

**MSJChem**

**Tutorials for IB Chemistry**

**Topic 20**

**Organic chemistry HL**

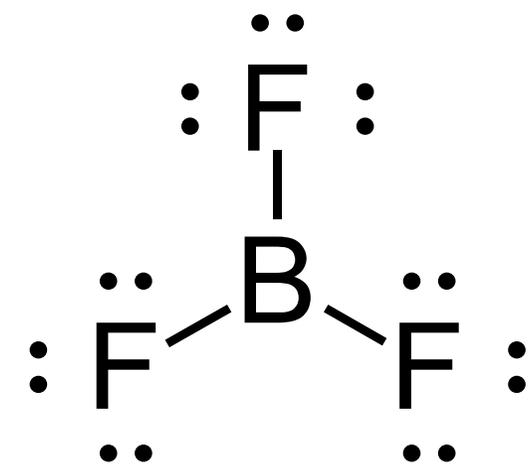
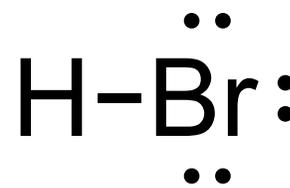
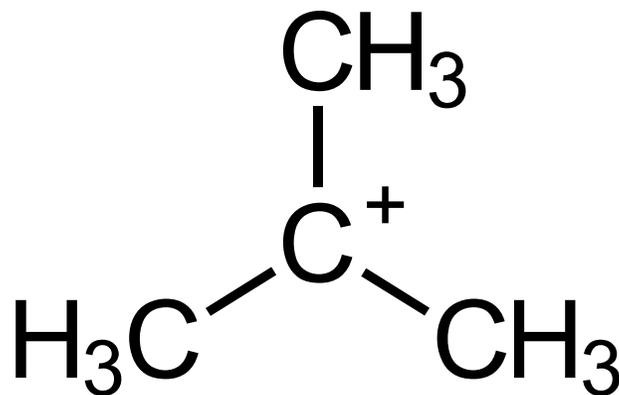
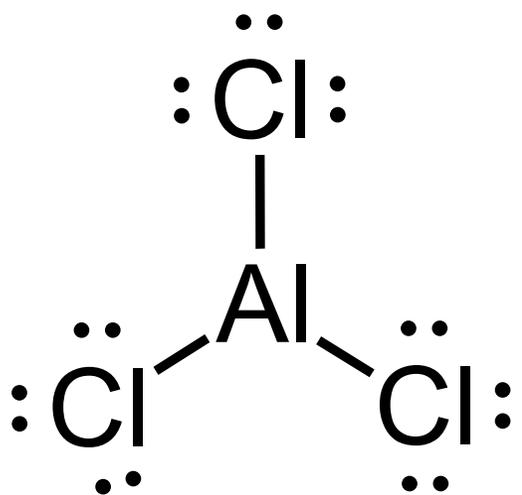
**MSJChem**

**Tutorials for IB Chemistry**

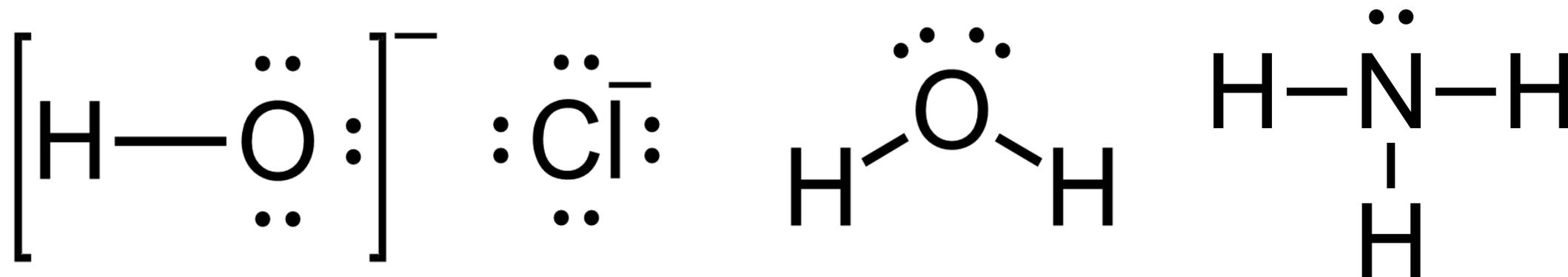
**Electrophiles and  
nucleophiles**

# Electrophiles and nucleophiles

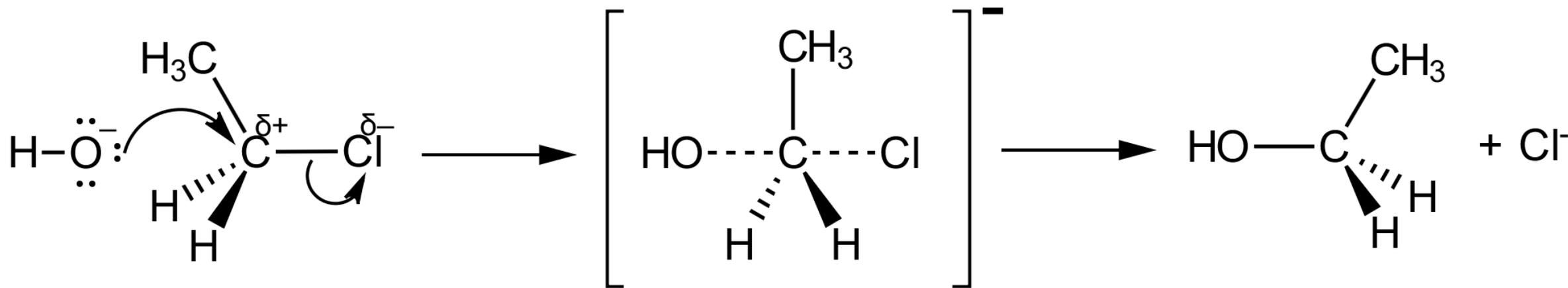
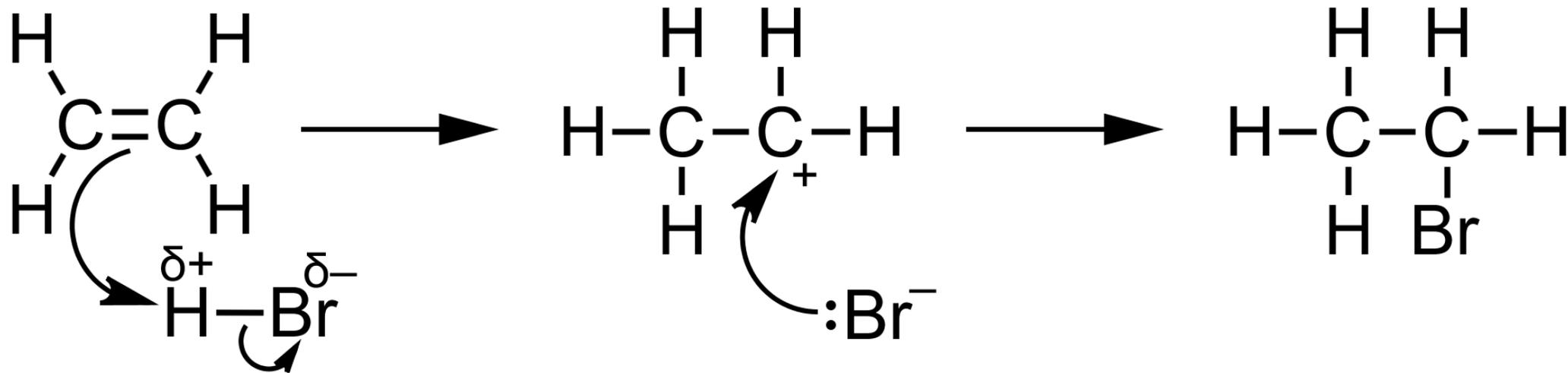
An electrophile is an electron deficient species that accepts a lone pair of electrons (Lewis acids). Electrophiles are attracted to regions of negative charge (C=C bond).



A nucleophile is an electron rich species that donates a lone pair of electrons (Lewis bases). Nucleophiles are attracted to regions of positive charge.



# Electrophiles and nucleophiles



# Electrophiles and nucleophiles

Many organic reactions can basically be described as 'nucleophile reacts with electrophile'.

Electrophiles have a positive charge or a partial positive charge and accept a lone pair of electrons.

Nucleophiles have a negative charge or a partial negative charge and donate a lone pair of electrons.

Reactions between electrophiles and nucleophiles result in the formation of a covalent bond

(electrophilic addition and nucleophilic substitution).

**MSJChem**

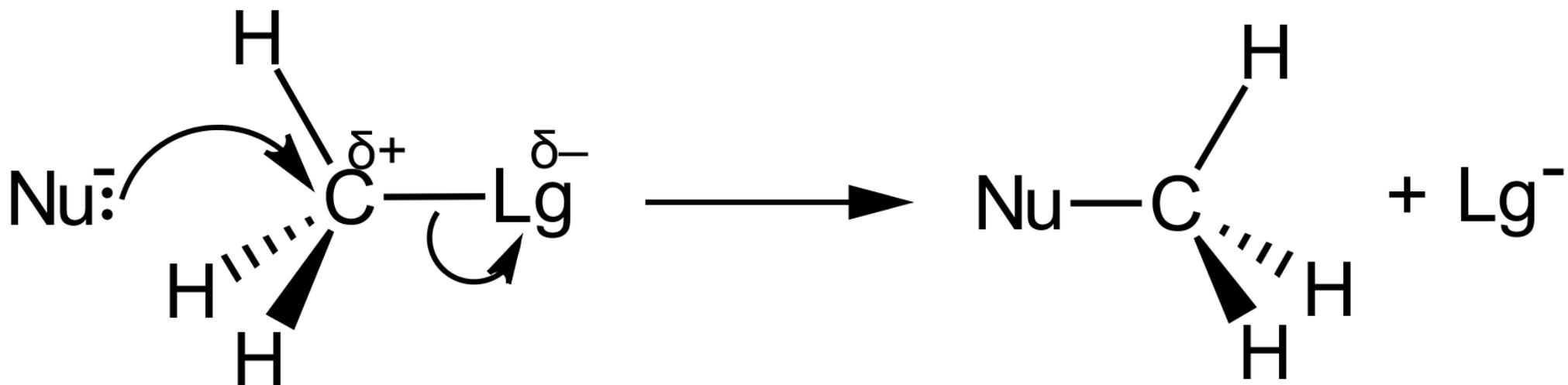
**Tutorials for IB Chemistry**

**Nucleophilic**

**substitution reactions**

# Nucleophilic substitution reactions

A nucleophilic substitution reaction ( $S_N$ ) involves the replacement of an atom (leaving group) by a nucleophile. Nucleophiles are electron rich species that are attracted to regions of positive charge.



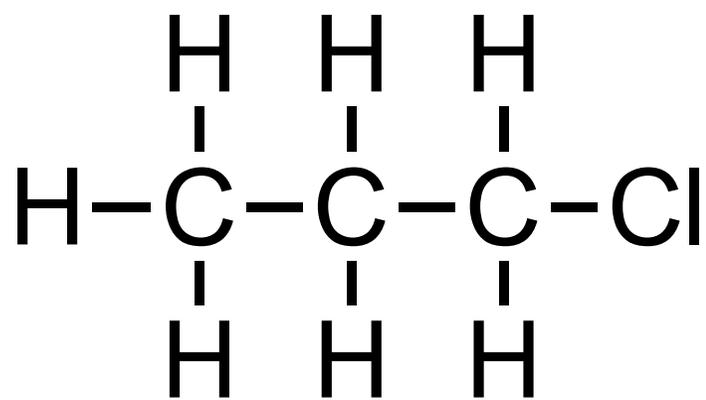
# Nucleophilic substitution reactions

Nucleophilic substitution reactions can occur via  $S_N1$  or  $S_N2$  mechanisms.

$S_N1$  stands for nucleophilic substitution unimolecular.

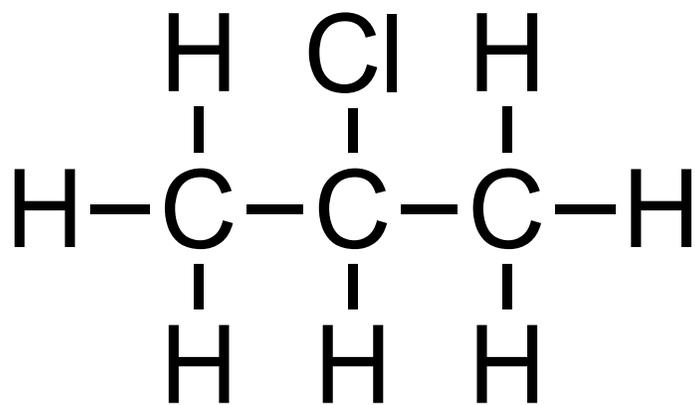
$S_N2$  stands for nucleophilic substitution bimolecular.

Primary halogenoalkane



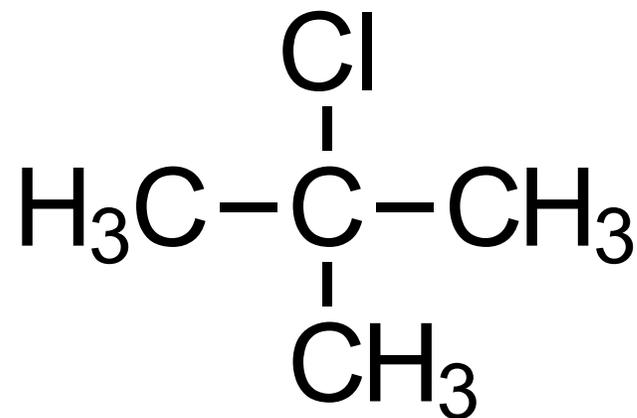
$S_N2$

Secondary halogenoalkane



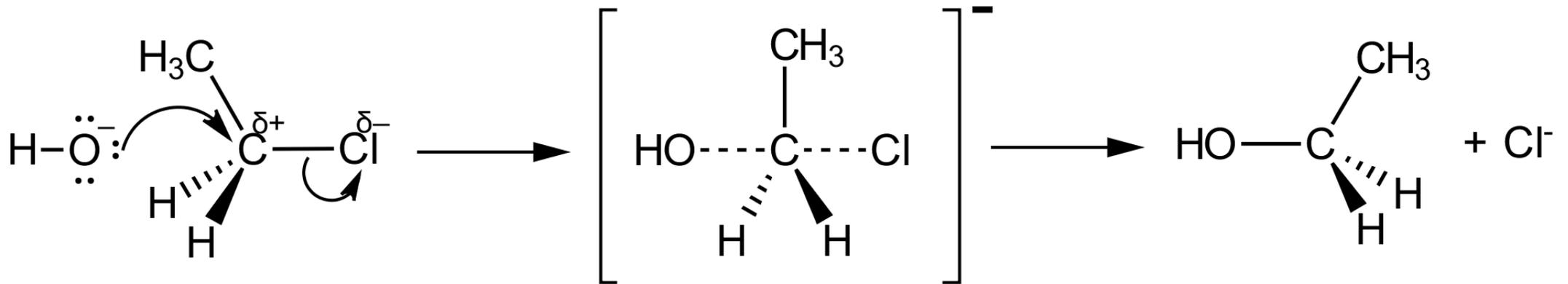
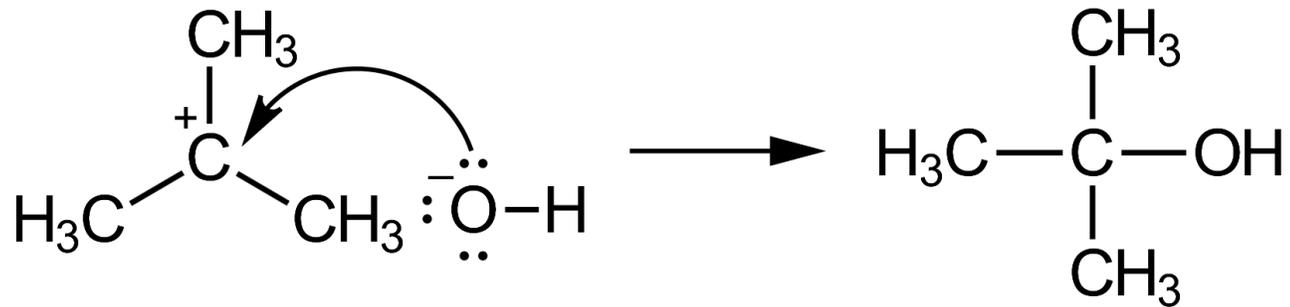
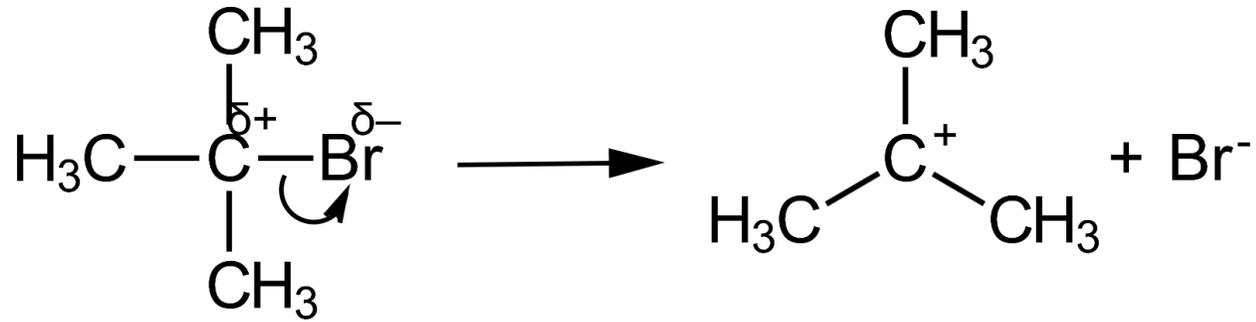
$S_N1 / S_N2$

Tertiary halogenoalkane



$S_N1$

# Nucleophilic substitution reactions

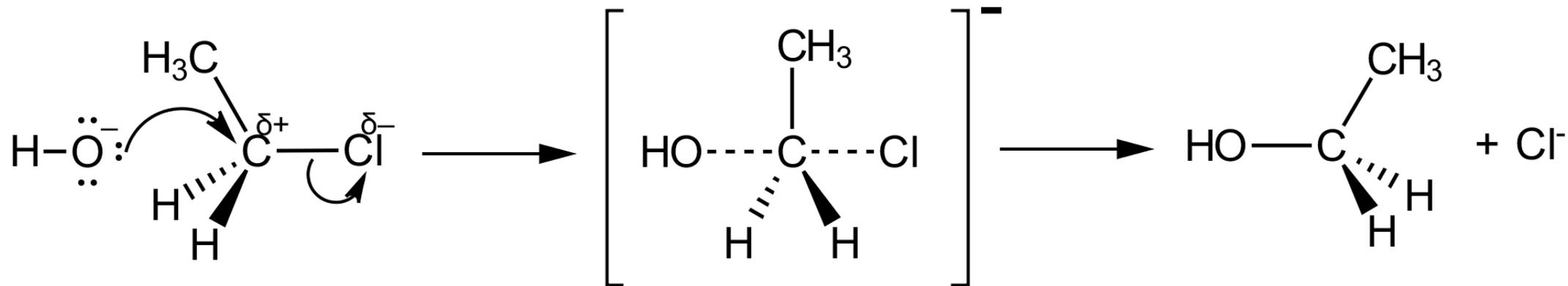
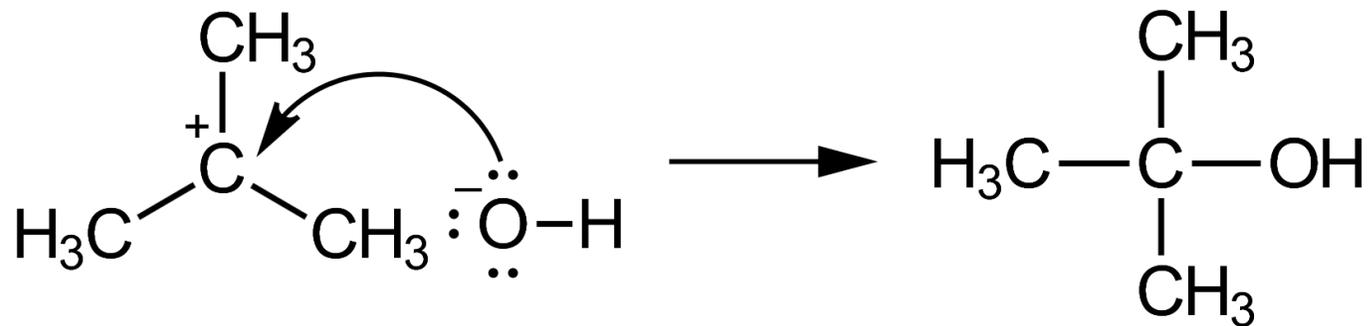
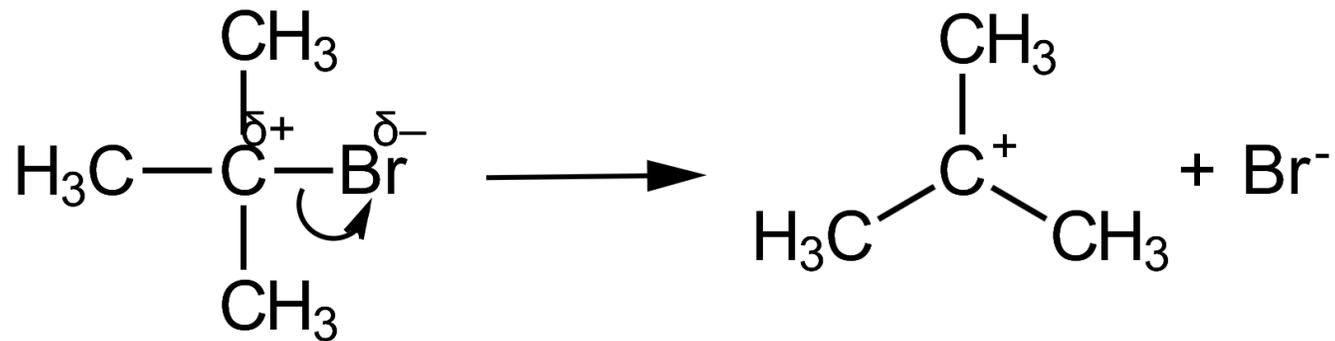


**MSJChem**

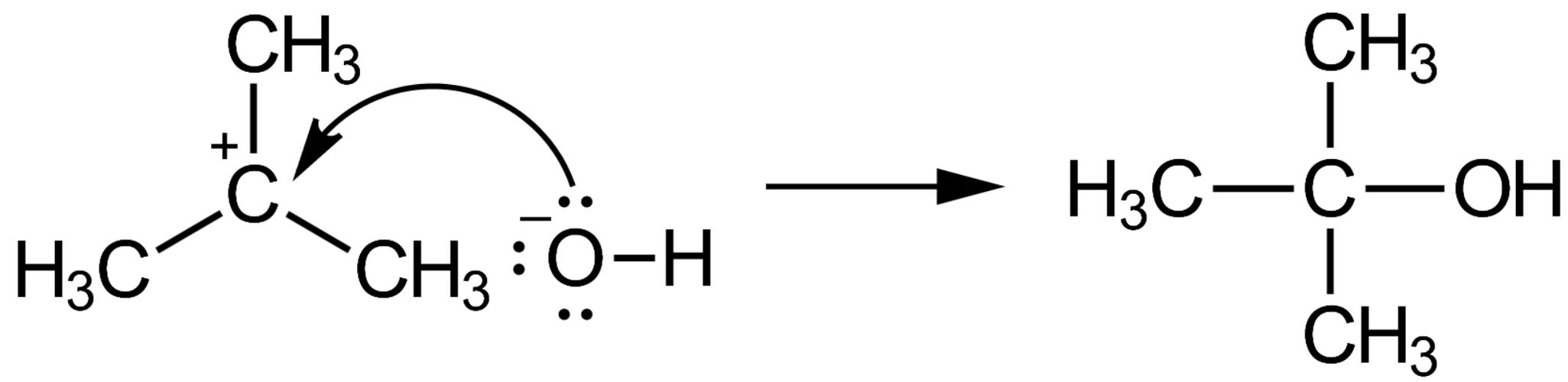
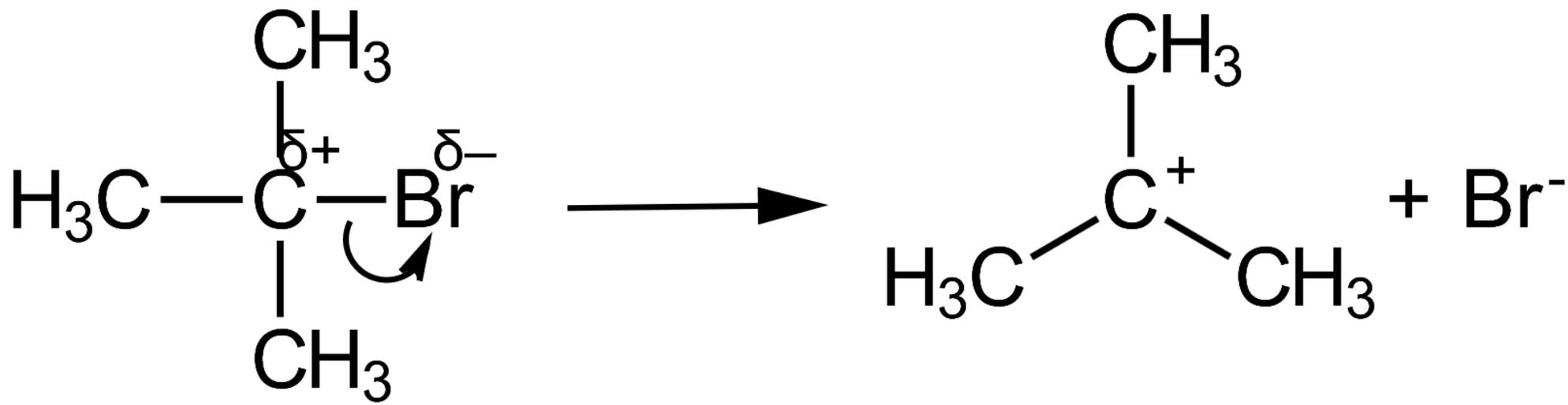
**Tutorials for IB Chemistry**

**$S_N1$  and  $S_N2$   
mechanisms**

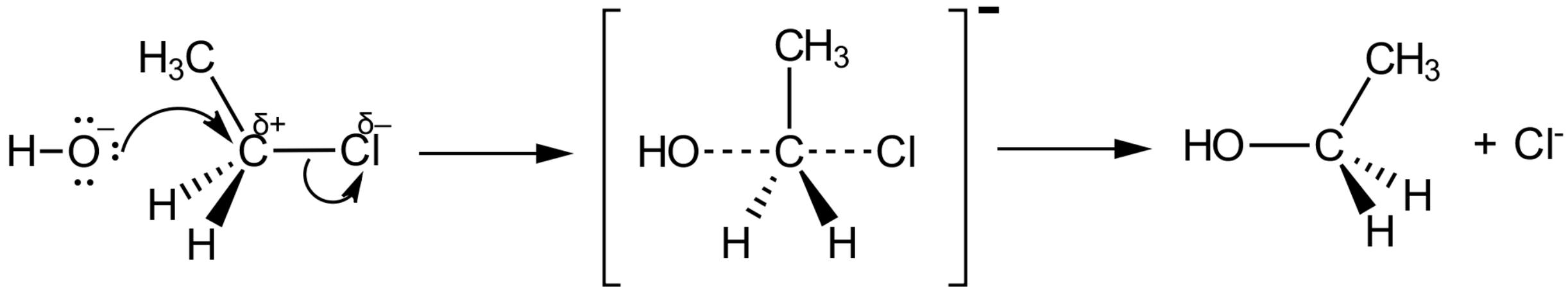
# $S_N1$ and $S_N2$ mechanisms



# $S_N1$ and $S_N2$ mechanisms



# $S_N1$ and $S_N2$ mechanisms



# **S<sub>N</sub>1 and S<sub>N</sub>2 mechanisms**

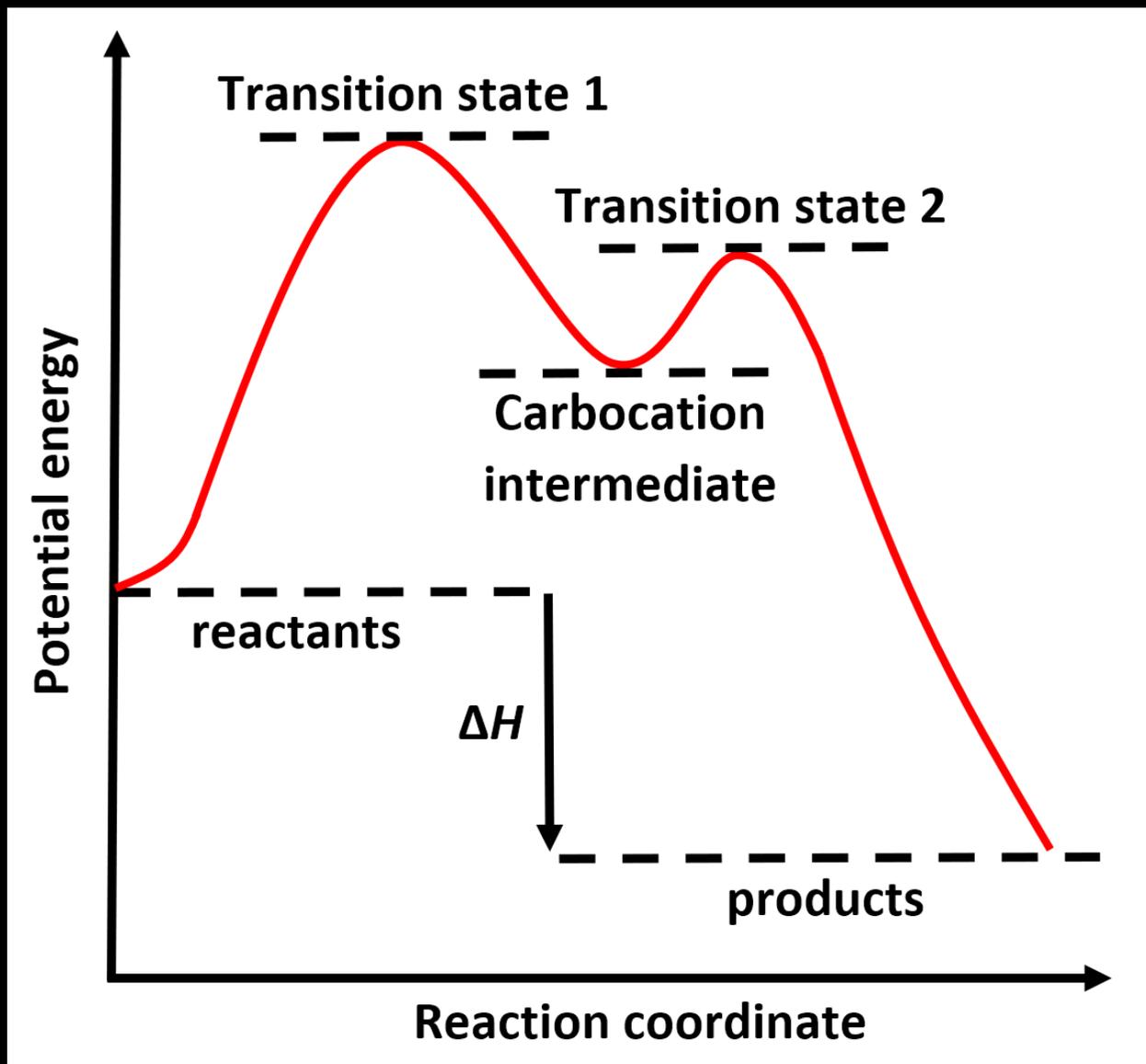
The rate of reaction of the S<sub>N</sub>1 mechanism depends on the concentration of the halogenoalkane only.

