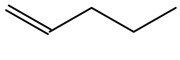
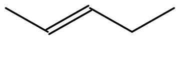
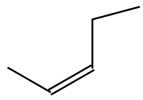
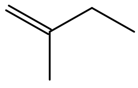
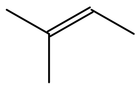
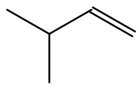
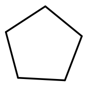
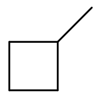
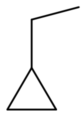
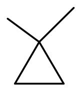
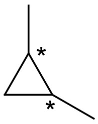
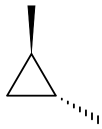
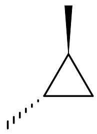
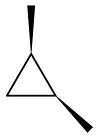
Raffles Institution
Year 5 H2 Chemistry 2025
Tutorial 9 – Introduction to Organic Chemistry

Suggested Solutions to Tutorial 9: Introduction to Organic Chemistry

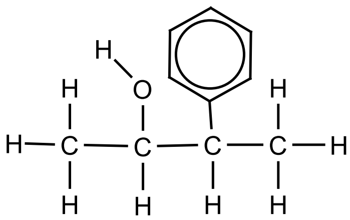
6. C_5H_{10} can either be an alkene (C_nH_{2n}) or a cycloalkane (C_nH_{2n}).

Steps to draw isomers of alkenes	Structures
(1) Draw **positional isomers** of pentene. **II** exhibits cis-trans isomerism. Draw its cis-isomer **III**.	 **I**  **II**  **III**
(2) Draw **positional isomers** of the branched chain	 **IV**  **V**  **VI**

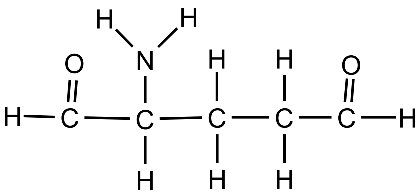
Steps to draw isomers of cycloalkanes	Structures
(1) Draw the cyclopentane (with the biggest number of carbon in the ring) and methylcyclobutane .	 **VII**  **VIII**
(2) Draw cyclopropane with one ethyl group and two methyl groups on the same C.	 **IX**  **X**
(3) Draw stereoisomers of 1,2-dimethylcyclopropane. This compound has 2 chiral carbons and will have a maximum of 2^2 = 4 stereoisomers. However, *cis*-1,2-dimethylcyclopropane (**XIII**) has a plane of symmetry and is a meso compound. Thus, there are only 3 stereoisomers for 1,2-dimethylcyclopropane. 	 **XI**  **XII**  **XIII**

Type of isomerism	Examples of isomers which exhibit the isomerism
Constitutional isomerism	I, IV, V, VI, VII, VIII, IX, X, (one of XI, XII or XIII) and (one of II or III)
Cis-trans isomerism	**II** and **III** ; **XI** (or **XII**) and **XIII**
Enantiomerism	**XI** and **XII**

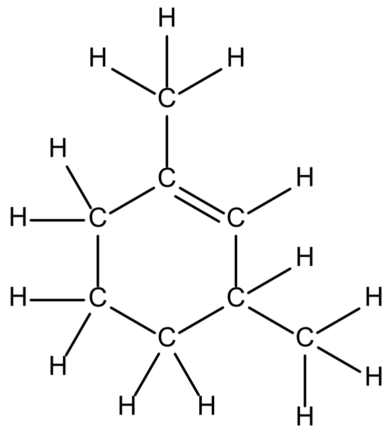
7a



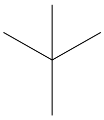
b



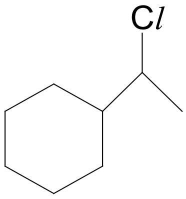
7c



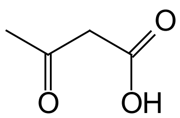
8 (a)



