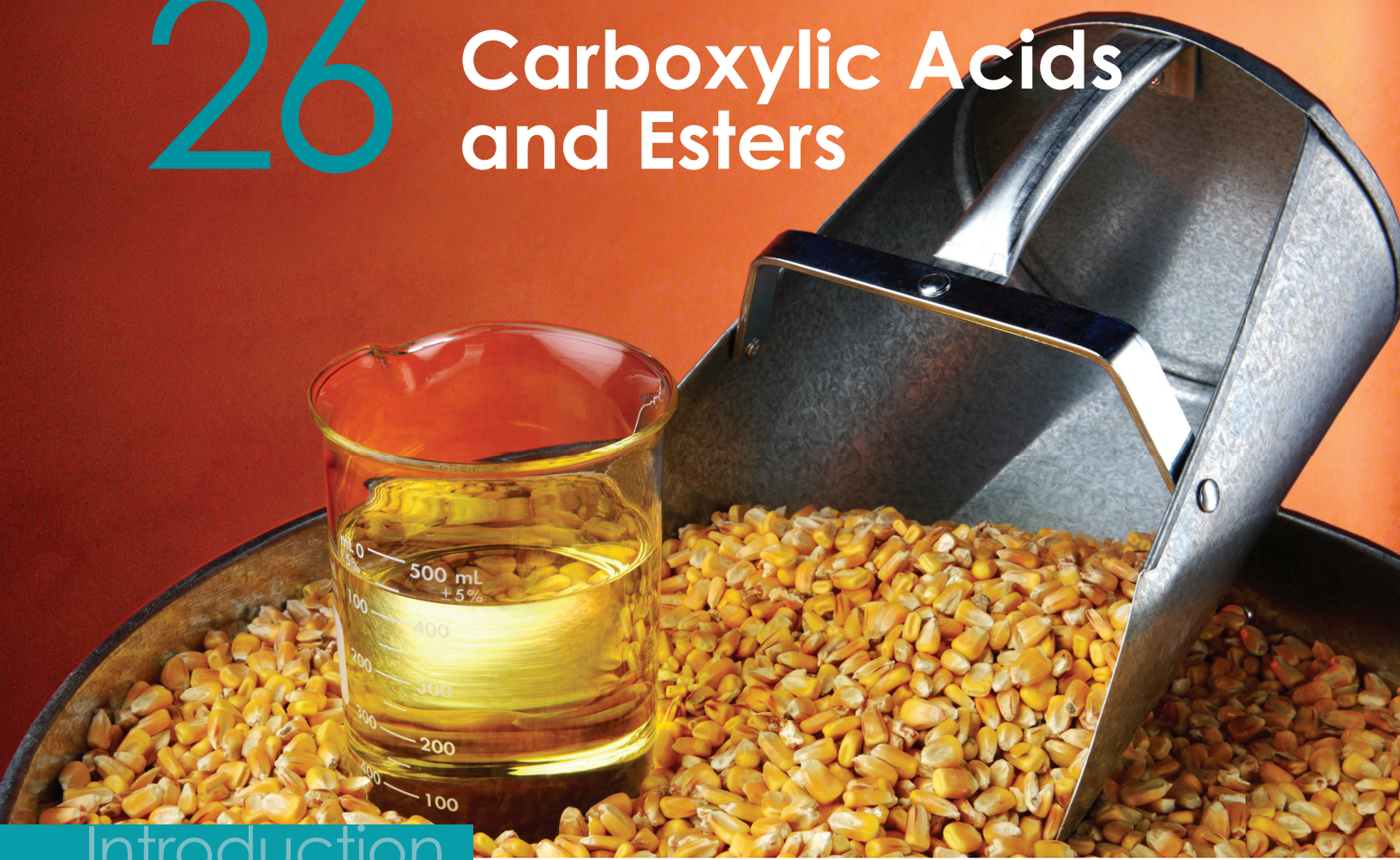
26 Carboxylic Acids and Esters



Introduction

Two hydrocarbon homologous series, the alkanes and alkenes, were studied in Chapter 25. In this chapter, the structure and properties of two homologous series, whose members contain oxygen as well as carbon and hydrogen, are studied, viz. the alcohols and the organic (carboxylic) acids. Particular attention is given to ethanol and ethanoic acid, the most important members of each series. Esters, which are not a homologous series, are also studied.

Chapter Opener (page 418)

1. To open the chapter, the following questions could be discussed. Precise answers are not needed at this stage.

   Alcohols are a homologous series. What elements to alcohol molecules contain? What functional group do they have?

   Answer: All alcohol molecules contain carbon, hydrogen and oxygen and the hydroxyl functional group.

   How is ethanol made?

   Answer: Ethanol is made by fermentation of sugars and by reacting ethene with steam over a catalyst.

   Ethanoic acid is a very common organic acid. What is its molecular formula and what functional group does it have?

   Answer: $C_2H_4O_2$, usually written as CH_3COOH to show the functional group -COOH.

2. Carry out an 'Inquiry Preview.'

Learning Outcomes

After completing this chapter, the students should be able to:

- describe the alcohols and organic acids as homologous series containing the –OH and –COOH groups respectively
- draw the structures of the first four members of each homologus series and name the unbranced structures
- describe some properties and reactions of alcohols and organic acids
- describe the formation of ethanol and ethanoic acid and state some of their uses
- describe the formation of esters and state some of their commercial uses

Teaching pointers

26.1 What are Alcohols? (page 419)

Stimulation

Introduce the topic with a brief discussion on the uses of ethanol and ethanoic acid, two organic compounds widely used in everyday life. (Although ethanol is used in alcoholic drinks, it is not advisable to bring any into the classroom; photographs can be used instead.) Discuss the questions in the Chapter Opener and lead into alcohols and carboxylic acids as homologous series.

