

1 Cognitive reasoning in the chemical sciences 4.7

1. The questions in this set require knowledge of formal charge, oxidation states, Lewis structures, and VSEPR.
 - (a) An oxide is a compound in which elements have reacted with oxygen to make a pure compound. Binary oxides contain only oxygen plus one other element. What is the stoichiometry of the stable oxide, where the non-oxygen element is in its highest possible oxidation state, for carbon oxide, sulfur oxide, aluminum oxide, and phosphorus oxide? What are the oxidation states of the elements in these oxides?
 - (b) When mixed with either oxygen or halogen atoms, the common sulfur oxidation states are IV and VI. Of the three molecules SF_2 , SF_4 , and SF_6 , only two are easily synthesized. Which two? What are the shapes of these two molecules?
 - (c) There are at least two stable phosphorus oxides. They differ in their phosphorus oxidation states (+V and +III). What are the stoichiometries of these two compounds?
 - (d) The P(III) oxide forms a molecule. There are four phosphorous atoms in this molecule. All the phosphorus atoms are in the same chemical environment. The same is true for the oxygen atoms. There are no multiple P-O bonds and all chemical bonds are between P-O bonds. Please draw the Lewis structure for this molecule.
 - (e) A chloride is a compound in which elements have reacted with chlorine to make a pure compound. Binary chlorides contain only chlorine plus one other element. What is the stoichiometry of a stable carbon chloride, sulfur chloride, aluminum-potassium chloride and phosphorus chloride?
 - (f) The best Lewis structures either obey the octet rule or minimize the number of non-zero formal charges. Very often, one can find a Lewis structure which does both. But not always. Please draw two Lewis structures for SO_4^{2-} , one which minimizes formal charge and the other which obeys the octet rule.
 - (g) Two molecules or ions are said to be isoelectronic if they have the same number of valence electrons and the same ratio of central to outer atoms. For example CCl_4 and SO_4^{2-} are isoelectronic. Which of the above two Lewis structures best reveals the isoelectronic similarity between the SO_4^{2-} and CCl_4 species?
 - (h) The following are examples of some of the major families of polyatomic ions and molecules: CO_3^{2-} , SbF_6^- and CCl_4 . Find the different charges n which lead to isoelectronic species with one of these three compounds, for each of the following common species. ClO_4^{n-} , SO_4^{n-} , NO_3^{n-} , PO_4^{n-} , SiF_6^{n-} , SCl_6^{n-} , POCl_3^{n-} , TeF_6^{n-} .
 - (i) Please draw traditional Lewis structures for CO_3^{2-} , SbF_6^- and CCl_4 .

- (j) Please draw two Lewis structures, for each of the following three molecules or ion, one which minimizes the formal charge, the other which rigorously adheres to the octet rule: XeO_4 , PO_4^{3-} , and TeF_6 .
- (k) For the above problem, identify both the formal charges and the oxidation state of the central atoms for both types of Lewis structures. Is oxidation state or formal charge invariant with respect to type of Lewis structure?
- (l) The anions in the above lists are all bases. It is possible to take each of the -O^- and bond them to separate H^+ to generate an acidic molecule. (Acids are molecule which can release H^+ upon chemical reaction.) For the five -O^- containing compounds, listed in the problem given three problems ago, please convert these bases into acids. Please state the common names of these acids.
- (m) For the above problem, identify the formal charges and the oxidation state of the central atoms.
- (n) Please draw the most stable Lewis structures and molecular shape you can think of for each of the following species: HNO_3 , $\text{H}_5\text{P}_3\text{O}_{10}$, AsO_4^{3-} , H_3PO_4 , $\text{Te}_2\text{F}_{10}\text{O}$, $\text{S}_2\text{O}_7^{2-}$. Try to find structures where the local environment (including the oxidation state) around each of the “central” atoms is as similar as possible to the environments to the ions and molecules in the preceding problems.
- (o) Please draw the Lewis structure and the molecular shapes of the following molecules: IF_5O , ClO_3F , ClO_2F , IF_3O , BrO_2 , ClOF , XeF_2 , BF_3 , XeOF_4 . Adopt the rule that the most electropositive atom is the “central” atom of the molecule or ion.
- (p) The molecule $\text{I}_3\text{O}_6\text{F}_9$ contains a ring and has no I-I bonds. All iodine atoms are in the same environment as are all the fluorine atoms. There are two kinds of oxygen atoms. The iodine atoms have a local environment similar to the I atoms in the previous problem. Please draw the Lewis structure and molecular shape of this molecule.