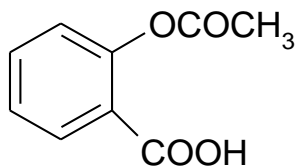


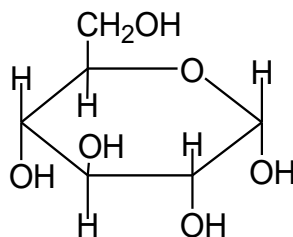
WHAT IS ORGANIC CHEMISTRY?

- Organic chemistry is the chemistry of **carbon compounds**.
- Organic compounds** contain **H** as well as **C**, while **other** common elements are **O**, **N**, the **halogens**, **S** and **P**.

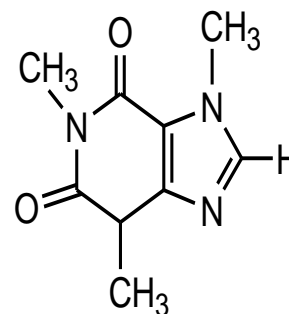
Examples of organic compound



methyl salicylic acid (**aspirin**)



glucose



Caffeine

4.1 Molecular and Structural Formulae

At the end of the lesson, student should be able to:

- a) Define structural formula. (C1)
- b) Show structural formula in the form of expanded, condensed and skeletal structures based on molecular formula. (C2)
- c) Classify carbons into primary, secondary, tertiary or quaternary and hydrogen into primary, secondary or tertiary. (C2)

Structural Formula

Formula that shows how the atoms of a molecule are bonded to one another

Structural
formula

```
graph TD; A[Structural formula] --- B[Expanded structure]; A --- C[Condensed structure]; A --- D[Skeletal structure];
```

Expanded
structure

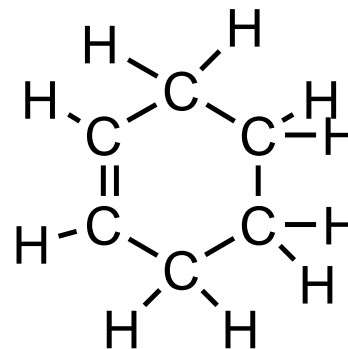
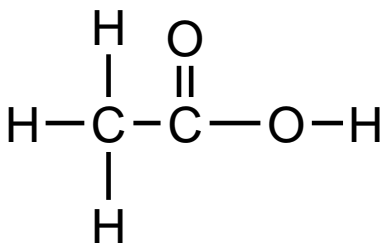
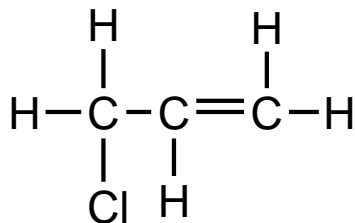
Condensed
structure

Skeletal
structure

Expanded structure

A structural formula that shows **all atoms in a molecule** and **all bonds connecting the atoms**.

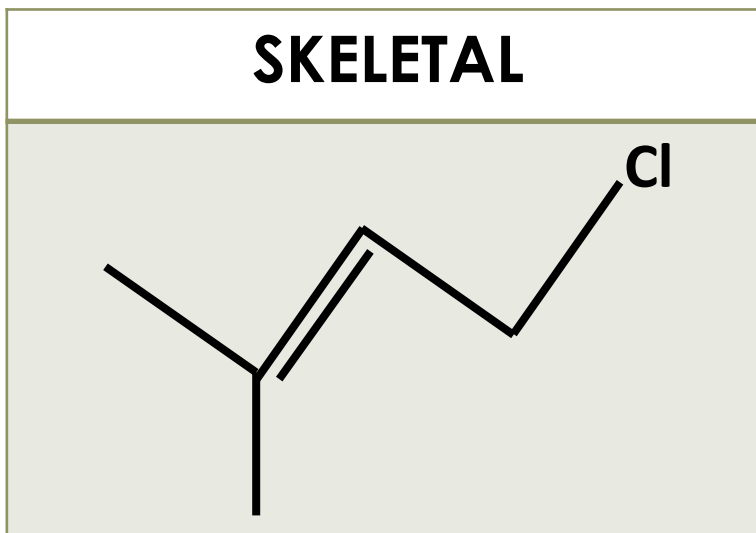
Example:



Skeletal structure

- ❖ C chains are drawn **zigzag**, and rings are drawn as **polygons**
- ❖ C atoms and H atoms are usually **not shown**
- ❖ Functional groups are **shown**

Example



Condensed structure

■ C–H and C–C single bonds are normally **not shown**

Example

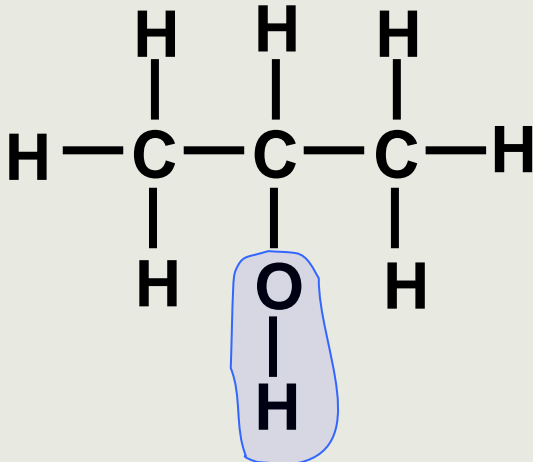
EXPANDED	CONDENSED
<pre> H H H H-C - C - C-H H C H H</pre>	$(\text{CH}_3)_3\text{CH}$

USES OF () IN CONDENSED STRUCTURE

■ To show **heteroatoms**, **functional groups**, **alkyl groups**, at the **side chain**

Example

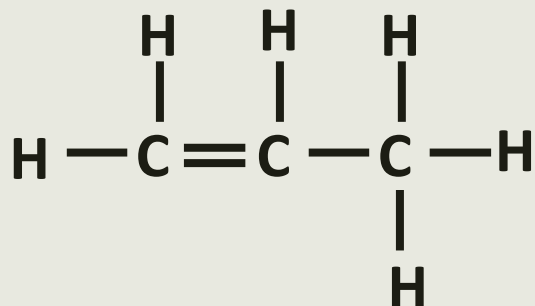
2-propanol ($\text{C}_3\text{H}_8\text{O}$)

EXPANDED	CONDENSED
	CH_3CHCH_3 OH $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$ $\text{CH}_3\text{CHOHCH}_3$ $(\text{CH}_3)_2\text{CHOH}$

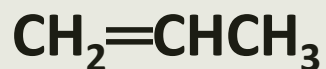
Example



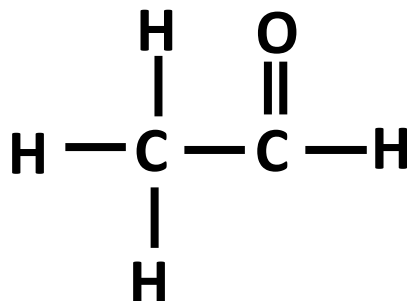
EXPANDED



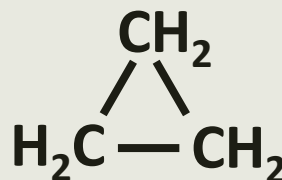
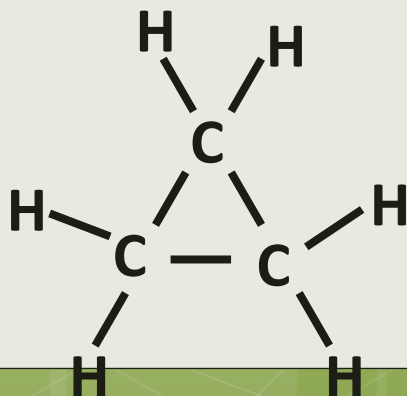
CONDENSED



Multiple bond in condensed structure (show double bond / triple bond)



Condensed structure containing C = O bond

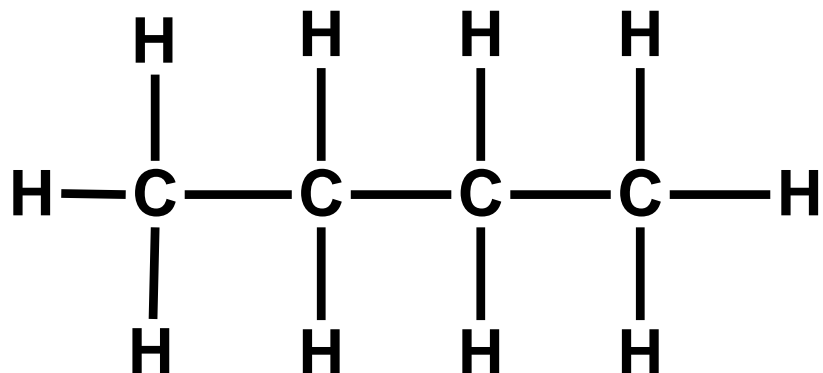


Condensed structure of cyclic compound

EXAMPLE 1:

Butane, C_4H_{10}

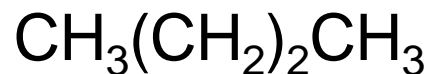
Expanded
structure



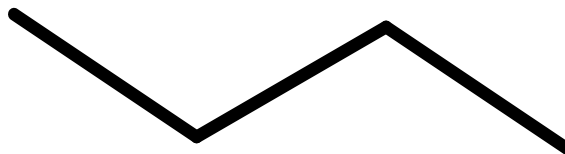
Condensed
structure



or



Skeletal
structure



[BACK](#)

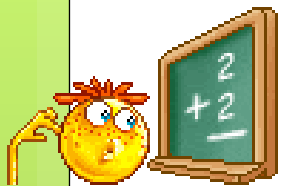


Exercise 1



Convert each molecule into skeletal structure.





Exercise 1



Convert each molecule into skeletal structure.

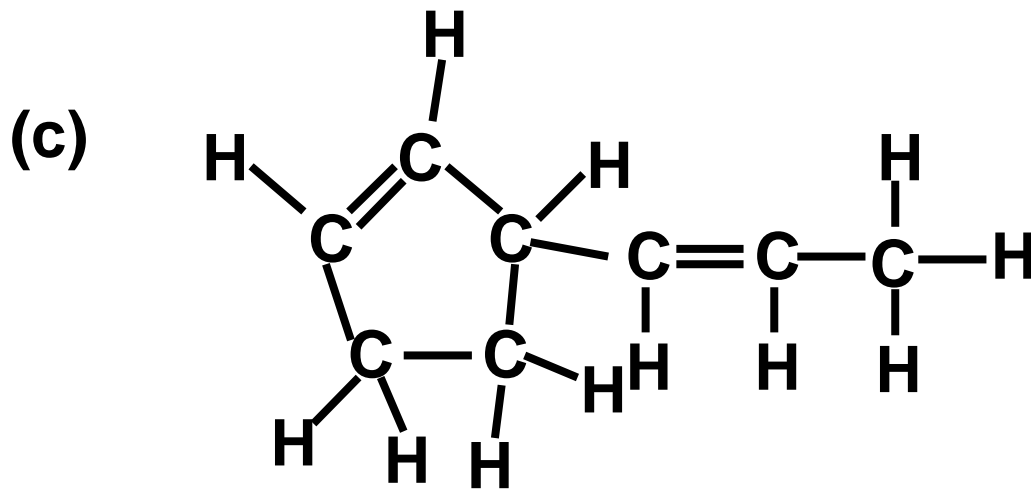


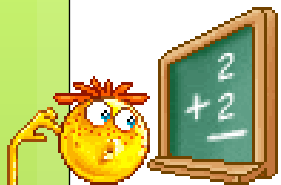


Exercise 1



Convert each molecule into skeletal structure.



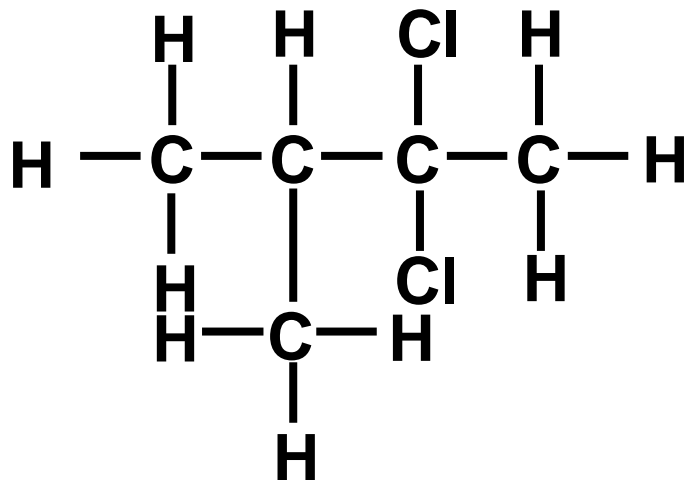


Exercise 2

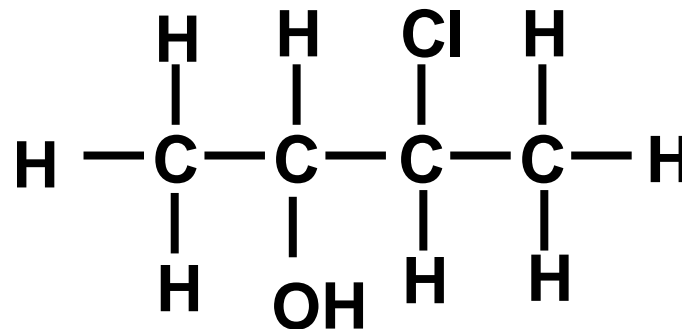


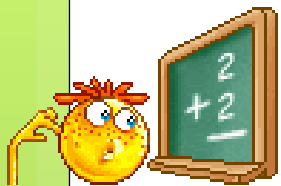
Write a condensed structural formula for each of the following compounds.

(a)



(b)



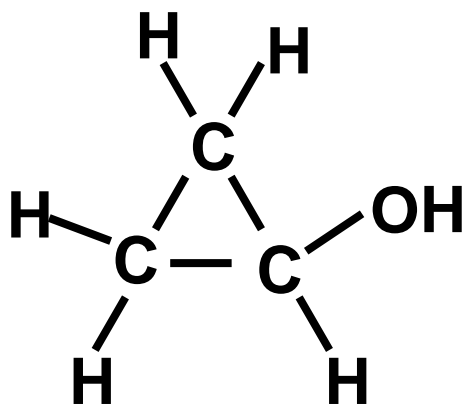


Exercise 2

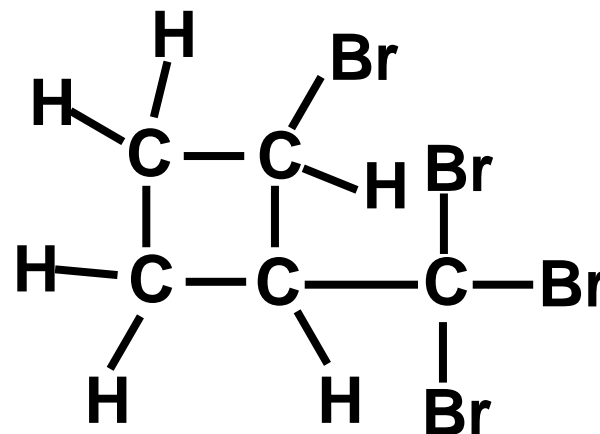


Write a condensed structural formula for each of the following compounds.

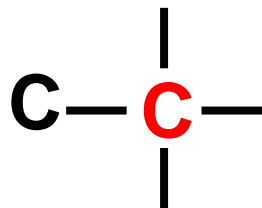
(c)



(d)

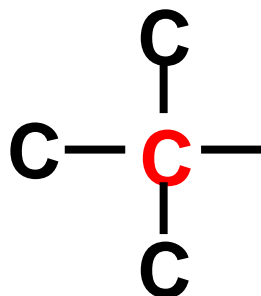


CLASSIFICATION OF C ATOMS



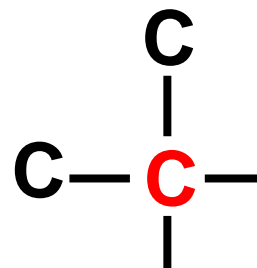
primary carbon (1°)

Number of C atoms
attached to it = **1**



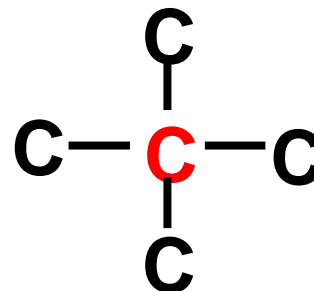
tertiary carbon (3°)

Number of C atoms
attached to it = **3**



secondary carbon (2°)

Number of C atoms
attached to it = **2**



quaternary carbon (4°)

Number of C atoms
attached to it = **4**

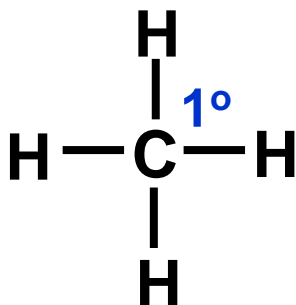


Info

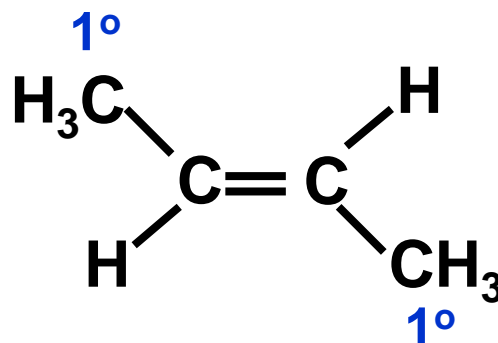
- + No classification for C atoms in methane and in multiple bonds
- + Only for sp^3 C atom

Example

WRONG WAY

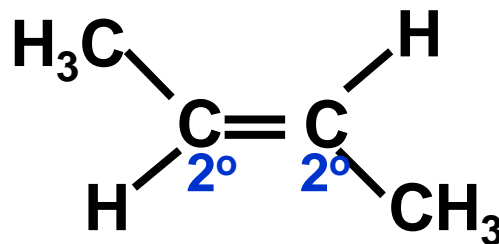


methane



2-butene

☒ correct



2-butene

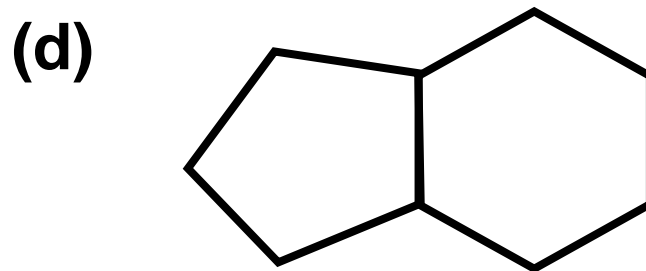
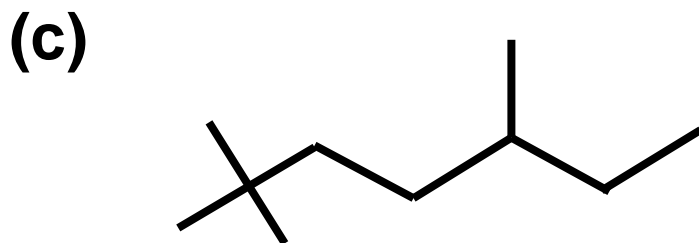
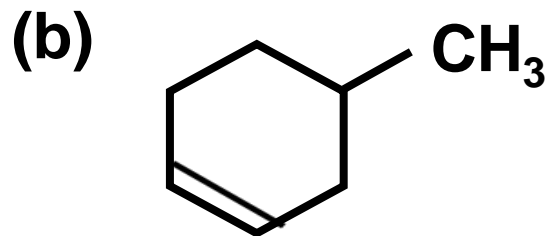
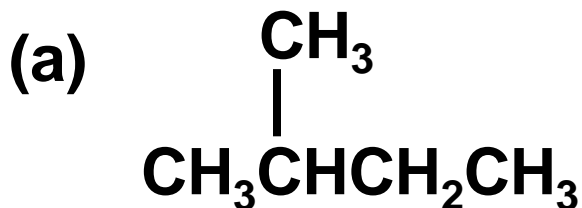
WRONG WAY



