25 Alkanes and Alkenes

Introduction

This chapter deals with the chemistry of the alkanes and the alkenes. The general formula, naming, structure, trends in physical properties and reactions of each groups of compounds are discussed. New concepts include homologous series, functional group, isomerism, substitution reaction and addition reaction. Students also build models to visualise the structure of molecules. The cracking of alkanes and its importance in the petrochemical industry are also discussed.

Chapter Opener (page 398)

1. Begin the chapter by discussing the following question. Precise answers are not needed at this stage.

   Alkanes and alkenes are hydrocarbons. What does this mean?

   Answer: Alkane and alkene molecules contain carbon and hydrogen only.

   The structural formula for the alkane C_4H_{10} can be drawn in two ways. Try to draw them. What term is used to describe different compounds with the same molecular formula?

   Answer: Refer to page 410. They are called isomers.

   What is meant by cracking and how does the process work?

   Answer: Cracking is a process whereby larger alkane molecules in petroleum are broken down into smaller molecules. Refer to Section 25.7 on pages 413–414 of the Textbook.

2. Carry out an 'Inquiry Preview'.

Learning Outcomes

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

- describe a homologous series and its general characteristics
- describe the alkanes and alkenes as homologous series in terms of their general formulae, similar chemical properties and gradation in physical properties
- draw the structures of the C1 to C3 alkanes and C2 to C3 alkenes and name the unbranched structures
- describe the properties of alkanes and alkenes
- describe the differences between saturated and unsaturated hydrocarbons from the structures and use of aqueous bromine
- define isomerism and identify isomers
- state the meaning of polyunsaturated when applied to food products
- describe the manufacture of margarine
- describe the manufacture of alkenes and hydrogen by cracking hydrocarbons

Teaching pointers

25.1 What Are Organic Compounds? (page 399)

Stimulation

Bring to class some examples of everyday organic and inorganic products. Ask the class to classify them into compounds that come from living things and those from non-living things. Introduce the idea of an organic compound and how the German chemist, Friedrich Wohler changed the belief that organic compounds could only be made by living things.

You may also show the class a picture of a street scene and use it to illustrate the wide use of organic compounds in daily life (see 'Notes for Teachers' below).

Notes for Teachers

History

The development of Organic Chemistry started in the 19th century when chemists began to study compounds found in living organisms such as sugar, proteins and plant oils. The name organic was given to these compounds. Other compounds, such as salt, water and chalk that are not from living things were called inorganic compounds.

At first, chemists believed that organic compounds could only be made by living things. But that belief changed in 1828 when a young German chemist named Friedrich Wohler made the organic compound urea in the laboratory. (Urea is the main compound in human urine.)

The study of organic compounds is now a branch of chemistry called organic chemistry. Today, organic chemistry includes both compounds found in living things and those made by chemists that are not found in living things.

Organic compounds in daily life

A photograph of people and vehicular traffic in some part of Singapore can be used. Here are examples of where organic compounds may appear in the photograph:

- Tyres of vehicles are made of rubber.
- Fuels used in vehicles may be petrol, diesel or CNG.
- Oil used in the engines of vehicles is lubricating oil.
- Road surface is made of bitumen.

- Clothes worn by people may be made from cotton or polyester.
- Shoes worn by people may be made of leather or artificial leather (polymers).
- Paint on buildings may be a plastic-based paint.

Carbon compounds but not organic compounds
Chemists consider the carbonates and oxides of carbon as inorganic compounds rather than organic compounds, even though they contain the element carbon.

Teaching pointers

25.2 How Can We Classify Organic Compounds? (page 399)

1. In Chapters 11 and 12, students were introduced to families (groups) of elements in the Periodic Table which have similar chemical properties. In this chapter, they are introduced to families (homologous series) of organic compounds which also have similar chemical properties.
2. At this stage, just introduce and define a homologous series. The characteristics need not be introduced until alkanes and alkenes are studied.