$$\text{rate} = k[\text{halogenoalkane}]$$

The rate of reaction of the S<sub>N</sub>2 mechanism depends on both the concentration of the halogenoalkane and the nucleophile.

$$\text{rate} = k[\text{halogenoalkane}][\text{nucleophile}]$$

# $S_N1$ and $S_N2$ mechanisms



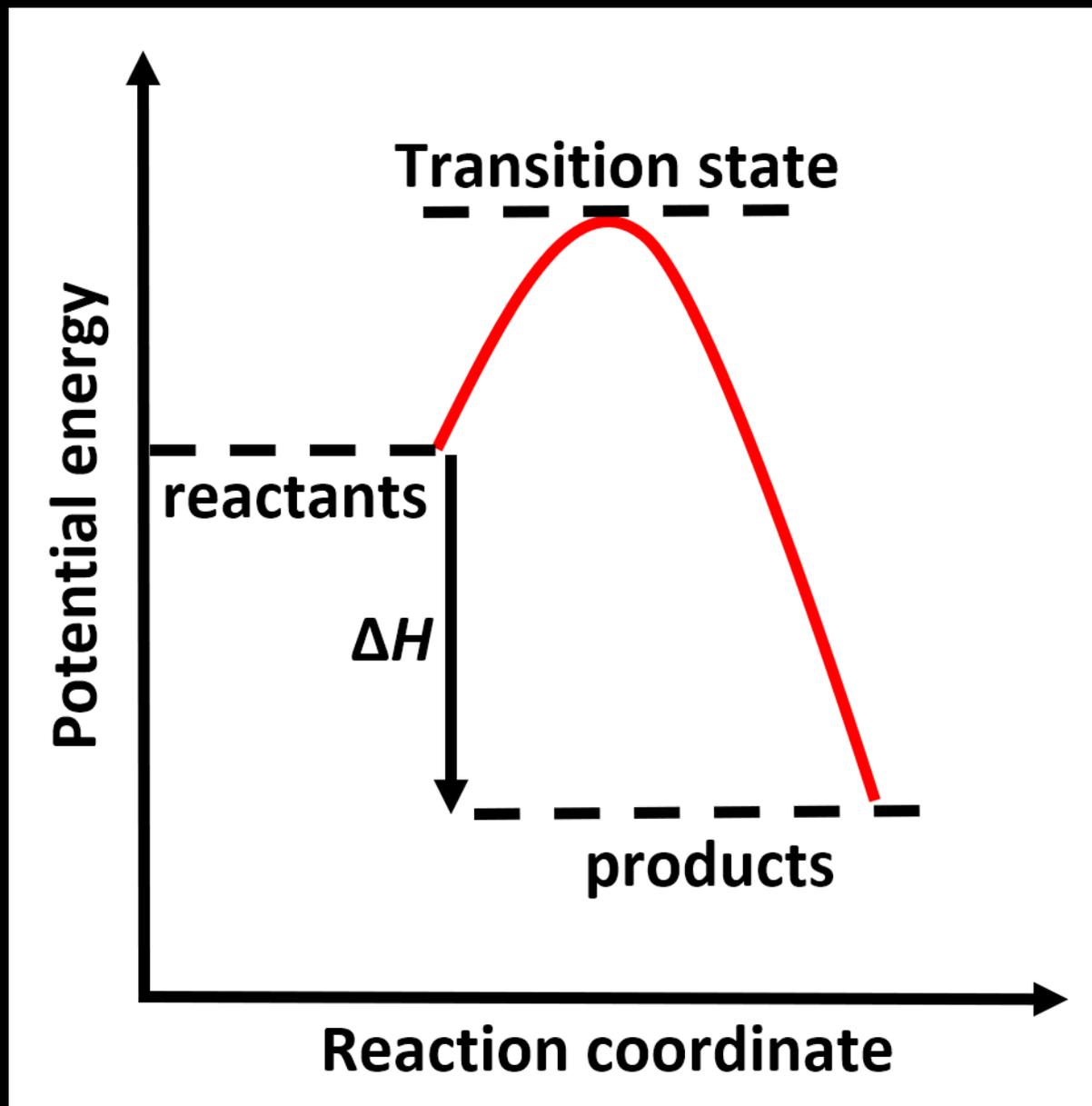
**Step one:**

- involves the formation of carbocation intermediate
- is the step with the highest activation energy,  $E_a$
- is the rate-determining step.

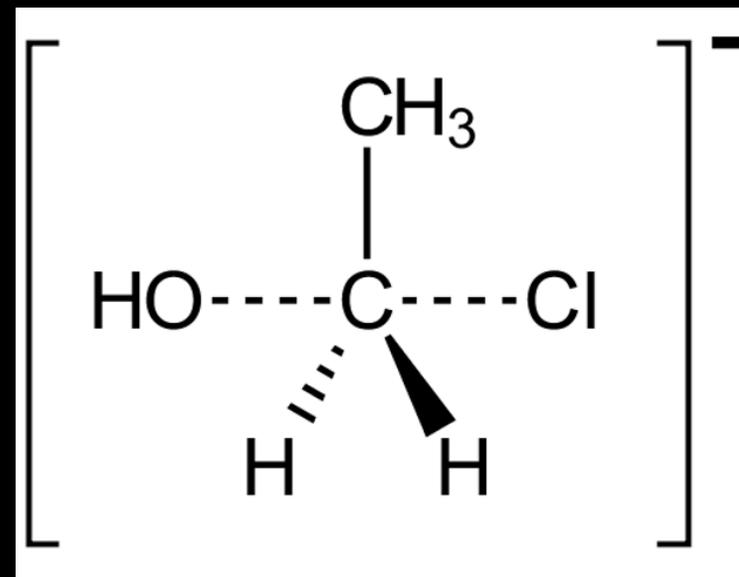
**Step two**

- is the step with the lowest activation energy,  $E_a$
- attack by nucleophile on carbocation intermediate.

# $S_N1$ and $S_N2$ mechanisms



- Transition state with both the nucleophile and leaving group weakly bonded to the carbon atom.



# **S<sub>N</sub>1 and S<sub>N</sub>2 mechanisms**

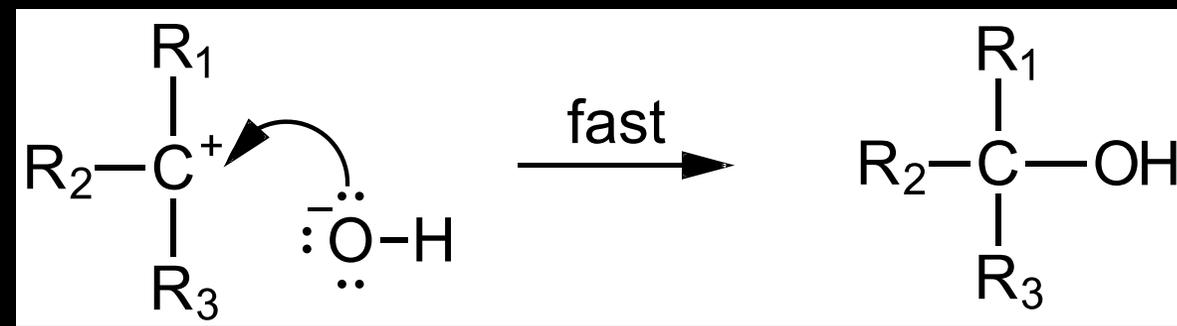
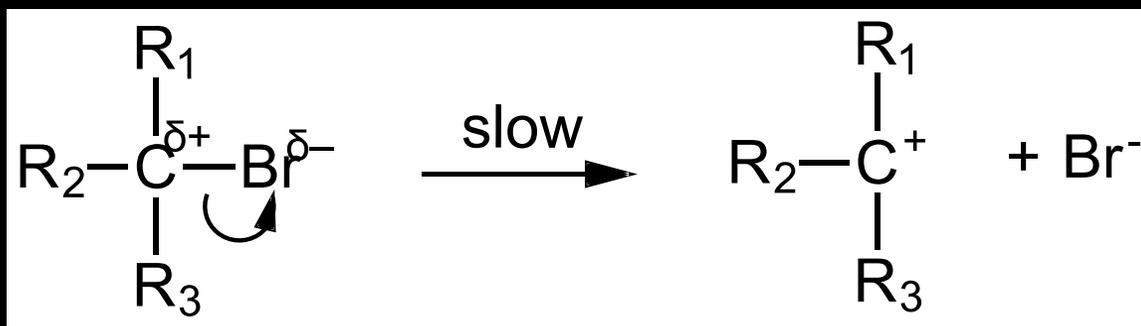
<b>S<sub>N</sub>1</b>	<b>S<sub>N</sub>2</b>
Two-step mechanism with formation of carbocation intermediate	One-step mechanism with formation of transition state
Bond between carbon atom and leaving group breaks first and then nucleophile bonds to carbocation (stabilised by inductive effect)	Back-side attack by nucleophile results in transition state with nucleophile and leaving group both weakly bonded to carbon atom
Steric hindrance caused by bulky alkyl groups	Lack of steric hindrance allows for back-side attack by nucleophile
Rate of reaction depends on [halogenoalkane] only	Rate of reaction depends on [halogenoalkane] and [nucleophile]

**MSJChem**

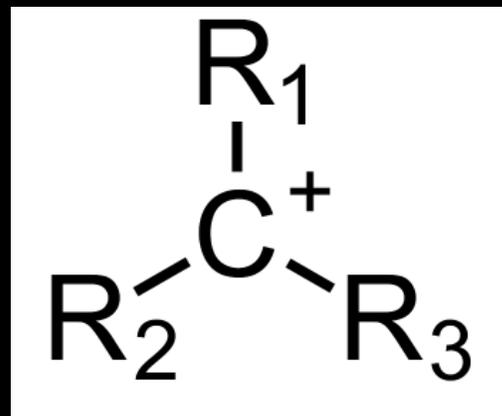
**Tutorials for IB Chemistry**

**Stereochemistry of  $S_N$   
reactions**

The S<sub>N</sub>1 mechanism involves the formation of a carbocation intermediate.

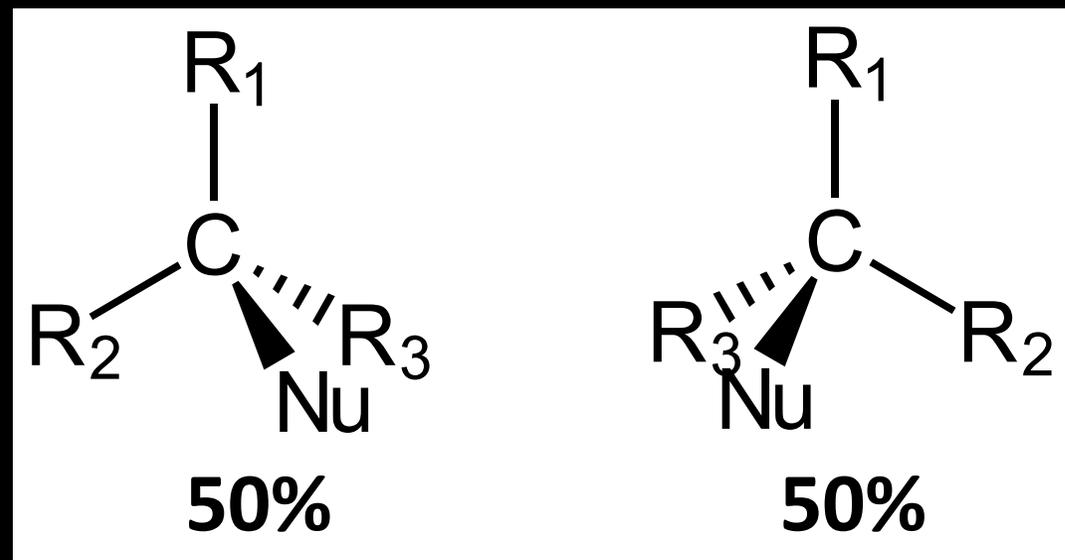
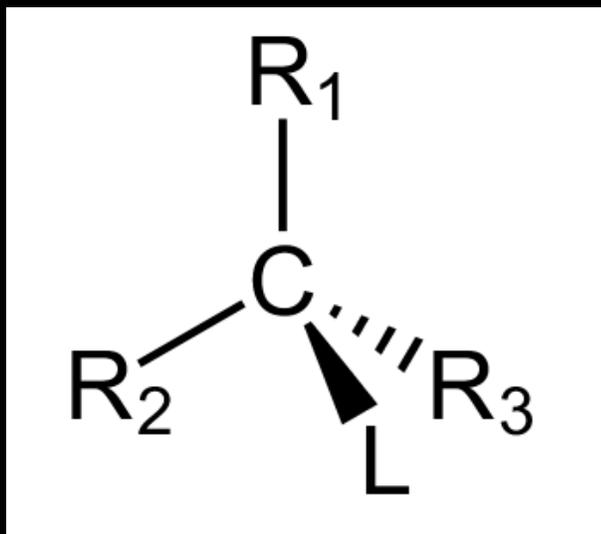
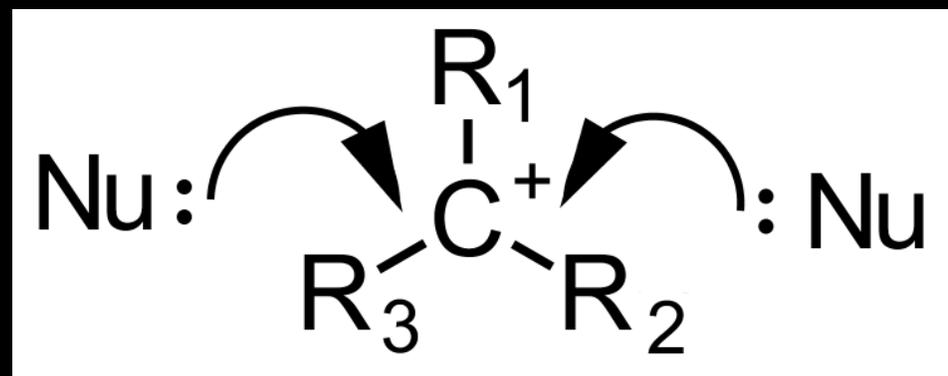


The carbocation formed is sp<sup>2</sup> hybridised with a trigonal planar geometry.



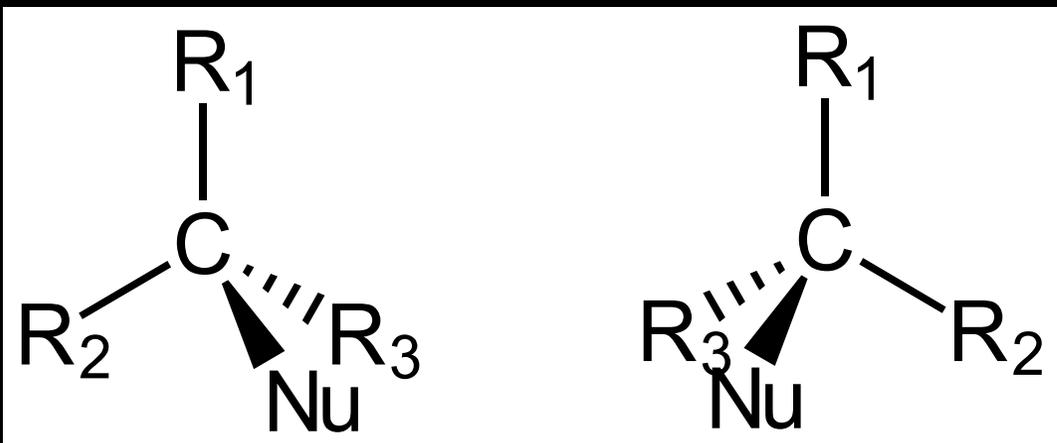
# Stereochemistry of S<sub>N</sub> reactions

The nucleophile can attack on either side of the carbocation intermediate.



The product can have the same stereochemical configuration as the reactant (retention) or opposite configuration (inversion).

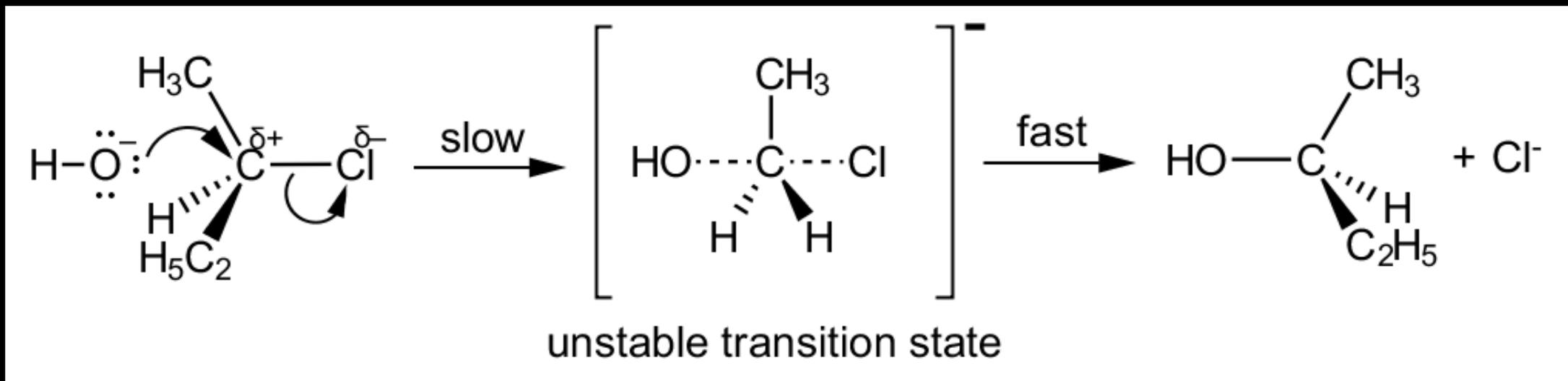
Retention



Inversion

This produces a racemic mixture with equal amounts of both enantiomer (optically inactive).

The S<sub>N</sub>2 mechanism is stereospecific – the backside attack by the nucleophile produces inversion of the configuration.



The inversion of the configuration produces only one enantiomer (optically active).

The S<sub>N</sub>1 reaction produces a racemic mixture of the two enantiomers which is optically inactive. It has no effect on the plane of plane-polarised light.

The S<sub>N</sub>2 reaction is stereospecific with inversion of the configuration – the product is optically active.

It will rotate the plane of plane-polarised light.

**MSJChem**

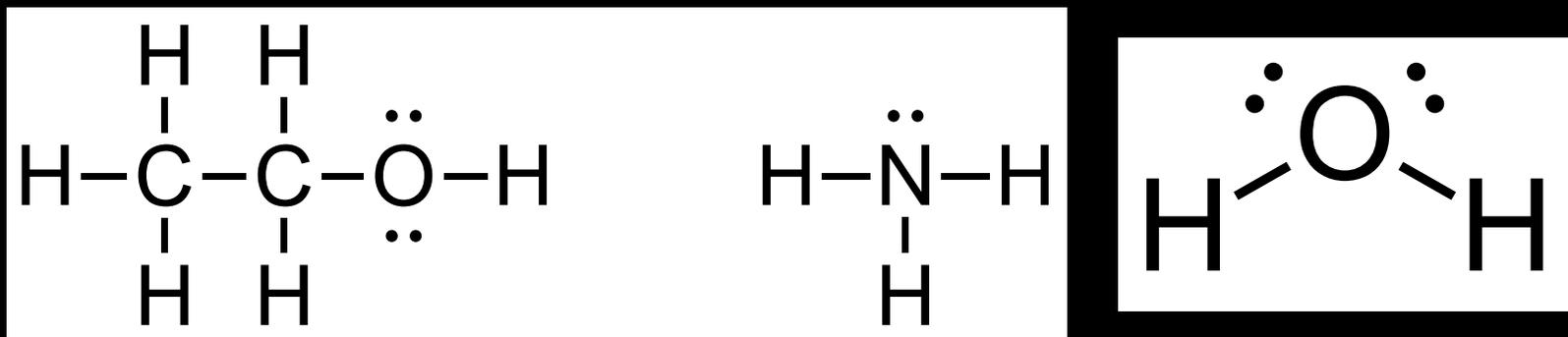
**Tutorials for IB Chemistry**

**Choice of solvent for**

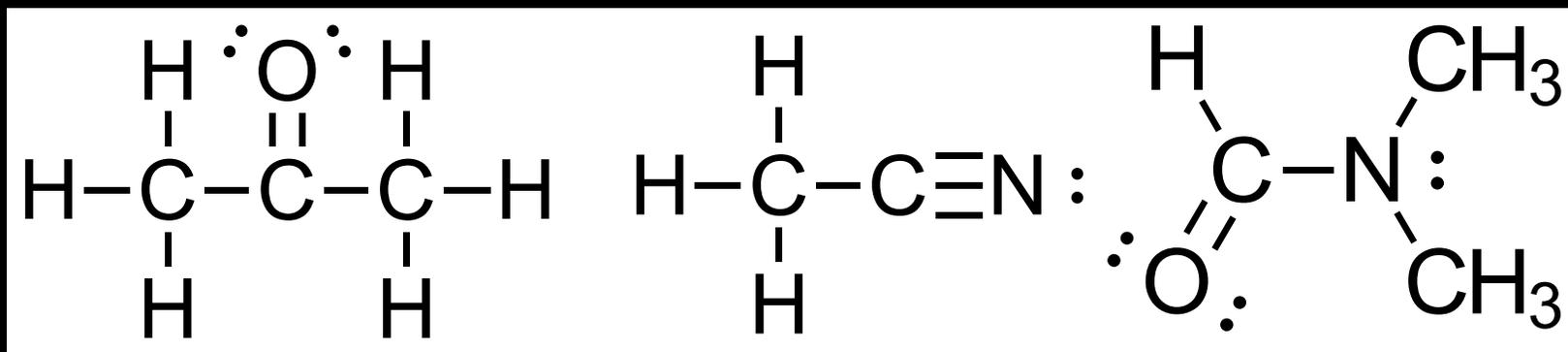
**$S_N1/S_N2$**

# $S_N1$ / $S_N2$ choice of solvent

Polar protic solvents contain O-H or N-H bonds and are able to form hydrogen bonds.

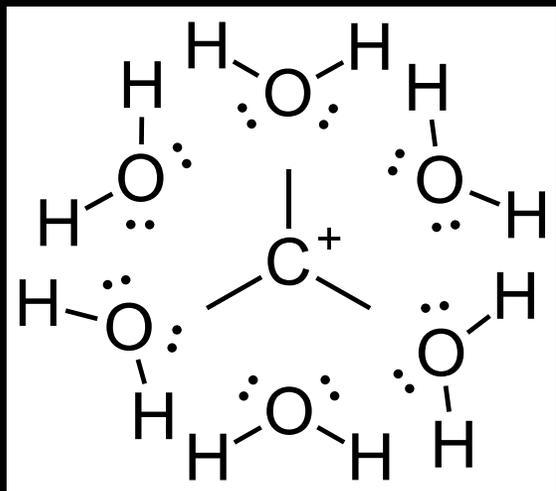


Polar aprotic solvents do not contain O-H or N-H bonds and are unable to form hydrogen bonds.

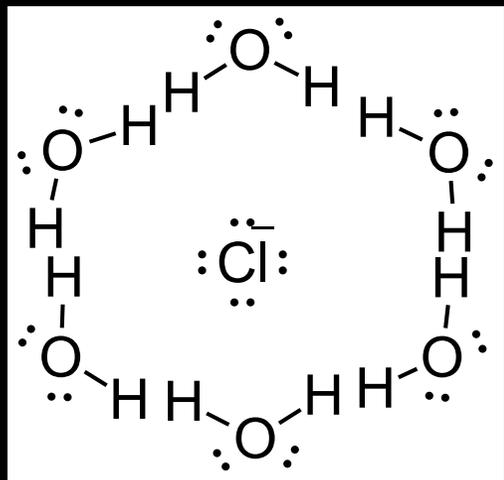


# **S<sub>N</sub>1 / S<sub>N</sub>2 choice of solvent**

**S<sub>N</sub>1 reactions are favoured by the use of polar protic solvents.**



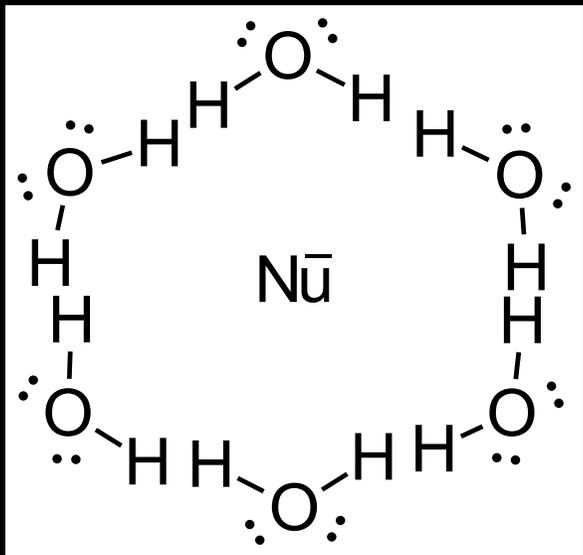
**The solvent molecules solvate the carbocation intermediate through ion-dipole interactions. This has the effect of stabilising the carbocation intermediate.**



**The solvent also stabilises the anion (the leaving group) by forming hydrogen bonds, which also favours S<sub>N</sub>1 reactions.**

# $S_N1$ / $S_N2$ choice of solvent

$S_N2$  reactions are favoured by the use of polar aprotic solvents.



Polar protic solvents solvate the nucleophile (due to hydrogen bonding), reducing its reactivity.

Polar aprotic solvents do not solvate the nucleophile, maintaining its reactivity – this favours the  $S_N2$  reaction.

**MSJChem**

**Tutorials for IB Chemistry**

**Comparison of  $S_N1$   
and  $S_N2$  reactions**

	<b>S<sub>N</sub>1</b>	<b>S<sub>N</sub>2</b>
<b>Class of halogenoalkane</b>	<b>Tertiary</b>	<b>Primary</b>
<b>Number of steps</b>	<b>Two-step</b>	<b>One-step</b>
<b>Transition state or reaction intermediate</b>	<b>Carbocation intermediate</b>	<b>Transition state</b>
<b>Type of solvent</b>	<b>Polar protic</b>	<b>Polar aprotic</b>
<b>Type of bond fission</b>	<b>Heterolytic</b>	<b>Heterolytic</b>

# Nucleophilic substitution reactions

	<b>S<sub>N</sub>1</b>	<b>S<sub>N</sub>2</b>
<b>Molecularity</b>	<b>Unimolecular</b>	<b>Bimolecular</b>
<b>Example rate expression</b>	<b>rate = k[(CH<sub>3</sub>)<sub>3</sub>CBr]</b>	<b>rate = k[CH<sub>3</sub>CH<sub>2</sub>Br][OH<sup>-</sup>]</b>
<b>Relative rate of reaction</b>	<b>3° &gt; 2° &gt; 1°</b>	<b>1° &gt; 2° &gt; 3°</b>
<b>Change in stereochemistry</b>	<b>50/50 mix of enantiomers (racemic mixture - optically inactive)</b>	<b>Inversion of configuration (optically active)</b>

**MSJChem**

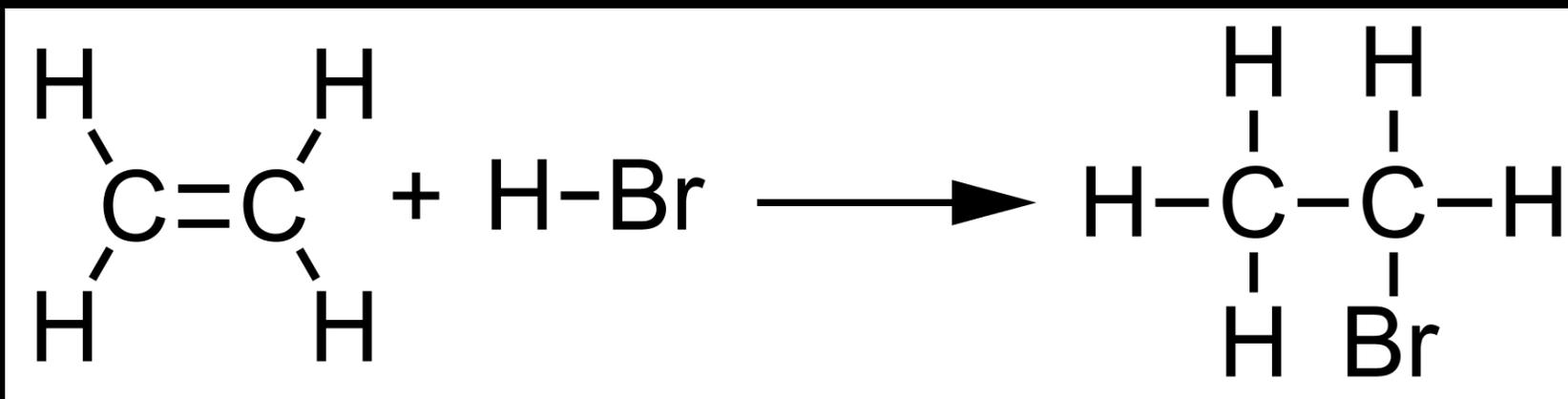
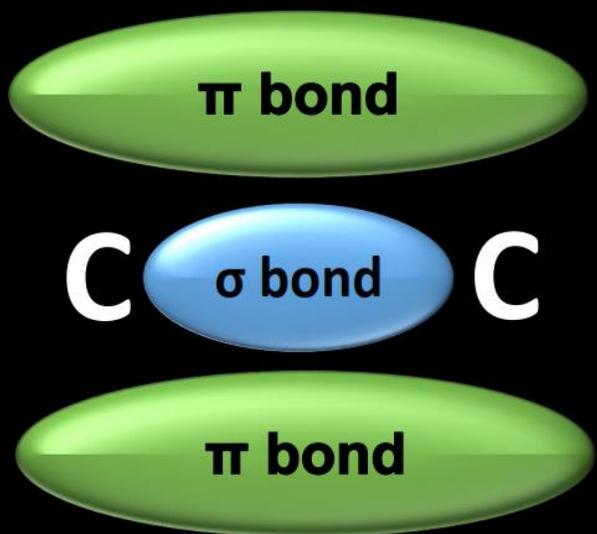
**Tutorials for IB Chemistry**

**Electrophilic addition  
reactions**

# Electrophilic addition reactions

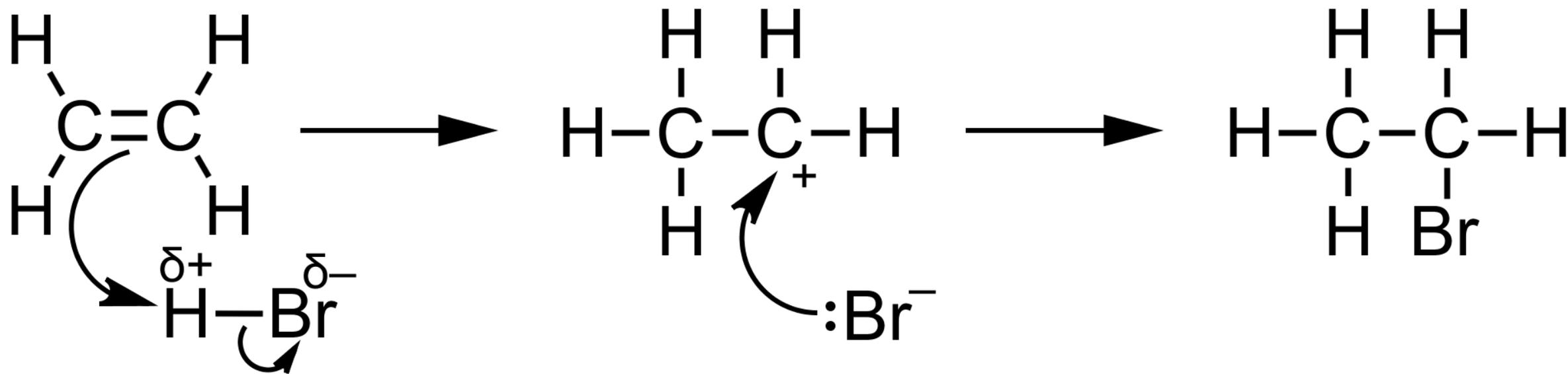
The carbon to carbon double bond in an alkene is a region of high electron density.

