MEGA MOLECULES

Name ______________________________

Lesson 2: Resonance and acid-base chemistry

Lesson two discusses electron bookkeeping through formal charge and oxidation state methods. It also describes resonance, a phenomenon in which multiple Lewis structures have the same arrangement of atoms but different electron distributions. Lastly, lesson two discusses the concepts of Bronsted-Lowry acids and bases and provides a procedure for simulating acid-base reactions.

THINK! What are the two methods of electron bookkeeping, and why is it important for chemists to learn them?

> The two methods of electron bookkeeping are formal charge and oxidation state. It is important for chemists to learn these methods because if they are unable to count electrons effectively, their days as a chemist will be numbered!

Go to https://www.khanacademy.org/science/organic-chemistry
Watch the videos on Counting electrons.

Formal charge and oxidation state are calculated using the same formula.

(number of VE, valence electrons, in free atom) - (number of VE in bonded atom)

The key difference between formal charge and oxidation state is that formal charge is the charge of an atom in a molecule we calculate assuming that electrons in chemical bonds are shared equally between atoms whereas oxidation state is the number of electrons an atom loses or gains or shares with another atom.

1. Build a model of methylamine, CH_3NH_2. Use a 40 mm gray or black bond between carbon and nitrogen atoms.

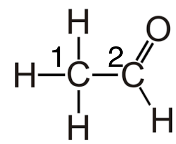
Formal charge of carbon atom = ____________________ - ____________________ = ________________

Formal charge of nitrogen atom = ____________________ - ____________________ = ________________

Oxidation state of carbon atom = ____________________ - ____________________ = ________________

Oxidation state of nitrogen atom = ____________________ - ____________________ = ________________

2. Build a model of ethanal, C_2H_4O. On the structural formula, draw dots to represent the unshared electrons on the oxygen atom.

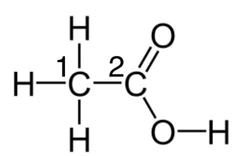


Oxidation state = ____________________ - ___________________ = ________________
of carbon 1 (C1) atom

Oxidation state = ____________________ - ___________________ = ________________
of carbon 2 (C2) atom

Oxidation state = ____________________ - ___________________ = ________________
of oxygen atom
with double bond

3. Build a model of ethanoic acid, $C_2H_4O_2$. On the structural formula, draw dots to represent the unshared electrons on the oxygen atoms.



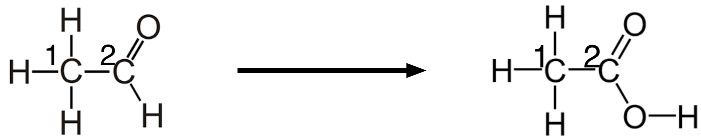
Oxidation state = ____________________ - ___________________ = ________________
of C1 atom

Oxidation state = ____________________ - ___________________ = ________________
of C2 atom

Oxidation state = ____________________ - ___________________ = ________________
of oxygen atom
with double bond

Oxidation state = ____________________ - ___________________ = ________________
of oxygen atom
with single bonds

4. Let's look at the change in oxidation state of the carbon 2 atom.



ethanal   ethanoic acid

Oxidation state of C2 = ________   Oxidation state of C2 = ________

Was the C2 atom oxidized or reduced? What are the requirements of an organic oxidation-reduction reaction?

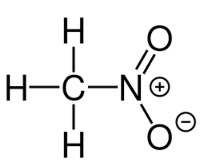
Disassemble the molecules!

THINK! What is resonance, and how does it occur?

Resonance occurs when two or more Lewis structures have identical arrangements of atoms but different distributions of electrons. It happens when electrons can be delocalized over several atoms or bonds, resulting in the stabilization of the molecule.

Go to https://www.khanacademy.org/science/organic-chemistry
Watch the videos on Resonance structures.

5. Build a model of nitromethane, CH_3NO_2. On the structural formula, draw dots to represent the unshared electrons on the oxygen atoms.



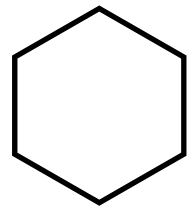
Formal charge of the nitrogen atom = ______________________

Formal charge of the single bonded oxygen atom = __________

Sometimes one drawing is not enough to accurately describe the distribution of electron density. Resonance occurs when two or more Lewis structures have identical arrangements of atoms but different distributions of electrons. A structure in which the formal charge is as close to zero as possible is preferred.

