

Lecture 1

Date: 24-2-2025, Monday
organic chemistry

Ch-1

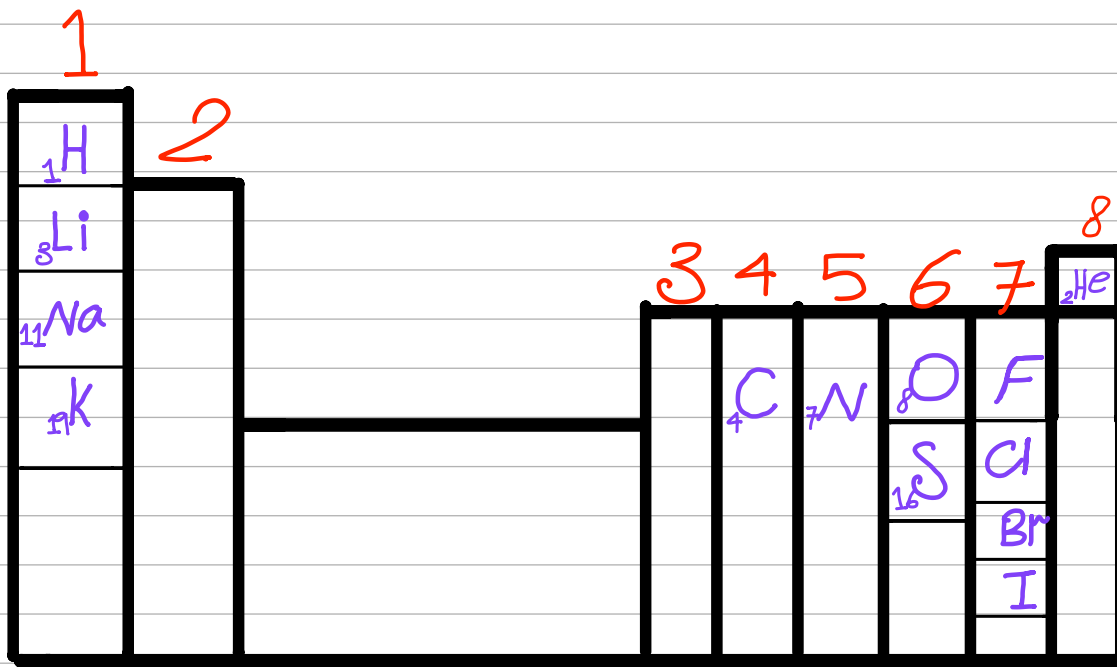
دکتر کمال سویدان

Notes of the lecturer.

These slides aren't sufficient for the examination purposes.

The required things from the periodic table in our course to the last lecture

Approximate shape.



In the periodic table, there are:

metals \leftarrow main metallic elements (main elements) like: Li, Na, Mg ...
Transition metals like: Cs, Zr, Cu ...

Non-metals like: F, I, Br, Cl, N, O ...

metalloids like: Sb, Ge, Si ...

The number of valence electrons is equivalent to the number of the group.

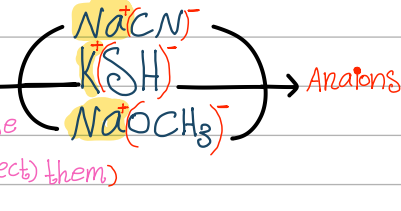
metals \rightarrow lose electrons.

non-metals \rightarrow gain electrons.

(Chemical bonds)

Ionic

metal-Non-metal
like:



Note: - in OCH_3 refers to (O) and in the same way in both CN^- and SH^-

Covalent (Molecular)

non-metal + non-metal
non-metal + metalloid

Polar

like: C-Cl
O-H
N-H
C-Br

Non-Polar

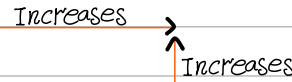
like: C-C
C-H
Cl-Cl
H-H

According to the: **Electronegativity**

Electronegativity: It is the ability of an atom to pull (attract) the bond's electrons to its own side as much as it can for the longest possible time.

• Too helpful chain:
Electronegativity
I > Br > Cl > N > O > F

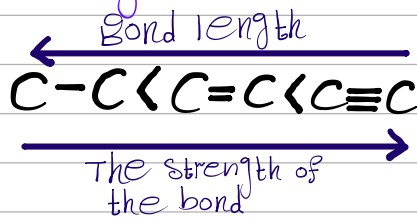
Electronegativity in the periodic table:



• If there isn't any difference in electronegativity between covalently bonded atoms, then the covalent bond is non-polar and vice versa.

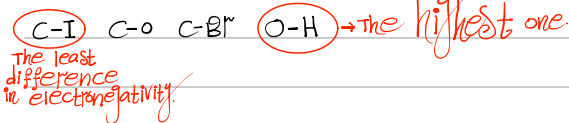
• Bond length: distance between two nuclei of atoms.

Bond length is inversely proportional with the strength of the bond (Energy bond)



• Polarity of the bond is linearly proportional with the difference in the electronegativity.

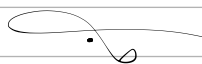
• The least polar bond is:



• The most polar bond is:



The highest difference in electronegativity

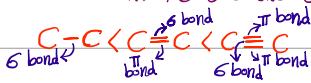


Note: In formation of bonds, valence electrons are involved in this operation.

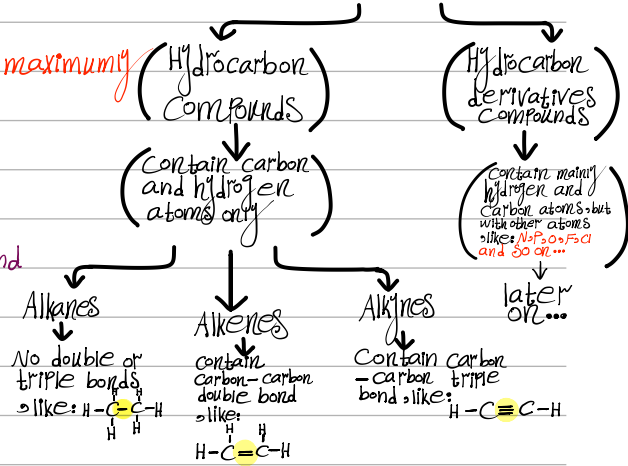
Note: Always recall that: Each carbon atom can form **four bonds maximumly** and it can form **less than this**.

Note: (σ) bond → Head by head overlap. (π) bond → Side by side overlap

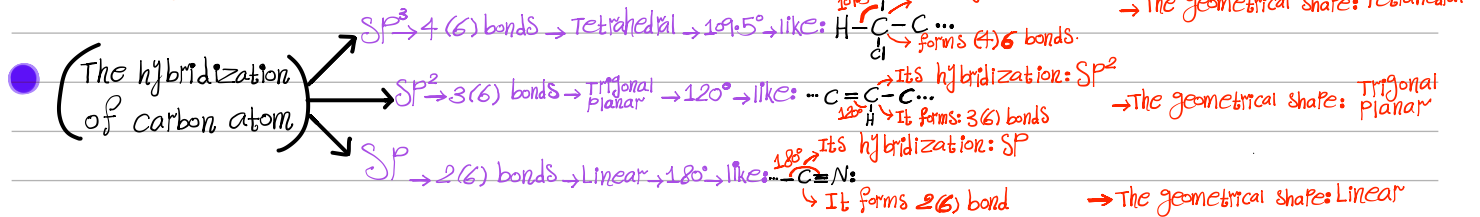
(σ) bond is stronger than (π) bond, so the combination between π and σ bonds increases the strength of the bond (total one) like:



(Organic compounds)

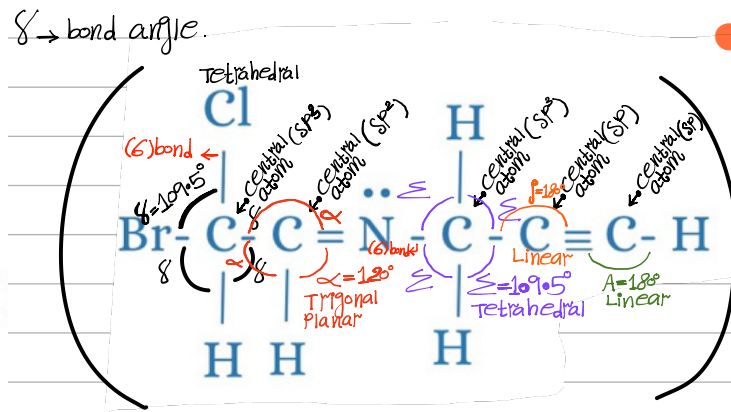


The strength of the bond



Exercise:

Find of each:- hybridization bond angle geometry



Note: when you determine the bond angle, focus on the central atom in each geometrical shape. Trust me, you will never make mistake.