Example 1

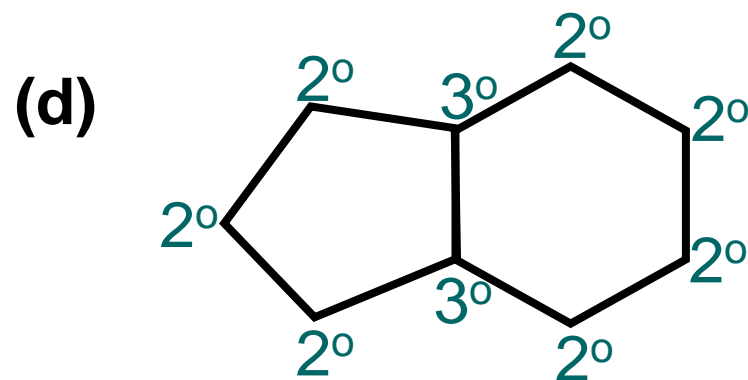
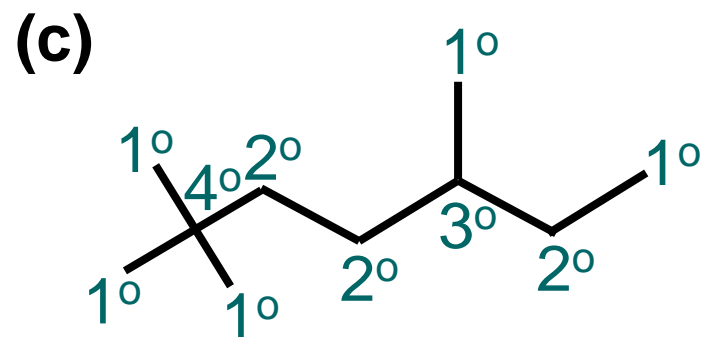
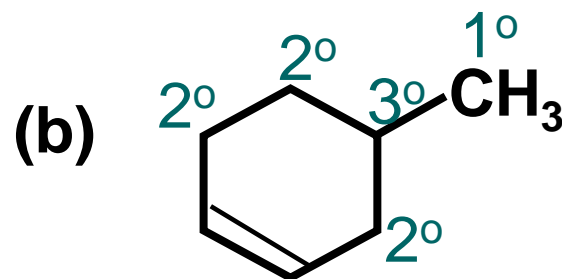
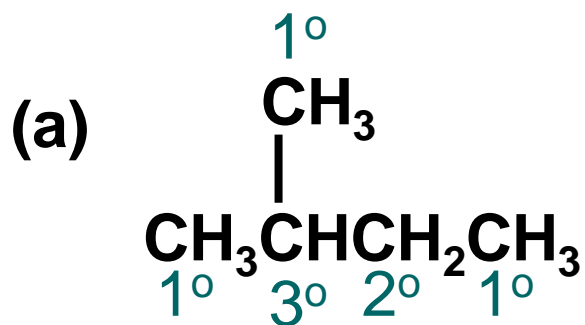


Identify the types of carbons (1° , 2° , 3° , or 4°) in the following molecules. Label at each C atom.



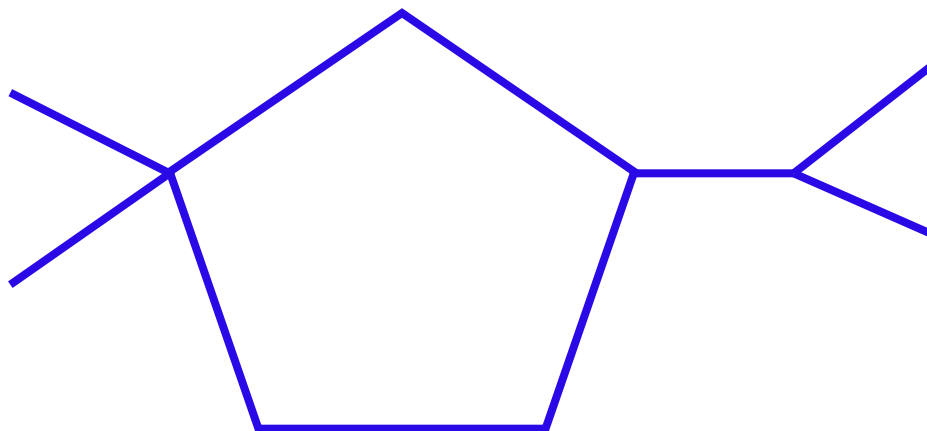


Answer



EXERCISE 3:

Count the amount of **primary carbon**, **secondary carbon**, **tertiary carbon** and **quaternary carbon** present in the following structure:



Primary Carbon = ____

Tertiary Carbon = ____

Secondary Carbon = ____

Quaternary Carbon = ____

4.2 Functional Group and Homologous Series

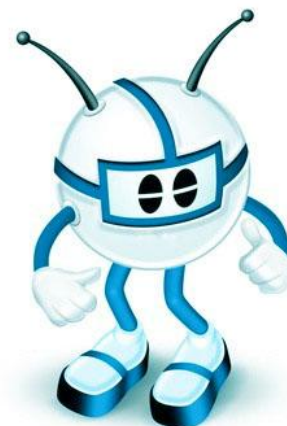
At the end of the lesson, student should be able to:

- a) **define functional group (C1)**
- b) **state functional groups of the following class of compounds. (C1)**
- c) **identify functional groups in a given compound.(C1,C2)**
- d) **define homologous series. (C1)**
- e) **explain general characteristics of homologous series. (C2)**

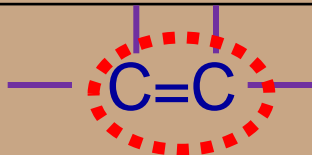
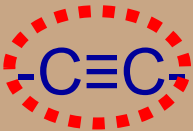
Functional group

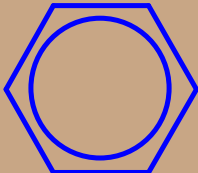
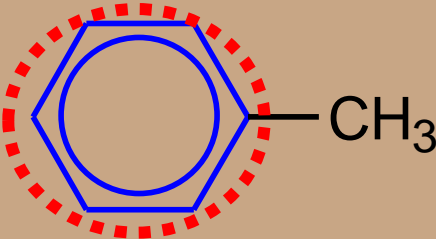
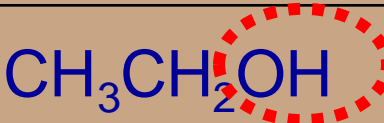
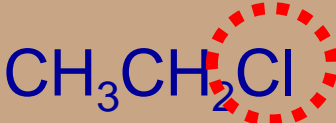
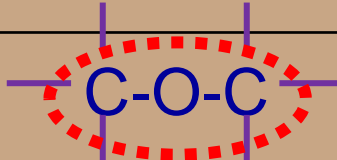

Definition

- Is an atom or group of atoms in an organic molecule which characterised the molecule and enables it to react in specific ways which determines its chemical properties.



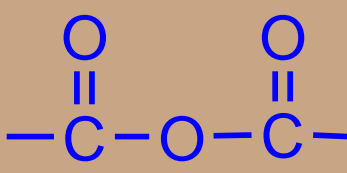
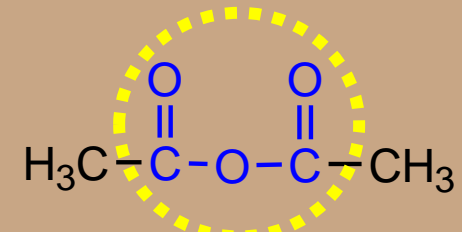
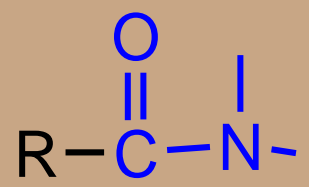
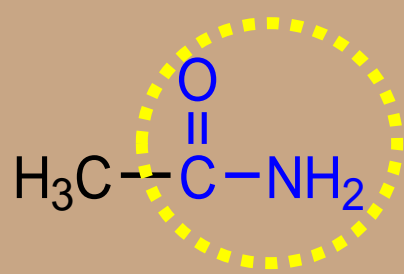
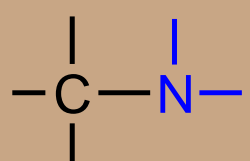
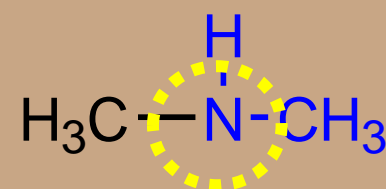

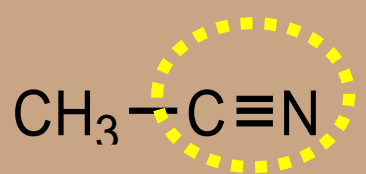
(b) & (c) Identifying and Classifying Functional groups of different class of compounds

Class of compounds	Functional Group		Example
	Structure	Name	
Alkane C_nH_{2n+2}	none	-	CH_3-CH_3
Alkene C_nH_{2n}		carbon-carbon double bond	$H_2C=CH_2$
Alkyne C_nH_{2n-2}		carbon-carbon triple bond	$HC\equiv CH$

Class of compounds	Functional Group		Example
	Structure	Name	
Aromatic/Arene C_nH_{2n-6}		Aromatic ring	
Alcohol $C_nH_{2n+1}OH$	-OH	Hydroxyl	
Haloalkane $C_nH_{2n+1}X$	-X (F,Cl,Br,I)	Halogen	
Ether $C_nH_{2n+2}O$		Alkoxy	

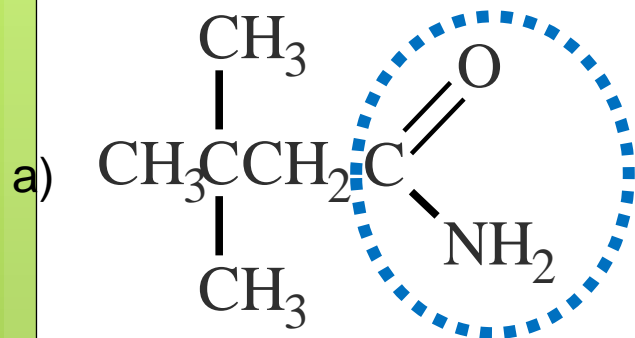


Class of compounds	Functional Group		Example
	Structure	Name	
Aldehyde $C_nH_{2n}O$	$\begin{array}{c} O \\ \\ -C-H \end{array}$	Carbonyl	$H_3C-\begin{array}{c} O \\ \\ C-H \end{array}$
Ketone $C_nH_{2n}O$	$\begin{array}{c} O \\ \\ R-C-R \end{array}$	Carbonyl	$H_3C-\begin{array}{c} O \\ \\ C-CH_3 \end{array}$
Carboxylic acid $C_nH_{2n}O_2$	$\begin{array}{c} O \\ \\ -C-OH \end{array}$	Carboxyl	$H_3C-\begin{array}{c} O \\ \\ C-OH \end{array}$
Ester $C_nH_{2n}O_2$	$\begin{array}{c} O \\ \\ -C-O-R \end{array}$	Ester /carboalkoxy	$H_3C-\begin{array}{c} O \\ \\ C-O-CH_3 \end{array}$
Acyl chloride $C_nH_{2n+1}COCl$	$\begin{array}{c} O \\ \\ -C-Cl \end{array}$	Acyl	$H_3C-\begin{array}{c} O \\ \\ C-Cl \end{array}$

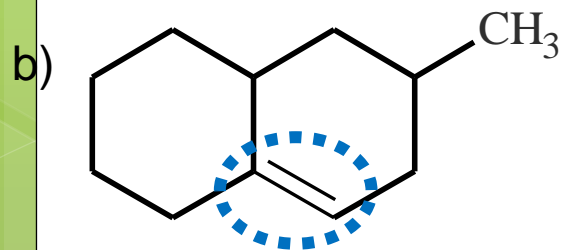
Class of compounds	Functional Group		Example
	Structure	Name	
Anhydride $(C_nH_{2n+1}CO)_2O$		Anhydride	
Amide $C_nH_{2n+1}CONH_2$		Amide / carboxamide	
Amine $C_nH_{2n+1}NH_2$		Amino	
Nitrile $C_nH_{2n+1}CN$		Cyano	

example 1

1. Identify the function groups in the following molecules.



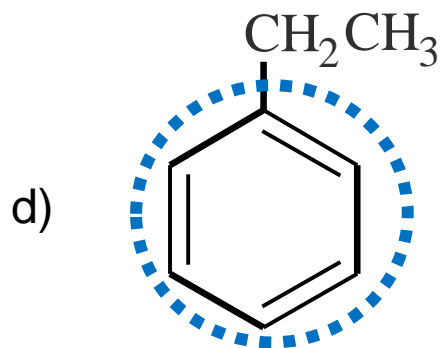
Carboxamide / Amide



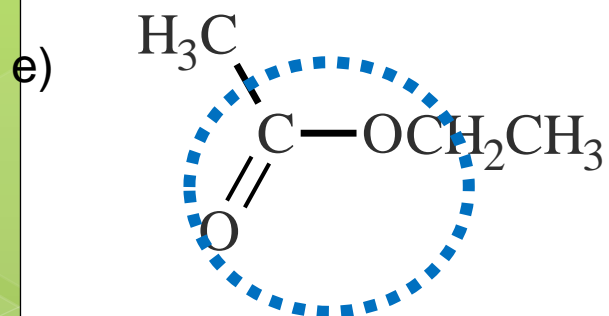
Carbon – carbon double bond



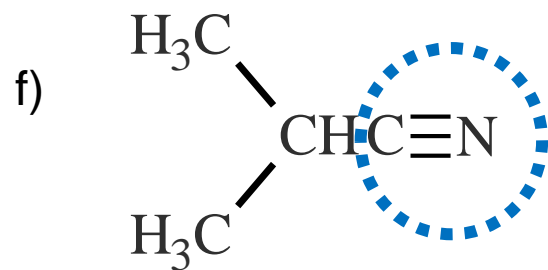
Alkoxy



Aromatic ring



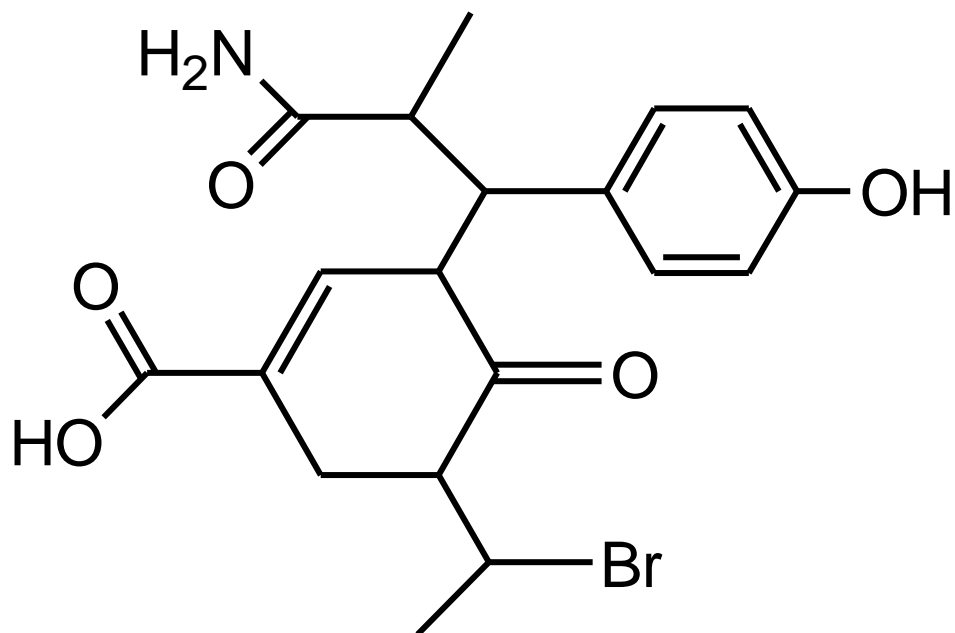
Carboalkoxy / Ester



cyano

EXERCISE 1

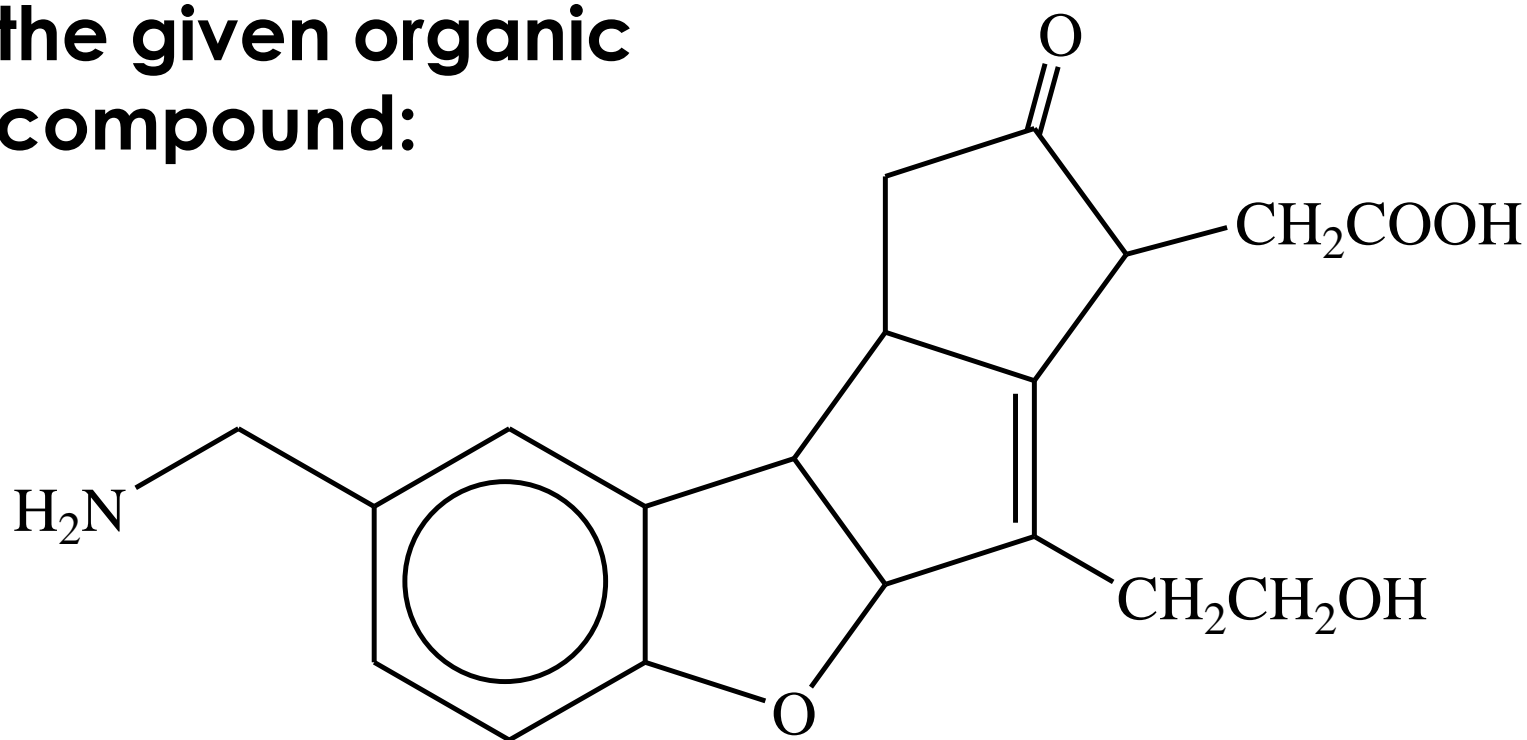
Identify the functional groups in the following molecule:



