product P exists as a pair of *cis-trans* isomers.

It contains a carbon-carbon double bond. There is restricted rotation of atoms or groups around a carbon-carbon double bond. (1)

There are two different atoms or groups on each carbon atom of the carbon-carbon double bond. (1)

 Unit Exercise (p.140)

c) Compound X can be oxidised by heating under reflux with acidified  $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$ .

Write the structural formula of the organic product.



 Unit Exercise (p.140)

33 Propanal is a useful intermediate in manufacturing processes.

a) Propanal has an isomer which is also a carbonyl compound but does not react with acidified  $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$ .

i) What would be observed when propanal is warmed with acidified  $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$ ?

**The solution changes from orange to green. (1)**

ii) Give the name of the isomer of propanal.

**Propanone (1)**

b) Propanal can be reduced to a compound that is used as a solvent in the pharmaceutical industry.

i) Give a reagent for this reaction.

**$\text{NaBH}_4 / \text{H}_2\text{O}$  (1)**

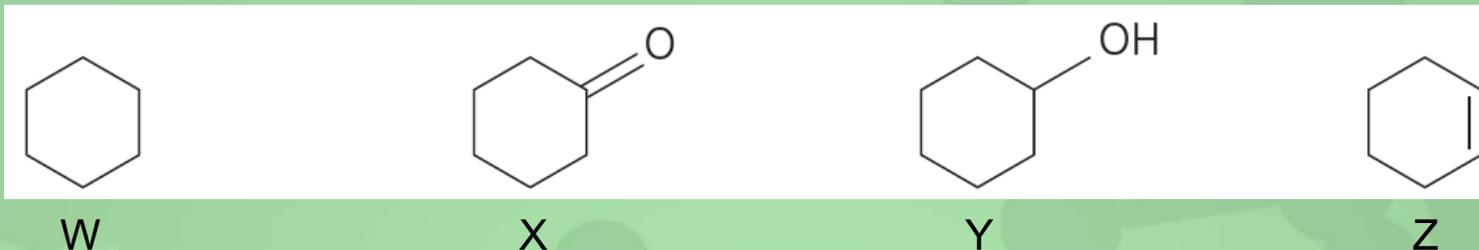
ii) Name the product.

**Propan-1-ol (1)**



## Unit Exercise (p.140)

34 Consider the four cyclic compounds W, X, Y and Z:



a) Suggest a simple chemical test that can be used to distinguish between compounds W and Z. State also the expected observations.

Any one of the following:

- Add  $\text{Br}_2(\text{aq})$  to each compound separately and shake. (1)

The yellow-brown  $\text{Br}_2(\text{aq})$  turns colourless quickly when added to compound Z.  
There is no observable change for compound W. } (1)

- Add cold acidified dilute  $\text{KMnO}_4(\text{aq})$  to each compound separately and shake. (1)

The purple  $\text{KMnO}_4(\text{aq})$  turns colourless quickly when added to compound Z.  
There is no observable change for compound W. } (1)



## Unit Exercise (p.140)

- b) • Compound X can be converted into compound Y.  
• Compound Y can be converted into compound Z.

For each conversion,

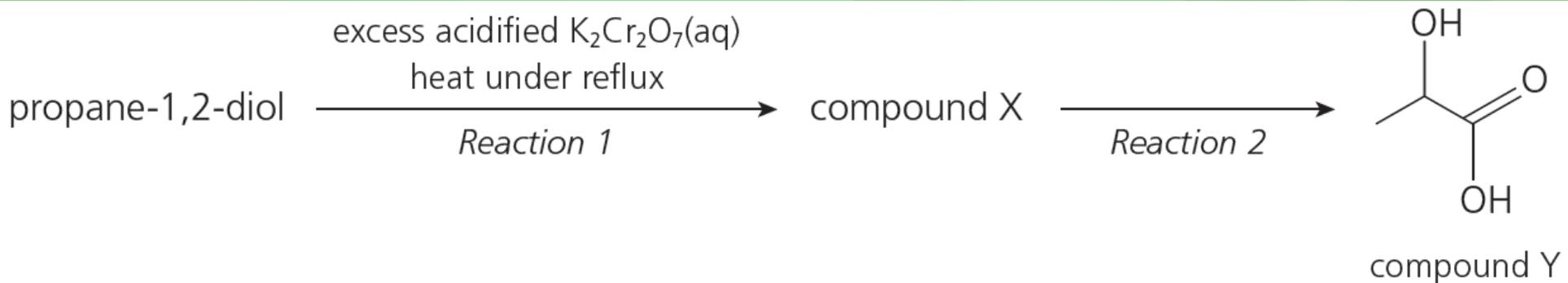
- i) give a reagent or combination of reagents that can be used for this reaction;  
ii) state the type of reaction that takes place.

