Class Activity 2

Resonance Structures

Prior Knowledge:
Before beginning this activity, students should be familiar with the following concepts:

- Formal Charge
- Lewis structures
- Bonding
- Isomers

Learning Objectives
Content Learning Objectives:
After completing this activity, students should be able to:

- Describe the relationship between resonance structures (that they differ by movement of double bond and lone pair electrons).
- Draw resonance structures of a given compound using curved arrows to show electron movement.
- Determine the major resonance contributor among a series of resonance structures.

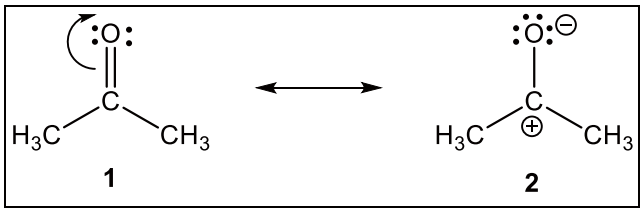
Process Objectives:

- Critical Thinking. Students analyze the model of resonance structures to determine how resonance structures differ. They synthesize information from the examples to make conclusions about the purpose of curved arrows and to determine the major resonance contributors in a group.

Class Activity 2

Resonance Structures

Model 1: Resonance Structures for a Carbonyl Group



Questions:

1. (a) Count the electrons in each bond and each lone pair to determine how many total electrons are in structure **1** (_____) and structure **2** (_____).

   Is the total number of electrons in each structure the same? (*Circle one*) yes / no.

   (b) How many single (sigma) bond electrons are in structure **1** (_____) and structure **2** (_____)?

   Is the number of single (sigma) bond electrons the same in each structure? (*Circle one*) yes / no.

   (c) How many lone pair electrons are found in structure **1** (_____) and structure **2** (_____)?

   Is the number of lone pair electrons the same in each structure? (*Circle one*) yes / no.

   (d) How many double (pi) bond electrons are found in structure **1** (_____) and structure **2** (_____)?

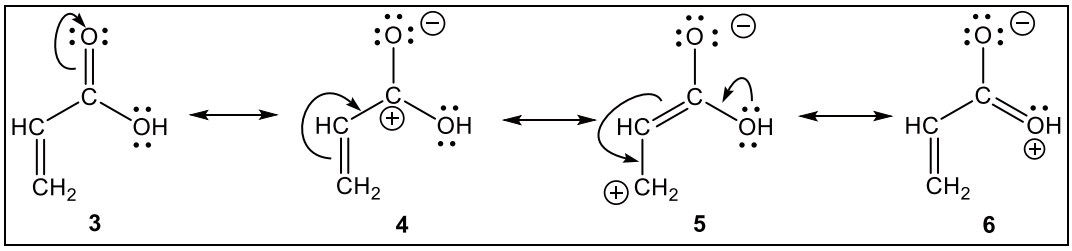
   Is the number of double (pi) bond electrons the same in each structure? (*Circle one*) yes / no.

   (e) Based on the answers above, describe what is different between structures **1** and **2** (in terms of electrons)?

2. Is the total net charge of structure 1 the same as the total net charge of structure **2** ? (*Circle one*) yes / no.

3. As a group discuss what the curved arrow drawn on structure **1** represents.

Model 2: Resonance Structures of Acrylic Acid



Questions:

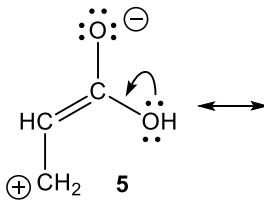
4. Consider the resonance structures of acrylic acid shown in Model 2:
   (a) Is the total charge for each resonance form the same? (*Circle one*) yes / no.
   (b) Is the total number of electrons for each resonance form the same? (*Circle one*) yes / no.
   (c) Have any single bonds been broken to form another resonance form? (*Circle one*) yes / no.
   (d) Are any atoms bonded to a different atom in other resonance forms? (*Circle one*) yes / no.
   (e) Do all atoms have eight electrons or less? (*Circle one*) yes / no.

5. Curved arrows are used to show movement of electron pairs. Consider the curved arrows depicted on the structures in Model 2:
   (a) What does the curved arrow on structure **3** show (be specific)?

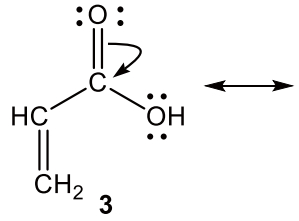
   (b) What does the curved arrow on structure **4** show (be specific)?

   (c) What do the curved arrows on structure **5** show (be specific)?

   (d) In converting structure **5** to **6**, it is necessary to move two pairs of electrons. Draw the resonance structure that would form if only the <u>one</u> lone pair of electrons on oxygen were moved (indicated by the arrow below-remember to only move the pair of electrons shown by the arrow). Describe why this is <u>not</u> a valid resonance form.



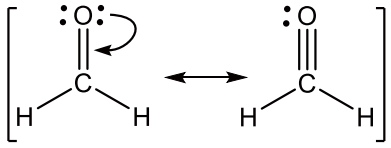
6. (a) In structure **3** of Model 2, the double bond electrons move to form a lone pair on <u>oxygen</u>. The arrow below shows the double bond electrons moving to form a lone pair on <u>carbon</u>. Draw the resulting resonance form (make sure to put in charges).

