Mastering Chemistry

- Book 3B
- Topic 8 Chemistry of Carbon Compounds

Content

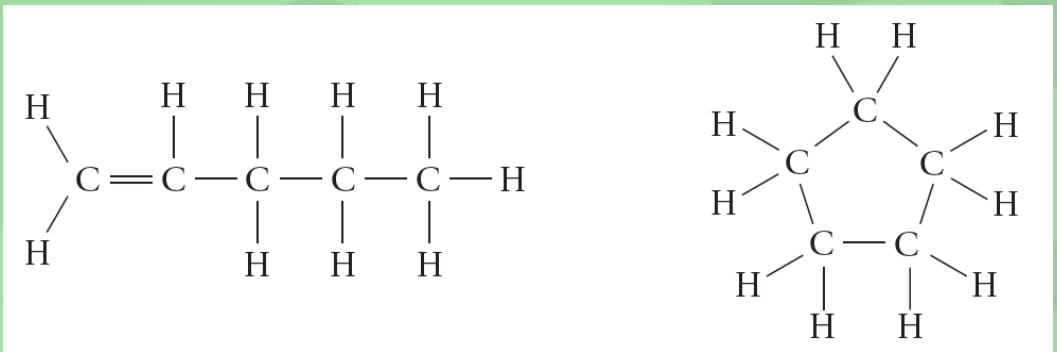
Continued on next page

Content

- Key terms
- Summary
- Unit Exercise

30.1 Isomerism (p.57)

- Below are two different compounds. However, their molecular formulae are the same — they can both be represented by C_5H_{10}. They are simple examples of **isomers (同分異構體)**.



Isomerism (同分異構) is the property of two or more compounds (called isomers) that have the same molecular formula but different arrangement of atoms.

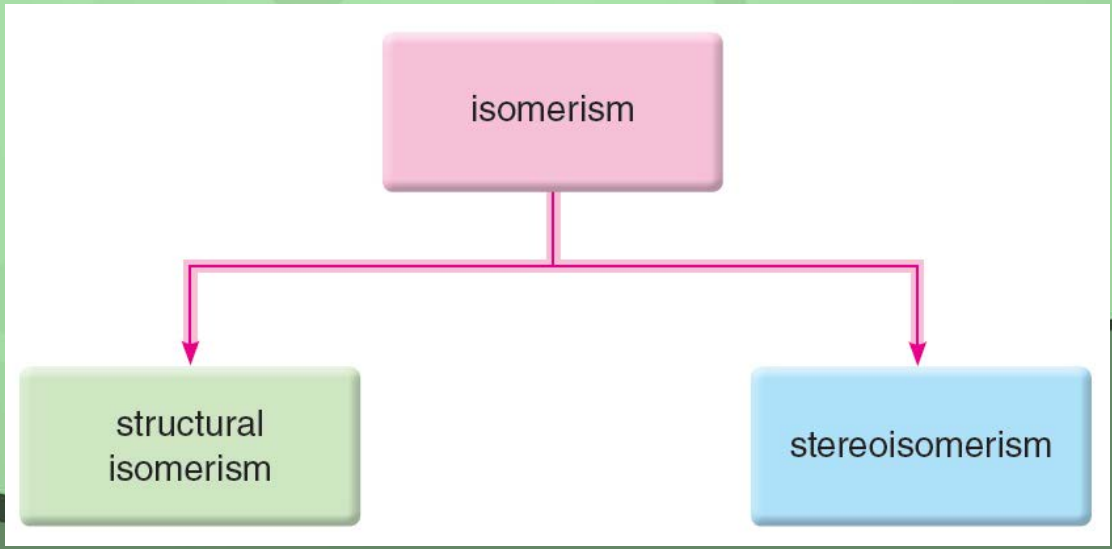
Isomerism *Ref.*

30.1 Isomerism (p.57)

There are two ways in which atoms can be arranged differently in isomers:

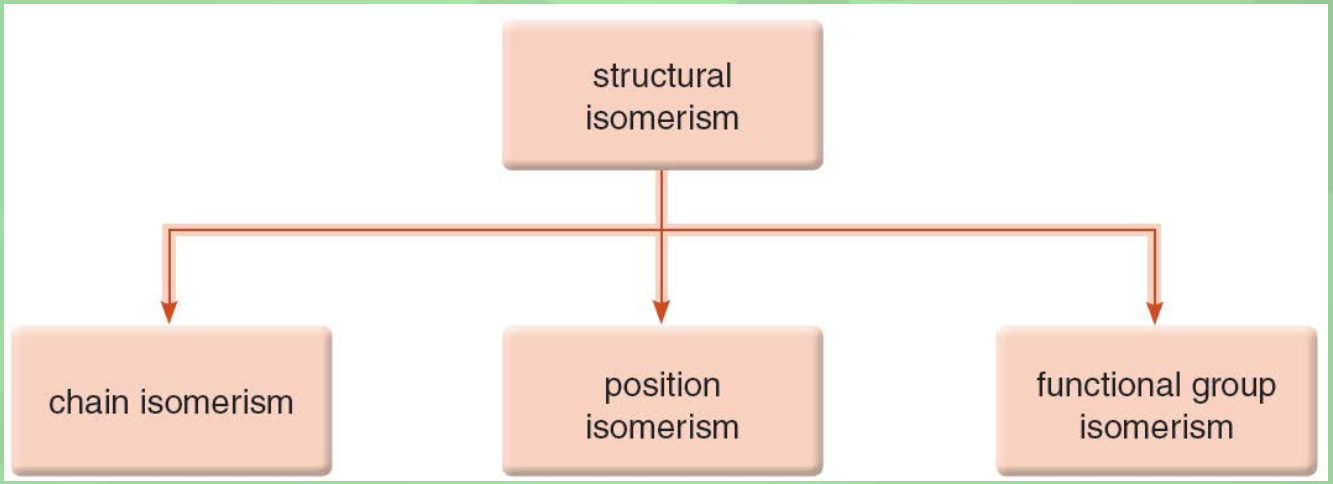
1 The atoms are bonded together in a different order in each isomer— these are called **structural isomers (結構異構體)**.

2 The atoms are bonded together in the same order, but the arrangement of the atoms in space is different in each isomer —these are called **stereoisomers (位置異構體)**.



30.2 Structural Isomerism (p.58)

Structural isomers are two or more compounds that have the same molecular formula but the atoms are bonded together in different orders (i.e. with different structures).



Building molecular models of structural isomers

30.2 Structural Isomerism (p.58)

There are three ways in which structural isomerism can arise:

1 a different arrangement of carbon atoms in the longest chain —this is called **chain isomerism (鏈異構)**;

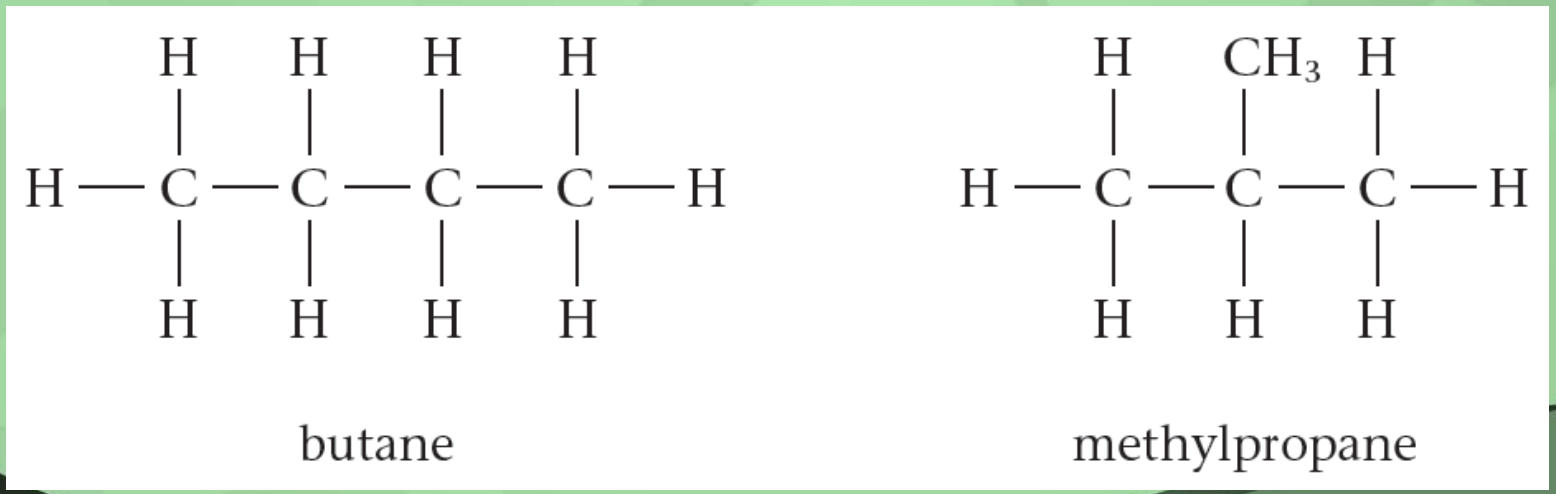
2 the same functional group attached to the carbon chain at different points—this is called **position isomerism (位置異構)**; and

3 functional groups that are different—this is called **functional group isomerism (官能基異構)**.

30.2 Structural Isomerism (p.58)

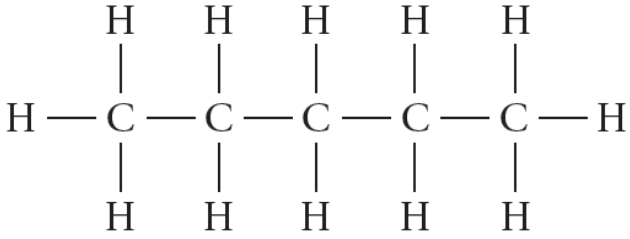
Chain isomerism

- These isomers arise because of the possibility of branching in carbon chains. The only way in which chain isomers differ is in the length of the carbon chain.
- Chain isomers of C_4H_{10}

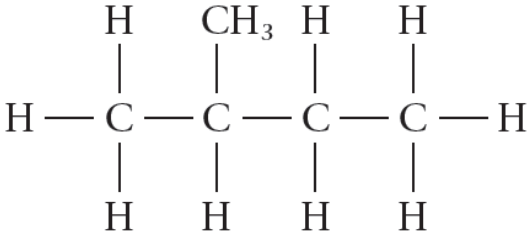


30.2 Structural Isomerism (p.58)

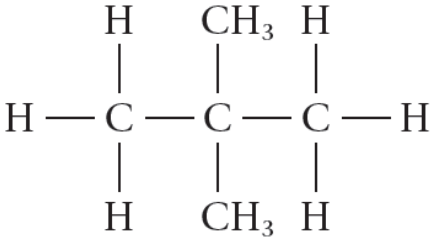
- Chain isomers of C_5H_{12}



pentane



2-methylbutane



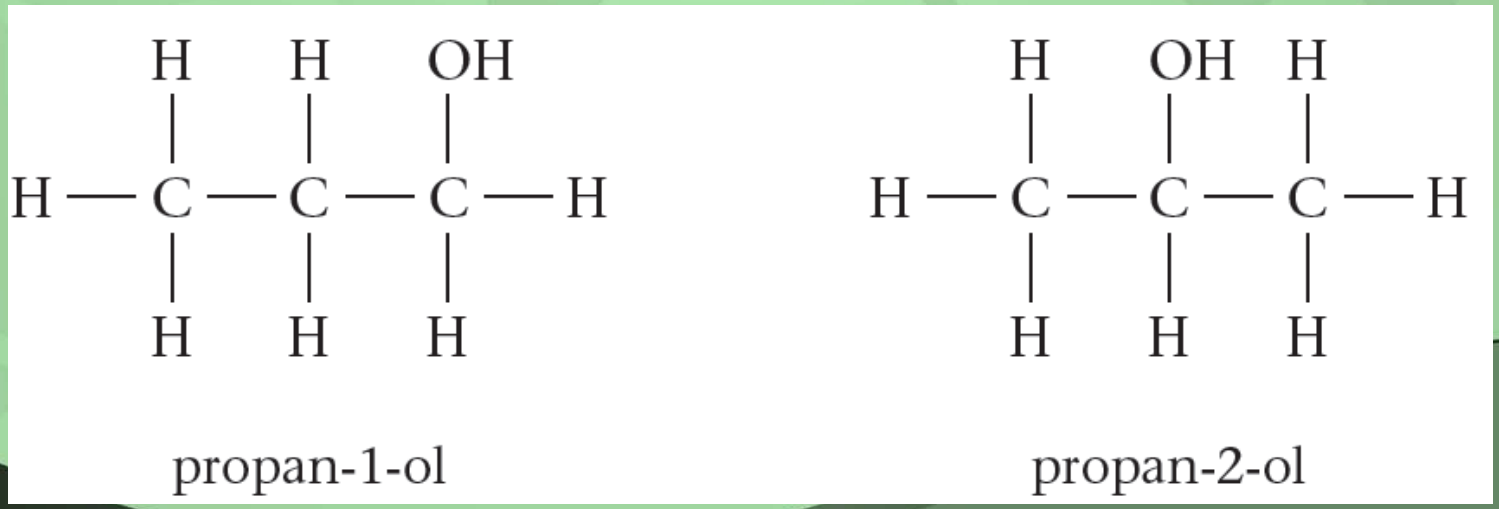
dimethylpropane

- These three isomers are alkanes. That means they have similar chemical properties. However, they have slightly different physical properties. The more branched the isomers, the weaker are the van der Waals' forces between their molecules and the lower is the boiling point.

30.2 Structural Isomerism (p.58)

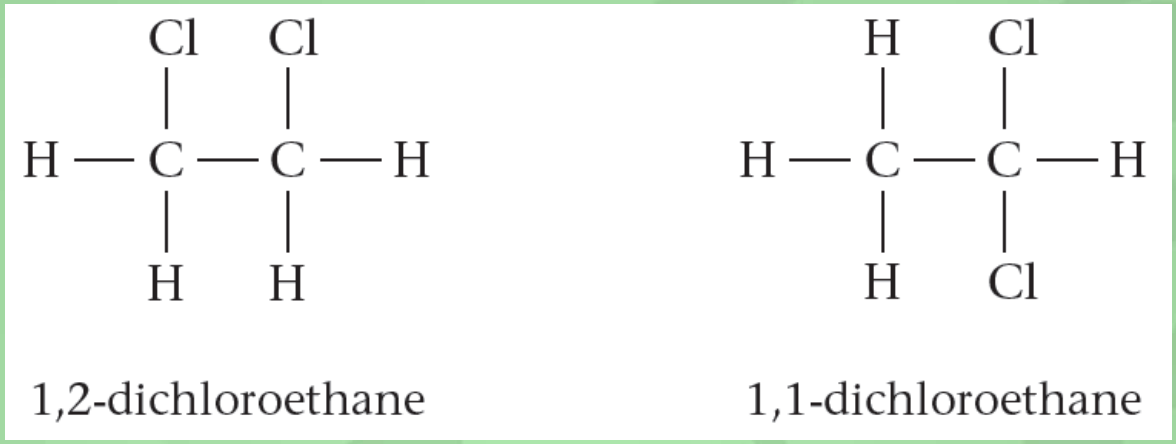
Position isomerism

- Position isomers have the same carbon skeleton, but the positions of their functional groups differ. Position isomers are chemically similar because they possess the same functional group.
- Position isomers of C_3H_7OH

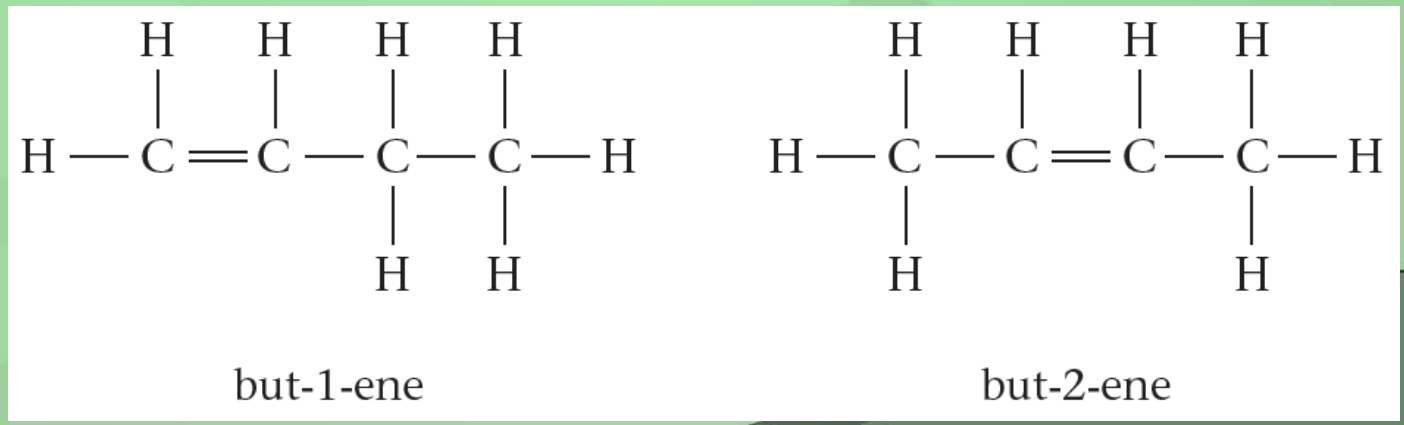


30.2 Structural Isomerism (p.58)

- Position isomers of $C_2H_4Cl_2$



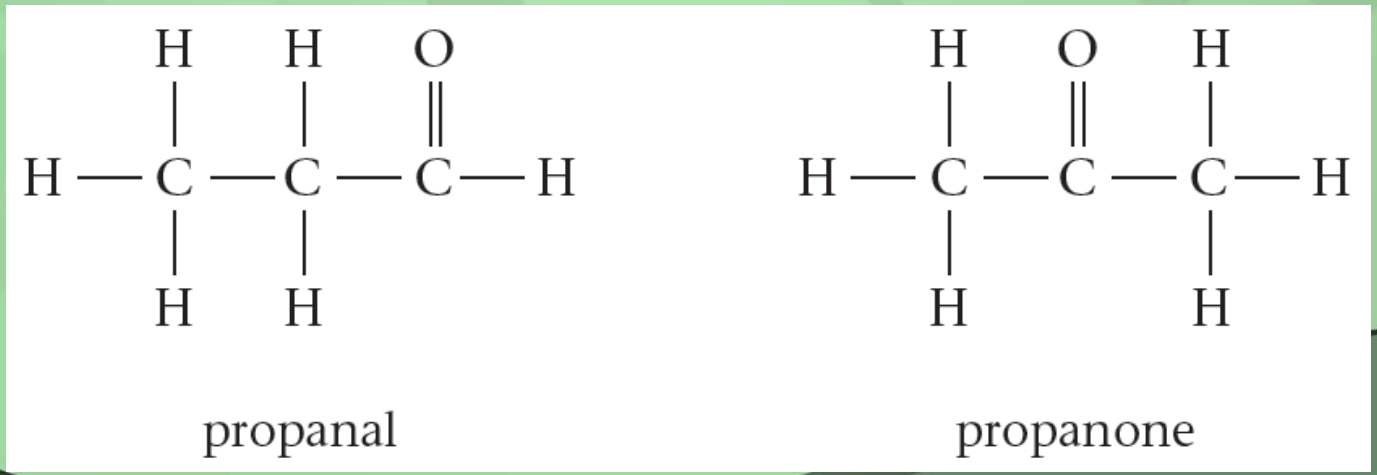
- Position isomers of C_4H_8



30.2 Structural Isomerism (p.58)

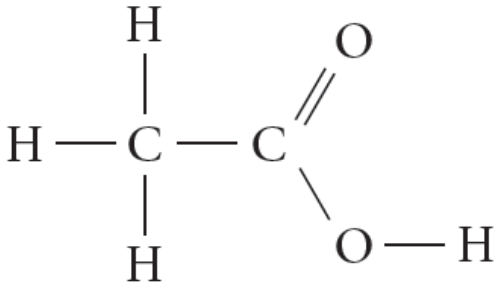
Functional group isomerism

- Functional group isomerism occurs when two or more compounds with the same molecular formula are members of different homologous series and have different functional groups.
- Functional group isomers of C_3H_6O