EXERCISE

2

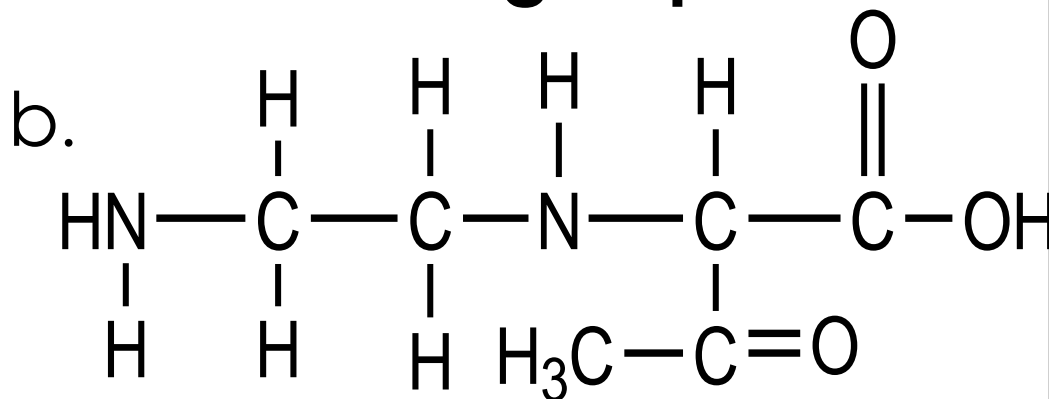
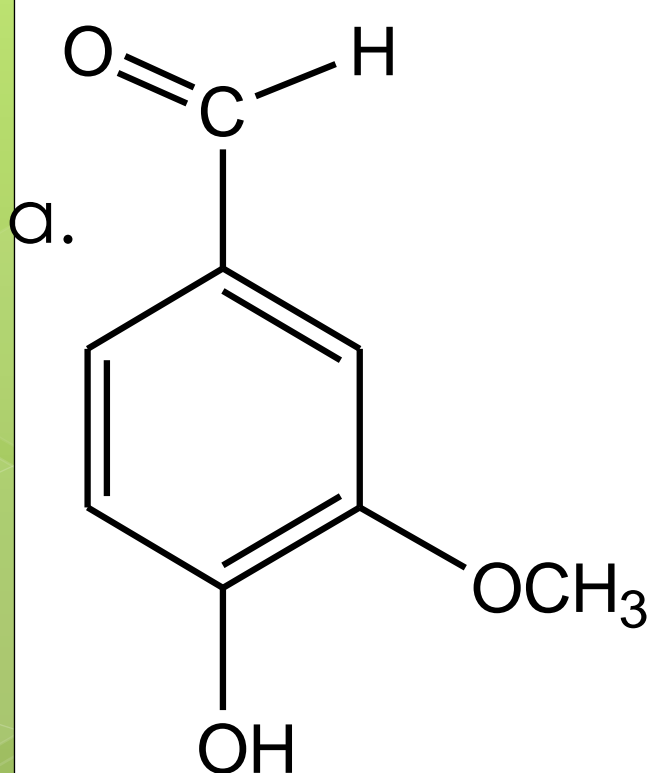
Identify and name the functional groups in the given organic compound:



EXERCISE

3

Identify the functional groups in the following structures. Name the functional group.



Homologous Series

- is series of compounds where each member differs from the next member by a constant – **CH₂ unit**
- Members of the same homologous series are called **homologs**.

General Formula

Homologous Series

SERIES	GENERAL FORMULA	ENDING NAME
ALKANE	C_nH_{2n+2}	<i>...ane</i>
ALKENE	C_nH_{2n}	<i>...ene</i>
ALKYNE	C_nH_{2n-2}	<i>...yne</i>
ALCOHOL	R-OH	<i>...ol</i>
ALDEHYDE	RCHO	<i>...al</i>
KETONE	RCOR'	<i>...one</i>
CARBOXYLIC ACID	RCOOH	<i>...oic acid</i>
AMINE	RNH_2	<i>...amine</i>
AMIDE	$RCONH_2$	<i>...amide</i>

Note: R normally refer to **alkyl group**: C_nH_{2n+1}

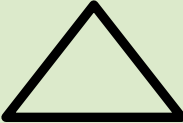

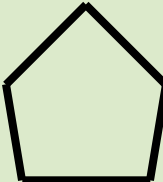
Reduce 2 atom H for **cyclic compound**

R normally refer to **alkyl group**: C_nH_{2n+1} (reduced 1 H atom from alkane formula)

ALKANE	C_nH_{2n+2}	ALKYL	C_nH_{2n+1}
METHANE	CH_4	METHYL	$-CH_3$
ETHANE	CH_3CH_3	ETHYL	$-CH_2CH_3$
PROPANE	$CH_3CH_2CH_3$	PROPYL	$-CH_2CH_2CH_3$
BUTANE	$CH_3CH_2CH_2CH_3$	BUTYL	$-CH_2CH_2CH_2CH_3$
PENTANE	$CH_3CH_2CH_2CH_2CH_3$	PENTYL	$-CH_2CH_2CH_2CH_2CH_3$


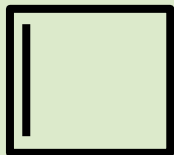
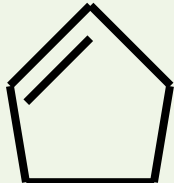
Reduce 2 atom H for cyclic compound

EXAMPLE: ALKANE AND CYCLOALKANE

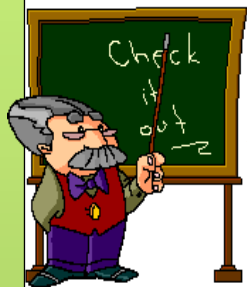
ALKANE	C_nH_{2n+2}	CYCLOALKANE	C_nH_{2n}
METHANE	CH_4	—	—
ETHANE	CH_3CH_3	—	—
PROPANE	$CH_3CH_2CH_3$	CYCLOPROPANE	C_3H_6 
BUTANE	$CH_3CH_2CH_2CH_3$	CYCLOBUTANE	C_4H_8 
PENTANE	$CH_3CH_2CH_2CH_2CH_3$	CYCLOPENTANE	C_5H_{10} 

Reduce 2 atom H for cyclic compound

EXAMPLE: ALKENE AND CYCLOALKENE

ALKENE	C_nH_{2n}	CYCLOALKENE	C_nH_{2n-2}
ETHENE	$CH_2=CH_2$	—	—
PROPENE	$CH_2=CHCH_3$	CYCLOPROPENE	C_3H_4 
BUTENE	$CH_2=CHCH_2CH_3$ 1-BUTENE $CH_3CH=CHCH_3$ 2-BUTENE	CYCLOBUTENE	C_4H_6 
PENTENE	$CH_2=CHCH_2CH_2CH_3$ 1-PENTENE	CYCLOPENTENE	C_5H_8 

Keep in Mind



Alkanes and **cycloalkanes** belong to the **same class** of compounds but **different homologous series**

HOMOLOGOUS SERIES OF ALKANES		HOMOLOGOUS SERIES OF CYCLOALKANES	
methane	CH_4	cyclopropane	C_3H_6
ethane	C_2H_6	cyclobutane	C_4H_8
propane	C_3H_8	cyclopentane	C_5H_{10}
butane	C_4H_{10}	cyclohexane	C_6H_{12}
pentane	C_5H_{12}	cycloheptane	C_7H_{14}

4.3 Isomerism

At the end of the lesson, student should be able to:

- a) define isomerism, constitutional isomerism and stereoisomerism. (C1)
- b) construct constitutional isomers: (C3)
 - i. chain isomers
 - ii. Positional isomers
 - iii. Functional group isomers
- c) describe *cis-trans* isomerism due to restricted rotation about: (C2)
 - i. C=C bond
 - ii. C-C bond in cyclic compounds
- d) identify *cis-trans* isomerism of a given structural formula. (C1, C2)
- e) define chirality centre and enantiomers. (C1)
- f) identify chirality centre(s) in a molecule. (C1, C2)
- g) determine optical activity of a compound. (C3)
- h) draw a pair of enantiomers using 3-dimensional formula. (C3)
**restricted to molecules with one chirality centre*

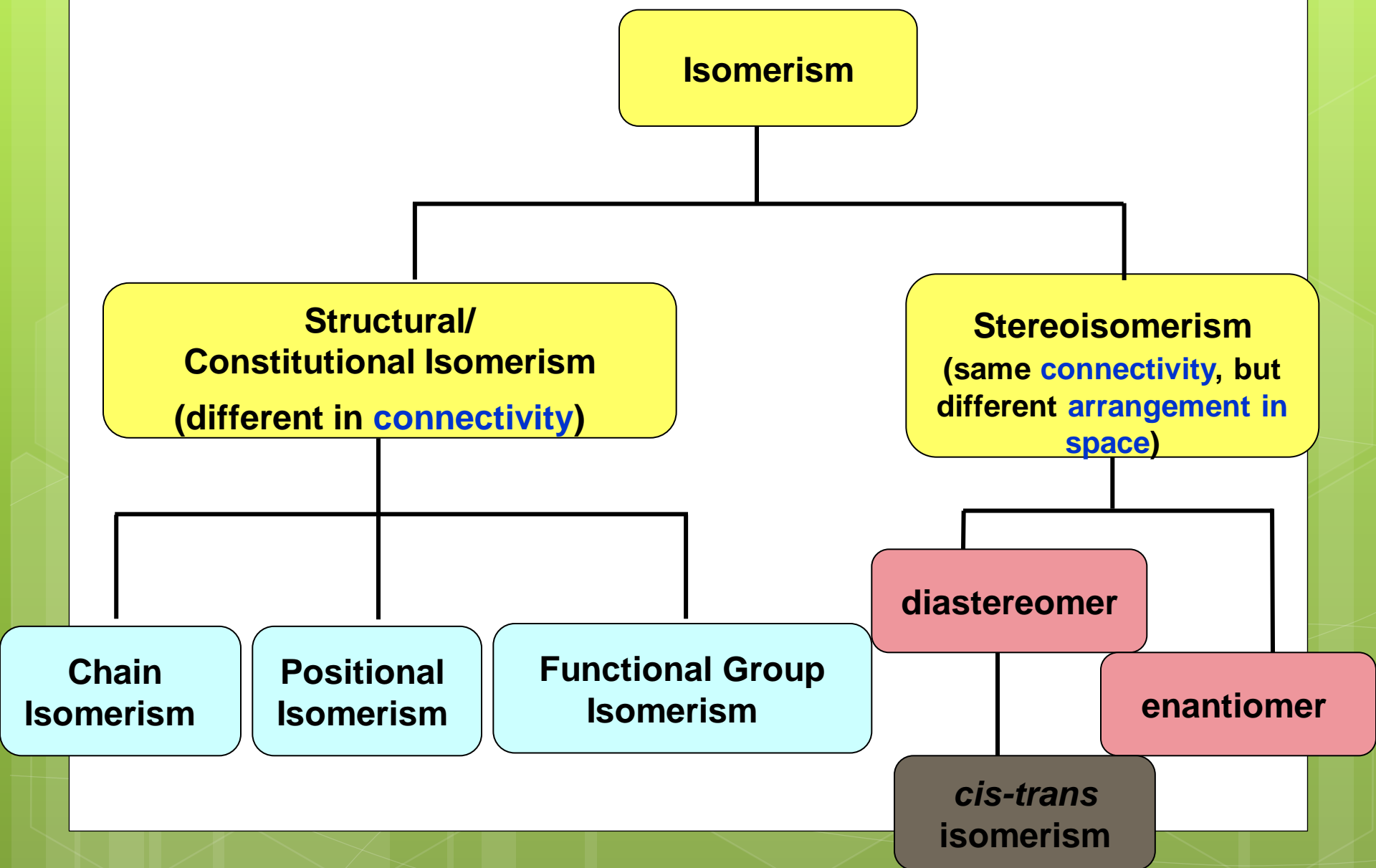
ISOMERISM

Definition



■ The existence of chemical compounds that have **same molecular formula** but **different molecular structure** or **arrangement in space**

TYPES OF ISOMER



STRUCTURAL ISOMERISM/ CONSTITUTIONAL ISOMERISM

■ molecules that have **same molecular formula** but **different structure**.

■ 3 types:

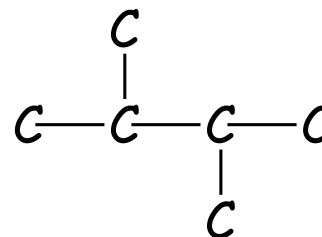
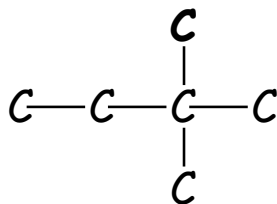
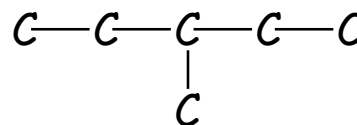
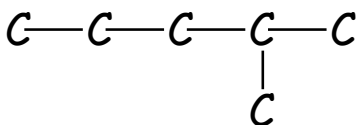
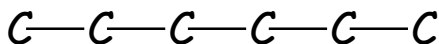
- a) Chain isomerism
- b) Positional isomerism
- c) Functional group isomerism



Question 1

Draw structural **isomers** of compound with the molecular formula C_6H_{14}

Strategy: First draw all possible skeletal structures (without the H atoms), beginning with the longest possible structure.



CHAIN ISOMERS

■ due to different in carbon skeleton

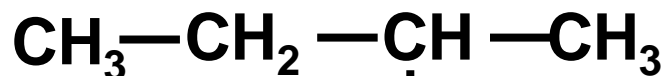
Question: How many structural isomers does pentane, C_5H_{12} , have?

Step 1: draw the longest carbon skeleton, in this case 5-C



Condensed structure
of **cyclic compound**

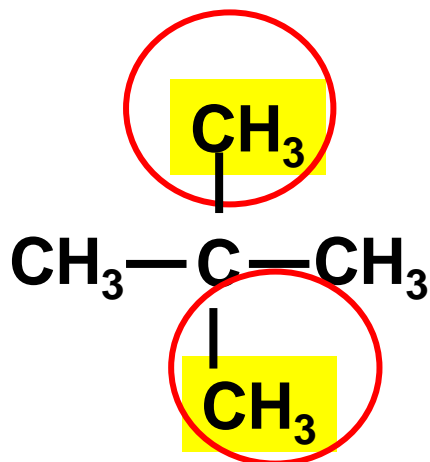
Step 2: Shorten the carbon backbone to 4-C, so now you will get one branch



Now you get one branch!

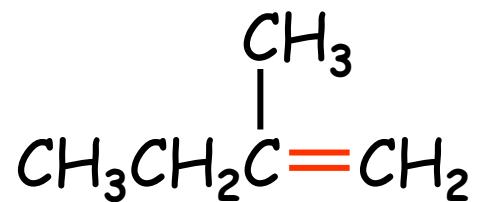
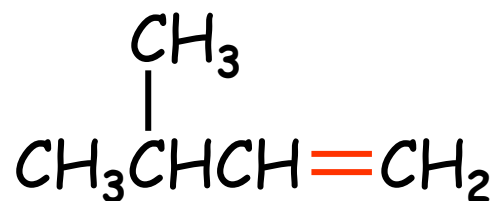
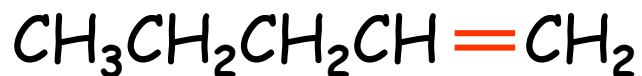
Helpful
Tips

Step 3: Shorten it some more to 3-C carbon backbone, and now you will get 2 branches!



Can you further shorten the carbon backbone?

Example 1: Draw structural isomers of
alkene (C_5H_{10})

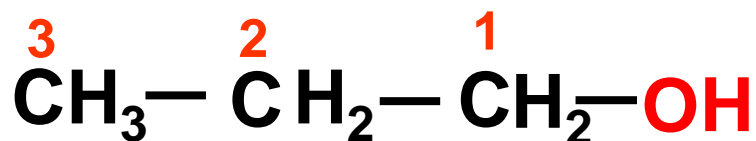


POSITIONAL ISOMERS

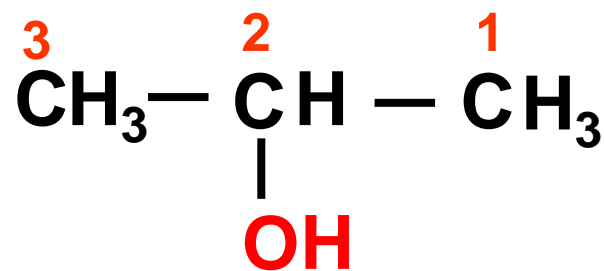
- due to different position of functional group

Example

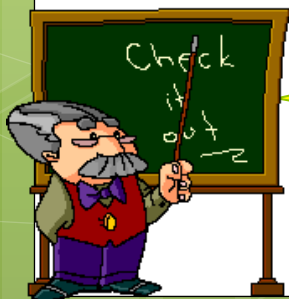
Molecular formula = $\text{C}_3\text{H}_8\text{O}$



1-propanol

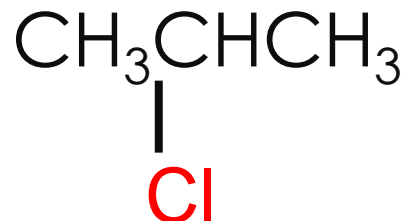
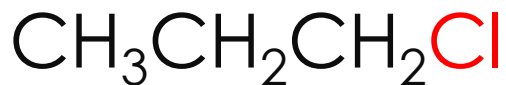


2-propanol

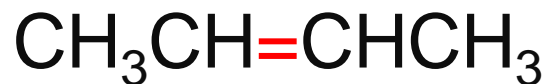


Both isomers have **same carbon skeleton**. They are only **different in the position of -OH group**!