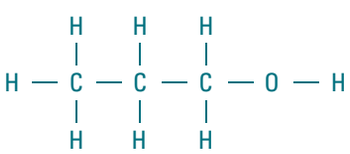
Teaching pointers

1. Point out that the alcohols are also called the *alkanols*, as students may come across this alternative name when referring to other material.
2. As with other homologous series, students must be able to name and write the formulae of just the unbranched alcohols with no more than four carbon atoms. Get the class to use ball-and-stick models to make these four alcohols.
3. Emphasise that the covalent hydroxyl group, –OH, is not the same as the ionic hydroxide group, OH^-.
4. Alcohols with up to three carbon atoms are completely miscible with water. As the length of the carbon chain increases, solubility decreases rapidly. Thus hexan-1-ol is almost insoluble in water.

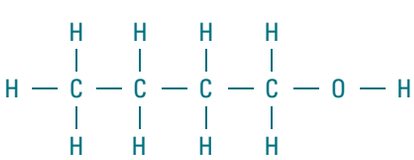
Skills Practice (page 420)

1. Writing the formula of methanol as CH_3OH shows the presence of the –OH group.
2. Structural formulae for:

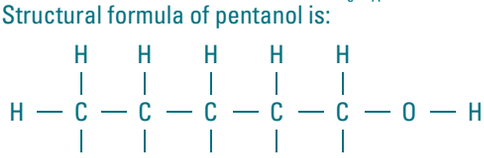
propanol



butanol



3. Yes. Ethanol does not conduct electricity, has a low boiling point and is volatile. However, unlike covalent compounds, ethanol is soluble in water (though the higher alcohols are insoluble in water).
4. **(a)** This boiling point suggests that ethanol is covalent. Like other covalent substances, ethanol has a low boiling point.
   (b) The boiling point of propanol should be higher than 78 °C as it is a higher member of the homologous series than ethanol, i.e. it has more carbon atoms per molecule than ethanol. (The actual boiling point of propan-1-ol is 97.1 °C.)
5. Molecular formula of pentanol is $C_5H_{11}OH$.
   Structural formula of pentanol is:



Teaching pointers

26.2 How Do We Manufacture and Use Ethanol? (page 420)

1. The use of living organisms (or parts of organisms) to make useful products or carry out useful processes is a branch of science called biotechnology. Thus fermentation, which uses yeast, is a biotechnology process.

   Note: There are several different definitions for fermentation. In the definition used here, only sugars (and not larger molecules such as starch) are converted into ethanol.

2. The amount of ethanol produced annually by the catalytic hydration of steam is about 700 million tonnes.

3. An additional experiment is provided at the end of this chapter for the preparation of ethanol by fermentation. This can be carried out as a teacher demonstration. The worksheet may be photocopied and distributed to students who may complete it during the demonstration. Refer also to the notes below on carrying out this experiment.

4. Ethanol is a useful solvent as it is soluble in both oils (due to the hydrocarbon/hydrophobic part of the molecule) and also in water (due to the hydrophilic hydroxyl group in the molecule). Toiletries, such as perfumes and after-shave lotion contain fragrant oils and water. Without the ethanol, the oils would not mix with the water.

5. Methylated spirit is a widely used industrial solvent. It is a mixture of ethanol and methanol. As alcohols are toxic (especially methanol), a purple substance is added to cause the liquid to be vomited up if swallowed.

6. Ethanol as a liquid is a renewable fuel substitute for petrol. Link this with the 'Chemistry in Society' on page 422 of the Textbook.

(page 422)

Mystery Clue

On burning, petrol provides more energy as the numerical value for its heat content is greater compared with that for the same mass of ethanol.

Additional Experiment 1: Preparation of Ethanol

In the preparation of ethanol by fermentation, remind the class that limewater is used to test for the presence of carbon dioxide (see page 276 of the Textbook).

Pointers on how to carry out the experiment:

- The proportion of yeast, glucose and water is not important.
- Fermentation starts very quickly if yeast is added to a warm solution of glucose.
- The water bath can be omitted for the experiment which works well at room temperature.
- If this experiment is carried out as a demonstration, the experiment could be set up shortly before the lesson so that when the class arrives, bubbles of gas can be observed. Use fresh limewater to show that carbon dioxide is produced.
- Fermentation is anaerobic, i.e. it works in the absence of oxygen. The test tube of limewater with the delivery tube helps to ensure that air does not enter the reaction flask.
- The fermentation products contain only 10 – 12% of ethanol as a higher concentration of ethanol poisons/kills the yeast and stops the fermentation.
- If desired, the contents of the flask can be fractionally distilled to obtain almost pure ethanol. To test for the presence of ethanol, set fire to a little ethanol in an evaporating basin. The ethanol should catch fire easily and burn with a clean flame.

Notes for Teachers

Ethanol in alcoholic drinks

Fermentation is used to make alcoholic drinks. A mixed fermented beverage of rice, honey and fruit was being produced as far back as 9000 years ago in Northern China. This is approximately the same time that barley beer and grape wine were beginning to be made in the Middle East.

Different alcoholic drinks use different raw materials, different methods of preparation and contain different amounts of ethanol. The table below shows these differences for some common alcoholic drinks.

Alcoholic drink	Raw material	Method of preparation	Concentration of ethanol (% by volume)
Beers Wines	barley grapes, rice	fermentation	low (3 – 8%) medium (8 – 18%)
Whisky Brandy Vodka	barley grapes potatoes	fermentation plus distillation	high (30 – 60%)

The sugars needed for fermentation to produce these alcoholic drinks are formed from the raw materials by other reactions that occur during the preparations. They are:

- Beers: starch ⟶ maltose
- Wines and brandy: sucrose ⟶ maltose (mainly)
- Rice wine: starch ⟶ maltose
- Whisky: starch ⟶ maltose
- Vodka: starch ⟶ maltose

Drinks prepared by the distillation of fermented liquids are called *spirits*.

IT Link

Student research on fermentation
http://webcache.googleusercontent.com/search?q=cache:http://youth.net/nsrc/sci/sci061.html

Project 1.

