A valid Lewis structure for CH$_3$NO$_2$ is shown above. You may have realized that the double bond between oxygen and nitrogen could just as well have been drawn from the top oxygen. In other words, no single Lewis structure accurately represents the distribution of electrons in CH$_3$NO$_2$. Rather, to better represent the electron configuration, this structure requires two resonance contributors. The two contributors are shown below, along with the resonance hybrid. The two contributors are identical; therefore, we expect each to be equally important to the structure’s “true” electron configuration. Consequently, the two oxygen atoms share the negative charge equally, as shown in the hybrid. Notice that we don’t bother showing lone pairs in the hybrid, since there is no easy way to represent 2.5 lone pairs (showing a half pair as a single dot • is not a good idea, because the • symbol has a different meaning to chemists). This example reinforces the idea that when considering the structure of organic molecules, always remember to draw as many valid Lewis structures as you can generate.

The delocalization of electrons allows us to write alternative Lewis structures in which the formal charges move.
Curved Arrow Notation

Curved arrow notation is a convention to show changes in electron configuration. It is one of the most practically useful skills that you will develop in CHEM 232, and you'll continue to use it in CHEM 332, biochemistry and beyond. Curved arrows will be used to show changes in electron configuration that accompany each step of a chemical reaction. Here we will use curved arrows to change one resonance contributor into another. The figures below outline the step-by-step process. The process begins (Step 1) by identifying electron pairs associated with electron “rich” regions of the molecule – atoms having a surplus of electron density. For the structure in question, the most obvious electron rich building block is the negatively charged oxygen. There are three electron lone pairs on this oxygen. One has been circled but any one of the three could have been selected. We will call this pair the electron source (Step 2). In step 3, a curved arrow is used to depict the process of transferring the electron source to a position located between oxygen and nitrogen to which it is bonded. Curved arrows are highly revered in organic chemistry. When you draw arrows, be careful to precisely position the tail and head. The tail of the arrow is located exactly on the electron pair undergoing the transfer. The arrow’s head ends precisely at the location to where this electron pair travels.

**step 1 - identify electron pairs associated with electron rich building blocks**

```
 H
        O:
        H       H
C − N
H
```

**step 2 - circle the electron source**

```
 H
        O:
        H       H
C − N
H
```

**step 3 - depict electron pair transfer with a curved arrow**

```
 H
        O:
        H       H
C − N
H
```
Curved Arrow Notation Step-by-Step

The result of this electron pair transfer is drawn in step 4. The structure shown in step 4 should make you feel terribly uncomfortable. There is a glaring error in that the nitrogen atom has an electron count of 10 and thus violates the octet rule. We can rectify this situation by continuing the process of transferring electron pairs. Obviously, one of the electron pairs bonded to the erroneous nitrogen must move. By transferring one pair of electrons of the nitrogen-oxygen double bond as indicated in step 5, we have returned the erroneous nitrogen back to an acceptable structure. The tail of the second arrow will be positioned on one of these bonding electron pairs. The head of this arrow terminates on oxygen and this is the only reasonable place to position it. Why? For one thing, we are at the end of the connectivity trail. There are no other atoms left. The oxygen atom is called the termination point or electron sink. You have just produced a resonance contributor of the CH₃NO₂ (step 6). Every atom satisfies the octet rule. The total, or overall charge on the new resonance contributor is the same as it was on the original (zero). Thus, the new resonance contributor is a perfectly acceptable alternative way to represent the CH₃NO₂. This process helps you to gain an intuitive understanding of why chemists consider resonance contributors as having “delocalized electrons”.

**step 4** - draw the resulting structure; note the error

\[
\begin{align*}
\text{H} & \text{H-C-N} \text{O} \\
\text{H} & \text{H} \\
\text{O} & \text{O}
\end{align*}
\]

**step 5** - rectify the problem by continuing the transfer process

\[
\begin{align*}
\text{H} & \text{H-C-N} \text{O} \\
\text{H} & \text{H} \\
\text{O} & \text{O}
\end{align*}
\]

**step 6** - draw the resulting structure; its an alternative representation of CH₃NO₂
The Mechanics of Generating Resonance
Contributors Using Curved Arrow Notation

• The tail of the first arrow begins at the electron-pair called the source.
• Each arrow represents one of the following types of electron transfers:
  * A nonbonding pair to an adjacent bond (vertex-to-edge transfer)
    \[
    \begin{array}{c}
    \text{vertex-to-edge} \\
    \text{A} \rightarrow \text{A}
    \end{array}
    \]
  * A bonding pair to an adjacent atom (edge-to-vertex transfer)
    \[
    \begin{array}{c}
    \text{edge-to-vertex} \\
    \text{A} \rightarrow \text{A}:
    \end{array}
    \]
  * A bonding pair to an adjacent bond (edge-vertex-edge transfer)
    \[
    \begin{array}{c}
    \text{edge-vertex-edge} \\
    \text{A} \rightarrow \text{A}
    \end{array}
    \]
• The transfer process must continue until all building blocks are error-free.
• The head of the last arrow points to the electron pair’s destination called the sink.
The Double Headed-Arrow (↔)

The step-by-step process outlined above has broken down the interconversion of one resonance contributor to another into fine details. However, with just a little experience, you will be able to perform many of these steps mentally, writing down a combined set of curved arrows to directly show how the electrons rearrange or “flow” to produce the new configuration. This combined process is illustrated below. Note that this shortcut avoids the cumbersome and undesirable act of drawing structures that contain erroneous Lewis structures. Take special note of the double headed-arrow (↔) that was previously introduced as a convention denoting that the two structural representations are related as resonance contributors; the position of the atoms remains fixed and only the location of the electrons has changed.

Resonance considerations show us that no single structure can represent CH₃NO₂. As the name implies, each of the resonance contributors makes a “contribution” to the actual structure. Resonance contributors do not really interconvert from one to another in the way we draw them (that’s why we use ↔ instead of ⇄). We use the set resonance contributors or the resonance hybrid to represent the actual structure.

Now try CO₃²⁻ and use your resonance contributors to determine the average charge on each oxygen.