First-Year SL & HL Chemistry

6. Bonding I: Ionic, Covalent and Metallic

Read: Zumdahl[2] Chapter 8: Sections 1-7, 9-11, 12 (pp. 383-385, Formal charge NOT required), 13; Chapter 9: Section 1, 5; Chapter 10: Section 4 (pp. 465-466).

Presumed knowledge (from GCSE)

- Ionic and covalent bond, ionic compound, covalent compound, structure,
- maleability, ductility, electrical and thermal conductivity

Concepts to be mastered:

To master a concept, you must be able to do three things:

1. define the concept
2. explain the concept, and
3. give an example of the concept.

- lattice enthalpy (energy), Born-haber cycle, enthalpy of atomization, electron affinity [**only HL**]
- Lewis structure, central atom, outer atom, electron configuration of the central atom
- bonding pair, lone pair, octet rule
- valence bond theory, bonding region, expanded octet, electron deficient [**only HL**]
- bond, bond enthalpy, single bond, double bond, triple bond
- s bond, p bond, head-head overlap, side-side overlap [**only HL**]
- resonance, localization of electrons, delocalization of electrons [**only HL**]
- **V**alence **S**hell **E**lectron **P**air **R**epulsion Theory, bond angle, molecular geometry, molecular shape, linear, trigonal planar, tetrahedral, trigonal pyramidal
- trigonal bipyramidal, seesaw, t-shaped, octahedral, square pyramidal, square planar [**only HL**]
- trigonal bipyramidal, octahedral [**only HL**]
- hybridization, hybrid atomic orbital, sp hybrid, sp^2 hybrid, sp^3 hybrid, dsp^3 or sp^3d hybrid, d^2sp^3 or sp^3d^2 hybrid [**only HL**]
- polarization, polarity, molecular dipole, polar, nonpolar, bond dipole, electronegativity, bond strength, bond length
- polarizing power, polarizability, dipole moment, ionic character, covalent character [**only HL**]
- metallic bond

Skills to be mastered:

To master a skill, you must be able to

1. recognize when the skill is needed,
2. recognize what information is needed to execute the skill,
3. execute the skill, and
4. assess whether the skill has been executed correctly.

	Zumdahl[2] problem	Further problems
• Describe the nature of ionic, covalent and metallic bonds		
• Predict which ions will be formed when metals in group 1, 2 and 3 of the periodic table lose electrons		1

• Predict the ions which will be formed when elements in groups 6 and 7 gain electrons (restrict to O, S, F, Cl, Br and I)		2
• Predict the effect of the relative sizes and charges of ions on the relative lattice enthalpies of different ionic compounds [**only HL**]	**8**.45, 46	
• Construct a Born-Haber cycle and determine lattice enthalpy or enthalpy of formation [**only HL**]	**8**.41-42, 44,	7, 8
• Explain the difference between experimental and theoretical lattice enthalpy values [**only HL**]	**8**.39-40	9, 10, 17
• Given the formula for a molecule or polyatomic ion containing only one central atom:	**9**.21-22	
♦ determine the Lewis structure	**8**.61-68	13
♦ determine arrangement of electron pairs around the central atom		14
♦ determine the shape about the central atom	**8**.79-84	14
♦ determine the bond angle(s)	**8**.77-78	21
♦ draw the structure in proper 3 dimensional perspective(s)		
♦ determine the polarity of bond based on electronegativity values	**8**.23-28	
♦ determine polarity of molecules based on bond polarity and molecular shape	**8**.85-90, 93, 94	15, 16
♦ predict hybridization in the central atom [**only HL**]	**9**.15-20, 23-27	20
♦ determine if resonance structures can be drawn [**only HL**]	**8**.69,	18
♦ determine the number of σ or π bonds present [**only HL**]	**9**.25-27	22
• Describe single, double, and triple bonds		
• Describe the relationship between the number of bonds (single, double, or triple) and bond length and strength	**8**.70-72	19
• Determine relative electronegativity of atoms from position in the periodic table	**8**.21-22	
• Describe compounds as stable or unstable with respect to specified substances, using the enthalpy of reaction or of formation [**only HL**]	**8**.43, 99	11

Problems:

Further Problems

1. Write the symbol and charge for the ion most likely to be formed from each of the following (a) lithium, (b) barium, (c) magnesium, (d) aluminum, (e) potassium
2. Answer problem 1 for the following elements: (a) sulfur, (b) chlorine, (c) nitrogen, (d) iodine, (e) oxygen
3. Write the formulas and give the names of the binary compounds formed from each of the following pairs of elements: (a) Li, Br; (b) Mg, Se; (c) Cl, Sr; (d) Al, S; (e) P, Ca.
4. Write the formulas of the compound formed from the following ions: (a) NH_4^+, SO_4^{2-}, (b) Al^{3+}, CO_3^{2-}
5. Name the following using IUPAC rules:
   (a) $CaCO_3$, (b) NH_4HCO_3, (c) Na_3PO_4, (d) $KHSO_4$, (e) $Mg(NO_3)_2$, (f) $Ba(OH)_2$

6. Write chemical formulas for the following compound: (a) aluminum nitrate, (b) ammonium dihydrogenphosphate, (c) magnesium hydroxide, (d) hydroiodic acid
7. Construct a Born-Haber cycle for the formation of KBr(s) from K(s) and Br_2(l). Indicate which steps are endothermic and which are exothermic.
8. Given the following data, calculate the lattice enthalpy of $CaCl_2$ in kJ per mole. Energy needed to vaporize Ca(s) = 192 kJ/mol; first ionization energy of Ca = 589.5 kJ/mol; second ionization energy of Ca = 1146 kJ/mol; electron affinity of Cl = −348 kJ/mol; bond enthalpy of Cl_2 = 238 kJ/mol of Cl-Cl bonds; energy change for the reaction, $Ca_{(s)} + Cl_{2\,(g)} \rightarrow CaCl_{2\,(s)}$ −795 kJ/mol of $CaCl_2$ formed.
9. Using the table of lattice enthalpies in the data booklet, account for the difference between the members of the following pairs of compounds: (a) NaF, NaCl; (b) LiBr, CsBr; (c) $SrCl_2$, SrS
10. Answer this question by looking at the lattice enthalpies in the data booklet. Which types of compounds show the greatest discrepancies between experimental and theoretical values of lattice enthalpy? What might be a possible explanation for large differences?
11. In general, what conditions cause two atoms to combine to form a bond that is mainly covalent?
12. Use a dot density (charge cloud) diagram to represent the electron density of a chlorine molecule.
13. Draw electron dot (Lewis) structures for each of the following:

    (a) NF_3, (b) FNNF, (c) H_2NOH, (d) NO^+, (e) PH_4^+, (f) C_3H_8, (g) SiF_4, (h) N_2, (i) PO_4^{3-}, (j) C_2H_2, (k) CH_2Cl_2, (l) CO_2, (m) C_2H_4 (n) PCl_3, (o) H_2S, (p) SCl_2, (q) ClO^-, (r)SeF_6, (s) ICl_3, (t) BCl_3, (u) ICl_4^-
14. For each of the following, indicate the arrangement of the electrons and the shape of the molecule: (a) NCl_3, (b) H_2S, (c) PCl_3, (d) $H_2C{=}O$
15. Which of the following molecules are polar? Show the direction of the net dipole moment for each polar molecule. (a) H_2S, (b) CS_2, (c) $CHCl_3$, (d) Cl_2O, (e) PCl_3, (e) $AlCl_3$, (f) PH_3.
16. Explain why (b) CH_2Cl_2 is polar but CCl_4 is not.
17. Use electronegativity values to characterize the bonds in each of the following as mainly ionic, polar covalent, or non-polar covalent: (a) $AlCl_3$, (b) MgO, (c) NF_3, (d) Ca_3P_2, (e) NH_3, (f) BCl_3, (g) F_2, (h) NaH.
18. Draw resonance structures for (a) NO_2^- and (b) N_3^-
19. Which bond in the compounds in problem 4 would be expected to have the largest bond enthalpy? Explain.
20. What pure atomic orbitals are combined to form sp^2 hybrid orbitals? How can the geometric arrangement of the hybrid orbitals be explained?
21. What angles exist between the orbitals in the following hybrids: (a) sp^3, (b) sp^2 (c) sp, (d) sp^3d^2
22. How many σ and π bonds are there in the following?