25.3 What are Alkanes? (page 400)

1. Show examples of the uses of alkanes as fuels, such as those shown in Figure 25.2 on page 401 of the Textbook. Link this with the different fractions obtained from the fractional distillation of petroleum.
2. Students must know the prefixes for C1 to C4. They could create a mnemonic to facilitate their learning.
3. The idea of structural formula was introduced in Section 9.4 of Chapter 9 but is extended here to organic compounds. The term condensed structural formula is new to students. Use ball-and-stick models so that student can match the formulae written on paper to the actual three-dimensional molecules of compounds. The models clearly show the idea of a straight chain, a branched chain and a ring structure, and also that a 'straight' chain is not actually straight but has a zigzag shape.
4. The syllabus requires that students be able to draw the structures for the C1 to C4 branched and unbranched alkanes and to name the C1 to C4 unbranched alkanes. However, as the more able students may find the writing of structural formulae and the naming of isomers interesting, alkanes with more than four carbon atoms could be included.
5. Compare the numbers of carbon atoms and the boiling points for the alkanes in Table 25.2 on page 402 of the Textbook with those for petroleum fractions in Table 24.1 on page 392 of the Textbook. As petroleum fractions consist of alkanes, the data will overlap.
6. Alkanes used to be called *paraffins* (Latin: parum = little; affinities = affinity). This is because alkanes undergo few chemical reactions.

7. The substitution reaction on pages 404–405 of the Textbook can be effectively demonstrated using a magnetic board. Cut polystyrene spheres of different sizes in half, attach them to magnets and write on the spheres C, H and *Cl*. Attach them to the magnetic board as CH_4 and Cl_2. Use a felt pen to draw the Sun and light rays falling on the chlorine molecule. Then separate the chlorine molecule into chlorine atoms to show the action of the light energy. Next, separate and rearrange the atoms in the molecules to form the products.

8. Mention that the reaction of bromine with alkanes is similar to but slower than the reaction of chlorine with alkanes. (This can be used to make a comparison with alkenes in Section 25.4.)

(page 402)

Mystery Clue

Refer to Table 25.1 for the C3 and C4 alkanes. The C5 to C12 alkanes are written in a similar way using the general formula C_nH_{2n+2}.

Chemistry in Society (page 403)

How are Alkanes Used to Control the Spread of Mosquitoes?

Exercise

1. Diesel has a higher boiling point and does not evaporate readily and so remains on the surface of the water for a longer time. However, if the heavier fraction has a higher density than water, it will sink to the bottom and not be suitable for use.

2. Fumigation uses gaseous pesticides to control insects and is thus more effective as it can be carried out in buildings and on goods directly. Placing kerosene on water surfaces only works if there are water surfaces to work with.

However, the gaseous pesticides are harmful to not only insects but also humans. Thus the fumigation process takes a longer time as humans need to be evacuated before the area is set up for fumigation. After the fumigation, time is also needed for the poisonous gases to escape and render the place safe for humans. Placing kerosene on water surfaces is faster.

Skills Practice (page 405)

1. Alkanes have the general formula C_nH_{2n+2}.
   The formula for methane is CH_4 which is when $n = 1$. It fits the general formula.
   The formula for ethane is C_2H_6 which is when $n = 2$. It fits the general formula.
   The formula for propane is C_3H_8 which is when $n = 3$. It fits the general formula.
   The formula for butane is C_4H_{10} which is when $n = 4$. It fits the general formula.
2. **(a)** Pentane
   (b) C_5H_{12}
3. Molecular formula: $C_{20}0H_{42}$
   M.p.: About 36 °C
   B.p.: About 334 °C
   State (at r.t.p.): Solid
4. The higher alkanes are solids whereas the lower alkanes are gases. A solid has a higher density than an equal volume of a gas as the molecules are packed close together.
5. **(a)** Molecules in petrol have approximately 5 to 10 carbon atoms. Some of these alkanes have the molecular formulae C_5H_{12} and $C_{10}H_{22}$.
   (b) Petrol has an approximate boiling point range of 35 °C to 75 °C. Petrol is a mixture of compounds and so boils over a temperature range.