This makes the C=C bond attractive to electrophiles (species that are electron deficient).



This is an electrophilic addition reaction.

# Electrophilic addition reactions



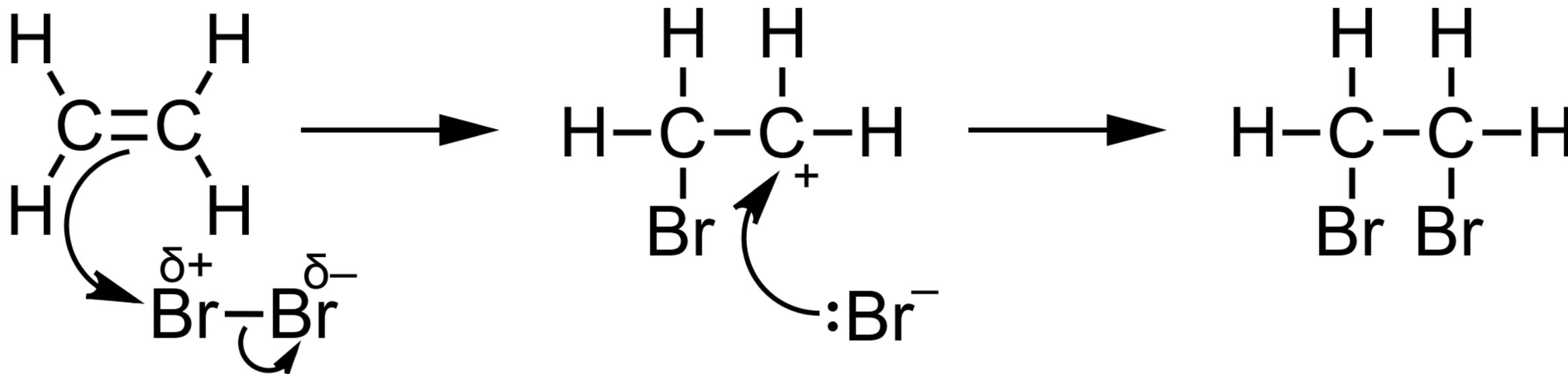
H-Br undergoes heterolytic bond fission.

The proton ( $\text{H}^+$ ) bonds with the carbon atom of the  $\text{C}=\text{C}$  bond.

This results in the formation of a carbocation intermediate.

The bromide ion forms a bond with the carbocation producing bromoethane.

# Electrophilic addition reactions

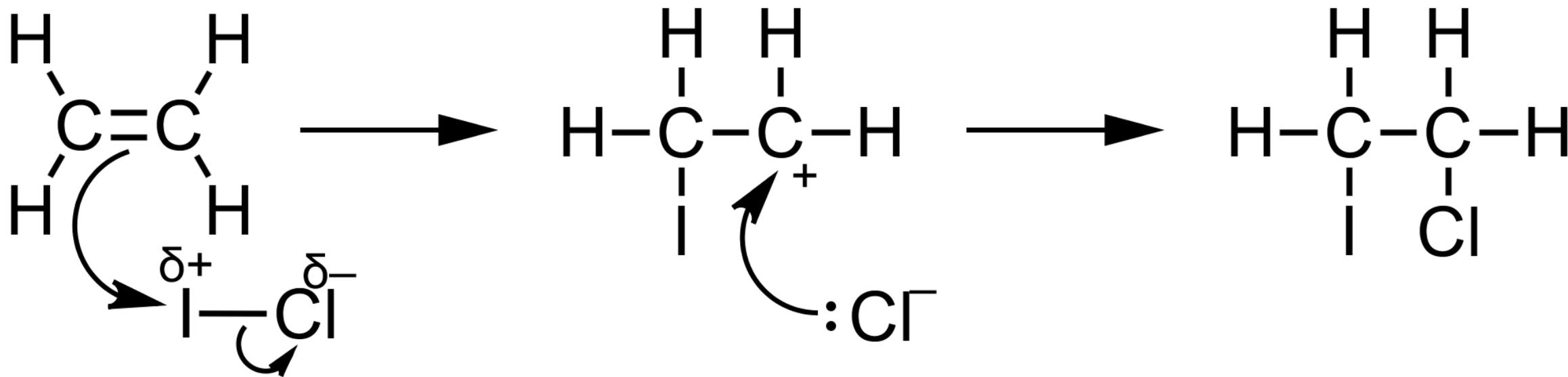


The Br-Br bond undergoes heterolytic bond fission.

A bromine atom bonds to one of the carbon atoms of the  $\text{C}=\text{C}$  bond forming a carbocation intermediate.

The bromide ion bonds with the carbocation producing 1,2-dibromoethane.

# Electrophilic addition reactions



# Electrophilic addition reactions

The electrophiles (HBr, Br<sub>2</sub> and ICl) are attracted to the electron density of the C=C bond.

The bond between the atoms undergoes heterolytic bond fission with one of the atoms (the electrophilic portion of the molecule) bonding to one of the carbon atoms from the C=C bond.

This results in the formation of a carbocation intermediate and an anion.

The anion then uses a lone pair of electrons to form a bond with the carbocation.

**MSJChem**

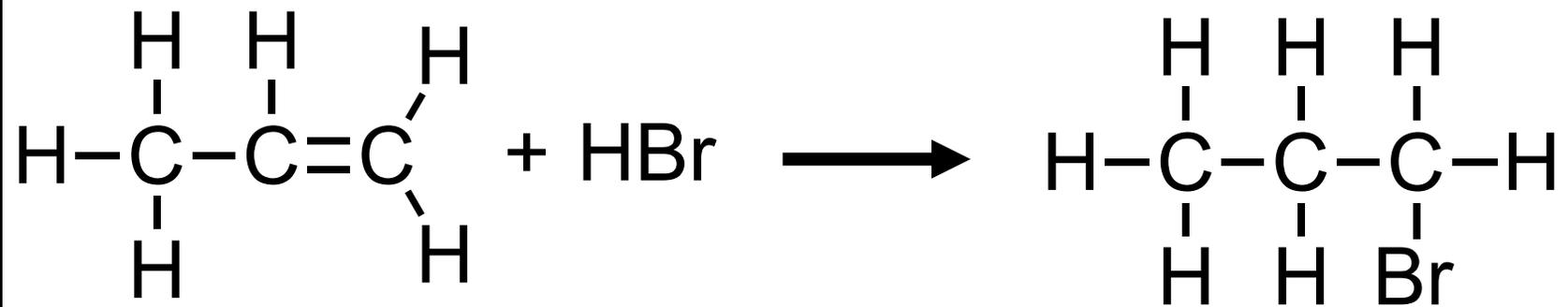
**Tutorials for IB Chemistry**

**Markovnikov's rule**

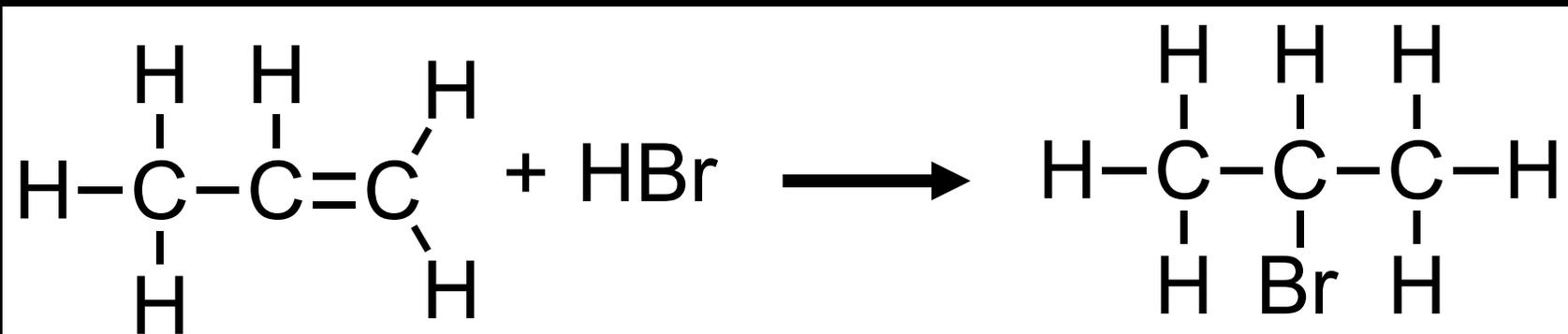


# Markovnikov's rule

When propene (an asymmetrical alkene) reacts with hydrogen bromide, there are two possible products:



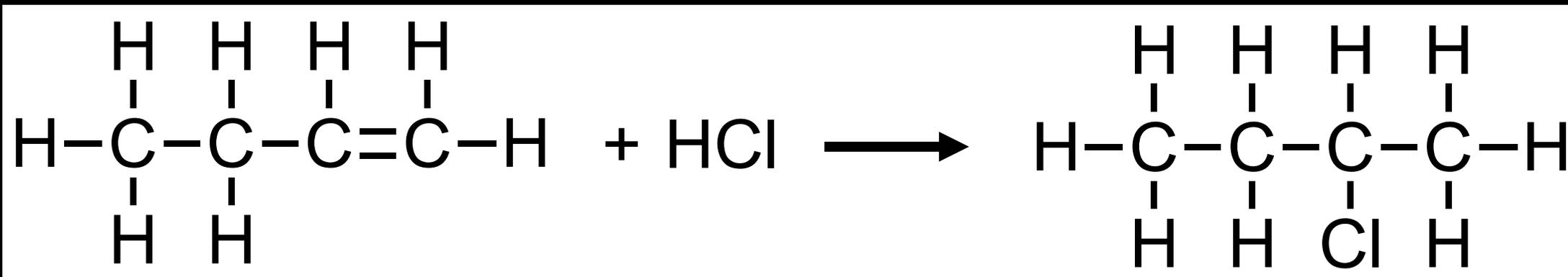
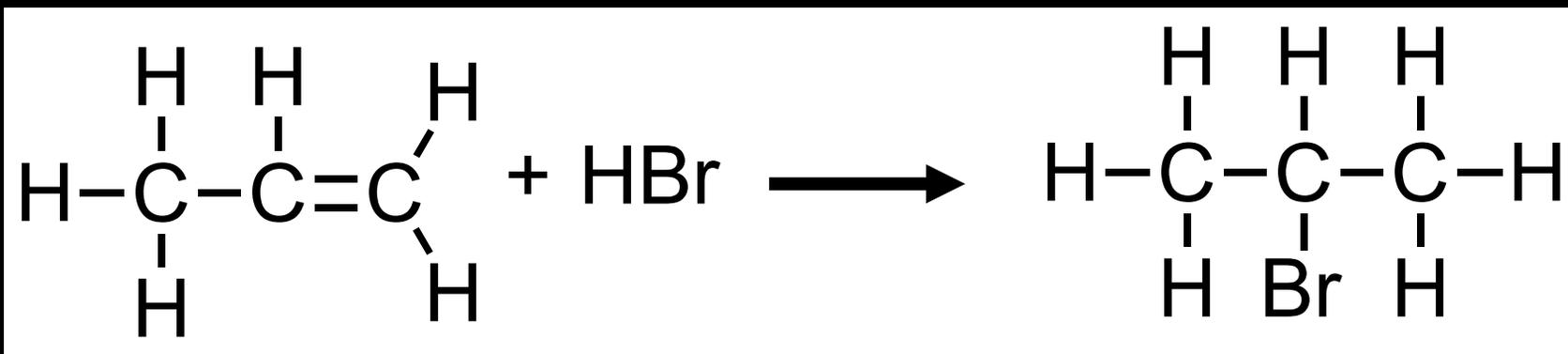
**1-bromopropane**



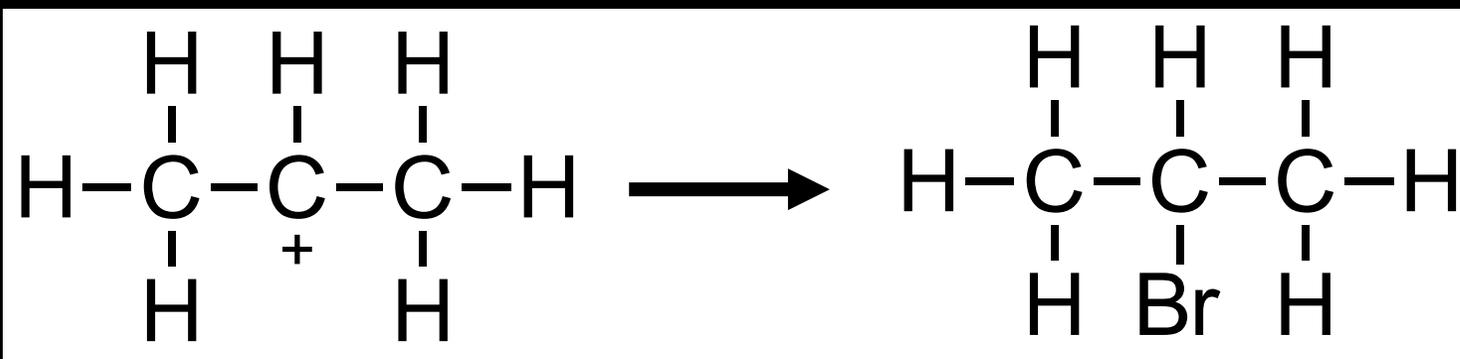
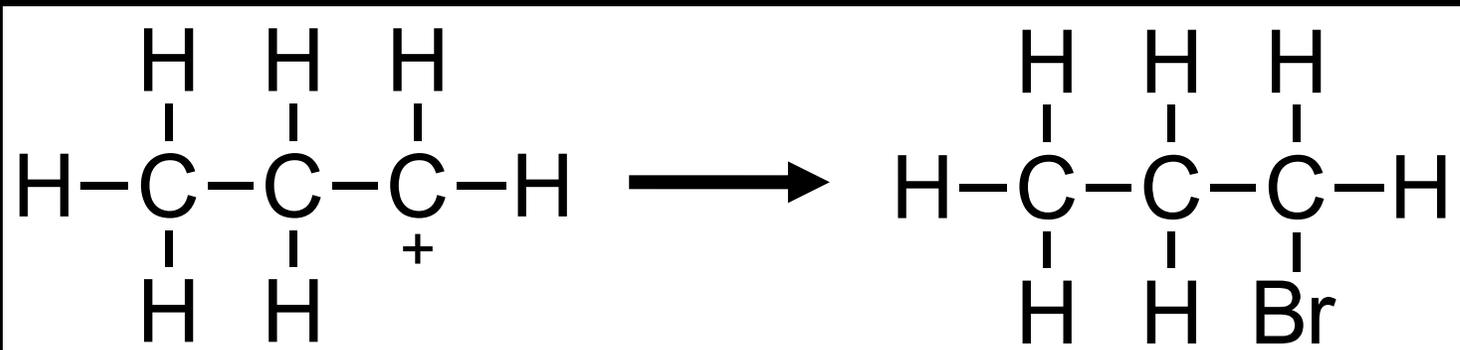
**2-bromopropane**

# Markovnikov's rule

When an asymmetrical alkene reacts with a hydrogen halide, the hydrogen adds to the carbon atom that is already bonded to the greatest number of hydrogens.



# Markovnikov's rule

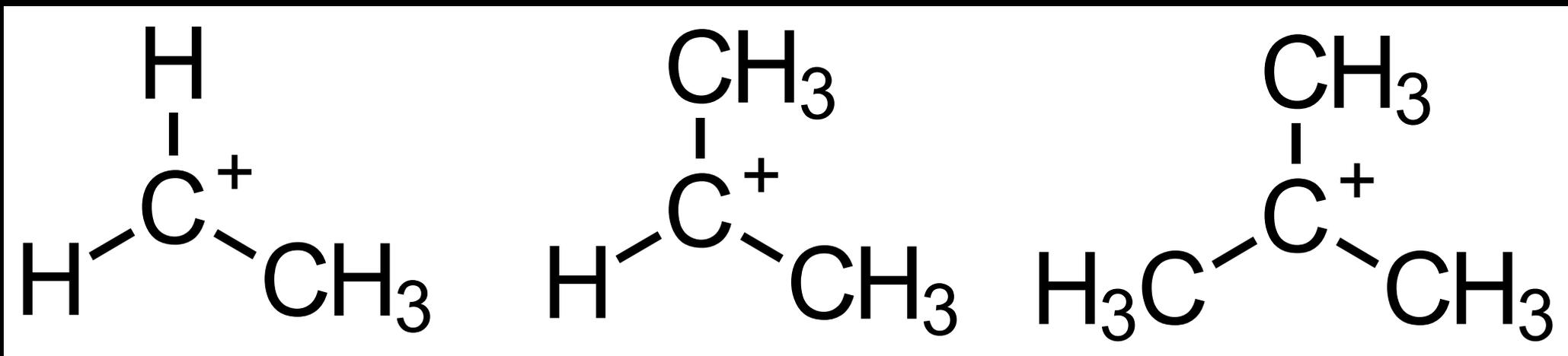


The primary carbocation is less stable than the secondary carbocation.

The order of stability is:  
 $1^\circ < 2^\circ < 3^\circ$

The major product will be 2-bromopropane because of the greater stability of the secondary carbocation.

# Markovnikov's rule



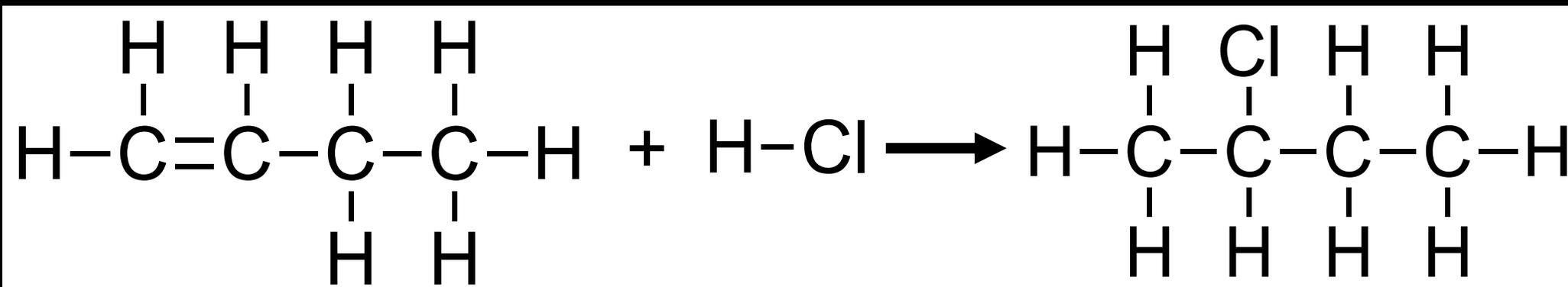
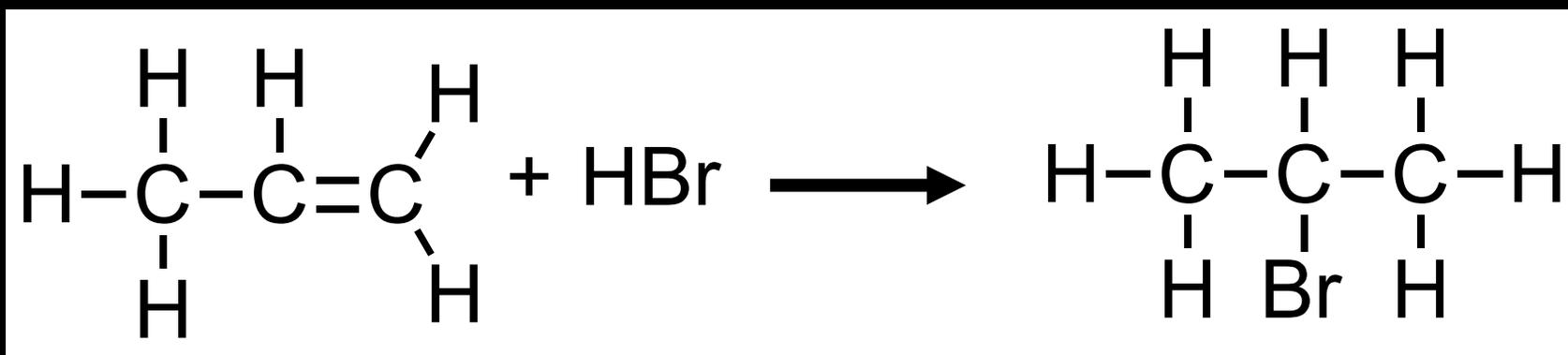
Increasing stability 

Carbocations are stabilised by electron-donating alkyl groups (positive inductive effect).

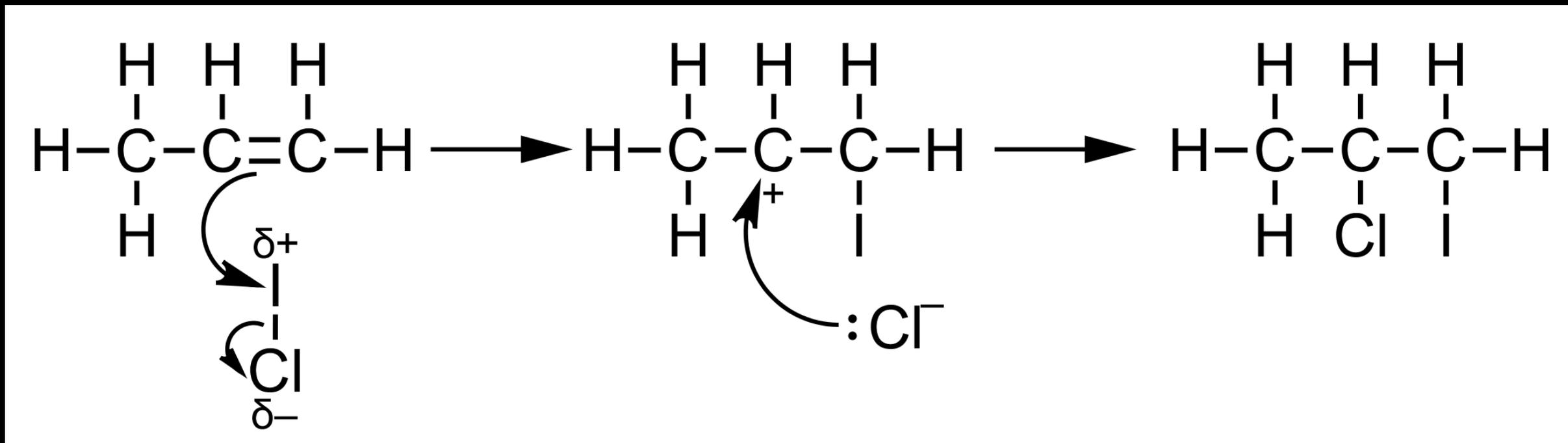
The more substituted the carbocation, the greater the stability.

# Markovnikov's rule

When an asymmetrical alkene reacts with a hydrogen halide, the hydrogen adds to the carbon that is already bonded to the greatest number of hydrogens.



# Markovnikov's rule



**When an unsymmetrical alkene reacts with an interhalogen (I-Cl), the electrophilic portion of the molecule bonds to the carbon that is bonded to the greatest number of hydrogens.**

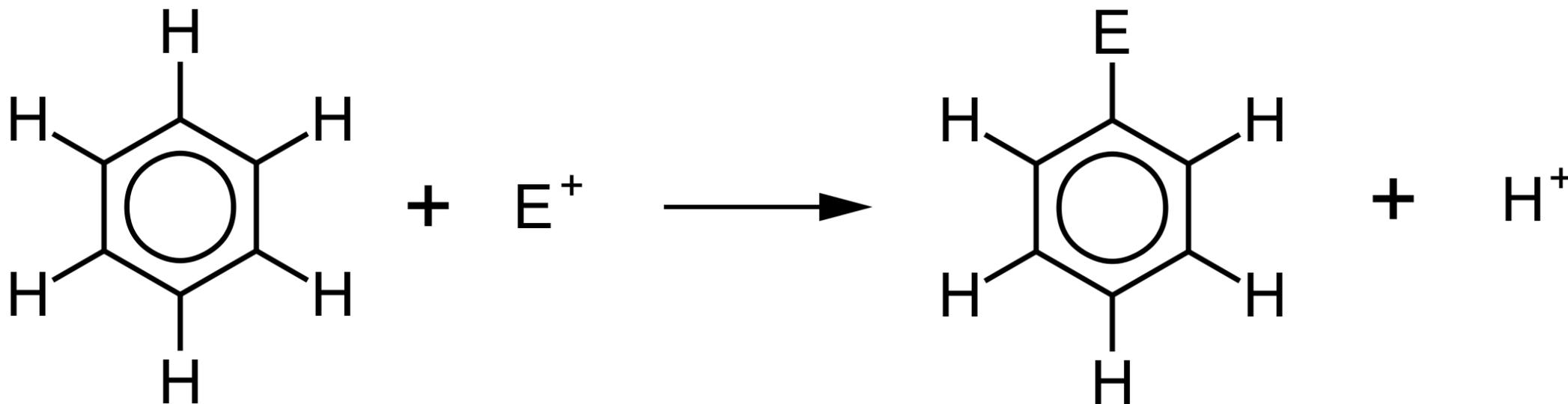
**MSJChem**

**Tutorials for IB Chemistry**

**Nitration of benzene**

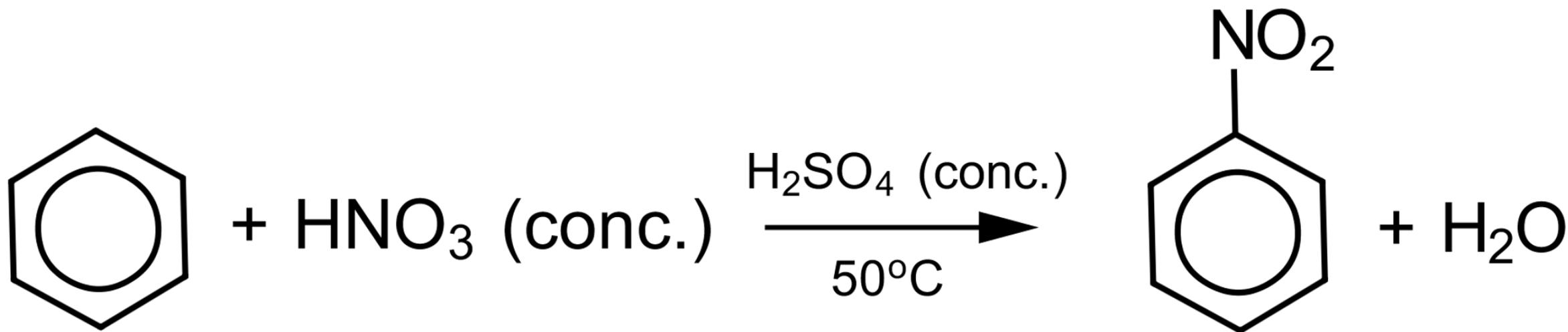
# Nitration of benzene

Benzene undergoes electrophilic substitution reactions in which a hydrogen atom is replaced by an electrophile. An electrophile is a species which is electron deficient (either a positive ion or have a partial positive charge).