Chemistry in Society (page 422)

How Do We Get Ethanol Fuel from Plants?

You may want to demonstrate the burning of petrol, ethanol and gasohol (about 20% ethanol, 80% petrol by volume). To do this, place six drops of each solution in three evaporating dishes separately. Ignite the liquids carefully with a long taper. Petrol ignites more easily than ethanol. Ethanol burns with a non-luminous flame while petrol gives a yellow-coloured flame with some soot. The gasohol gives results between those for petrol and ethanol. Be careful not to spill any fuel which might burn on the bench.

Exercise

Pointers for Exercise Discussions

As an optional activity, carry out the discussion exercises. Here are some points that you may give to the students:

- Brazil has almost no petroleum resources. Petroleum, which is expensive, must be imported; ethanol provides a much cheaper fuel.
- A modern country needs a source of fuel for transportation.

- Brazil can export ethanol to obtain revenue to help in the development of the country. The money can also be used to purchase food.
- Brazil should use more gasohol rather than pure ethanol. This will reduce the amount of land needed to produce ethanol. The land could be used for agricultural purposes.
- Burning ethanol and gasohol produce less air pollution than burning petrol and so ethanol and gasohol should be used.
- Farmers may switch from growing rice, wheat or other foods to growing sugar cane if they can get more profit from growing sugar cane.
- The primary purpose of land should be used for agricultural purposes before using them for growing sugar cane, even if this reduces the amount of ethanol that can be produced.
- The ethanol programme could lead the government to divert investment from food production to ethanol production and this will result in an increased hardship for the poor.
- Singapore could import ethanol fuel produced in other countries. This could be used as a fuel directly of blended with petrol as gasohol. Also, petrol produced from plants can be imported. Alternative non-ethanol fuels are CNG (already in use) and hydrogen for use in fuel cell vehicles (refer again to Chapter 19).

Additional Exercise 3: Comparing Fuels

An additional exercise on comparing petrol, ethanol and gasohol can be found at the end of this chapter. The worksheet can be photocopied and distributed to students. Based on the comparison of these fuels, students can decide which fuel could be most suitable for Singapore.

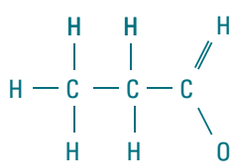
Teaching pointers

26.3 What are the Reactions of Ethanol? (page 423)

1. Part of the reason why ethanol burns cleanly in air is due to the atom of oxygen present in the molecule which enables it to burn completely forming carbon dioxide rather than carbon monoxide or carbon.
2. In Experiment 26.1B, the acidified potassium manganate(VII) is an oxidising agent and is reduced to colourless manganese(II) ions. The ethanol is oxidised to ethanoic acid. The distillate has the smell of vinegar and turns universal indicator red, indicating acidity.
3. As this reaction in Experiment 26.1C involves the formation of an ester, it could be left until Section 26.4. Refer to the notes on this reaction in the next section.

Skills Practice (page 424)

1. The unreacted ethene and steam is passed over the catalyst many times, which increases the yield.
2. $2CH_3OH(aq) + 3O_2(g) \longrightarrow 2CO_2(g) + 4H_2O(l)$
3. The molecular formula of the product is $C_3H_6O_2$ or C_2H_5COOH. The structural formula of the product is:



The product is an acid.

(page 423)

Mystery Clue

Using food crops for the production of green gasoline runs the risk of driving up food prices. This is not an issue when non-food plant sources are used. Leftovers could include cornstalks, remains from wheat plants, waste wood, sawdust, and grasses.

IT Link

Additional websites on ethanol as a fuel for cars
http://encyclopedia.kids.net.au/page/et/Ethanol#Ethanol_as_fuel
http://en.wikipedia.org/wiki/Ethanol_fuel
http://www.eia.gov/kids/energy.cfm?page=tl_ethanol
http://environment.nationalgeographic.com/environment/global-warming/biofuel-profile/
http://www.need.org/needpdf/Ethanol.pdf
http://auto.howstuffworks.com/fuel-efficiency/alternative-fuels/ethanol-facts.htm
http://www.energy-secure.com/EIA-KIDS-Search/search.php?zoom_query=ethanol

Teaching pointers

26.4 What are Carboxylic Acids? (page 424)

1. These organic acids are known as the *carboxylic* acids because they contain the carboxyl group, –COOH.
2. Students sometimes think that because the prefix 'eth' refers to two carbon atoms, ethanoic acid has a CH_3CH_2– then a –COOH. Emphasise that the C in the –COOH group counts as one of the carbon atoms.
3. Link the discussion on the properties of ethanoic acid with previous work in Chapter 15.
4. The traditional method of producing vinegar uses the ethanol formed by the fermentation of grains. The production of vinegar probably dated back to the invention of wine since wine starts to become acidic when left in the open air for any length of time. The word 'vinegar' is a combination of two French words, 'vin' (wine) and 'aigre' (sour), that is, sour wine.
5. The production of vinegar using bacteria is an example of biotechnology. As the production of vinegar from natural gas is part of the petrochemical industry, this vinegar can be regarded as a petrochemical.
6. An interesting use of organic acid is in the gut of anteaters. Like us, anteaters are mammals. But unlike us, their guts contain no hydrochloric acid to help in the digestion of food. These animals use the acids present in ants and other insects they eat for this purpose.

Experiment 26.1C (PWB pages 173 – 174)

In this experiment, ensure that there is good ventilation. Remind students not to smell the vapour directly but to waft it towards the nose. This is because high concentrations of esters can be harmful.

In the preparation of the ester in the experiment, the reaction mixture is added to a sodium hydrogencarbonate solution which neutralises any unreacted acid present in the mixture. The ester, which is insoluble in water, floats on the water and so can be easily separated using a separating funnel.

Note: In the method shown in Figure 26.10 on page 427 of the Textbook, the reaction mixture is added to water only.

