Objective 1: Identify organic functional groups, bond types and IR, draw skeletal structures, and distinguish between the same compound, isomers, different compounds, and resonance structures.

Quiz Practice problems:

Key ideas:

Most substances are organic compounds. Biomolecules are organic compounds.

Organic compounds contain C, H, O, N, S, P, X

Organic compounds are classified by functional groups – a small group of 2 to 5 atoms within an organic compound that has specific properties.

Organic compounds are represented by Lewis structures.

General bonding rules: C = 4 bonds + 0 lone pairs, N = 3 bonds + 1 lone pairs, O = 2 bonds + 2 lone pairs, X = 1 bonds + 3 lone pairs, H = 1 bonds + 0 lone pairs.

In a Lewis structure, a covalent bond shows electrons shared between 2 atoms only --> localized electrons.

But electrons can be shared between 3 or more atoms – delocalized electrons. Need to show resonance structures to represent delocalized electrons.

Experiments show electrons are delocalized – see infrared (IR) spectroscopy.

Organic compounds can be large – use skeletal structure as a shortcut for a Lewis structure.

Organic compounds can be large – there are different ways to connect (bond) atoms in a compound. Two compounds that have the same chemical formula but different connectivity (bonding) are called isomers.

When a substance is exposed to infrared (IR) radiation, bonds between atoms vibrate (stretch or bend).

IR spectroscopy is used to determine bond types, e.g., C-H, O-H, in a compound.

IR spectroscopy is used to help determine structure of a molecule.

Skills: Given Lewis structure, draw skeletal structure and vice versa.

Draw isomers of a compound.

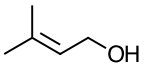
Given two or more structures, determine whether compounds are the same compound, isomers, or different compounds.

Identify functional groups in organic compounds.

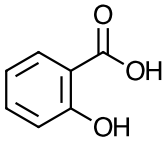
Identify bond types in a compound.

Interpret an IR spectrum – match IR peak to specific bond type, determine molecular structure.

1. a. Prenol has a fruity odor and is used in perfumes. This compound contains an alkene group and alcohol group. Circle each group.

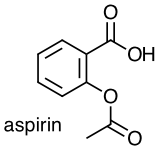


b. Salicylic acid is a pain reliever and contains an alcohol group, acid group, and aromatic group. Circle each group.

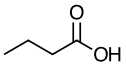


c. What is the difference between an alkene and aromatic group?

d. Aspirin is a common over-the-counter pain reliever. Butyric acid smells so bad it is sometimes used in stink bombs. Identify the functional group(s) in the following molecules:



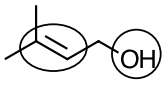
aspirin



butyric acid - a very bad smelling compound

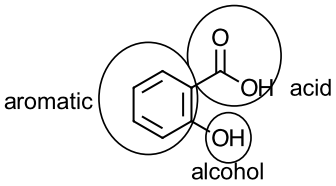
Answers:

a.

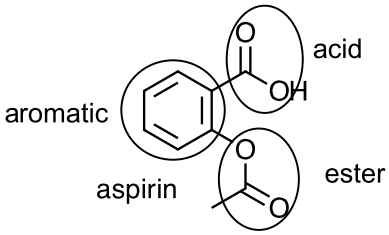


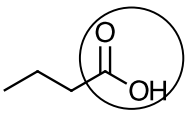
alkene alcohol

b.



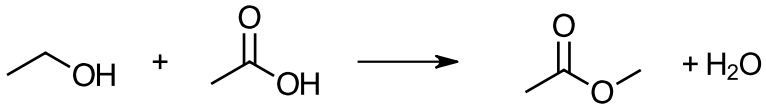
c. Alkene group is a C=C bond. Aromatic group is a ring with C=C alternating with C-C bonds.
An alkene group is more reactive (less stable) than an aromatic group.
d. Note: Some compounds contain the same functional groups but have different properties.





butyric acid - a very bad smelling compound

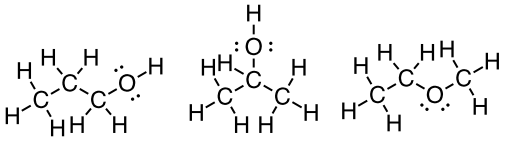
2. Ethanol reacts with acetic acid to form ethyl acetate (finger nail polish remover) and water.



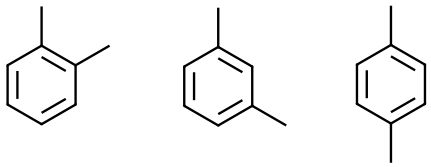
Infrared (IR) spectroscopy is used to identify substances. When a molecule is exposed to IR radiation, bonds in the molecule will vibrate (stretch or bend or both). You measure the IR spectrum of a pure sample of each reactant. How could you distinguish between ethanol and acetic acid using IR? Identify specific peaks and bonds in one compound that you won't see in the other.
Answers:
Ethanol = CH_3CH_2OH has C-H, C-C, C-O, and O-H bonds.
Acetic acid = CH_3COOH has C-H, C-C, C-O, O-H, and C=O bonds.
Acetic acid has a C=O bond that is not in ethanol.

3. a. C_3H_8O has three isomers. Draw the Lewis structure of each isomer.
b. Xylene, which is a benzene ring with 2 methyl groups, has three isomers. Draw the Lewis structure of each isomer. These compounds are found in petroleum.