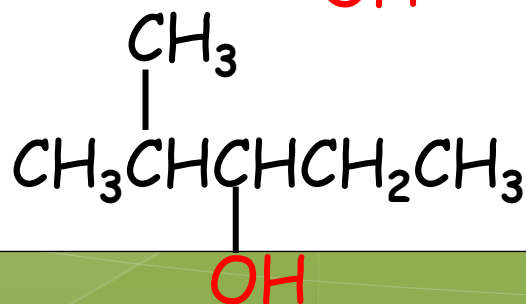
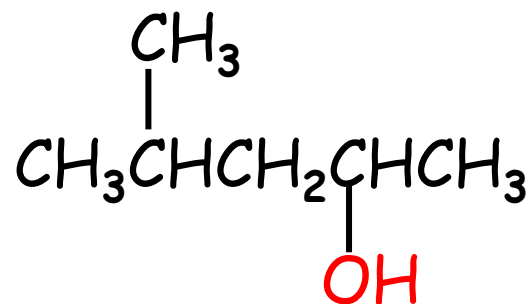
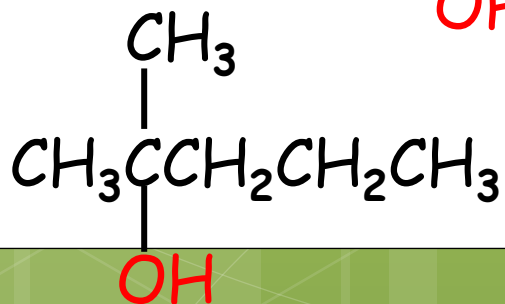
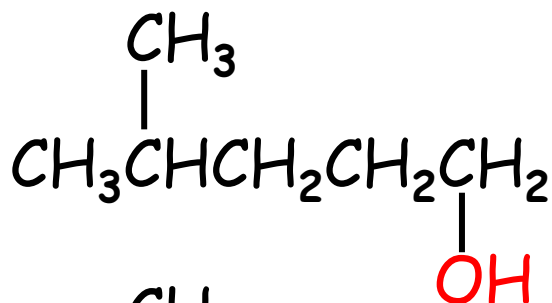
Example 1: C_3H_7Cl



Example 2: C_4H_8



Example 3: $C_6H_{14}O$ (alcohol)

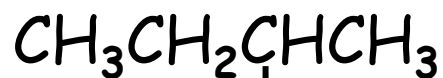


iii) Functional Group Isomerism

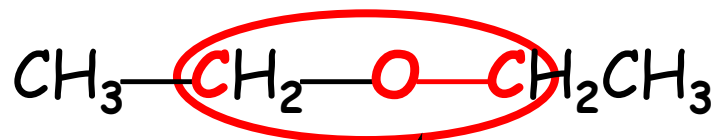
- These isomers have **different functional groups** and belong to **different homologous series** with the **same general formula**.

Classes of compounds	General Formula
Alcohol & Ether	$C_nH_{2n+2}O$
Aldehyde & Ketone	$C_nH_{2n}O$
Carboxylic acid & Ester	$C_nH_{2n}O_2$
Alkene & Cycloalkane	C_nH_{2n}

Example 1: $C_4H_{10}O$ (General Formula : $C_nH_{2n+2}O$)

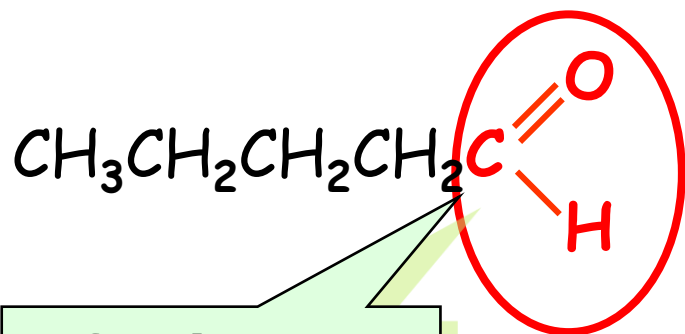


Hydroxyl
(alcohol)

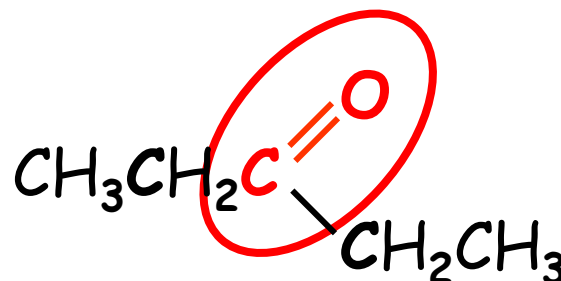


Alkoxy
(ether)

Example 2: $C_5H_{10}O$ (General Formula : $C_nH_{2n}O$)



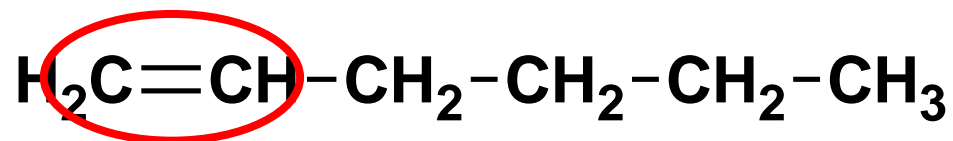
Carbonyl
(aldehyde)



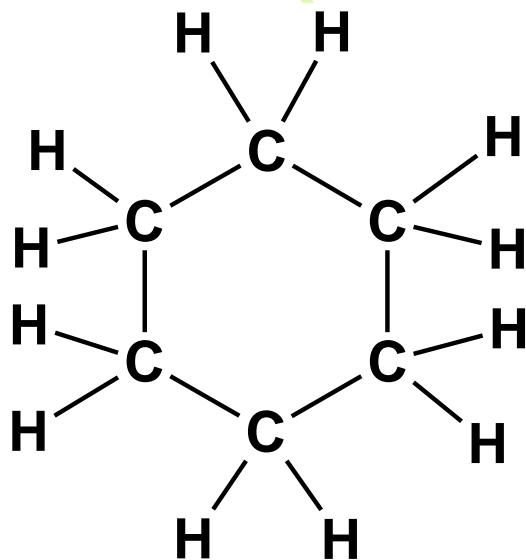
Carbonyl
(ketone)

Example 3: C_6H_{12}

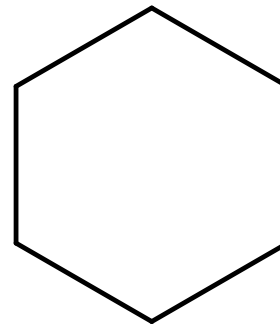
(General Formula : C_nH_{2n})



Carbon carbon double bond
(alkene)



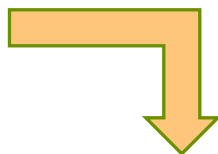
or



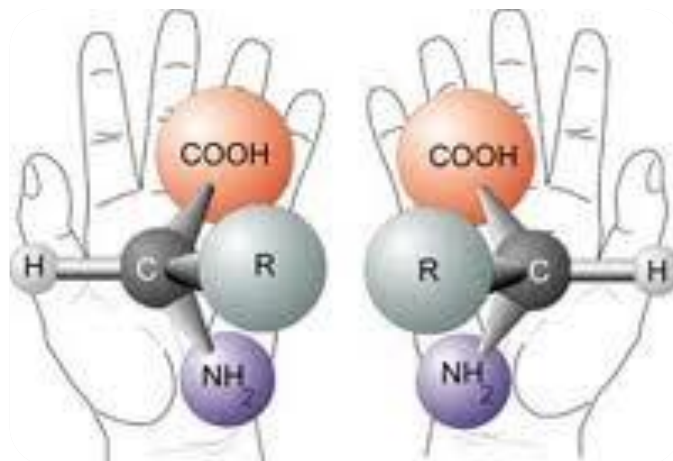
(Cycloalkane)

STEREoisomerism

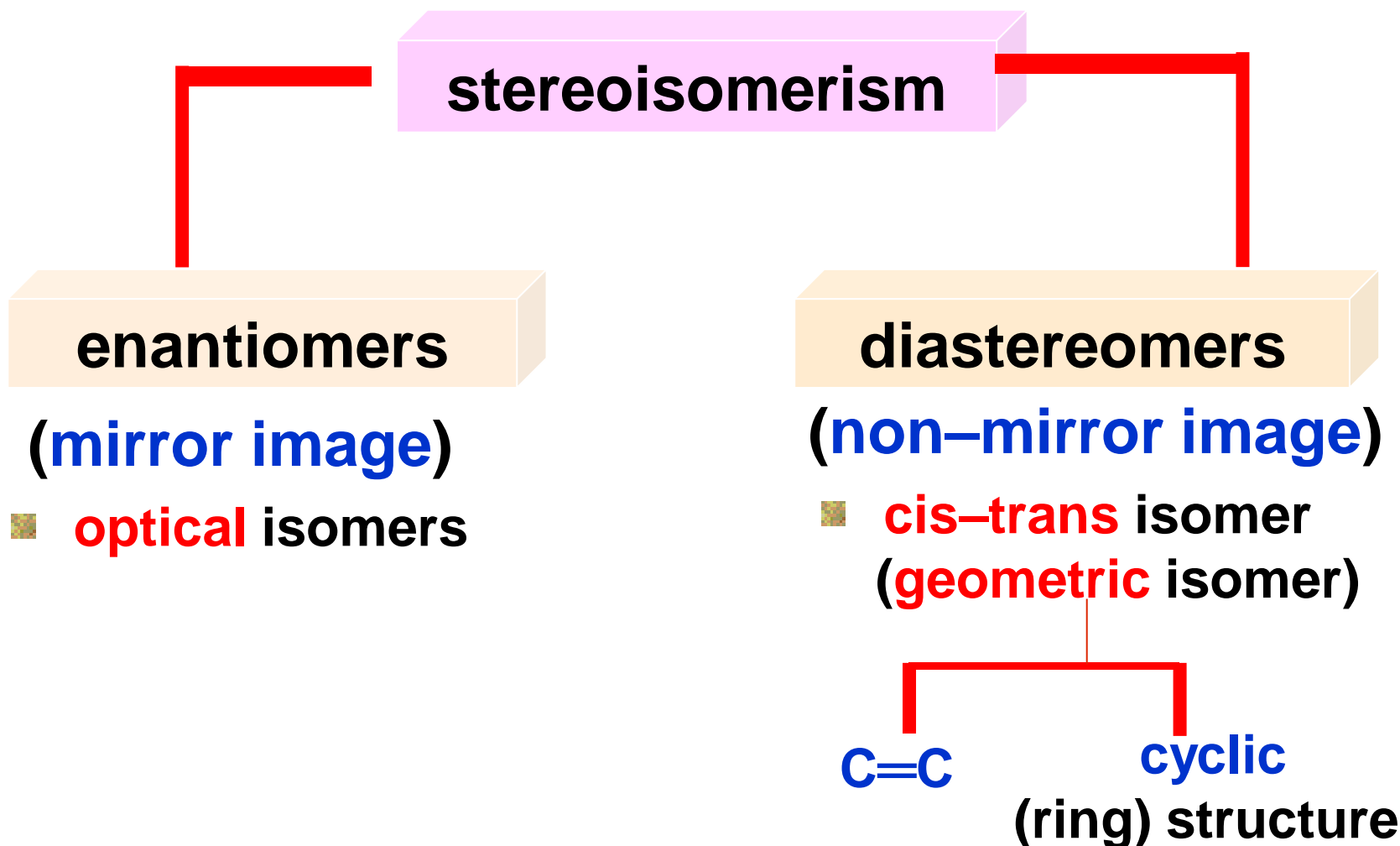
Definition



The existence of chemical compounds which have their atoms connected in same order but **differ in arrangement in space**



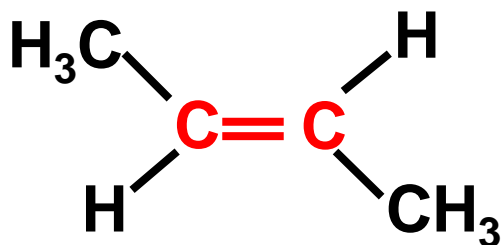
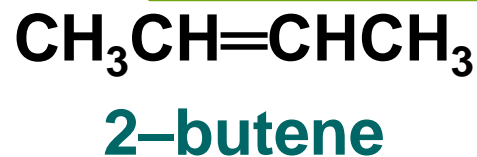
TYPES OF STEREOISOMERISM



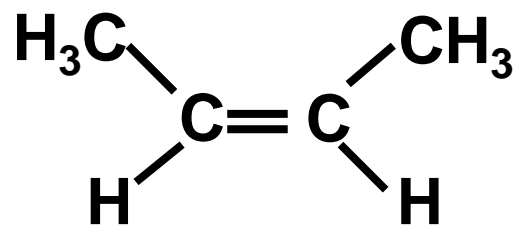
HOW TO IDENTIFY *CIS-TRANS* ISOMERS

- Restricted rotation of carbon–carbon bonds due to:
 - $C=C$
 - **cyclic** (ring) structure
- Two different atoms or group of atoms attached to each of **C atoms** which form **double bond** or **cyclic structure**

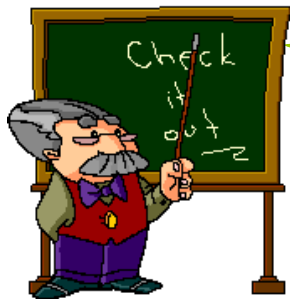
Example



trans-2-butene

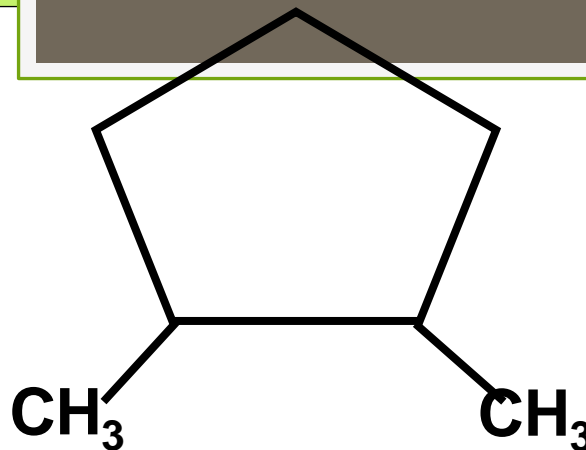


cis-2-butene

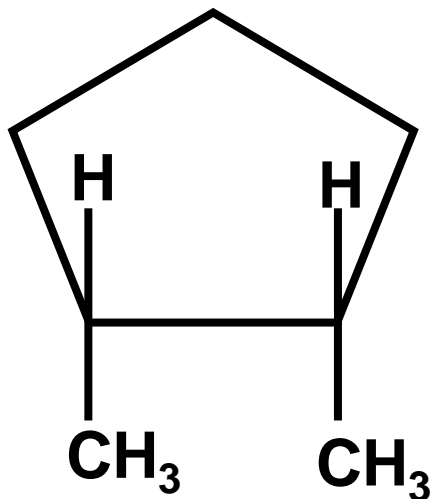


- Two groups on the **same side**
☞ *cis*
- Two groups on **opposite side**
☞ *trans*

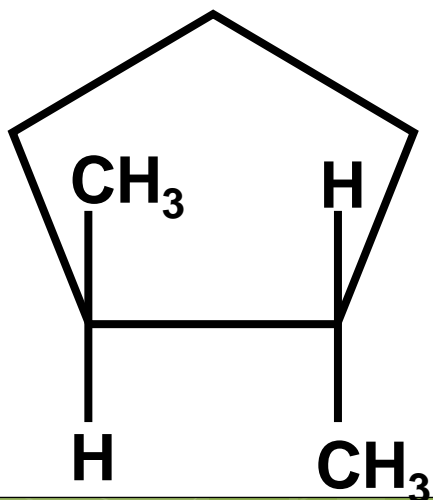
Example



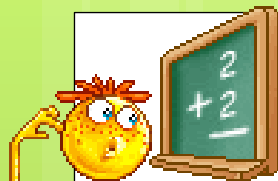
1,2-dimethylcyclopentane



cis-1,2-dimethylcyclopentane



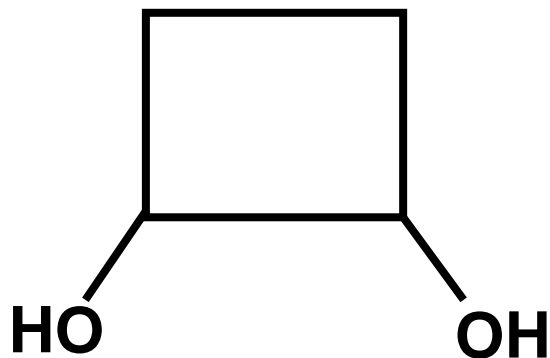
trans-1,2-dimethylcyclopentane



Exercise 1



Draw the structure of cis–trans isomer of 1,2–cyclobutanediol.