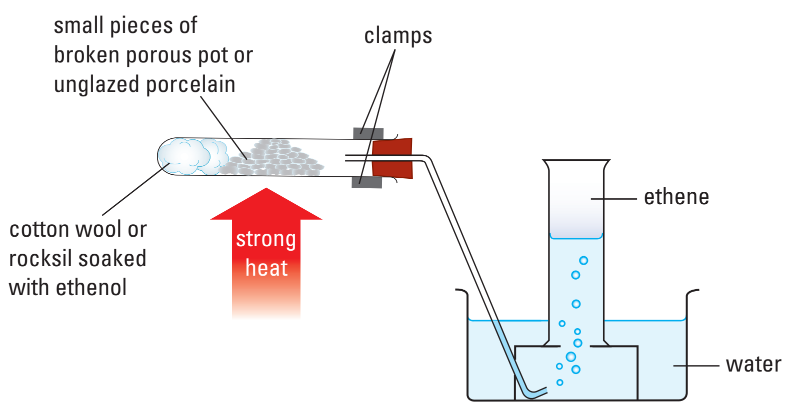
Teaching pointers

25.4 What are Alkenes? (page 405)

1. Ensure that students understand the difference between saturated and unsaturated compounds. Alkenes are unsaturated as they do not contain the maximum number of hydrogen atoms per carbon molecule.
2. Emphasise that when writing the condensed formula of an alkene, the C = C double bond *must* be included. For example, the condensed formula of propene is $CH_3CH = CH_2$ and *not* CH_3CHCH_2.
3. Singapore is one of the biggest producers of ethene and propene in Asia. These chemicals are produced in the cracking plants on Jurong Island and Pulau Bukom.
4. Compare the addition reactions of alkenes with substitution reaction reactions of alkanes. See 'Notes for Teachers' below.
5. Point out that the test given for alkenes is a general test for *all* unsaturated compounds and so will include the alkynes, which have the C ≡ C triple bond (though alkenes are the only unsaturated compounds studied in this course). Emphasise that the reaction is fast and no light is needed (unlike the substitution reactions of alkanes with bromine or chlorine).
6. After studying about the alkanes and alkenes, students are able to appreciate the characteristics of a homologous series.

Experiment 25.1 (PWB pages 165–166)

In this experiment, students investigate the reactions of some alkenes. To prepare test-tubes of ethene, the apparatus shown in the diagram below can be used:.

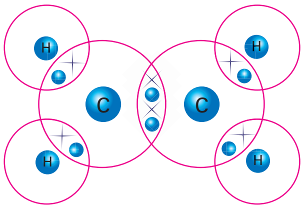


The bromine solution should be a 2% w/w in the solvent, i.e. 1 g of bromine in 100 g of solvent. Keep the solution in a dropper bottle placed in the fume cupboard.

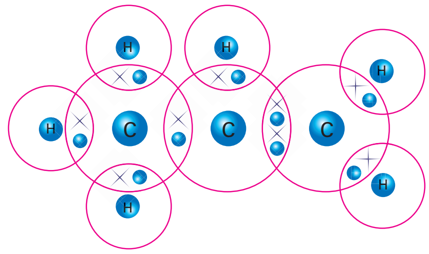
Note: The solvent 1,1,1-trichloroethane, CCl_3CH_3, has been the common solvent used to prepare the solution. Due to its hazardous nature, it is being phased out and may not be available. A suitable alternative is the chemical Volasil 244.