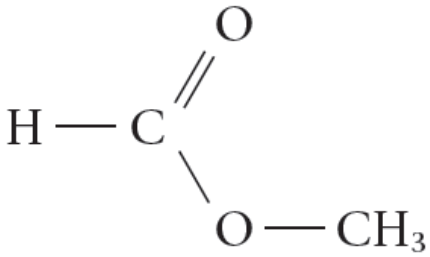


30.2 Structural Isomerism (p.58)

- Functional group isomers of $C_2H_4O_2$



ethanoic acid

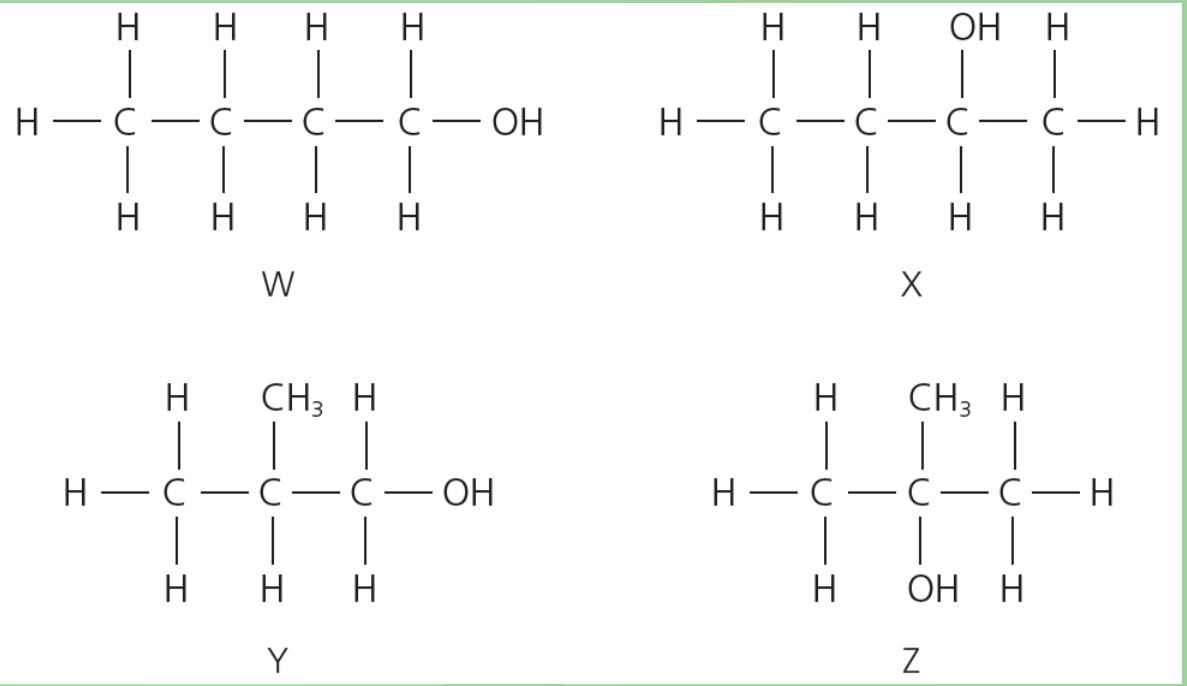


methyl methanoate

30.2 Structural Isomerism (p.58)

Practice 30.1

The structural formulae of four alcohols with the molecular formula C_4H_9OH are shown:



a) Identify TWO alcohols that are chain isomers.

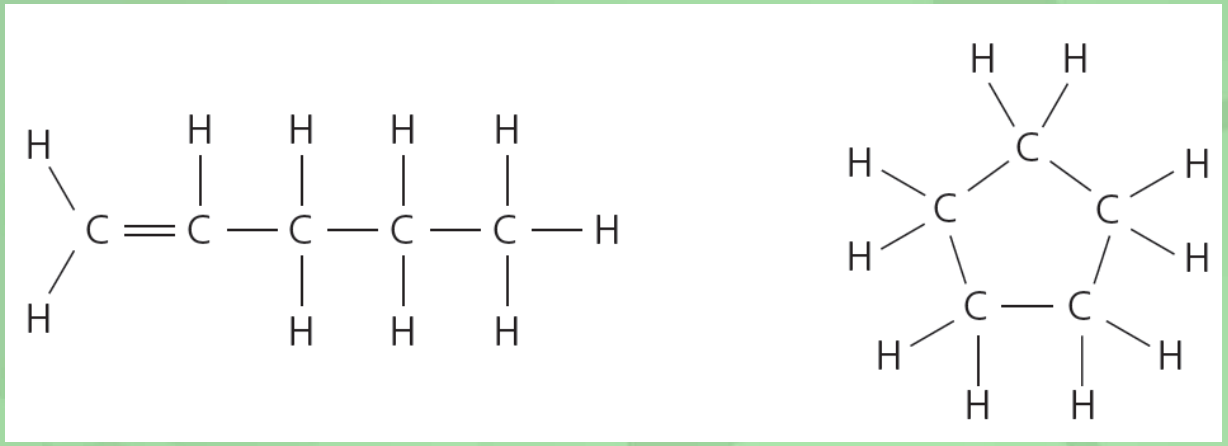
Any one of the following: • W and Y; • X and Z

b) Identify TWO alcohols that are position isomers.

Any one of the following: • W and X; • Y and Z

30.2 Structural Isomerism (p.58)

2 What type of structural isomerism is shown in the two compounds below?



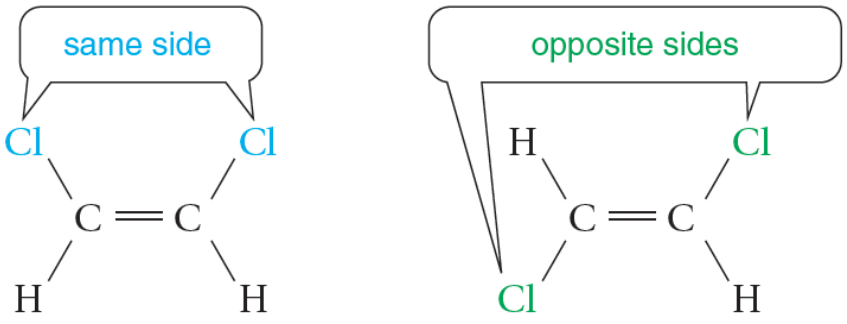
Functional group isomerism

A pent-1-ene molecule has a carbon-carbon double bond whereas a cyclopentane molecule is cyclic with no carbon-carbon double bond.

30.3 *Cis-trans* isomerism (p.64)

Stereoisomers have the same structural formula (the atoms are bonded together in the same way—same connectivity), but the atoms are arranged differently in space.

- ***Cis-trans* isomerism (*順-反異構*)** is a type of stereoisomerism. The fact that rotation of atoms or groups around a carbon-carbon double bond is restricted gives rise to *cis-trans* isomerism.

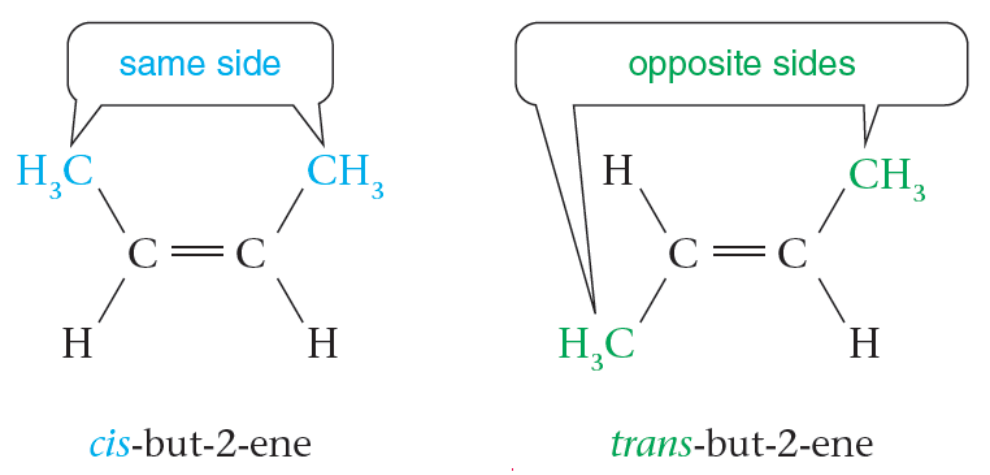


cis-1,2-dichloroethene *trans*-1,2-dichloroethene

Building molecular models of *cis-trans* isomers

30.3 *Cis-trans* isomerism (p.64)

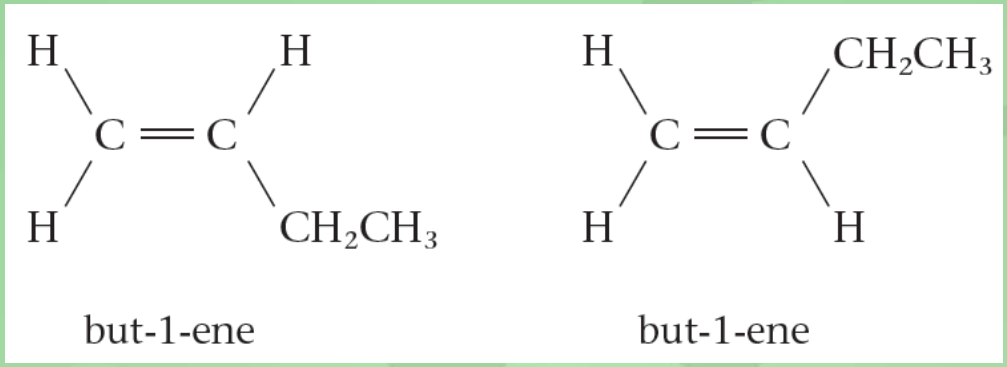
- The chlorine atoms are arranged either on the same side of the carbon-carbon double bond—forming the *cis* isomer, or on opposite sides of the carbon-carbon double bond—forming the *trans* isomer.
- These cannot be interconverted because the carbon-carbon double bond restricts rotation of atoms or groups around the bond.
- Consider but-2-ene:



cis-but-2-ene *trans*-but-2-ene

30.3 *Cis-trans* isomerism (p.64)

- Now consider but-1-ene:



- They are not cis-trans isomers. The two arrangements are identical. When you flip over the first arrangement, you get the second one. But-1-ene cannot exhibit cis-trans isomerism because one carbon atom of the carbon-carbon double bond has two identical hydrogen atoms attached.

30.3 *Cis-trans* isomerism (p.64)

A compound will exhibit cis-trans isomerism if it satisfies both of the following conditions:

- **it contains a carbon-carbon double bond;**
- **there are two different atoms or groups on each carbon atom of the carbon-carbon double bond.**

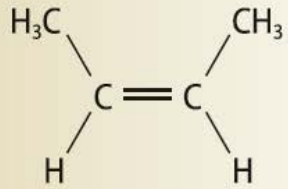
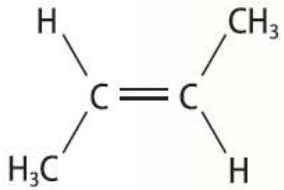
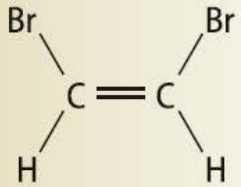
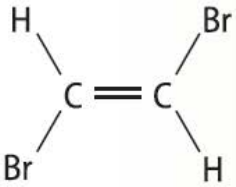
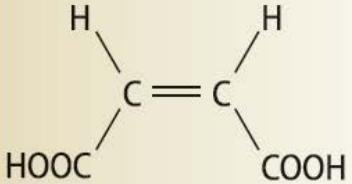
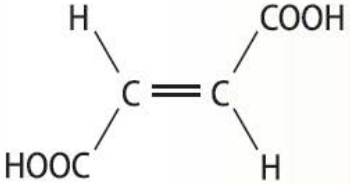
- *Cis* and *trans* isomers are different compounds, so they have different properties.

30.3 *Cis-trans* isomerism (p.64)

- The melting point of a carbon compound depends on the strength of intermolecular attractions as well as molecular symmetry.
- Van der Waals' forces exist in the *cis* and *trans* isomers of but-2-ene and the forces are of comparable strength.
- The *trans* isomer has a more regular and symmetrical structure than the *cis* isomer. Molecules of the *trans* isomer can pack more compactly in the solid. More heat is required to overcome the van der Waals' forces between the molecules. Hence the *trans* isomer has a higher melting point than the *cis* isomer.

30.3 *Cis-trans* isomerism (p.64)

Table 30.1 Physical properties of *cis-trans* isomers of but-2-ene, 1,2-dibromoethene and butenedioic acid

Cis isomer	Melting point (°C)	Density (g cm^{-3})	*Trans* isomer	Melting point (°C)	Density (g cm^{-3})
	−139 °C	0.621		−105 °C	0.604
	−53 °C	2.25		−6 °C	2.23
	139 °C	1.59		300 °C	1.64

30.3 *Cis-trans* isomerism (p.64)

Q (Example 30.1)

The compound known as 'gamma-linolenic acid' is found in the seeds of the Evening Primrose plant.

$$CH_3(CH_2)_4CH=CHCH_2CH=CHCH_2CH=CH(CH_2)_4COOH$$

gamma-linolenic acid

How many *cis-trans* isomers does gamma-linolenic acid have?

30.3 *Cis-trans* isomerism (p.64)

A

In the carbon-carbon double bond on the left, there are two different atoms or groups on each carbon atom of the bond. Hence the compound has one pair of cis-trans isomers due to the left carbon-carbon double bond.

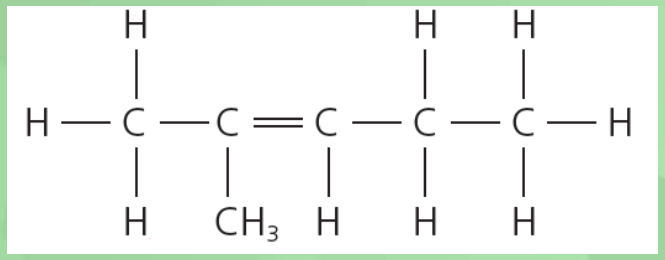
The compound has one pair of cis-trans isomers due to each of carbon-carbon double bonds in the middle and on the right.
The compound has a total of 8 cis-trans isomers due to the following combinations:
cis-cis-cis
cis-cis-trans
cis-trans-cis
cis-trans-trans
trans-cis-cis
trans-cis-trans
trans-trans-cis
trans-trans-trans

30.3 *Cis-trans* isomerism (p.64)

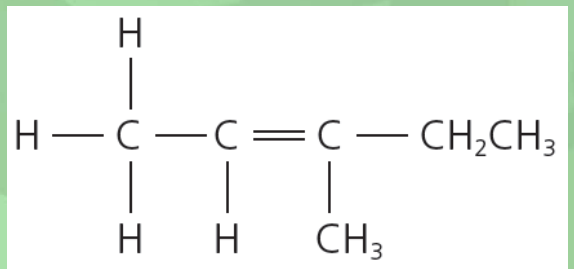
Practice 30.2

1 Decide whether each of the following compounds can exhibit *cis-trans* isomerism. Explain your answer in each case.

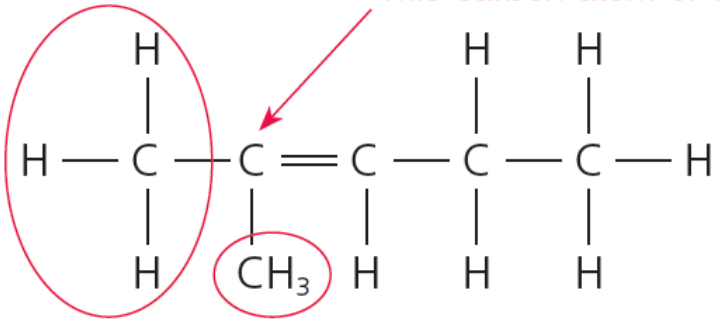
a)



b)

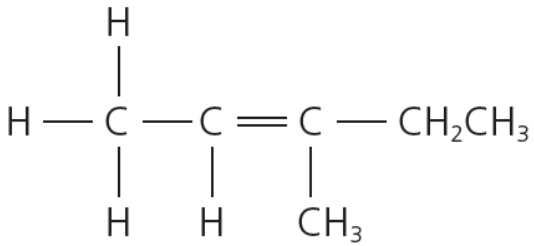


a)



The compound cannot exhibit *cis-trans* isomerism.