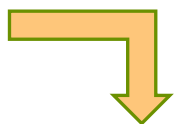
1,2–cyclobutanediol

Enantiomers

- ❑ **Stereoisomers** that **nonsuperimposable** mirror images of one another.
- ❑ occur only with compounds whose molecules are **chiral molecule**

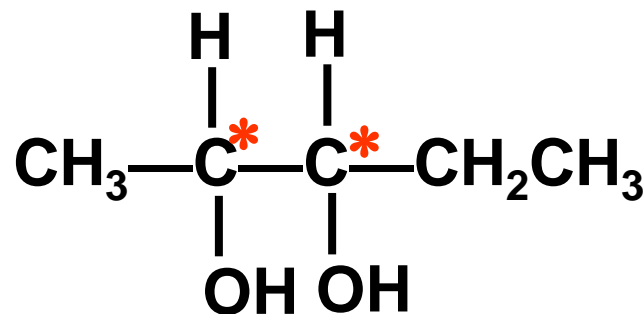
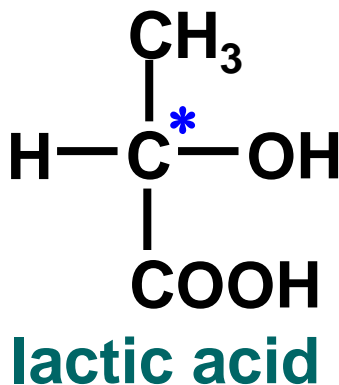
CHIRALITY CENTER

Definition



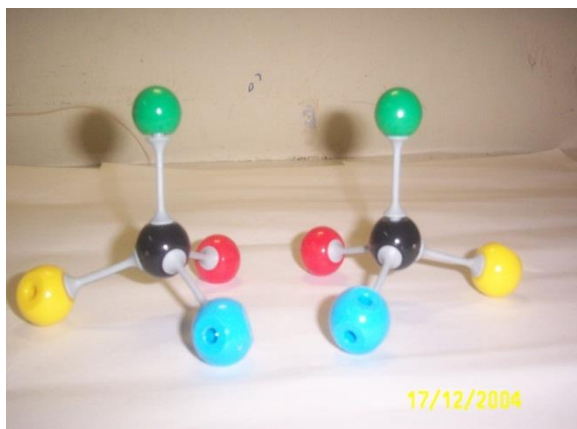
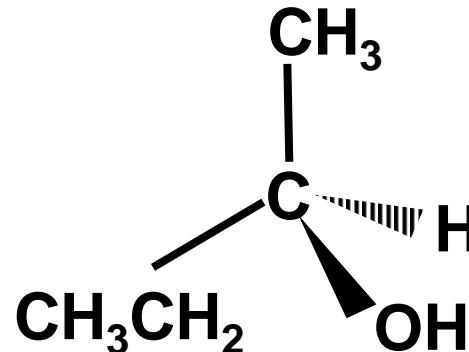
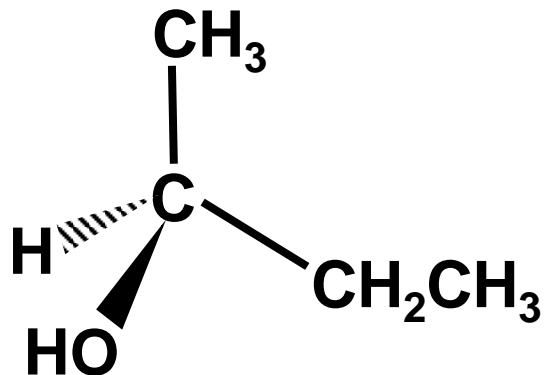
- sp^3 hybridized carbon bonded to four different atoms or groups.
- Also called **chiral carbon**, **asymmetric center**, **stereogenic center**
- Labeled as “*”

Example



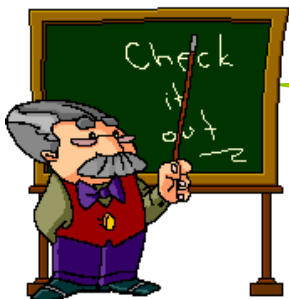
👉 **chiral**

molecule is **not superimposable** with its mirror image



a pair of stereoisomers with structures that are mirror-images of each other but nonsuperimposable.

3-D REPRESENTATION



How to show the 3-D structure on paper?



Wedge-line:



bond **in front**



Wedge-dashed:



bond **behind**



Solid-line:

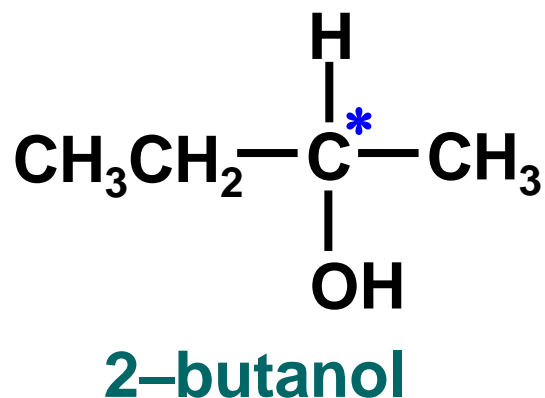


bond lies **in** the plane

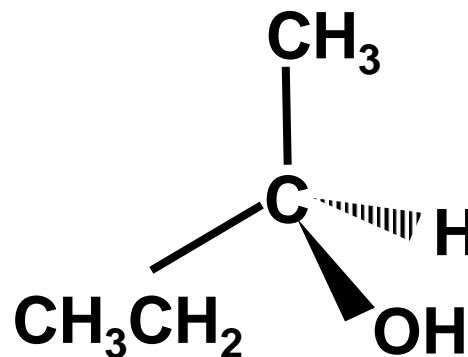
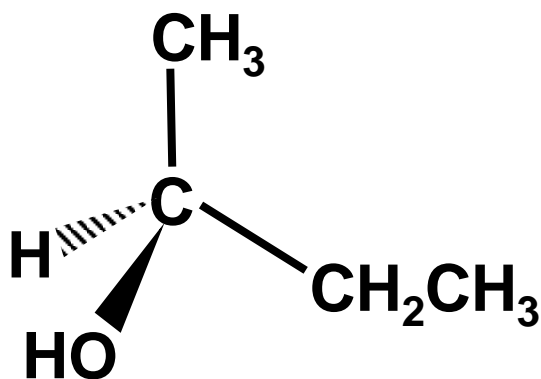


DRAWING A PAIR OF ENANTIOMERS IN 3D

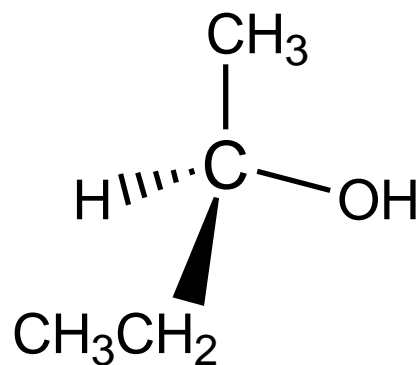
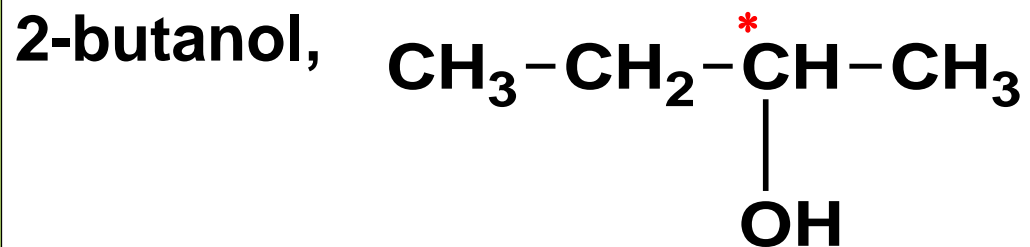
Example



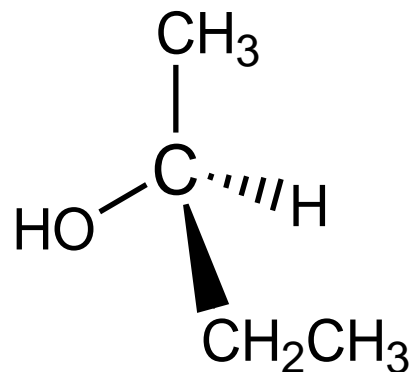
This formula is called
3-D formula or
wedge-dashed-wedge-line
formula



Example : 1



2-butanol

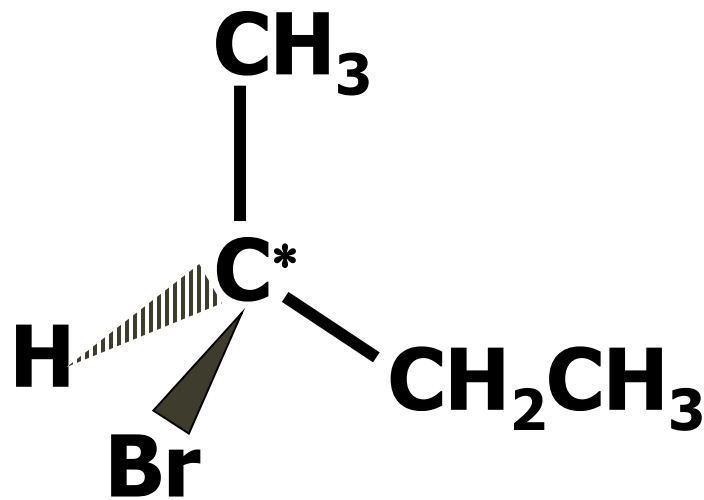
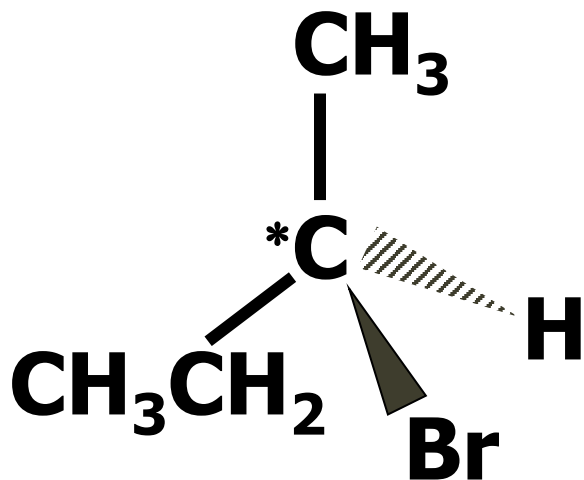
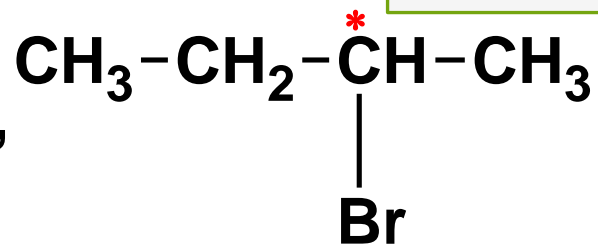


2-butanol

enantiomers

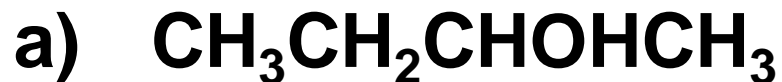
Example : 2

2-bromobutane,

**a pair of enantiomers**

Exercise 1

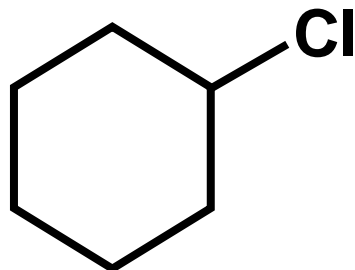
Label(“*”) at the chiral carbons (chirality center) in each of the following molecules:



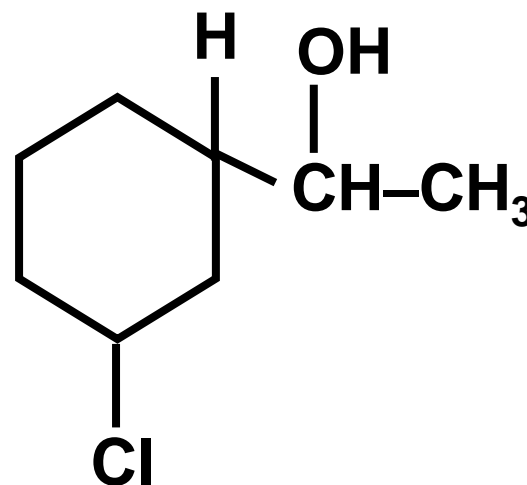
Exercise 2

Label (“*”) at the chiral carbons (if any) in each of the following molecules:

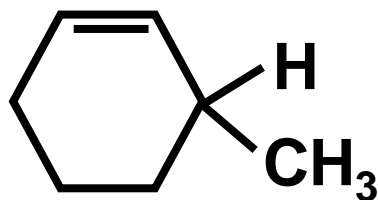
a)



b)

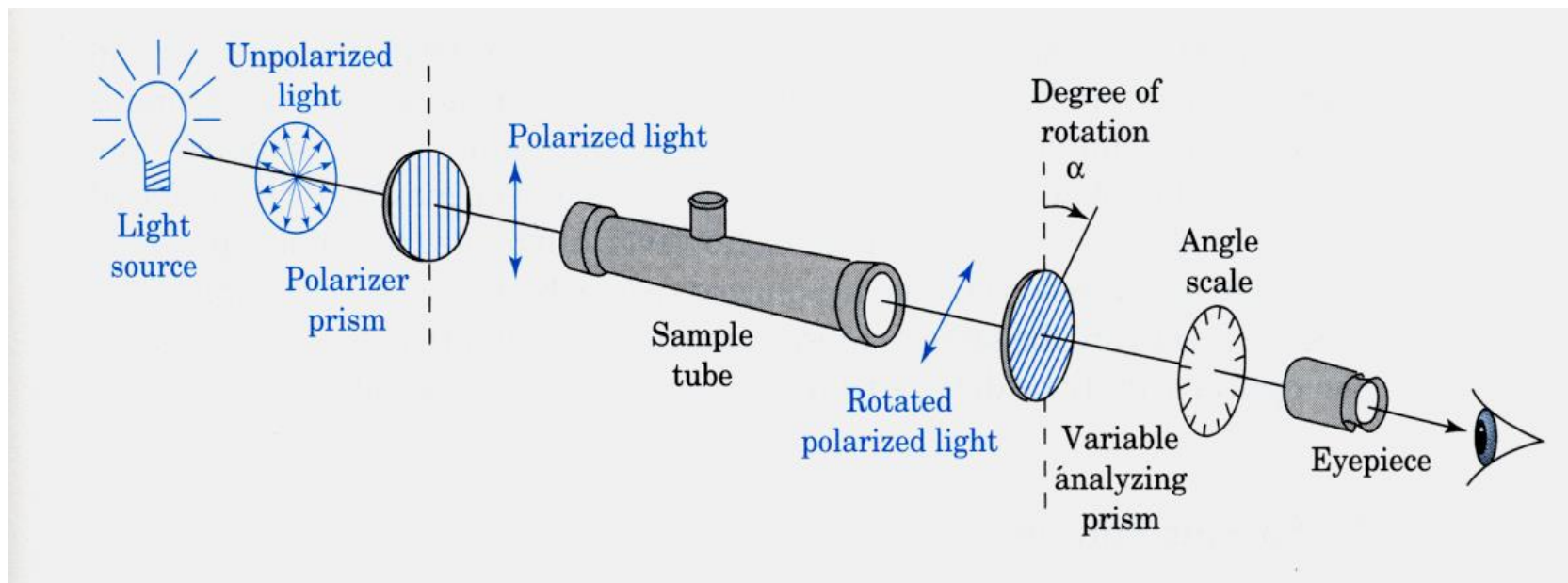


c)



Optical activity

- ✓ Molecules that are optically active are the molecules that have the ability to rotate the plane polarized light.
- ✓ **Polarimeter** is used to determine the optical activity of a compound.



polarimeter

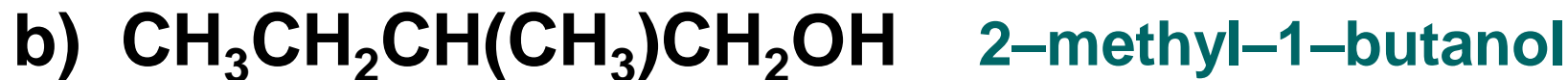
Optical activity

The requirements for optical active compounds :-

- 1 molecule contains **a chirality centre** / stereogenic centre / asymmetric carbon(*).
- 2 molecule is **not superimposable** with its mirror image.

Exercise 3

Some of the molecules listed here have a stereogenic (chiral) carbon; some do not. Write the three dimensional formula for both enantiomers of those molecules that do have a chiral carbon.



4.4 Reactions of Organic Compounds

At the end of the lesson, student should be able to:

- a) explain covalent bond cleavage : homolytic & heterolytic. (C2)
- b) Differentiate between homolytic cleavage and heterolytic cleavage. (C3)
- c) state the relative stabilities of 1° , 2° , 3° free radicals, carbocations and carbanions. (C1)
- d) compare the stabilities of carbocations and carbanions by using the inductive effect of alkyl group. (C4)
- e) define: (C1)
 - i) electrophile and nucleophile
 - ii) Lewis acid and Lewis base.
- f) explain the types of organic reactions : (C2)
addition, substitution, elimination, rearrangement.
- g) predict the type of organic reaction given a reaction equation. (C3)

REACTIONS IN ORGANIC COMPOUNDS

Reactions in Organic Compound

Covalent Bond Cleavage

Homolytic
Heterolytic

Relative stabilities

Free radicals
Carbocations
Carbanions

} Inductive effect

Electrophile

Define
Types

Lewis acid
Cation
Electron deficient site

Nucleophile

Define
Types

Lewis base
Anion
Electron rich site

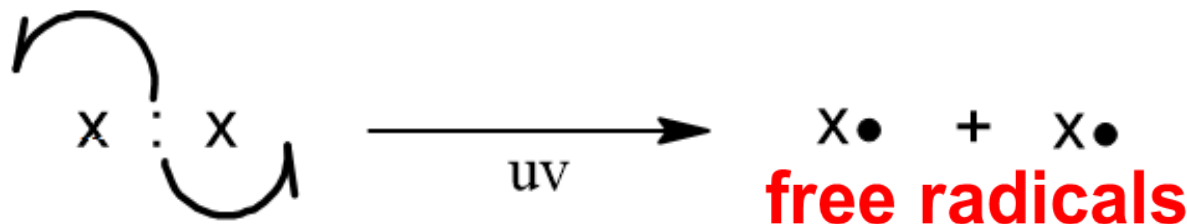
General type of Organic Reactions

Addition
Elimination
Substitution
Rearrangement

HOMOLYTIC CLEAVAGE

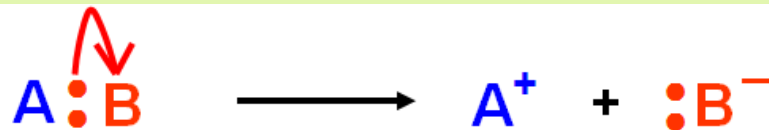
- Occurs in **a non-polar bond** involving two atoms of **similar electronegativity**.
- A single bond breaks **symmetrically** into two equal parts, leaving each atom with one unpaired electron.
- Formed **free radicals**.