# Nitration of benzene

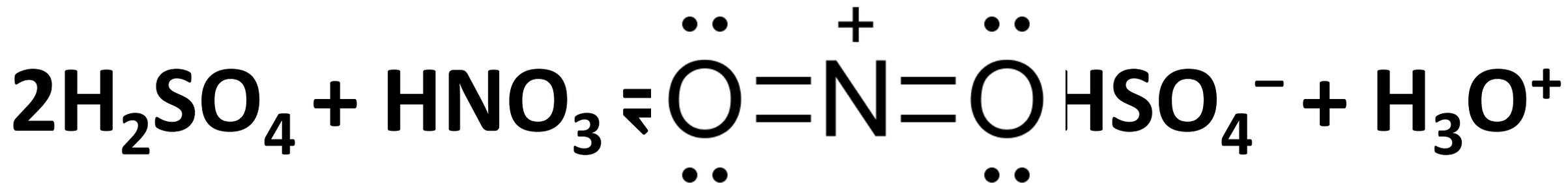
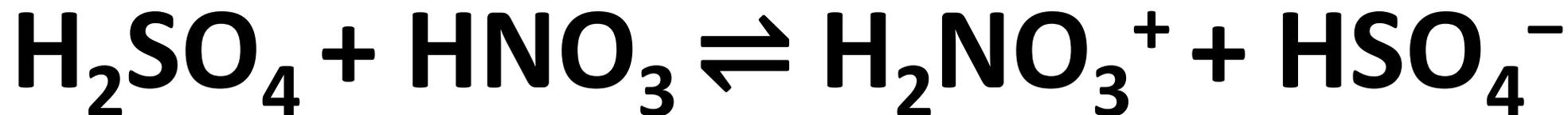
Benzene reacts with a mixture of concentrated nitric acid ( $\text{HNO}_3$ ) and concentrated sulfuric acid ( $\text{H}_2\text{SO}_4$ ) to form nitrobenzene ( $\text{C}_6\text{H}_5\text{NO}_2$ ) and water.



The electrophile is the nitronium ion,  $\text{NO}_2^+$ .

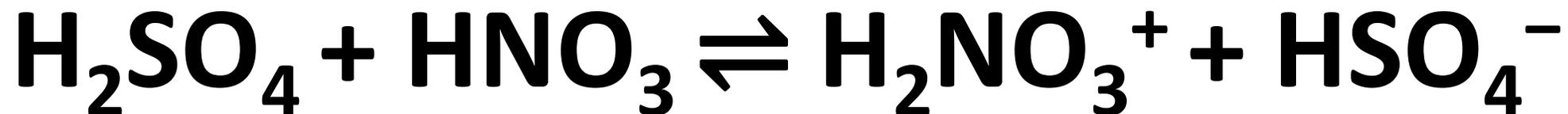
# Nitration of benzene

The nitrating mixture is a mixture of concentrated nitric acid and concentrated sulfuric acid.



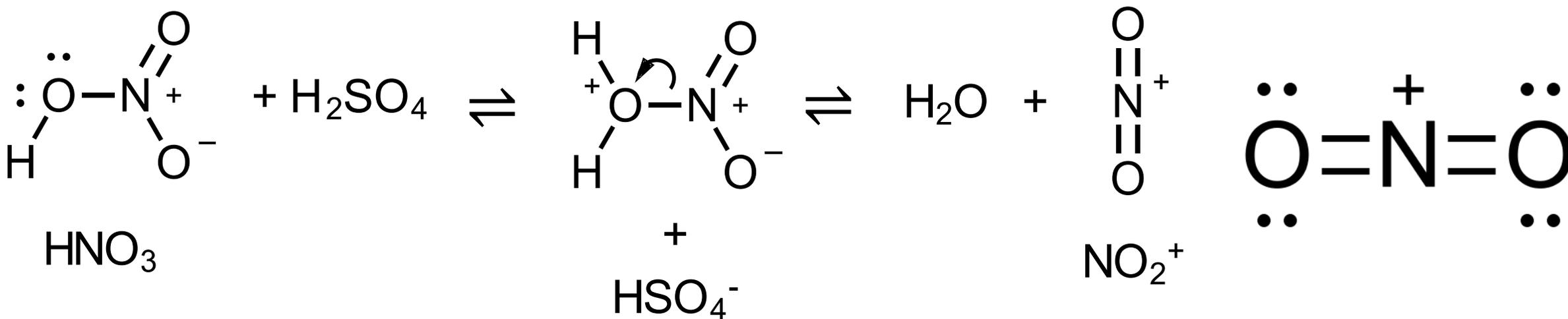
# Nitration of benzene

The nitrating mixture is a mixture of concentrated nitric acid and concentrated sulfuric acid.

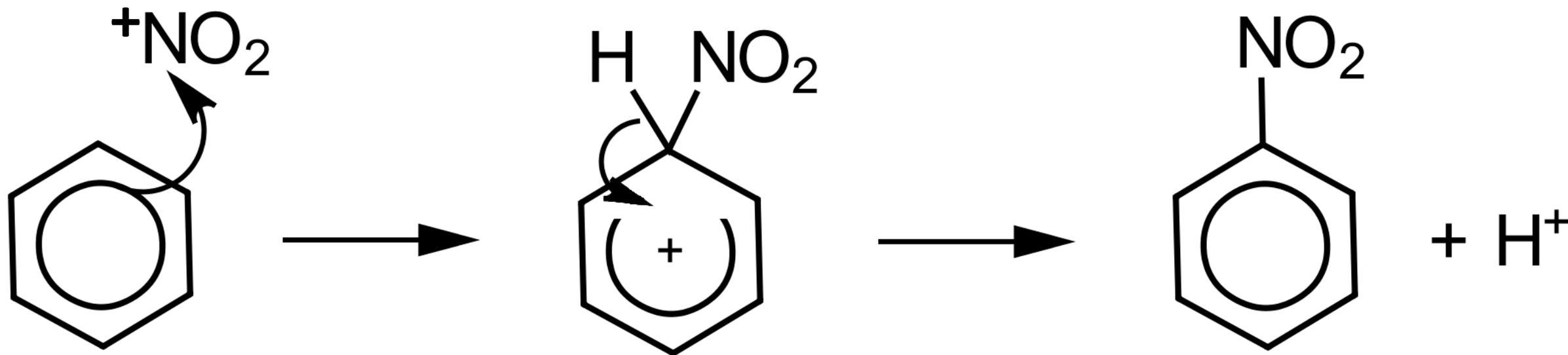


# Nitration of benzene

The nitrating mixture is a mixture of concentrated nitric acid and concentrated sulfuric acid.



# Nitration of benzene



The electrophile,  $\text{NO}_2^+$ , is attracted to the delocalised  $\pi$  electrons in the benzene molecule.

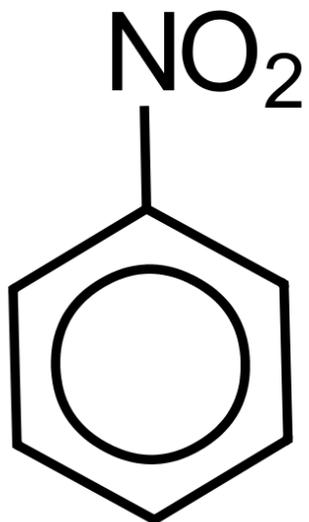
A bond is formed between a carbon atom and the electrophile producing a carbocation intermediate.

The C-H bond breaks and leads to the reforming of the benzene ring.

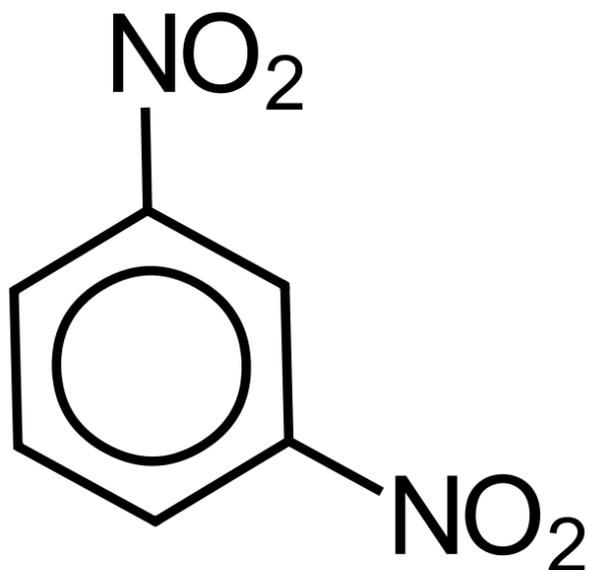
The hydrogen ion reacts with the  $\text{HSO}_4^-$  to reform the sulfuric acid catalyst.

# Nitration of benzene

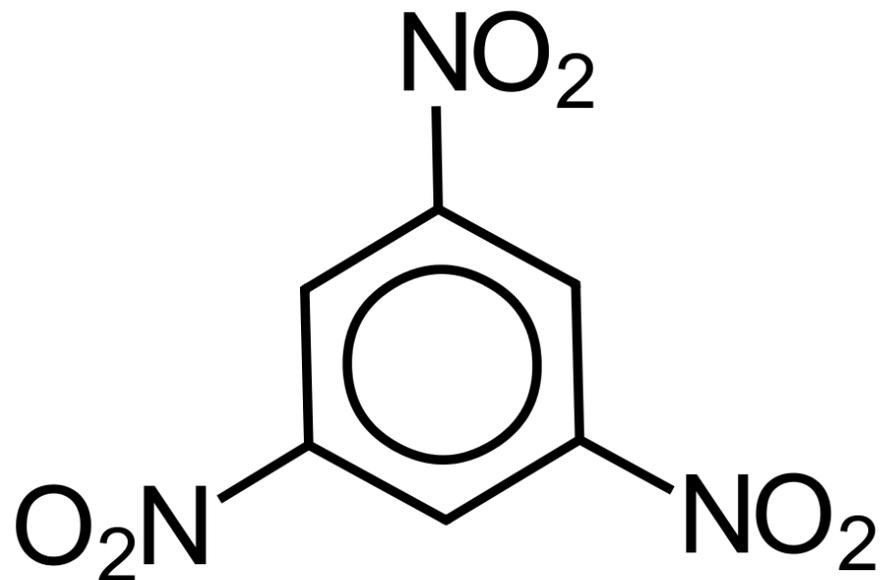
At higher temperatures, the products will have greater substitution.



**50 °C**

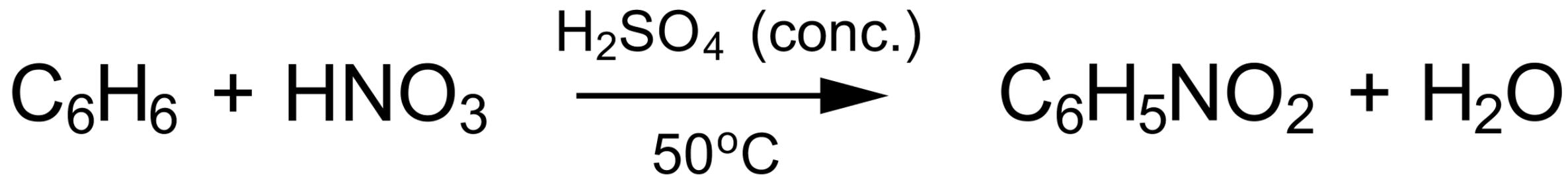
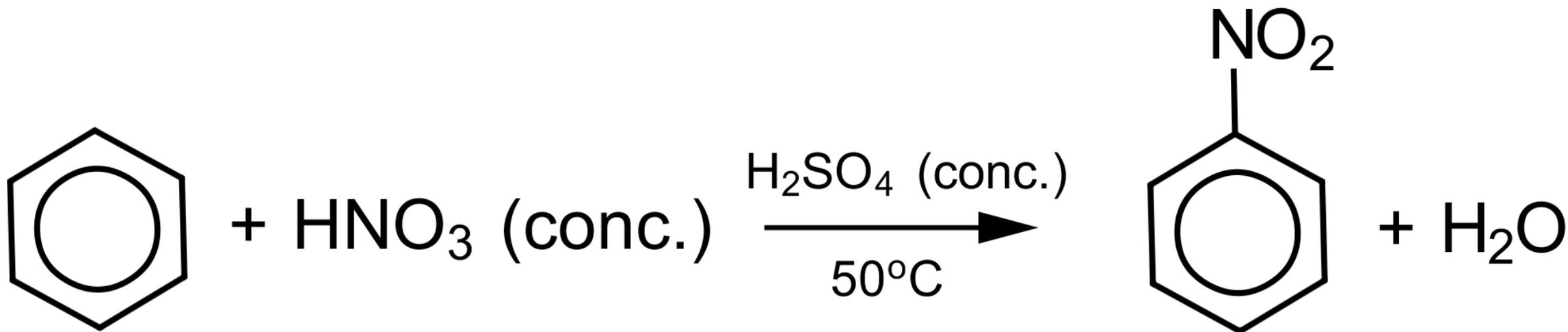


**65 °C**



**110 °C**

# Nitration of benzene



**MSJChem**

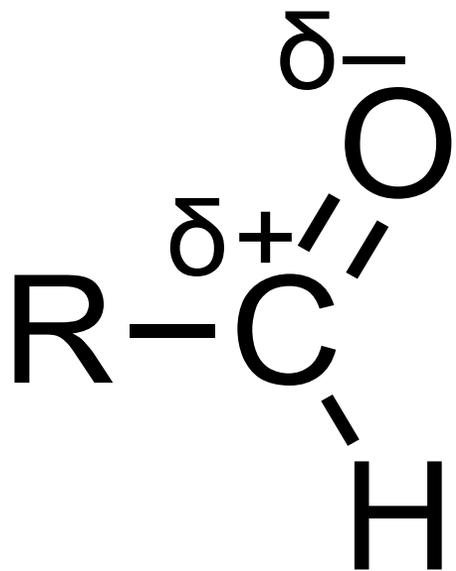
**Tutorials for IB Chemistry**

**Reduction of carbonyl  
compounds**

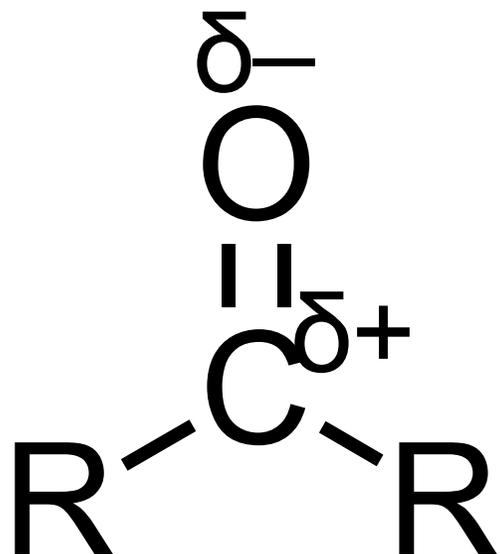
# Reduction of carbonyl compounds

Carbonyl compounds are compounds that contain a carbonyl group (C=O).

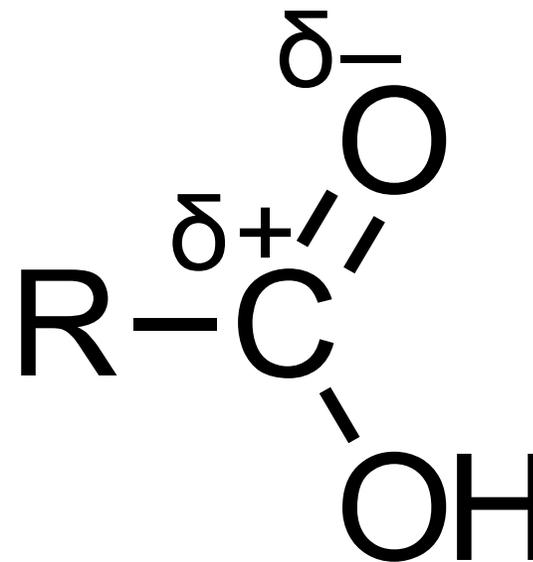
**Aldehydes**



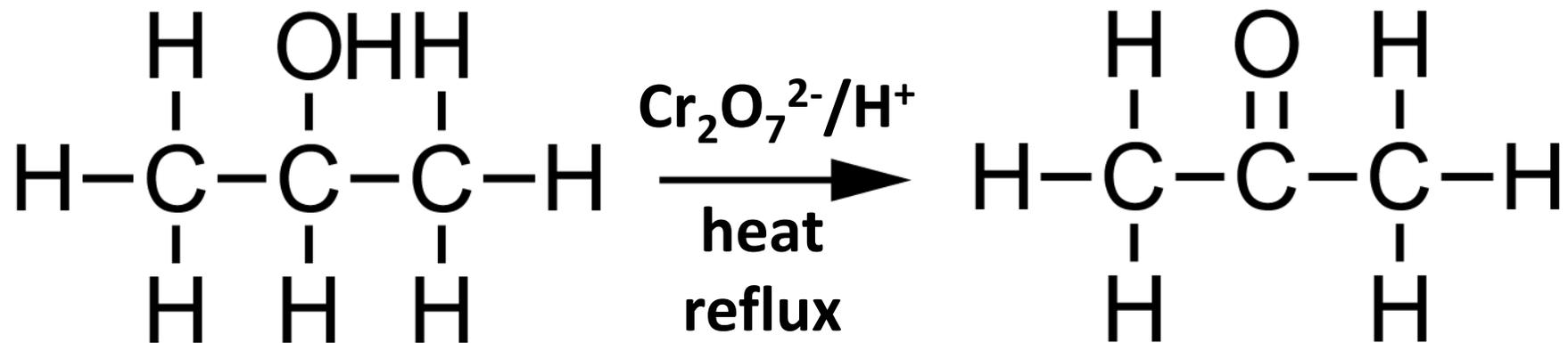
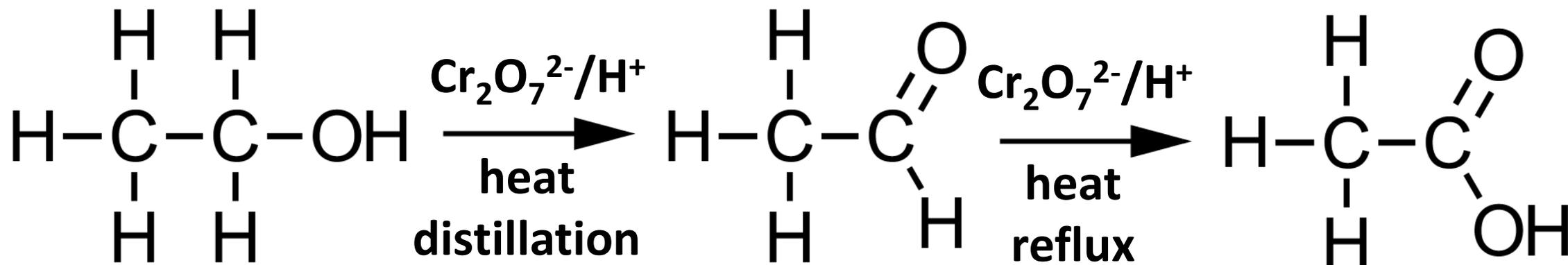
**Ketones**

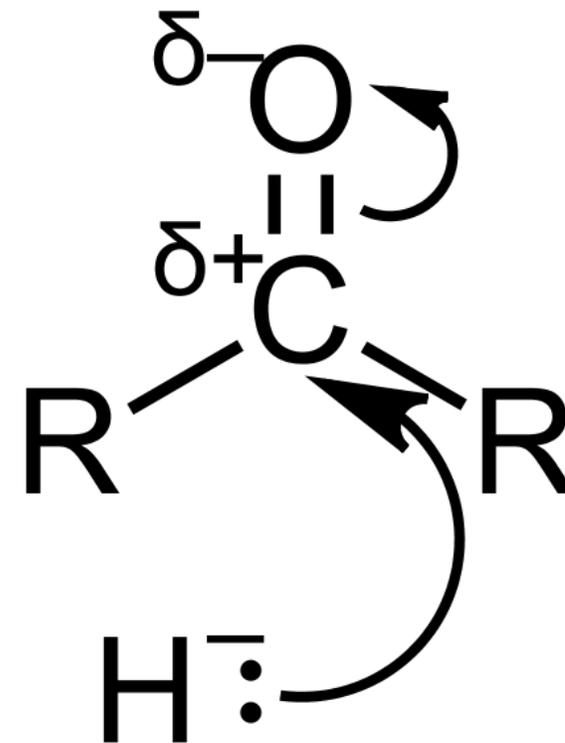
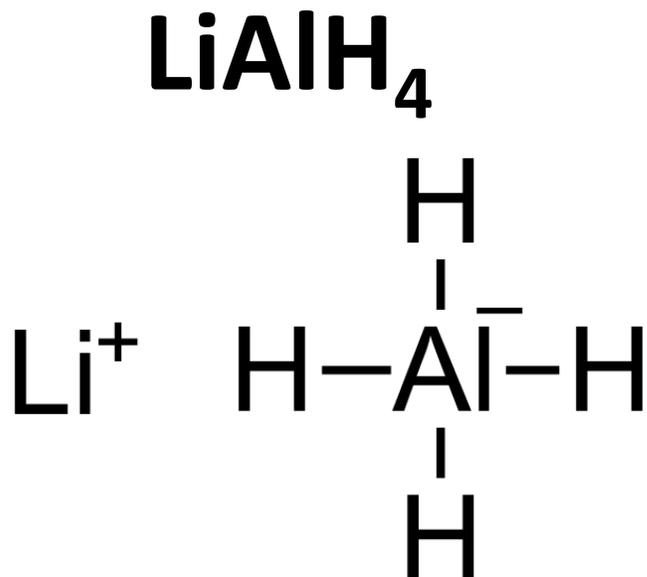
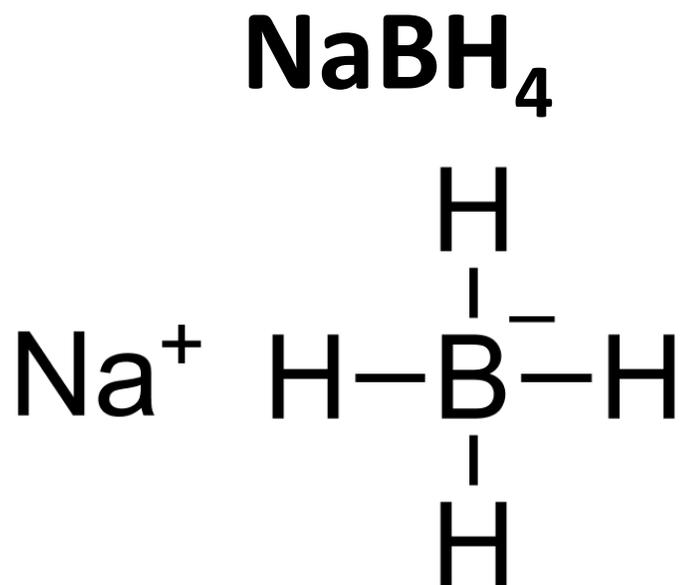


**Carboxylic acids**



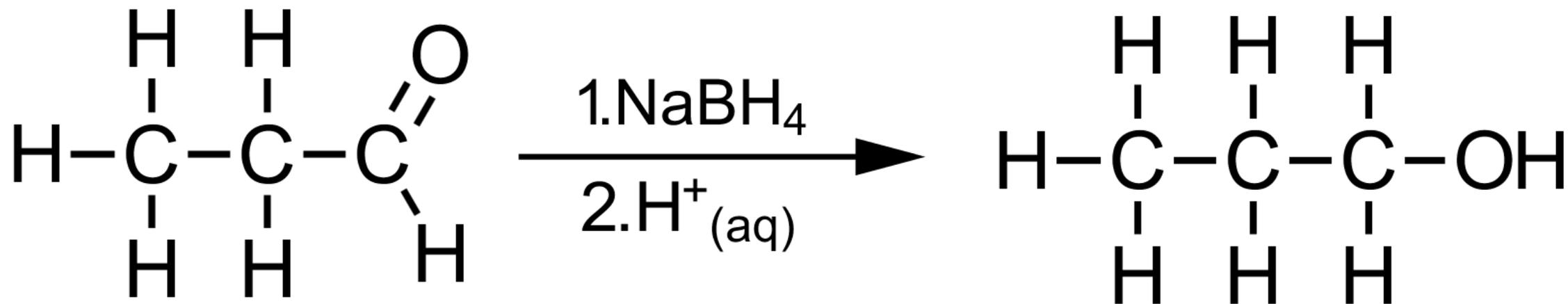
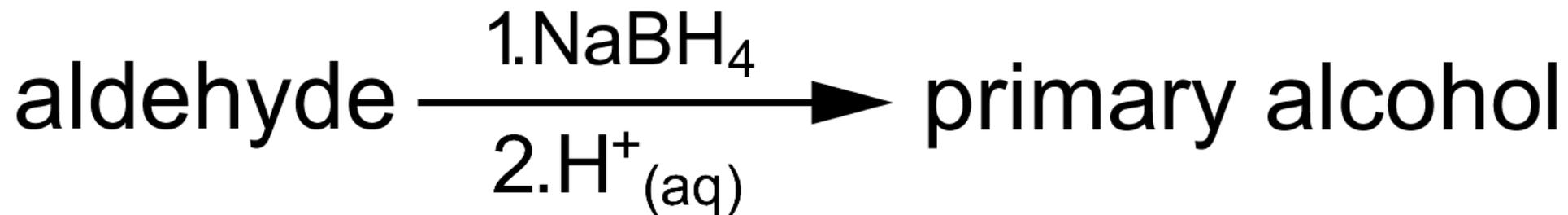
# Reduction of carbonyl compounds





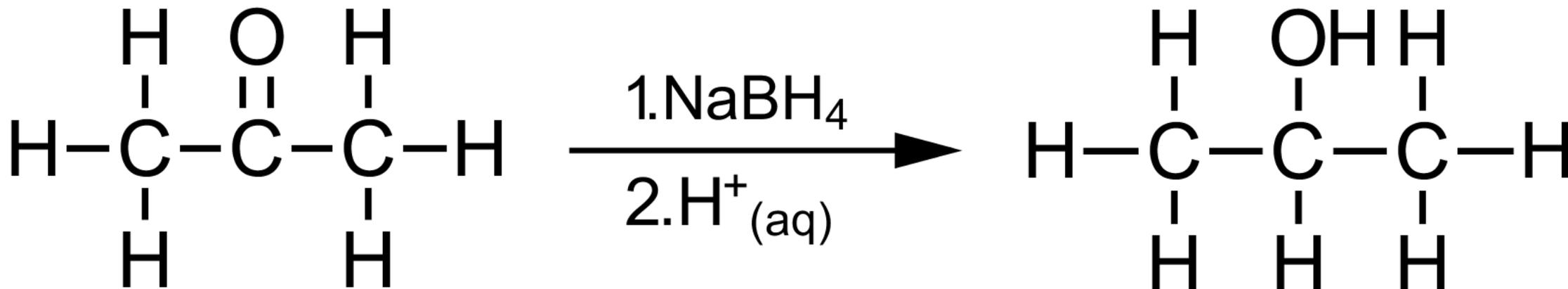
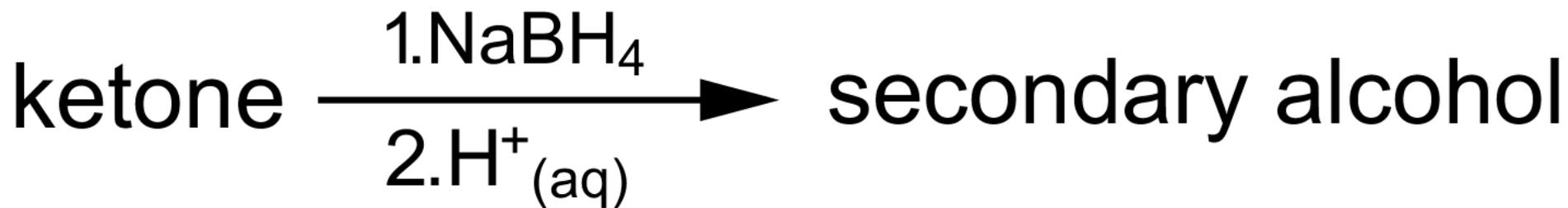
**These reducing agents provide hydride ions ( $\text{H}^-$ ) that act as nucleophiles (nucleophilic addition reactions).**

# Reduction of carbonyl compounds



Conditions: heat with  $\text{NaBH}_4$ , then acidify.