Skills Practice (page 427)

(a) **X** is ethyl ethanoate; **Y** is ethanol; **Z** is ethanoic acid.
(b) **(i)** Oxidation
(ii) Potassium dichromate(VI) and sulfuric acid (or air).
(c) Mix **Y** and **Z** together and add a little concentrated sulfuric acid. Then boil the mixture.
(d) **(i)** Deodorant
(ii) Vinegar in preserved chillies or tomato ketchup.

Notes for Teachers

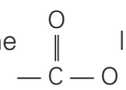
Ethanoic acid from petroleum

Ethanoic acid can also be produced using hydrocarbons obtained from petroleum. For example, air is passed through liquid butane under pressure in the presence of a catalyst. The main product of the reaction is ethanoic acid:

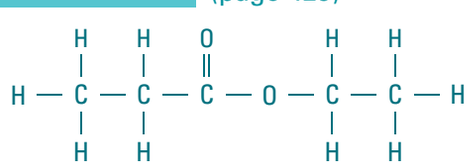
$$2C_4H_{10}(l) + 5O_2(g) \longrightarrow 4CH_3COOH(l) + 2H_2O(l)$$

Teaching pointers

26.5 What are Esters? (page 427)

1. Bring to class some examples of foods and other products that contain esters and get students to smell them and note their 'fruity' smell.
2. The  linkage is present in all esters and is called the ester link. It is also present in the synthetic plastics known as polyesters (see Chapter 27).
3. Discuss the naming of esters slowly as students often have difficulty remembering which part of the name is derived from the alcohol and which is from the organic acid. By convention, the left-hand part of the structure comes from the acid while the right-hand part comes from the alcohol. In naming esters, name the alcohol part before the parent acid which gives the suffix –oate. Give the class some practice in working out the names and structural formulae of some esters.
4. In Experiment 26.2 of the Practical Workbook, students have to design and carry out an experiment to prepare an ester. This experiment is a modification of the method used in Experiment 26.1C. Although this modification may appear simple to teachers, it is not necessarily so obvious to students who may have just followed the instructions rather than analysing the procedure when carrying out Experiment 26.1C.

Skills Practice (page 429)

1. 

2. **(a)** Propyl methanoate
   (b) Methanoic acid, HCOOH, and propanol, $CH_3CH_2CH_2OH$ (or C_3H_7OH).
3. **(a)** It suggests that ester is covalent. The bonding between the atoms in the ester is covalent and the compound consists of molecules. One of the characteristics of compounds with simple molecular structures is that they have low boiling points.
   (b) Compounds with simple molecular structures are generally insoluble in water. Therefore, we can infer that ethyl ethanoate is insoluble in water.

Notes for Teachers

Esters used in food flavouring

The following information is for reference. You can decide how much, if any, need be given to a particular class. Natural fruit flavours are a complex mixture of alcohols, acids and esters. Very few esters dominate the flavour in a food.

Ester	The ester resembles the smell of
Ethyl ethanoate Methyl butanoate Ethyl butanoate Butyl butanoate	Pineapple
Pentyl butanoate	Pear or apricot
3-methylbutyl ethanoate	Banana
Pentyl ethanoate	
2-methylbutyl propanoate	Rum
Ethyl methanoate	Raspberry
Pentyl pentanoate Methyl butanoate	Apple
Octyl ethanoate	Orange
Benzyl ethanoate	Peach

Are esters a homologous series?
Unfortunately, in Chemistry, there are different definitions and characteristics for what constitutes a homologous series. In this book, a homologous series is taken to be a family of compounds with the same general formula and a member differing from the next by a $–CH_2–$ group. This works well for the alkanes, alkenes, alcohols and carboxylic acids. For example, the alcohols have a general formula written as $C_nH_{2n+1}OH$, and adjacent members such as methanol CH_3OH and ethanol CH_3CH_2OH do differ by a $–CH_2–$ group.

But this same approach does not work well for esters as we cannot write a single general formula involving n carbon atoms. This is because esters, unlike the other families of compounds, contain two hydrocarbon chains (from alcohols and carboxylic acids), in which the number of carbon atoms can vary independently. So using the definition in this book, esters are not a homologous series.

Note: The definition would work if a family of esters was formed from one alcohol and different organic acids (or vice versa). But there would then be an ester homologous series for each alcohol (or acid) rather than just a single homologous series.

However, a general formula for esters can be written as $RCOOR^1$, where R and R^1 represent the two hydrocarbon groups which may be the same or different. If a homologous series does not require adjacent members to differ by a $–CH_2–$ unit, then all esters belong to a single homologous series.

Animations on esterification
The following websites provide animations on the preparation of an ester and the reaction that takes place:
http://www.lstlcw.edu.hk/t9544/animation/esterification/esterification.html
http://www.ausetute.com.au/esters.html

Teaching pointers

26.6 Key Summaries (page 429)

1. This section contains two useful summaries. Flow charts are a useful way to show a series of chemical reactions and how they are interconnected. In fact, many multi-step organic syntheses are written in the form of flow charts rather than as balanced equations.
2. Additional Exercise 3, located at the end of this chapter, requires students to complete and extend a flow chart involving organic reactions. The worksheet may be photocopied and distributed to the class.

26 Chapter Review

Self-Management

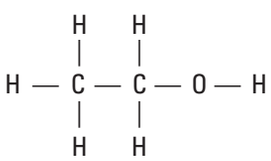
Misconception Analysis (page 431)

1. **True** The –OH functional group, called the hydroxyl group, is present in all alcohols and is responsible for their *chemical* properties.
2. **False** Most ethanol is prepared by the catalysed addition of steam to ethene, i.e. the reaction of ethene with steam in the presence of a catalyst.
3. **True** Petrol burns incompletely to form a yellow/sooty flame. Ethanol burns completely to form carbon dioxide and water, resulting in a clean flame.
4. **False** On standing, ethanol is oxidised by air to ethanoic acid through the action of bacteria. The ethanoic acid produces the sour taste.
5. **False** The first carboxylic acid in the homologous series is methanoic acid. It has the formula HCOOH with n = 0 in the general formula.
6. **False** Ethanoic acid is the most common carboxylic acid because of its use in vinegar. Other acids are prepared in order to make artificial esters.
7. **True** This is a characteristic of all esters.