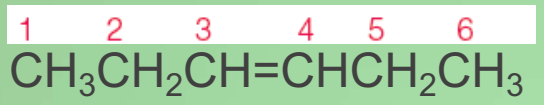
b)



The compound can exhibit *cis-trans* isomerism. There are two different atoms or groups on each carbon atom of the carbon-carbon double bond.

30.3 *Cis-trans* isomerism (p.64)

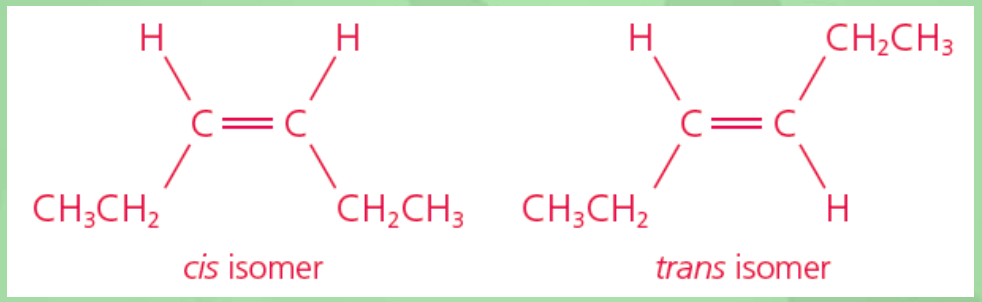
2 The hydrocarbon below exists in two stereoisomeric forms.



a) Give the systematic name of this hydrocarbon.

This hydrocarbon contains 6 carbon atoms, with the C=C bond between carbon atoms 3 and 4. Thus, the systematic name of this hydrocarbon is hex-3-ene.

b) Draw and label the structures of the *cis* and *trans* isomers of this hydrocarbon.



c) i) Write the structural formula of a straight-chain isomer of the hydrocarbon which does NOT exist as *cis* and *trans* isomers. $CH_3CH_2CH_2CH_2CH=CH_2$

ii) Explain why this isomer does NOT exist as *cis-trans* isomers.

One carbon atom of the carbon-carbon double bond has two hydrogen atoms attached.

30.3 *Cis-trans* isomerism (p.64)

3 A student states that the compound below has four *cis-trans* isomers:

$H_3C–CH=CH–CH=CH–CH_3$

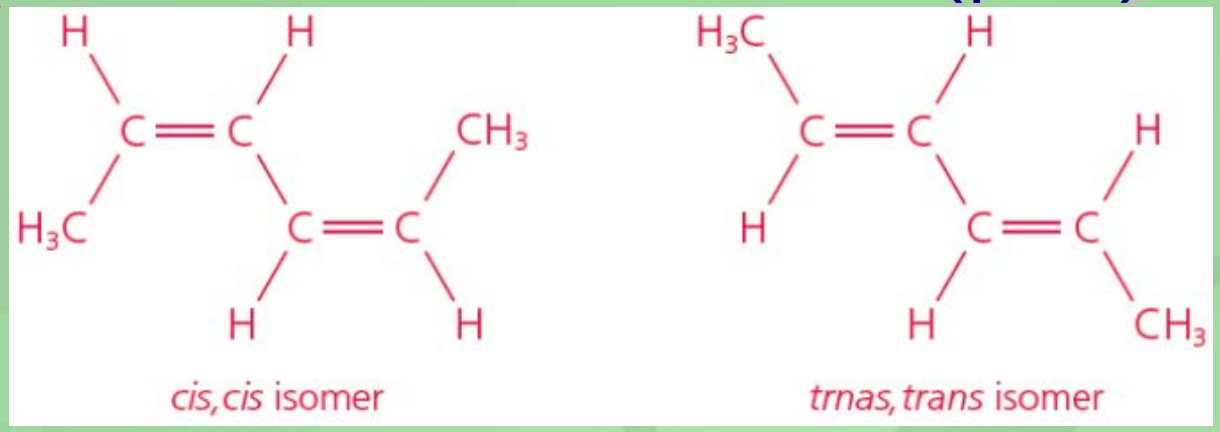
Explain whether you agree with the student.

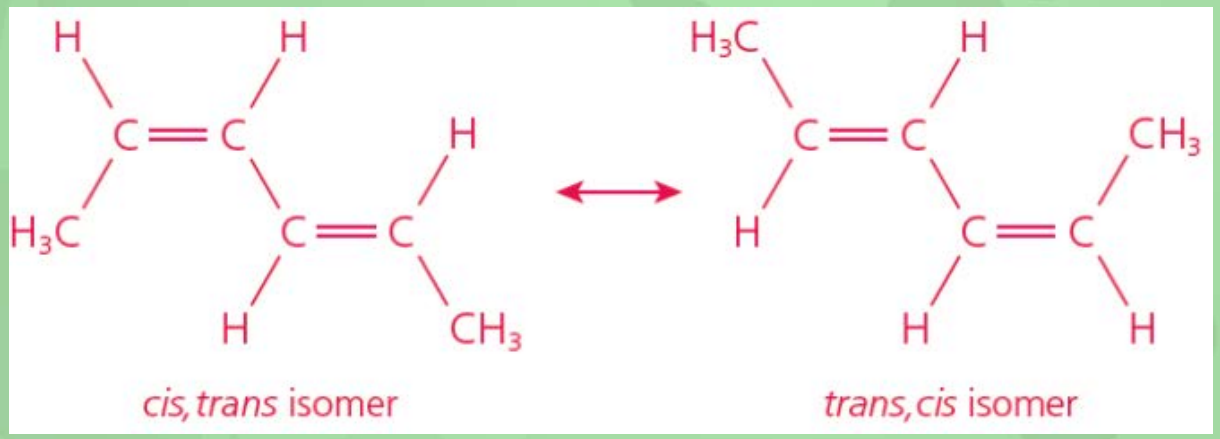
In the left C=C bond, one carbon atom has two different groups ($–CH_3$ and –H) attached, while the other carbon atom also has two different groups (–H and $–CH=CH–CH_3$) attached. Hence the compound has one pair of *cis-trans* isomers due to the left C=C bond.

Similarly, the compound has one pair of cis-trans isomers due to the right C=C bond.

The isomers are shown below.

30.3 *Cis-trans* isomerism (p.64)



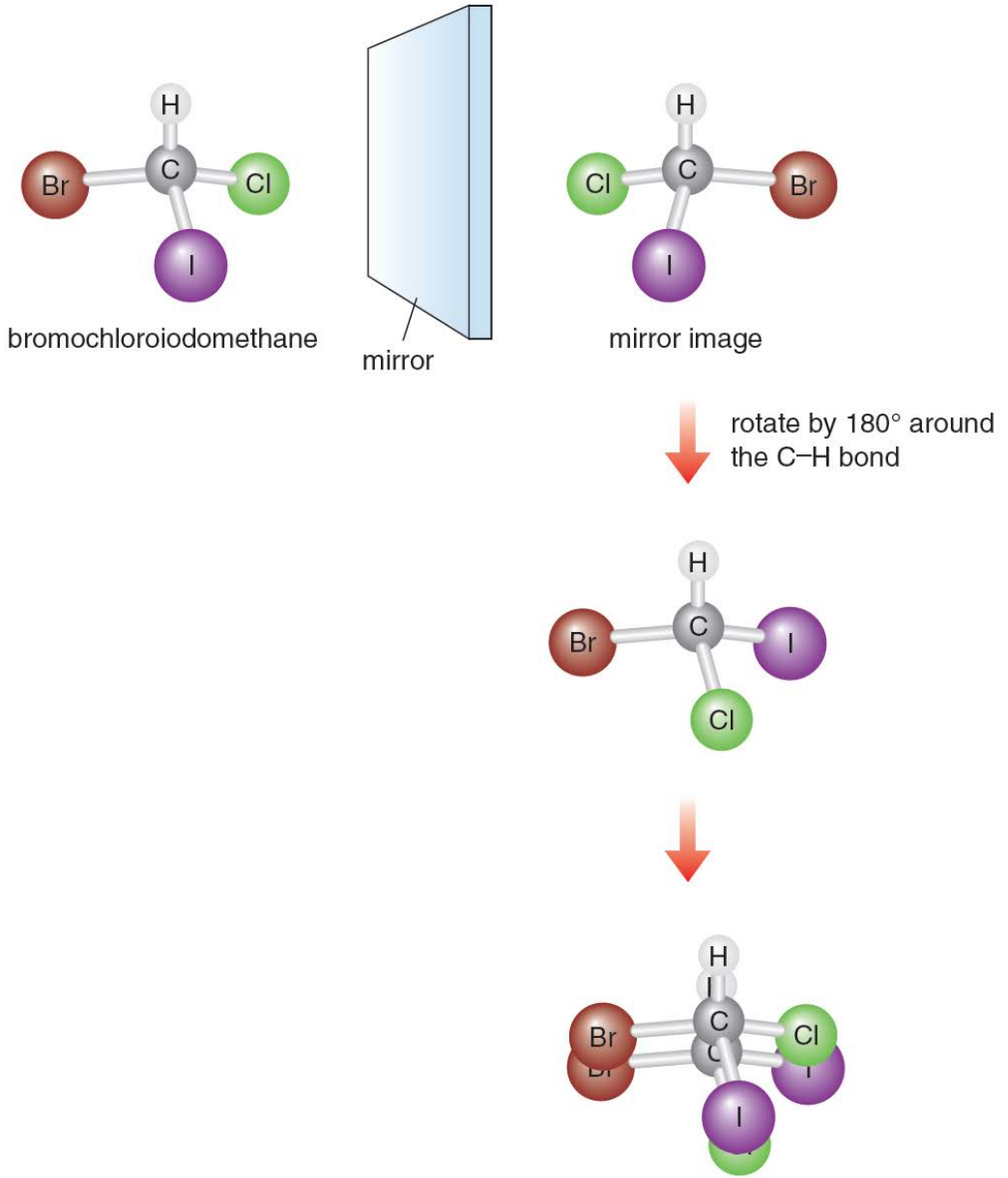


As the compound is symmetrical, its *cis,trans* isomer and its *trans,cis* isomer are identical. Hence it has three *cis-trans* isomers.

30.4 Enantiomerism (p.69)

- Every molecule has a mirror image. Generally, the mirror image of a molecule can be turned around to show that it is identical to the original molecule.
- Sometimes, however, it turns out that a molecule and its mirror image are not the same — the molecule and its mirror image are not **superposable (可疊合的)**。

- Four different atoms around central carbon
- After rotation, only two of the atoms (Br and H, not Cl and I) of the molecule can coincide with its mirror image.
- The molecules are not identical but isomers of each other.

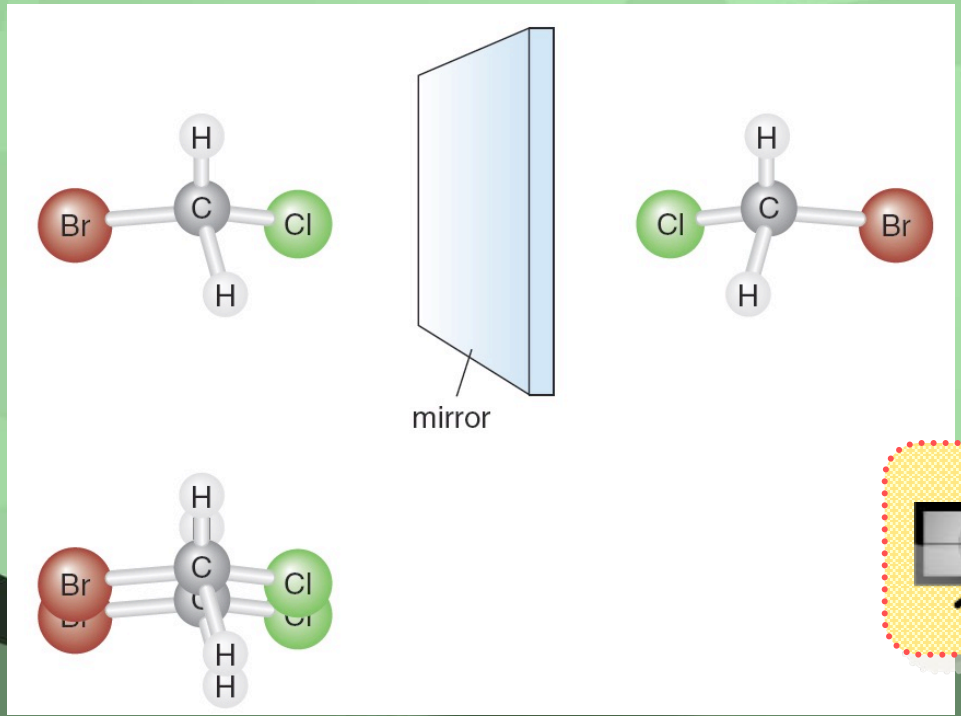


30.4 Enantiomerism (p.69)

- Bromochloroiodomethane exhibits **enantiomerism (對映異構)** — another type of stereoisomerism.
- Two molecules that are non-superposable mirror images of each other are called **enantiomers (對映異構體)**.
- Enantiomerism occurs in molecules that have a carbon atom with four different atoms (or groups) attached to it.
- A carbon atom with four different atoms (or groups) attached to it is called a **chiral centre (手性中心)**.
- Some molecules have more than one chiral centre.

30.4 Enantiomerism (p.69)

- A molecule that cannot be superposed on its mirror image is said to be **chiral (手性的)**. A molecule that can be superposed on its mirror image is said to be **achiral (非手性的)**.
- The molecule below can be superposed on its rotated mirror image. They are identical. The molecule is achiral.



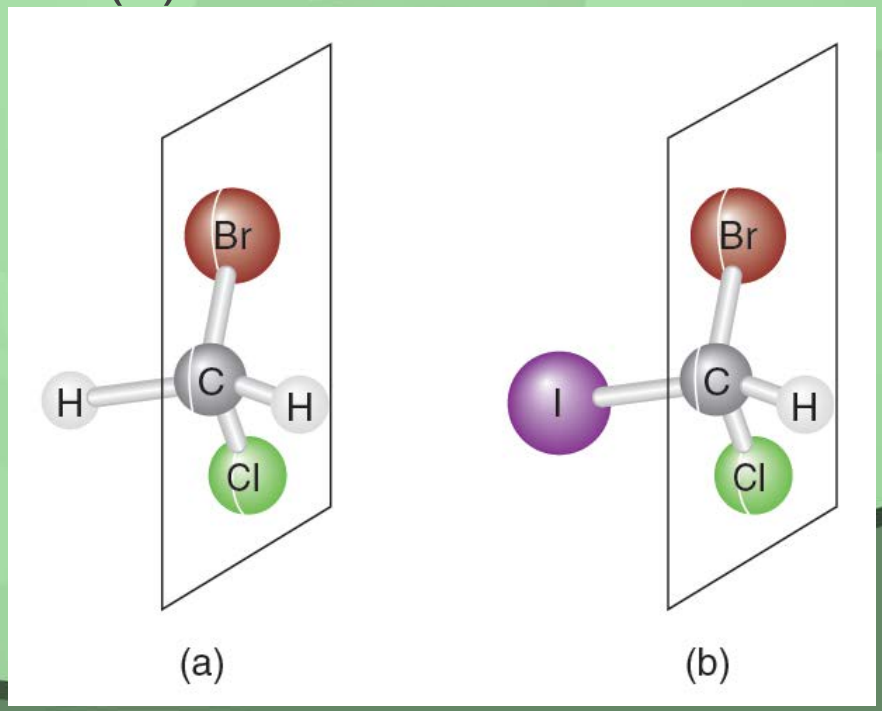
Chirality *Ref.*

Building models of some molecules and determining whether the molecules are chiral

30.4 Enantiomerism (p.69)

- A test for achirality is the presence of a **plane of symmetry (對稱面)**, i.e. an imaginary plane that bisects a molecule in such a way that the two halves are mirror reflections of each other. Thus, lack of such a plane indicates a molecule is chiral.

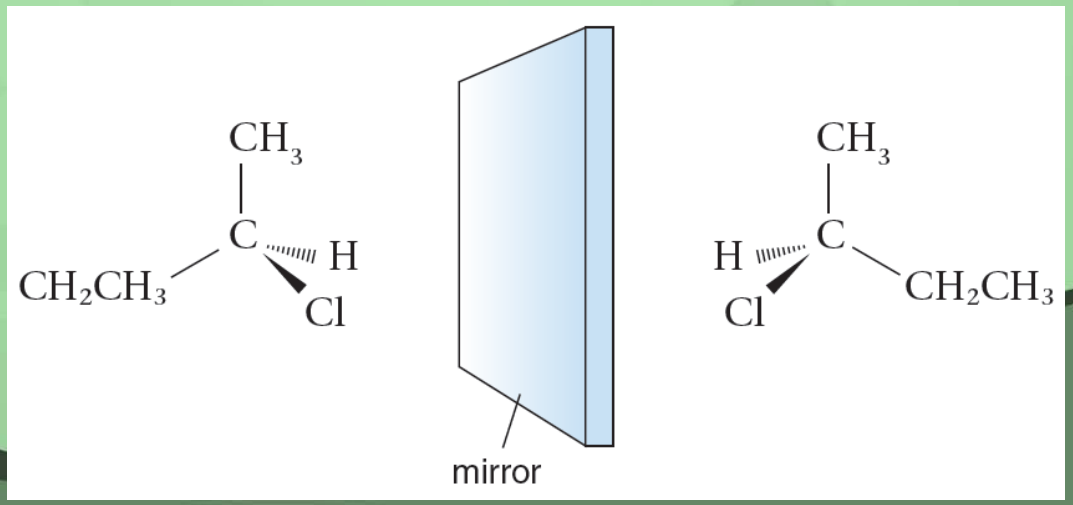
- So (a) is achiral but (b) is chiral.