Skills Practice (page 409)

1. Two C atoms are needed to form a C = C double bond, so the smallest alkene has two C atoms.
2. Alkene with five carbon atoms: Pentene, C_5H_{10}.
   Alkene with six carbon atoms: Hexene, C_6H_{12}.
3. Electron diagram of ethene:



Electron diagram of propene:



4. (a) $C_4H_8Br_2$
   (b) C_4H_9OH
   (c) C_4H_{10}
5. The reddish-brown bromine solution is decolourised.
6. Flask **A** contains C_3H_6 which is an unsaturated alkene and will quickly decolourise the bromine solution. Flask **B** contains C_4H_{10} which is a saturated alkane and will not have any effect on the bromine solution.

Notes for Teachers

Comparing substitution reactions of alkanes with addition reactions of alkenes
Key points of the substitution reactions of alkanes with chlorine:
- A chlorine atom is replaced.
- The reaction is slow.
- Light is needed.

Key points of the addition reactions of alkenes with chlorine:
- Chlorine atoms are added.
- The reaction is fast.
- No light is needed.

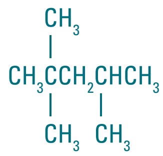
Teaching pointers

25.5 What are Isomers? (page 410)

1. When teaching isomerism, distinguish the term isomer from the similar-looking term isotope. The Word Analysis table on page 458 of the Textbook shows that 'iso-' = the same, '-mer' = part. Therefore isomers have the same parts (atoms) but different structures.
2. Do not expect students to be able to name the branched isomers; just focus on the drawing of the structural formulae. And again use ball-and-stick models to give students an idea of the three-dimensional orientation of these structures.

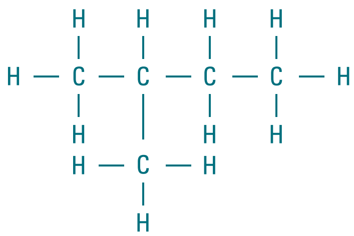
Skills Practice (page 411)

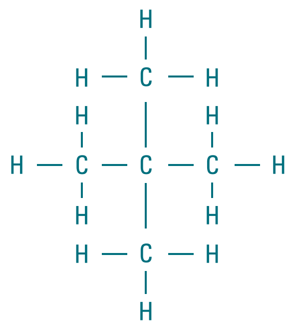
1. $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$



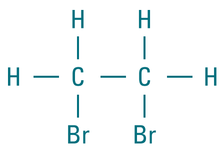
or $CH_3C(CH_3)_2CH_2CH(CH_3)CH_3$

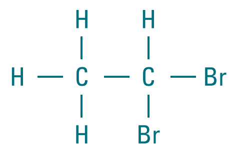
2.





3.





Notes for Teachers

Numbers of isomers

The number of possible isomers increases enormously as the number of carbon atoms increases:

- C_8H_{18} has 18 different isomers.
- $C_{30}H_{62}$ has over 4 000 000 000 possible isomers though only a few of them actually exist.

Teaching pointers

25.6 What Foods Contain Unsaturated Compounds? (page 412)

1. The terms *saturated*, *unsaturated* and *polyunsaturated* appear on the containers of some foods such as margarine.
2. Ethene gas is produced during the ripening of fruits such as bananas. You may demonstrate the effect of ethene on ripening fruit by using three unripe bananas.
   - Place one banana in a sealed plastic bag containing ethene. The banana should ripen quickly (i.e. it should turn a certain degree of yellow).
   - Place another banana in a sealed plastic bag of air. This banana will ripen more slowly from the ethene gas the banana produces itself.
   - Leave the third banana in an open place. As any ethene gas produced will diffuse away, this banana will take the longest to ripen.

   The following website describes a similar experiment:
   http://mattson.creighton.edu/C2H4/index.html [Experiment 9]

Skills Practice (page 413)

1. Shake the vegetable oil with bromine solution. If the vegetable oil is unsaturated, the reddish-brown colour of the bromine would be decolourised.
2. Addition reaction.
3. One possible experiment is to place a few unripe bananas in a large plastic bag. Leave the bag to allow the bananas to ripen. Once they have ripened, pass the air from the bag through bromine solution (or add a few drops of bromine solution to the bag and shake). If ethene is present, the bromine solution will be decolourised. (Acidified $KMnO_4$ solution could also be used as it will be decolourised if ethene is present.)