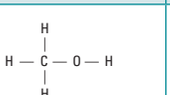
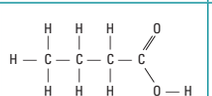
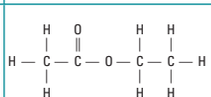
Practice

Structured Questions (pages 431–433)

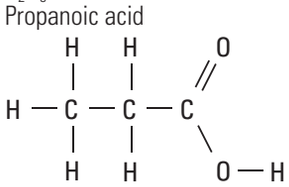
1. (a) Fermentation
   (b) When the reaction flask is heated, the speed of the reaction decreases as heat damages/destroys the enzyme in the yeast so that it no longer acts on the reaction.
   (c) (i) Carbon dioxide gas
   (ii) The carbon dioxide dissolves and forms a weakly acidic solution as indicated by the pH value of about 4.
   (d) $C_6H_{12}O_6(aq) \longrightarrow 2C_2H_5OH(aq)/2CH_3CH_2OH(aq) + 2CO_2(g)$
   (e) (i) By filtration
   (ii) By distillation
   (f)



2.

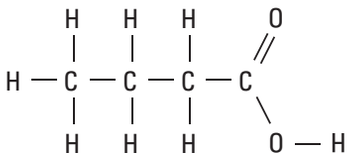
Name of compound	Molecular formula	Structural formula	Type of compound	Products of complete combustion
methanol	CH_3OH		alcohol	carbon dioxide and water
butanoic acid	$C_4H_8O_2$		carboxylic acid	carbon dioxide and water
ethanoate	$CH_3CO_2C_2H_5$			

3. (a) By the cracking of petroleum fractions.
   (b) High pressure (65 atm) and a catalyst (H_3PO_4).
   (c) $C_2H_4(g) + H_2O(g) \longrightarrow C_2H_5OH(g)/CH_3CH_2OH(g)$
4. (a) Sugar cane
   (b) Fermentation
   (c) Distillation
   (d) It produces no air pollutants.
   (e) $C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)$
5. (a) (i) C_2H_5COOH
   (ii) Propanoic acid
   (iii)

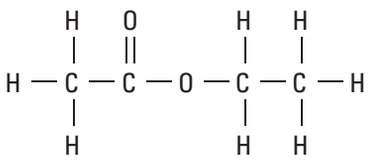


   (b) (i) An ester.
   (ii) A little concentrated sulphuric acid and warmth.
   (iii) Ethyl propanoate
6. (a) They have the same elements and same number of carbon atoms. Both have C – H, C – C, C – O and O – H bonds.
   (b) They have different numbers of oxygen atoms and different numbers of hydrogen atoms. Only ethanoic acid has a C = O bond.
7. (a) A water bath heats the mixture more gently so that the ester formed does not evaporate and escape from the test tube.
   (b) 1. Effervescence occurs (as excess acid in the reaction mixture reacts with the water).
   2. A thin immiscible layer (of ester) forms/floats on top of the water.
   (c) (i) Methyl propanoate
   (ii) Methyl propanoate is insoluble in water, has a characteristic fruity smell, is volatile and has a low boiling point.
   (iii) Esterification

8. (a) Molecular formula of X is $C_4H_8O_2$; empirical formula of X is C_2H_4O.
   (b) (i) An isomer of X which is an acid is butanoic acid. The structural formula is:



   (ii) An isomer of X which is an ester is ethyl ethanoate. The structural formula is:



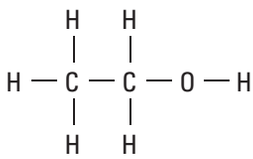
   (c) Methanoic acid and propanol.

9. (a) Ethanol (alcohol) and carbon dioxide.
   (b) The dough rises due to the carbon dioxide gas formed which spreads throughout the dough and forms many gas spaces.
   (c) Heat damages (changes the structure of) the enzymes in the yeast so that their biological activity is diminished or eliminated.
   (d) The heat evaporates off the alcohol.

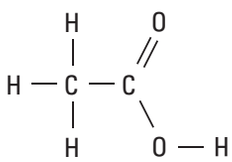
10. (a) **C** (b) **B**
    (c) **D** (d) **B**
    (e) **A** and **D** (both are carboxylic acids)
    (f) (i) Ethanoic acid and ethanol.
    (ii) An ester (ethanol ethanoate).

11. (a) **A** – Ethanol
    B – Carbon dioxide
    C – Ethanoic acid
    D – Ethyl ethanoate
    (b) (i) $C_2H_4(g) + H_2O(g) \longrightarrow C_2H_5OH(g)$
    (ii) $C_2H_4(g) + 3O_2(g) \longrightarrow 2CO_2(g) + 2H_2O(l)$
    (c) Acidified potassium dichromate(VII) solution.
    (d) (i) Any carbonate or hydrogencarbonate, e.g. $NaHCO_3$.
    (ii) $CH_3COOH(aq) + NaHCO_3(s/aq)$
    $CH_3COONa(aq) + CO_2(g) + H_2O(l)$

   (e) Structural formula of compound **A**:



   Structural formula of compound C:



   (f) (i) Compound **C**
   (ii) Compound **D**

II. Free Response Questions (page 433)

1. Responses to this question may include the following points:
   - Using ethanol as fuel:
     - Advantages: For example, little air pollution when burned / cheap / a renewable energy source.
     - Disadvantages: For example, less energy is produced when compared to using the same amount of petrol / shorter engine life / engines need modification / large areas of land are needed to grow crops used to produce ethanol.
   - Using petrol as fuel:
     - Advantages: For example, higher energy value than ethanol / no need to modify engines / no need to change the present situation.
     - Disadvantages: For example, produces air pollutants / comes from a non-renewable source that may run out soon.