30.4 Enantiomerism (p.69)

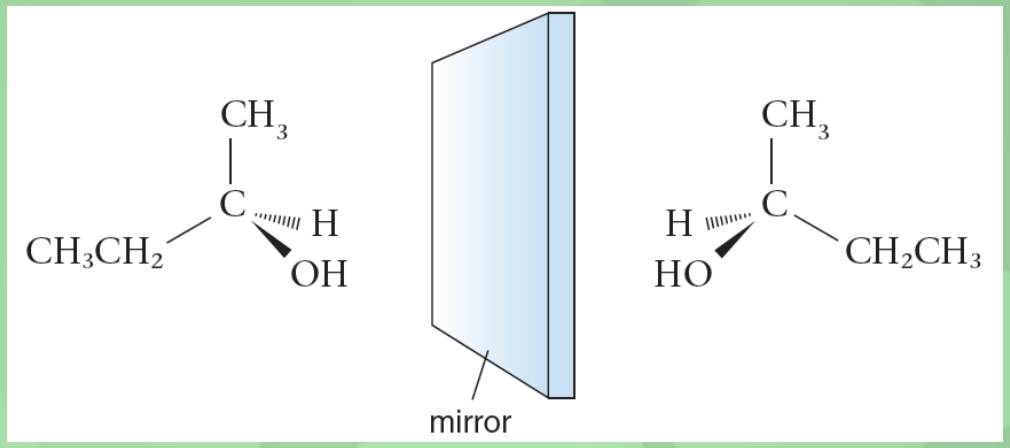
Drawing enantiomers

- Enantiomers are drawn to show the three-dimensional tetrahedral arrangement of the four different atoms or groups around the chiral centre.
- Once one isomer has been drawn, the other isomer is drawn as a mirror image.
- Example 1: 2-chlorobutane

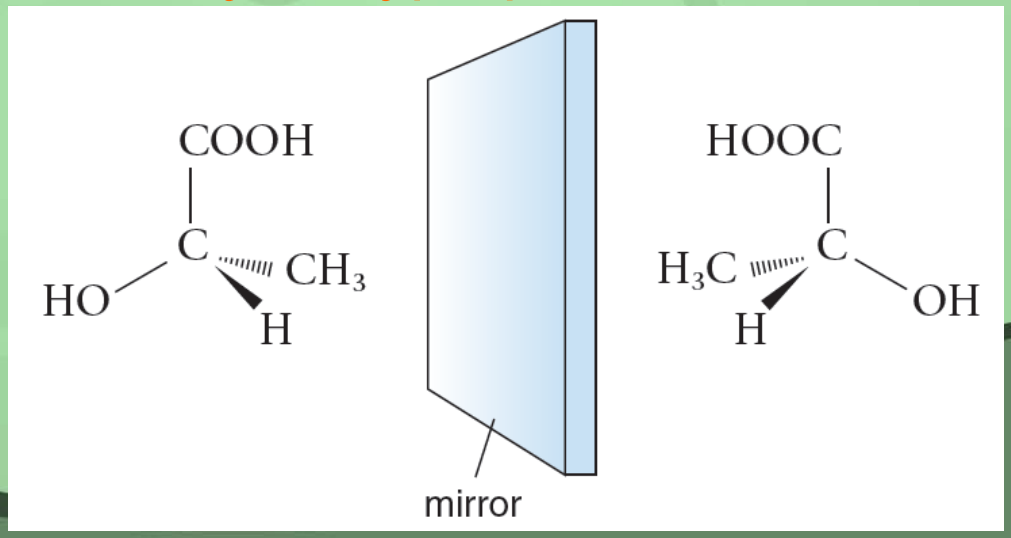


30.4 Enantiomerism (p.69)

- Example 2: Butan-2-ol



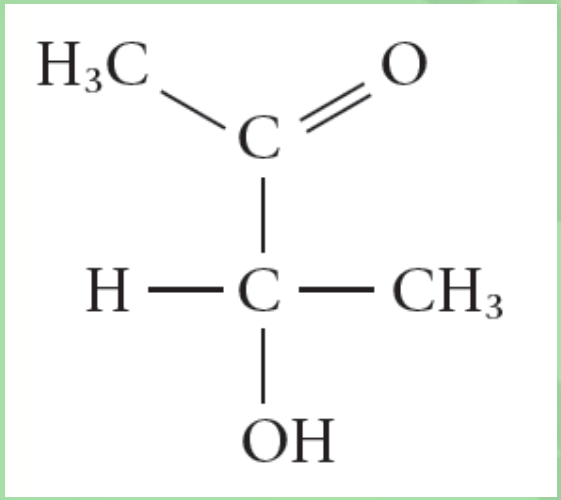
- Example 3: 2-hydroxypropanoic acid



30.4 Enantiomerism (p.69)

Q (Example 30.2)

A compound has the structural formula shown below:



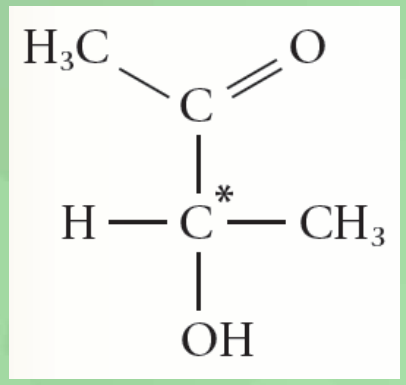
a) Label the chiral centre of the structural formula by using '*'.

b) Draw the structures of the two enantiomers of the compound.

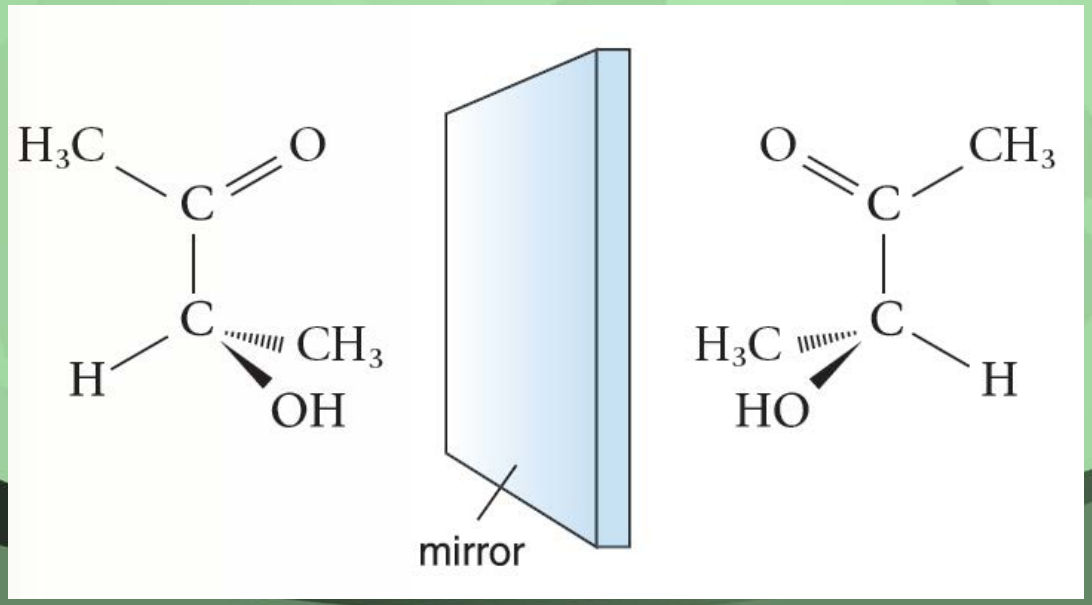
30.4 Enantiomerism (p.69)

A

a)



b)

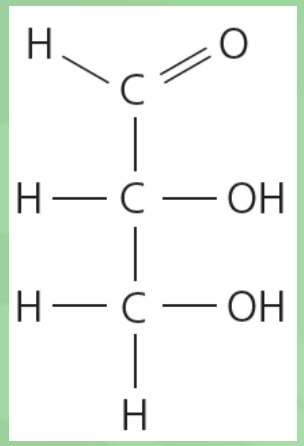


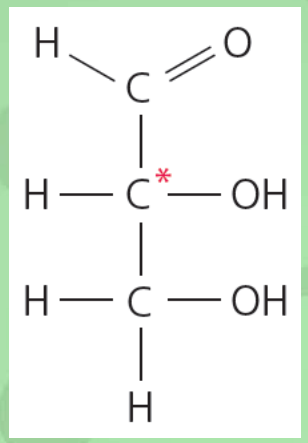
30.4 Enantiomerism (p.69)

Practice 30.3

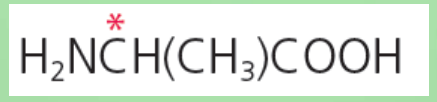
Label the chiral centre(s) in each of the following molecules by using '*'.

a)

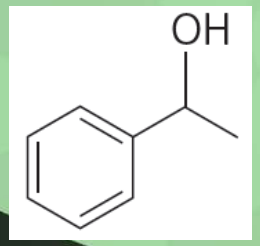


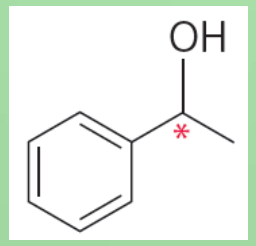


b) $H_2NCH(CH_3)COOH$



c)





30.5 Properties of enantiomers (p.76)

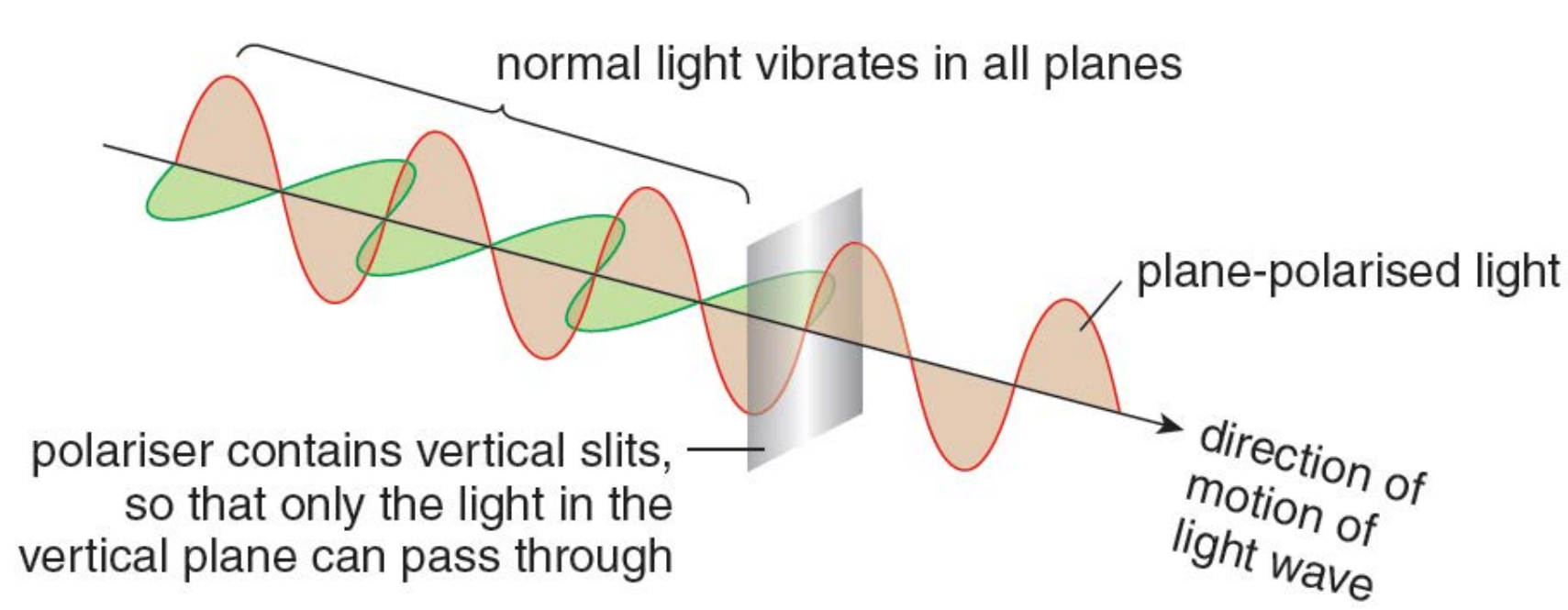
- Pairs of enantiomers have identical physical and chemical properties (such as melting and boiling points, water solubility and so on) with two exceptions:
  - they interact differently with plane-polarised light;
  - they interact differently with other chiral reagents.

Plane-polarised light

- Light is a form of electromagnetic radiation. A beam of light consists of vibrating electric and magnetic fields. You can think of it as waves which vibrate in all directions at right angles to the direction of motion of the light wave.

30.5 Properties of enantiomers (p.76)

- If the light passes through a special filter, called a **polariser (起偏鏡)**, all the vibrations are cut out except those in one plane, for example, the vertical plane. The light is said to be **plane-polarised (平面偏振)**.

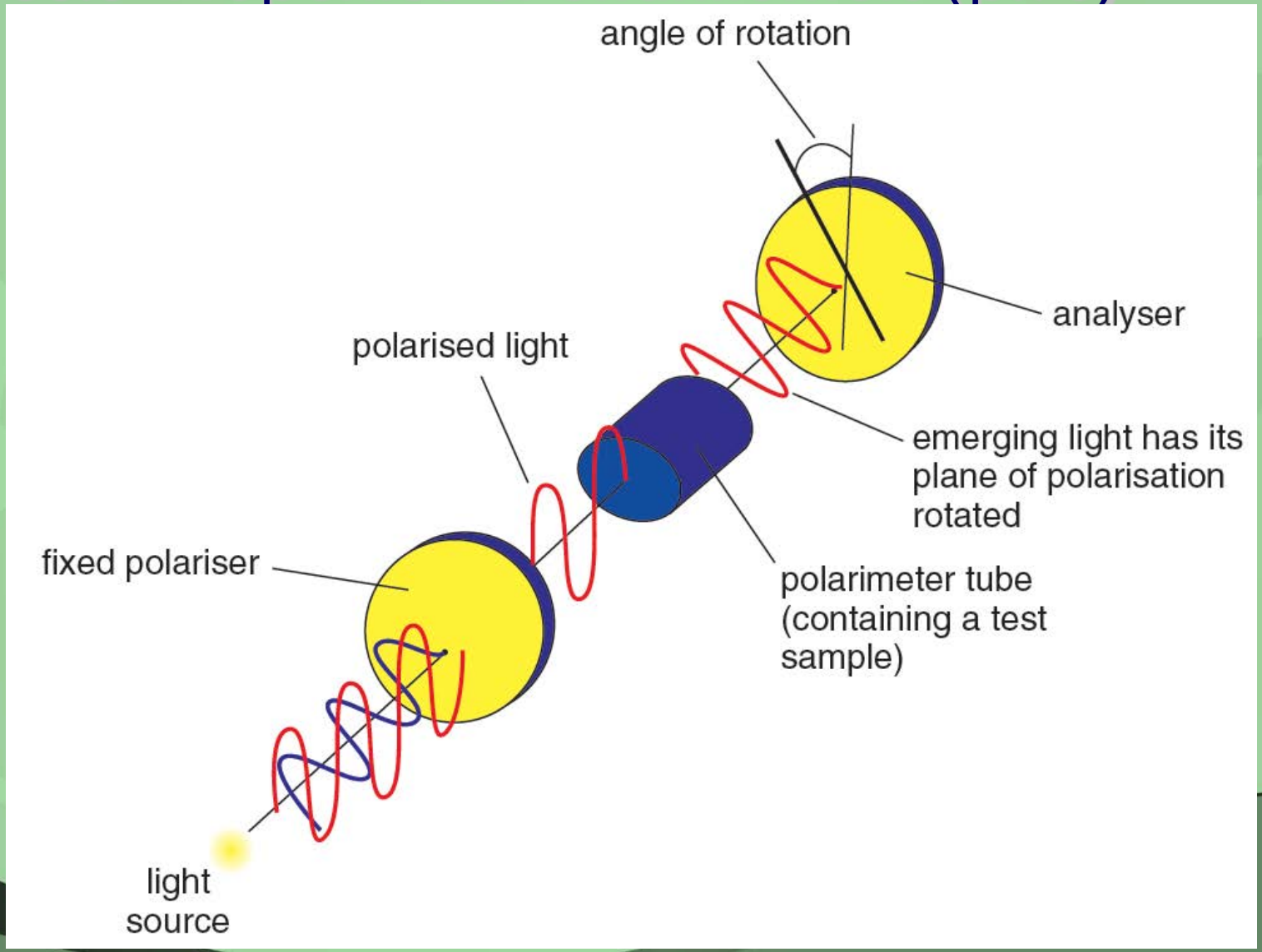


30.5 Properties of enantiomers (p.76)

Optical activity of enantiomers

- A substance that can rotate the plane of polarisation of plane-polarised light is said to be **optically active (旋光的)**.
- The ability of enantiomers to rotate the plane of polarisation of plane-polarised light can be shown by a **polarimeter (旋光計)**.
- When plane-polarised light passes through a solution of just one of a pair of enantiomers, its plane of polarisation is rotated.
- One isomer rotates the plane of polarisation clockwise while the other isomer rotates the plane of polarisation anticlockwise to the same extent.