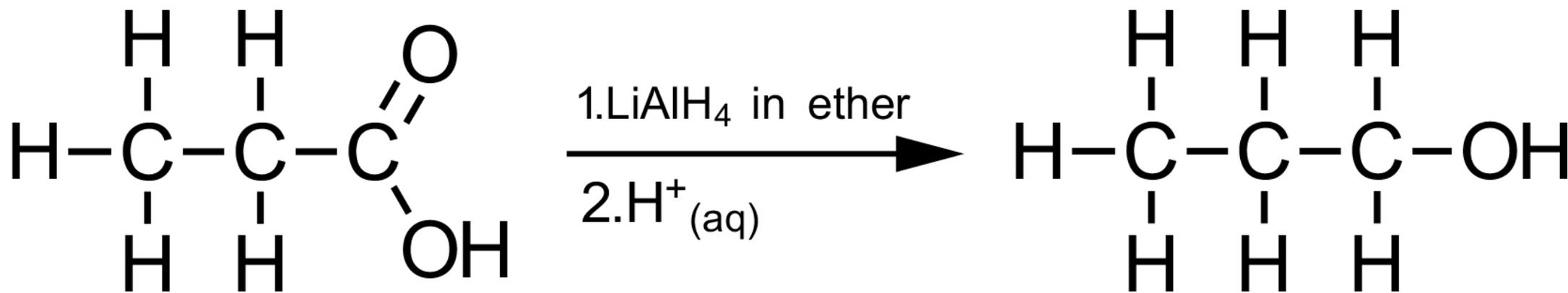
# Reduction of carbonyl compounds



**Conditions: heat with  $\text{NaBH}_4$ , then acidify.**

# Reduction of carbonyl compounds

carboxylic acid  $\xrightarrow[2.H^+_{(aq)}]{1.LiAlH_4 \text{ in ether}}$  primary alcohol



**Conditions: heat with  $LiAlH_4$  in dry ether, then acidify.  
( $NaBH_4$  is not a strong enough reducing agent to reduce carboxylic acids).**

# Reduction of carbonyl compounds

<b>Reactant</b>	<b>Reducing agent</b>	<b>Product</b>
<b>Aldehyde</b>	<b>NaBH<sub>4</sub> or LiAlH<sub>4</sub></b>	<b>Primary alcohol</b>
<b>Ketone</b>	<b>NaBH<sub>4</sub> or LiAlH<sub>4</sub></b>	<b>Secondary alcohol</b>
<b>Carboxylic acid</b>	<b>LiAlH<sub>4</sub> only</b>	<b>Aldehyde or primary alcohol</b>

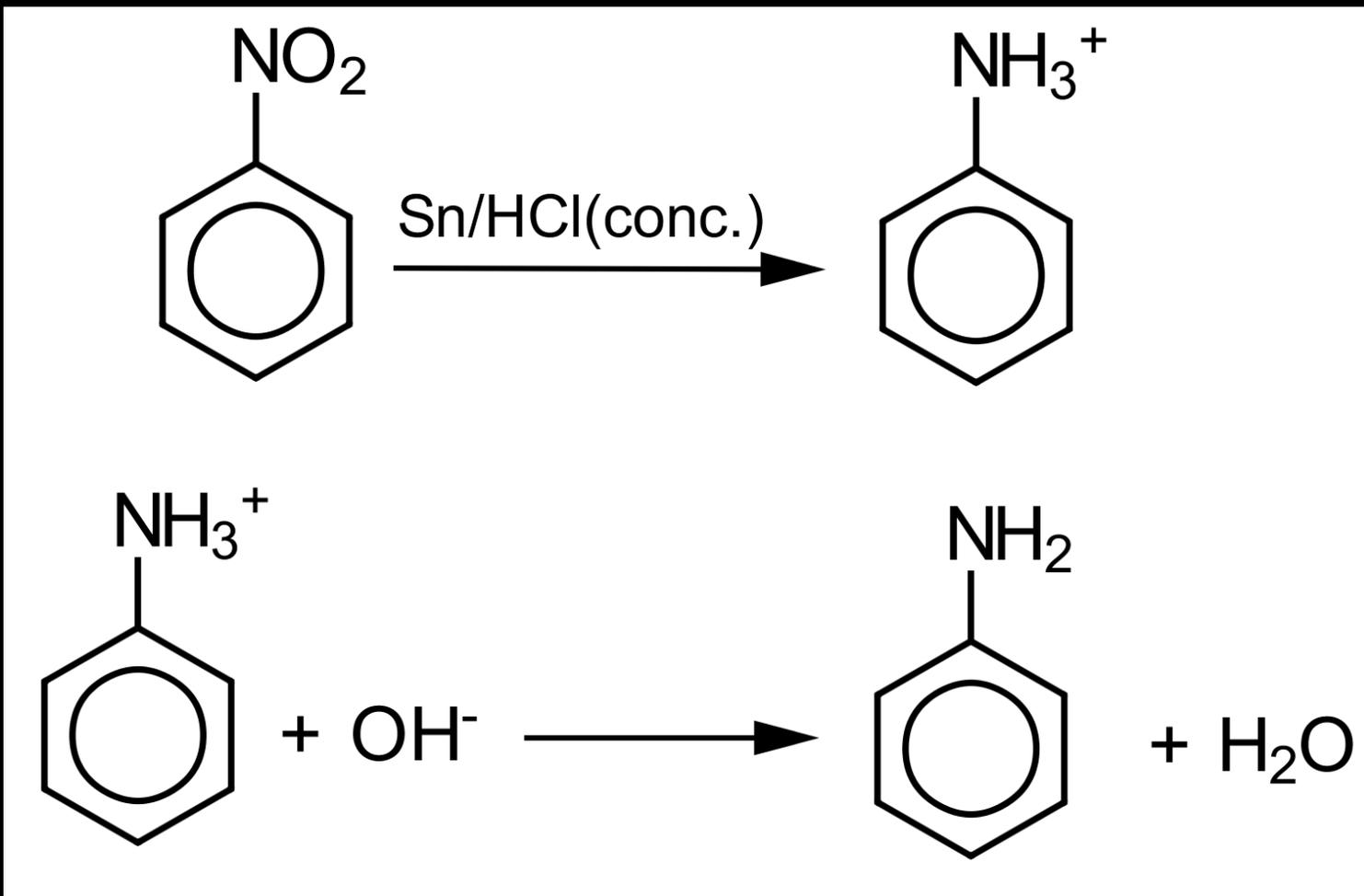
**MSJChem**

**Tutorials for IB Chemistry**

**Reduction of  
nitrobenzene**

# Reduction of nitrobenzene

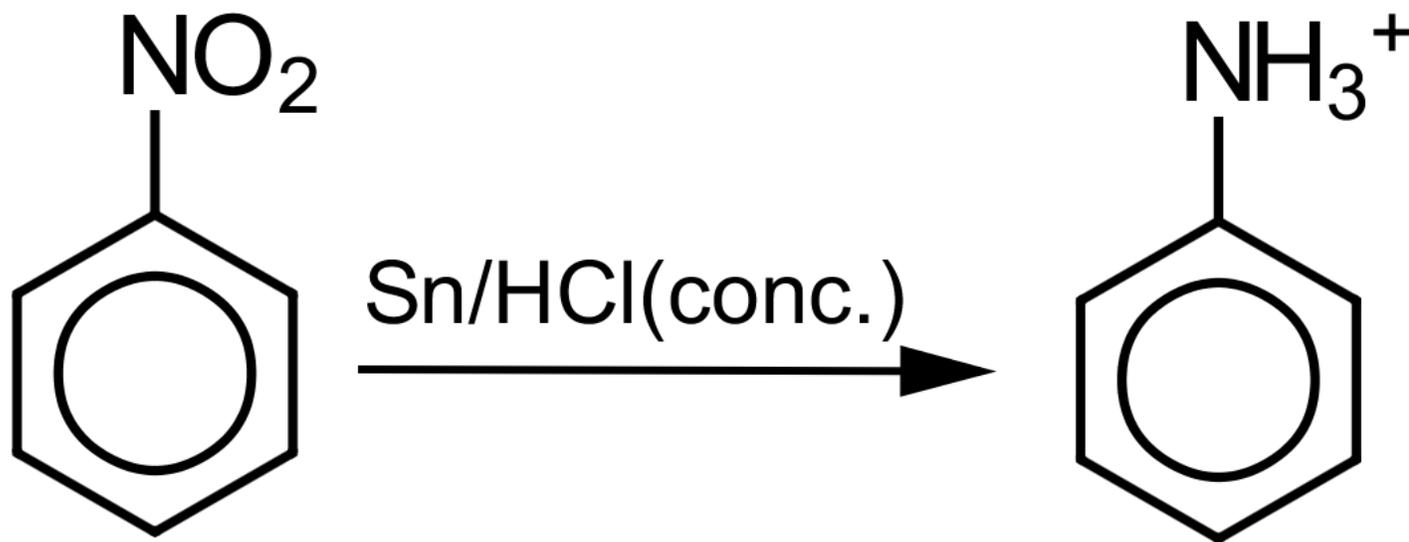
Nitrobenzene,  $C_6H_5NO_2$ , can be reduced to phenylamine (aniline),  $C_6H_5NH_2$ , in a two-stage reaction.



# Reduction of nitrobenzene

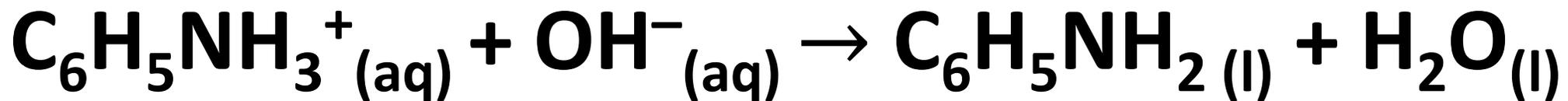
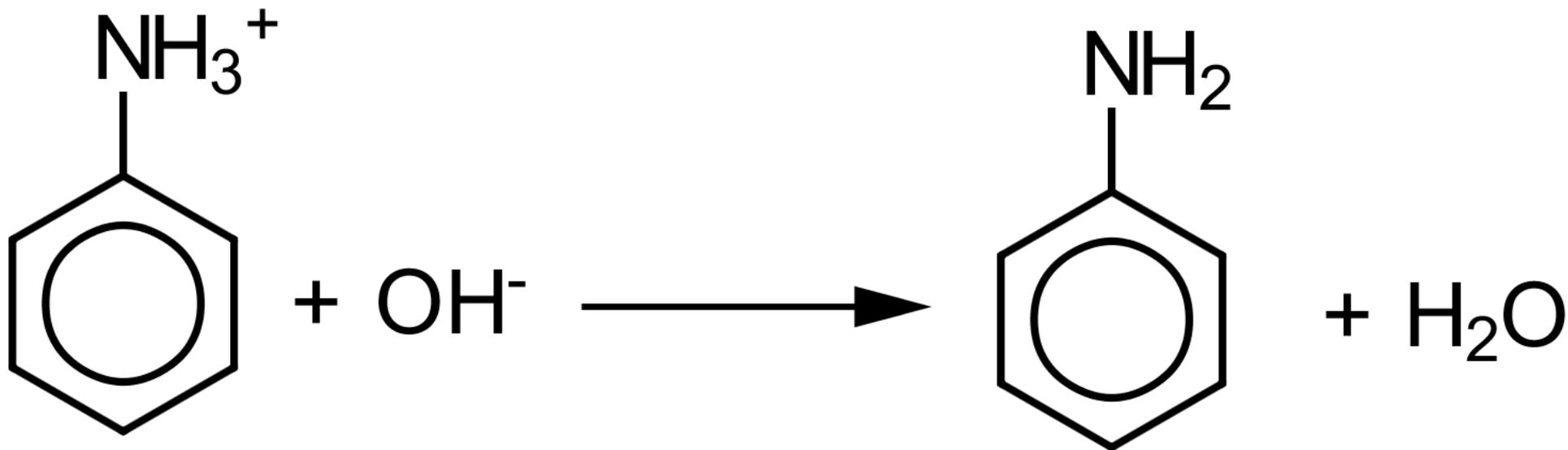
Stage 1 –  $C_6H_5NO_2$  is reacted with Sn and conc. HCl (heat under reflux in a boiling water bath).

The product is the phenylammonium ion ( $C_6H_5NH_3^+$ ).



# Reduction of nitrobenzene

Stage 2 –  $\text{C}_6\text{H}_5\text{NH}_3^+$  is reacted with  $\text{NaOH}$  to remove the hydrogen ion ( $\text{H}^+$ ) and produce phenylamine ( $\text{C}_6\text{H}_5\text{NH}_2$ ).



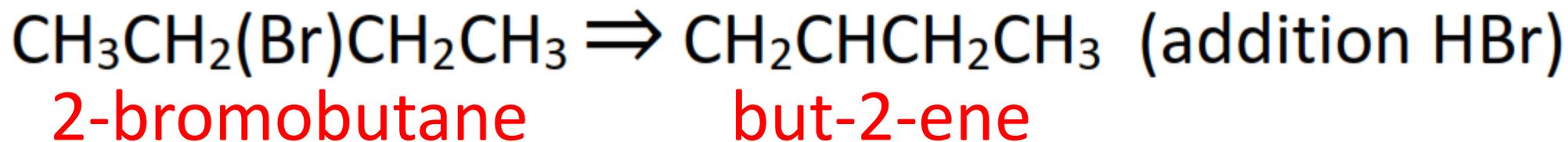
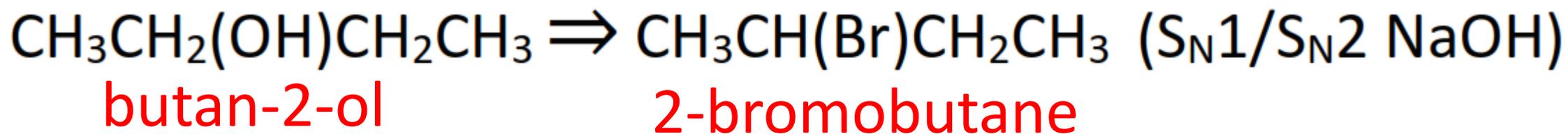
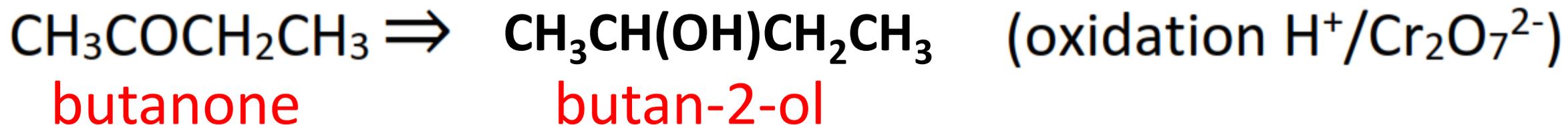
**MSJChem**

**Tutorials for IB Chemistry**

**Retrosynthesis**

# Retrosynthesis

Outline the steps involved in the retrosynthesis of butanone starting with an alkene.



# Retrosynthesis

Retrosynthesis involves planning a synthesis backwards, by starting at the product, (the target molecule) and taking it back one step at a time to simple, available starting materials (precursors).

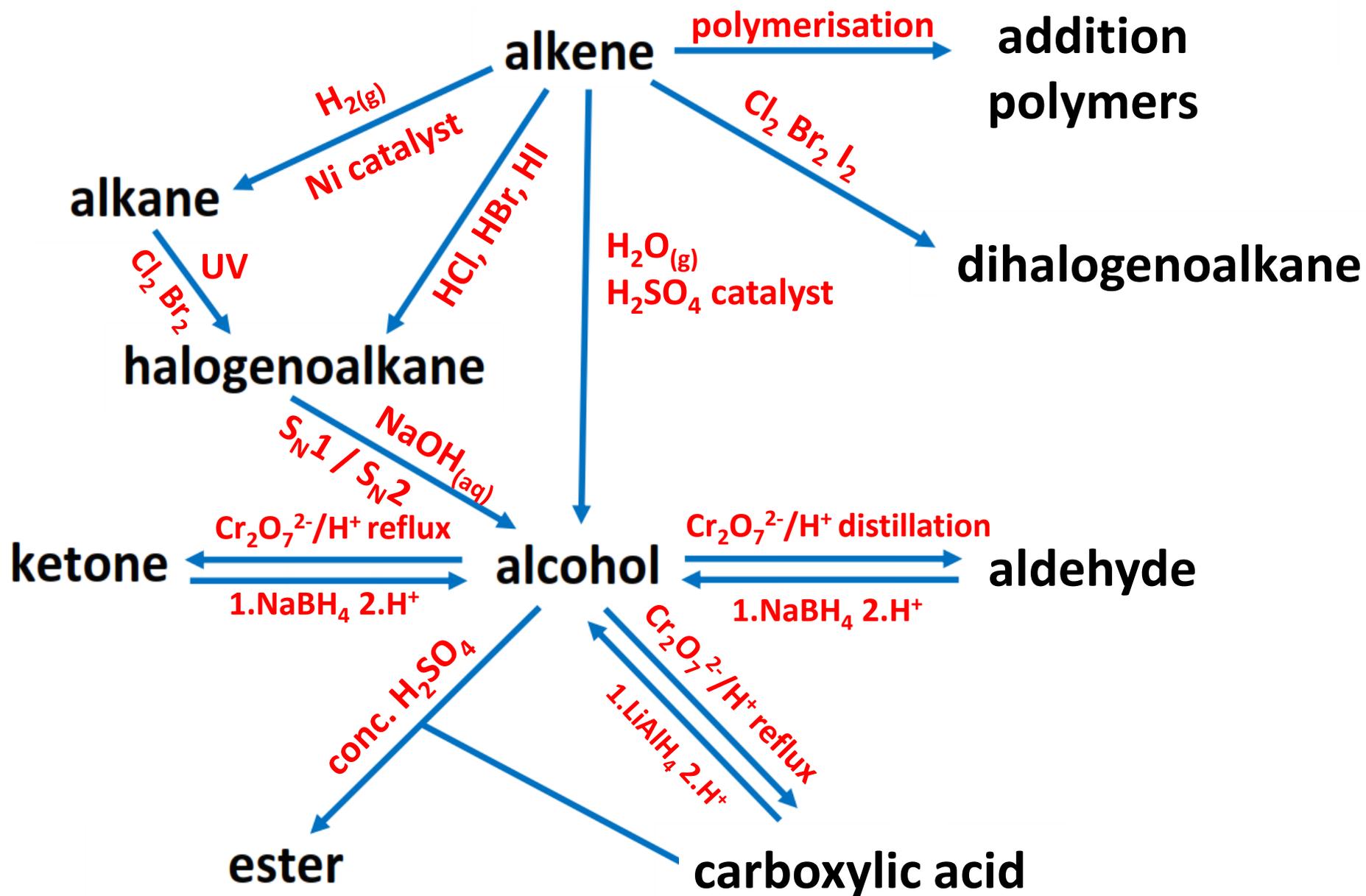
target molecule  $\Rightarrow$  precursor 1  $\Rightarrow$  precursor 2  $\Rightarrow$  starting material

**MSJChem**

**Tutorials for IB Chemistry**

**Organic reaction  
pathways**

# Organic reaction pathways



**MSJChem**

**Tutorials for IB Chemistry**

**Isomerism**

# Isomerism

Isomerism – compounds with same molecular formula but different arrangement of atoms

Stereoisomerism –  
different spatial  
arrangement of atoms

Structural isomerism –  
atoms and functional  
groups attached in  
different ways

# Isomerism

## Stereoisomerism

**Configurational  
isomerism –  
interconvert only by  
breaking a bond**

**Conformational  
isomerism –  
interconvert by rotation  
around a  $\sigma$  bond**

# Isomerism

**Configurational isomerism**

```
graph TD; A[Configurational isomerism] --> B["cis-trans and E/Z isomerism – restricted rotation around atoms"]; A --> C["Optical isomerism – asymmetric or chiral carbon atom"];
```

*cis-trans* and *E/Z*  
isomerism –  
restricted rotation  
around atoms

Optical isomerism –  
asymmetric or chiral  
carbon atom

**MSJChem**

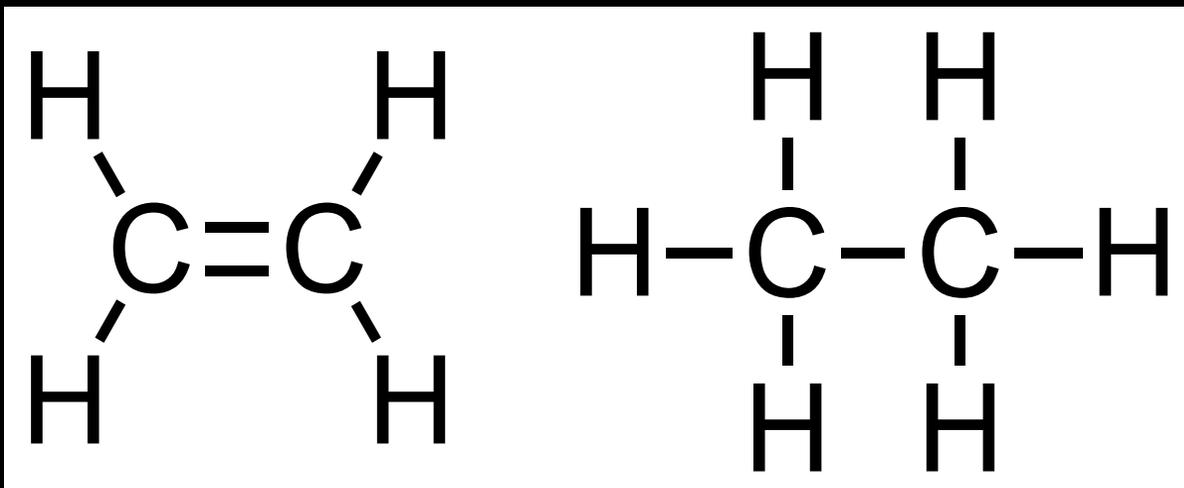
**Tutorials for IB Chemistry**

**Conformational  
isomerism**

# Conformational isomers

Conformational isomers (conformers) are stereoisomers produced by rotation about carbon-carbon single bonds.

C=C bond  
made of 1  $\sigma$   
and 1  $\pi$  bond  
(restricted  
rotation)



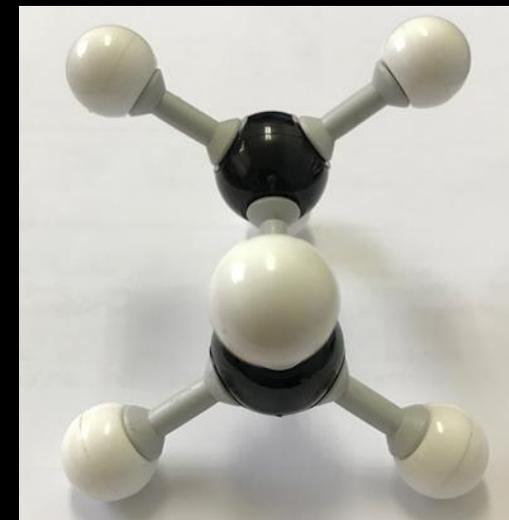
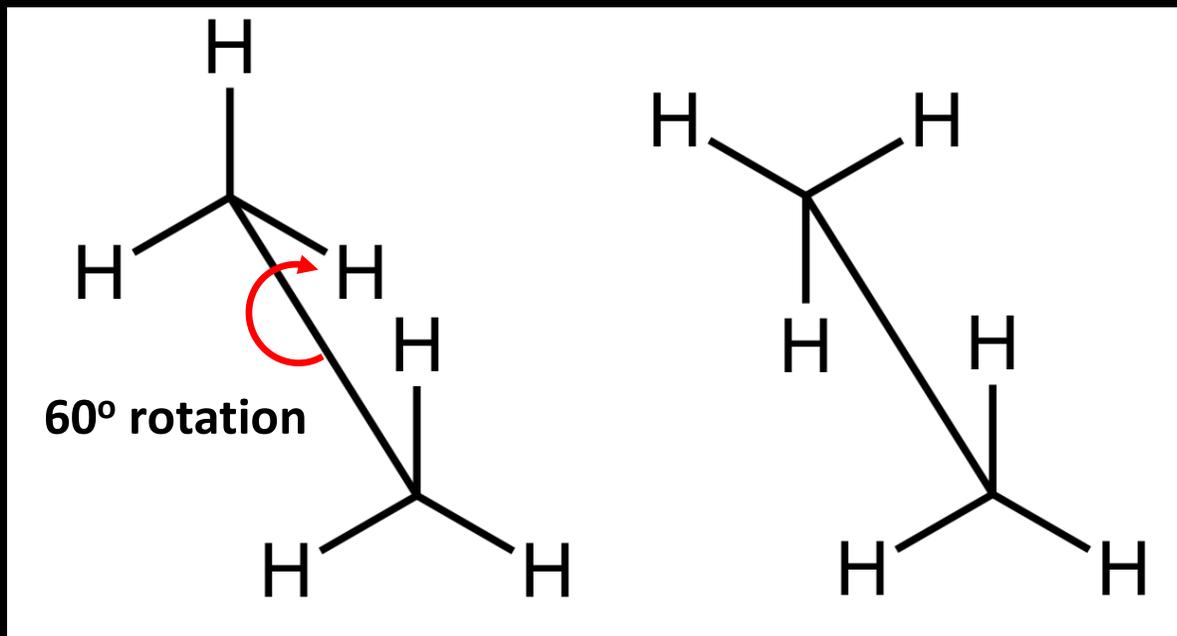
C-C bond  
made of 1  $\sigma$   
bond  
(free rotation)

The two conformers can interconvert readily at room temperature.

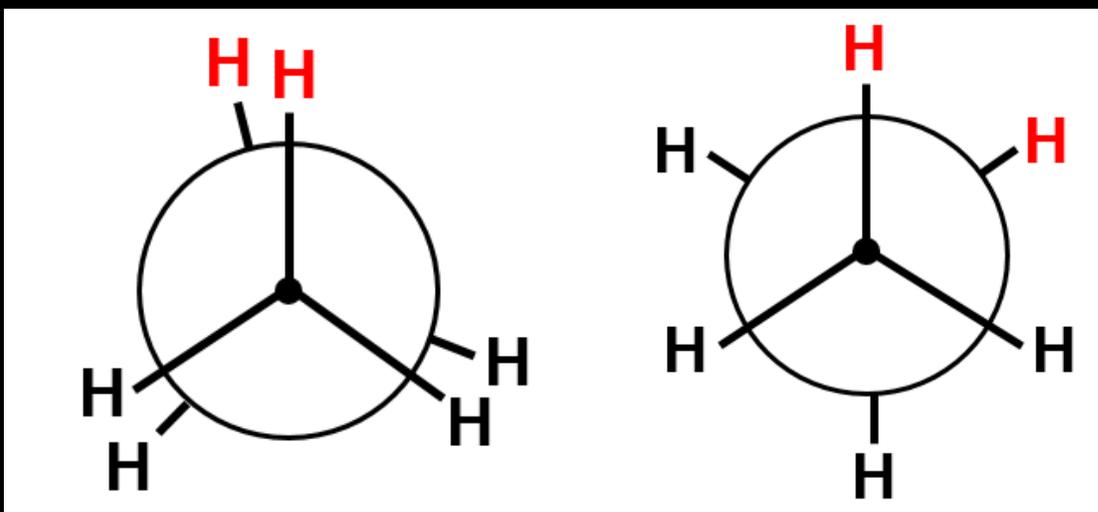
# Conformational isomers



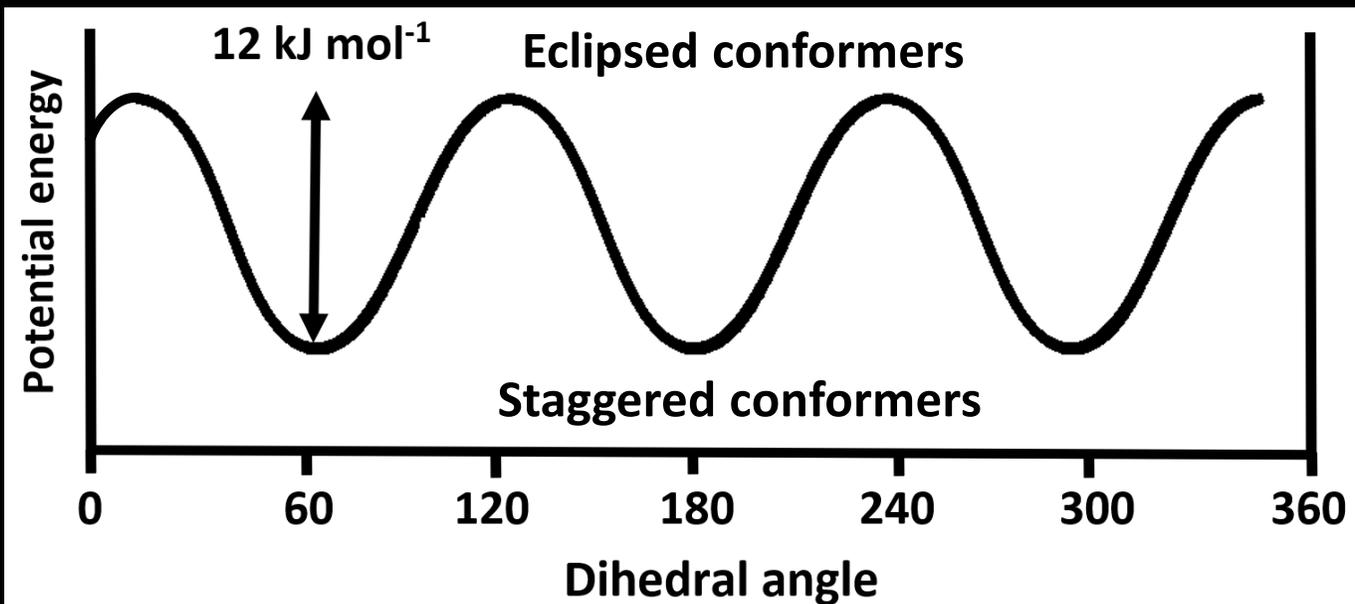
**Eclipsed conformer**



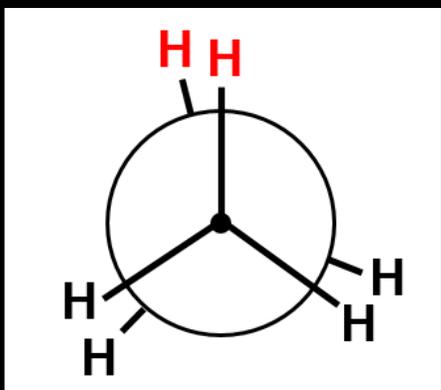
**Staggered conformer**



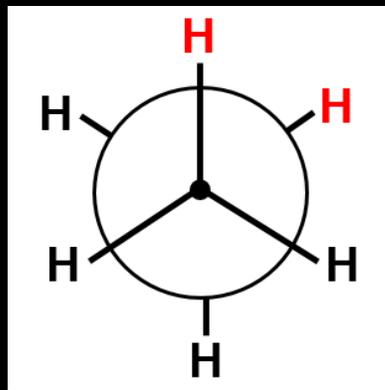
# Conformational isomers



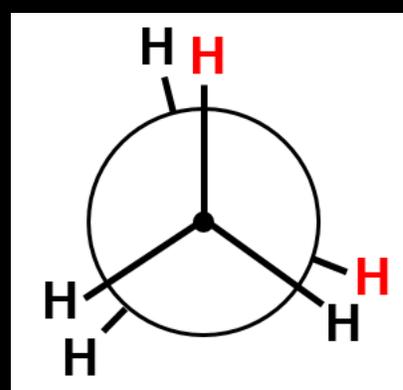
The staggered conformation is more stable by approximately 12 kJ mol<sup>-1</sup>



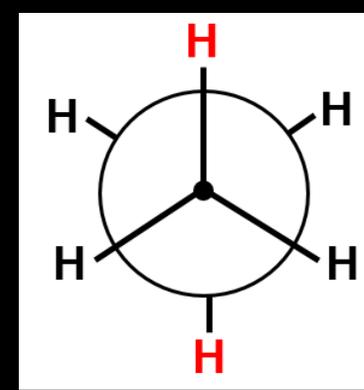
Dihedral angle = 0°



Dihedral angle = 60°



Dihedral angle = 120°



Dihedral angle = 180°

# Conformational isomers

Conformational isomers occur because of the free rotation around a carbon-carbon single bond (composed of one  $\sigma$  bond).

The staggered conformers are more stable than the eclipsed conformers.

The two conformers interconvert rapidly at room temperature because of the small difference in energy between them.