Notes for Teachers

The manufacture of margarine
In the manufacture of margarine, hydrogen gas is bubbled through vegetable oils at a temperature of about 150 °C in the presence of a nickel catalyst. Soft fats are formed if only a few double bonds in the oils are saturated. With more hydrogen, hard fats with higher melting points are formed. As soft fats still have many double bonds, soft margarines are often described as 'polyunsaturated'.

Teaching pointers

25.7 The Cracking of Alkanes (page 413)

1. Comment on the mismatch between the amounts of fractions obtained from petroleum for use as fuels, and the demands from the modern industry (refer to the table in 'Notes for teachers' on the next page).

   For example, one source of petroleum may provide just 10% of petrol whereas the demand from modern industry is about 25%. On the other hand, the amount of fuel oil obtained exceeds the demand for it. Introduce the cracking of heavier fractions as a mean of making up the shortfall.
2. There are different kinds of cracking including *thermal cracking* (less common today) which uses high temperature and pressure, *catalytic cracking* which uses catalysts but lower temperatures and pressures (sometimes atmospheric pressure) and *steam cracking*. Steam cracking is included in the textbook as it is used in the catalytic plants in Singapore.
3. Both larger, heavier alkane molecules in petroleum fractions, such as fuel oil, and some of the lighter fractions, such as naphtha, are commonly used in cracking. Naphtha is a common feedstock for steam cracking.
4. Emphasise that cracking always results in a mixture of products, with one or more alkenes *always* being formed. Large alkane molecules cannot be cracked into smaller alkanes only as there are insufficient hydrogen atoms available.
5. Steam cracking, as used in Singapore, is the principal industrial method for producing lighter alkenes. The plants in Singapore produce large amounts of the lower alkenes such as ethene, propene and butene. These are used to make a variety of products, especially monomers for making plastics (which is discussed in Chapter 27).
6. In Experiment 25.2A of the Practical Workbook, the catalytic cracking of alkanes in medicinal paraffin is carried out. In Experiment 25.2B of the Practical Workbook, thermal cracking is carried out with fat molecules and

(page 413)

Mystery Clue

Plants, unlike petroleum, do not contain hydrocarbons, and so do not contain the larger alkanes used for cracking to produce petrol.

not alkanes. In Part B, add a few drops of liquid bromine to the conical flasks. Use a minimum amount of bromine to prevent the formation of too much bromine vapour.

7. Activity 25.4 of the Theory Workbook looks at the production of petrol from coal as an alternative to obtaining petrol from petroleum by cracking. This technology is available now but is not widely used as it is expensive. It was used in the past years in South Africa where, for political reasons, the importation of petroleum was restricted. China, which has large coal reserves of coal, is building plants to convert the coal into gas and petrol.

Skills Practice

1. For example,

$$\underset{\text{decane}}{C_{10}H_{22}(l)} \longrightarrow \underset{\text{pentene}}{C_5H_{10}(l)} + \underset{\text{pentane}}{C_5H_{12}(l)}$$

$$\underset{\text{decane}}{C_{10}H_{22}(l)} \longrightarrow \underset{\text{butene}}{C_4H_8(g)} + \underset{\text{hexane}}{C_6H_{14}(l)}$$

$$\underset{\text{decane}}{C_{10}H_{22}(l)} \longrightarrow \underset{\text{ethene}}{3C_2H_4(g)} + \underset{\text{butane}}{C_4H_{10}(g)}$$

$$\underset{\text{decane}}{C_{10}H_{22}(l)} \longrightarrow \underset{\text{decene}}{C_{10}H_{20}(l)} + \underset{\text{hydrogen}}{H_2(g)}$$

2. Petrol and diesel are manufactured from the cracking of lubricating oil fraction. This provides more of these fuels as there is not enough petrol and diesel in petroleum to meet the demand for them.