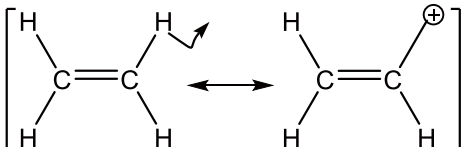


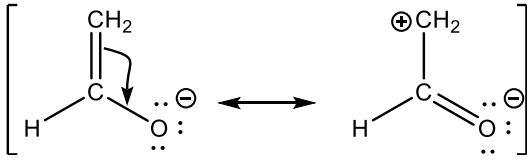
3

(b) Although this form is possible, it is <u>not likely</u>. As a group, discuss why the lone pair is more likely to reside on oxygen than on carbon.

7. Follow the resonance structure guidelines developed in question #4 above. For each pair below, determine whether the resonance structure on the right is an acceptable resonance structure of the form on the left. Place an X through any incorrect structures on the right of each pair, and indicate which of the items listed in question 4 were not followed. Once everyone in your group agrees, draw a correct resonance form.





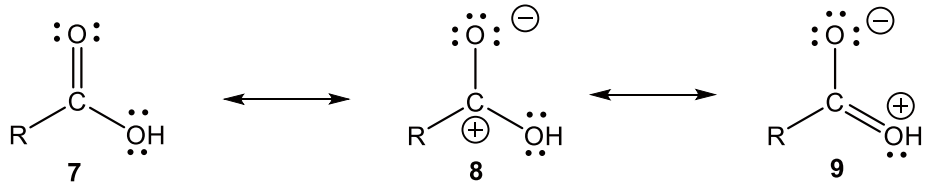


Model 3: Stability of Resonance Forms

Not all resonance forms have the same energy; some forms may be more stable than others.

The major resonance contributor is determined by the following factors (where 1 is more important and 5 is less important):

1. complete octet
2. as many bonds as possible
3. no charge on individual atoms
4. if charges exist, then negative charge resides on more electronegative atom, or positive charge resides on less electronegative atom
5. if charges exist, then small charge separation between charged atoms

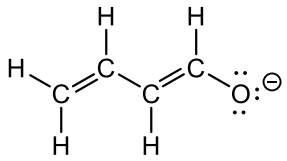


Questions:

8. For the resonance forms shown in Model 3:
   (a) Circle any atoms in Model 3 that do not have complete octets.
   (b) Indicate the total number of bonds for each structure shown in Model 3.
   (c) Which structure has no charges on any individual atoms?
   (d) If charges exist, which atom is most likely to hold the negative charge? (C, H, or O)
   (e) Based on the rules in Model 3, which structure would be the major contributor? Explain.

9. Add curved arrows to show the conversion of **7** → **8** and **8** → **9** in Model 3.

10. For the following structure, use curved arrows to draw **<u>three</u>** additional resonance structures and predict which form, if any, would be the major contributor. (HINT: move double bond or lone pair electrons only and try moving one pair at a time).



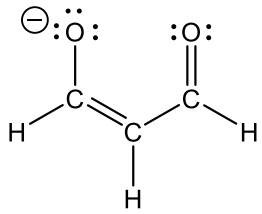
Reflection: on a separate sheet of paper.

As a group, describe three concepts your group has learned from this activity and the one most important unanswered question about this activity that remains with your group. Turn this in before leaving class.

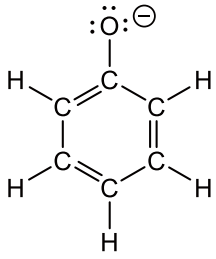
Additional Questions:

11. Use curved arrows to draw any additional resonance structures for the following compounds. Predict which form, if any, would be the major contributor.

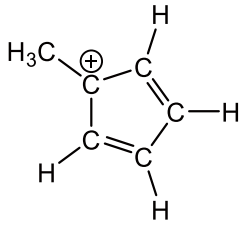
(a)



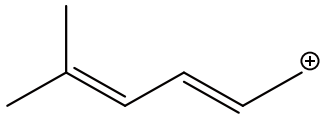
(b)



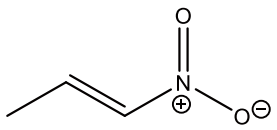
(c)



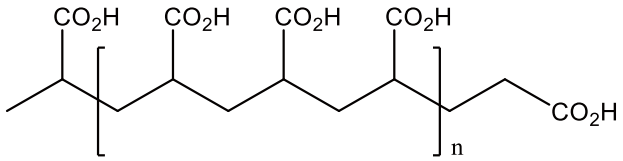
(d)

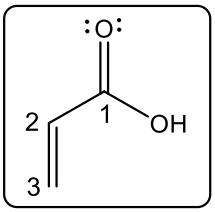


(e)



12. Polyacrylic acid shown below is a polymer (many parts) made up of many units of the monomer acrylic acid (from Model 2). Circle the three carbon acrylic acid monomer units in the polymer below. Using resonance structures, explain why carbon 2 of one acrylic acid molecule might be attracted to carbon 3 of another acrylic acid molecule.





Acrylic Acid