Example:

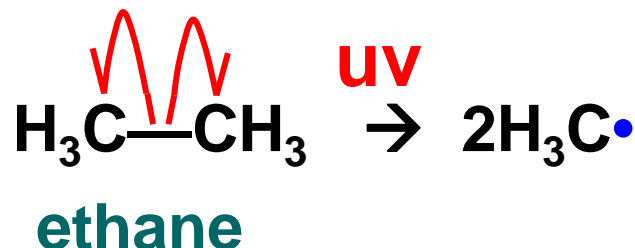
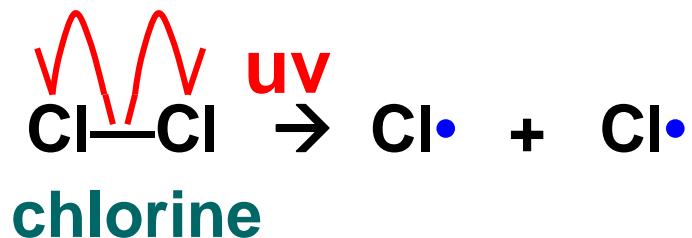


HETEROLYTIC CLEAVAGE

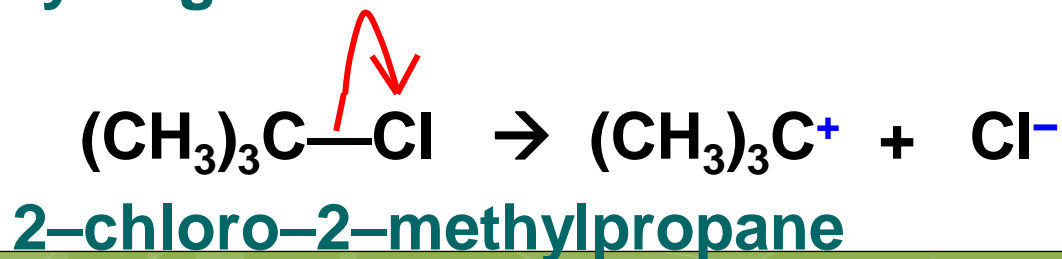
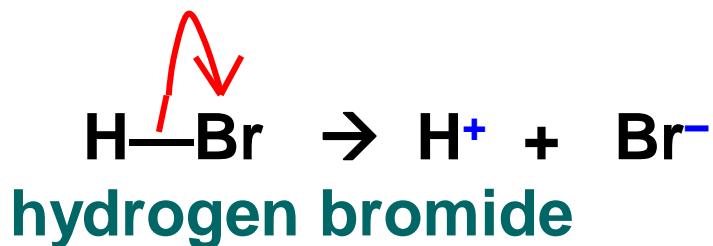
- Occurs in a polar bond involving unequal sharing of electron pair between two atoms of different electronegativities.
- A single bond breaks unsymmetrically.
- Both the bonding electrons are transferred to the more electronegative atom.
- Formed cation and anion.



Example of homolytic cleavage :



Example of heterolytic cleavage :

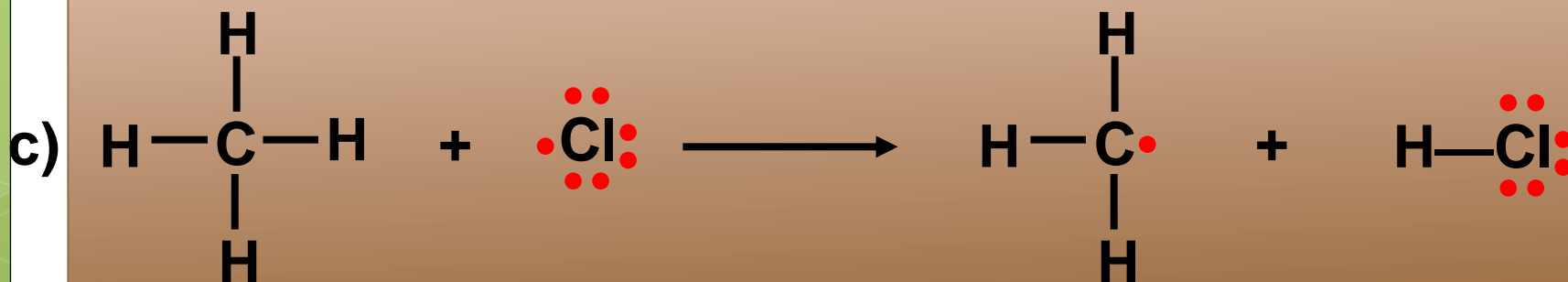
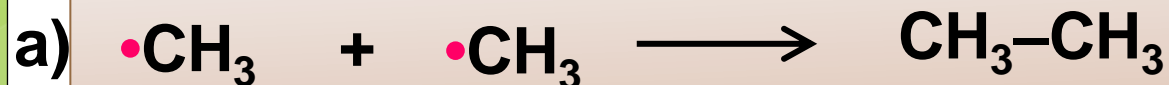




Exercise 1



Use half-headed curved arrows to show the movement of electrons in each reaction:

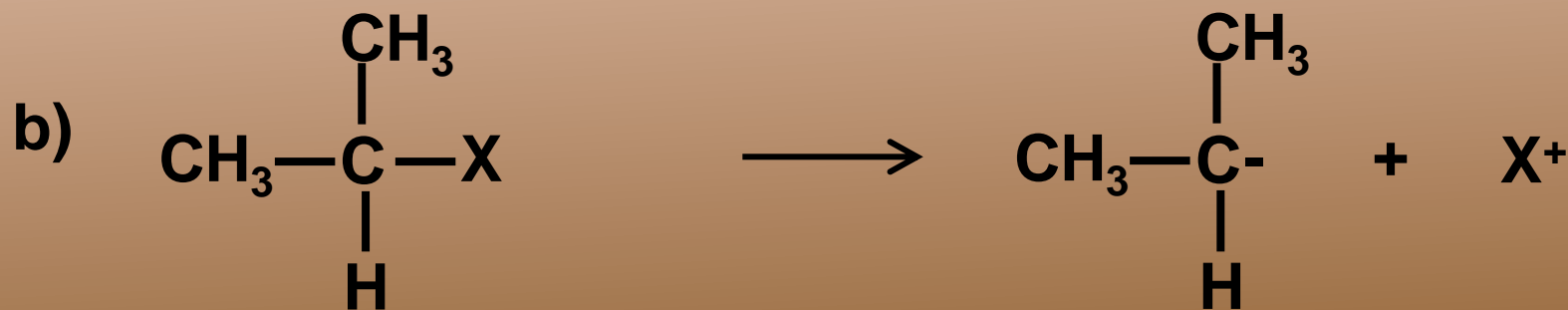
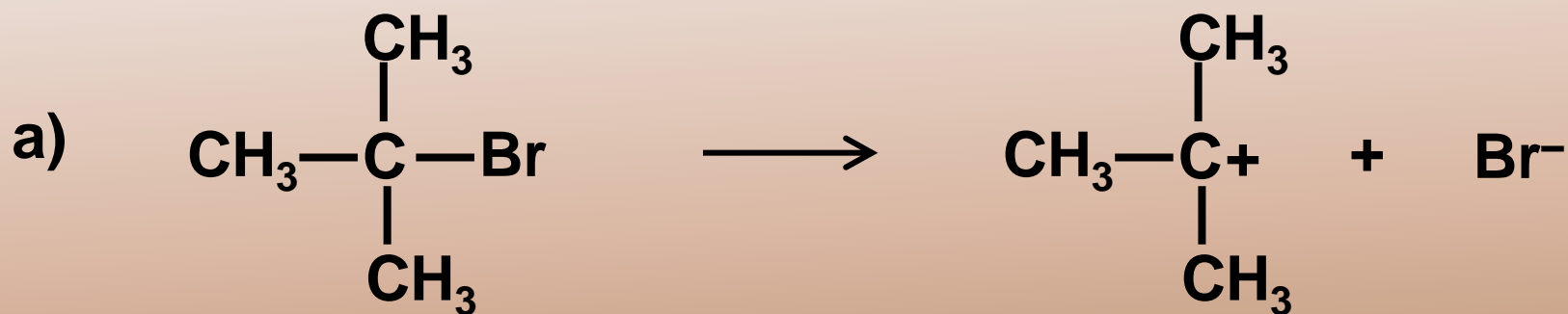


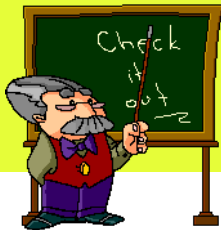


Exercise 2



Use full-headed curved arrows to show the movement of electron in each equation:



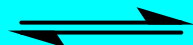


Info

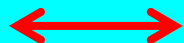
■ Arrow types in chemical reactions:



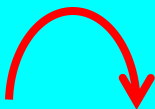
☞ **reaction** (reactant → product)



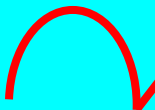
☞ **equilibrium**



☞ **resonance structures**

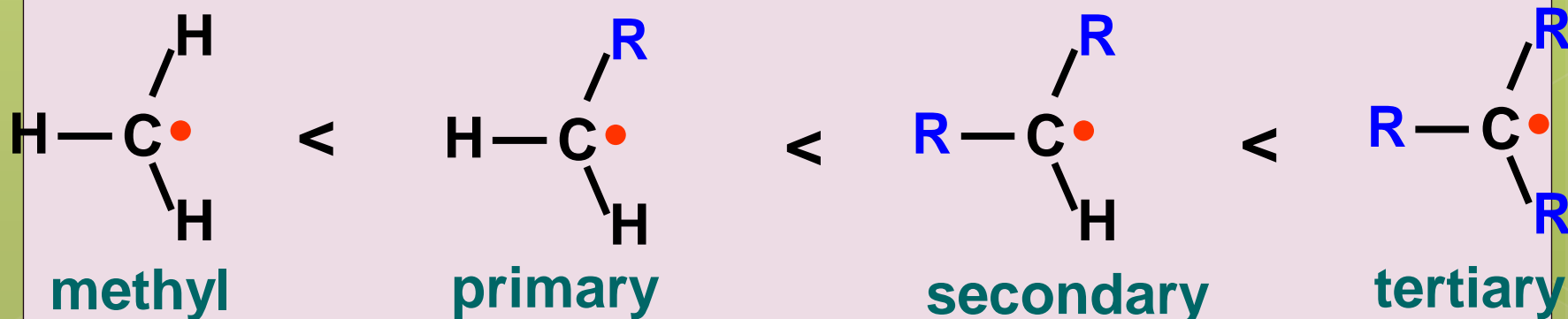



☞ **movement of an electron pair**



☞ **movement of a single electron**

EFFECT OF ALKYL SUBSTITUTION ON FREE RADICAL



- Radical carbon is **electron deficient**
- Has an **unfilled 2p orbital**
- Stabilized by **substituents** such as **alkyl groups**; CH_3- , CH_3CH_2- , etc
- Alkyl group  **electron releasing**

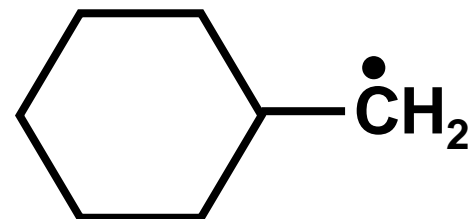
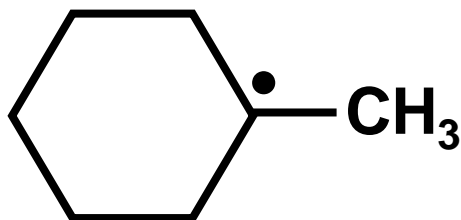
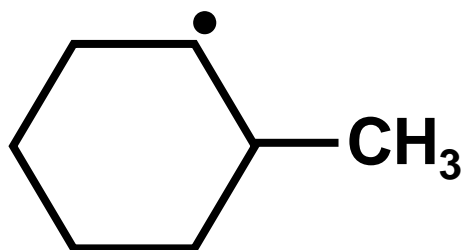
number of alkyl groups \uparrow

stability of radical \uparrow



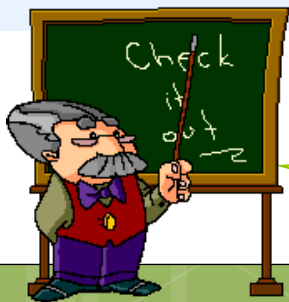
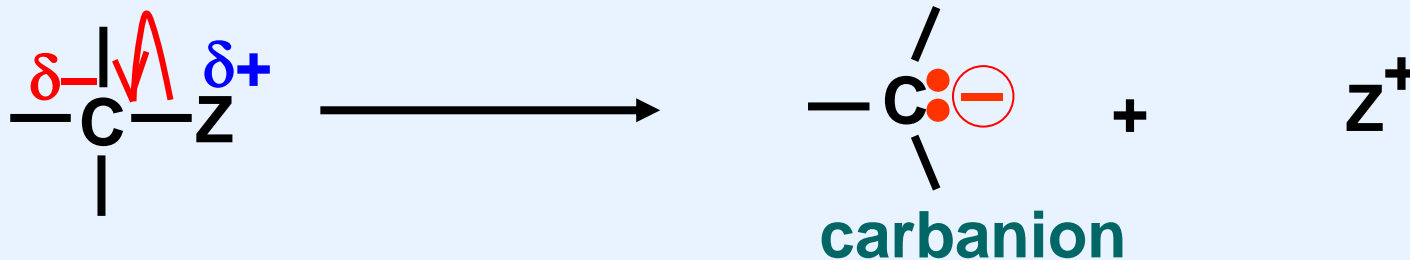
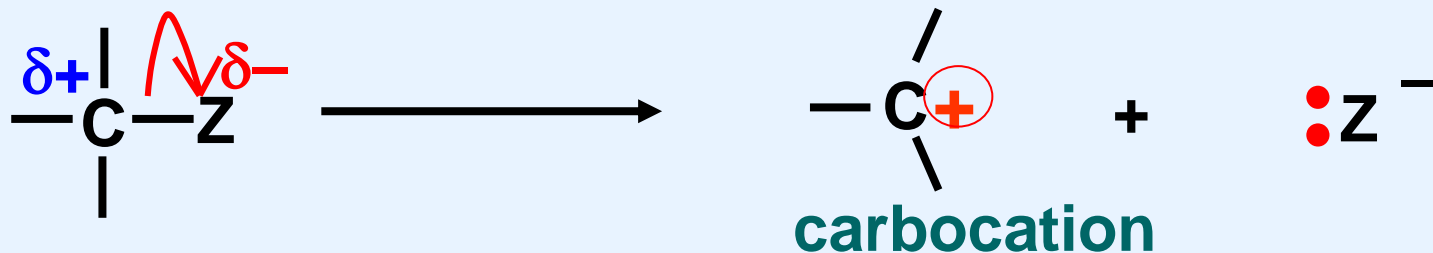
Exercise 3

List the following radicals in order of decreasing stability:



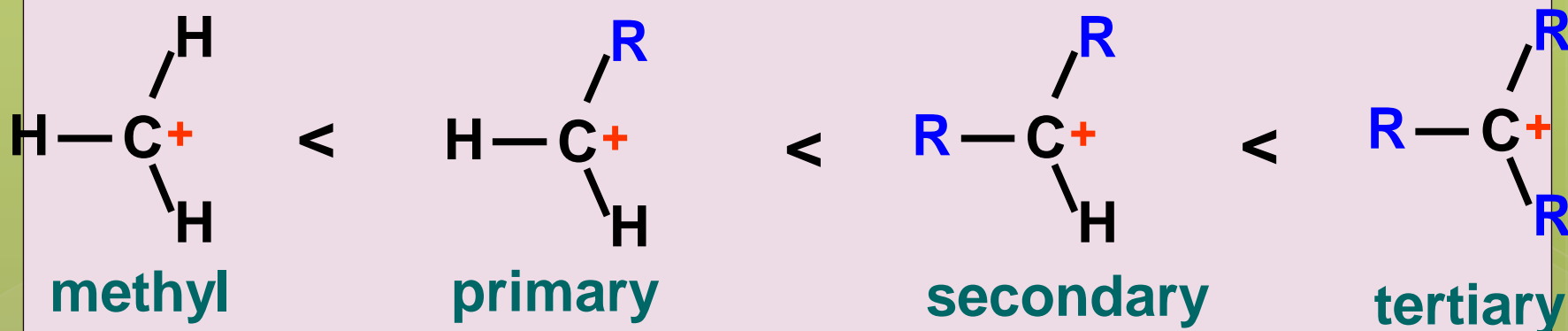
CARBOCATION AND CARBANION

■ Heterolysis of a bond to C atom:

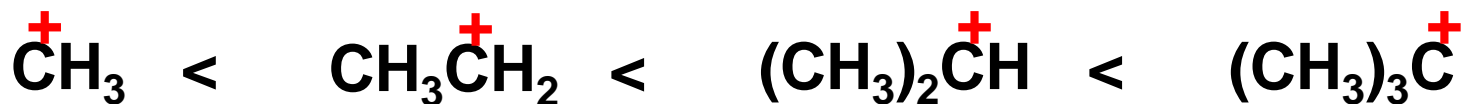


Carbocations and carbanions can be intermediates in polar reactions

RELATIVE STABILITIES OF CARBOCATION

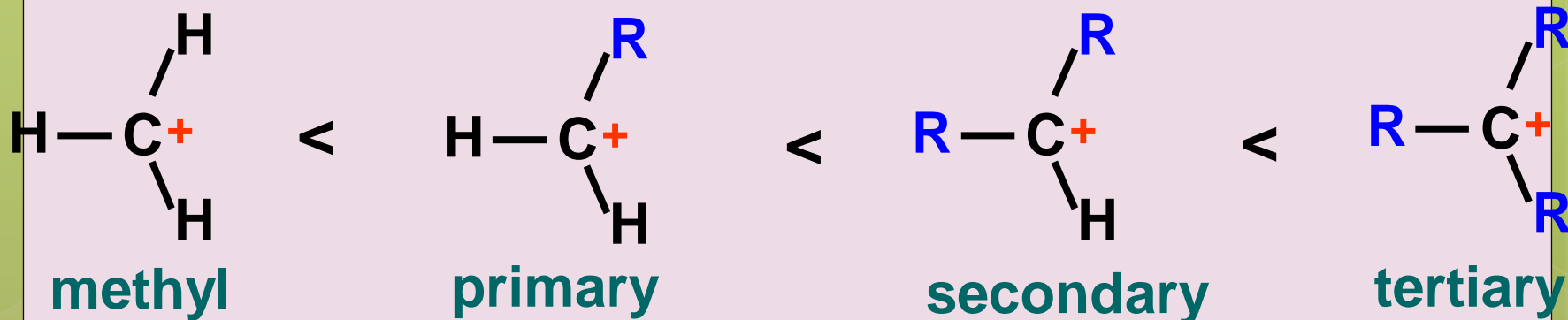


Example:

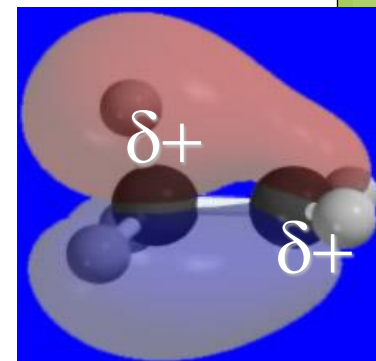


increasing alkyl substitution
increasing carbocation stability

EFFECT OF ALKYL SUBSTITUTION ON CARBOCATION



- Carbocation is **electron deficient**
- Has an **empty 2p orbital**
- Stabilized by **substituents** such as **alkyl groups**; CH₃–, CH₃CH₂–, etc.
- Alkyl group **electron releasing**