Conversion	Reagent(s)	Type of reaction
$X \longrightarrow Y$	$\text{NaBH}_4 / \text{H}_2\text{O}$ (1)	reduction (1)
$Y \longrightarrow Z$	$\text{Al}_2\text{O}_3$ or conc. $\text{H}_2\text{SO}_4$ as catalyst (1)	dehydration / elimination (1)



## Unit Exercise (p.140)

35 A student prepared a sample of compound Y starting from propane-1,2-diol.



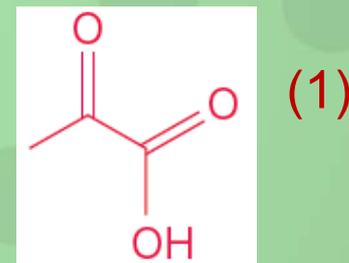
a) Complete the flow chart to show the structural formula of compound X and the reagent needed for *Reaction 2*.

**Structural formula of compound X:**

**Reagent for *Reaction 2*: NaBH<sub>4</sub> / H<sub>2</sub>O (1)**

b) What would you observe during *Reaction 1*?

**Colour changes from orange to green (1)**





## Unit Exercise (p.140)

- c) In *Reaction 1*, propane-1,2-diol was heated under reflux with excess acidified  $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$ . Suggest why these conditions were used, rather than having the reaction mixture being distilled during the process.

To ensure that a carboxylic acid is formed. / To prevent the formation of an aldehyde. (1)



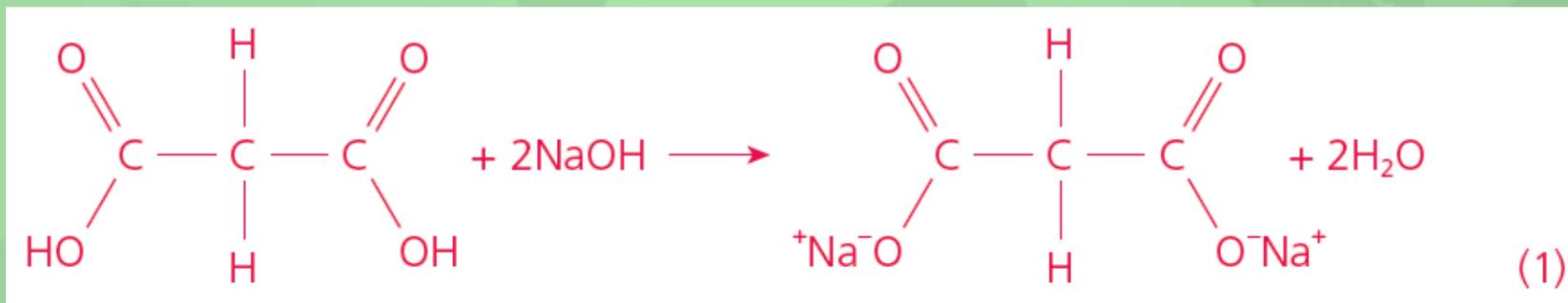
## Unit Exercise (p.140)

36 Write balanced equations, using structural formulae for the following reactions. 

a) propanoic acid and sodium carbonate solution



b) propanedioic acid and sodium hydroxide solution



c) ethanoic acid and ethane-1,2-diol heated in the presence of concentrated sulphuric acid

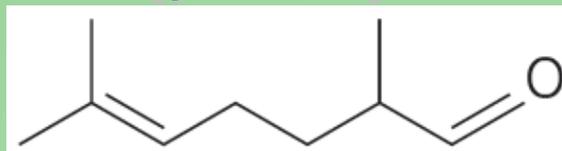




## Unit Exercise (p.140)



37 The compound



is sometimes known as

melonal because its smell is similar to watermelon.

a) Give the systematic name of melonal.