Each central atom, refers to its own geometrical shape.

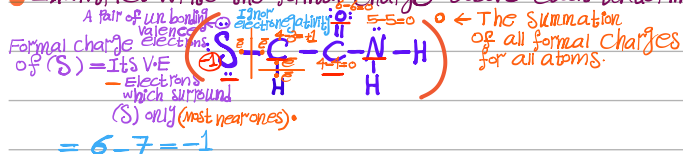
The entire structure contains more than one geometrical shape.

• Additional note: If you noticed that the summation of bond angles into the trigonal planar is 360° , but in tetrahedral is more than this, can you justify this? Surely, in the trigonal planar all bond angles are distributed on the same plane (two axes) but in tetrahedral bond angles are distributed on three axes.

• Formal charge: It is the actual charge for a certain atom.

• Note: In determination of the formal charge ignore the electronegativity.

• Example: write the formal charge above each underlined atom in the below:



• Note: oxygen atom (O) forms (2) bonds without any formal charge → like: H_2O : $\text{H}-\overset{\cdot\cdot}{\underset{\cdot\cdot}{\text{O}}}-\text{H}$

(3) bonds with positive formal charge → like: H_3O^+ : $\text{H}-\overset{+1}{\underset{\cdot\cdot}{\text{O}}}-\text{H}$

(1) bond with negative formal charge → like: OH^- : $\text{H}-\overset{\cdot\cdot}{\underset{\cdot\cdot}{\text{O}}}-$

• Note: Carbon atom with negative formal charge its hybridization is ignored.

• Example: $(\text{:}\overset{\cdot\cdot}{\underset{\cdot\cdot}{\text{S}}}-\overset{\text{H}}{\underset{\cdot\cdot}{\text{C}}}-\overset{\text{O}}{\underset{\cdot\cdot}{\text{C}}}-\text{H})$ Study the adjacent structure then answer of the following questions:

1 - What is the hybridization of the underlined atom? 3 (6) bonds → mean: (sp^2)

2 - If the underlined atom represents a central atom, what is the name of the geometrical shape which it is involved in it? Trigonal Planar.

3 - What is the bond angle in the above geometrical shape? 120°

4 - How many geometrical shapes in the listed structure in the above? Two ones → Trigonal Planar, Tetrahedral

Resonance Structures

Resonance structures are a set of two or more Lewis Structures that collectively describe the electronic bonding of a single polyatomic species including fractional bonds and fractional charges.

← Quoted from Safari (A browser for ios devices).

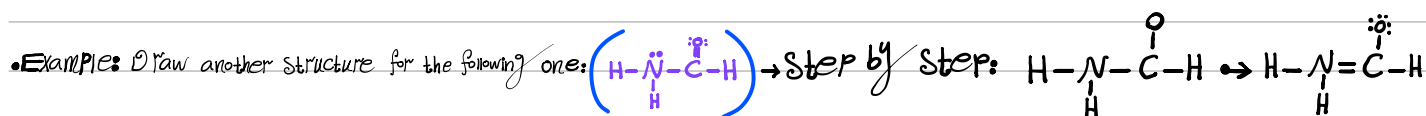
• How we can write resonance structures for a given structure?

• You must acquire some things like:

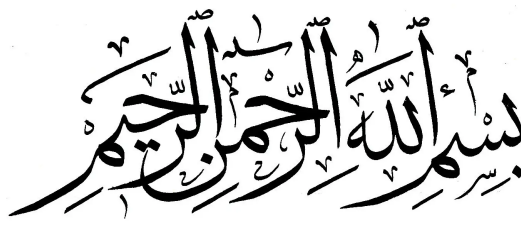
1 - Draw atoms and (6) bonds → Localized things

2 - Manipulate by one pair of unshared valence electrons and (π) bonds (you can reformulate the structure as you want) → Delocalized things

3 - Total formal charges should be the same.



AS SIMPLE AS THAT.



Resonance structures:

definition: A molecule or ion can be written by two or more structures with identical arrangements of the atoms but different arrangements of the electrons.

Do the resonance structures represent the real structure of the structure? No, they don't.

What about a combination of them? Yeah, and this is known as: a resonance hybrid structure.

How to write resonance structures?

- 1- Draw the atoms and (σ) bonds → Localized things
- 2- Manipulate by (π) bonds and non-bonding pairs of valence electrons (lone pairs) between adjacent atoms → Delocalized things.
- 3- make ensure that the total formal charge is the same in each structure.

The resonance hybrid structure: If a molecule or ion has resonance structures, then the resonance hybrid structure is formed by contributing its resonance structure.

Note: writing the resonance hybrid structure is resembled to take the average of the resonance structures.

Note: The total formal charge of the resonance hybrid structure is equally distributed on involved atoms.

Note: If a molecule or ion has many resonance structures, this doesn't mean that the real structure of it alternate between its resonance structures, never! Its real structure a combination of its resonance structures.

Note: Sulfur, bromine, chlorine and iodine have (d) orbitals so each atom of them can accommodate 10 e⁻ in valence orbitals.

Note: sp³ hybridization isn't involved in the resonance structures, so any atom has sp³ hybridization don't change or add any thing that surrounds it during writing the resonance structures.

Note: The resonance hybrid structure can be represented by one formula and in that formula:
Solid line (—) for each full bond
Dotted line (···) for each partial bond

Note: Between each two adjacent resonance structures, use a double-headed arrow (↔) (Not (⇌) → indicates to the equilibrium between the compounds)

Note: Number of resonance structures can be experimentally (by trying) extracted.

Isomers:

Plural → Isomers

definition: They are molecules with the same number and kinds of atoms but different arrangements of the atoms.

Single → isomerism.

Note: Isomers aren't related with resonance structures absolutely.

Note: Isomers

(equal → Isos, part → mers) → Greek suffix

Structural (constitutional) isomers: compounds have the same molecular formula, but different structural formulas.

Note: At the ultimate slides, there are multi comprehensive questions.