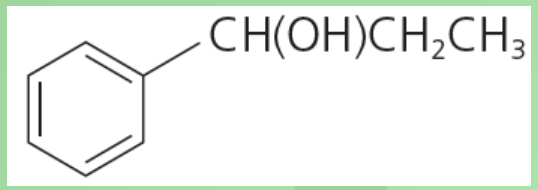
30.5 Properties of enantiomers (p.76)

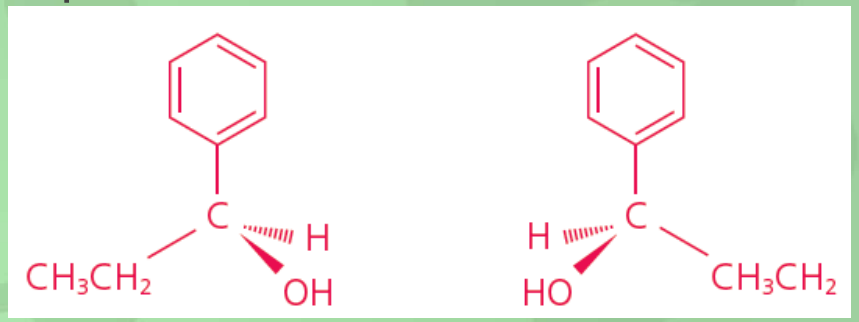


30.5 Properties of enantiomers (p.76)

Practice 30.4

The structural formula shown below can represent two isomers, P and Q.





a) What type of isomers are P and Q?

Enantiomerism

b) Draw the three-dimersional structures of P and Q.

c) State ONE different physical property between P and Q.

They rotate the plane of polarisation of a beam of plane-polarised light by the same amount but in opposite directions, one clockwise and the other anticlockwise.

d) Explain whether a mixture of P and Q can be separated by fractional distillation.

No.

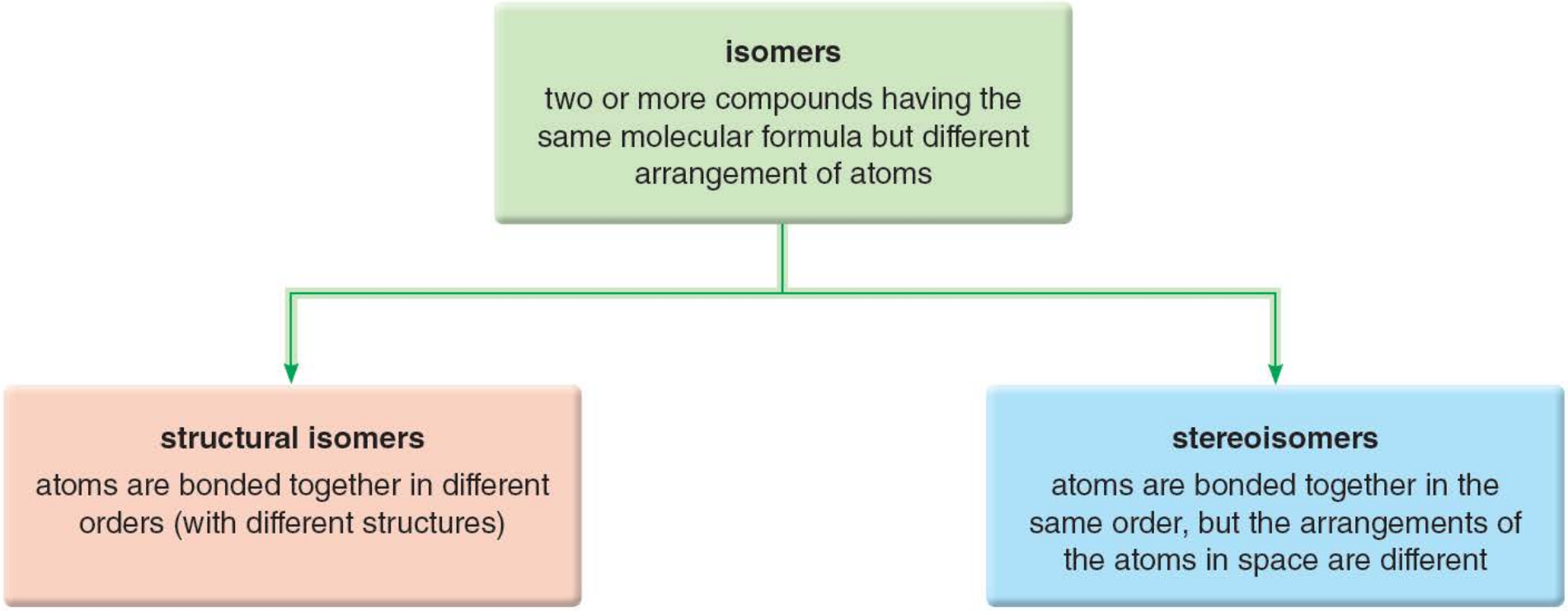
P and Q have the same boiling point.

Key terms (p.79)

isomer	同分異構體	enantiomer	對映異構體
isomerism	同分異構	chiral centre	手性中心
structural isomer	結構異構體	chiral	手性的
stereoisomer	立體異構體	achiral	非手性的
chain isomerism	鏈異構	plane of symmetry	對稱面
position isomerism	位置異構	polariser	起偏鏡
functional group isomerism	官能基異構	plane-polarised	平面偏振
cis-trans isomerism	*順-反*異構	optically active	旋光的
superposable	可疊合的	polarimeter	旋光計
enantiomerism	對映異構		

Summary (p.80)

1 The following charts show the classification of isomers.



Summary (p.80)

structural isomers

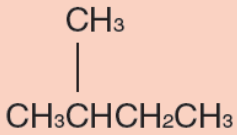
chain isomers

different arrangements of carbon atoms in the longest chain

e.g.

$CH_3CH_2CH_2CH_2CH_3$

and



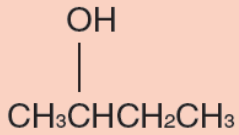
position isomers

the same functional group attached to the carbon chain at different points

e.g.

$CH_3CH_2CH_2CH_2OH$

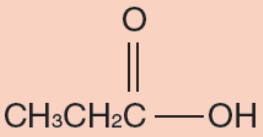
and



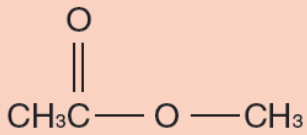
functional group isomers

functional groups are different

e.g.



and



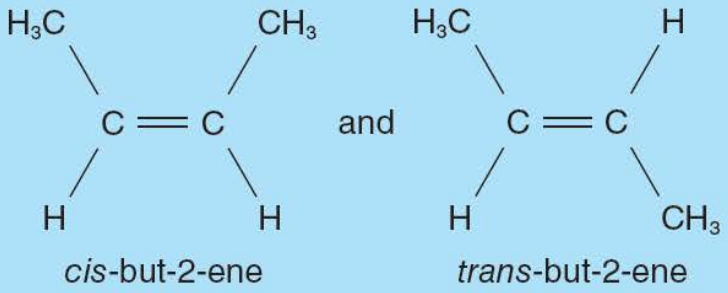
Summary (p.80)

stereoisomers

cis-trans isomers

rotation of atoms or groups around a carbon-carbon double bond is restricted

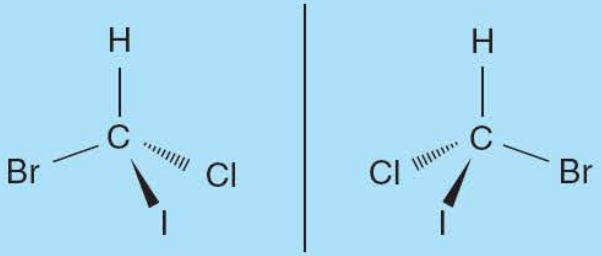
e.g.



cis-but-2-ene *trans*-but-2-ene

enantiomers

two molecules are non-superposable mirror images of each other



Summary (p.80)

2 If a compound satisfies both of the following conditions, it will exhibit *cis-trans* isomerism:
- it contains a carbon-carbon double bond;
- there are two different atoms or groups on each carbon atom of the carbon-carbon double bond.

3 *Cis* and *trans* isomers are different compounds, so they have different properties.

4 Enantiomerism occurs in molecules that have a carbon atom with four different atoms (or groups) attached to it.

Summary (p.80)

5 A carbon atom with four different atoms (or groups) attached to it is called a chiral centre. A molecule that cannot be superposed on its mirror image is chiral.

6 Pairs of enantiomers have identical physical and chemical properties (such as melting and boiling points, water solubility and so on) with two exceptions:
- they interact differently with plane-polarised light;
- they interact differently with other chiral reagents.

7 A substance that can rotate the plane of polarisation of plane-polarised light is optically active.

Unit Exercise (p.82)

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.82)

PART I KNOWLEDGE AND UNDERSTANDING

1 Complete the following concept map.

isomers

compounds with the same molecular formula but atoms bonded together in different orders

(a)

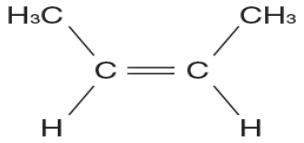
(b) examples $CH_3CH_2CH_2CH_3$ and CH_3CHCH_3 (CH_3 branch)

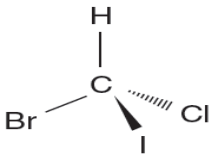
(c) examples $CH_3CH_2CH_2OH$ and (e)

(d) examples CH_3CH_2CHO and (f)

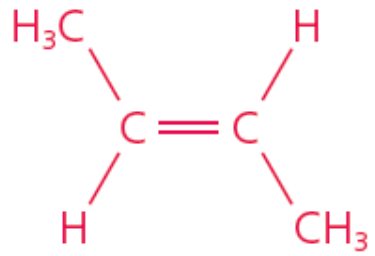
compounds with the same structure but atoms arranged differently in space

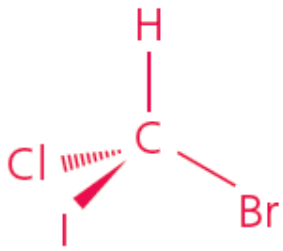
(g)

(h) examples  and (j)

(i) examples  and (k)

Unit Exercise (p.82)

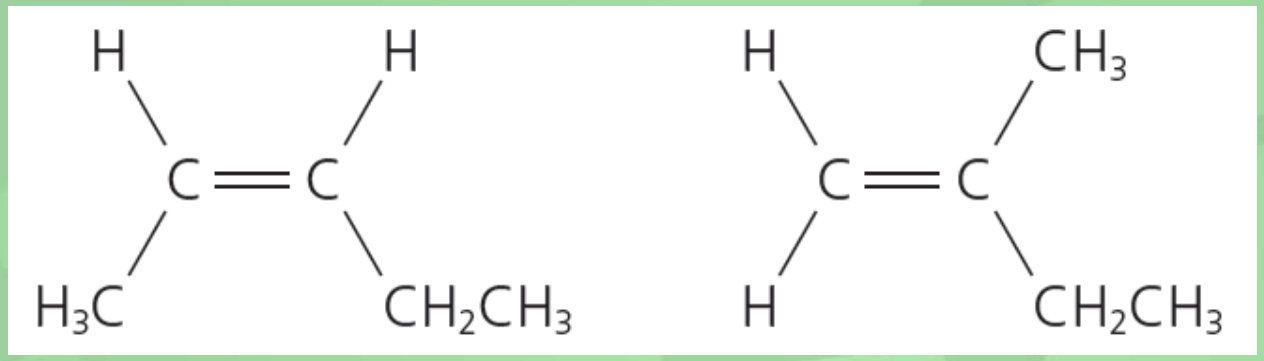
a) structural isomers
b) chain isomers
c) position isomers
d) functional group isomers
e) CH_3CHCH_3 (OH)
f) CH_3COCH_3
g) stereoisomers
h) *cis-trans* isomers
i) enantiomers
j) 

k) 

Unit Exercise (p.82)

PART II MULTIPLE CHOICE QUESTIONS

2



The two compounds are
A the same.
B *cis-trans* isomers.
C enantiomers.
D structural isomers.

Answer: D

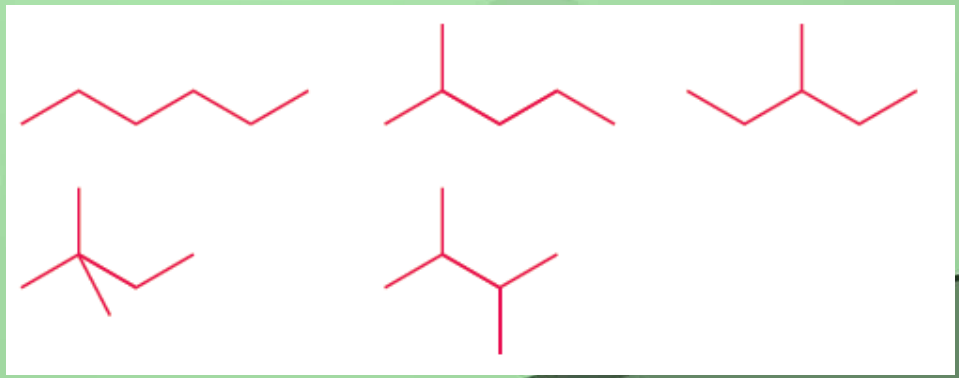
Unit Exercise (p.82)

3 How many structural isomers have the molecular formula C_6H_{14}?

A 5
B 4
C 3
D 2

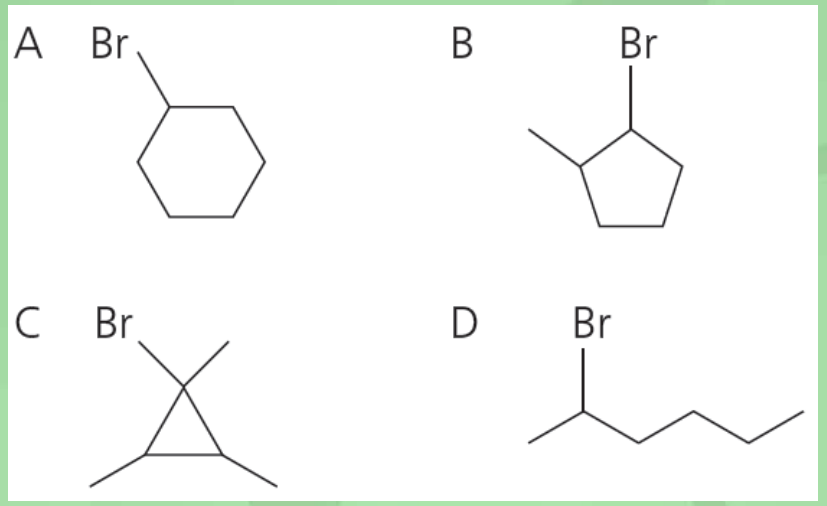
Answer: A

Explanation:
The following structural isomers have the molecular formula C_6H_{14}:



Unit Exercise (p.82)

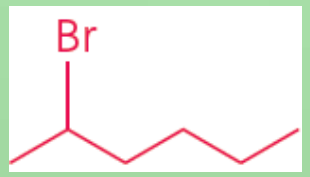
4 The skeletal formulae of some 6-carbon bromoalkanes are shown below.



Answer: D

Which of the above bromoalkanes is NOT a structural isomer of the others?

(Edexcel Advanced Subsidiary GCE, Unit 2, Jun. 2014, 5(a))

Explanation:
The molecular formula of 

is $C_6H{=}Br$, which is different from those of the other bromoalkanes ($C_6H_{11}Br$).

Unit Exercise (p.82)

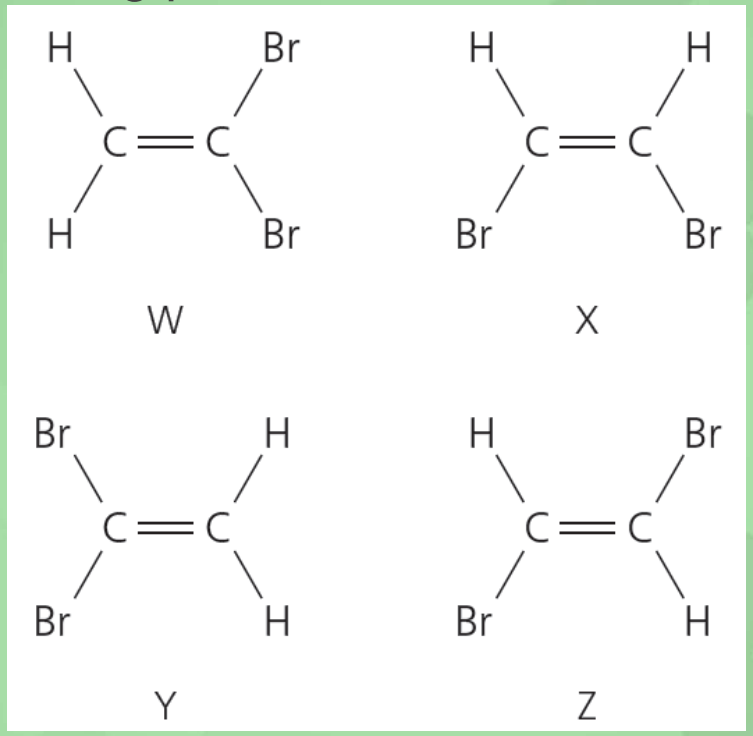
5 Butan-1-ol and butan-2-ol are

A *cis-trans* isomers.
B enantiomers.
C chain isomers.
D position isomers.