2. Responses to this question may include the following points:
   - The compounds formed are esters.
   - The important property of esters is their sweet smell / fragrance.
   - Uses: For example, artificial flavours for food and drinks / perfumes / cosmetics / as solvent for fingernail polish.
   - A small quantity of ethyl ethanoate can be prepared by first placing a mixture of ethanoic acid, ethanol and a few drops of concentrated sulphuric acid in a large test tube / boiling tube.

   Heat the mixture gently for a while and then pour the reaction mixture into a beaker of cold water. A thin immiscible layer of the ester floats on the water which can be separated using a separating funnel.

3. Apply a flame to each liquid. Only ethanol will burn.

Extension (page 433)

1. What is the Question?

Some possible questions:

- What is the formula of the acid with four carbon atoms per molecule?
- What is the formula of the next compound after propanoic acid in the acid homologous series?
- What is the formula of the acid produced when butanol is oxidised?
- What is the formula of the carboxylic acid with relative mass 88?

2. IT Link: Shapes and Formulae of Some Alcohols and Carboxylic Acids

Although branched chain compounds are not in the syllabus, many students find the generation of such structures very interesting. This can be carried out using either physical models or computer-generated models.

Additional Teaching Material

Additional Exercise 1: Ethane and Ethanol

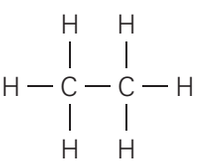
Objective

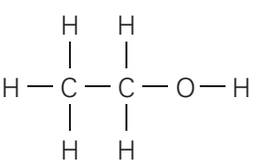
- To compare the structures of an alkene and an alcohol

Key Competency

CIT: sound reasoning [*comparing*]

Alcohols are a family of organic compounds. The most important alcohol is called ethanol. The structural formula of ethane and ethanol are shown below.

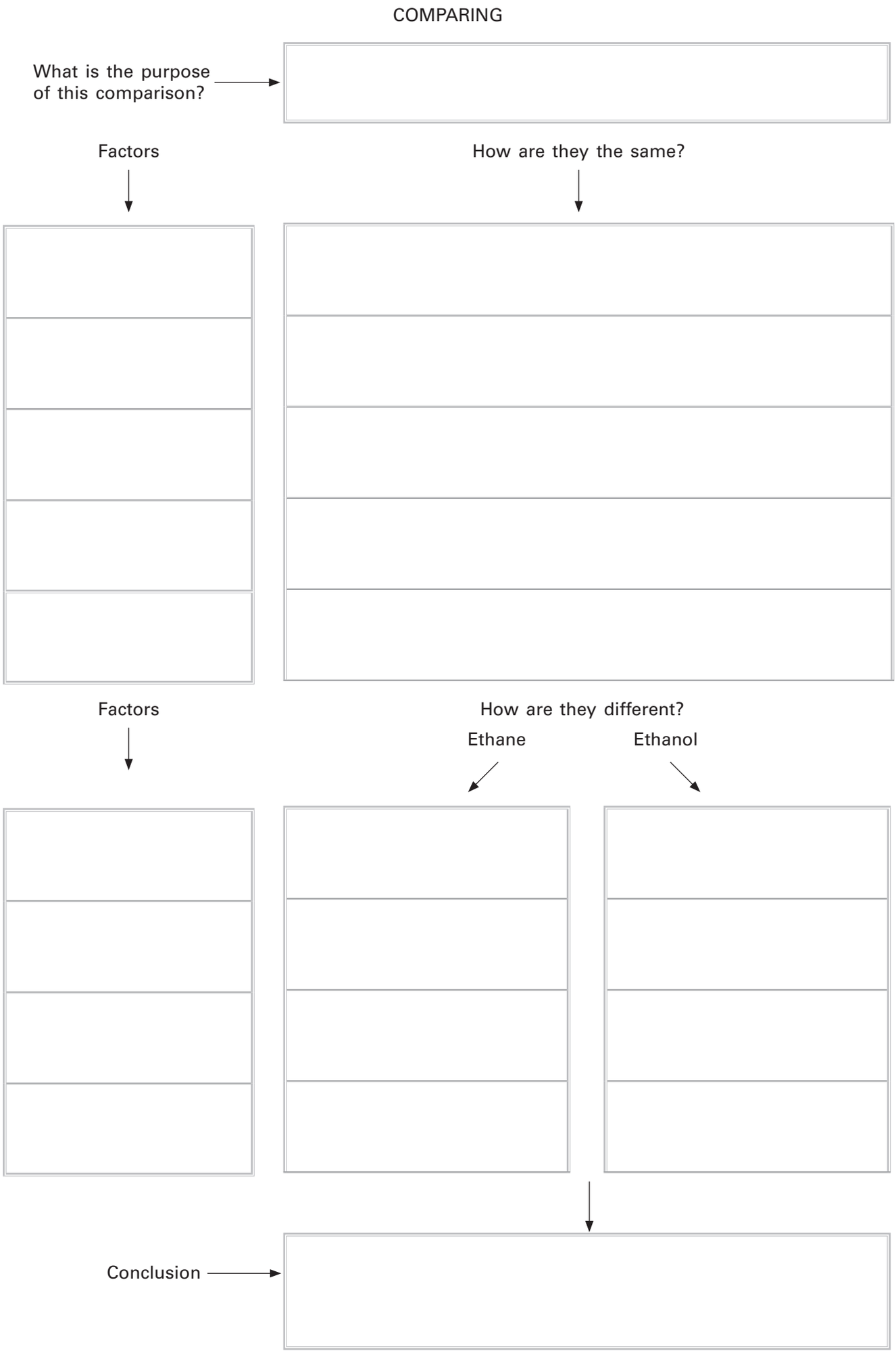




Think carefully about the structures of these two molecules. Then list all the features of the **atoms**, **elements** and **bonds** which are the same for both molecules and, all the features which are different.

