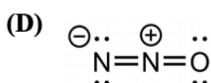
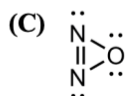
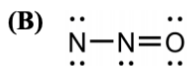
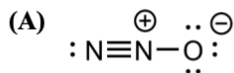


Bonding

Here are some practice problems!
-Venky & Anugrah

2019 USNCO Local

9. Which solid is least soluble in water at 298 K?
- (A) CaF_2 (B) AgF
(C) $\text{Ba}(\text{OH})_2$ (D) CoSO_4
14. Ammonia (NH_3) has a higher normal boiling point (-33°C) than its heavier congeners PH_3 (bp -88°C) or AsH_3 (bp -63°C). Which is the best explanation for this difference?
- (A) NH_3 is trigonal pyramidal and polar while PH_3 and AsH_3 are trigonal planar and nonpolar.
(B) NH_3 is much more acidic than PH_3 or AsH_3 .
(C) $\text{NH}_3(l)$ experiences stronger London dispersion forces than $\text{PH}_3(l)$ or $\text{AsH}_3(l)$.
(D) $\text{NH}_3(l)$ has extensive hydrogen bonding while $\text{PH}_3(l)$ and $\text{AsH}_3(l)$ do not.
15. In which are the ionic solids ranked in order of increasing melting point?
- (A) $\text{KBr} < \text{NaCl} < \text{NaF} < \text{MgO}$
(B) $\text{NaF} < \text{NaCl} < \text{MgO} < \text{KBr}$
(C) $\text{KBr} < \text{NaCl} < \text{MgO} < \text{NaF}$
(D) $\text{MgO} < \text{NaF} < \text{KBr} < \text{NaCl}$
49. Which statements correctly describe the geometry of the carbonate ion, CO_3^{2-} ?
- I. All three carbon-oxygen bond distances are the same.
II. All three bond angles are 120° .
- (A) I only (B) II only
(C) Both I and II (D) Neither I nor II
50. Which molecule has a trigonal pyramidal geometry?
- (A) PCl_3 (B) BCl_3 (C) IF_3 (D) SO_3
52. Which resonance structure contributes the most to the overall bonding in nitrous oxide, N_2O ?



53. How many σ bonds and how many π bonds are present in allene, H_2CCCH_2 ?
- (A) One σ , one π (B) Five σ , one π
(C) Six σ , two π (D) Seven σ , two π

2018 USNCO Local

49. Which compound contains both ionic and covalent bonds?
- (A) PF_3 (B) KF
(C) CH_3COOH (D) MgSO_4
50. Which gas-phase molecule is NOT linear?
- (A) CS_2 (B) SO_2 (C) HCCH (D) BrCN
51. In the Lewis structure of the chlorate ion, ClO_3^- , how many lone pairs of electrons does the chlorine atom have?
- (A) 0 (B) 1 (C) 2 (D) 3

2015 USNCO Local

49. Which species are linear?
- I. NO_2^+ II. I_3^-
- (A) I only (B) II only
(C) Both I and II (D) Neither I nor II
51. Which statement about bonding is correct?
- (A) A σ bond has cylindrical symmetry about the bonding axis.
(B) A π bond is twice as strong as a σ bond.
(C) A double bond consists of two π bonds.
(D) A π bond results from the sideways overlap of hybridized orbitals.

2014 USNCO Local

49. Which atom is least likely to violate the octet rule in its compounds?
- (A) B (B) Cl (C) F (D) H
50. In the Lewis structure for formic acid, HCOOH , how many bonding pairs and lone pairs of electrons are present?
- (A) 4 bonding, 2 lone (B) 4 bonding, 5 lone
(C) 5 bonding, 0 lone (D) 5 bonding, 4 lone
51. Which ionic compound has the largest lattice energy?
- (A) LiF (B) BeO (C) KBr (D) CaS

52. When 1.0 mole of H_2O_2 decomposes to form H_2O and O_2 , 103 kJ of energy is released. Given the bond energies below, what is the bond energy of the O—O single bond in H_2O_2 ?

Bond	H—O	O=O
Bond Energy, $\text{kJ}\cdot\text{mol}^{-1}$	463	498

- (A) $+395 \text{ kJ}\cdot\text{mol}^{-1}$ (B) $+249 \text{ kJ}\cdot\text{mol}^{-1}$
 (C) $+146 \text{ kJ}\cdot\text{mol}^{-1}$ (D) $+103 \text{ kJ}\cdot\text{mol}^{-1}$
53. Which species has a different number of pi bonds than the others?
 (A) C_2H_2 (B) CO_2 (C) N_2 (D) O_3
54. Which molecule is correctly matched with its shape as predicted by VSEPR theory?
 (A) PCl_3 trigonal pyramidal
 (B) OF_2 linear
 (C) ClF_3 trigonal planar
 (D) SF_6 hexagonal

