General Chemistry Flipped Classroom Module

In-class Activity

"Lewis Structures of Industrially and Environmentally Relevant Molecules"

Introduction:

The macroscopic properties of substances, such as the physical state of matter, the melting/boiling point, chemical reactivity, heat of combustion, etc. can be explained by the molecular structure of the molecules that comprise the substance. We can use Lewis structures to draw models of covalently bonded molecules, and then use these models of the molecular structure to explain the macroscopic properties of the substance. In this activity, you will practice drawing Lewis structures of molecules that have applications in industrial settings and/or environmental science. You will also use formal charge calculations to predict the most likely structure for a molecule when more than one possible Lewis structure is possible.

Group Learning Questions:

When your car's engine does not completely combust the gasoline fuel to carbon dioxide, carbon monoxide can be emitted from your car's exhaust. Since carbon monoxide is a hazardous pollutant, cars are required to have a catalytic converter that can complete the oxidation of carbon monoxide to carbon dioxide.

1) Draw the Lewis structure of carbon monoxide. How many non-bonding electrons are located on the oxygen atom?

Sulfur dioxide is another pollutant that can be emitted from your car's exhaust. This compound is formed when sulfur impurities from the fuel and oxygen react during the combustion process in your engine (sulfur is often an impurity in petroleum fuels, particularly in diesel fuel; it can react with the oxygen in the high temperature environment of the piston chamber). If sulfur dioxide is emitted from your car's exhaust it can react with water in the atmosphere to form acid rain, and is therefore an undesired pollutant.

2) Draw the Lewis structure of sulfur dioxide. You have two possible valid Lewis structures that can be drawn for sulfur dioxide. If you draw the Lewis structure with one double bond, how many non-bonding electrons are located on the sulfur atom?

3) If you draw the Lewis structure with two double bonds, how many non-bonding electrons are located on the sulfur atom? (hint: remember sulfur can exceed the octet rule)

4) Calculate the formal charge for each atom in both versions of your sulfur dioxide molecules. Use the formal charges to choose the most likely structure for sulfur dioxide.

Nitrogen dioxide is yet another pollutant that can be emitted from your car's exhaust. This compound is formed when nitrogen and oxygen react during the combustion process in your engine (nitrogen is naturally present in air, therefore it can react with the oxygen in the high temperature environment of the piston chamber). Nitrogen dioxide is involved in a series of reactions that lead to the formation of smog, and is therefore an undesired pollutant.

5) Draw the Lewis structure of nitrogen dioxide. You have two possible valid Lewis structures that can be drawn for this molecule. If you draw the molecule with one double bond, how many non-bonding electrons are located on the nitrogen atom?

6) If you draw nitrogen dioxide with two single bonds, how many non-bonding electrons are located on the nitrogen atom?

7) Calculate the formal charge of each atom in both versions of your nitrogen dioxide molecules. Use the formal charges to choose the most likely structure for nitrogen dioxide.

Ozone (O_3) can be formed in the atmosphere when nitrogen monoxide reacts with oxygen in the presence of other pollutants and ultraviolet sunlight. Ozone is a major component of smog, and high levels of ground level ozone can cause respiratory problems for humans.

8) Assuming the three oxygen atoms bond in a linear fashion, draw the Lewis structure for ozone. How many non-bonding electrons are on the central oxygen atom?

9) Write out the formal charges for ozone and molecular oxygen (O_2). Use the formal charges to explain why ozone is a stronger oxidant than oxygen (more reactive than oxygen), and hence causes irritation in the lungs when inhaled.

Hydrocarbon molecules can react with oxygen in combustion reactions, and in the process generate significant amounts of heat. Methane (CH_4) is used to produce large scale energy in natural gas power plants, and is also used in home heating systems. Acetylene (C_2H_2) is commonly used in welding torches due to the fact that the combustion of this gas is so exothermic.

10) Draw the Lewis structures of both methane and acetylene and determine what types of bonds are present on the carbon atom (single, double, or triple bonds).