3. Compound **X** is ethane, C_2H_6.

4. **(a)** $C_{16}H_{34}(l) \longrightarrow C_6H_{14}(l) + C_{10}H_{20}(l)$

   (b) $C_{16}H_{34}(l) \longrightarrow 4C_2H_4(g) + C_8H_{18}(l)$

Notes for Teachers

Supply and demand of petroleum fractions

The table below shows the approximate percentages of the fractions obtained from *one* source of petroleum and the percentages demanded by modern industry. (The percentages of fractions from petroleum obtained from various parts of the world are not the same.)

Fraction	Amount of fraction from petroleum	Amounts needed by industry
Gases	5%	5%
Petrol	10%	25%
Naphtha	5%	5%
Kerosene	20%	25%
Diesel	15%	35%
Fuel oil	45%	5%

25 Chapter Review

Self-Management

Misconception Analysis (page 415)

1. **True** For example, the boiling points, viscosity and densities of alkanes increase as the number of carbon atoms in the molecules increases.
2. **False** Alkenes have the C = C bond. Therefore, the simplest alkene must have two carbon atoms. By contrast, the simplest alkane, methane, has one carbon atom.
3. **False** Only alkanes and alkenes with four or more carbon atoms have isomers.
4. **True** Alkenes undergo addition reactions because atoms such as hydrogen and chlorine can 'add' to the carbon atoms in the C = C bonds.
5. **True** The colour of bromine is decolourised when an alkene is added but not with an alkane.
6. **True** When an alkane breaks into two or more simpler substances, at least one of the products is an alkene as there are insufficient hydrogen atoms to form only alkanes.

Practice

Structured Questions (pages 416 – 417)

1. (a)

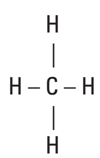
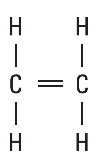
Name of the homologous series	Name of the first member	Structural formula of the first member	Molecular formula of the first member	General formula of the series
alkanes	methane		CH_4	C_nH_{2n+2}
alkenes	ethene		C_2H_4	C_nH_{2n}

Table 22.5

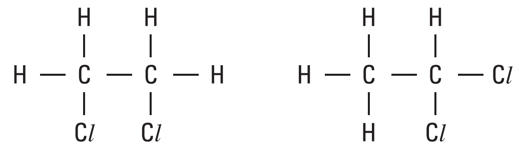
(b) (i) C_2H_6

(ii) For example, they have different melting/boiling points and different densities.

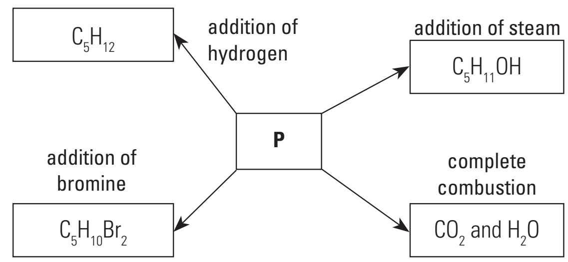
(c) (i) A functional group is an atom or group of atoms responsible for the chemical properties of a compound.

(ii) Alkenes have a functional group which is the C = C group.

2. (a) C_2H_4 (b) C_8H_{18}
(c) C_2H_2 (d) $C_{40}H_{82}$
(e) C_2H_4

3. 

4. (a) **P** is a hydrocarbon with a C = C bond.

(b) 

5. (a) (i) **P** is propane and **Q** is propene. Both contain carbon and hydrogen only; both contain 3 carbon atoms; both contain C – H bonds and both contain C – C bonds.

(ii) **Q** contains a C = C bond whereas **P** does not; **P** has more hydrogen atoms than **Q**.

(b) **Q** is unsaturated because it contains a C = C bond.