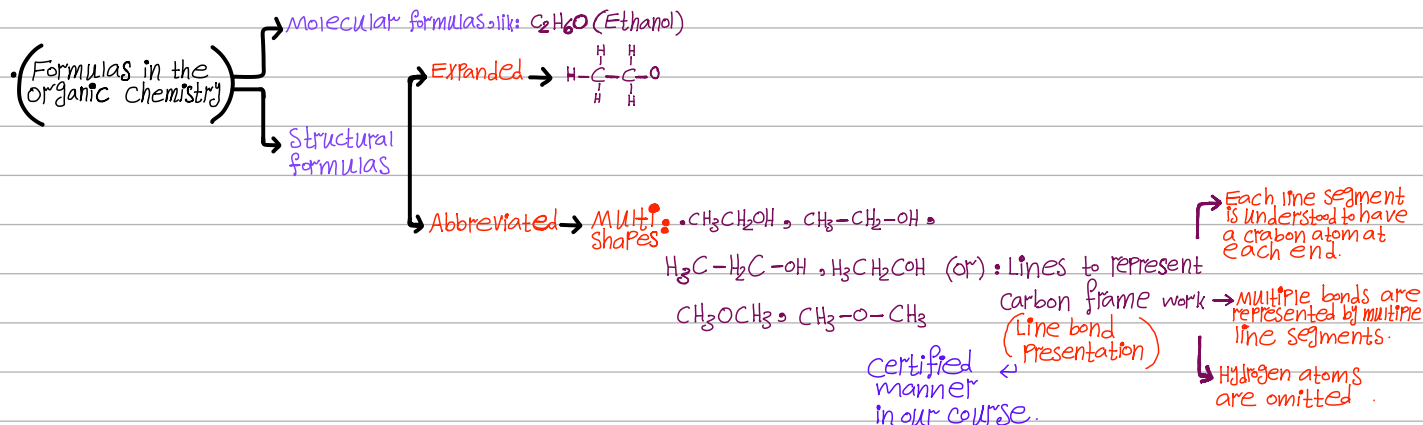
Don't worry.

• **Molecular formula** of a substance: It gives the number of different atoms present.

• **Structural formula** of a substance: It indicates how those atoms are arranged.

• **Continuous chain**: Atoms are bonded one after another.

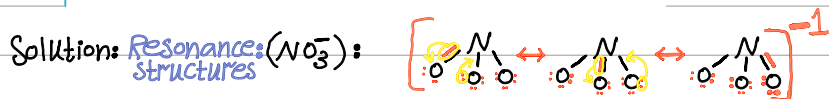
• **Branched chain**: Some atoms form branches from the longest continuous chain.



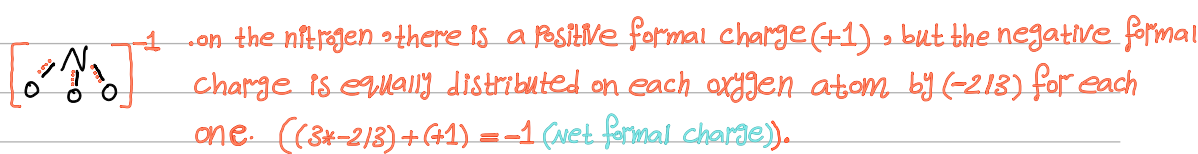
• **Examples on: Resonance Structures, Isomers and writing formulas:**

• **Resource for the following questions: The Bartemaster book (Brief course):**

• Q-1: **PROBLEM 1.27** Draw the three equivalent contributing resonance structures for the nitrate ion, NO_3^- . What is the formal charge on the nitrogen atom and on each oxygen atom in the individual structures? What is the charge on the oxygens and on the nitrogen in the resonance hybrid structure? Show with curved arrows how the structures can be interconverted.

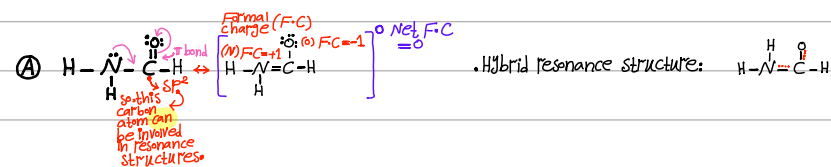


hybrid resonance structures

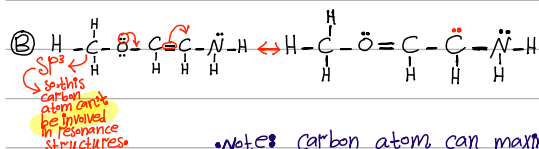


This justifies isony for the hybrid resonance structure.

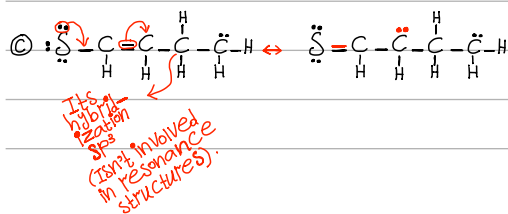
• Q-2: Draw resonance structures for each of the following:

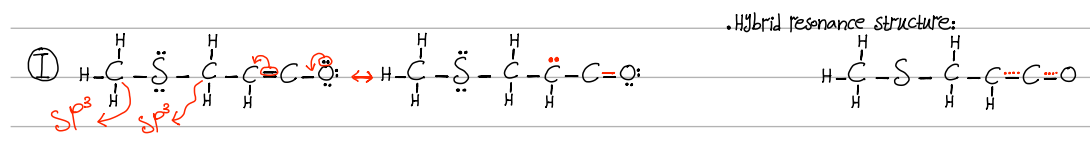
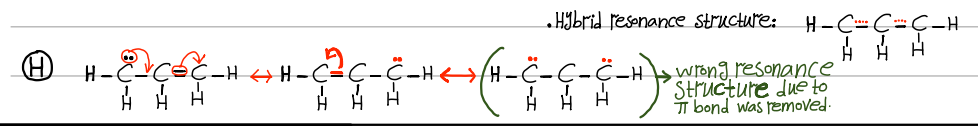
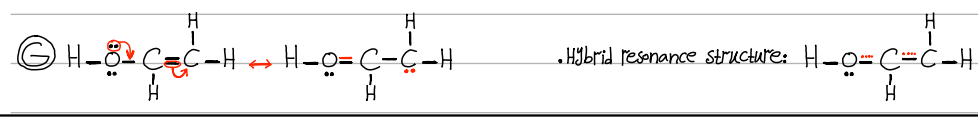
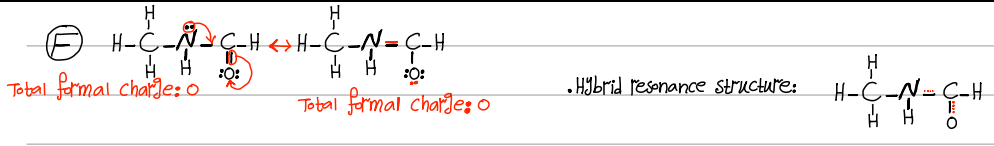
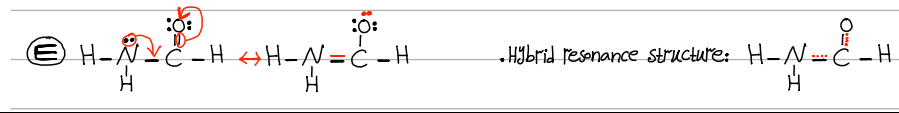
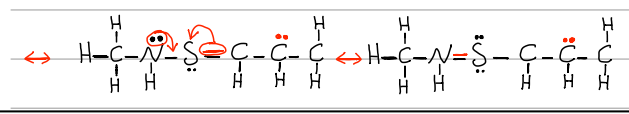
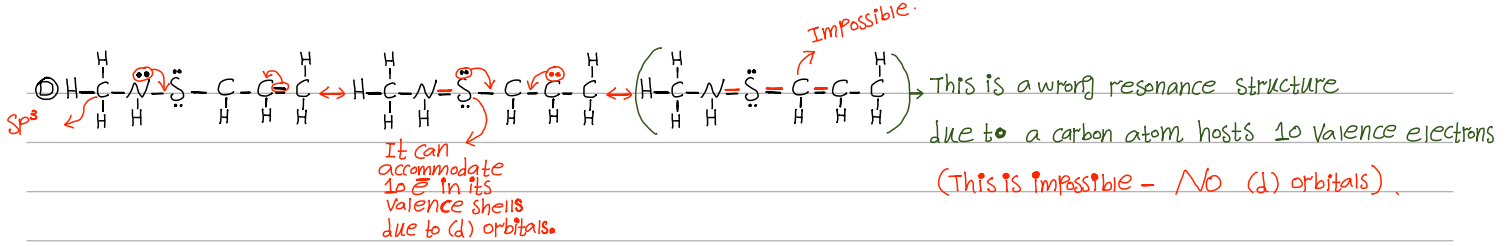


Note as size as Jordan: Lone pairs of electrons can't be transmitted to another atom as long as it is adjacent for the first one (during writing resonance structures).