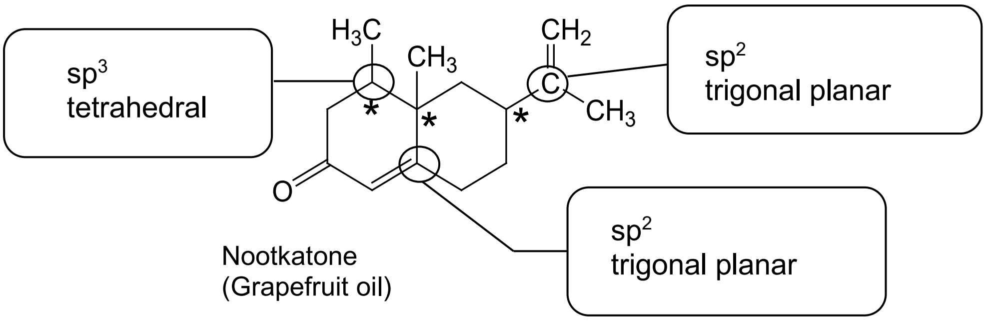
(b)



(c)

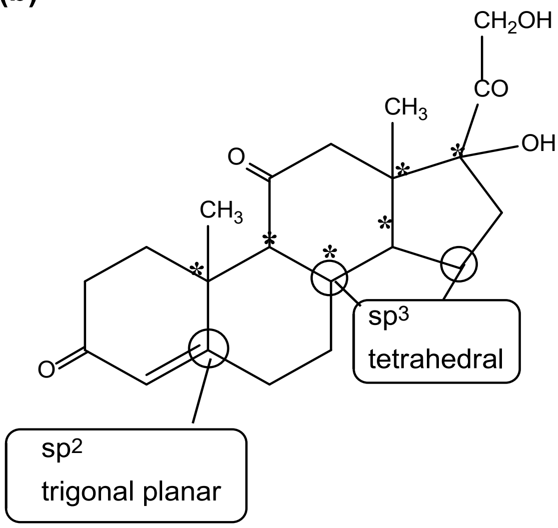


9(a)

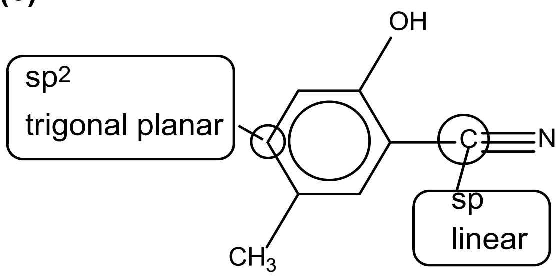


Nootkatone
(Grapefruit oil)

(b)

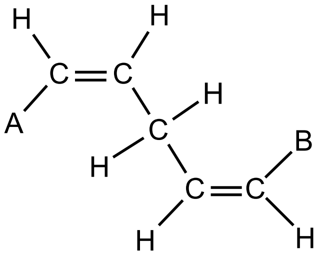


(c)

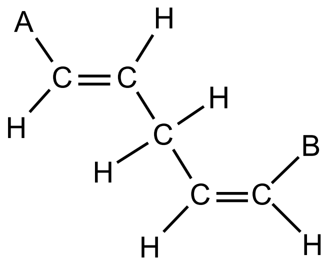


10. **(a)**	substitution	**(b)**	reduction	**(c)**	addition
(d)	elimination	**(e)**	substitution	**(f)**	elimination
(g)	hydrolysis	**(h)**	**step 1:** addition	**step 2:** substitution	

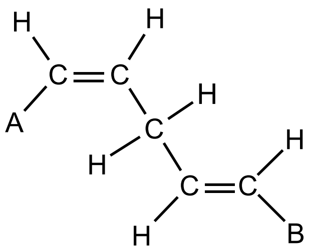
11



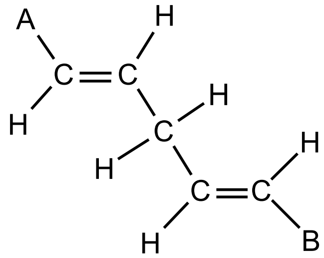
cis,cis-isomer



trans,cis-isomer



cis,trans-isomer



trans,trans-isomer

Note:

- As each C atom in the C=C bonds has two different groups attached to it, the maximum number of cis-trans isomers is $2^2 = 4$.]
- When drawing cis-trans isomers, the trigonal planar geometry around each sp^2 C in the C=C bonds must be shown.

