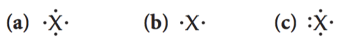
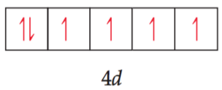
Chemical Bonding
Problem Set

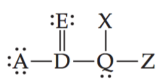
8.1 For each of these Lewis symbols, indicate the group in the periodic table in which the element X belongs: [Section 8.1]



8.4 The orbital diagram that follows shows the valence electrons for a 2+ ion of an element. **(a)** What is the element? **(b)** What is the electron configuration of an atom of this element? [Section 8.2]



8.5 In the Lewis structure shown here, A, D, E, Q, X, and Z represent elements in the first two rows of the periodic table (H—Ne). Identify all six elements so that the formal charges of all atoms are zero. [Section 8.3]



8.6 Incomplete Lewis structures for the nitrous acid molecule, HNO_2, and the nitrite ion, NO_2^-, are shown below. **(a)** Complete each Lewis structure by adding electron pairs as needed. **(b)** Is the formal charge on N the same or different in these two species? **(c)** Would either HNO_2 or NO_2^- be expected to exhibit resonance? **(d)** Would you expect the N═O bond in HNO_2 to be longer, shorter, or the same length as the N—O bonds in NO_2^-? Explain. [Sections 8.5 and 8.6]

H—O—N═O   O—N═O

8.7 The partial Lewis structure that follows is for a hydrocarbon molecule. In the full Lewis structure, each carbon atom satisfies the octet rule, and there are no unshared electron pairs in the molecule. The carbon–carbon bonds are labeled 1, 2, and 3. **(a)** Determine where the hydrogen atoms are in the molecule. **(b)** Rank the carbon–carbon bonds in order of increasing bond length. **(c)** Rank the carbon–carbon bonds in order of increasing bond enthalpy. [Sections 8.3 and 8.8]

$$C \overset{1}{=} C \overset{2}{-} C \overset{3}{\equiv} C$$

8.9 **(a)** What are valence electrons? **(b)** How many valence electrons does a nitrogen atom possess? **(c)** An atom has the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^2$. How many valence electrons does the atom have?

8.11 Write the electron configuration for silicon. Identify the valence electrons in this configuration and the nonvalence electrons. From the standpoint of chemical reactivity, what is the important difference between them?

8.14 What is the Lewis symbol for each of the following atoms or ions: **(a)** K, **(b)** As, **(c)** Sn^{2+}, **(d)** N^{3-}?

8.15 Using Lewis symbols, diagram the reaction between magnesium and oxygen atoms to give the ionic substance MgO.

8.16 Use Lewis symbols to represent the reaction that occurs between Ca and F atoms.

8.17 Predict the chemical formula of the ionic compound formed between the following pairs of elements: **(a)** Al and F, **(b)** K and S, **(c)** Y and O, **(d)** Mg and N.

8.19 Write the electron configuration for each of the following ions, and determine which ones possess noble-gas configurations: **(a)** Sr^{2+}, **(b)** Ti^{2+}, **(c)** Se^{2-}, **(d)** Ni^{2+}, **(e)** Br^-, **(f)** Mn^{3+}.

8.21 **(a)** Define the term *lattice energy*. **(b)** Which factors govern the magnitude of the lattice energy of an ionic compound?

8.26 Explain the following trends in lattice energy: **(a)** NaCl > RbBr > CsBr; **(b)** BaO > KF; **(c)** SrO > $SrCl_2$.

8.27 Energy is required to remove two electrons from Ca to form Ca^{2+} and is required to add two electrons to O to form O^{2-}. Why, then, is CaO stable relative to the free elements?

8.31 **(a)** What is meant by the term *covalent bond*? **(b)** Give three examples of covalent bonding. **(c)** A substance XY, formed from two different elements, boils at −33 °C. Is XY likely to be a covalent or an ionic substance? Explain.

8.32 Which of these elements are unlikely to form covalent bonds: S, H, K, Ar, Si? Explain your choices.

8.34 Use Lewis symbols and Lewis structures to diagram the formation of PF_3 from P and F atoms.

8.38 **(a)** What is the trend in electronegativity going from left to right in a row of the periodic table? **(b)** How do electronegativity values generally vary going down a column in the periodic table? **(c)** How do periodic trends in electronegativity relate to those for ionization energy and electron affinity?