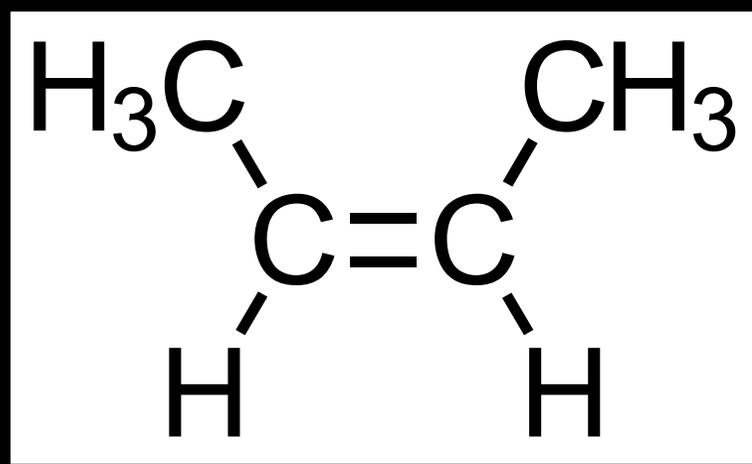
**MSJChem**

**Tutorials for IB Chemistry**

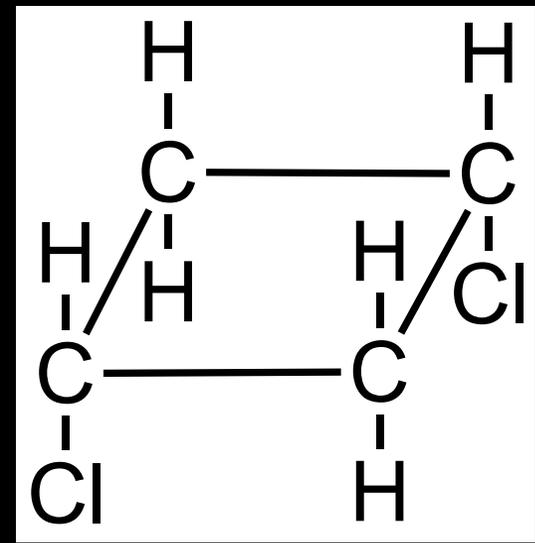
***cis-trans* isomerism**

# *cis-trans* isomerism

*cis-trans* isomerism occurs where there is restricted rotation around a carbon to carbon bond.



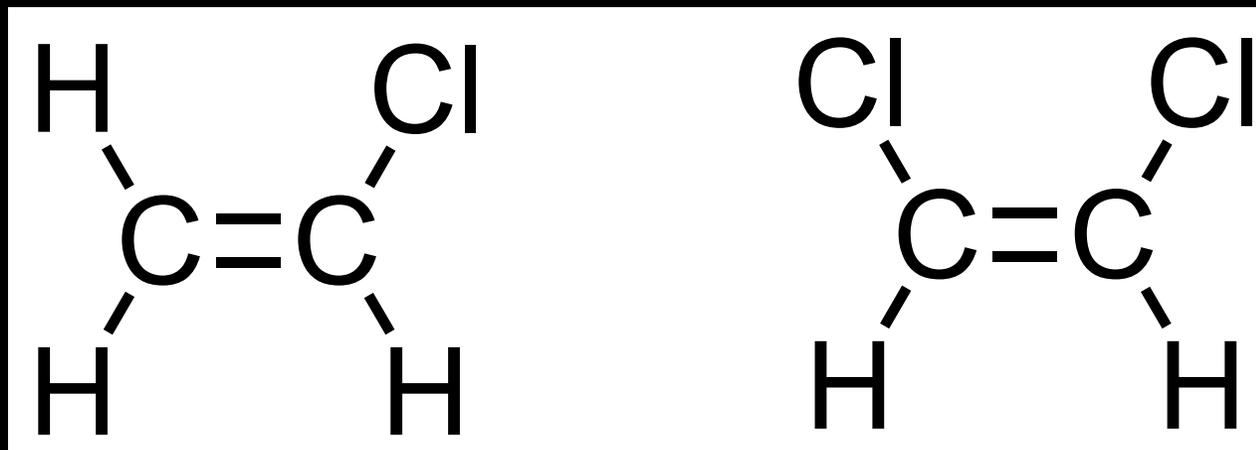
Restricted rotation around a C=C bond



Restricted rotation in a cyclic compound

# *cis-trans* isomerism

For *cis-trans* isomerism to occur, there must be two different groups on each of the carbon atoms of the C=C bond.

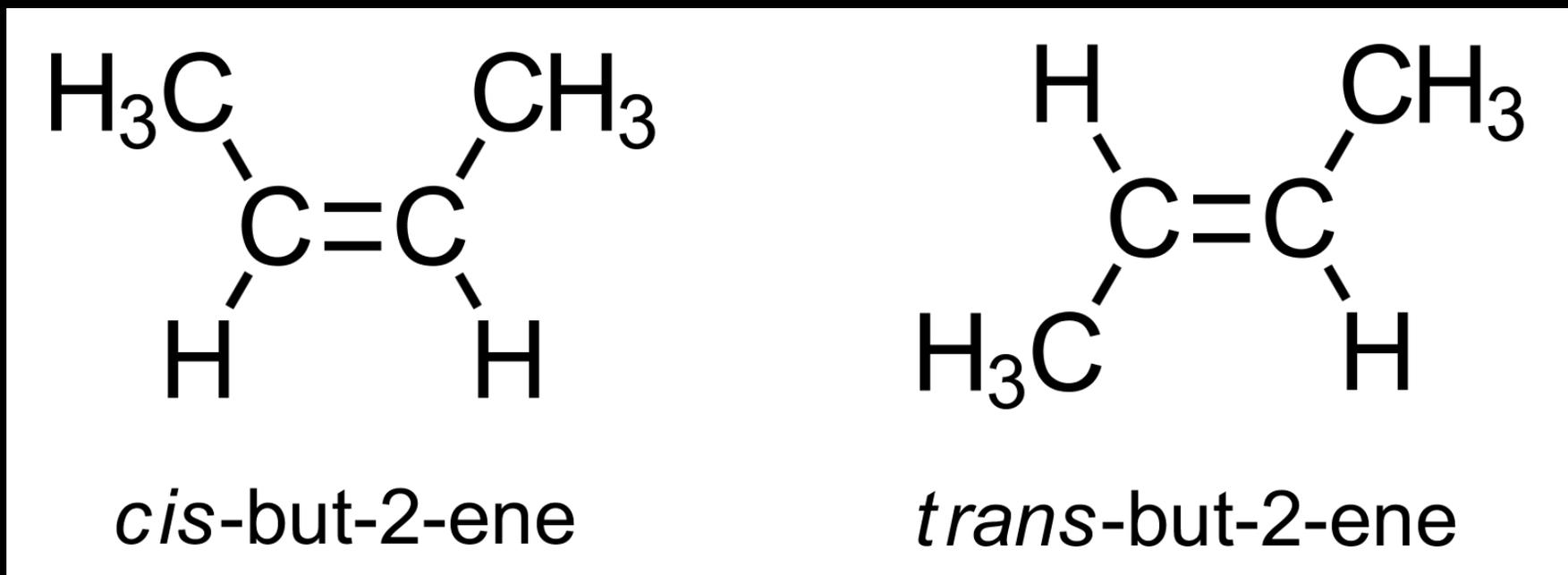


This molecule does not have *cis-trans* isomers

This molecule does have *cis-trans* isomers

# *cis-trans* isomerism

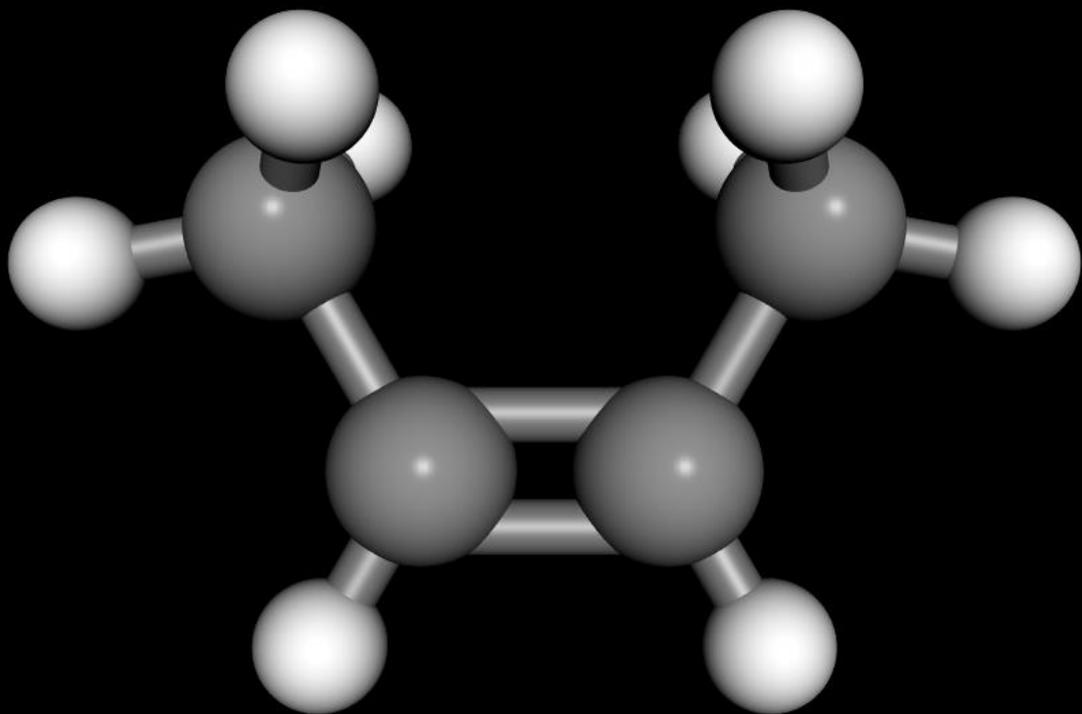
The  $\pi$  bond in the C=C bond restricts rotation, forming two different isomers.



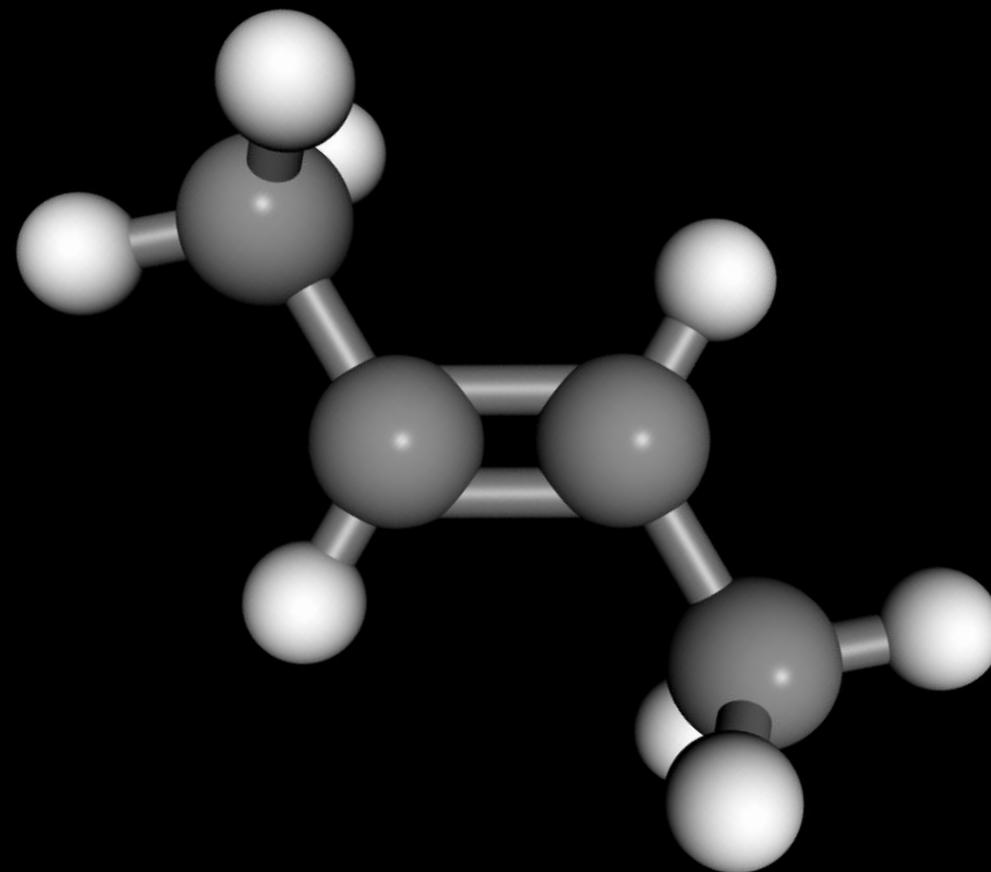
*cis* isomer – same groups on the same side of C=C bond.

*trans* isomer – same groups on opposite sides of C=C bond.

# *cis-trans* isomerism



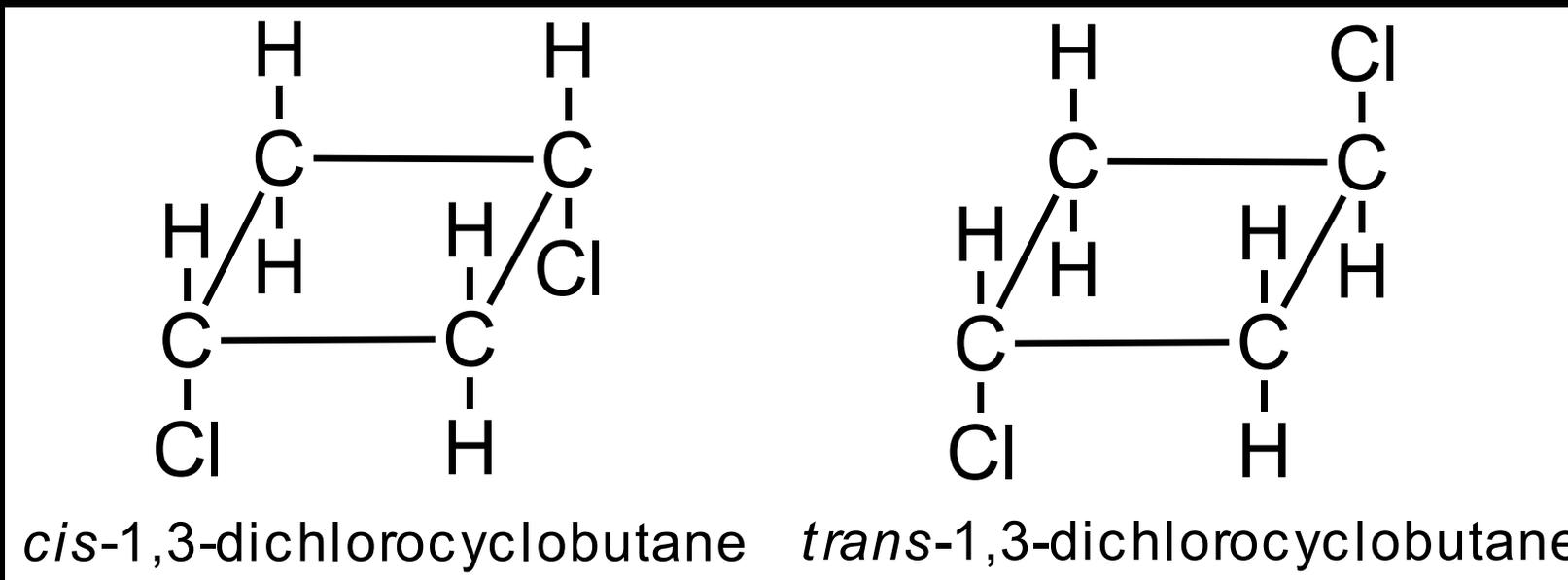
*cis-but-2-ene*



*trans-but-2-ene*

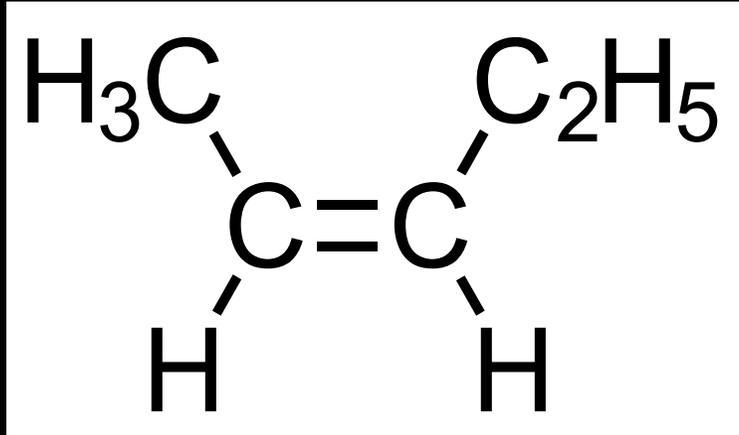
# *cis-trans* isomerism

Cyclic compounds contain a ring structure that restricts rotation. When the molecule contains two or more different substituents attached to the ring, two different isomers are formed.

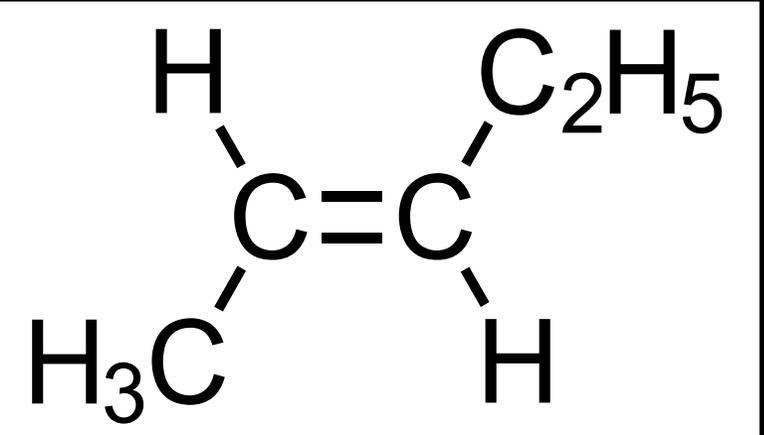


*cis* isomer has the substituents on the same side of the ring, *trans* isomer has the substituents on opposite sides of the ring.

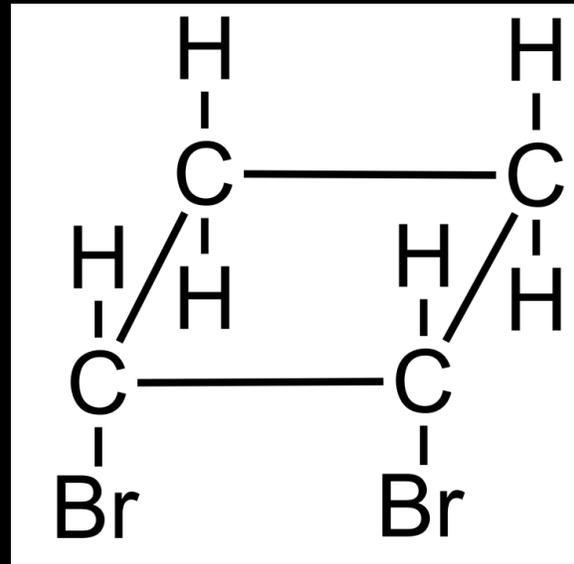
# *cis-trans* isomerism



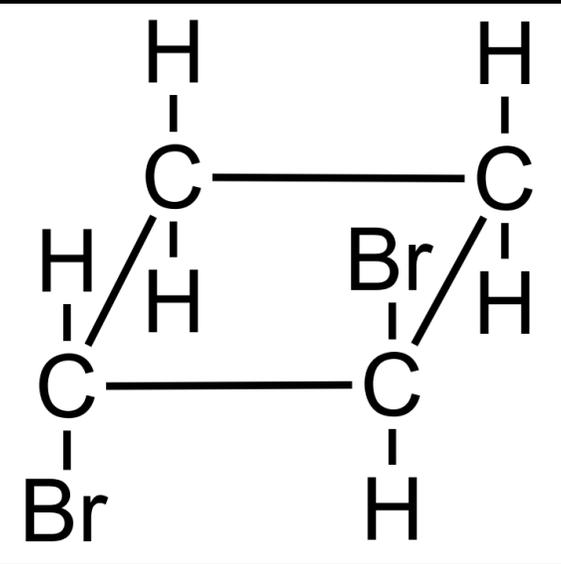
*cis*-pent-2-ene



*trans*-pent-2-ene



*cis*-1,2-dibromocyclobutane



*trans*-1,2-dibromocyclobutane

**MSJChem**

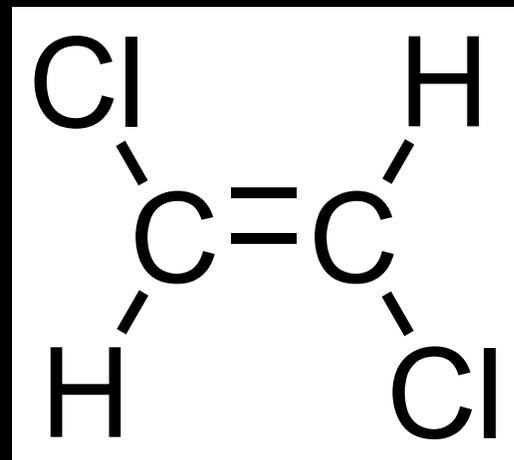
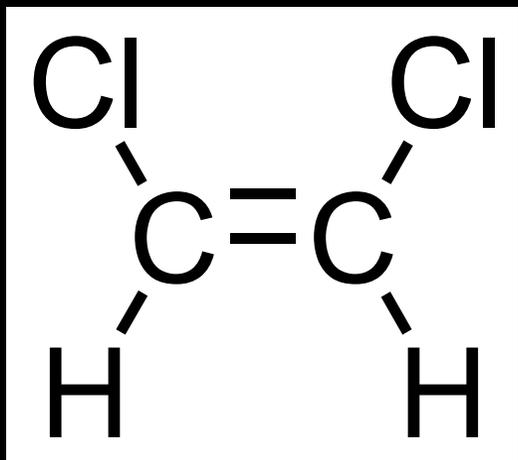
**Tutorials for IB Chemistry**

**Physical properties of  
*cis-trans* isomers**

**cis-1,2-dichloroethene**

**trans-1,2-dichloroethene**

polar  
molecule  
B.P. 60°C  
M.P. -80°C



non-polar  
molecule  
B.P. 48°C  
M.P. -50°C

The polarity of the molecule influences the boiling point.  
The symmetry of the molecule influences the melting point (closely packed molecules have stronger intermolecular forces).

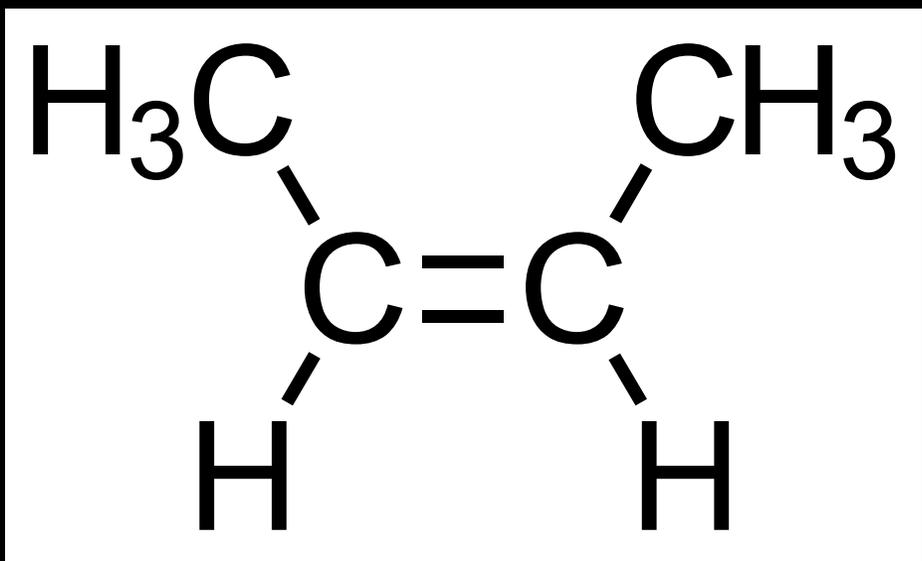
**MSJChem**

**Tutorials for IB Chemistry**

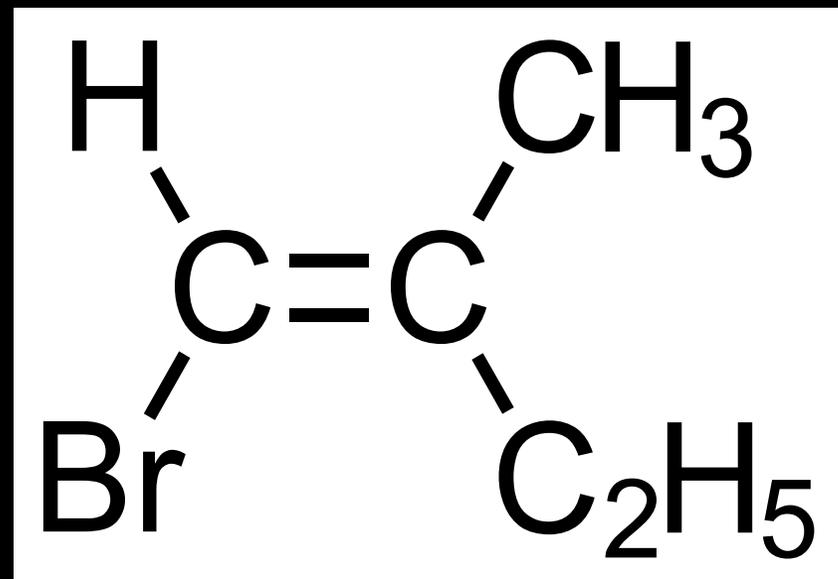
***E/Z* isomerism**

# ***E/Z* isomerism**

***E/Z* notation is used when there are up to four different substituents bonded to the two carbon atoms of the C=C bond.**



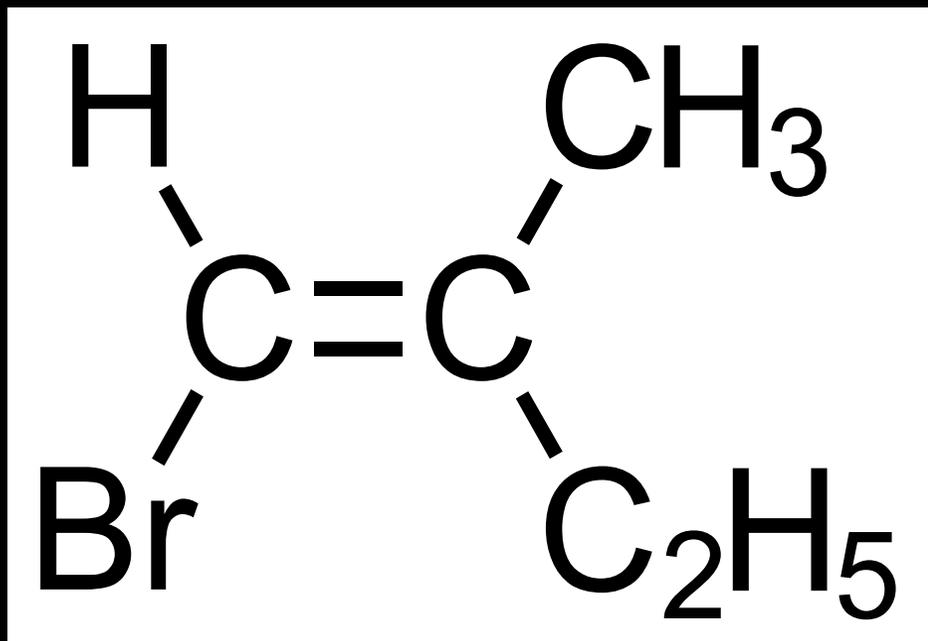
***cis-but-2-ene***



# **E/Z isomerism**

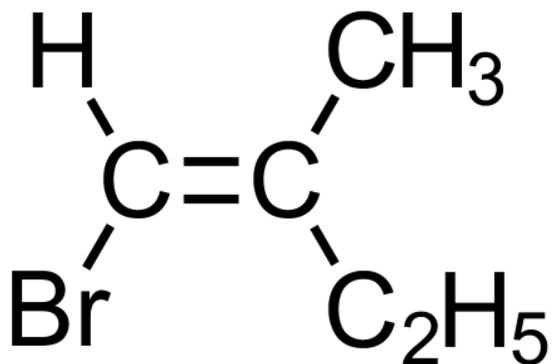
**E/Z isomerism is based on the Cahn-Ingold-Prelog (CIP) rules of priority which assign priority to each atom or group of atoms around the C=C bond.**

**H Z = 1**  
**Br Z = 35**

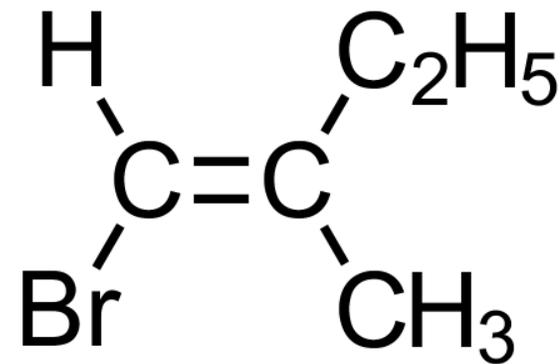


**C-H Z = 1**  
**C-C Z = 6**

# *E/Z* isomerism



[Z]-1-bromo-2-methylbut-1-ene

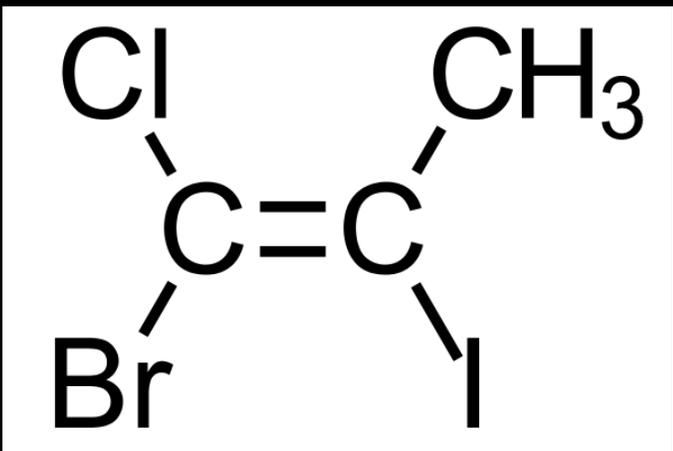


[E]-1-bromo-2-methylbut-1-ene

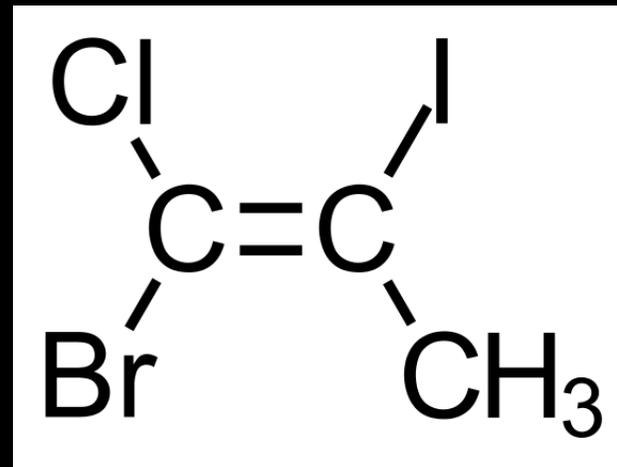
If the highest priority groups are on the same side of the C=C, it is the *Z* isomer.

