

1 Cognitive reasoning in the chemical sciences 5.1

1. Isoelectronic compounds

- (a) 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.
- Please count the number of valence electrons for both CCl_4 and SO_4^{2-} . Are they isoelectronic?
 - Isoelectronic compounds often have the same structures. What are the SN for CCl_4 and SO_4^{2-} . Would these two compounds/ions have the same structure?
 - Find the SN (steric number) for the three prototype compounds/ions, CO_3^{2-} , SbF_6^- and CCl_4 .
 - Determine the values of n for ClO_4^{n-} , SO_4^{n-} , and NO_3^{n-} to be isoelectronic to any of the above prototype species. What are the shapes of these three ions?
 - Determine the values of n for PO_4^{n-} , SiF_6^{n-} , and SbCl_6^{n-} to be isoelectronic to any of the above prototype species. What are the shapes of these three ions?
 - Determine the values of n for POCl_3^{n-} and TeF_6^{n-} to be isoelectronic to any of the above prototype species. What are the shapes of these three ions?
 - Please identify the oxidation states of the central atoms for all the above ions/molecules.
- (b) **Acids and bases:** Many of the above molecules have an $-\text{O}^-$ in their traditional Lewis structure. It is possible to add an H^+ to each of these traditional Lewis structure $-\text{O}^-$ and thus generate an acidic molecule.
- Please draw traditional Lewis structures for the ClO_4^{n-} , SO_4^{n-} , and NO_3^{n-} you determined in a previous problem. How many different acids can we generate from these three species? State which of the three prototypes, CO_3^{2-} , SbF_6^- and CCl_4 , these different acids are isoelectronic to.
 - Please draw traditional Lewis structures for the PO_4^{n-} and POCl_3^{n-} you determined in a previous problem.. How many different acids can we generate from these two species? State which of the three prototypes, CO_3^{2-} , SbF_6^- and CCl_4 , these different acids are isoelectronic to.
- (c) **Making bigger molecules and ions.** Larger ions and molecules often have more than one central atom. Think of two people holding hands. In this analogy, the heart of each person is a different central atom and the separate parts of the person are the peripheral atoms. But one peripheral part, the pair of shared hands is held jointly by both people in the couple.

Think of the multiple central atom systems below as having two separate central atom systems each separate system with chemical environments similar to the simpler compounds you have already studied. Please draw the most stable Lewis structures and molecular shape you can think for:

- i. $\text{H}_5\text{P}_3\text{O}_{10}$
 - ii. $\text{Te}_2\text{F}_{10}\text{O}$
 - iii. $\text{S}_2\text{O}_7^{2-}$.
- (d) 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.

2. Review

- (a) Use VSEPR to determine the shape of ClO_2F . Please draw two Lewis structures: one which optimizes the formal charge and the other which optimizes adherence to the octet rule.
- (b) The amino acid alanine has the chemical formula $\text{CH}_3\text{CHNH}_2\text{CO}_2\text{H}$. Please draw its structure. Use VSEPR to determine all the approximate bond angles.
- (c) Which of the following two compounds is less likely to exist: KrF_2 and NeF_2 . Explain your reasoning.
- (d) Draw the Lewis structure and use VSEPR to determine the molecular structure of $\text{S}_2\text{O}_5\text{F}_2$.
- (e) The most stable form of sulfur is the molecule S_8 . Please draw its structure and state its approximate bond angles. Is the molecule planar?
- (f) Draw the Lewis structure and use VSEPR to determine the shape of BiCl_5^{2-} .
- (g) Use the previous results and the idea that stable compounds often have similar bonding environments around similar atoms to determine the structure of $\text{I}_2\text{Cl}_6\text{S}_2$.
- (h) Ba_3XeO_6 is a salt. Use VSEPR to determine the shape of the anion of this salt. Please also draw its Lewis structure.
- (i) Draw a plausible structure for realgar, As_4S_4 . Note all As and all S atoms are in the same chemical environment.
- (j) Please draw the most plausible Lewis structure for $\text{N}_2\text{O}_3^{2-}$.
- (k) The molecule $\text{B}_3\text{N}_3\text{H}_6$ is isoelectronic and isostructural to that of benzene. Please draw its Lewis structure.
- (l) Naphthalene, C_{10}H_8 is one of the ingredients of moth-balls. All bond angles are at the ideal angles set by VSEPR. The molecule is planar. What is its Lewis structure?