8.39 Using only the periodic table as your guide, select the most electronegative atom in each of the following sets: **(a)** Na, Mg, K, Ca; **(b)** P, S, As, Se; **(c)** Be, B, C, Si; **(d)** Zn, Ge, Ga, As.

8.42 Arrange the bonds in each of the following sets in order of increasing polarity: **(a)** C—F, O—F, Be—F; **(b)** O—Cl, S—Br, C—P; **(c)** C—S, B—F, N—O.

8.46 In the following pairs of binary compounds determine which one is a molecular substance and which one is an ionic substance. Use the appropriate naming convention (for ionic or molecular substances) to assign a name to each compound: **(a)** $TiCl_4$ and CaF_2, **(b)** ClF_3 and VF_3, **(c)** $SbCl_5$ and AlF_3.

8.47 Draw Lewis structures for the following: **(a)** SiH_4, **(b)** CO, **(c)** SF_2, **(d)** H_2SO_4 (H is bonded to O), **(e)** ClO_2^-, **(f)** NH_2OH.

8.49 **(a)** When talking about atoms in a Lewis structure, what is meant by the term *formal charge*? **(b)** Does the formal charge of an atom represent the actual charge on that atom? Explain. **(c)** How does the formal charge of an atom in a Lewis structure differ from the oxidation number of the atom?

8.51 Write Lewis structures that obey the octet rule for each of the following, and assign oxidation numbers and formal charges to each atom: **(a)** OCS, **(b)** $SOCl_2$ (S is bonded to the two Cl atoms and to the O), **(c)** BrO_3^-, **(d)** $HClO_2$ (H is bonded to O).

8.57 **(a)** Use the concept of resonance to explain why all six C—C bonds in benzene are equal in length. **(b)** Are the C—C bond lengths in benzene shorter than C—C single bonds? Are they shorter than C=C double bonds?

8.59 **(a)** State the octet rule. **(b)** Does the octet rule apply to ionic as well as to covalent compounds? Explain using examples as appropriate.

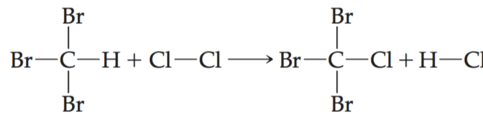
8.62 For elements in the third row of the periodic table and beyond, the octet rule is often not obeyed. What factors are usually cited to explain this fact?

8.63 Draw the Lewis structures for each of the following ions or molecules. Identify those that do not obey the octet rule, and explain why they do not: **(a)** SO_3^{2-}, **(b)** AlH_3, **(c)** N_3^-, **(d)** CH_2Cl_2, **(e)** SbF_5.

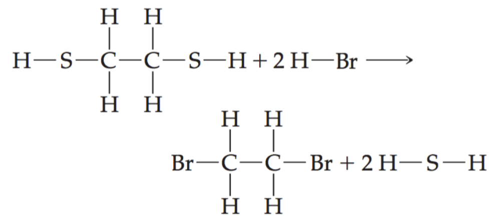
8.55 Predict the ordering of the C—O bond lengths in CO, CO_2, and CO_3^{2-}.

8.70 Using Table 8.4, estimate ΔH for the following gas-phase reactions:

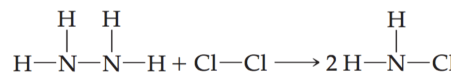
(a)



(b)



(c)



8.71 Using Table 8.4, estimate ΔH for each of the following reactions:

(a) $2\,CH_4(g) + O_2(g) \longrightarrow 2\,CH_3OH(g)$

(b) $H_2(g) + Br_2(g) \longrightarrow 2\,HBr(g)$

(c) $2\,H_2O_2(g) \longrightarrow 2\,H_2O(g) + O_2(g)$

8.73 Ammonia is produced directly from nitrogen and hydrogen by using the Haber process. The chemical reaction is

$$N_2(g) + 3\,H_2(g) \longrightarrow 2\,NH_3(g)$$

(a) Use Table 8.4 to estimate the enthalpy change for the reaction. Is it exothermic or endothermic? **(b)** Compare the enthalpy change you calculate in (a) to the true enthalpy change as obtained using ΔH_f° values.