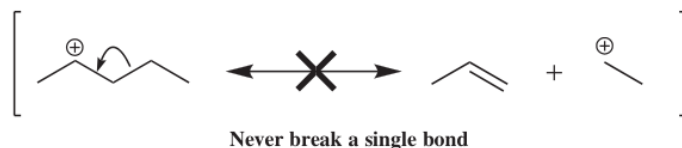
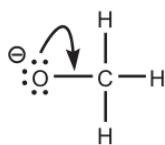


THE TWO COMMANDMENTS

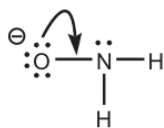
1. *Never break a single bond* when drawing resonance structures. By definition, resonance structures must have all the same atoms connected in the same order.



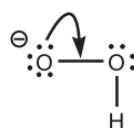
2. *Never exceed an octet for second-row elements.* Elements in the second row (C, N, O, F) have only four orbitals in their valence shell. Each of these four orbitals can be used either to form a bond or to hold a lone pair. Each bond requires the use of one orbital, and each lone pair requires the use of one orbital. So the second-row elements can never have five or six bonds; the most is four. Similarly, they can *never* have four bonds and a lone pair, because this would also require five orbitals. For the same reason, they can never have three bonds and two lone pairs. The sum of (bonds) + (lone pairs) for a second-row element can never exceed the number four. Let's see some examples of arrow pushing that violate this second commandment:



BAD ARROW

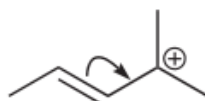


BAD ARROW

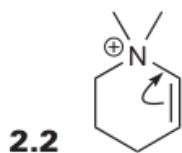


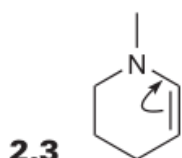
BAD ARROW

EXERCISE 2.1 For the compound below, look at the arrow drawn on the structure and determine whether it violates either of the two commandments for drawing resonance structures:



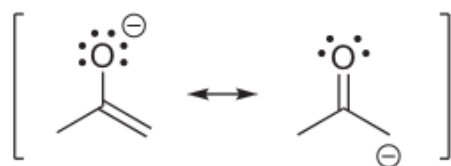
PROBLEMS For each of the problems below, determine which arrows violate either one of the two commandments, and explain why. (Don't forget to count all hydrogen atoms and all lone pairs. You must do this to solve these problems.)



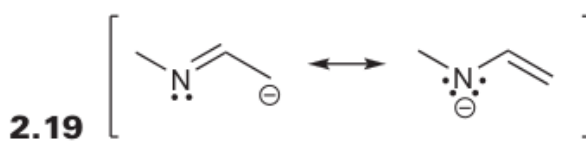
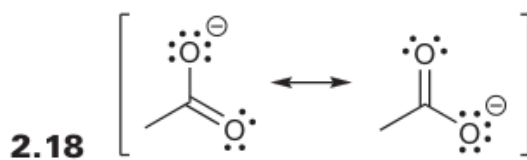
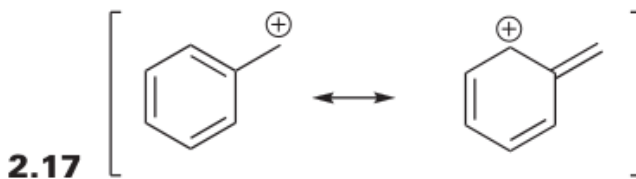
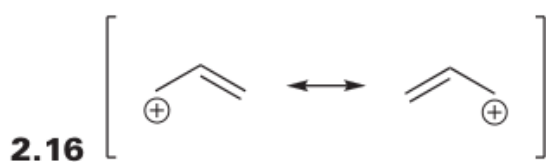
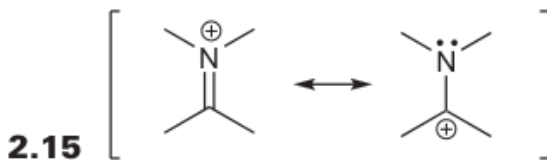
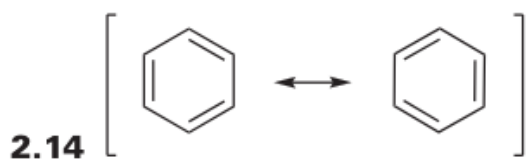




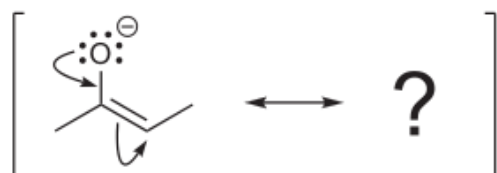
EXERCISE 2.13 For the two structures below, try to draw the curved arrows that get you from the drawing on the left to the drawing on the right:



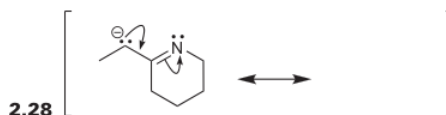
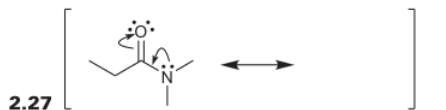
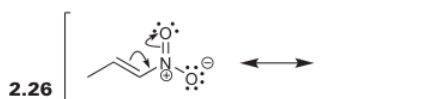
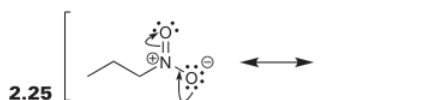
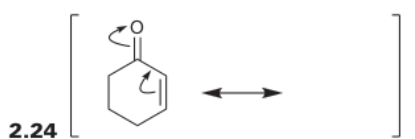
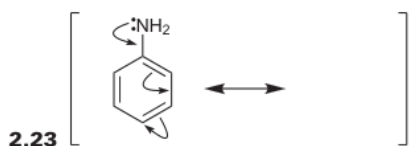
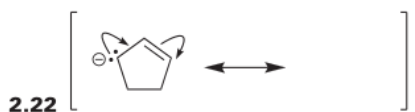
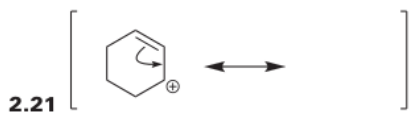
PROBLEMS Try to draw the curved arrows that get you from one drawing to the next. In many cases you will need to draw more than one arrow.



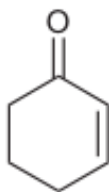
EXERCISE 2.20 Draw the resonance structure that you get when you push the arrows shown below. Be sure to include formal charges.



PROBLEMS For each of the structures below, draw the resonance structure that you get when you push the arrows shown. Be sure to include formal charges. (*Hint:* In some cases the lone pairs are drawn and in other cases they are not drawn. Be sure to take them into account even if they are not drawn—you need to train yourself to see lone pairs when they are not drawn.)



EXERCISE 2.29 Draw all resonance structures for the following compound:



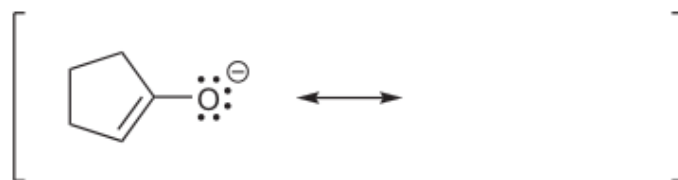
PROBLEM 2.30 For the following compound, go through all three steps (making sure not to violate the two commandments) and draw the resonance structures.



There are five patterns that you should learn to recognize to become proficient at drawing resonance structures. First we list them, and then we will go through each pattern in detail, with examples and exercises. Here they are:

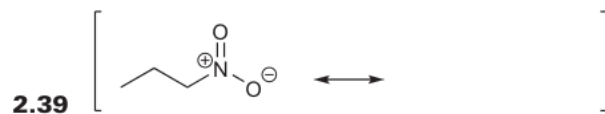
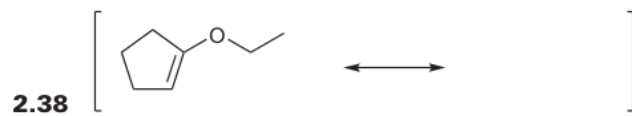
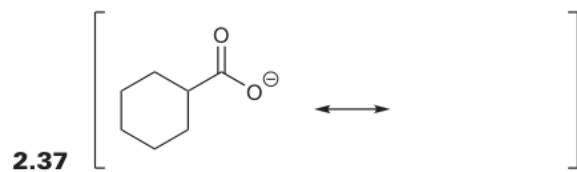
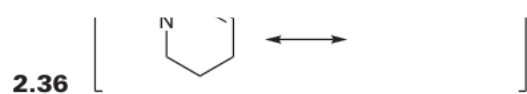
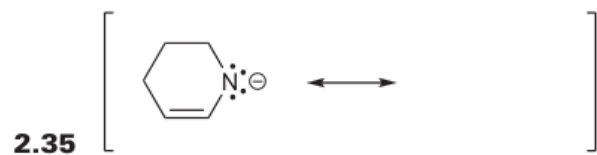
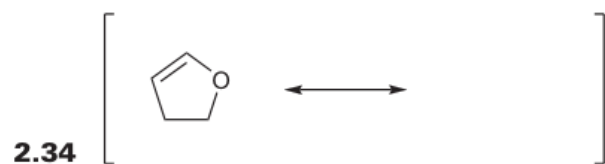
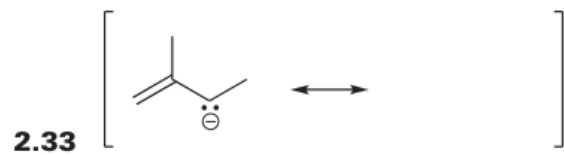
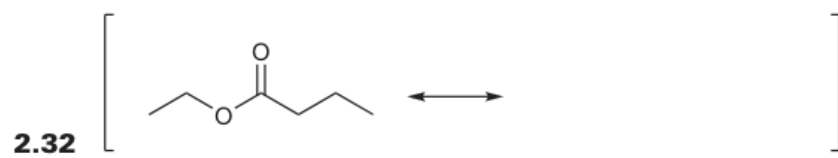
1. A lone pair next to a pi bond.
2. A lone pair next to a positive charge.
3. A pi bond next to a positive charge.
4. A pi bond between two atoms, where one of those atoms is electronegative.
5. Pi bonds going all the way around a ring.