If the highest priority groups are on opposite sides of the C=C, it is the *E* isomer.

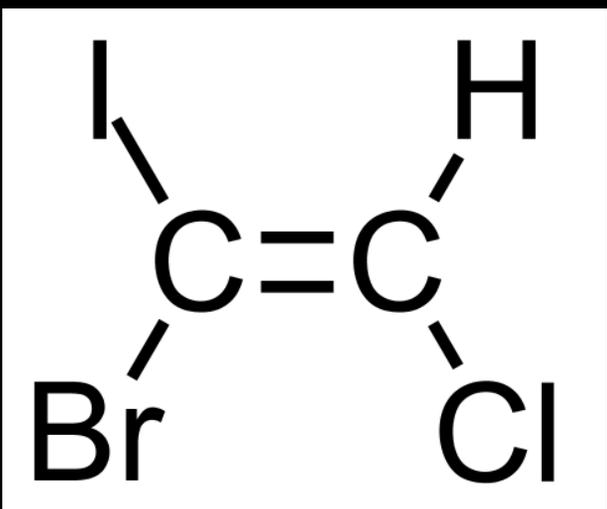
# *E/Z* isomerism



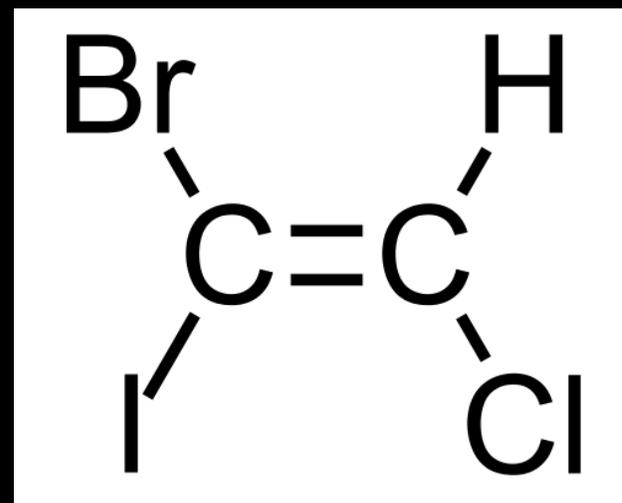
(Z)-1-bromo-1-chloro-2-iodo-1-propene



(E)-1-bromo-1-chloro-2-iodo-1-propene



(E)-1-bromo-2-chloro-1-iodoethene



(Z)-1-bromo-2-chloro-1-iodoethene

# *E/Z* isomerism

How to determine if the isomer is *E* or *Z*:

1. Assign priority to the atoms or groups of atoms on each carbon atom of the C=C double bond



2. If the highest priority groups are on the same side of the C=C bond, it is the *Z* isomer (together).
3. If the highest priority groups are on opposite sides of the C=C bond, it is the *E* isomer (opposite).

**MSJChem**

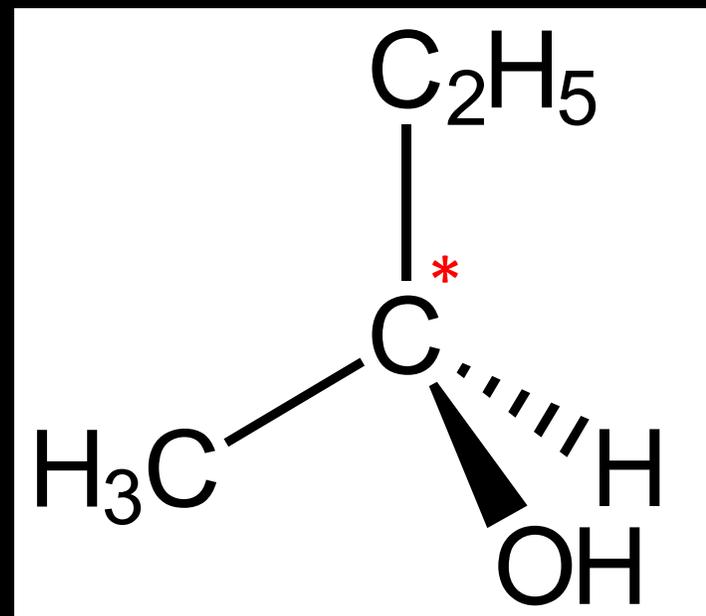
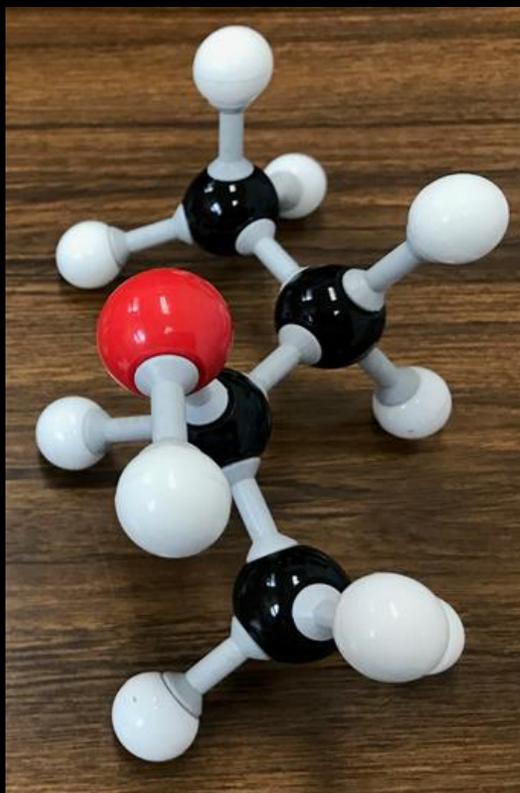
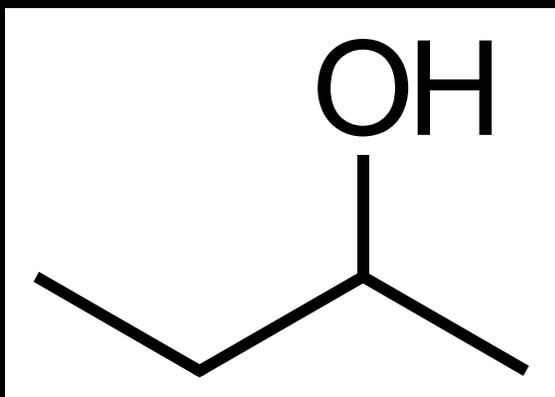
**Tutorials for IB Chemistry**

**Optical isomerism**

# Optical isomerism

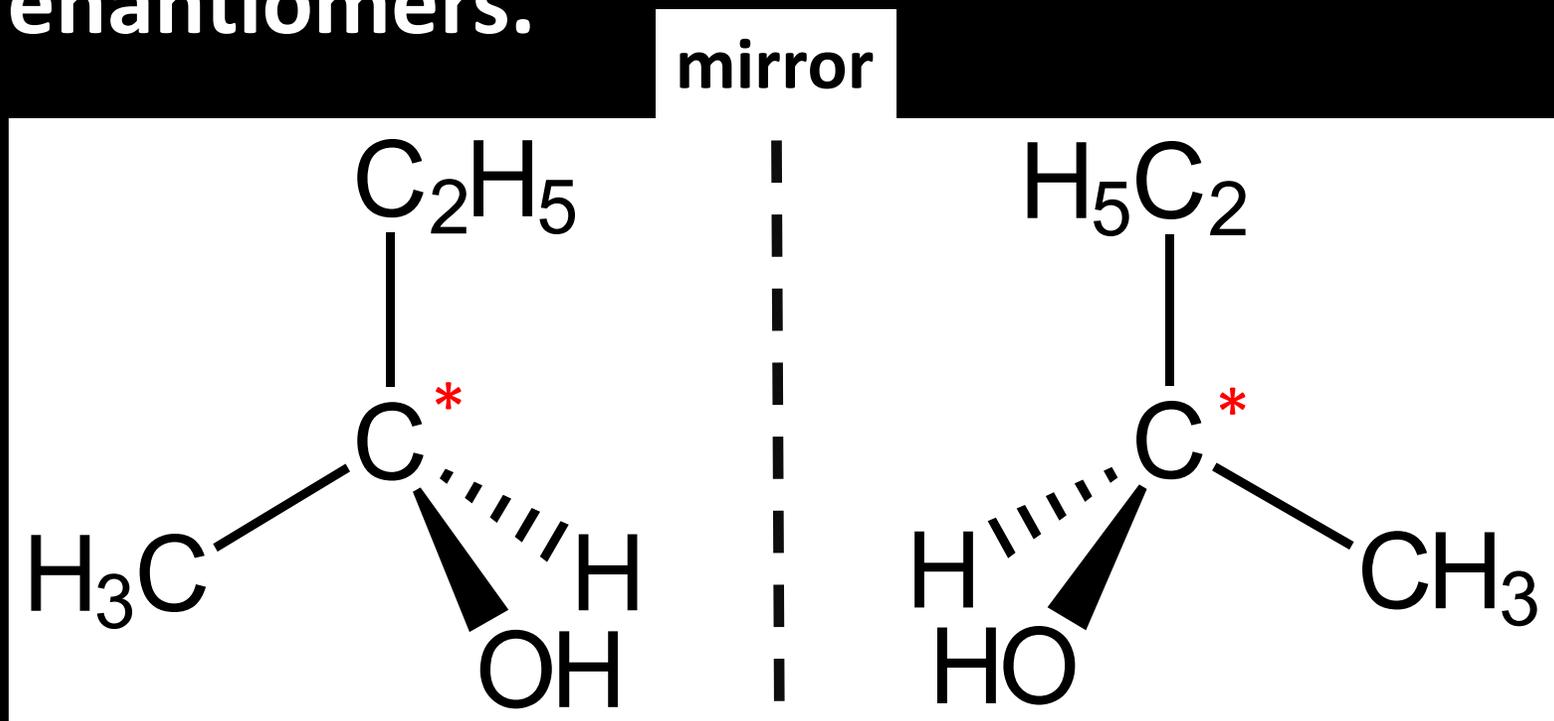
Optical isomerism is shown by chiral molecules that have a carbon atom bonded to four different atoms or groups (chiral center or asymmetric carbon).

butan-2-ol



# Optical isomerism

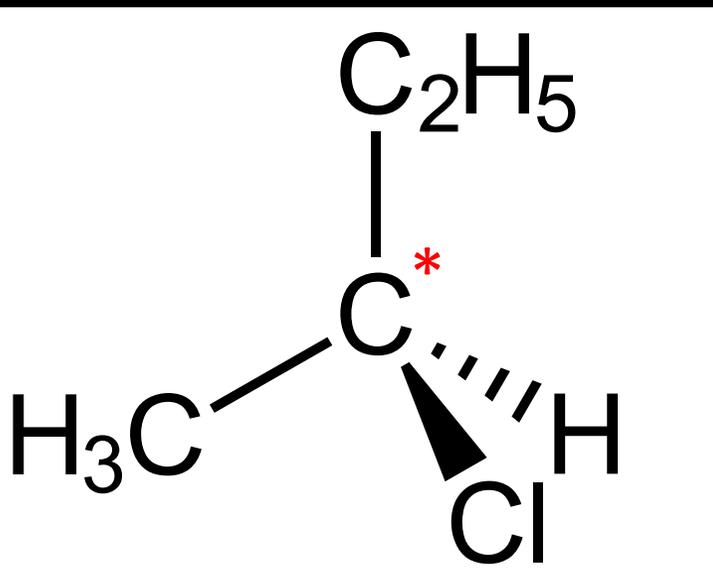
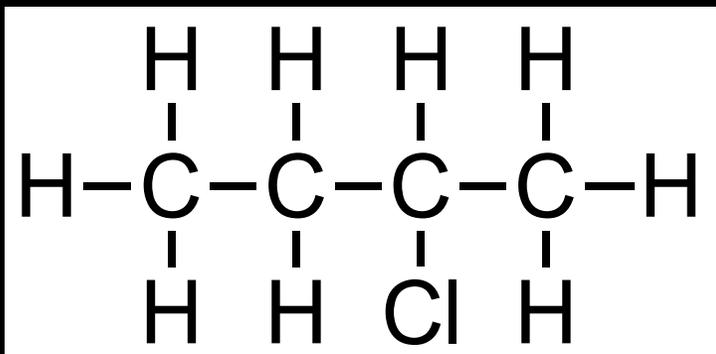
The four groups can be arranged in two three-dimensional configurations which are mirror images of each other. The two mirror images are non-superimposable and are known as enantiomers.



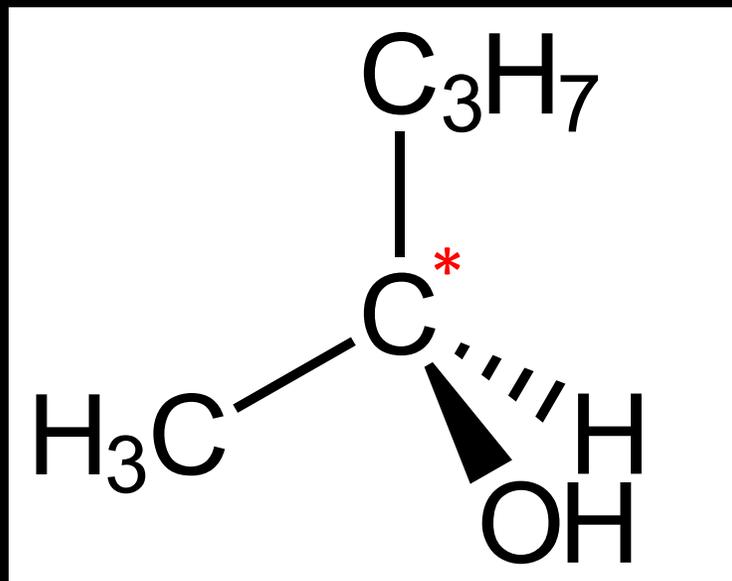
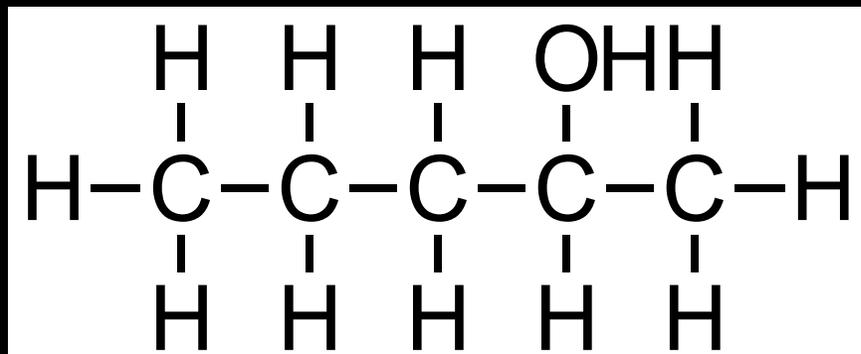
butan-2-ol

# Optical isomerism

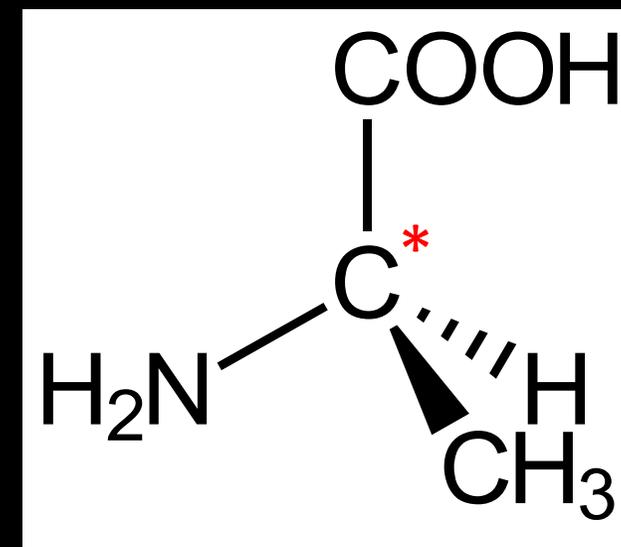
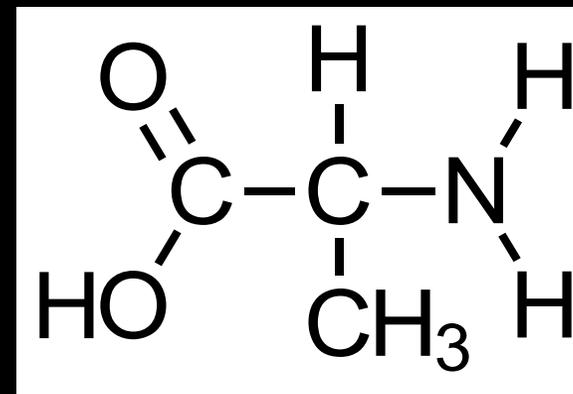
## 2-chlorobutane



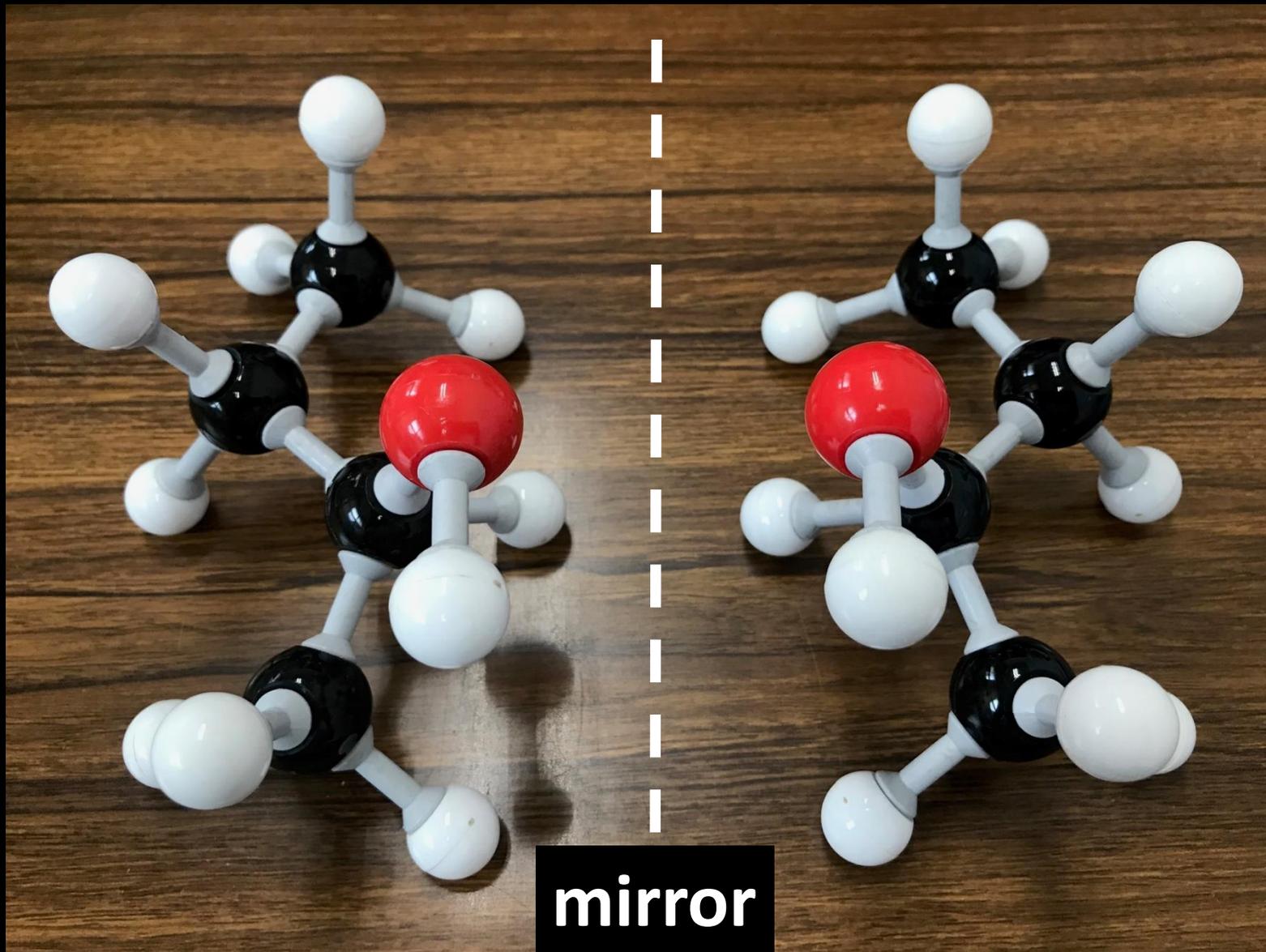
## Pentan-2-ol



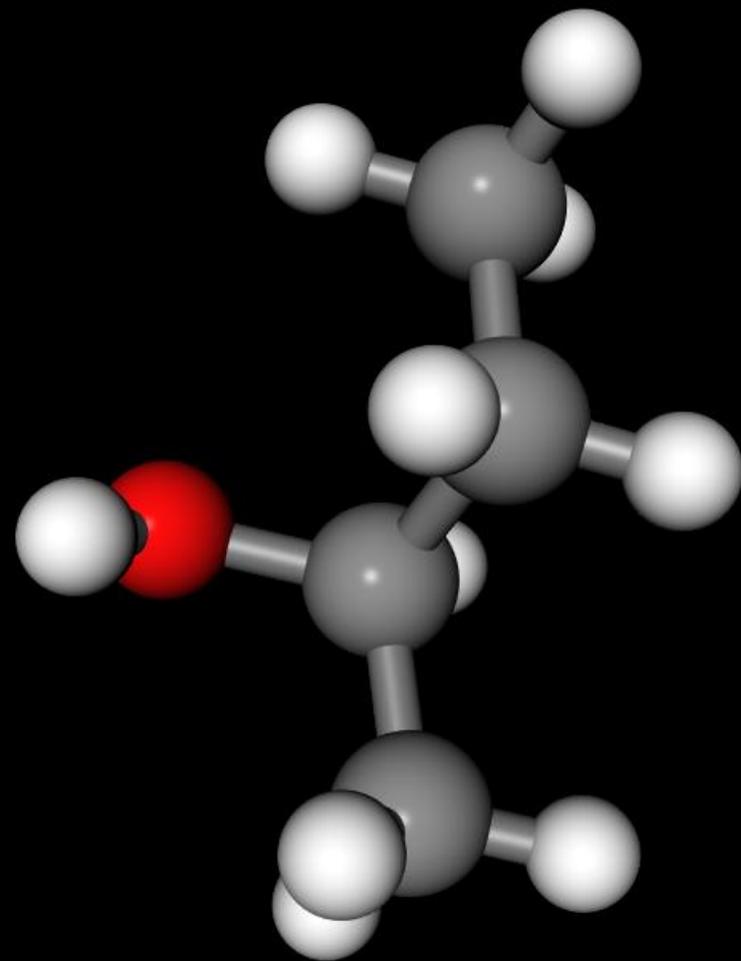
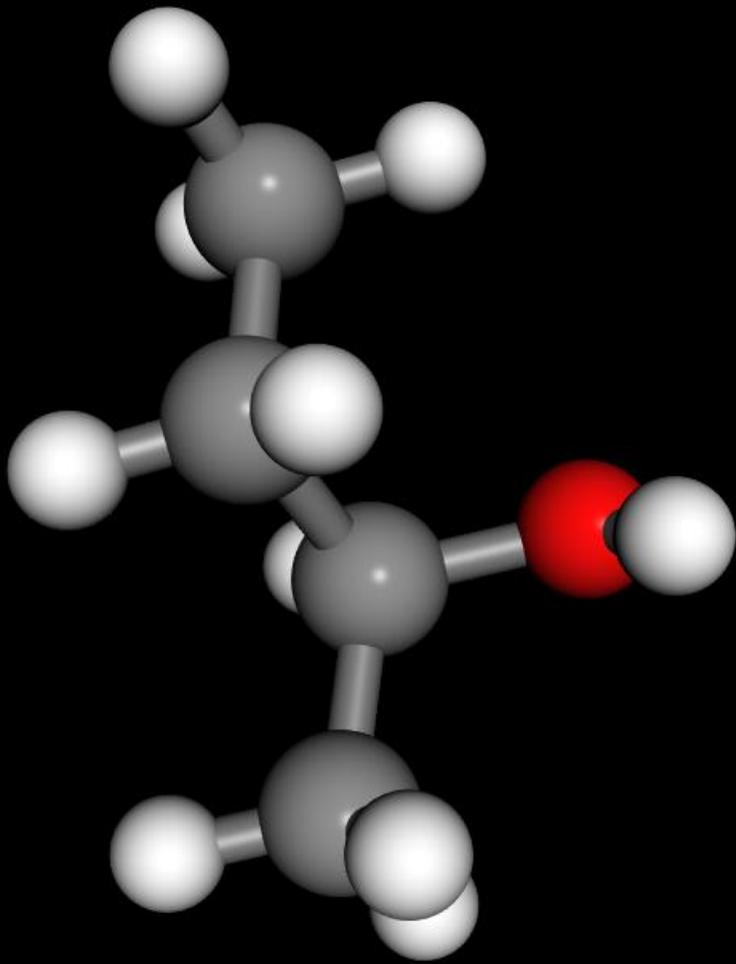
## Alanine



# Optical isomerism

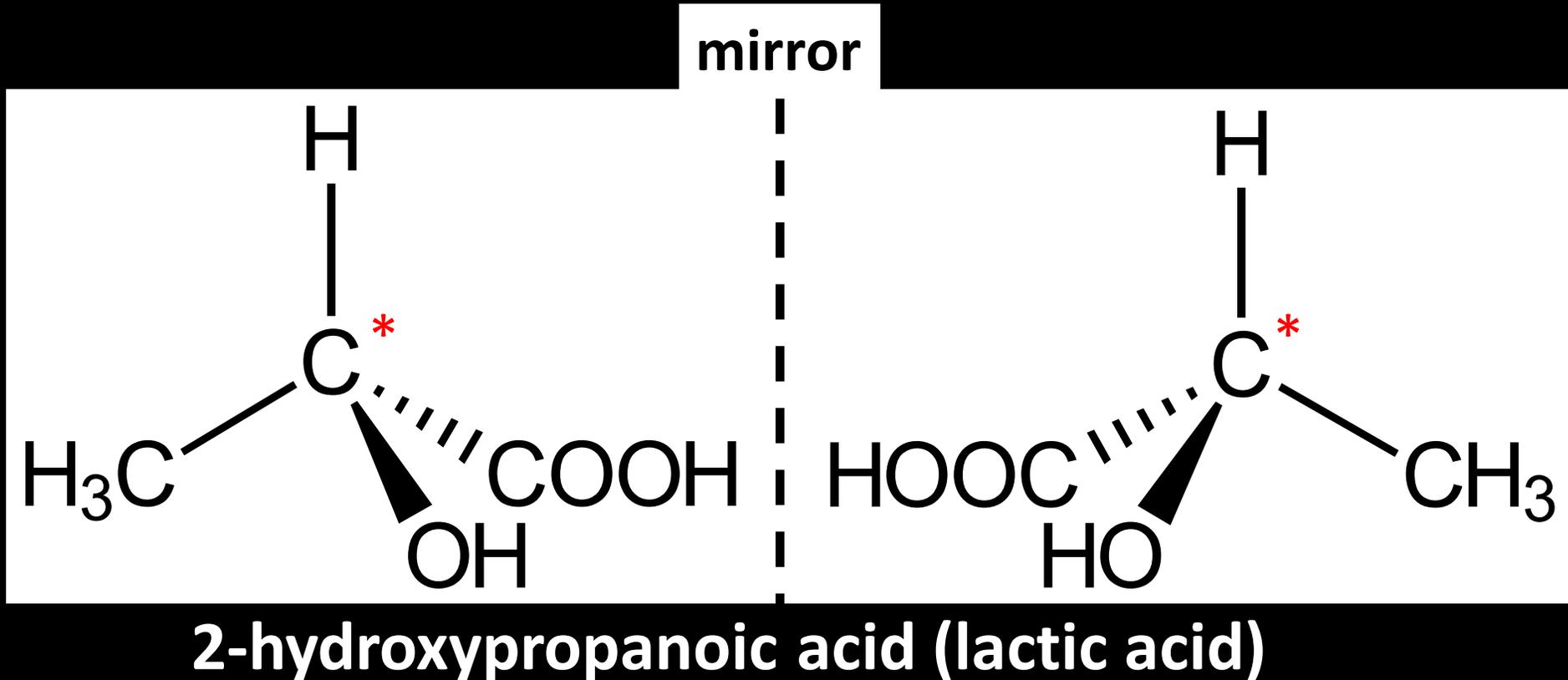


# Optical isomerism



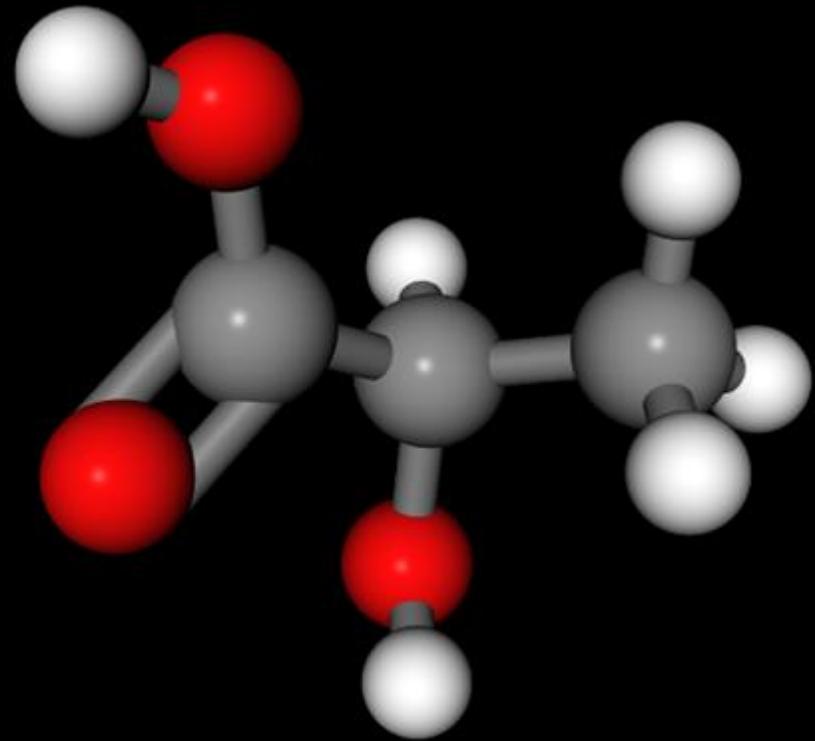
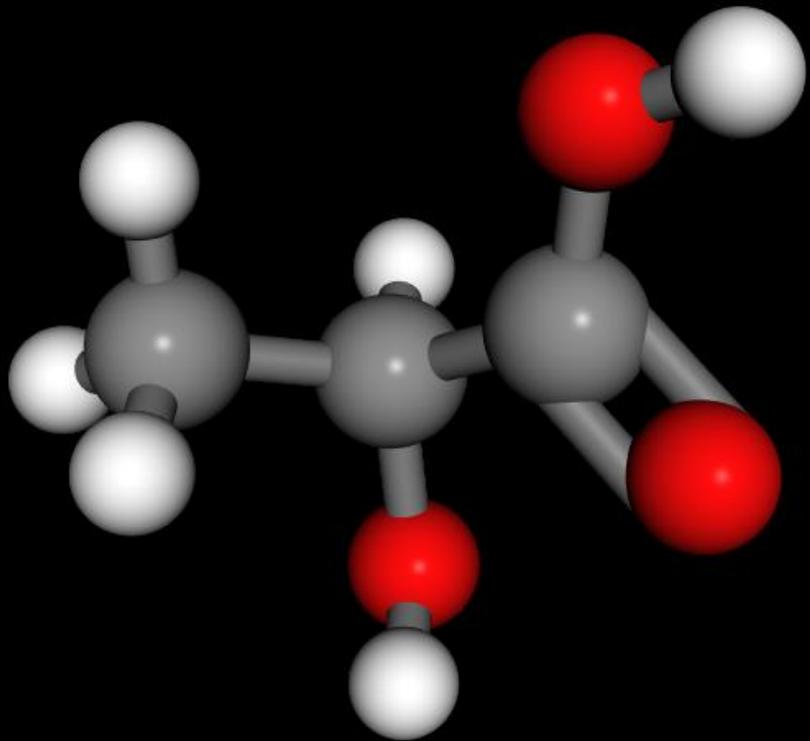
mirror

# Optical isomerism



The two optical isomers (enantiomers) are optically active with plane-polarised light.