**2,6-dimethylhept-5-enal (1)**

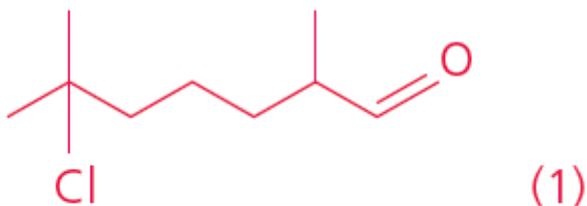
b) Give the structure of the major organic product(s) formed when melonal reacts with the following reagents:

i) HCl

ii) NaBH<sub>4</sub> / H<sub>2</sub>O

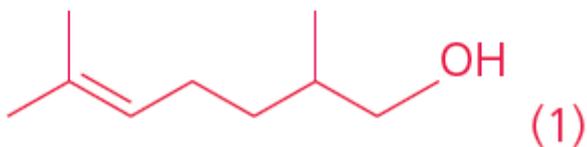
Name the type of reaction that takes place in each case.

i)



addition (1)

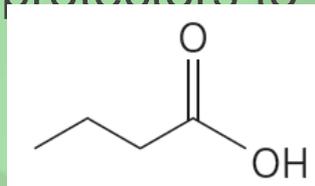
ii)



reduction (1)

 Unit Exercise (p.140)

38 Butanoic acid (often called 'butyric acid') is a foul-smelling liquid that has been used by anti-whaling protectors to throw on board whaling ships.



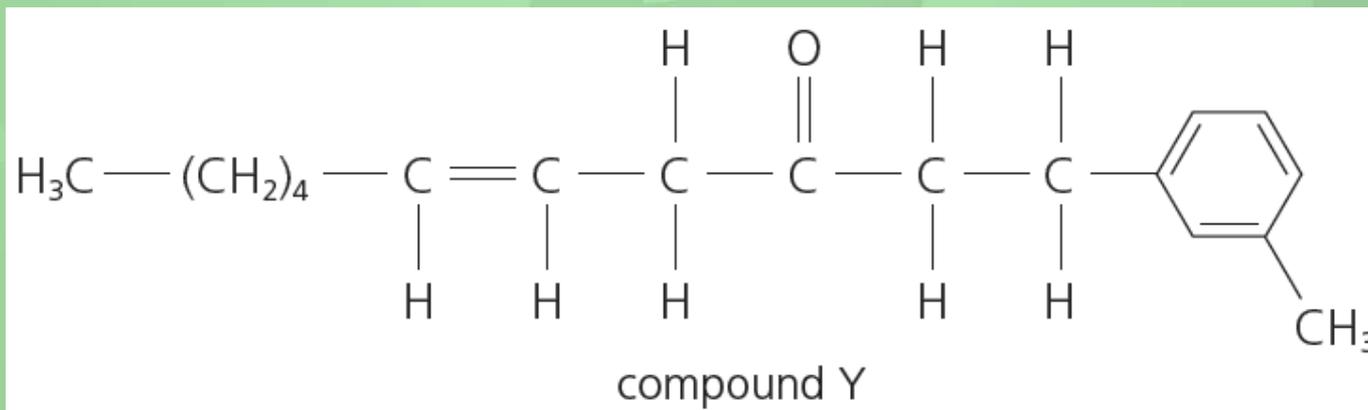
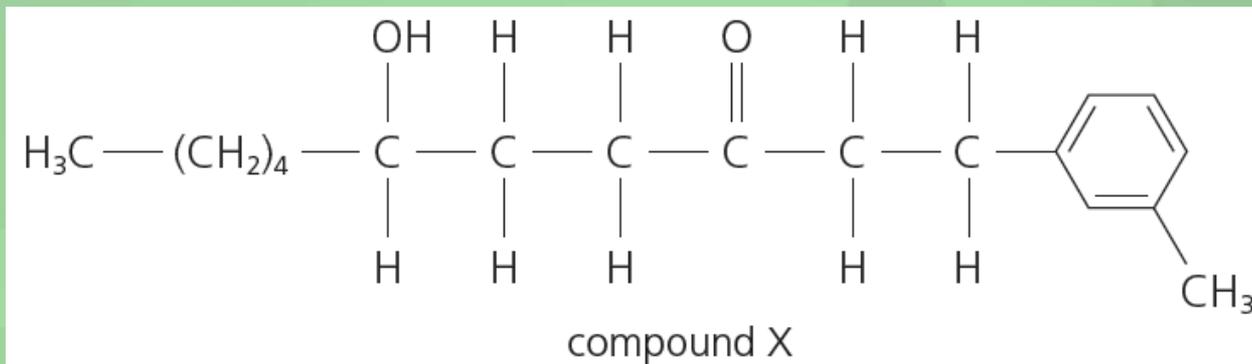
- a) 'Isobutyric acid' is an isomer of butanoic acid. Give the systematic name of isobutyric acid. **Methylpropanoic acid (1)**
- b) Esters of butanoic acid are used as food flavourings. Methyl butanoate, for example, smells and tastes of pineapples. It is made by heating butanoic acid with an alcohol in the presence of concentrated sulphuric acid. Suggest TWO functions of the concentrated sulphuric acid in the esterification process.
- **As a catalyst (1)**
  - **To remove the water formed (1)**
- c) Explain whether methyl butanoate has a higher or lower boiling point than butanoic acid.
- Methyl butanoate has a lower boiling point than butanoic acid.**  
**Van der Waals' forces in methyl butanoate are less strong compared with hydrogen bonds in butanoic acid. (1)**