From your lists, you are to decide how you can tell from the structure of a hydrocarbon molecule that it is an alcohol.

Use the graphic organiser on the next page to help you.


COMPARING
What is the purpose of this comparison?
Factors
How are they the same?
Factors
How are they different?
Ethane
Ethanol
Conclusion

Additional Teaching Material

Additional Exercise 2: Comparing Fuels

Objective

- To compare three kinds of motor car fuels

Key Competencies

CIT: sound reasoning and decision making [*analysing data*, *comparing*]

Three kinds of motor car fuels used around the world are petrol, ethanol and gasohol (petrol with up to 20% of ethanol). Gasohol can be used in cars with petrol engines without any modification to the engine. For ethanol, engines need only slight modifications.

A. Comparing the three fuels

The table below shows some characteristics of the three fuels.

	Petrol	**Ethanol**	**Gasohol***
Ease of ignition	easy	less easy	easy
Appearance of flame	yellow, dirty	pale blue, clean	yellow, clean
Amount of heat released (kJ/g)	42	30	41
Cost per litre (approx)	$1.645	$0.85**	$1.44
Effect on car engines	normal	shorter engine life	almost normal
*For a 10% gasohol. **Cost varies depending on where it is made.			

1 Which fuel produces
   (a) the least air pollution when burnt in air? _____

   (b) the most power in a car engine? _____

2 Which fuel is
   (a) a renewable energy source? _____

   (b) a non-renewable energy source? _____

B. You decide: Which fuel should cars in Singapore use?

You are to decide which of the three fuels is most suitable for Singapore.

1 In the table on the next page, write some advantages and disadvantages of the three fuels. To help you, you can use the data from Part A.

Fuel	Advantages	Disadvantages
Petrol		
Ethanol		
Gasohol*		

2. Which fuel do you (or your group) think will best serve the long-term needs of Singapore? List your main reasons.

Additional Teaching Material

Additional Exercise 3: A Flow Chart for Organic Reactions

Objective

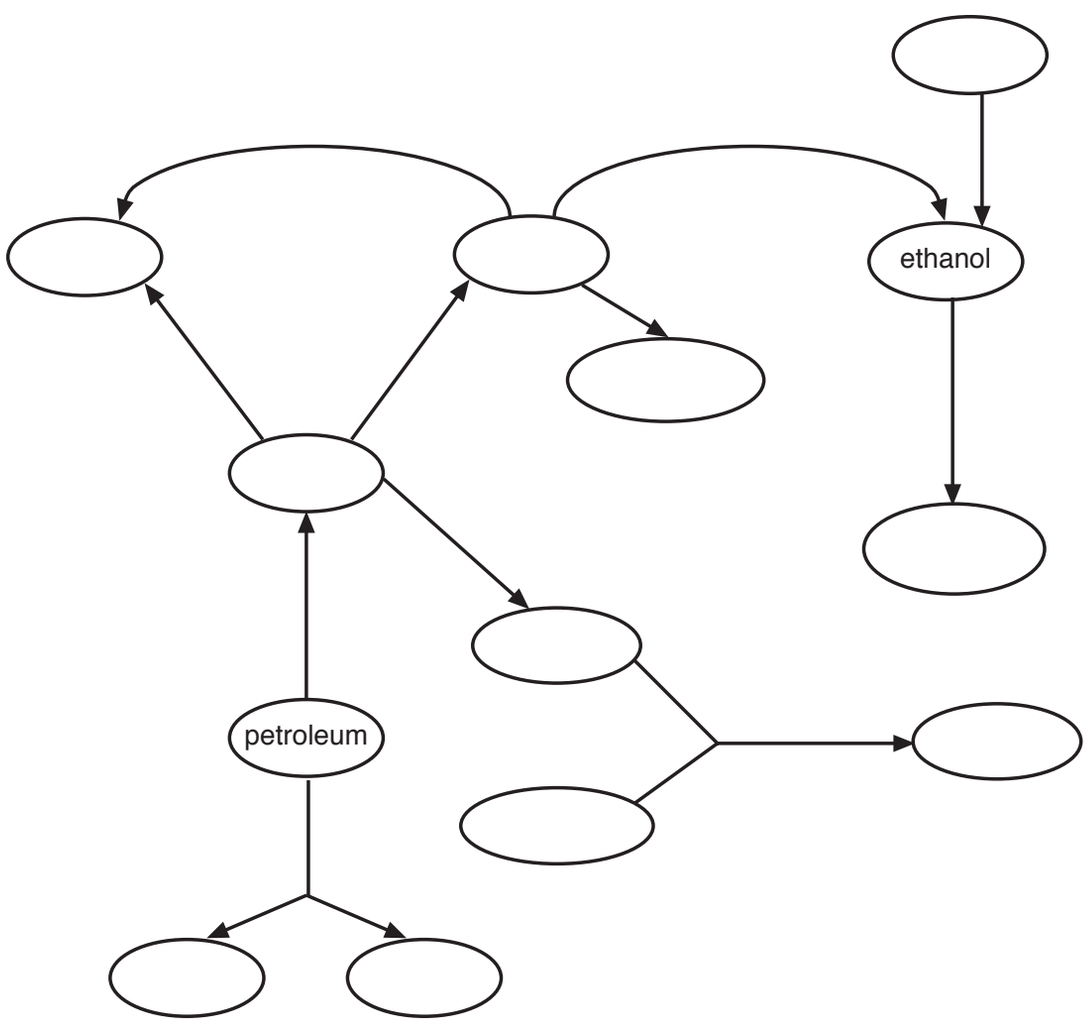
- To summarise some important organic reactions

Key Competency

ICS: communicating effectively [*using a flow chart*]

An incomplete flow chart is shown below for the formation of substances starting with petroleum. Complete the flow chart using the words given in the box below.

ethane	ethene	naphtha
vegetable oil	margarine	cracking (3 times)
addition of hydrogen	addition of steam	fractional distillation
react together		



Answers

Additional Exercise 1: COMPARING

What is the purpose of this comparison? → To find out how to identify an alcohol from its structure

Factors	How are they the same?
Elements	They both contain carbon and hydrogen.
Atoms	They both contain 2 carbon atoms.
Atoms	They both have 6 hydrogen atoms.
Bonds	They both have C — C and C — H bonds.
Bonds	They both have covalent bonds.