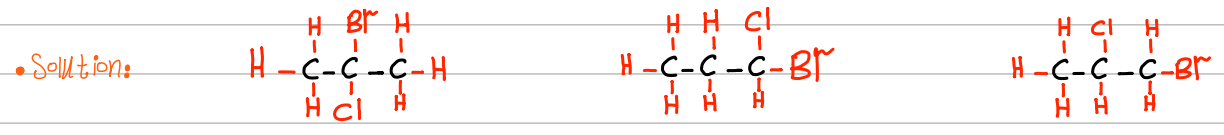


• Note: carbon atom can maximumly accommodate $8e^-$ only (not more than this), and this justify why $H-C \equiv O-C \equiv N$ is a wrong suggested resonance structure.

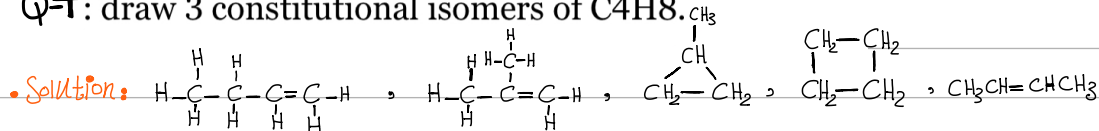




Q-3: draw 5 constitutional isomers of C₃H₆BrCl.

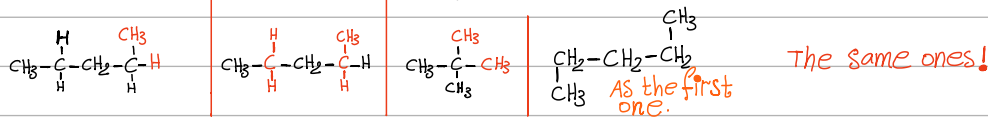


Q4: draw 3 constitutional isomers of C₄H₈.

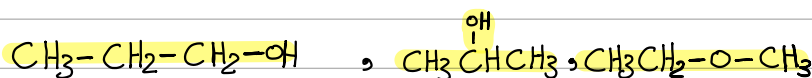


Note: Don't repeat the same constitutional isomer and account it as a new one.

Like: $\left(\text{CH}_3-\overset{\text{H}}{\underset{\text{H}}{\text{C}}}-\text{CH}_2-\overset{\text{H}}{\underset{\text{H}}{\text{C}}}-\text{CH}_3 \right)$, $\left(\text{CH}_3-\overset{\text{CH}_3}{\underset{\text{H}}{\text{C}}}-\text{CH}_2-\overset{\text{H}}{\underset{\text{H}}{\text{C}}}-\text{H} \right)$, $\left(\text{CH}_3-\overset{\text{CH}_3}{\underset{\text{CH}_3}{\text{C}}}-\text{CH}_3 \right)$ → (C₅H₁₂) has only three constitutional isomers.



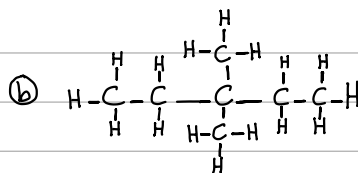
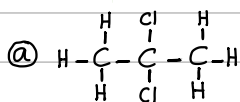
• Q-5: Draw structural formulas for the three possible isomers of C₃H₈O.



Q-6: Write a structural formula (that shows all bonds) for each of the following:

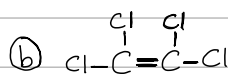
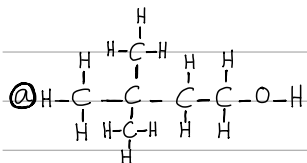
- a. CH₃CCl₂CH₃ b. (CH₃)₂C(CH₂CH₃)₂

Expanded structural formulas.



• Q-7: Write a structural formula that shows all bonds for each of the following:

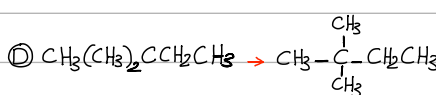
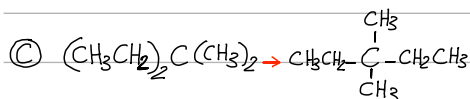
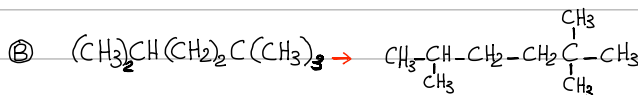
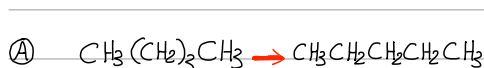
- a. (CH₃)₃CCH₂CH₂OH b. Cl₂C=CCl₂



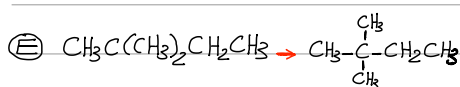
Note: Notice that the non-bonded electron pairs on oxygen and chlorine are not shown. Non-bonded electron pairs are frequently omitted from organic structures, but it is important to know that they are there.

Note: In like these questions each carbon atom has to have four bonds around it.

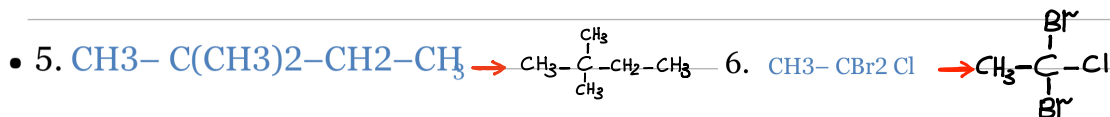
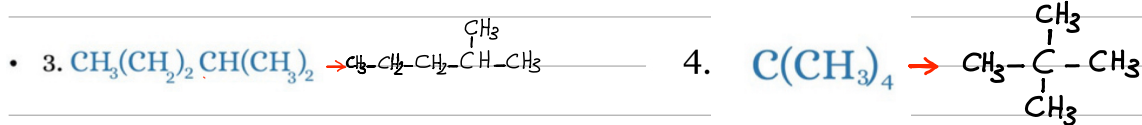
• Q-8: Expand the following structures: Note: Not necessarily expanded formulas just simplify them.



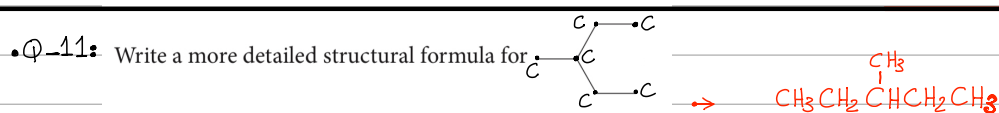
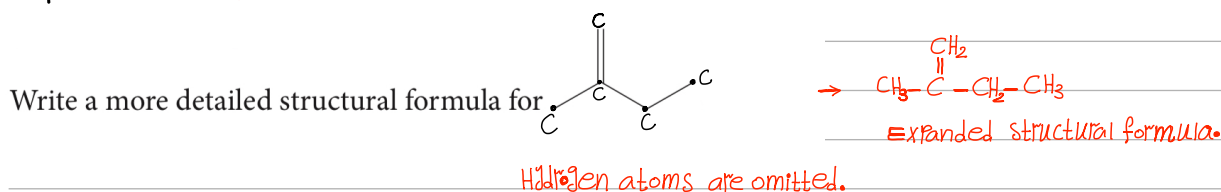
Note: In like this question there is only one correct answer.