## Unit Exercise (p.140)



39 Two compounds that contribute to the flavour of food are shown below:



a) Name ONE functional group common to X and Y.

**Carbonyl group (1)**



## Unit Exercise (p.140)

b) Choose a chemical reagent for each of the following situations and state what you would expect to observe.

i) A reagent that reacts with X but NOT with Y.

ii) A reagent that reacts with Y but NOT with X.

i) Acidified  $K_2Cr_2O_7(aq)$  (1)

The hydroxyl group in X will be converted to a carbonyl group when warmed with acidified  $K_2Cr_2O_7(aq)$ .

The mixture with X changes from orange to green. (1)

ii)  $Br_2(aq)$  (1)

An addition reaction occurs.

$Br_2(aq)$  changes from yellow-brown to colourless when added to Y. (1)

c) X could be converted into Y in the laboratory.

State the reagent and reaction condition for this reaction.

Heat

Aluminium oxide or concentrated sulphuric acid as catalyst (1)

## Unit Exercise (p.140)

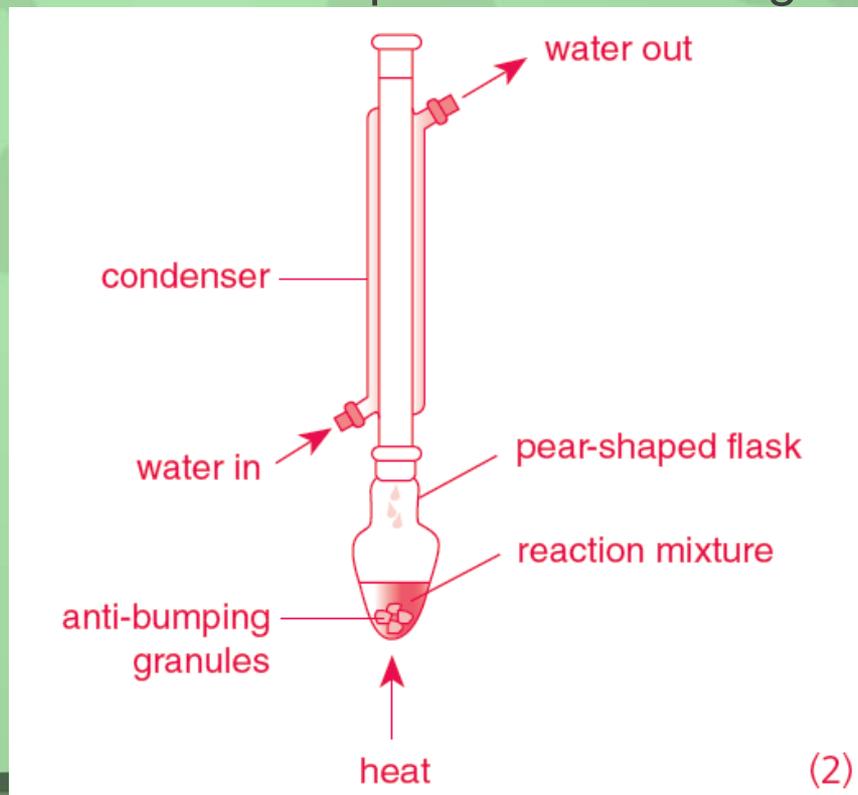
40 An ester X is used as a solvent for paints and varnishes.

