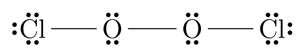
Key for Take-Home Assignment 04

In the first take-home assignment you provided names and formulas for a variety of inorganic compounds. In some cases, such as CBr_4, the compounds were neutral molecules held together by covalent bonds, and in some cases, such as $BaCl_2$, they were ionic compounds in which the anion was a polyatomic ion that, itself, is held together by covalent bonds. For each of these compounds or ions listed here, draw a Lewis structure and answer any questions.

dichlorine dioxide

Draw the Lewis structure for Cl_2O_2 given that its skeletal structure is Cl–O–O–Cl. Do you expect the oxygen-oxygen bond in dichlorine dioxide to be stronger or weaker than the oxygen-oxygen bond in O_2 or in O_3? Explain your reasoning in 1–2 sentences.

There are $(2 \times 7) + (2 \times 6) = 26$ electrons in Cl_2O_2. Given the skeletal structure of Cl–O–O–Cl, the Lewis structure is

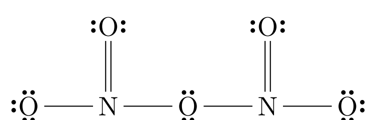


We know from our earlier work in class that O_2 has a double bond between its oxygens and that O_3 has an average bond order of 1.5 between its oxygens. The strength of a bond increases with bond order; therefore, because Cl_2O_2 has a single bond between its oxygens, its oxygen-oxygen bond is weaker than in O_2 or O_3.

dinitrogen pentoxide

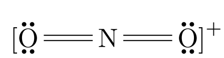
Draw the Lewis structure for $N_2O_5(g)$ given that each nitrogen is connected to three oxygens and report the formal charge on each nitrogen and oxygen. When isolated as a solid, dinitrogen pentoxide consists of the nitronium cation, NO_2^+, and the nitrate anion, NO_3^-. Draw Lewis structures for these two ions—for both, the skeletal structures consists of N–O bonds—and report the formal charge on each nitrogen and oxygen.

There are $(2 \times 5) + (5 \times 6) = 40$ electrons in $N_2O_5(g)$. The only way to draw a skeletal structure in which each nitrogen is connected to three oxygens is to have one oxygen connected to both nitrogens, with each nitrogen connected to two other oxygens; this leaves us with the following Lewis structure

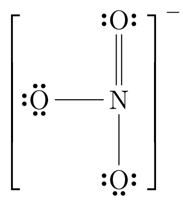


Each nitrogen carries a formal charge of $5 - 0 - 8/2 = +1$. The central oxygen carries a formal charge of $6 - 4 - 4/2 = 0$. The oxygens with double bonds to nitrogen have formal charges of $6 - 4 - 4/2 = 0$ and the oxygens with single bonds have formal charges of $6 - 6 - 2/2 = -1$.

The nitronium ion has $(1 \times 5) + (2 \times 6) - 1 = 16$ electrons and has the following Lewis structure



in which the nitrogen carries a formal charge of $5 - 0 - 8/2 = +1$ and the oxygens each carry formal charges of $6 - 4 - 4/2 = 0$. The nitrate ion has $(1 \times 5) + (3 \times 6) + 1 = 24$ electrons and a Lewis structure of

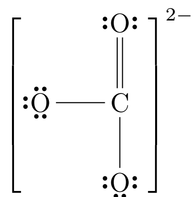


in which the nitrogen carries a formal charge of $5 - 0 - 8/4 = +1$, the oxygen with a double bond to nitrogen carries a formal charge of $6 - 4 - 4/2 = 0$, and the oxygens with single bonds to nitrogen each carry a formal charge of $6 - 6 - 2/2 = -1$.

carbonate

Draw the Lewis structure for CO_3^{2-} given that the skeletal structure contains only C–O bonds. What is the bond order for the C–O bonds?

There are $(1 \times 4) + (3 \times 6) + 2 = 24$ electrons in CO_3^{2-}, which gives a Lewis structure of

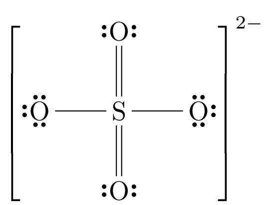


There are a total of four bonds between carbon and oxygen (one double bond and two single bonds) in three bonding areas, given an average bond order of $^4/_3 = 1.33$.

sulfate

Draw the Lewis structure for SO_4^{2-} given that the skeletal structure contains only S–O bonds. There are several ways you can draw this Lewis structure: in this case, provide a structure that places formal charges of -1 on two atoms and formal charges of 0 on all other atoms.

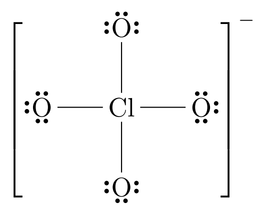
There are $(1 \times 6) + (4 \times 6) + 2 = 32$ electrons in SO_4^{2-}. A Lewis structure that has just two atoms carrying a formal charge of -1 is possible if we draw it with two oxygens with double bonds to sulfur (giving a formal charge of 0 on the oxygens) and two oxygens with single bonds to sulfur (giving a formal charge of -1 on the oxygens); thus



perchlorate

Draw the Lewis structure for ClO_4^- given that the skeletal structure contains only Cl–O bonds. There are several ways you can draw this Lewis structure: in this case, provide a structure that uses as many single bonds as possible and report the formal charge on each atom.

There are $(1 \times 7) + (4 \times 6) + 1 = 32$ electrons in ClO_4^-. We can draw a Lewis structure using only single bonds, as shown here



Each oxygen has a formal charge of $6 - 6 - 2/2 = -1$ and the chlorine has a formal charge of $7 - 0 - 8/2 = +3$.