Q-9: Expand each formula of the following:



• Q-10: (Line)



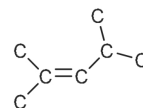
• Q-12: Write a line-segment formula for $\text{CH}_3\text{CH}_2\text{CH}=\text{CHCH}_2\text{CH}(\text{CH}_3)_2$.



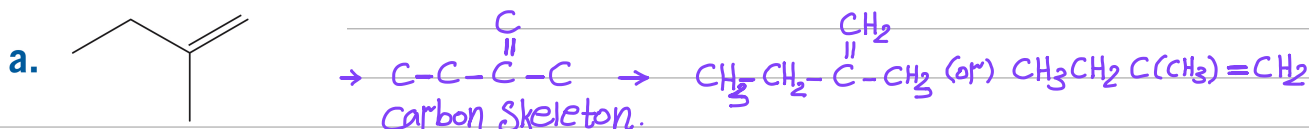
• Q-13: Write a line-segment formula for $(\text{CH}_3)_2\text{C}=\text{CHCH}(\text{CH}_3)_2$.



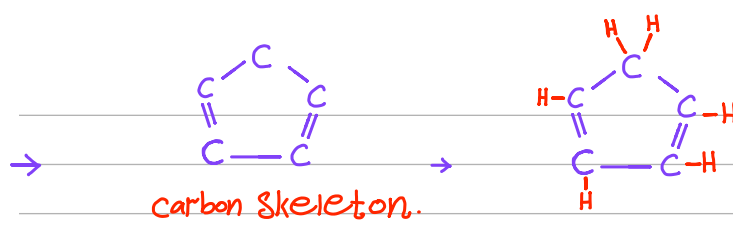
← stands for the carbon skeleton



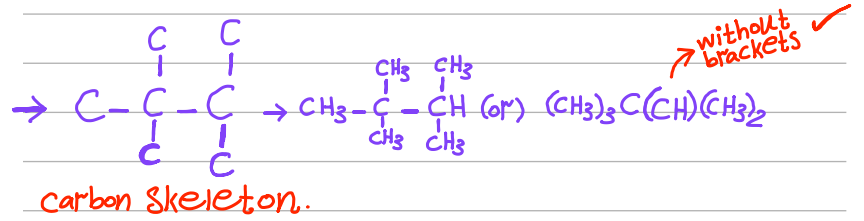
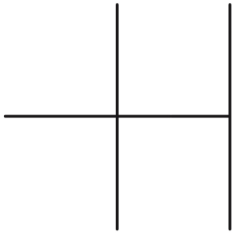
Q-14: Write structural formulas that correspond to the following abbreviated structures, and show the correct number of hydrogens on each carbon:



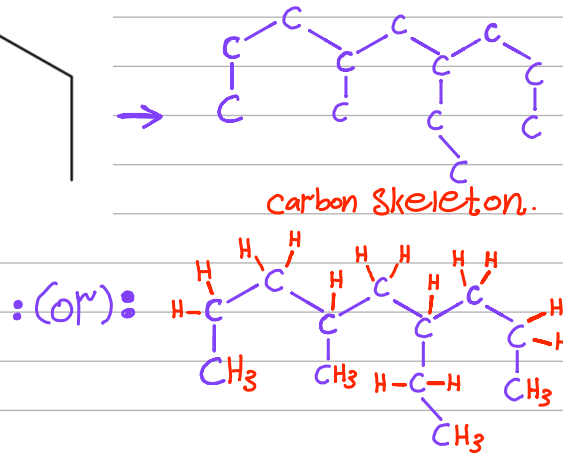
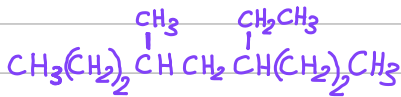
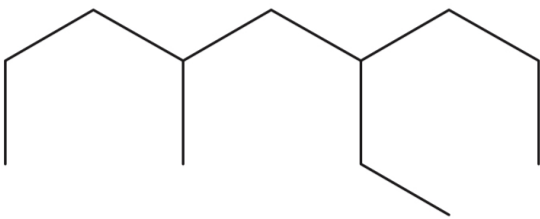
b.



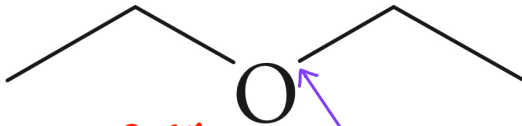
c.



d.



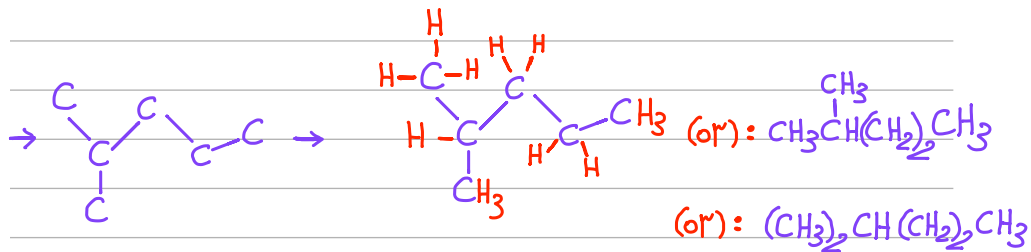
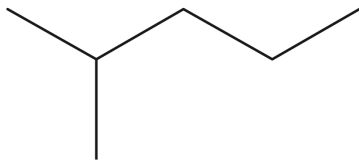
e.



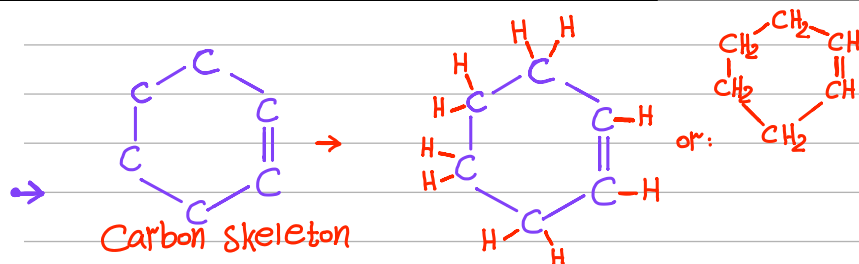
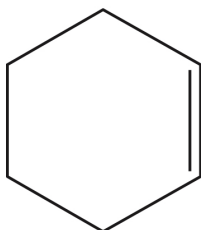
Common mistake → Here it isn't carbon atom (never)
 Just a vacuum.



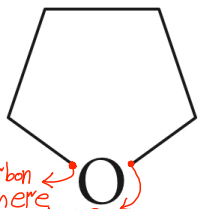
f.



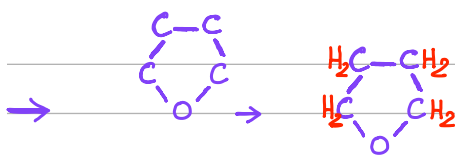
g.



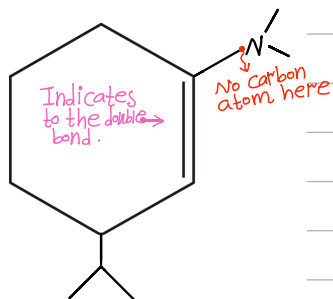
h.



No carbon atom here
Recall that!