 a) Ester X can be manufactured by heating an alcohol under reflux with ethanoic acid and a catalyst.

i) Suggest a suitable catalyst for this reaction.

**Concentrated sulphuric acid (1)**

ii) Draw a labelled diagram of the set-up used for heating the reaction mixture under reflux.



(2)

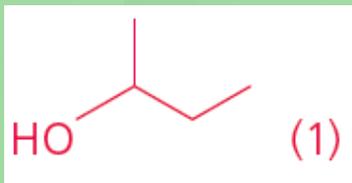
 Unit Exercise (p.140)

b) The skeletal formula of ester X is shown below:

i) Give the systematic name of ester X.

**2-butyl ethanoate (1)**

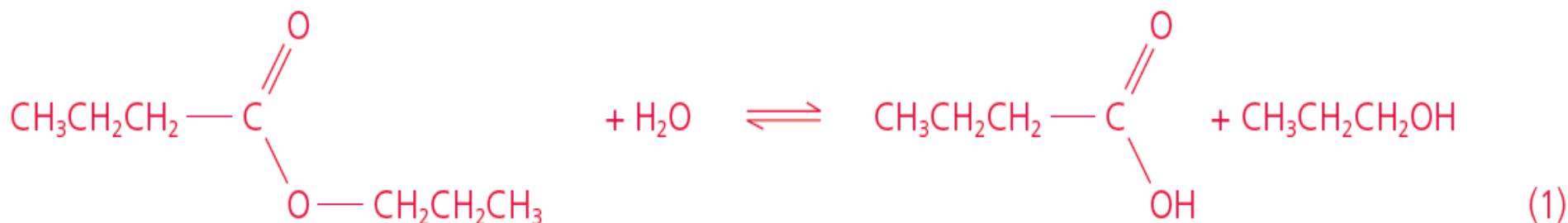
ii) Write the skeletal formula of the alcohol used to make ester X.



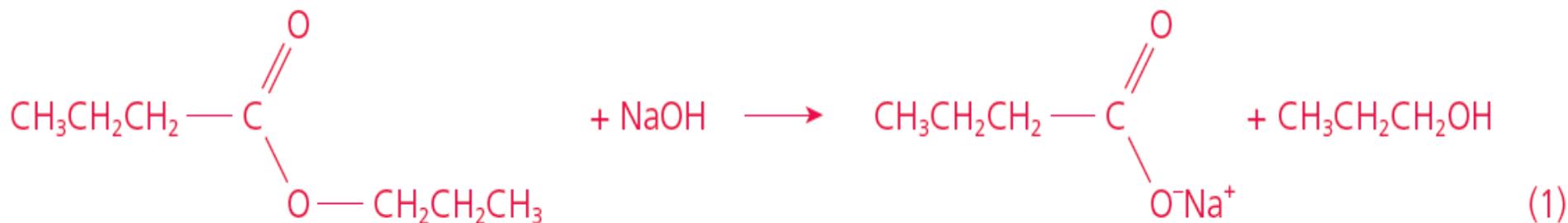
 Unit Exercise (p.140)