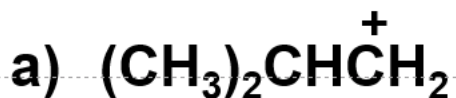


number of alkyl groups ↑ stability of carbocation ↑

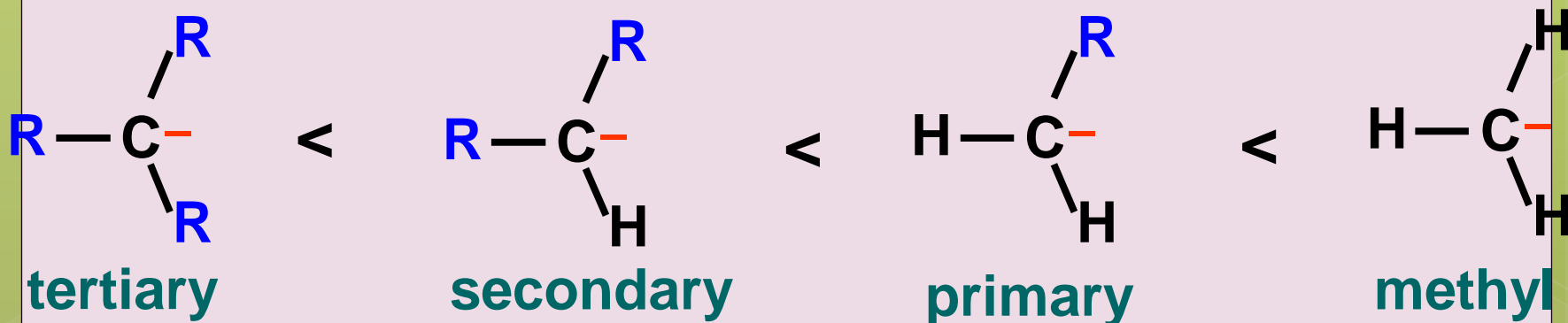


Exercise 4

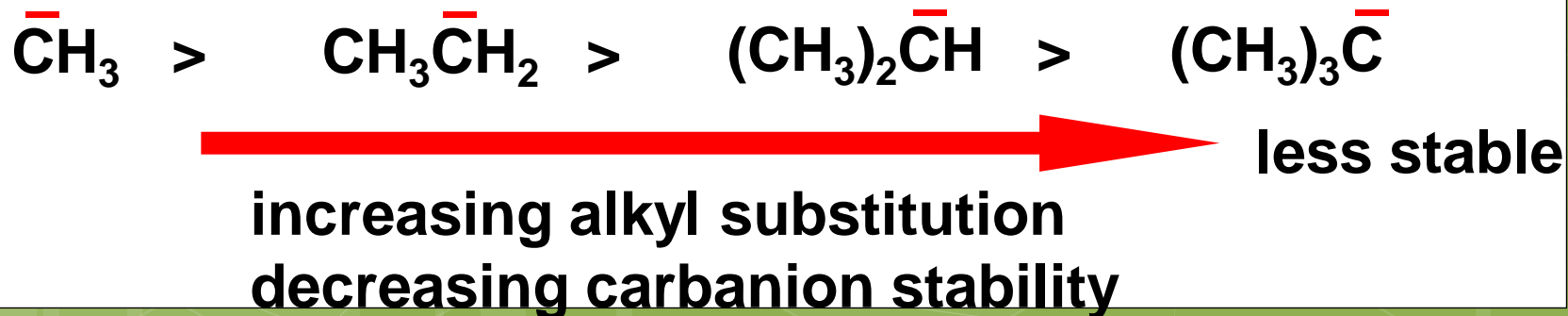
Rank the following carbocations in order of decreasing stability. Classify each as primary, secondary, or tertiary.



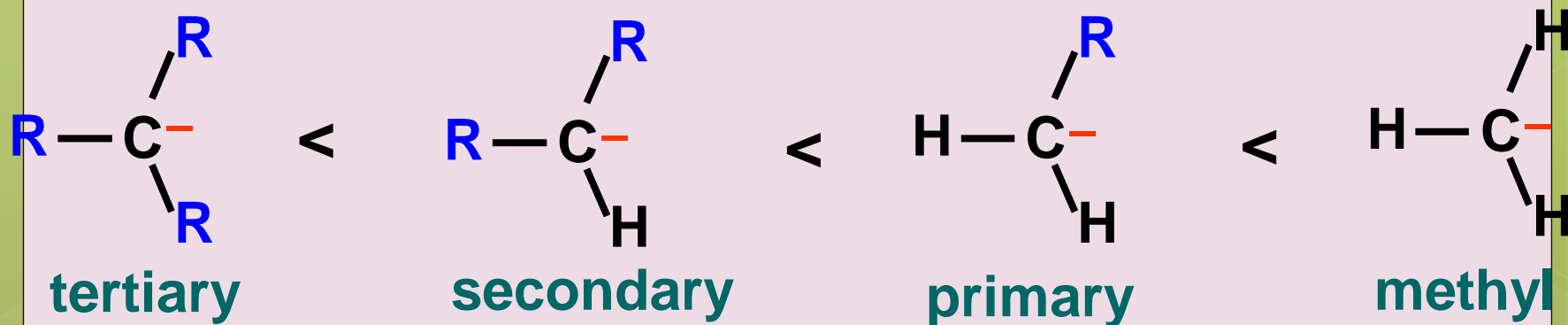
RELATIVE STABILITIES OF CARBANION




Example:



EFFECT OF ALKYL SUBSTITUTION ON CARBANION



- Carbanion is **electron-rich**
- High **electron density**
- Destabilized by **substituents** such as **alkyl groups**; CH_3- , CH_3CH_2- , etc.
- Alkyl group  **electron releasing**

number of alkyl groups \uparrow stability of carbanion \downarrow

REAGENTS AND SITES OF ORGANIC REACTIONS

A) Electrophile

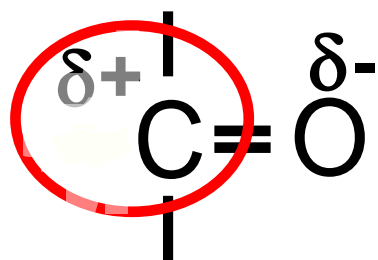
- **Definition** : A species that can accept an electron pair from a nucleophile
- Means 'electron loving'.
- Can be either neutral or positively charged.

Examples of electrophiles :

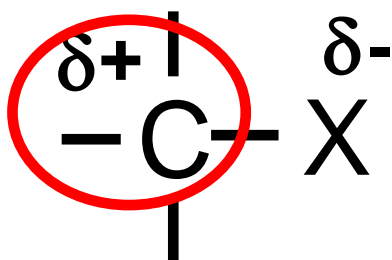
- ✚ Lewis acids such as AlCl_3 , FeCl_3 , BF_3 , cations and carbocations.
- ✚ **Definition lewis acid:** A substance that can accept one or more lone pairsof electrons into its valence shell: an electron pair acceptor.
- ✚ Oxidizing agents such as Cl_2 , Br_2 , etc.

Electrophilic sites are molecules with low electron density around a polar bond.

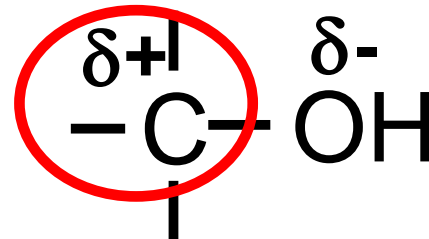
Examples:



(carbonyl)



(haloalkanes)



(hydroxy
compounds)



Electrophilic sites

B. Nucleophile

- **Definition** : An electron-rich species that can donate a pair of electrons to form a bond
- means 'nucleus loving'.
- A nucleophile can be either neutral or negatively charged.



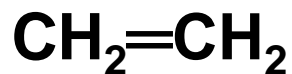
Examples of nucleophiles :

✚ Lewis base such as

- ✚ Anions (OH^- , RO^- , Cl^- , CN^- , etc)
- ✚ Carbanions (species with a negative charge on carbon atoms).

✚ **Definition lewis base:** A substance that can donate a lone pair electrons into the valence shell of a Lewis acid; an electron pair donor.

EXAMPLE: Nucleophilic Site



i) Electrophile

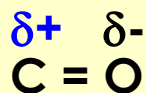
- ☐ An electron-**deficient** species
- ☐ An electron-pair **acceptor**
- ☐ Either **neutral or positively** charged species.
- ☐ Greek word means '**electron** loving'.

ii) Nucleophile

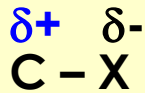
- ☐ An electron-**rich** species
- ☐ An electron-pair **donor**
- ☐ Either **neutral or negatively** charged species
- ☐ Greek word means '**nucleus** loving'.

Examples of electrophiles :

- cations such as H^+ , H_3O^+ , $^+\text{NO}_2$, Br^+ etc.
- carbocations (species with a positive charge on carbon atoms). e.g CH_3^+
- Lewis acids such as AlCl_3 , FeCl_3 , BF_3 and etc.
- Site of low electron density



Carbonyl



haloalkane

- oxidizing agents such as Cl_2 , Br_2 etc.

Examples of nucleophiles :

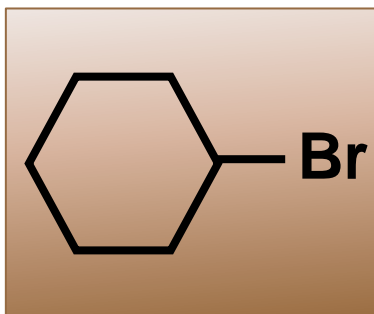
- ❖ anions such as ^-OH , RO^- , Cl^- , CN^- and etc.
- ❖ carbanions (species with a negative charge on carbon atoms). e.g CH_3^-
- ❖ Lewis bases which can donate lone pair electrons such as NH_3 , H_2O , H_2S etc.
- ❖ Site of high electron density (**carbon-carbon multiple bonds**):
 - $\text{C} = \text{C}$ (alkenes, arenes);
 - $\text{C} \equiv \text{C}$ (alkynes)



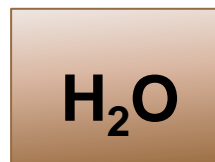
Exercise 5

Label the electrophilic and nucleophilic sites in each molecule:

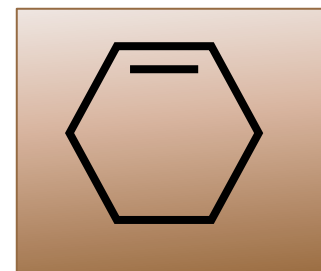
a)



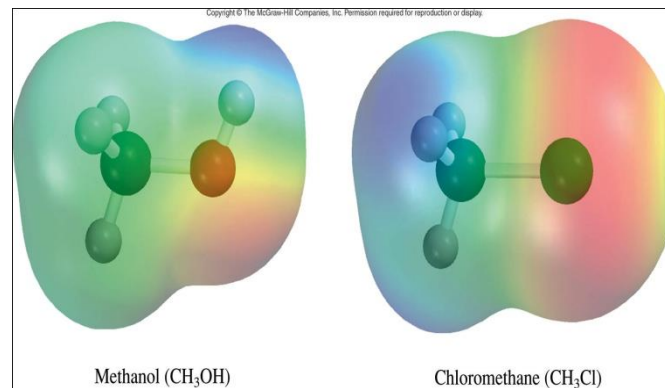
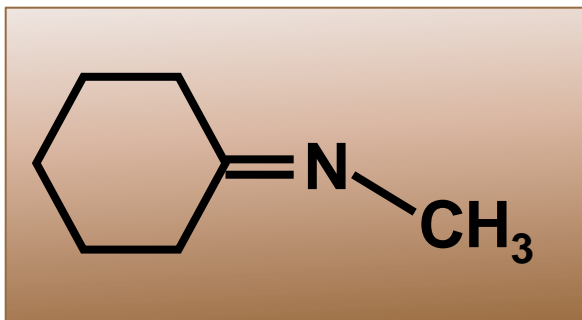
b)



c)



d)



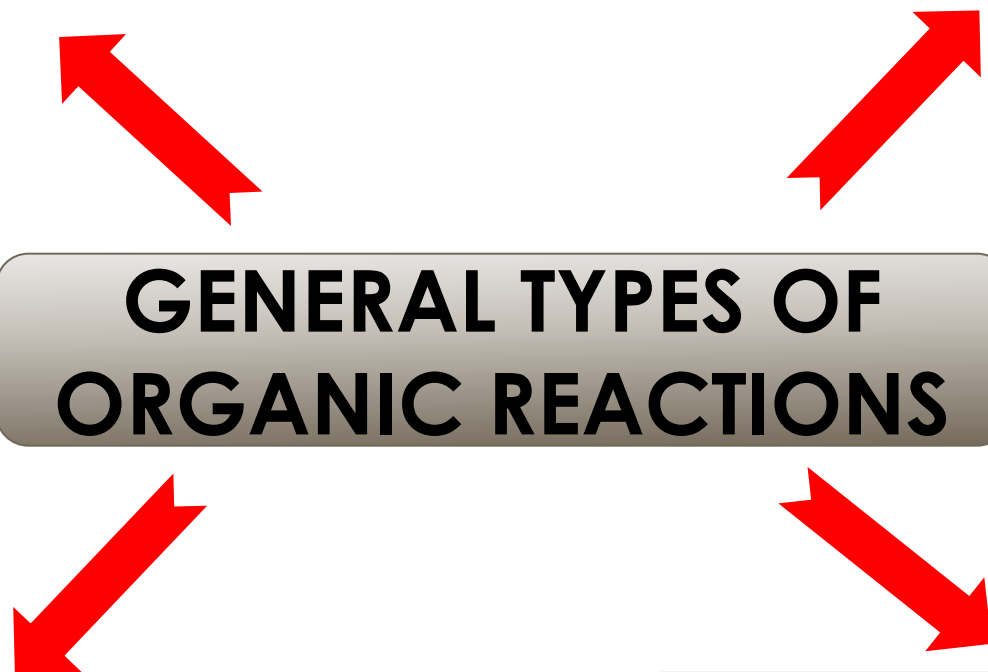
Addition

Elimination

**GENERAL TYPES OF
ORGANIC REACTIONS**

Substitution

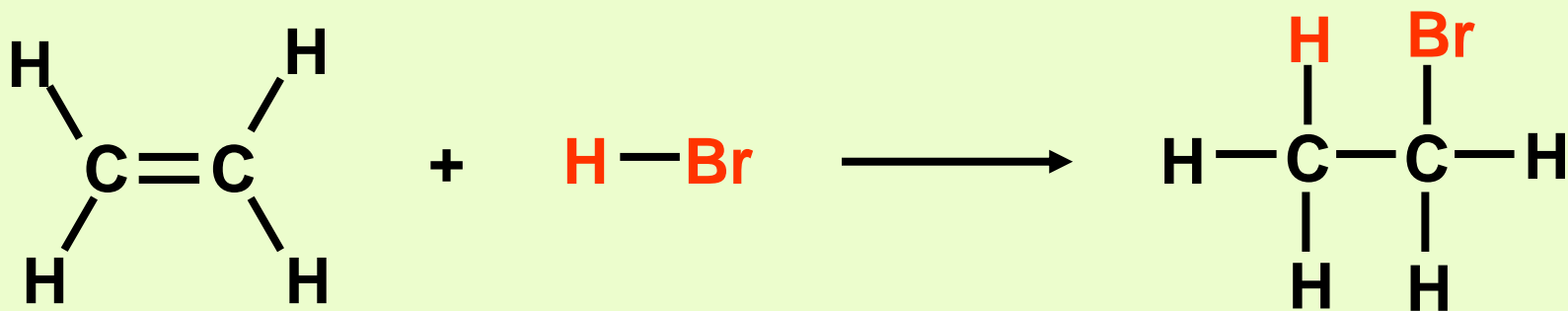
Rearrangement



ADDITION REACTION

- All parts of the adding reagent appear in the product
- **Two molecules** become **one**
- Characteristic reaction of compounds with **multiple bonds**

Example:



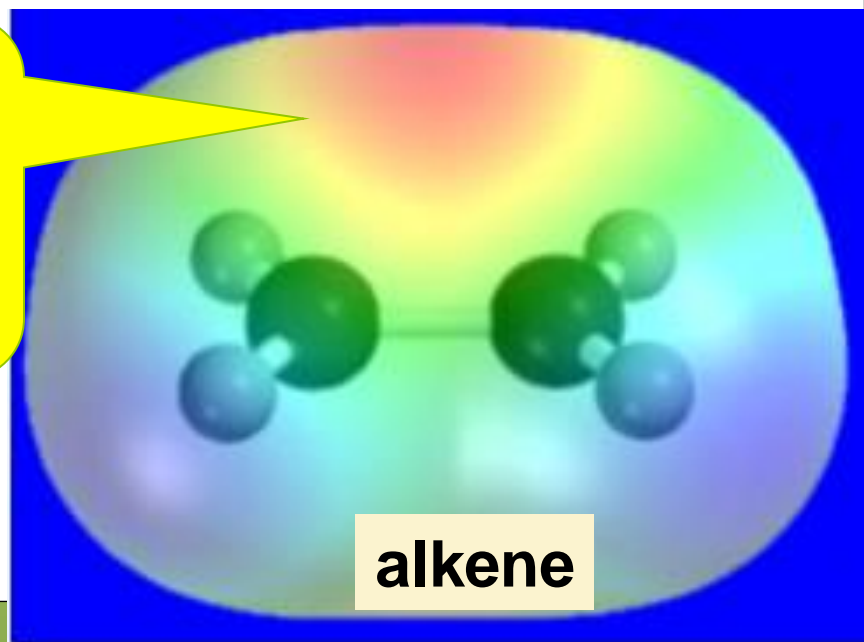
ethylene
(an alkene)

bromoethane
(an alkyl halide)