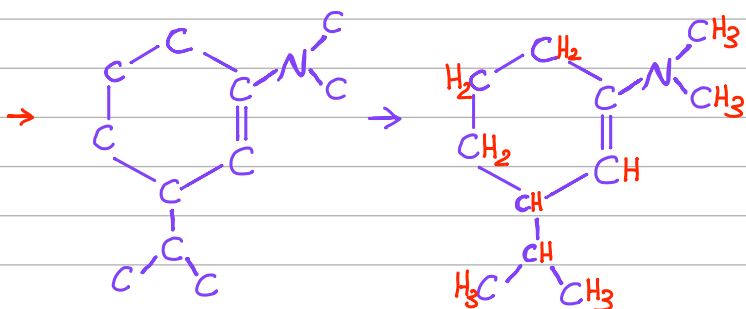


I.



Indicates to the double bond.

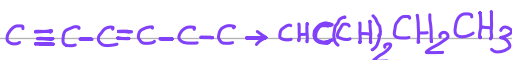
No carbon atom here



J.



stands for the triple bond.



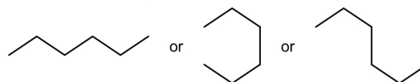
Q-15:

For each of the following abbreviated structural formulas, write a line-segment formula

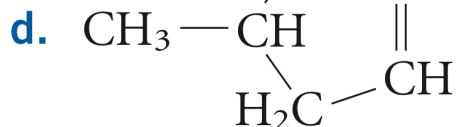
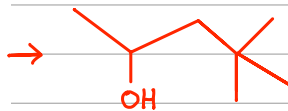


Note:

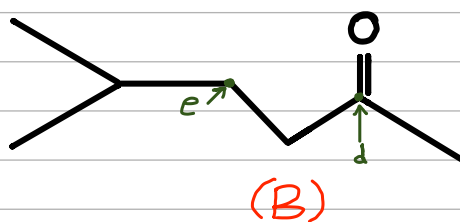
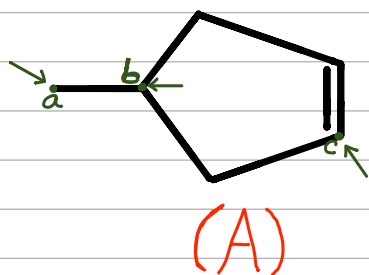
In line formulas, each line segment represents a C-C bond, and C-H bonds are not shown. There are a number of acceptable line structures for $CH_3(CH_2)_4CH_3$, three of which are shown here. The orientation of the line segments on the page is not important, but the number of line segments connected to each point is important.



• you can draw another shape
(This isn't important).



Q-16: (very significant question): Study each of the following structures carefully, then answer on the following questions:



Notice that hydrogen atoms are omitted.

Q1 what are the formal charge and hybridization for each indicated carbon atom in the figure (A)?

Formal charge: $a \rightarrow +3$, $b \rightarrow +1$, $c \rightarrow +1$, why?

When you determine the formal charge in the figures like ones above, deal with carbon atoms as they don't have hydrogen atoms absolutely, but when you specify the hybridization of carbon atoms, you must take care of the omitted hydrogen atoms. Done? Alright.

The hybridization: $a \rightarrow sp^3$, $b \rightarrow sp^3$, $c \rightarrow sp^2$

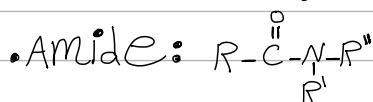
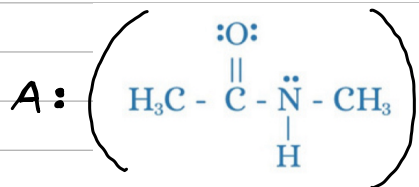
Q2 what are the formal charge and hybridization for each indicated carbon atom in the figure (B)?

Formal charge: $d \rightarrow 0$, $e \rightarrow +2$

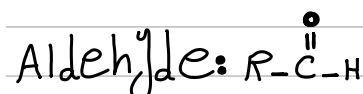
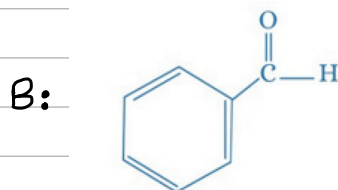
The hybridization: $d \rightarrow sp^2$, $e \rightarrow sp^3$

functional group: A cluster of atoms which attach to each other by bonds and it distinguishes the chemical compounds from each other.

Q-17: Find functional groups in each of the following structures.



Note: "The structure might have more than one functional group". Said by: Dr. Kamal Sweidan.

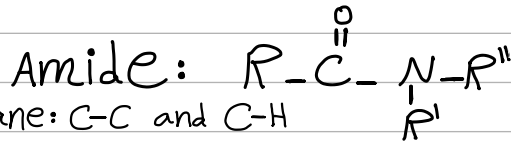
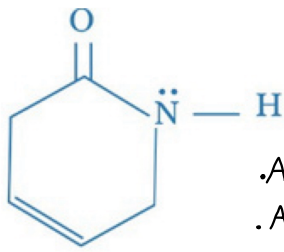


Alkane: C-C and C-H

Alkene: C=C

Only C-C and C-H	Alkane
C=C	Alkene
C (triple bond) C	Alkyne
	Arene "Aromatic"
C-X (X: halogen)	Alkyl halide
C-OH	Alcohol
C-O-C	Ether
	Aldehyde
	Ketone
	Ester
	Carboxylic acid
	Amide
$\text{R} - \text{NH}_2$	Amine
C-S-C	Sulfide

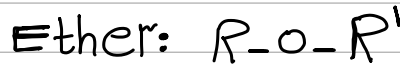
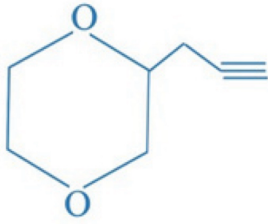
C:



.Alkane: C-C and C-H

.Alkene: C=C

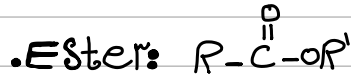
D:



.Alkane: C-C and C-H

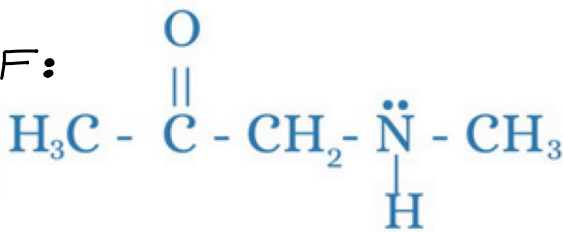
.Alkyne: $C\equiv C$

E:



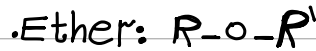
.Alkane: C-C and C-H

F:



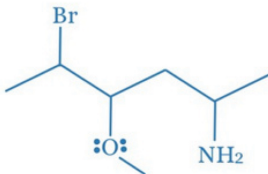
.Alkane: C-C and C-H

.Alkene: C=C



.Alcohol: $R'-OH$, Alkane: C-C and C-H

H:



.Alkyl halide: $R-X$

.Ether: $R-O-R'$, Alkane: C-C and C-H

.Amine: $R-NH_2$

Note: (X) belongs to halogens: Br, F, Cl, I, ...

most important ones

I:

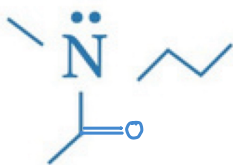


.Aromatic (Arene).

.Alkane: C-C and C-H

.Alkene: C=C

J:



... Amide

.Alkane: C-C and C-H

(Alkene: C=C) → wrong due to the double bond not formed between two adjacent carbon atoms.