53. A triple bond is found in which of the following species?

I CO II C_2H_2 III CN^-

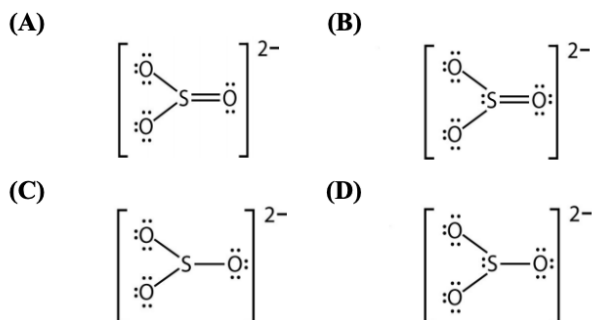
- (A) I only (B) II only
 (C) I and II only (D) I, II and III

54. Which of the following compounds has a non-zero dipole moment?

(A) CO_2 (B) AsH_3 (C) CCl_4 (D) PF_5

2012 USNCO Local

49. Which species contains only covalent bonds?
 (A) AlF_3 (B) NH_4NO_3
 (C) H_2SO_4 (D) $\text{K}_2\text{Cr}_2\text{O}_7$
50. In which species can we describe the central atom as having sp^2 hybridization?
 (A) BeF_2 (B) CO_2 (C) KrF_2 (D) SO_2
51. Which Lewis dot structure is a valid representation for the sulfite ion, $[\text{SO}_3]^{2-}$?



ANSWER KEYS:

2019 Local:

9: A
 14: D
 15: A
 49: C
 50: A
 52: A
 53: C
 2018 Local:
 49: D
 50: B
 51: B
 2015 Local:
 49: C
 51: A

2014 Local:

49: C
 50: D
 51: B
 52: C
 53: D
 54: A
 2012 Local:
 49: C
 50: D
 51: D
 53: D
 54: B

2015 USNCO National Part 2

7. [12] Chlorine is an industrially and biologically important element.
- Give the ground state electron configuration for gas-phase atomic Cl.
 - Draw a Lewis structure for molecular chlorine, including all lone pairs and any formal charges.
 - Which would have a greater first ionization energy, atomic Cl or molecular chlorine? Justify your answer.
 - Which would have a larger radius, atomic Cl or the chloride ion (Cl^-)? Justify your answer.
 - Explain why the oxoanions ClO^- , ClO_2^- , ClO_3^- , and ClO_4^- all form stable salts, but the oxoanion ClO_5^- is unknown.

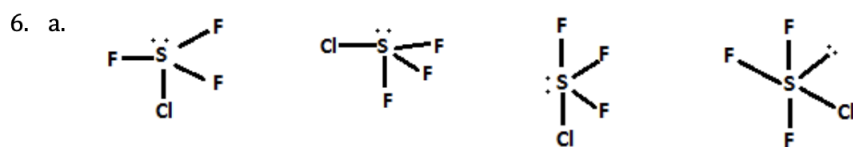
2013 USNCO National Part 2

6. [13] Consider the highly reactive molecule SF_3Cl .
- Draw all of the possible structures of SF_3Cl with S as the central atom.
 - Use VSEPR theory to predict the most stable structure in a. and justify your answer.
 - Recent calculations predict that the two structures that are lowest in energy differ by about 0.2 kJ/mol. Identify the second lowest energy structure and justify your answer.
 - While selenium and tellurium can potentially form SeF_3Cl and TeF_3Cl , an OF_3Cl species is not known even though oxygen has the same valence electron configuration. Account for this difference in the behavior of oxygen.

(Part d. Omitted)

Answer Key**2015 USNCO National Part 2**

7. [12 pts.]
- a. $1s^2 2s^2 2p^6 3s^2 3p^5$ or $[\text{Ne}] 3s^2 3p^5$
- b. $\text{:}\ddot{\text{Cl}}\text{---}\ddot{\text{Cl}}\text{:}$
- c. Cl has a higher ionization energy than Cl_2 . The highest-lying electrons in Cl_2 are π^* , so they are higher in energy, and hence require less energy to ionize, than the $3p$ electrons in atomic chlorine. (The experimental values are 13.0 eV for Cl, 11.5 eV for Cl_2 [Frost, D. C.; McDowell, C. A.; Vroom, D. A. *J. Chem. Phys.* **1967**, *46*, 4255-4259].)
- d. Cl^- would have a larger radius, since it has an additional electron.
- e. Cl has 7 valence electrons. An oxoanion with the formula ClO_5^- would require an oxidation state of +9 for Cl, which would require removing core electrons. This is not energetically feasible.

2013 USNCO National Part 2

- b. Structure is correct for most stable. Lone pair of electrons and the least electronegative atom (Cl) are in the equatorial plane at 120 degrees apart with very electronegative F atoms in axial positions, drawing bonding pairs of electrons away from S.

- c. Structure is correct for second most stable. Cl is in an apical position but the lone pair is still in the equatorial plane, minimizing its repulsion of the bonding pairs of electrons.

- e. The central atom in SF_3Cl has ten electrons around it. While S , Se and Te can all accommodate ten electrons, O (with fewer orbitals available) cannot do so.