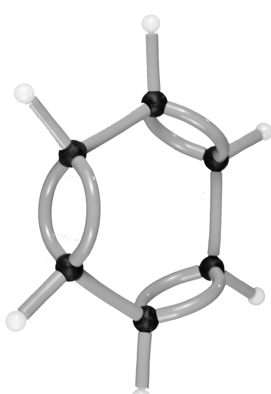
6. In nitromethane, a lone pair of electrons is next to a pi bond, leading to the formation of resonance structures. Draw the resonance structures for nitromethane. Be sure to include the brackets and formal charges.

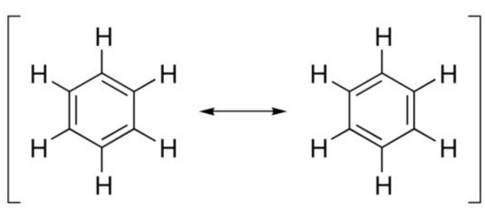
7. Benzene, C_6H_6, is a widely used industrial chemical. Benzene is found in crude oil and is a major part of gasoline. It's used to make adhesives, plastics, resins, synthetic fibers, rubber lubricants, dyes, detergents, drugs and pesticides. Benzene is produced naturally by volcanoes and forest fires. Add hydrogen atoms and double bonds, as necessary, to complete the structure of benzene.



8. August Kekulé was the first to suggest a structure for benzene in which the carbon atoms are arranged in a hexagon with alternating double and single bonds between them. Build a model of benzene. The model built using the Organic Chemistry Plus model set (Method 2) illustrates the correct hybridization around each carbon atom. What is the molecular geometry or shape of benzene, and what is the hybridization of each carbon atom?

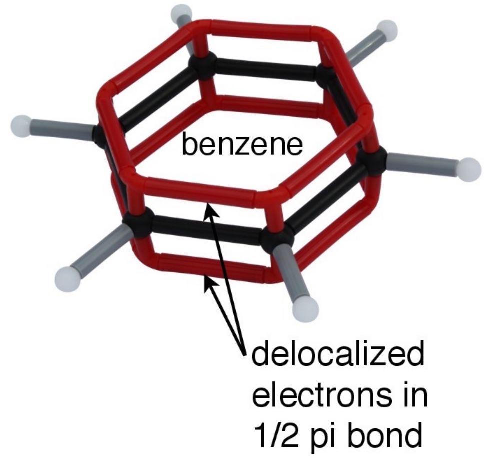
Method 1





Method 2

Although benzene has been drawn with alternating single and double bonds in the carbon ring structure, all of the carbon–carbon bonds in benzene are identical. The stabilization of benzene is enhanced due to the ability of the electrons in the π orbitals to delocalize. The model of benzene shown below can be built with the Organic Chemistry Plus model set.



Disassemble the molecules!

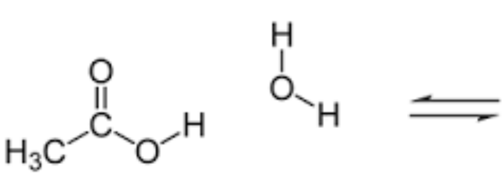
THINK! What is a Bronsted-Lowry acid and base, and how do you simulate an acid-base reaction?

A Bronsted-Lowry acid (BLA) is a proton donor, while a Bronsted-Lowry base (BLB) is a proton acceptor. To simulate an acid-base reaction, you can use models of the acid and base. The products of the reaction can be labeled as either a conjugate acid or a conjugate base.

Go to https://www.khanacademy.org/science/organic-chemistry
Watch the videos on Organic acid-base chemistry.

A Bronsted-Lowry acid (BLA) is a proton donor.
A Bronsted-Lowry base (BLB) is a proton acceptor.

9. Build models of acetic acid, CH_3COOH, and water, H_2O. Use the models to simulate the acid-base reaction. Using the reactants, remove a proton from acetic acid and transfer the proton to water. Write the structural formulas for the products on the right side of the equation.



BLB

BLA

10. Using the chemical equation in question #9, draw dots on the products to represent the unshared electrons on the oxygen atoms. Draw a curved arrow to show the movement of electrons in the BLA and BLB. Label the products as either a conjugate acid or a conjugate base.

In conclusion, lesson two provided the opportunity to learn organic chemistry using Mega Molecules models and Khan Academy videos. The lesson covered topics such as counting electrons and the calculation of formal charge and oxidation state. The procedures involved building models of organic molecules such as methylamine, ethanal, ethanoic acid, nitromethane, and benzene. The resonance structure of benzene was used to explain the true shape of the molecule and stability of a resonance hybrid. The lesson also covered organic acid-base chemistry, including the concepts of Bronsted-Lowry acid and base.