Q-18: write a structural formula for each of the following: _____

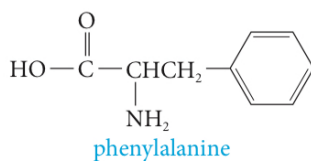
a. an alcohol, C_3H_8O → $CH_3CH_2CH_2OH$ b. an ether, $C_4H_{10}O$ → $CH_3(CH_2)_2-O-CH_3$ (or) $CH_3CH_2-O-CH_2CH_3$

c. an aldehyde, C_3H_6O → $CH_3CH_2-C(=O)-H$ d. a ketone, C_3H_6O → $CH_3-C(=O)-CH_3$

e. a carboxylic acid, $C_3H_6O_2$ → $CH_3CH_2-C(=O)-OH$ f. an ester, $C_5H_{10}O_2$ → $CH_3CH_2-C(=O)-OCH_2CH_3$ (one suggested answer of many ones).

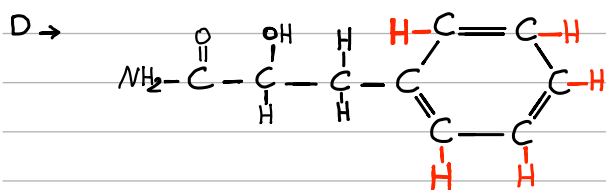
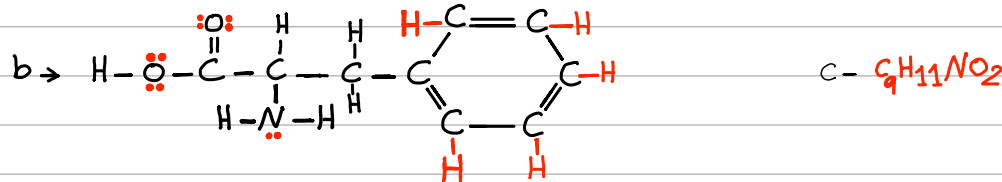
Q-19:

Many organic compounds contain more than one functional group. An example is phenylalanine (shown below), one of the simple building blocks of proteins (Chapter 17).



- What functional groups are present in phenylalanine?
- Redraw the structure, adding all unshared electron pairs.
- What is the molecular formula of phenylalanine?
- Draw another structural isomer that has this formula. What functional groups does this isomer have?

a → Carbonyl group (carboxylic acid): $R-C(=O)-OH$
 (Amino group) Amine: $R-NH_2$
 Arene (Aromatic group).



Functional groups:

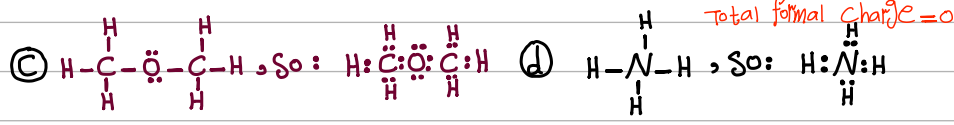
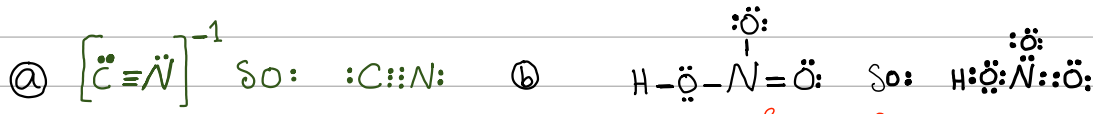
• Amide

• Alcohol.

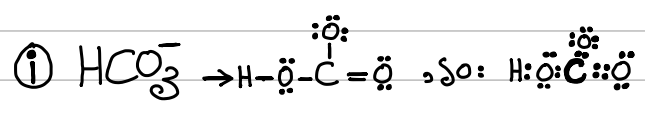
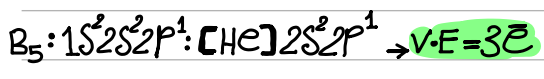
Q-20: Write electron-dot formulas for the following species. Show where the formal charges, if any, are located.

- a. cyanide ion, CN^-
- b. nitric acid, $HONO_2$
- c. dimethyl ether, CH_3OCH_3
- d. ammonium ion, NH_4^+
- e. nitrous acid, $HONO$
- f. carbon monoxide, CO
- g. boron trifluoride, BF_3
- h. hydrogen peroxide, H_2O_2
- i. bicarbonate ion, HCO_3^-

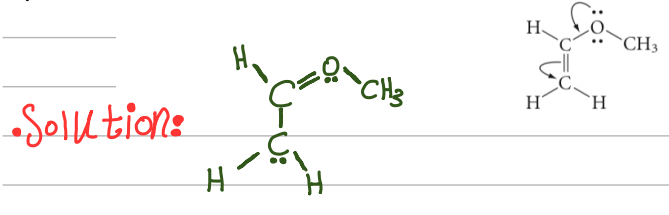
Rely on the total formal charge.



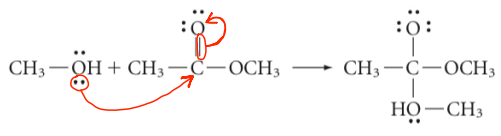
Note: There are 24 valence electrons (B = 3, F = 7). The structure is usually written with only 6 electrons around the boron.



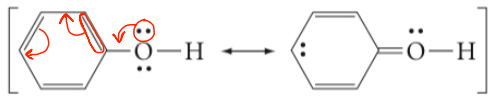
Q-21: Write the structure obtained when electrons move as indicated by the curved arrows in the following structure:



Q-22: Add curved arrows to show how electrons must move to form the product from the reactants in the following equation, and locate any formal charges.



Q-23: Add curved arrows to the following structures to show how electron pairs must be moved to interconvert the structures, and locate any formal charges.



• Transmission of electrons occur between the adjacent atoms only.

Q-24: Which of these are **true** and which are **false** about resonance?

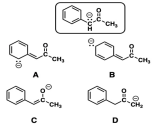
• Resonance structures are real, and molecules switch back and forth between them rapidly.	T	F
• All resonance forms for a given molecule make equal contributions toward the resonance hybrid	T	F
• Generally, neutral resonance forms make a greater contribution to the hybrid than charged resonance forms	T	F
• When choosing between two resonance structures, structures where all atoms have full octets is generally favored versus those that do not	T	F
• When interconverting resonance structures, it is OK to break both pi and sigma bonds	T	F
• Lone pairs can participate in resonance with adjacent pi bonds	T	F
• Atoms with less than a full octet can participate in resonance with adjacent lone pairs and pi bonds	T	F
• For atoms to be in resonance it is necessary that their p-orbitals must all be capable of lining up in the same plane	T	F
• In the resonance structure of the allyl cation ($C_3H_5^+$), the positive charge is delocalized over two carbon atoms, leading to equivalent C–C bond lengths.	T	F

Answers: Which of these are **true** and which are **false** about resonance?

• Resonance structures are real, and molecules switch back and forth between them rapidly. <i>False - resonance structures are not real entities; the actual structure is a hybrid of the resonance forms.</i>	T	F
• All resonance forms for a given molecule make equal contributions toward the resonance hybrid <i>False - some resonance forms make major contributions to the resonance hybrid, whereas the contribution of others can be extremely minor or negligible</i>	T	F
• Generally, neutral resonance forms make a greater contribution to the hybrid than charged resonance forms <i>Generally true since neutral molecules will have full octets, among other factors</i>	T	F
• When choosing between two resonance structures, structures where all atoms have full octets is generally favored versus those that do not <i>Yes - full octets more important</i>	T	F
• When interconverting resonance structures, it is OK to break both pi and sigma bonds <i>False - sigma bonds do not participate in resonance (although sometimes we break these rules when discussing hyperconjugation)</i>	T	F
• Lone pairs can participate in resonance with adjacent pi bonds <i>True - this is the concept of "pi-donation"</i>	T	F
• Atoms with less than a full octet can participate in resonance with adjacent lone pairs and pi bonds <i>True - this helps to distribute positive charge over a greater volume, which is stabilizing for carbocations</i>	T	F
• For atoms to be in resonance it is necessary that their p-orbitals must all be capable of lining up in the same plane <i>True - this is called "conjugation" and it's necessary for resonance</i>	T	F
• In the resonance structure of the allyl cation ($C_3H_5^+$), the positive charge is delocalized over two carbon atoms, leading to equivalent C–C bond lengths. <i>True - the positive charge is split over the two terminal carbon atoms</i>	T	F

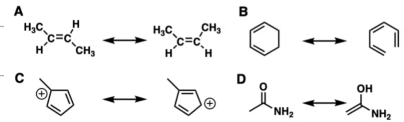
Note: The images are duplicated 😊
 • Depend on the arrows.