Answer: D

Unit Exercise (p.82)

6 Which of the following pairs are *cis-trans* isomers?

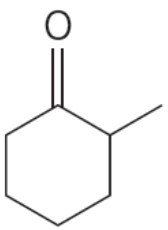


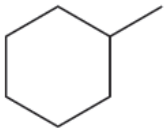
A W and X
B W and Y
C X and Z
D Y and Z

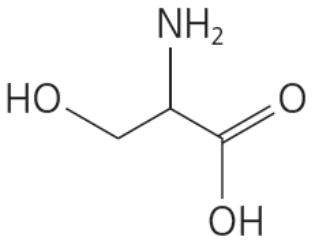
Answer: C

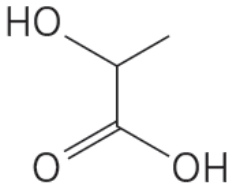
Unit Exercise (p.82)

7 Which of the following compounds is achiral?

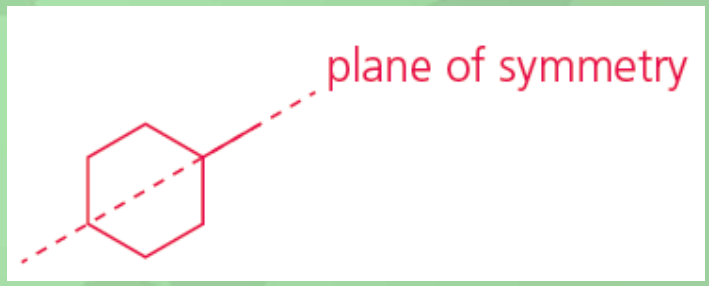
A 

B 

C 

D 

Answer: B



Unit Exercise (p.82)

8 Which of the following alkenes can exhibit *cis-trans* isomerism?

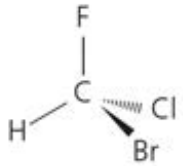
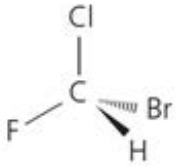
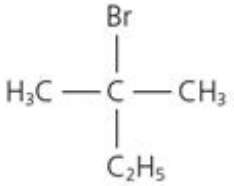
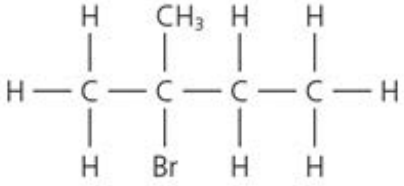
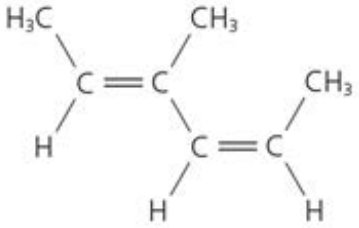
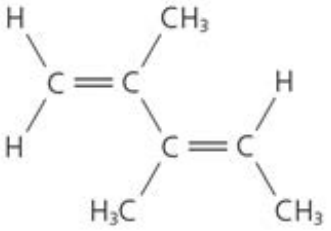
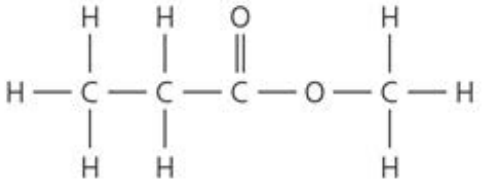
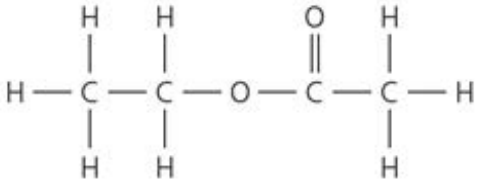
A $CH_3CH=CHCH_2CH_3$
B $CH_3CH_2CH_2CH=CH_2$
C $(CH_3)_2C=CHCH_3$
D $C_2H_5(CH_3)C=C(CH_3)_2$

Answer: A

Explanation:
In $CH_3CH=CHCH_2CH_3$, there are two different atoms or groups on each carbon atom of the C=C bond.

Unit Exercise (p.82)

9 In which of the following options are molecule Y and molecule Z identical?

	Molecule Y	Molecule Z
A		
B		
C		
D		

Answer: B

(HKDSE, Paper 1A, 2014, 29)

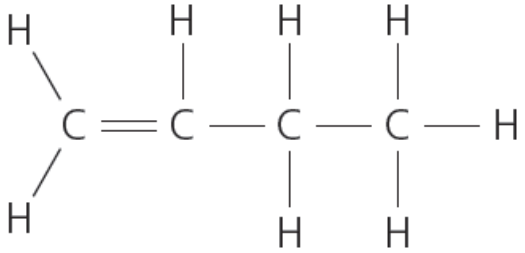
Unit Exercise (p.82)

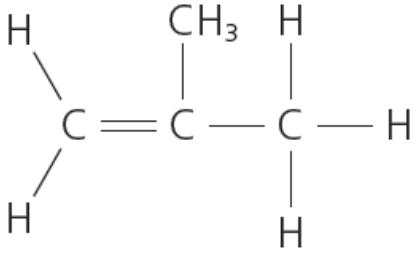
10 How many different unsaturated compounds have the molecular formula C_4H_8?

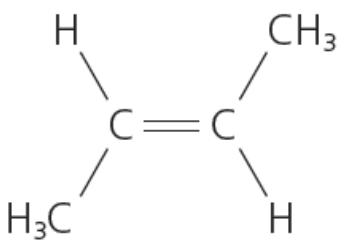
A 3
B 4
C 5
D 6

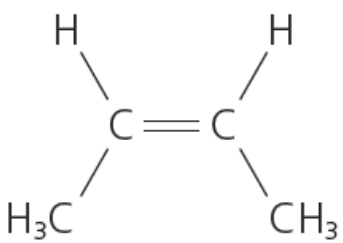
Answer: B

Explanation:
The following unsaturated compounds have the molecular formula C_4H_8:









Unit Exercise (p.82)

11 Which of the following statements about trans-1,2-dichloroethene is correct?

A It contains a chiral centre.

B It is optically active.

C It has the same boiling point as cis-1,2-dichloroethene.

D It forms a polymer with the same repeating unit as cis-1,2-dichloroethene.

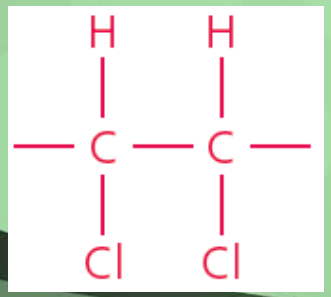
Answer: D

Explanation:

Option C — The two isomers have different structures and hence different boiling points.

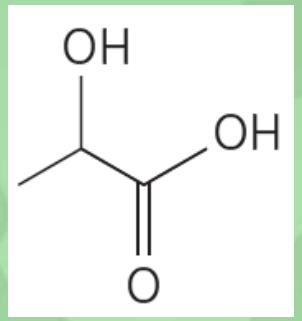
(boiling points: *cis*-1,2-dichloroethene (60 ˚C); *trans*-1,2-dichloroethene (48 ˚C))

Option D — The two isomers give a polymer with the same repeating unit:



Unit Exercise (p.82)

12 The skeletal formula shown below can represent two isomers.

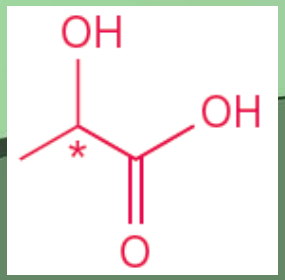


Which of the following statements concerning the two isomers is correct?

A They are *cis-trans* isomers.
B They have different melting points.
C They have different water solubilities.
D They have different effects on plane-polarised light.

Answer: D

Explanation:
The compound has a chiral centre. It is optically active.



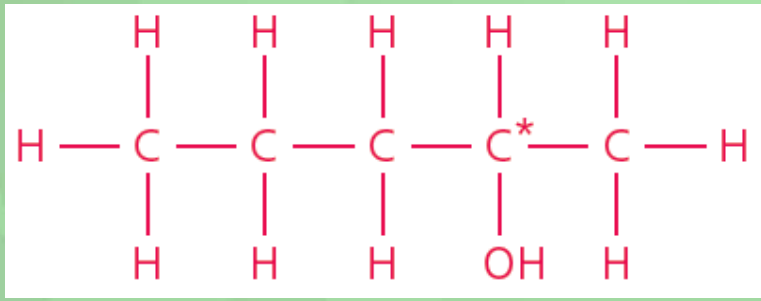
Unit Exercise (p.82)

13 Which of the following compounds can exist as enantiomers?

A 1-bromobutane
B But-2-ene
C Pentan-2-ol
D Pentan-3-ol

Answer: C

Explanation:
Pentan-2-ol has a chiral centre.



Unit Exercise (p.82)

14 Which of the following pairs are functional group isomers?

(1) $CH_3CH_2CHClCH_3$ and $CH_3CH_2CH_2CH_2Cl$

(2) CH_3CH_2COOH and $HCOOCH_2CH_3$

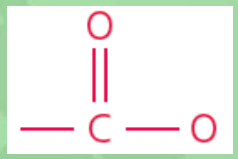
(3) $H_2NCH_2CH_2COOH$ and $CH_3CH(NH_2)COOH$

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

Answer: B

Explanation:

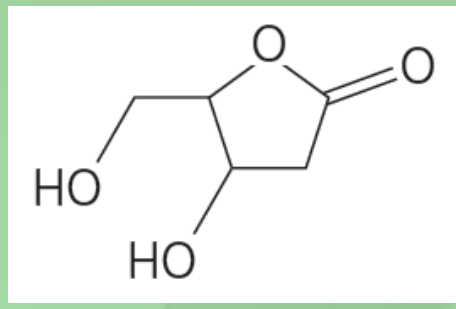
(1) Both $CH_3CH_2CHClCH_3$ and $CH_3CH_2CH_2CH_2Cl$ contain the –Cl group. They are NOT functional group isomers.

(2) CH_3CH_2COOH contains the –COOH group while $HCOOCH_2CH_3$ contains the  group. They are functional group isomers.

(3) Both $H_2NCH_2CH_2COOH$ and $CH_3CH(NH_2)COOH$ contain $–NH_2$ group and –COOH group. They are NOT functional group isomers.

Unit Exercise (p.82)

15 The structure of an organic compound is shown :



Which of the following statements about the compound is / are correct?

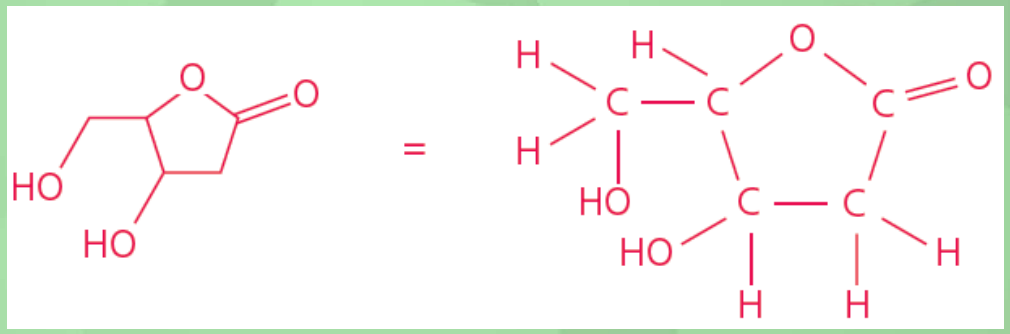
(1) Its molecular formula is $C_5H_6O_4$.
(2) It has two chiral centres.
(3) It contains a ketone group.

Answer: B

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

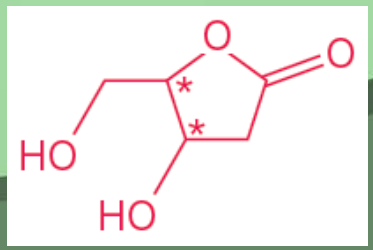
Explanation:

(1)



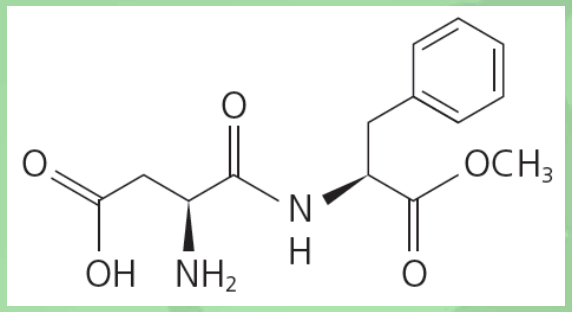
The molecular formula of the compound is $C_5H_8O_4$.

(2) The compound has two chiral centres.



Unit Exercise (p.82)

16 Aspartame is an artificial sweetener. The structure of it is shown below:



Which of the following statements concerning an aspartame molecule is / are correct?

(1) It has two ester groups.
(2) It has two chiral centres.
(3) It has two amide groups.

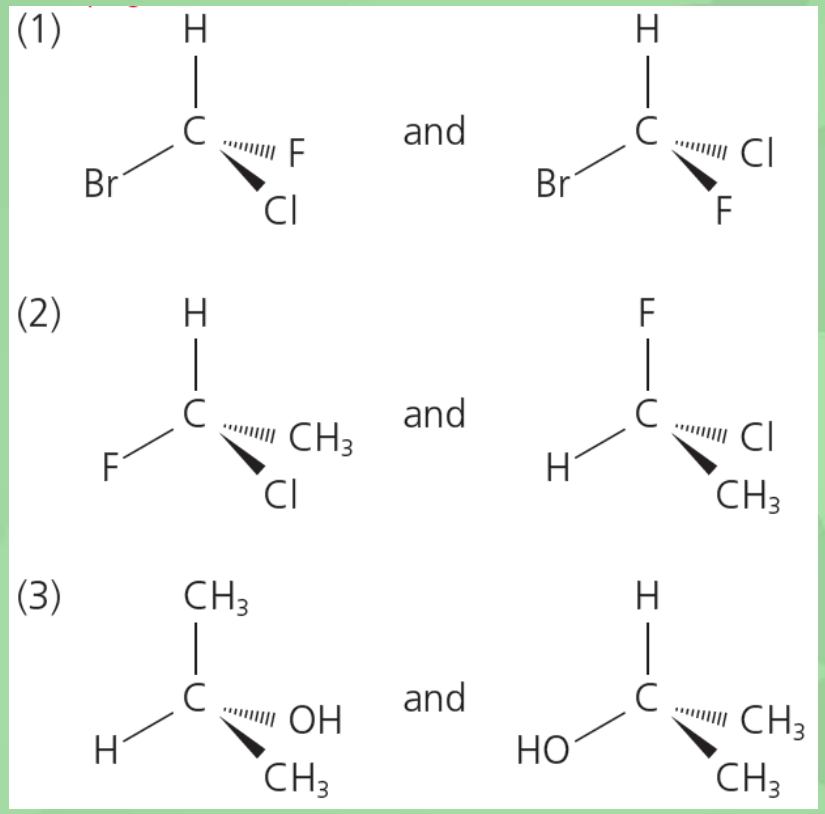
A (1) only
B (2) only
C (1) and (3) only
D (2) and (3) only

Answer: B

(HKDSE, Paper 1A, 2016, 32)

Unit Exercise (p.82)

17 In which of the following pairs are they enantiomers of each other?



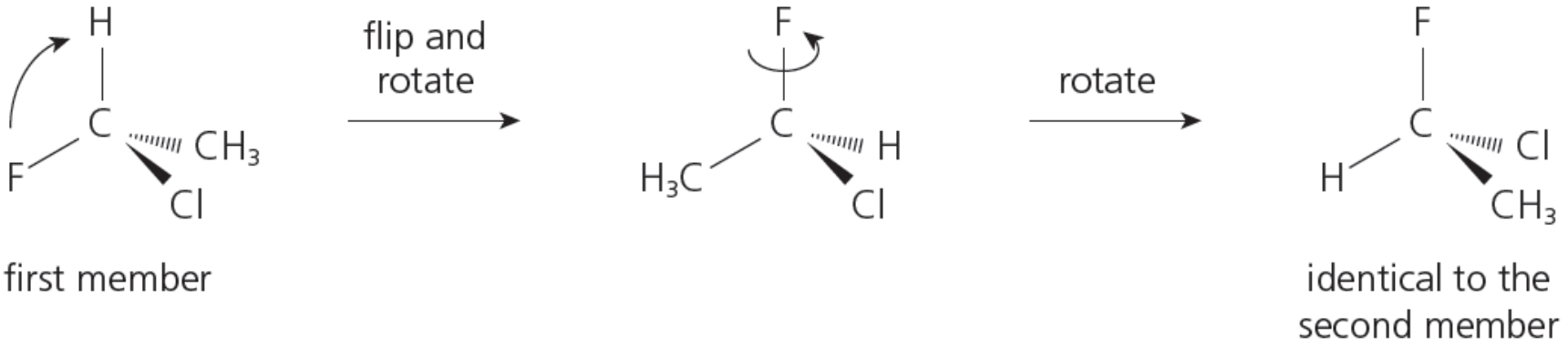
A (1) only
B (2) only
C (1) and (3) only
D (2) and (3) only

Explanation:
Refer to the next slide.

Answer: A

Unit Exercise (p.82)

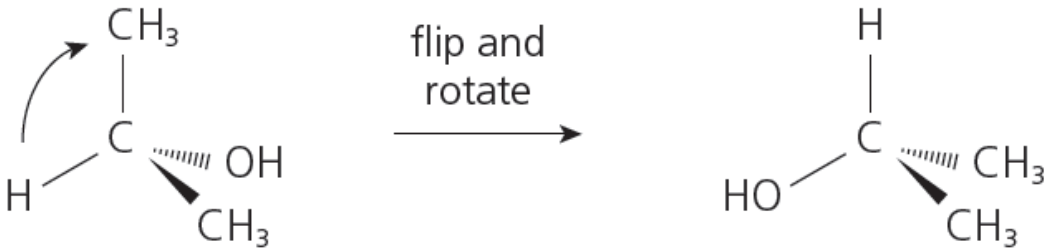
(2) The two members are identical.



first member

identical to the second member

(3) The two members are identical.



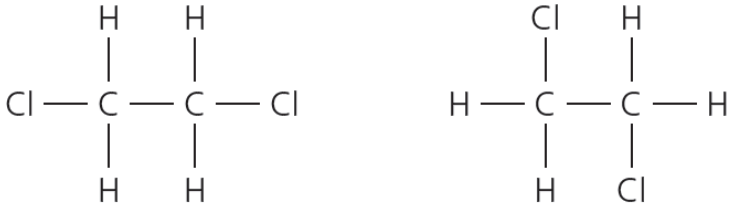
first member

identical to the second member

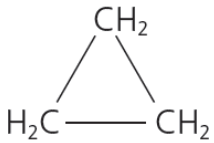
Unit Exercise (p.82)

PART III STRUCTURED QUESTIONS

18 Examine each of the following pairs of structures. Decide if the two are identical, isomers or different compounds.

a) 

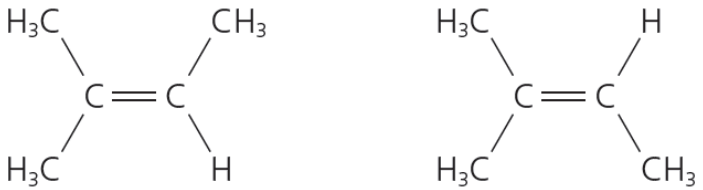
Identical (1)

b) $CH_3CH{=}CH_2$ 

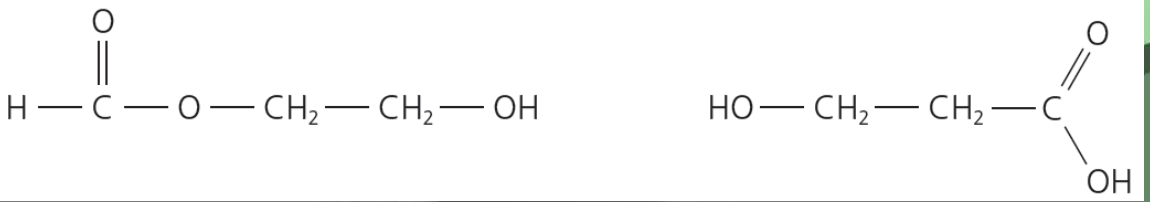
Isomers (1)

c) $CH_3CH_2NH_2$ CH_3NHCH_3

Isomers (1)

d) 

Identical (1)

e) 

Isomers (1)

Unit Exercise (p.82)

19 Write the structural formula of each of the following carbon compounds.

a) The hydrocarbon that is a chain isomer of methylpropene, but does not exhibit *cis-trans* isomerism.

