

Exercise walk-through

13.4

Isomerism: structural isomerism and stereoisomerism

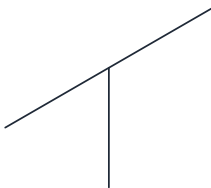
A-Level Chemistry

Structural isomerism

chain

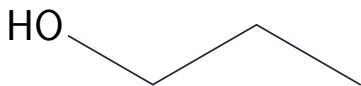


butane

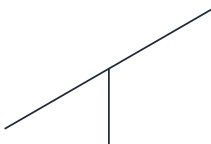


2-methylpropane

positional



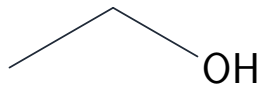
propan-1-ol



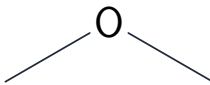
OH

propan-2-ol

functional



ethanol (alcohol)

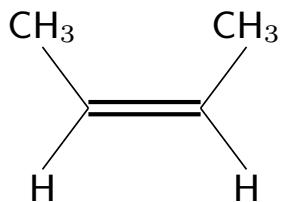


methoxymethane (ether)

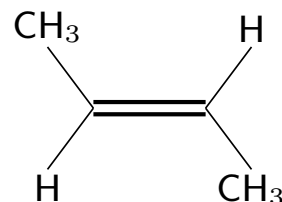
Same molecular formula, atoms joined differently:

- **chain**
- **positional**
- **functional group**

Stereoisomerism

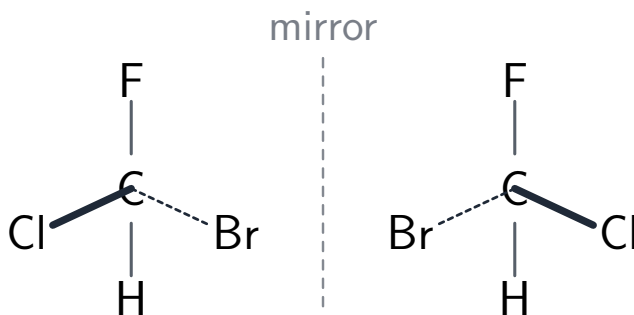


cis
both CH₃
same side

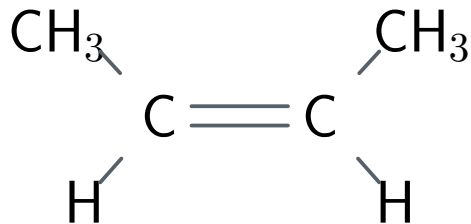


trans
CH₃
opposite sides

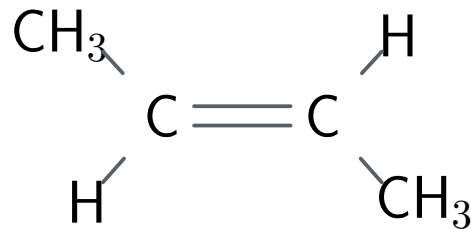
cis vs trans at C=C



Stereoisomerism, continued



cis: both CH₃ on
the same side



trans: CH₃ on
opposite sides

Cis-trans isomerism at a C=C bond: the methyl groups are fixed on the same side (cis) or opposite sides (trans) because the bond cannot rotate

Isomerism, and where stereoisomerism comes from

structural isomerism	the atoms are joined in a different order
chain, position, functional group	the three kinds – a different skeleton, a different position, or a different group entirely
stereoisomerism	the atoms are joined in the same order but point in different directions in space
<i>cis-trans</i>	restricted rotation about a C=C double bond, or around a ring (cyclic)
optical isomerism	a chiral centre : a carbon with four different groups
the test	a chiral molecule is non-superimposable on its mirror image, and rotates plane-polarised light

Look for the C=C or the four-different-groups carbon. At a C=C bond, check for two different groups on each carbon as well as restricted rotation.

The kinds of isomerism

Chain isomerism

Structural: the carbon skeleton is branched differently.

Positional isomerism

Positional isomerism : the same functional group sits on a different carbon.

Functional group isomerism

Functional group isomerism : the same atoms form a *different* functional group – an alcohol and an ether.

Geometrical isomerism

Stereo: **geometrical isomerism** (cis/trans) at a C=C double bond, because the double bond cannot rotate.

Optical isomerism

Stereo: a carbon with four different groups gives two non-superimposable mirror images.

saturated : only single C–C bonds. **unsaturated** : a C=C or C≡C is present.

Test each double-bond carbon separately

Your turn

But-1-ene is $\text{CH}_2=\text{CHCH}_2\text{CH}_3$. But-2-ene is $\text{CH}_3\text{CH}=\text{CHCH}_3$. Which has cis-trans isomers? Give both conditions and explain the difference.

Restricted rotation is necessary, but test the attached groups too.

Restricted rotation alone is insufficient

Molecule	Groups on C=C carbons	Result
But-1-ene	one carbon has H and H	no cis-trans pair
But-2-ene	each has H and CH ₃	cis and trans possible

Both have restricted rotation. Two different groups on each C=C carbon distinguish but-2-ene. Triple-bond unsaturation alone does not meet this test.