Q-25: Which of these molecules is NOT a resonance form of



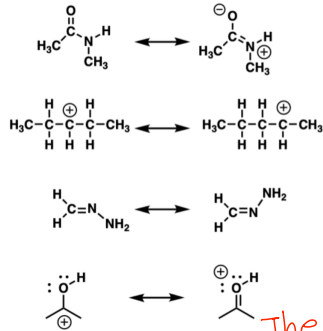
The answer: d

Q-26: Which of these molecules represents a pair of resonance forms?



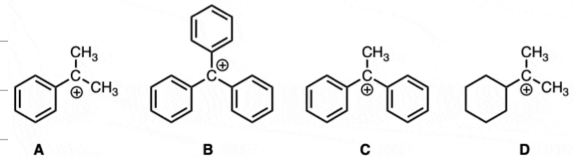
The answer: C

Q-27: Which of these drawings represents a pair of resonance forms?



The answer: A

Q-28: Rank the following carbocations in order of stability (1 = most stable, 4 = least stable)



The answer: All have the same total formal charge, so: more (σ) and (π) bonds, means more stability.
 (B > C > A > D)

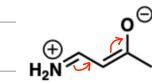
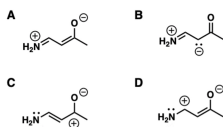
All of these carbocations are tertiary (attached to 3 carbons). They differ in the number of adjacent aromatic rings (capable of stabilizing the carbocation through resonance).

The more aromatic rings the carbocation is attached to, the more stable it is.

Q-29: Which resonance form contributes the most to the resonance hybrid of

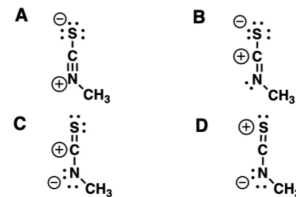
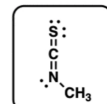


The answer: A



✓ possible transformations

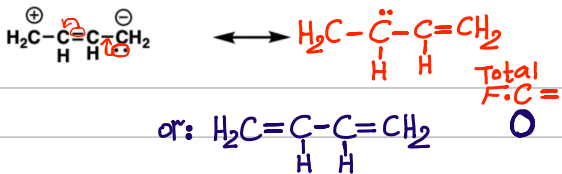
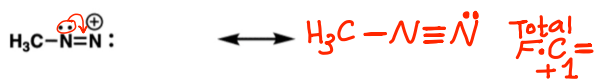
Q-30: Which resonance form contributes the most to the resonance hybrid of



The answer: A

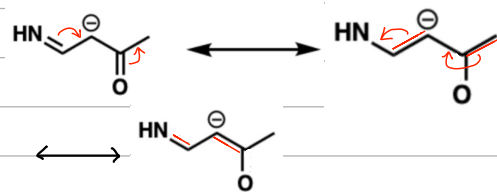


Q-31: Draw a more important contributing resonance structure for both examples below. Use curved arrows and show all formal charges.

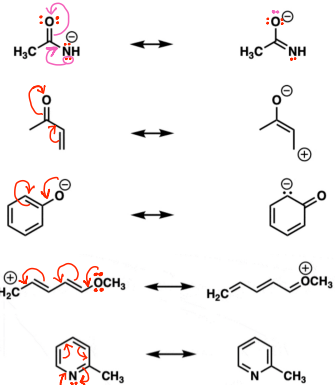


Q-32:

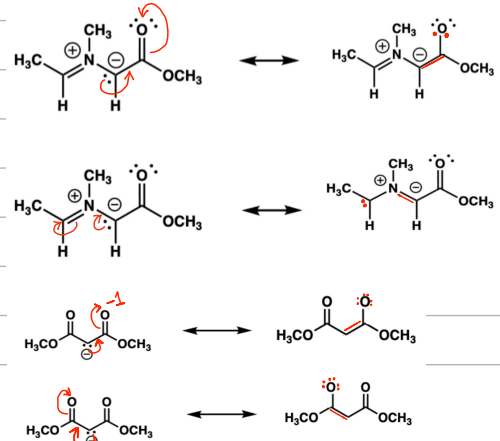
Draw the two other contributing structures for this species



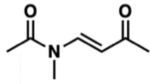
Q-33: Draw in the curved arrows to convert the left-hand resonance form to the right-hand resonance form



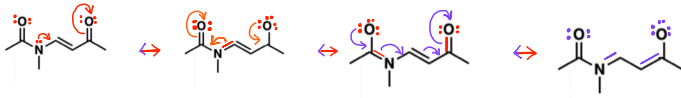
Q-34: Draw two resonance structures and use curved arrow notation to show how they can be interconverted.



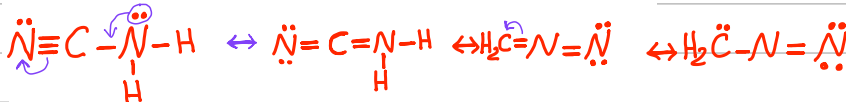
Q-35: Provide three (3) additional reasonable resonance structures for the following compound.



Solution:

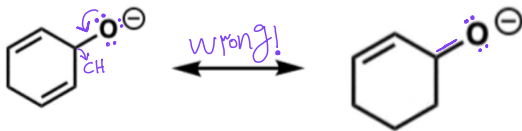


Q-36: Draw both resonance forms of diazomethane (CH_2N_2). Show lone pairs and any formal charge.

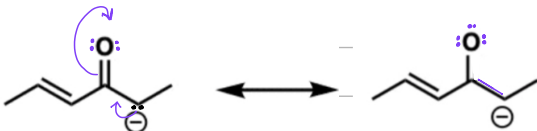
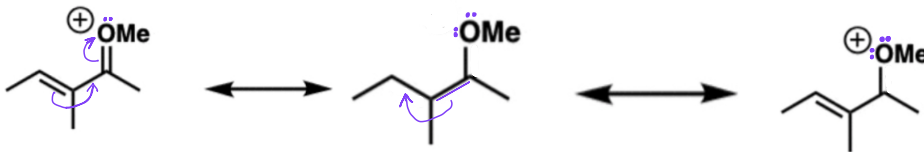


Q-37: Draw all other reasonable resonance structures of the following molecules

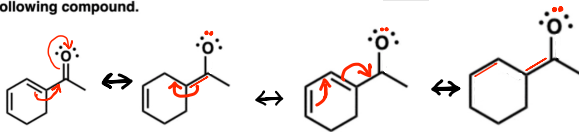
one only



No resonance structures (C forms 4 bonds maximum!)



Q-38: Provide three (3) additional reasonable resonance structures for the following compound.



Recall that:

The **formal charge** on an atom in a covalently bonded molecule or ion is the number of valence electrons in the neutral atom minus the number of covalent bonds to the atom and the number of unshared electrons on the atom.

Formal charge = number of valence electrons in the neutral atom - (unshared electrons + half the shared electrons)

or, in a simplified form,

Formal charge = number of valence electrons in the neutral atom - (dots + bonds)

Q-39 • Provide three (3) additional reasonable resonance structures for the following compound.