EXERCISE 2.31 Draw a resonance structure of the compound below:



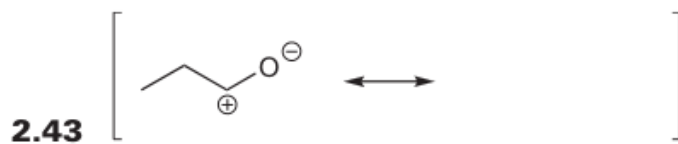
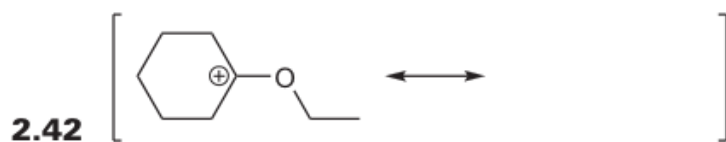
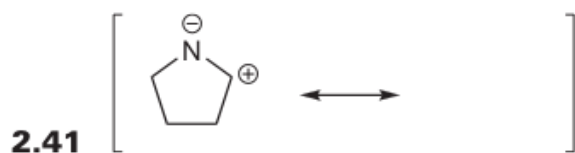
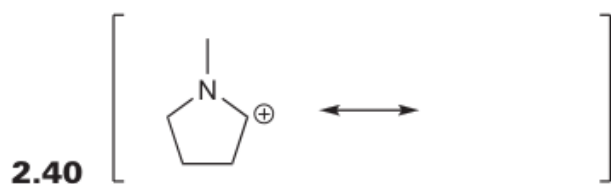
A Lone Pair Next to a Pi Bond

PROBLEMS For each of the compounds below, locate the pattern we just learned and draw the resonance structure.

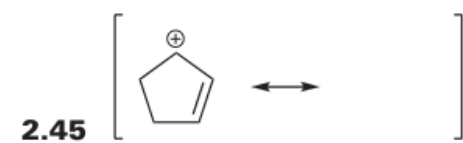
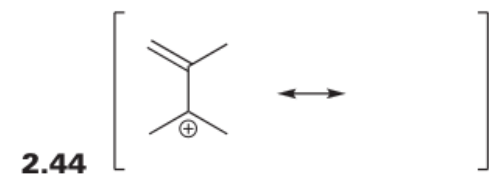


A Lone Pair Next to a Positive Charge

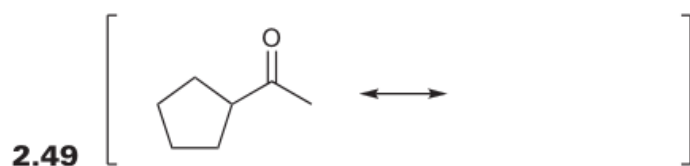
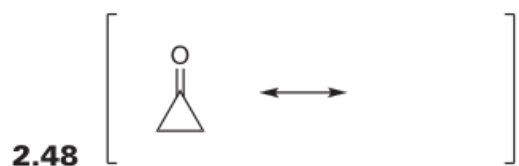
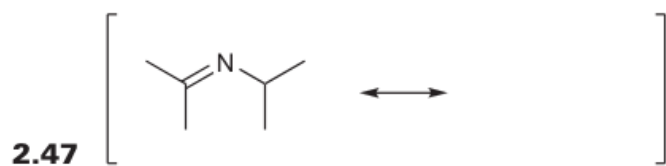
PROBLEMS For each of the compounds below, locate the pattern we just learned and draw the resonance structure.



A Pi Bond Next to a Positive Charge



A Pi Bond Between Two Atoms, Where One of Those Atoms Is Electronegative (N, O, etc.)



Pi Bonds Going All the Way Around a Ring

Example



Practice with all five patterns

PROBLEMS For each of the following compounds, draw the resonance structures.



PROBLEMS For each of the following compounds, draw all of the *significant* resonance structures.

