Chem / Envsty L111: Homework 3 Solutions

Chapter 2 – Protecting the Ozone Layer

Solve this problem:

We have learned that diatomic oxygen absorbs light with wavelengths less than 242 nm, and that ozone absorbs light with wavelengths less than 320 nm. What is the energy required to break the bonds in each of these molecules, in Joules? Can you explain these results using Lewis structures?

242 nm = 2.42 * 10^{-7} m

$$v = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \, m/s}{2.42 \times 10^{-7} \, m} = 1.24 \times 10^{15} \, s^{-1}$$

$$E = hv = 6.63x10^{-34} \, Js * 1.24x10^{15} \, s^{-1} = 8.22x10^{-19} \, J$$

Which must be the energy needed to break the bond in O_2.

320 nm = 3.20 * 10^{-7} m

$$v = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \, m/s}{3.20 \times 10^{-7} \, m} = 9.37 \times 10^{14} \, s^{-1}$$

$$E = hv = 6.63x10^{-34} \, Js * 9.37x10^{14} \, s^{-1} = 6.21x10^{-19} \, J$$

Which must be the energy needed to break the bond in O_3.

The Lewis structures tell us that the bond in O_2 is a double bond, but the bond in O_3 is a hybrid bond, between a single bond and a double bond. Thus, the bond in O_3 should be weaker, which is indicated by the smaller amount of energy needed to break it.

And the following questions from the text:

Fifth Edition Question Numbers:

Concentrating on Concepts - #34, 39, 43

Exploring Extensions - #53

#34. Since ozone has a bond that is between a single and a double bond, its bond length will be between that of a single bond (132 pm) and a double bond (121 pm). If we think of the bond length of ozone as being 1 ½ bond, then its bond length will be the average of a single and a double bond ½ (132 + 121) and have a length of 127 pm. Both oxygen-oxygen bonds in ozone will be identical with the same length.

#39. UV-C radiation is absorbed by diatomic oxygen and by ozone, and does not reach the surface of the Earth.

#43. Because chlorine is a **catalyst** in the destruction of ozone, a single chlorine atom can destroy many, many, many ozone molecules. In theory, there is no limit to the number of ozone molecules which could be destroyed by one Cl or one ClO, and so you should not be surprised to see a factor of 1000 or more difference between the amount of chlorine and the amount of ozone destroyed.

#53. Because nitrogen has 5 valence electrons, it needs to make three bonds in order to complete its octet. No matter how you try, you can't draw a Lewis structure with three nitrogen atoms each of which satisfies the octet rule. Alternatively, you could calculate S = N-A = 24 − 15 = 9, indicating that you need 9 electrons shared between the three atoms... which can't be evenly divided into 2-electron bonds. Perhaps the fastest solution: 3 sets of 5 valence electrons makes 15 total electrons. No matter what you do, this molecule will be a radical, and thus exceedingly reactive and unstable.