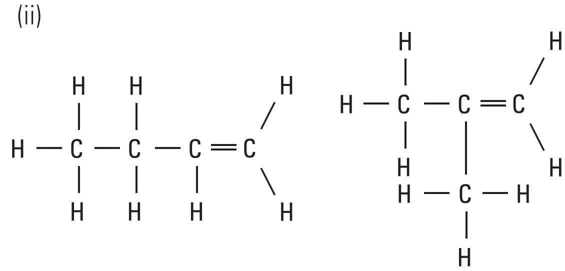
(c) (i) Shake the two substances with bromine solution.

(ii) **P** will decolourise bromine solution very slowly (in the presence of light). **Q** will decolourise bromine solution rapidly (in the absence of light).

(iii) **Q** contains the reactive C = C functional group whereas **P** does not contain any reactive group.

6. (a) (i) Isomers are different compounds with the same molecular formula but different structural formulae.

(ii)



(b) (i) Alkenes

(ii) Ethene, C_2H_4 does not have any isomers. There is only one way to arrange the atoms in ethene.

7. (a) It means that the margarine molecules contain many C = C bonds.

(b) (i) C = C bond

(ii) Shake some margarine with bromine solution. The reddish-brown bromine solution will be decolourised.

(c) vegetable oil + hydrogen ⟶ margarine

8. (a) Cracking is a process that involves the breaking down of large alkane molecules in petroleum fractions into smaller molecules.
   (b) A small alkene.
   (c) Cracking is used to produce fuel for motor vehicles, to produce alkenes and to produce hydrogen. The amount of petrol obtained from petroleum is insufficient to supply all the cars in the world; cracking is used to supply more petrol. Cracking is a way to obtain alkenes which are used to make a variety of products such as ethanol, detergents and plastics. Cracking produces hydrogen which is used as a fuel.
   (d) (i) For example,
   $C_{18}H_{38}(s) \longrightarrow C_2H_4(g) + C_{16}H_{34}(l)$
   $C_{18}H_{38}(s) \longrightarrow C_3H_6(g) + C_{15}H_{32}(l)$
   $C_{18}H_{38}(s) \longrightarrow C_4H_8(g) + C_{14}H_{30}(l)$
   (ii) For example,
   $C_{18}H_{38}(s) \longrightarrow 3C_2H_4(g) + C_{12}H_{26}(l)$
   $C_{18}H_{38}(s) \longrightarrow 5C_2H_4(g) + C_8H_{18}(l)$
   $C_{18}H_{38}(s) \longrightarrow 7C_2H_4(g) + C_4H_{10}(g)$

9. (a) A functional group is an atom or group of atoms responsible for the chemical properties of a compound. For example, the functional group of alkenes is the C = C group.
   (b) An unsaturated hydrocarbon is an organic compound that contains one or more double bonds.
   For example, C_2H_4 is an unsaturated hydrocarbon.
   (c) Cracking is a process that involves the breaking down of large alkane molecules in petroleum into smaller molecules. For example,
   $C_{18}H_{38}(s) \longrightarrow 7C_2H_4(g) + C_4H_{10}(g)$
   (d) Hydrogenation is a reaction that involves adding hydrogen to a C = C bond. For example, the hydrogenation of ethene gives ethane.
   (e) A polyunsaturated molecule is a large molecule that contains many C = C bonds. For example, vegetable oils are polyunsaturated molecules.

Free Response Questions (page 417)

1. Responses to this question may include the following points:
   - Cracking of larger alkane molecules is used to produce:
     (i) smaller alkanes which are used as fuel for motor vehicles,
     (ii) small alkenes which are used to make a variety of chemicals such as medicines and polymers,
     (iii) hydrogen which is used as an alternative fuel and as a raw material in the manufacture of ammonia in the Haber Process.
   - An experiment to show how cracking can be done in the school laboratory:
     (i) Place cotton wool soaked in medicinal paraffin at the bottom of a boiling tube.
     (ii) Clamp the test-tube horizontally onto a stand.
     (iii) Place a few pieces of unglazed porcelain in the centre of the test-tube. Insert a stopper with tubing.
     (iv) Heat the pieces of porcelain strongly with the Bunsen burner. Do not heat the paraffin directly. As medicinal paraffin vapour passes over the porcelain, alkanes in the paraffin break down on the surface of the porcelain to form gaseous alkanes and alkenes.
     (v) Collect the gases in a test-tube over water in a water trough.