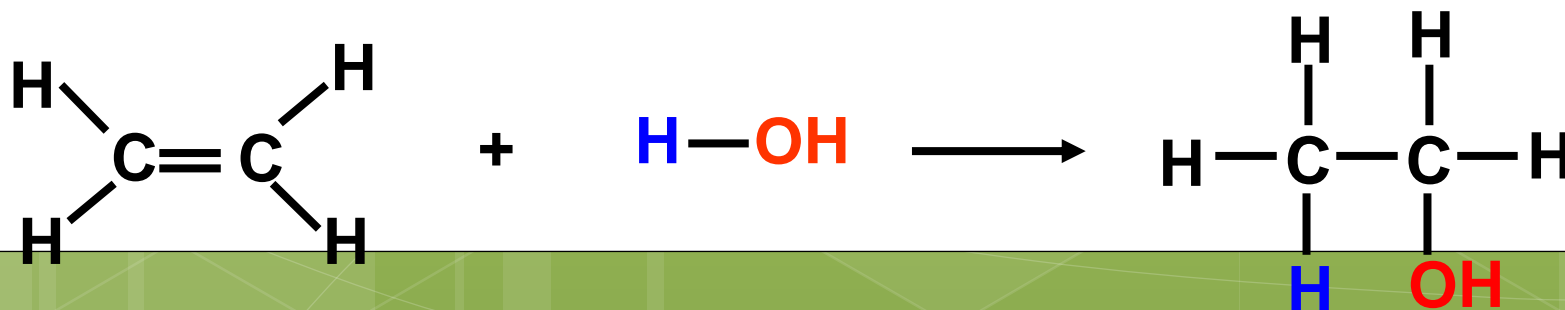
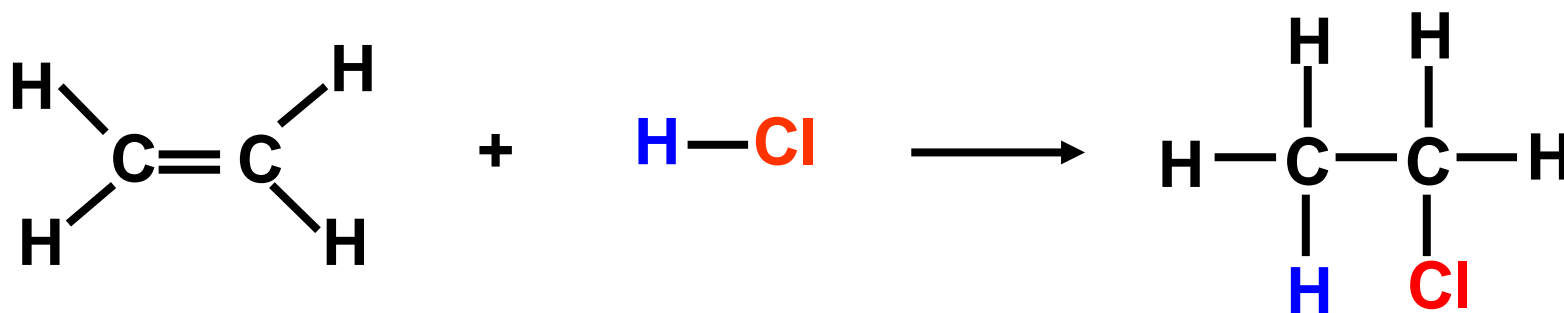
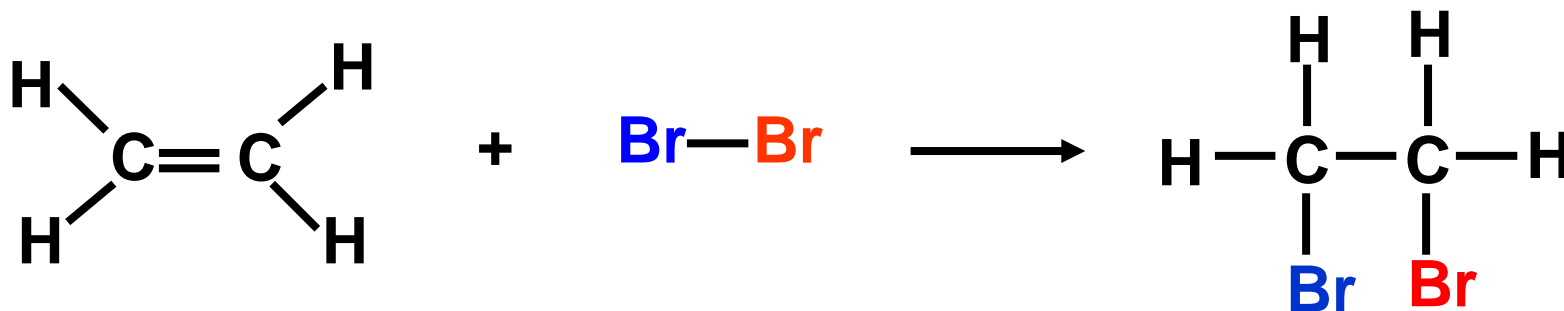
ELECTROPHILIC ADDITION

- Reactions involving $\text{C}=\text{C}$ and $\text{C}\equiv\text{C}$
- π bonds are **electron-rich** and located **above** and **below** the **plane** of the bond
 - ☞ susceptible to **attack** by **electrophiles**

Come attack me,
Mr. **electrophile**!
You **love electrons**, right?
I'm **electron-rich**!

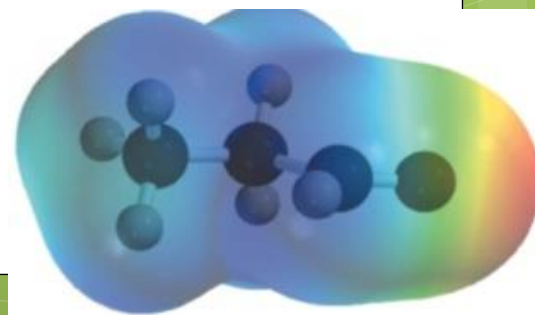
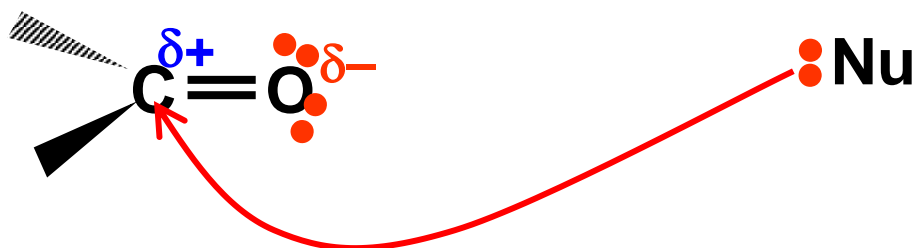


Example:

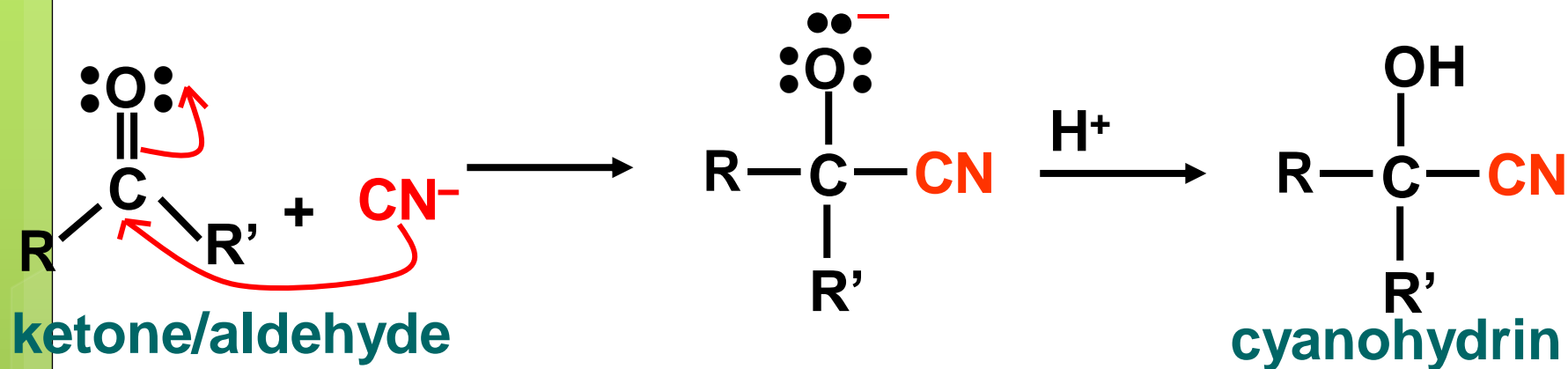


NUCLEOPHILIC ADDITION

- Most common reaction of **aldehydes** and **ketones**
- **Nucleophile** approach to the **electrophilic C** of **carbonyl group**



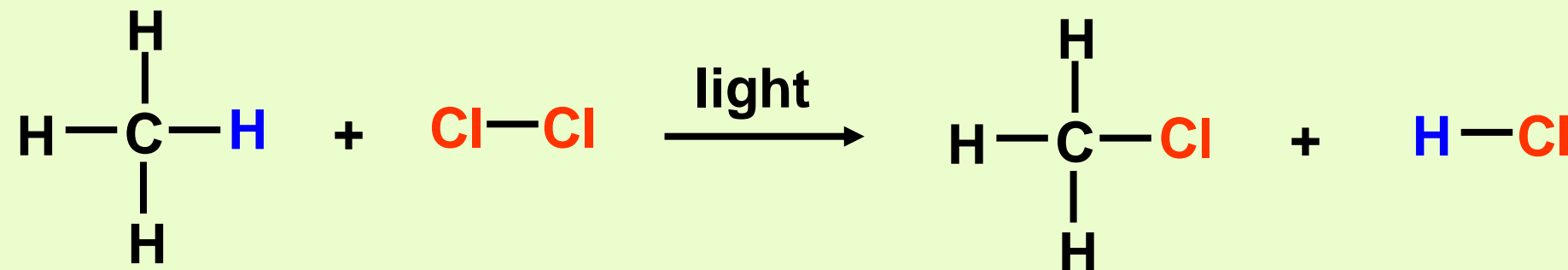
Example:



SUBSTITUTION REACTION

- Two reactants **exchange parts** to give new products
- Characteristic reaction of **saturated** and **aromatic** compounds

Example:

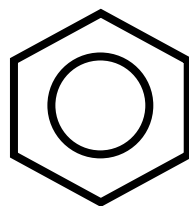
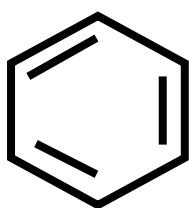


methane
(an alkane)

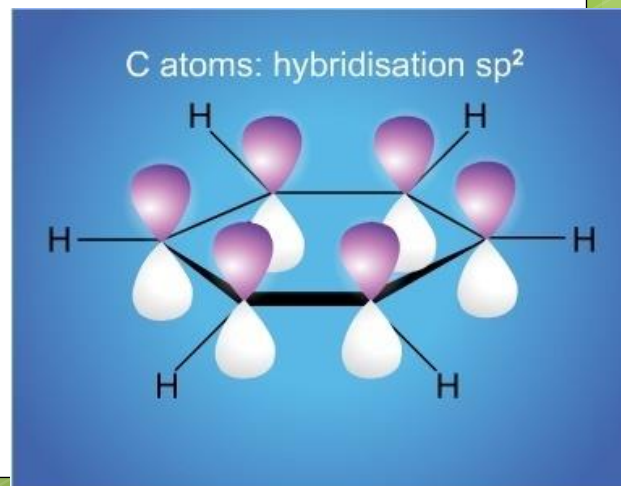
chloromethane
(an alkyl halide)

ELECTROPHILIC AROMATIC SUBSTITUTION

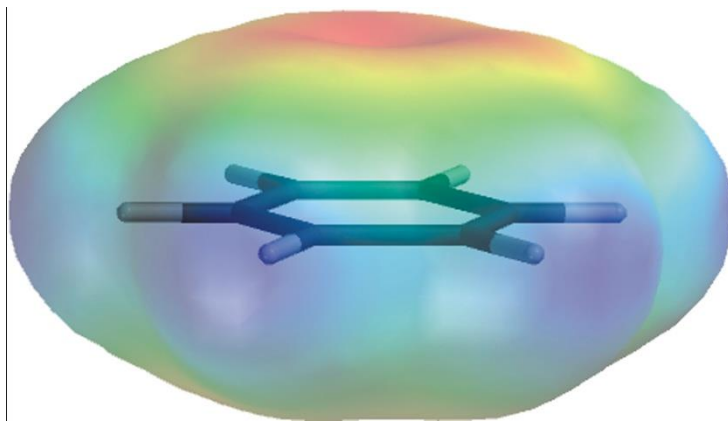
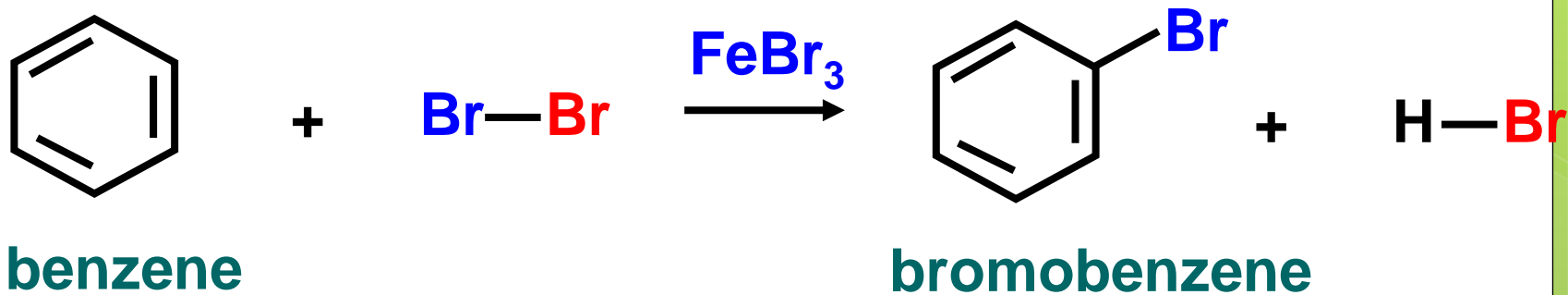
- The characteristic of all aromatic compounds
- Benzene has six π electrons delocalized in six π orbitals that overlap above and below plane of the ring (electron-rich)
 - ☞ susceptible to attack by electrophiles



benzene



Example:



NUCLEOPHILIC SUBSTITUTION

- Most common reaction of **alkyl halides** (**haloalkanes**)



Example:



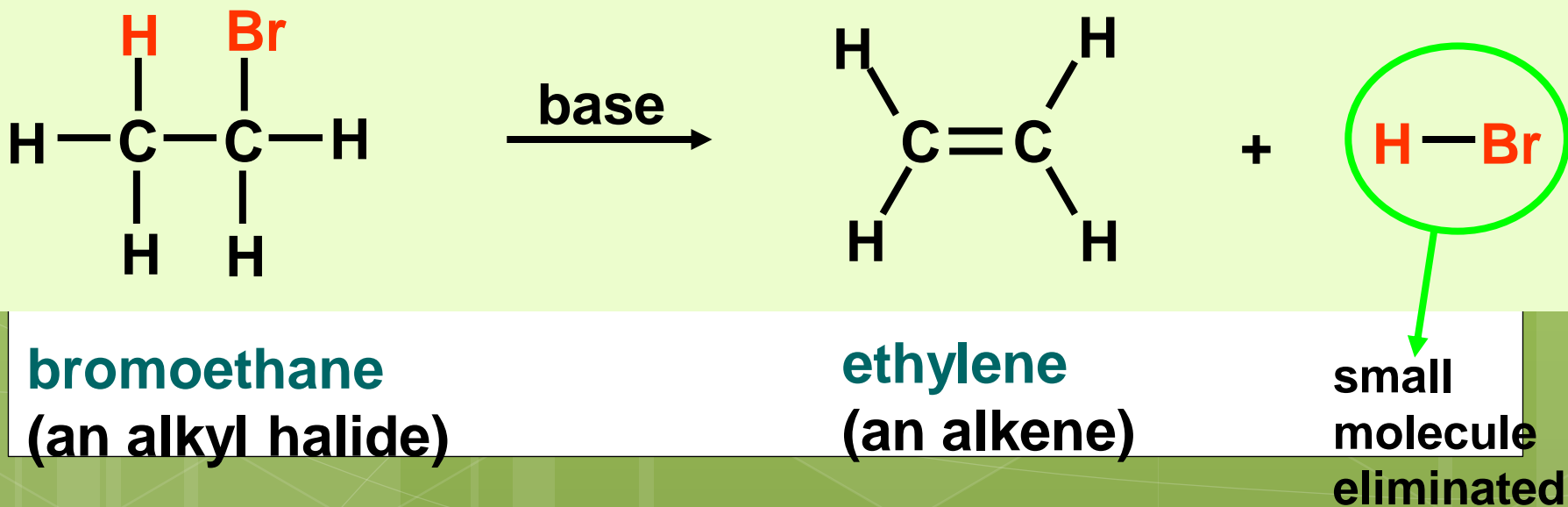
SUMMARY OF TYPES OF ORGANIC REACTIONS

- | | |
|---------------------------------------|----------------------|
| ■ Electrophilic addition | ☞ alkenes, alkynes |
| ■ Electrophilic aromatic substitution | ☞ aromatic compounds |
| ■ Nucleophilic addition | ☞ aldehydes, ketones |
| ■ Nucleophilic substitution | ☞ alkyl halides |
| ■ Free radical substitution | ☞ alkanes |

ELIMINATION REACTION

- Opposite of addition reaction
- A **single reactant** splits into **two products**
- Method for **preparing** compounds with **double** and **triple bonds**

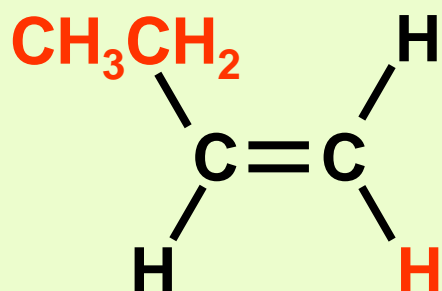
Example:



REARRANGEMENT REACTION

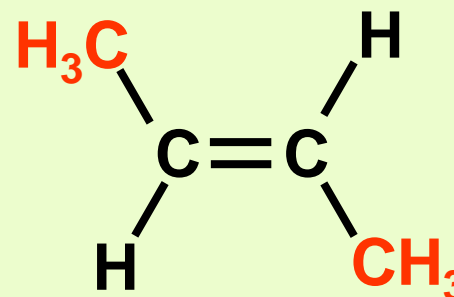
- A single reactant undergoes a reorganization of bonds and atoms

Example:



1-butene

acid catalyst
→



2-butene



Exercise 6

Classify each of the following reactions as an addition, elimination, substitution, or rearrangement:





GLOSARRY

1. **Structural Formula:** Formula that shows how the atoms of a molecule are bonded to one another.
2. **Functional group:** Is an atom or group of atoms in an organic molecule which characterised the molecule and enables it to react in specific ways which determines its chemical properties.
3. **Homologous series:** is series of compounds where each member differs from the next member by a constant $-\text{CH}_2$ unit
4. **Expanded structure:** A structural formula that shows **all atoms in a molecule** and **all bonds connecting the atoms**.
5. **Isomerism:** The existence of chemical compounds that have **same molecular formula** but **different molecular structure** or **arrangement in space**.
6. **Constitutional Isomerism:** molecules that have **same molecular formula** but **different structure**.
7. **Stereoisomerism:** The existence of chemical compounds which have their **atoms connected in same order** but **differ in arrangement in space**.



GLOSARRY

8. **Chirality center:** sp^3 hybridized carbon bonded to four different atoms or groups.
9. **Enantiomers:** Stereoisomers that nonsuperimposable mirror images of one another.
10. **Electrophile:** A species that can accept an electron pair from a nucleophile.
11. **Nucleophile:** An electron-rich species that can donate a pair of electrons to form a bond.
12. **Definition lewis acid:** A substance that can accept one or more lone pairsof electrons into its valence shell: an electron pair acceptor.
13. **Definition lewis base:** A substance that can donate a lone pair electrons into the valence shell of a Lewis acid; an electron pair donor.