Worked example – structural isomers

Draw and name the structural isomers of C_4H_{10} , and state the type of isomerism.

- Straight chain: $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ – **butane**.
- Branched: $(\text{CH}_3)_3\text{CH}$ – **2-methylpropane**.
- There are **only two**: a 3-carbon chain cannot take a CH_3 anywhere else.
- Same molecular formula, different skeleton
 $\Rightarrow$ **chain isomerism**.

Isomers share a **molecular** formula. **Chain** = different skeleton; **position** = group moved; **functional group** = a different group entirely.

Exercises 2.1·3.1

2.1 Name the three kinds of structural isomerism.

[3]

2.2 State what is meant by a **chiral centre**.

[1]

3.1 Cis/trans isomerism is possible because:

[1]

☐

A single bonds cannot rotate

B the π bond in $\text{C}=\text{C}$ prevents rotation

C the molecule is ionic

D the carbons are sp^3 hybridised

Exercises 2.1·3.1

2.1 Name the three kinds of structural isomerism.

[3]

2.1

- chain; positional; functional group isomerism
-

2.2 State what is meant by a **chiral centre**.

[1]

2.2

- a carbon atom bonded to four different groups
-

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[1]

☐

A single bonds cannot rotate

B the π bond in $C=C$ prevents rotation

C the molecule is ionic

D the carbons are sp^3 hybridised

3.1 B

- The π bond in the $C=C$ prevents rotation

Exercise 3.2

3.2 Which compound has a chiral centre?

[1]

☐

A $\text{CH}_3\text{CH}_2\text{CH}_3$

B $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$

C $\text{CH}_3\text{CH}_2\text{OH}$

D CH_2Cl_2

Exercise 3.2

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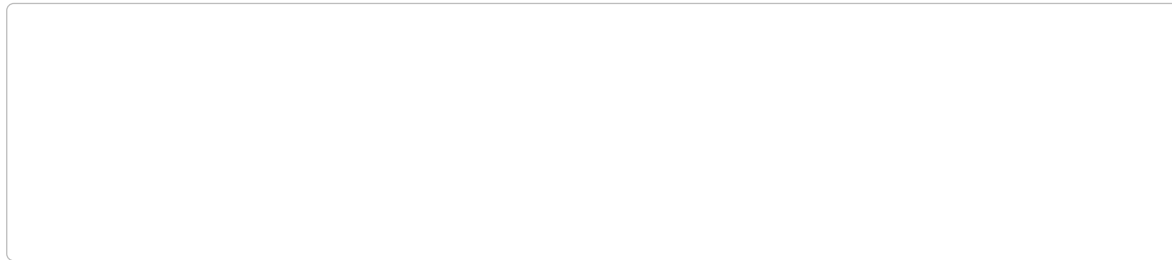
D CH_2Cl_2

3.2 B

- The second carbon in $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$ has four different groups

Exercise 3.3

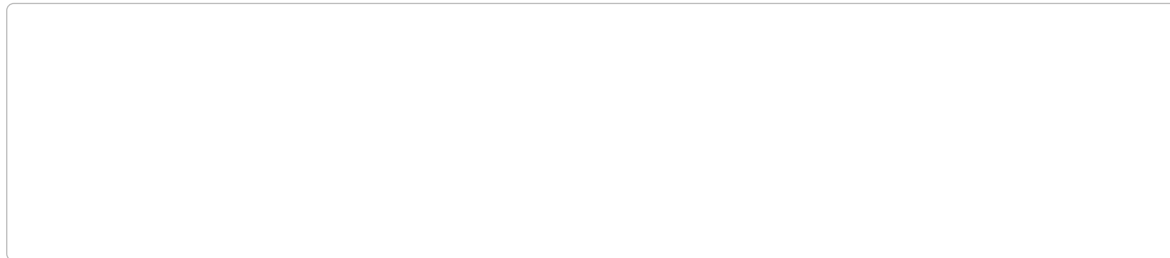
3.3 (a) Draw the cis and trans isomers of but-2-ene, $\text{CH}_3\text{CH}=\text{CHCH}_3$. [2]



(b) Explain why but-2-ene shows cis/trans isomerism but but-1-ene does not. [2]

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3.3 (a) Draw the cis and trans isomers of but-2-ene, $\text{CH}_3\text{CH}=\text{CHCH}_3$. [2]



(b) Explain why but-2-ene shows cis/trans isomerism but but-1-ene does not. [2]

3.3

(a)

- cis – both CH_3 groups on the same side of the $\text{C}=\text{C}$; trans – on opposite sides

(b)

- but-2-ene has a different group (H and CH_3) on each double-bond carbon, so cis/trans is possible; but-1-ene has two H atoms on the end carbon, so the groups can be swapped without making a new isomer

Exercise 3.4

3.4 2-hydroxypropanoic acid is $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$. State, with a reason, whether it has a chiral centre. [2]

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3.4 2-hydroxypropanoic acid is $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$. State, with a reason, whether it has a chiral centre. [2]

3.4

- yes; the second carbon is bonded to four different groups (CH_3 , OH , H , COOH), so it is a chiral centre