# Optical isomerism



mirror

# Optical isomerism

Enantiomers have identical physical properties, such as melting point and boiling point, except that they rotate the plane of plane-polarised light in opposite directions (optically active).

This property is used to distinguish between the two enantiomers of a chiral molecule.

The chemical properties of two enantiomers are also identical, except when they react with other chiral molecules (such as those found in the human body).

**MSJChem**

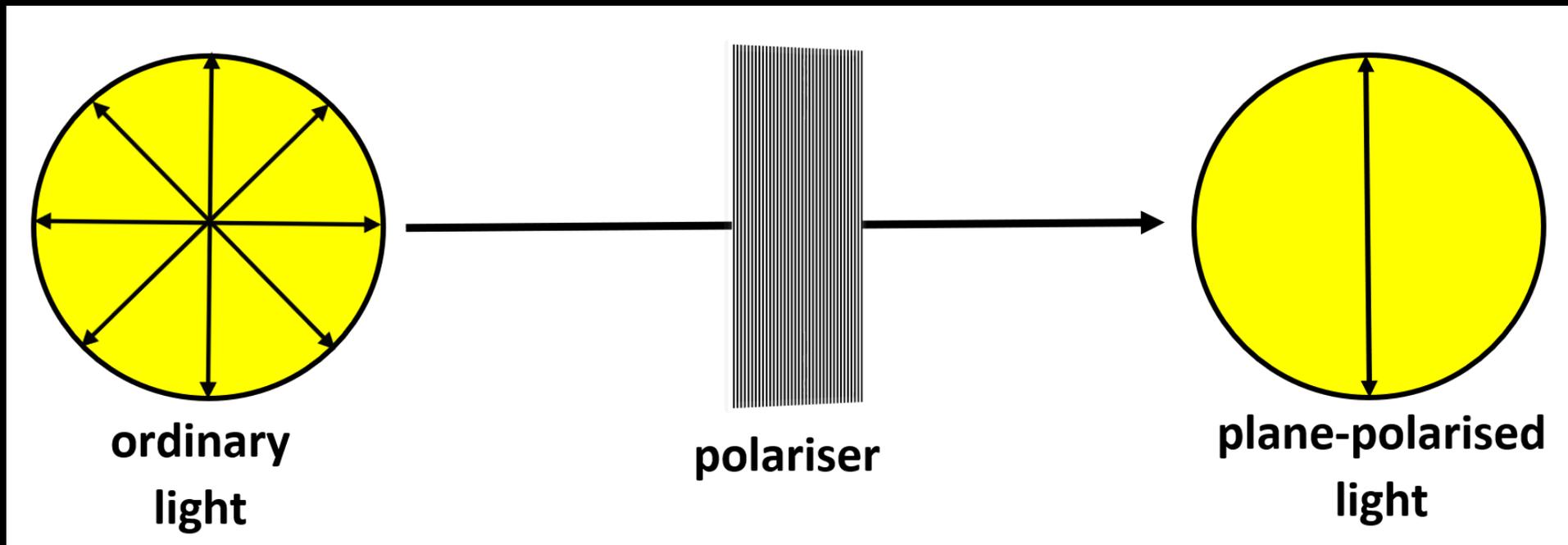
**Tutorials for IB Chemistry**

**How to distinguish  
between enantiomers of  
a chiral compound**

# Optical isomerism

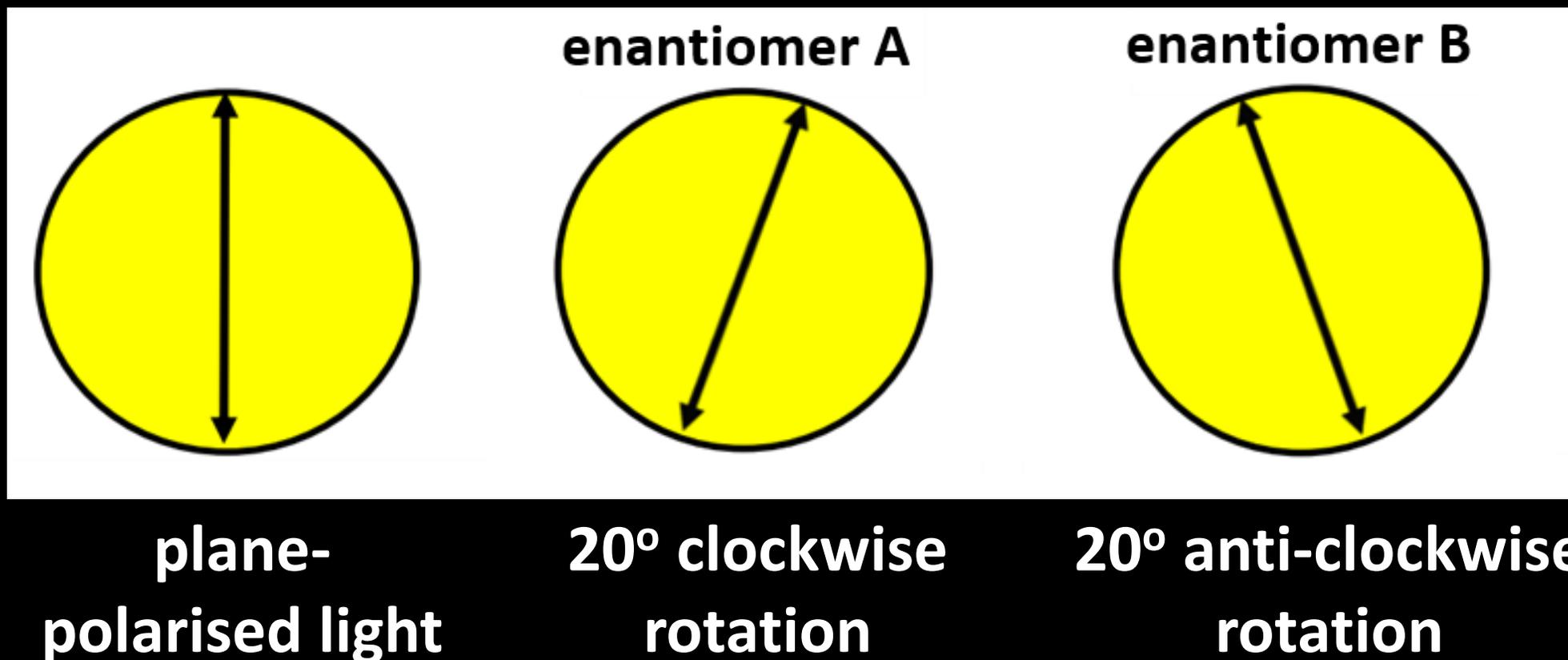
Ordinary light consists of waves that vibrate in all planes perpendicular to its direction of travel.

Plane-polarised light consists of waves vibrating in one plane only.

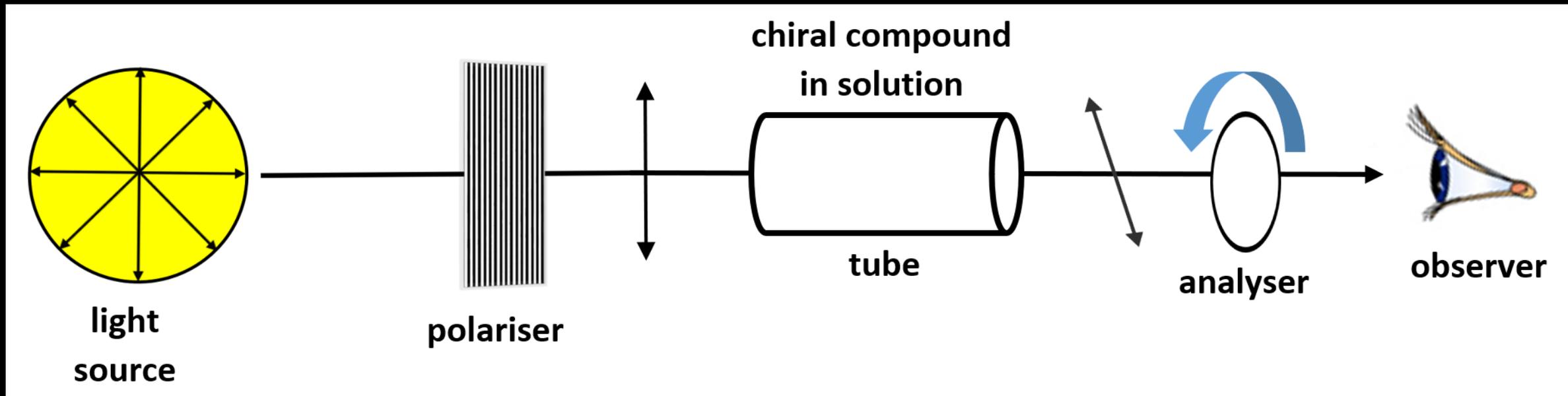


# Optical isomerism

The two enantiomers of a chiral compound rotate the plane of plane-polarised light by the same angle but in opposite directions.



# Optical isomerism



Plane-polarised light is passed through a tube containing a solution of the enantiomer.

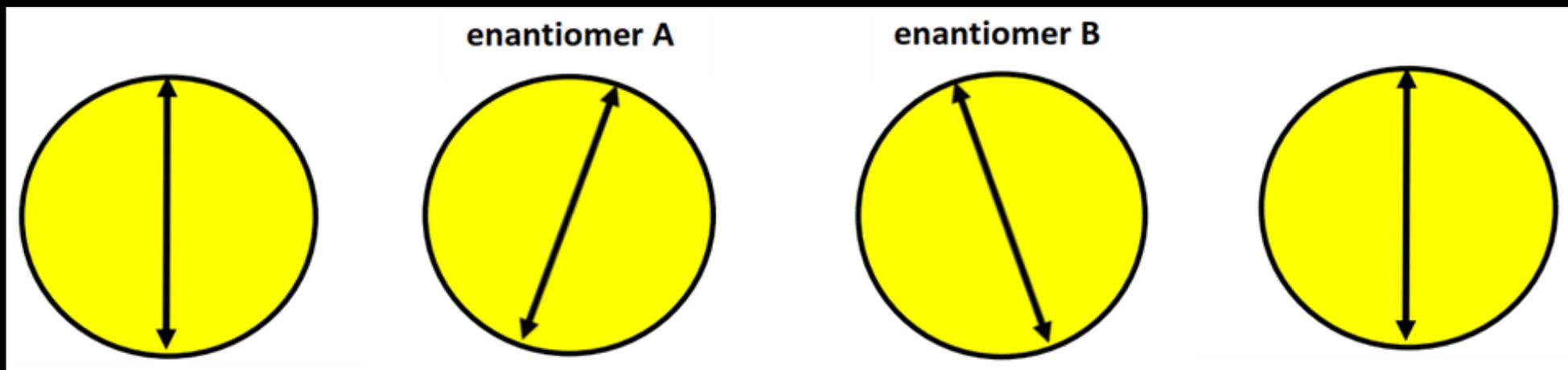
The plane of the plane-polarised light is rotated which then passes through the analyser.

The analyser is rotated until the light passes through and the angle and direction of rotation can be measured.

# Optical isomerism

A solution containing equal amounts of both enantiomers is known as a racemic mixture (racemate).

If both enantiomers are present in equal amounts, the two rotations cancel out and the mixture is said to be optically inactive.



plane-  
polarised light

20° clockwise  
rotation

20° anti-clockwise  
rotation

no overall  
rotation

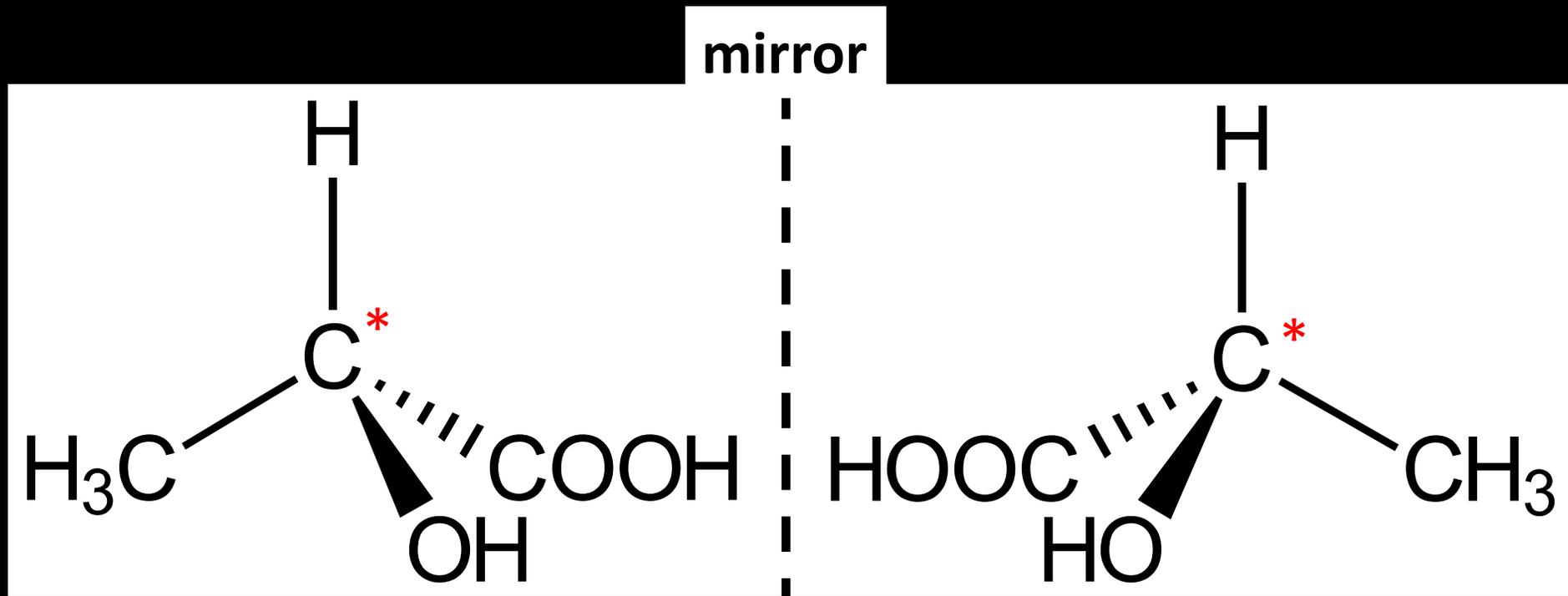
**MSJChem**

**Tutorials for IB Chemistry**

**Diastereomers**

# Enantiomers

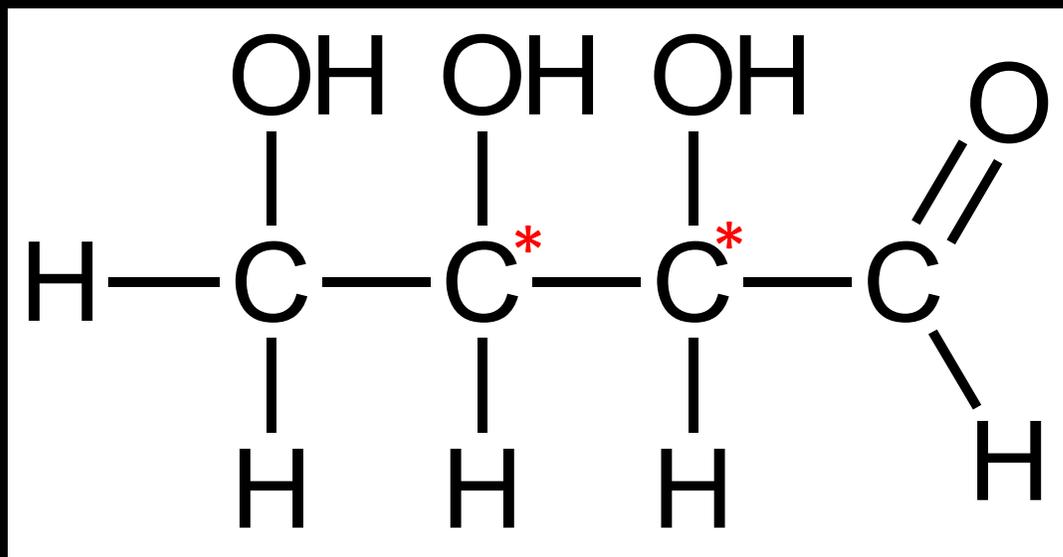
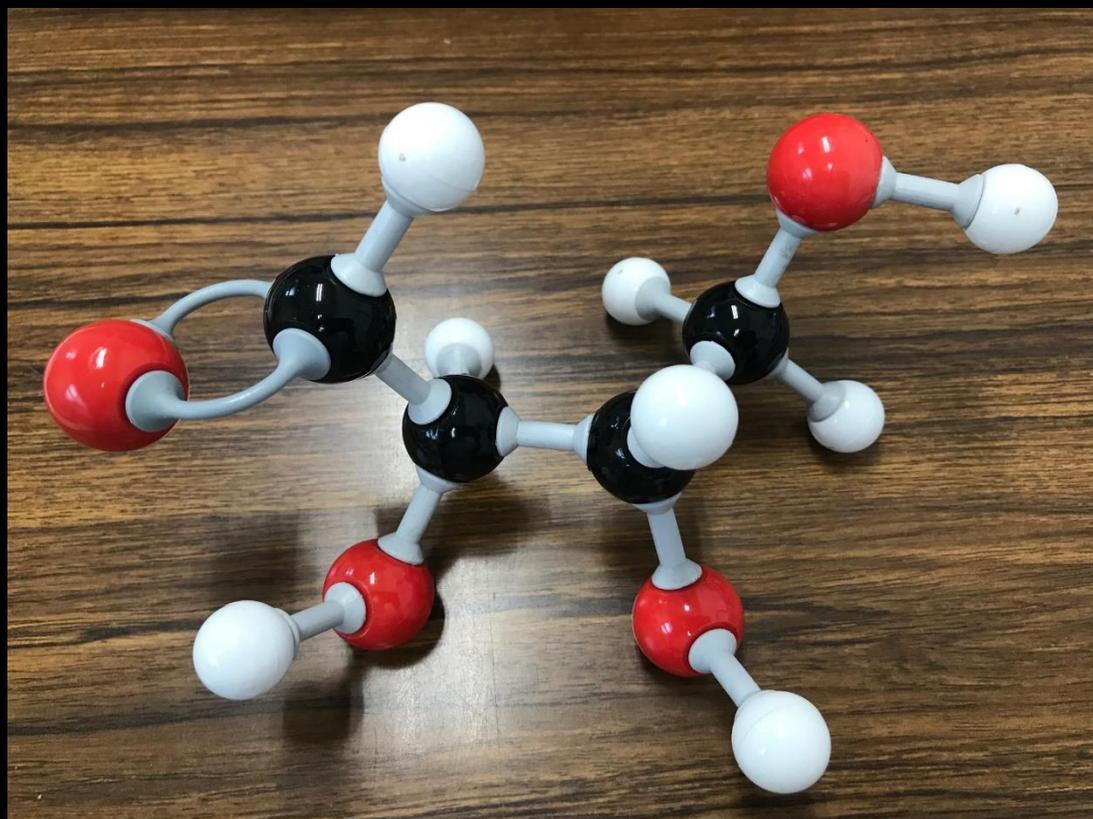
Enantiomers are stereoisomers that are mirror images of one another and are non-superimposable.



2-hydroxypropanoic acid (lactic acid)

# Diastereomers

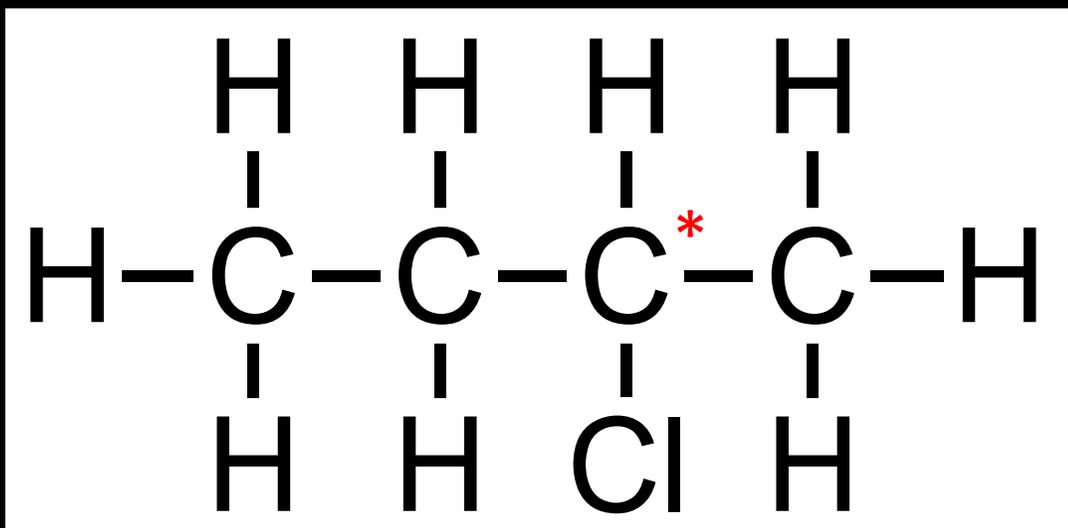
Diastereomers are stereoisomers that are not mirror images of one another and are non-superimposable.



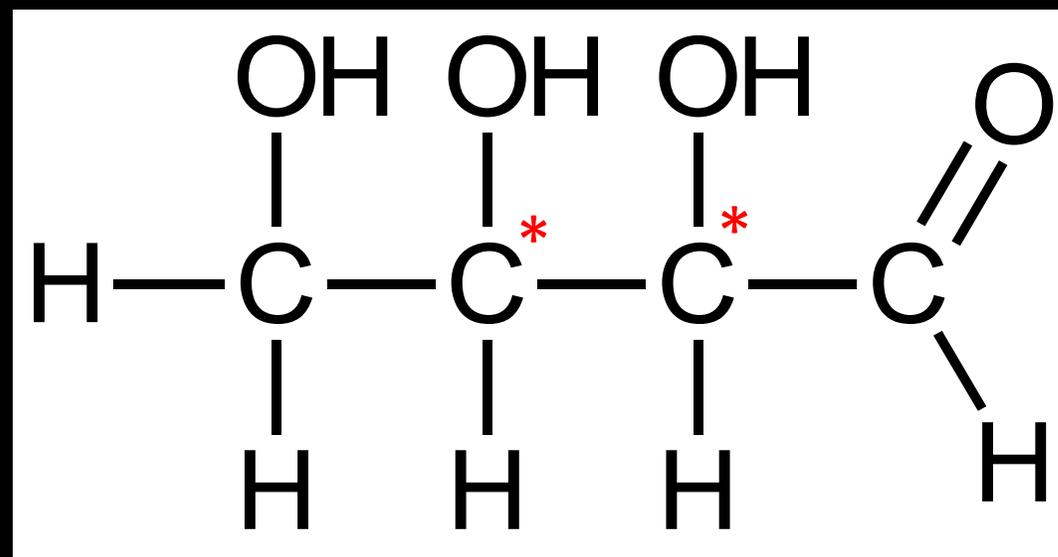
2,3,4-trihydroxybutanal

# Diastereomers

The number of possible optical isomers for a chiral molecule is  $2^n$ , where  $n$  is the number of chiral centres in the molecule.



2-chlorobutane

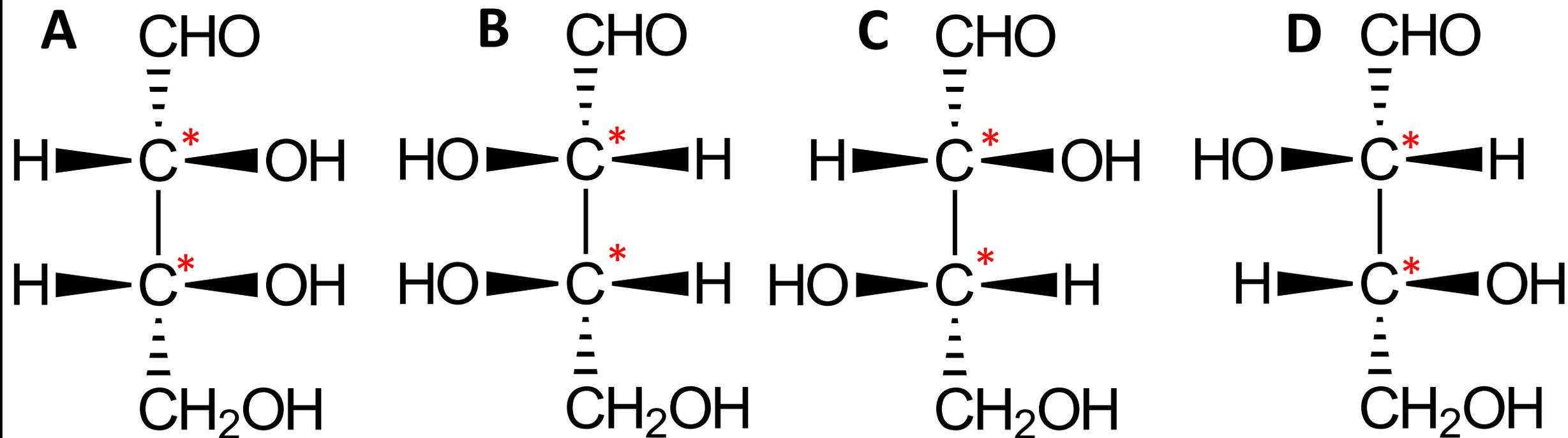


2,3,4-trihydroxybutanal

# Diastereomers

**A and B are enantiomers**

**C and D are enantiomers**

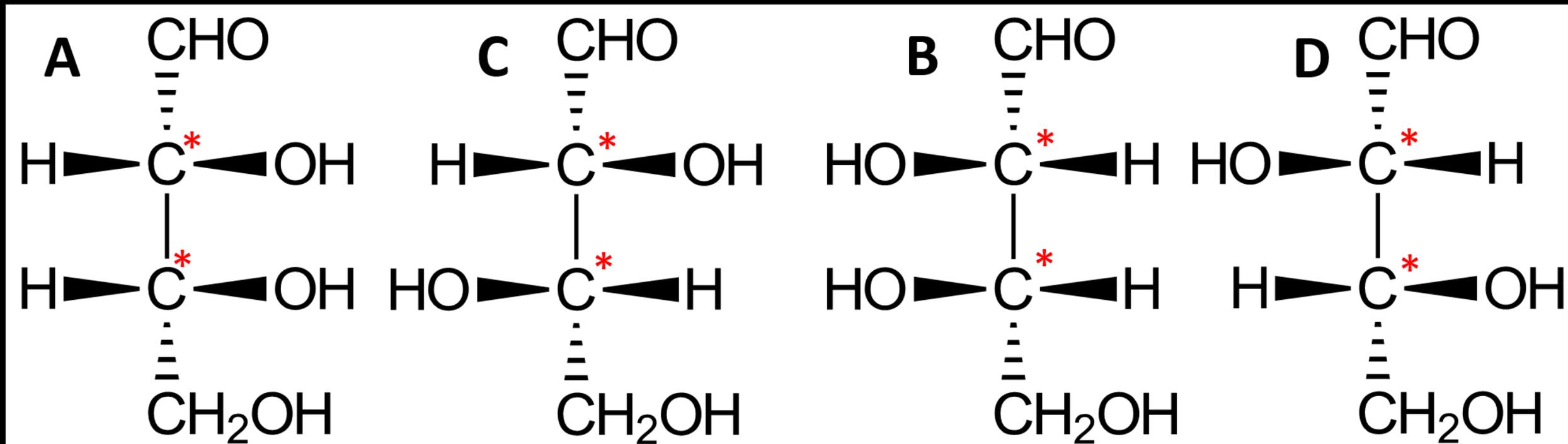


**Enantiomers are mirror images and non-superimposable. They have opposite configurations at all chiral centres.**

# Diastereomers

A and C are diastereomers

B and D are diastereomers



**Diastereomers are not mirror images and are non-superimposable. They have opposite configurations at some, but not all of the chiral centres.**

# Diastereomers

<b>Enantiomers</b>	<b>Diastereomers</b>
<b>Are mirror images and are non-superimposable</b>	<b>Are not mirror images and are non-superimposable</b>
<b>Have one or more chiral centres</b>	<b>Have at least two chiral centres</b>
<b>Have opposite configurations at all chiral centres</b>	<b>Have opposite configurations at some, but not all chiral centres</b>
<b>Have the same physical and chemical properties</b>	<b>Have different physical and chemical properties</b>
<b>Are optically active</b>	<b>Not all diastereomers are optically active</b>