$CH_3CH_2CH=CH_2$ (1)

b) The alcohol that is a position isomer of butan-2-ol.

$CH_3CH_2CH_2CH_2OH$ (1)

c) An ester that is a functional group isomer of butanoic acid.

Any one of the following:

$CH_3COOCH_2CH_3$ (1)

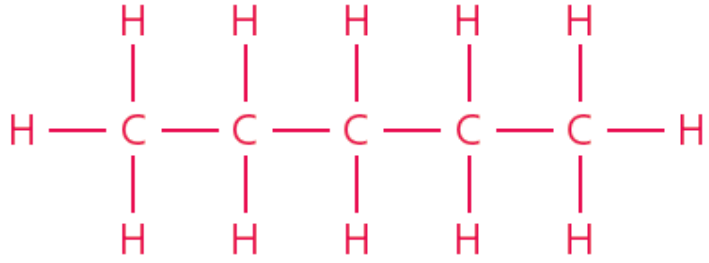
$CH_3CH_2COOCH_3$ (1)

$HCOOCH_2CH_2CH_3$ (1)

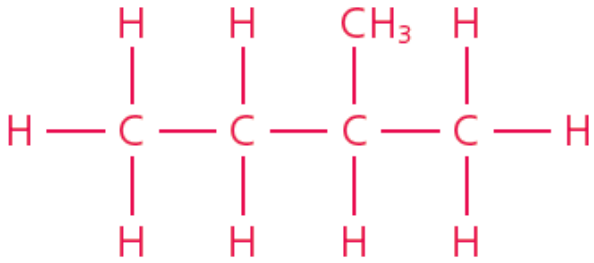
$HCOOCH(CH_3)_2$ (1)

Unit Exercise (p.82)

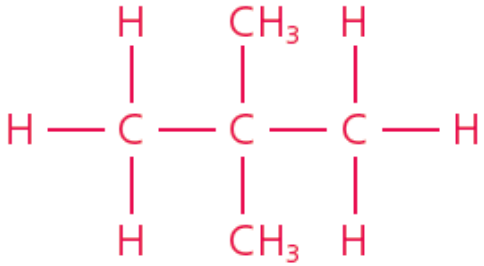
20 How many structural isomers have the molecular formula C_5H_{12}?
Give the structural formulae and systematic names of the isomers.



(1)



(1)



(1)

Three isomers:

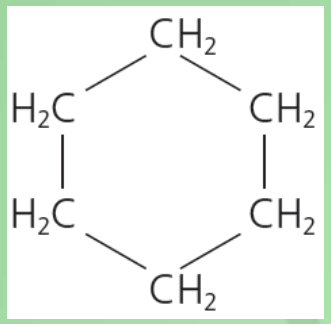
pentane, (1)

2-methylbutane and (1)

dimethylpropane (1)

Unit Exercise (p.82)

21 Four structural isomers with the molecular formula C_6H_{12} are shown:



Isomer W

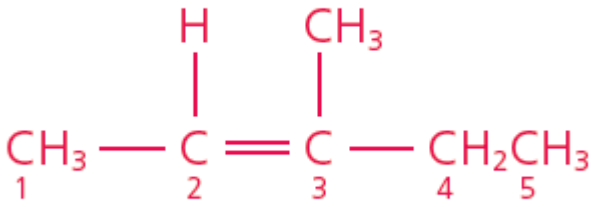
Isomer X $CH_3CH_2CH_2CH_2CH{=}CH_2$

Isomer Y $CH_3CH{=}C(CH_3)CH_2CH_3$

Isomer Z $(CH_3)_2C{=}C(CH_3)_2$

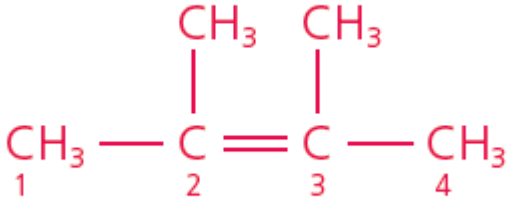
a) Give the systematic names of isomers Y and Z.

a) Isomer Y



3-methylpent-2-ene (1)

Isomer Z



2,3-dimethylbut-2-ene (1)

Unit Exercise (p.82)

b) State the meaning of the term 'structural isomers'.
Structural isomers are two or more compounds that have the same molecular formula but the atoms are bonded together in different orders (i.e. with different structures). (1)

c) State the type of structural isomerism shown by W when it is compared with the other isomers. Functional group isomerism (1)

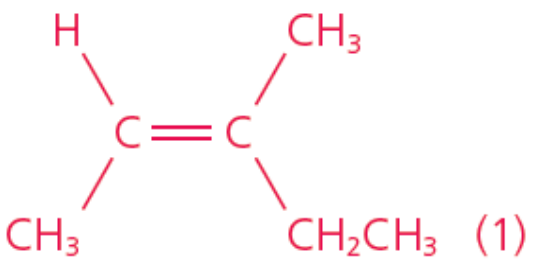
d) Write the structural formula of a position isomer of X.
$CH_3CH_2CH{=}CHCH_2CH_3$ or $CH_3CH_2CH_2CH{=}CHCH_3$ (1)

e) Isomer Y exists as stereoisomers.

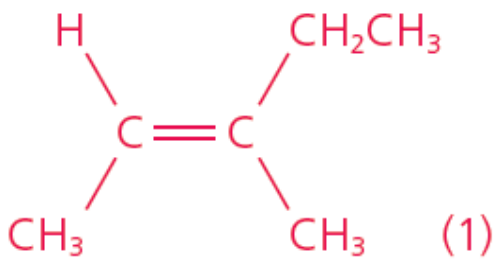
i) State the meaning of the term 'stereoisomers'.
Stereoisomers are isomers whose atoms are bonded together in the same order but the arrangement of the atoms in space is different. (1)

ii) Draw the structures of the two forms of Y.

e) ii)



(1)



(1)

Unit Exercise (p.82)

f) Suggest a chemical test that can be used to distinguish between separate samples of isomers W and X. State your expected observations.

Any one of the following:

• Add yellow-brown aqueous bromine to each isomer separately and shake. (1)

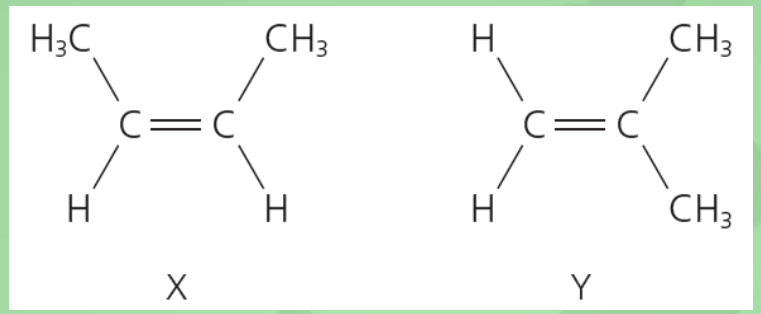
The yellow-brown aqueous bromine becomes colourless quickly when added to isomer X.
Isomer W gives no observable change. (1)

• Add a purple solution of cold acidified dilute potassium permanganate solution to each isomer separately and shake. (1)

The purple solution of potassium permanganate becomes colourless quickly when added to isomer X.
Isomer W gives no observable change. (1)

Unit Exercise (p.82)

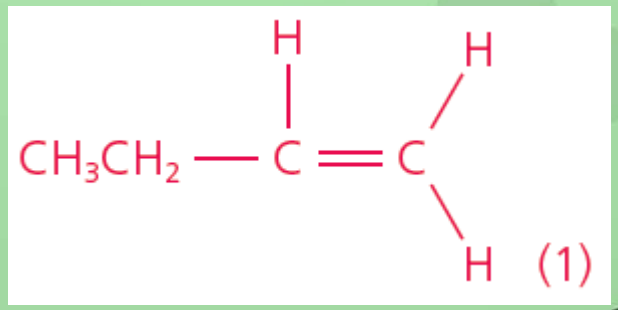
22 The structural formulae of two alkenes that are structural isomers are shown below:



a) Explain why these two alkenes are structural isomers.

They have the same molecular formula but their atoms are bonded together in different orders. (1)

b) Write the structural formula of an alkene that is another structural isomer of these two alkenes.



(1)

Unit Exercise (p.82)

c) Alkene X is one of a pair of *cis-trans* isomers.

i) Write the skeletal formula of the other isomer.

ii) Explain why $CH_3CH=CHCH_3$ can exhibit *cis-trans* isomerism while butane and propene cannot.

But-2-ene contains a carbon-carbon double bond while butane does not. There is restricted rotation of atoms or groups around a carbon-carbon double bond. (1)

In $CH_3CH=CHCH_3$, there are two different atoms or groups on each carbon atom of the carbon-carbon double bond.

In $CH_3CH=CH_2$, one carbon atom of the carbon-carbon double bond has two hydrogen atoms attached. (1)

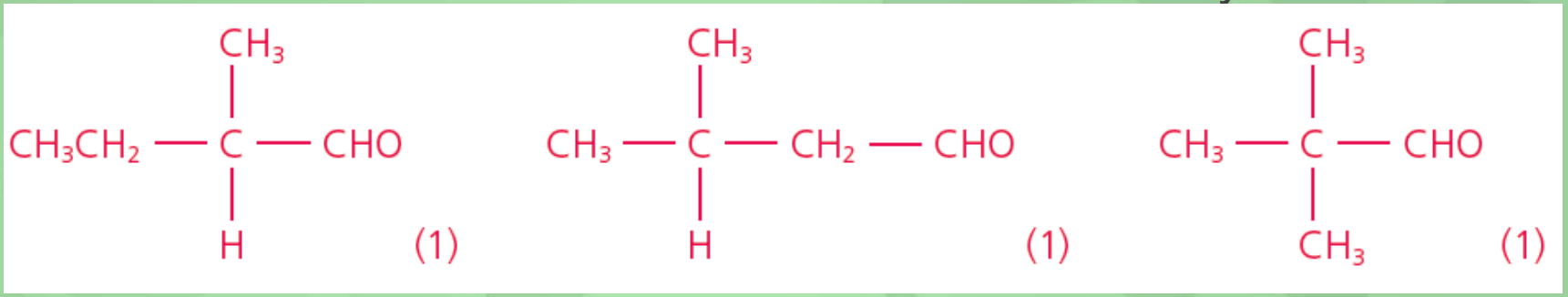
Unit Exercise (p.82)

23 The following compounds have the same molecular formula $C_5H_{10}O$.

W $CH_3CH_2COCH_2CH_3$ X $CH_3CH_2CH_2CH_2CHO$

Y $CH_3CH_2CH{=}CHCH_2OH$ Z $CH_2{=}CHCH_2CH(OH)CH_3$

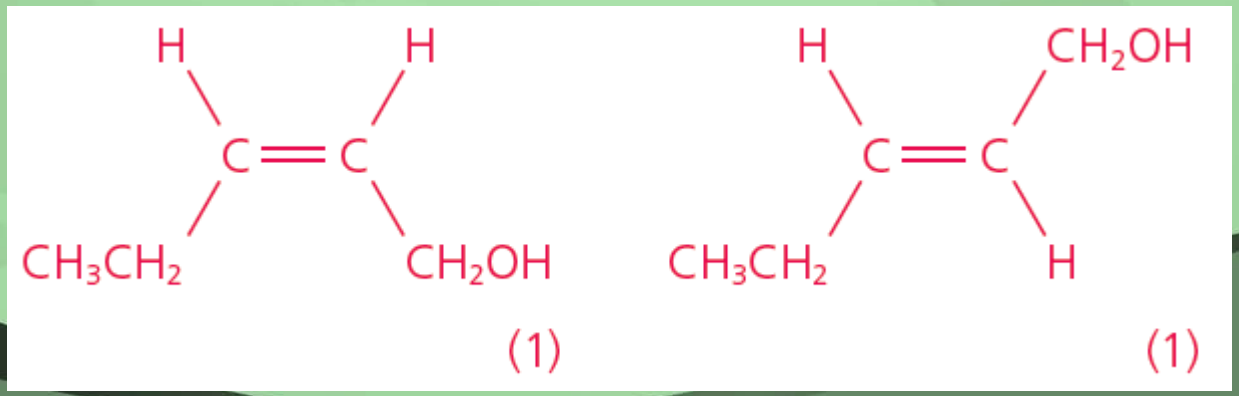
a) Write the structure of an isomer of X that is also an aldehyde.



b) i) State which one of the compounds exhibits *cis-trans* isomerism.

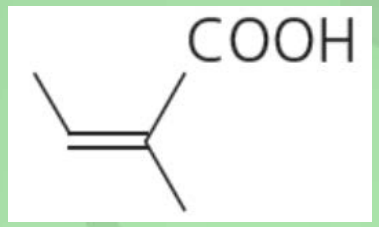
ii) Draw the structures of both isomers.

Y (1)



Unit Exercise (p.82)

24 Angelic acid is the traditional name for a compound produced by some plants as a defence against attack by beetles.

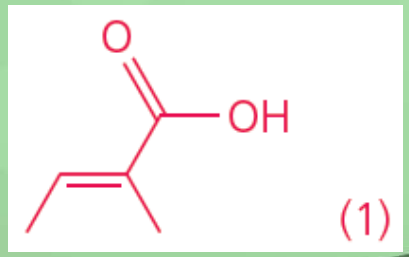


angelic acid

a) The acid is one of a pair of stereoisomers.
Explain 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)

b) Write the skeletal formula of the other stereoisomer of angelic acid.

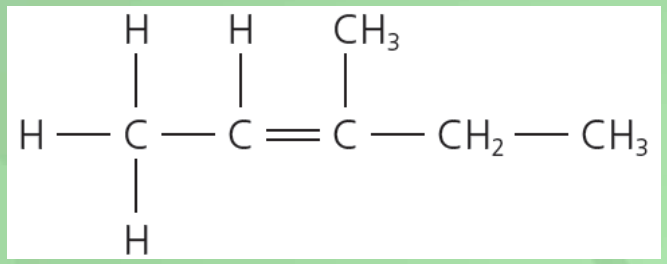


(1)

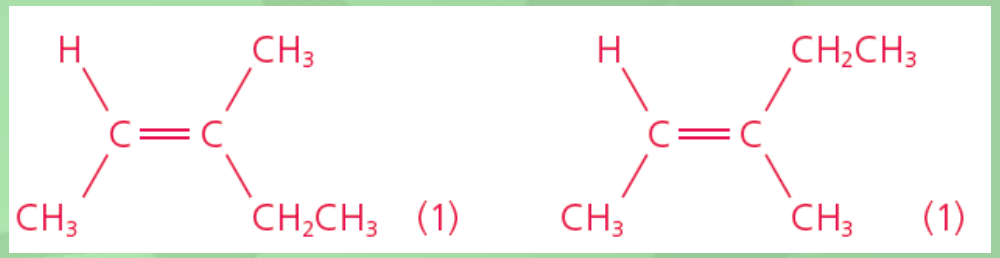
Unit Exercise (p.82)

25 Which of the following compounds can exhibit *cis-trans* isomerism? If the compound can exhibit *cis-trans* isomerism, draw the *cis* and *trans* forms.

a)

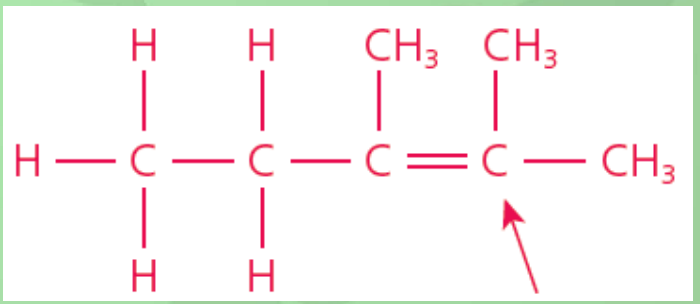


Yes



b) 2,3-dimethylpent-2-ene

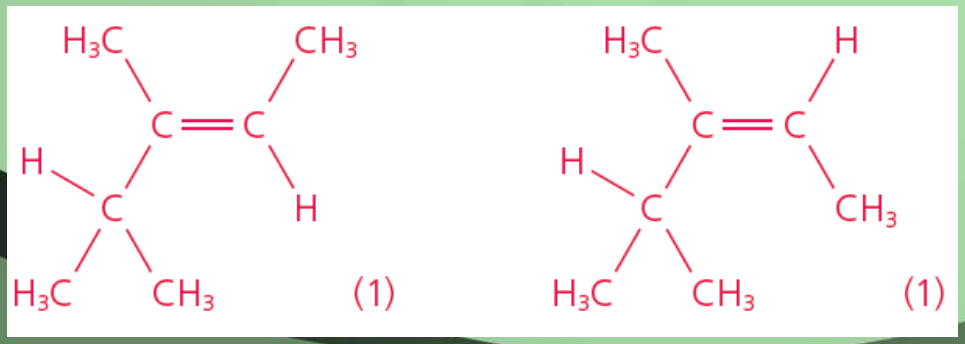
No



this carbon atom has two methyl groups attached (1)

c) 3,4-dimethylpent-2-ene

Yes



Unit Exercise (p.82)

26 There are several alkenes with the molecular formula C_5H_{10}. The alkenes are described as structural isomers. Some compounds with molecular formula C_5H_{10} can exhibit *cis-trans* isomerism.

a) What are 'structural isomers'?