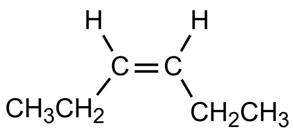
12(a) *Cis-trans* isomerism refers to the existence of two compounds with the same molecular and structural formulae but with different spatial arrangements of atoms due to restricted rotation about a double bond (e.g. C=C, C=N or N=N) or a bond in a ring structure. To exhibit *cis-trans* isomerism, the compound either has a double bond with two different groups attached to each of the two atoms in the double bond or a ring structure with two different groups attached to two atoms in the ring structure.

Enantiomerism refers to the existence of compounds with the same molecular and structural formulae but with different spatial arrangements of atoms and are non-superimposable mirror images of each other. Molecules do not have a plane of symmetry and usually contain one or more chiral centres. Enantiomers rotate plane-polarised light in opposite directions.

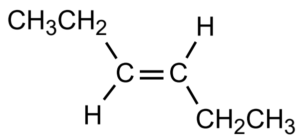
(b)(i) Hex-3-ene, $CH_3CH_2CH{=}CHCH_2CH_3$

Type of stereoisomerism: *cis-trans* isomerism   No of stereoisomers: 2

Hex-3-ene exhibits *cis-trans* isomerism since 2 different groups are attached to each of the carbon atoms in the C=C bond. Due to restricted rotation about the C=C bond, hex-3-ene has 2 stereoisomers:



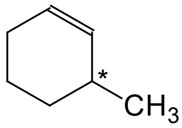
cis-hex-3-ene



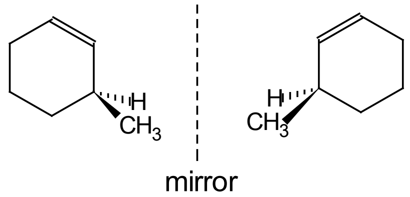
trans-hex-3-ene

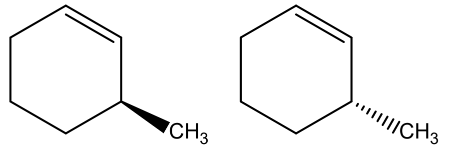
(ii) 3-methylcyclohexene

Type of stereoisomerism: Enantiomerism   No of stereoisomers: 2



3-methylcyclohexene has one chiral carbon and does not have a plane of symmetry. It forms mirror images that are non-superimposable and hence exhibits enantiomerism. It exists as 2 enantiomers:





can also be accepted.

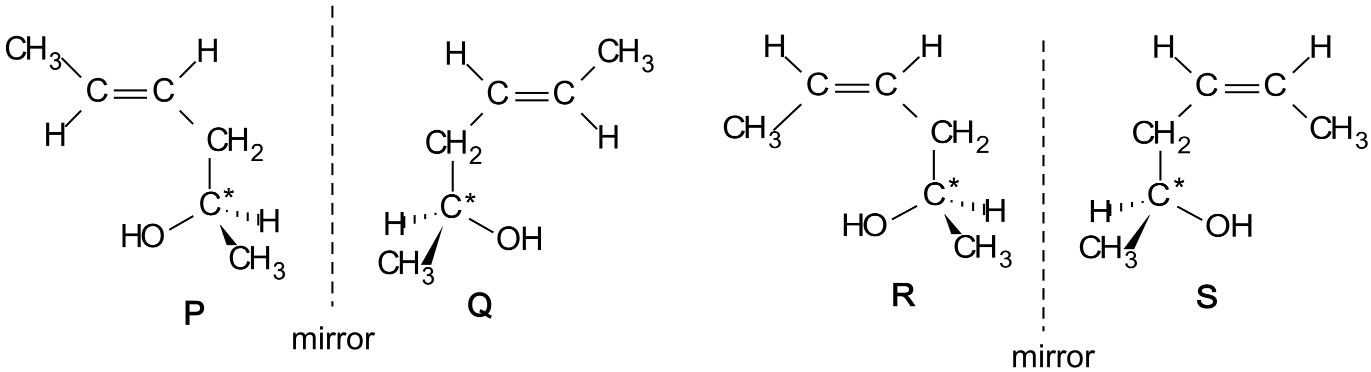
Note:
There is restricted rotation about the C=C bond in the ring and there are also two different groups attached to each C atom of the C=C bond. However, the trans-isomer does not exist in the case of cyclic alkene due to the presence of ring strain.