41 Write equations for the hydrolysis of 1-propyl butanoate in both acidic and alkaline conditions.

Acid hydrolysis



Alkaline hydrolysis





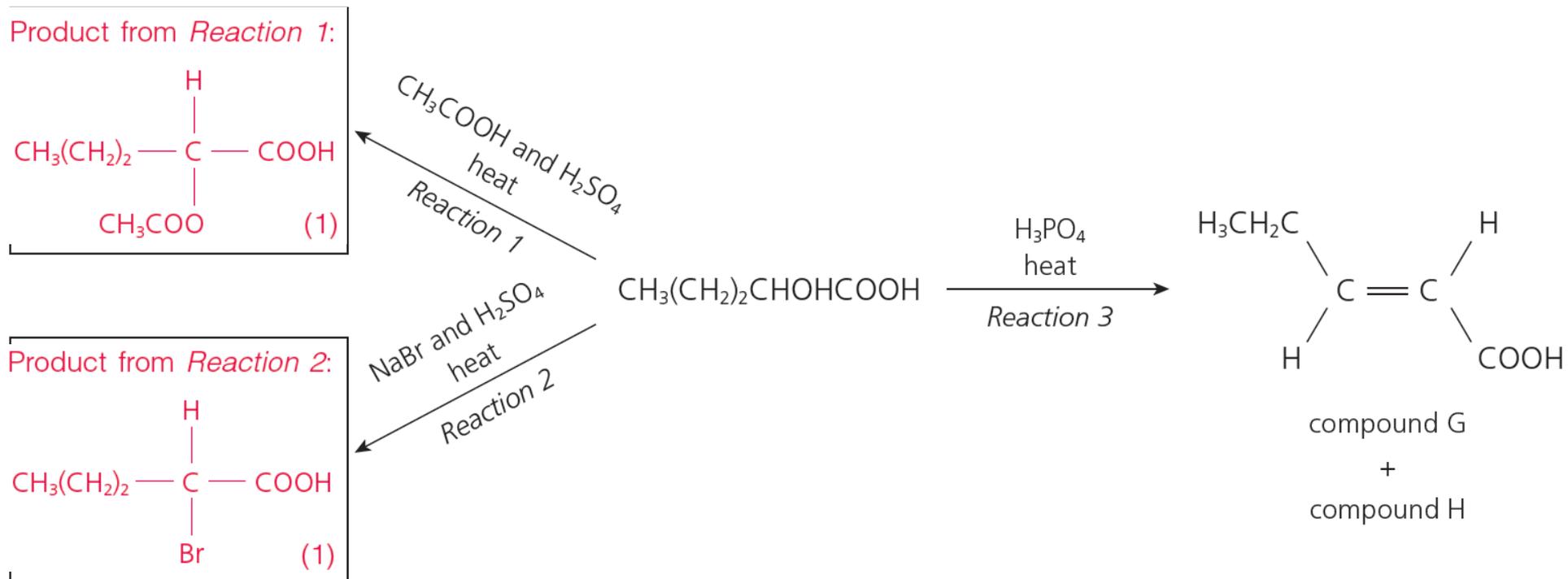
## Unit Exercise (p.140)

42  $\alpha$ -hydroxy acids (AHAs) are naturally occurring acids often used as cosmetics.



The flow chart below shows some reactions of an AHA,  $\text{CH}_3(\text{CH}_2)_2\text{CHOHCOOH}$ .

a) Fill in the boxes to show the structures of the organic products of *Reactions 1* and *2*, clearly showing the relevant functional groups.



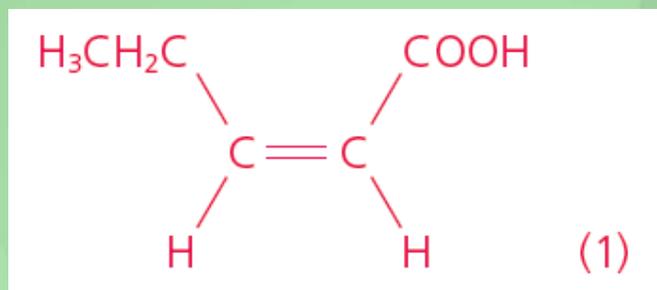
 Unit Exercise (p.140)

b) Give the full systematic name for compound G.