Structural isomers are two or more compounds that have the same molecular formula but the atoms are bonded together in different orders (i.e. with different structures). (1)

b) Give the structural formula and systematic name for an alkene of C_5H_{10} which does not exhibit *cis-trans* isomerism.

Correct structure

e.g.

$CH_3CH_2CH_2CH=CH_2$ (1)	pent-1-ene (1)
$CH_3CH_2C(CH_3)=CH_2$ (1)	2-methylbut-1-ene (1)
$(CH_3)_2CHCH=CH_2$ (1)	3-methylbut-1-ene (1)
$(CH_3)_2C=CHCH_3$ (1)	2-methylbut-2-ene (1)

Unit Exercise (p.82)

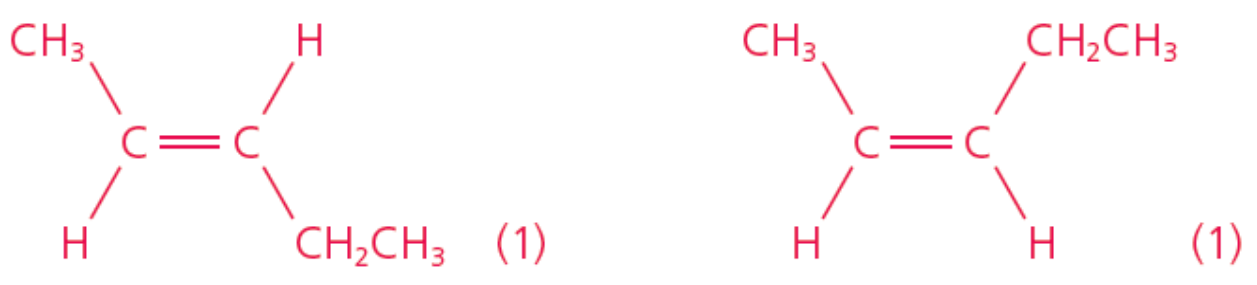
c) *Cis-trans* isomers are stereoisomers.

i) Give the systematic name for an alkene of C5H10 which exists as *cis-trans* isomers. Pent-2-ene

ii) Give TWO reasons why this alkene exists as *cis-trans* isomers.

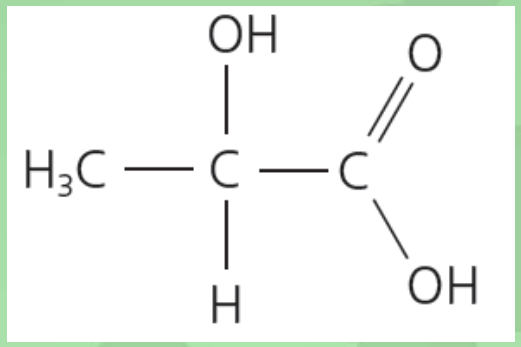
- It contains a carbon-carbon double bond. There is restricted rotation of atoms or groups around the carbon-carbon double bond. (1)
- There are two different atoms or groups on each carbon atom of the carbon-carbon double bond. (1)

iii) Draw the structures of the two *cis-trans* isomers.



Unit Exercise (p.82)

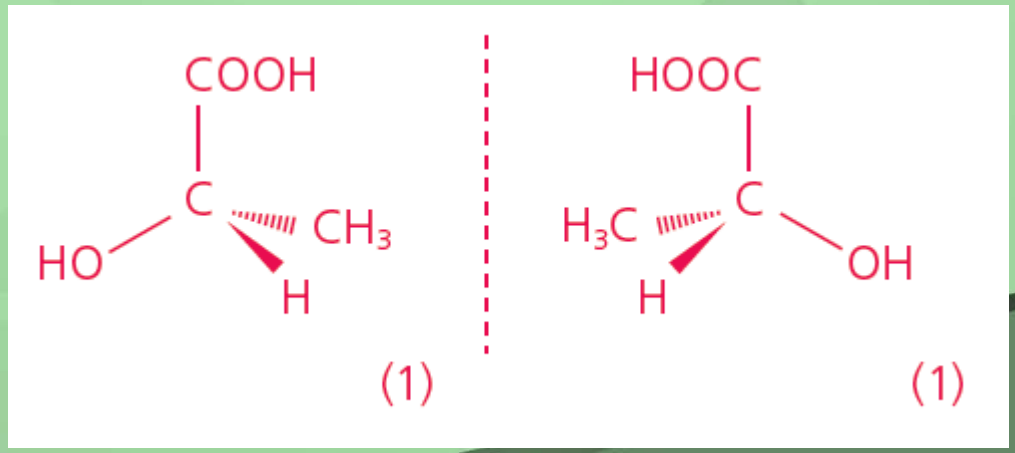
27 Lactic acid shown below is a naturally-occurring compound that shows optical activity.



a) Explain what is meant by 'a compound that shows optical activity'.

A compound that can rotate the plane of polarisation of plane-polarised light (1)

b) Draw diagrams to show the three-dimensional structures of isomers of lactic acid.



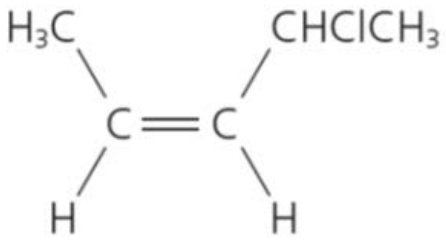
Unit Exercise (p.82)

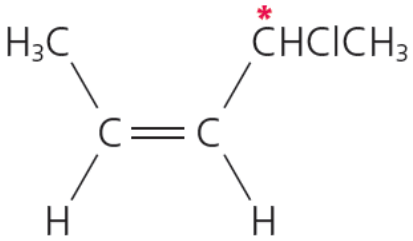
28 Mark all the chiral centres in the compounds below by using '*'.

a) $CH_3CHBrCl$

$CH_3\overset{*}{C}HBrCl$ (1)

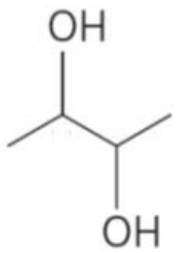
b)

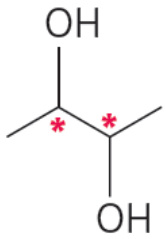




(1)

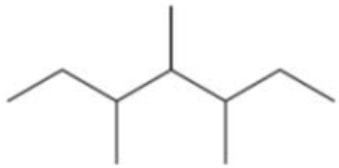
c)

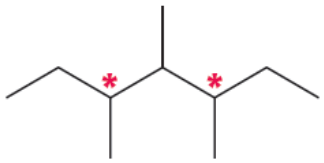




(1)

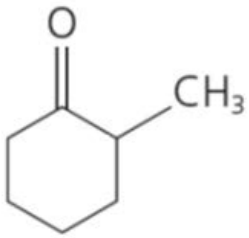
d)

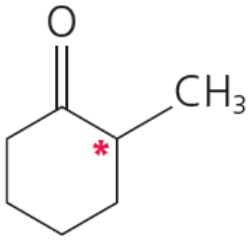




(1)

e)

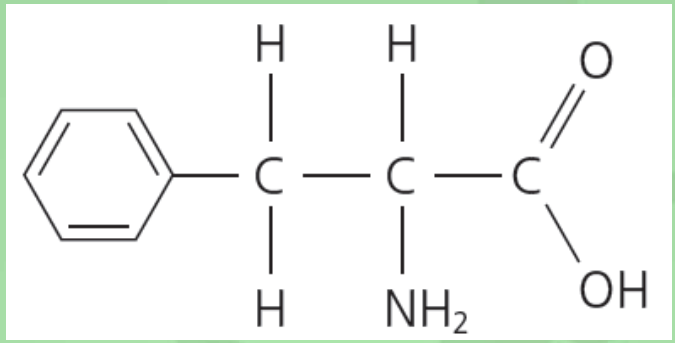




(1)

Unit Exercise (p.82)

29 The structure of phenylalanine is shown below.



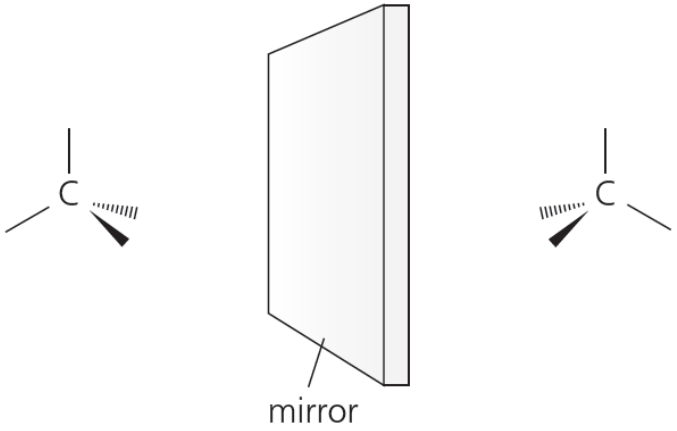
Phenylalanine has two stereoisomers.

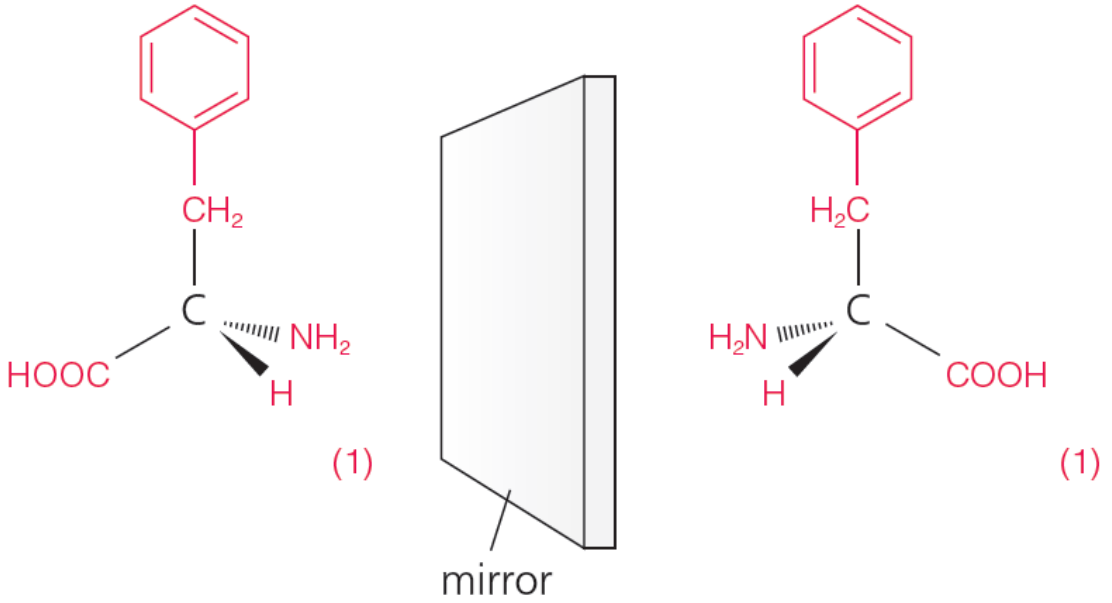
a) What is the name of the type of stereoisomerism shown by phenylalanine?

Enantiomerism (1)

Unit Exercise (p.82)

b) Complete the structures below to show the three-dimensional arrangements of the two stereoisomers of phenylalanine.



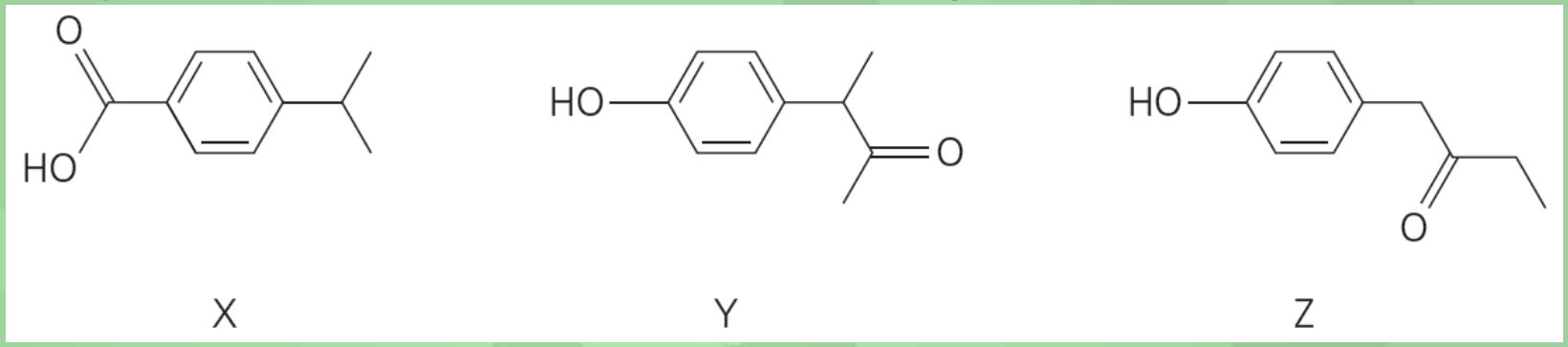


c) State ONE difference in physical properties of the two stereoisomers.

They rotate the plane of polarisation of plane-polarised light by the same amount but in opposite directions, one clockwise and the other anticlockwise. (1)

Unit Exercise (p.82)

30 Three compounds with the molecular formula $C_{10}H_{12}O_2$ are shown below.



a) Name the functional groups X and Y contain.

X: carboxyl group (1)

Y: hydroxyl group, carbonyl group (1+1)

b) Write the skeletal formula of an ester which is a structural isomer of the compounds above.

Any ester with the molecular formula $C_{10}H_{12}O_2$. Examples:

Unit Exercise (p.82)

c) Only one of the compounds exists as two enantiomers.

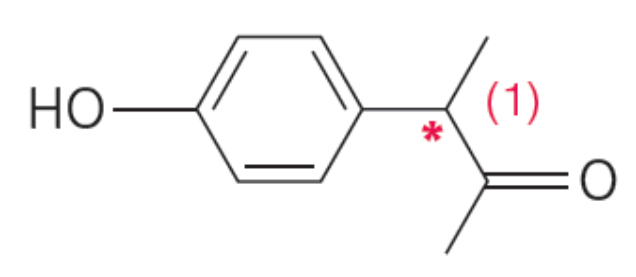
i) Identify the compound.

Y (1)

ii) Explain what is meant by the term 'enantiomers'.

Two molecules that are non-superposable mirror images of each other are called enantiomers. (1)

iii) Label the chiral centre in this compound by using '*'.

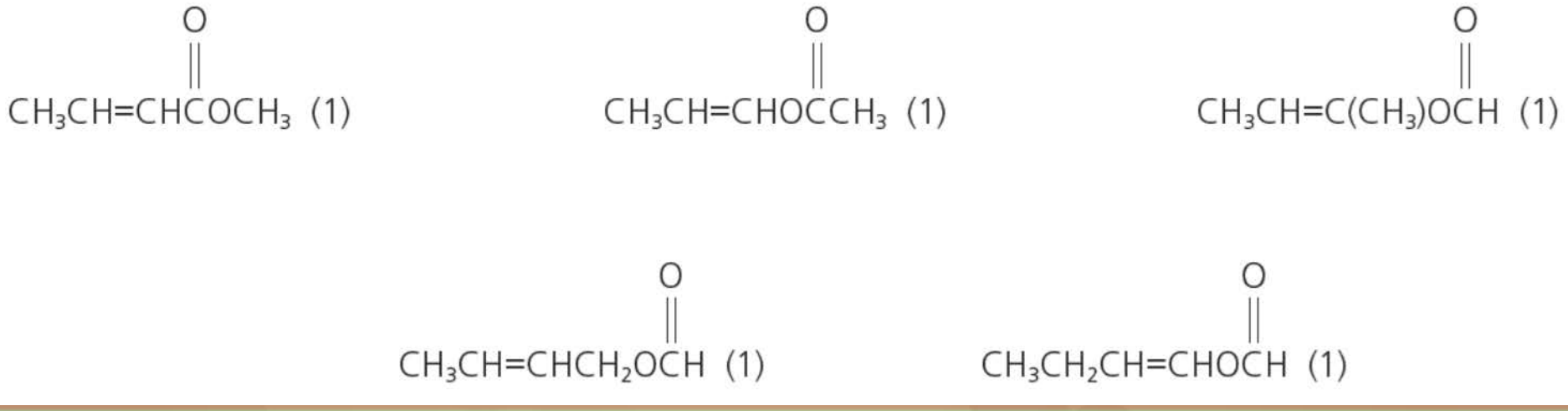


Unit Exercise (p.82)

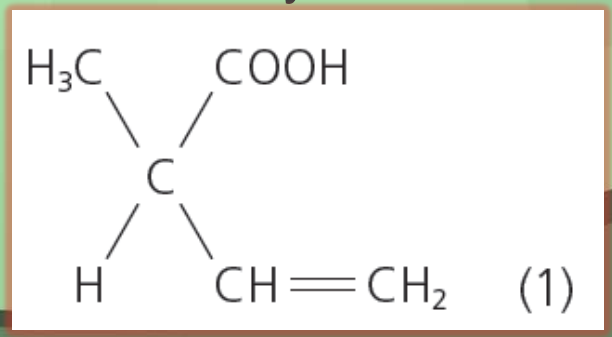
31 Write the structural formula of each of the following isomers of $C_5H_8O_2$.

a) X is an ester that exhibits *cis-trans* isomerism.

Any one of the following:



b) Y is an optically active carboxylic acid.



Unit Exercise (p.82)

32 Using $C_2H_5CH(OH)CH_3$ as an example, write a paragraph to illustrate 'enantiomerism'. Suitable diagram(s) should be included in your answer.

(HKDSE, Paper 1B, 2015, 13)

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