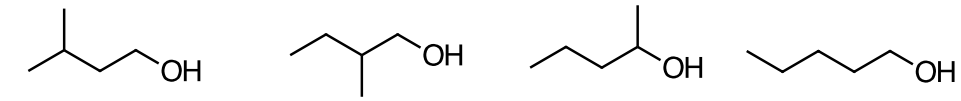
c. You used iso-amyl alcohol, $(CH_3)_2CHCH_2CH_2OH$, in Lab 1 when you made the banana ester. Iso-amyl alcohol, $(CH_3)_2CHCH_2CH_2OH$, has at least one structural isomer. Draw the Lewis structure of <u>one</u> structural isomer of this alcohol.
Answers:
a. n-propanol, iso-propanol (rubbing alcohol), ethyl methyl ether are common solvents.
The skeletal structure of each compound is also shown.



b. ortho-xylene, meta-xylene, para-xylene are found in petroleum.

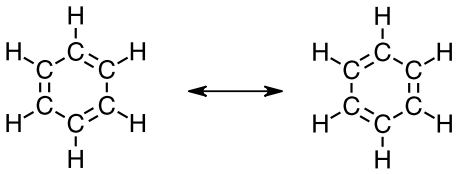


c. Three isomers of isoamyl alcohol are shown. There are more isomers!



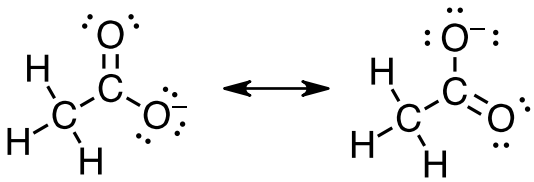
isoamyl alcohol

4. Scientists represent the structure of a molecule by drawing a Lewis structure. In a Lewis structure, electrons are shared between two atoms – this is called localized bonding and the electrons shared between the two atoms are called localized electrons. In some compounds, electrons are shared between three or more atoms - this is called delocalized bonding and the electrons shared between the three or more atoms are called delocalized electrons. A Lewis structure does not accurately represent electrons are shared between three or more atoms. Resonance Structures are used to represent delocalized electrons in a compound.
Benzene, C_6H_6, is a common organic aromatic compound that is used as an intermediate to make other chemicals, such as styrene to make styrofoam and nitrobenzene to make TNT. The benzene ring is part of the molecular structure of many chemicals, such as aspirin, capsaicin (the hot chemical in chili peppers), and dopamine (neurotransmitter involved in reward, motivation, and motor control). Small amounts are found in crude oil.
Experiments show benzene contains six C- C-C bonds of the same length. The Lewis structure of benzene does not accurately represent the bonding in benzene because the electons in the double bonds are delocalized.
a. Draw the two resonance structures of benzene.
b. Over how many atoms are the electrons in the double bonds delocalized?
Answers:
a. The Lewis structure of benzene shows three C-C bonds and three C=C bonds. C-C bonds are longer than C=C bonds so a single Lewis structure of benzene does not show the delocalization of the electrons in the three double bonds. These two resonance structures (note how the locations of the double bonds have changed) represent the delocalized electrons in benzene.



b. The electrons in the double bonds are delocalized (shared) over the six carbon atoms.

5. Determine structure from experimental data.
(from Spring 2009 Exam 1) You are trying to determine the identity of an organic ion. So far, your analysis shows that the compound contains:
(i) C and H and O with chemical formula $C_2H_3O_2$,
(ii) Three HCH bond angles and three CCH bond angles of 109.5°. (Note: methane, CH_4, has four HCH bond angles.)
(iii) Two carbon-oxygen bonds of length 1.26 Angstroms. (Note: A carbon-oxygen single bond has a bond length of 1.34 Angstroms. A carbon-oxygen double bond has a bond length of 1.20 Angstroms.)
Answers:
(ii) The C bonded to 3 H's has a tetrahedral shape. The three HCH bond angles and three CCH bond angles are 109.5°.
(iii) Experiments show a C-O single bond is longer than a C=O double bond.
For this ion, the two carbon-oxygen bonds are the same length. This suggests the electrons in the C=O bond and lone pair on O with the (-) charge are shared between more than 2 atoms ==> delocalized electrons.
The Lewis structure does not accurately represent the bonding (delocalized electrons) in this ion so resonance structures are drawn.



6. Compare the two compounds. Are these compounds the same compound, isomers, or different compounds? Support your answer by writing the chemical formula of each compound. If the formulas are the same, check the number of atom types on each carbon.

a 

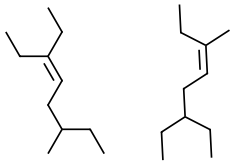
b 

c 

d 

e 

f 

g 

Answers:
a. same compound. Each structure has the same formula (C_6H_{14}) and same bonding.
b. isomers. Each structure has the same formula (C_6H_{12}) but the bonding is different. See position of C=C bond.
c. different compounds. Left = C_4H_8O. Right = $C_5H_{10}O$
d. isomers. Each structure has the same formula (C_4H_8O) but the bonding is different. Left = aldehyde functional group. Right = alkene and alcohol functional groups.
e. isomers. Each structure has the same formula (C_6H_{12}) but the bonding is different Left = 5 sided ring. Right = 6 sided ring.
f. different compounds. Left = C_6H_6. Right = C_6H_8
g. isomers. Each structure has the same formula ($C_{11}H_{22}$) but the bonding is different. See number of carbons bonded to C=C bond.