Factors	How are they different? Ethane	Ethanol
Elements	does not contain oxygen	contains oxygen
Atoms	has a total of 8 atoms	has a total of 9 atoms
Bonds	does not have a C — O bond	has a C — O bond
Bonds	does not have an O — H bond	has an O — H bond

Conclusion → The alcohol has a C — O bond and an O — H bond. (**Note:** Many molecules have oxygen, which means we do not consider it as a significant difference. The total number of atoms does not count as well, as this must depend on the number of carbon atoms in the molecule.

Additional Exercise 2:

A. Comparing the three fuels

1 **(a)** Ethanol
(b) Petrol

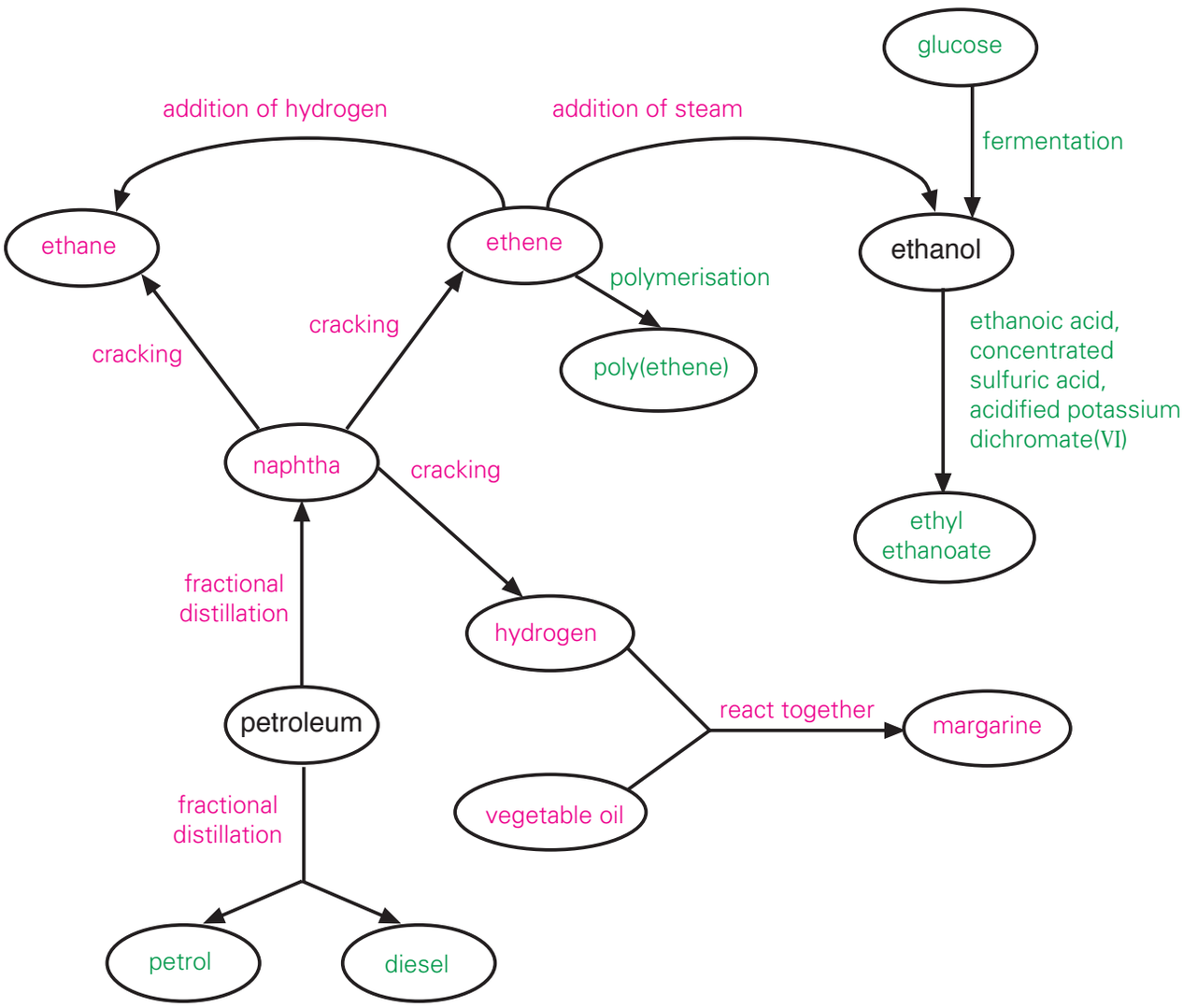
2 **(a)** Ethanol
(b) Petrol

B. You decide: Which fuel should cars in Singapore use?

1

Fuel	Advantages	Disadvantages
Petrol	• provides the most energy weight-for-weight • no need for engine modification • ignites easily in the engine	• more air pollution than other fuels (but use of catalytic converters in cars remove some pollutants) • produced from petroleum which is a non-renewable energy resource
Ethanol	• safer to transport than petrol • renewable energy source; can be used as world oil reserves decline • very clean/little or no air pollutants produced • much cheaper than petrol	• less energy/power • engines need to be modified • large areas of land needed to grow biomass
Gasohol*	• slightly cleaner than petrol • engines do not need modification	• slightly less energy than petrol • still mainly a non-renewable energy source

Additional Exercise 3:



Note: text in pink are answers for question 1 and text in green are anwers for question 2.

Blank