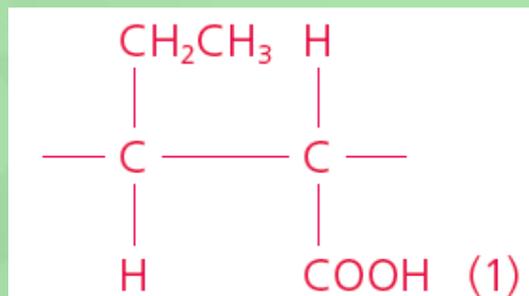
**Pent-2-enoic acid (1)**

c) Compound H is a stereoisomer of compound G.

i) Suggest a structure for compound H.



ii) Draw the repeating unit of the addition polymer that can be formed from compound H.



(OCR Advanced Level, Chem. A, H432, Sample Question Paper, 19(a)(i)–(iii))

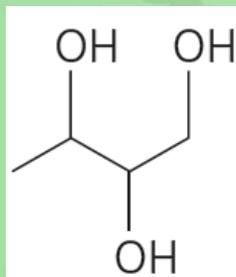


## Unit Exercise (p.140)

43 The two compounds X and Y are isomers with the molecular formula  $C_4H_8O$ . Results of some reactions of X and Y are listed below:



- Both X and Y react with phosphorus pentachloride to give steamy fumes.
- Both X and Y decolourise aqueous bromine.
- When reacted with cold acidified  $KMnO_4(aq)$ , both X and Y produce the same compound



- a) Suggest which functional group is responsible for the reaction with
- phosphorus pentachloride;
  - aqueous bromine.

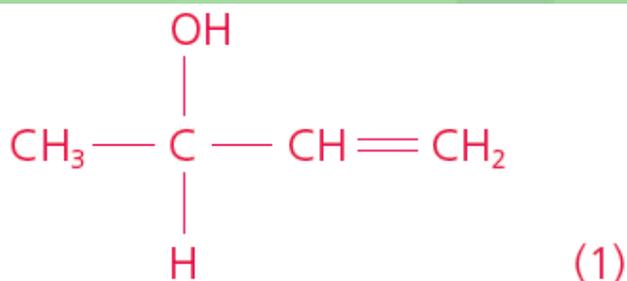
i)  $-OH$  (1)

ii)  $C=C$  (1)

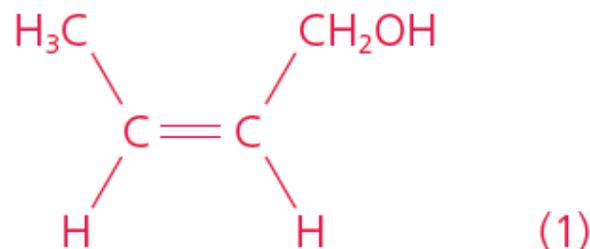
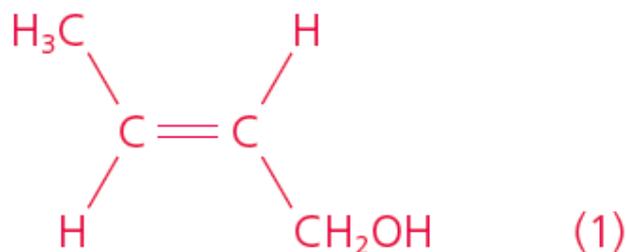


## Unit Exercise (p.140)

b) Suggest structures for X and Y.



c) One of the compounds, X or Y, exists as a pair of *cis-trans* isomers. Draw the structures of this pair of isomers.



 Unit Exercise (p.140)

44 Four unlabelled reagent bottles each contains one of the colourless liquids listed below:



Suggest chemical tests to distinguish the four liquids.

*(HKDSE, Paper 1B, 2017, 9)*

Answers for the questions of the public examinations in Hong Kong are not provided (if applicable).