2. Responses to this question may include the following points:
   Examples of reasons why models are useful:
   - To show the bonding between atoms in a molecule.
   - To show the three-dimensional shape of a molecule.
   - To compare a structural formula on paper with the actual shape of the molecule.
   - To compare sizes of atoms in molecules.
   - To visualise the changes that take place in a chemical reaction.

   Two different kinds of models:
   - Ball-and-stick models are useful for showing the bonds between the atoms in a molecule.
   - Space-filling models are useful for showing the shape of a molecule.

   An example using hydrocarbon molecules:
   - Ball-and-stick models of alkanes show C—H and C—C bonds.
   - Ball-and-stick models show the zigzag shape of the hydrocarbon chain.
   - Space-filling models can show that the C atoms are larger than the H atoms.
   - Models show that C—C—C and C—C drawn

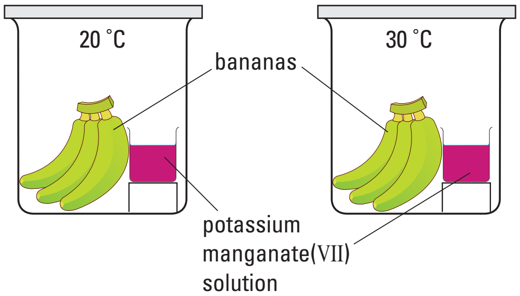
     with H bonded below the second C,

     on paper have the same three-dimensional structure.

3. Responses to this question may include the following points:
   Characteristics of a homologous series, using alkenes as an example:
- The members of a homologous series have the same general formula. All alkenes have the formula, C_nH_{2n}.
- Each member in a series differs from the next by a $-CH_2-$ group. For example, ethene, C_2H_4 and the next alkene in the series, propene, C_3H_6 differ by a $-CH_2-$ group.
- The physical properties of the members of a homologous series show a gradual change as the number of carbon atoms in the molecules increase. Thus, the boiling points of alkenes increase as the number of carbon atoms increase.
- Members of a homologous series have similar chemical properties. Alkenes react in a similar way as they all contain the C = C group of atoms.

4. Responses to this question may include the following points:
   - List of chemicals and apparatus:
     2 bunches of bananas
     potassium manganate(VII) or aqueous bromine
     2 beakers
     2 air-tight containers with lids
     2 boxes as a stand

- The experiment should show that bananas produce ethene twice as fast at 30 °C as compared to that at 20 °C. One possible method is shown in the diagram below:



- Characteristics of poly(ethene) that make it suitable for these uses: Strong, light in weight and cheap to produce.
- An outline of the procedure:
  1. Set up both containers at the same time.
  2. Keep one container at 20 °C and the other at 30 °C.
  3. Record the time taken for the potassium manganate(VII) to be decolourised.
- The time at 30 °C should be half that at 20 °C. This shows that the reaction at 30 °C is twice as fast. Theoretically, aqueous bromine can replace potassium manganate(VII).

Extension (page 457)

1. **What is the Question?**
   Possible questions:
   - What is the chemical name of C_2H_4?
   - What is the formula of the alkene with two carbon atoms?
   - What compound reacts with hydrogen to produce C_2H_6?
   - What is the formula of the hydrocarbon that reacts with steam to produce ethanol?
   - Two molecules are produced when $C_{12}H_{26}$ is cracked. One molecule is $C_{10}H_{22}$. What is the formula of the other molecule?
   - Which hydrocarbon has a relative molecular mass of 28?
   - What is the formula of the unsaturated hydrocarbon with two carbon atoms per molecule?

2. **IT Link: Investigating Some Simple Molecules and Bonding**
   –