(iii) Type of stereoisomerism: *cis-trans* isomerism and enantiomerism

No of stereoisomers: 4

The compound has one C=C double bond with 2 different groups attached to each of the C in C=C bond ⇒ it exhibits *cis-trans* isomerism.
The compound has one chiral carbon and lacks a plane of symmetry. Thus it has mirror images that are non-superimposable ⇒ it exhibits enantiomerism.

Total number of stereoisomers = $2^2 = 4$:



Enantiomers: **P** and **Q**; **R** and **S**

Cis-trans isomers: **P** and **R**; **Q** and **S**

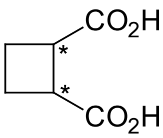
Self-practice:
Try drawing the skeletal formulae of the isomers.

(iv) Type of stereoisomerism: none

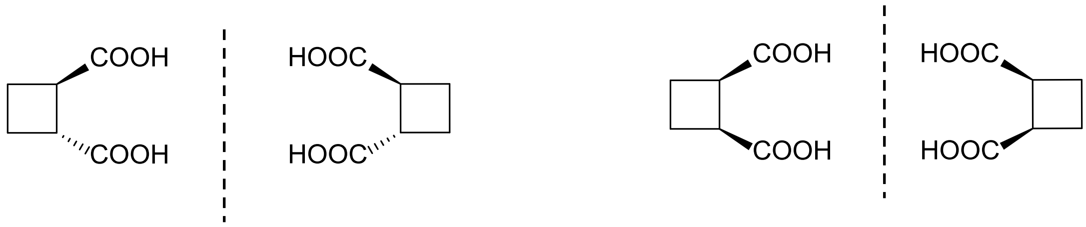
No of stereoisomers: not applicable

$(CH_3)_2C{=}CHCH_2CH(OH)CH_2CH{=}C(CH_3)_2$ does not exhibit enantiomerism as it has a plane of symmetry (or no chiral centre) and it does not exhibit cis-trans isomerism as one carbon in each of the C=C bonds has the same groups attached.

(v) Type of stereoisomerism: <u>*cis-trans* isomerism and enantiomerism</u>
No of stereoisomers: <u>3</u>



The compound has 2 chiral carbons and so, in theory, can have a maximum number of $2^2 = 4$ stereoisomers. However, this compound has only <u>3 stereoisomers</u>.



X **Y** **Z** **Z'**

mirror

Due to <u>restricted rotation about the bonds in the ring</u> and the <u>ring having two carbon atoms each attached to 2 different groups</u> (H and COOH), the compound exhibits *cis-trans* isomerism.

X (or **Y**) has <u>no plane of symmetry</u>. Therefore, it is not superimposable onto its mirror image, **Y** (or **X**). **X** and **Y** are non-superimposable mirror images of each other. **X** and **Y** are enantiomers.

However, one of the isomers, *cis*-cyclobutane-1,2-dicarboxylic acid (**Z**) has a <u>plane of symmetry</u>. **Z** is thus superimposable onto its mirror image (**Z'**). **Z** and **Z'** are thus <u>identical</u>. **Z** is a meso compound.

Enantiomers:	**X** and **Y**
Cis-trans isomers:	**X** (or **Y**) and **Z**