Definitions

Chemical Bond; Chemical Formula; Ionic Bond; Ion; Isoelectronic Ions; Covalent Bond; Molecule; Structural Formula; Lewis Structure; Lone Pair; Bonding Pair; Octet Rule; Duet Rule

Questions

1. Predict whether each of the following types of matter will be bonded with ionic, covalent, or metallic bonds, and identify whether each will be composed of atoms, ions, or molecules of particles.
   (a) $P_2O_3$  
   (b) $CaCl_2$  
   (c) $Zn$  
   (d) $HBr$

2. Write the electron configuration notation and the electron dot notation for each:
   (a) $Te$ atom  
   (b) $Te^{2-}$ ion  
   (c) $V$ atom  
   (d) $V^{3+}$ ion

3. Arrange each of the following groups of atoms and/or ions in order of increasing size:
   (a) $F^-, Cl^-, Br^-, I^-$  
   (b) $S^{2-}, Cl^-, K^+, Ca^{2+}$

4. Write the electron dot notation for each ionic compound:
   (a) $AlCl_3$  
   (b) $K_2S$

5. Draw Lewis structures that obey the octet rule for each of the following molecules or ions:
   (a) $NH_3$  
   (b) $HBr$  
   (c) $SCl_2$  
   (d) $CF_4$
HOMEWORK 2B

Definitions

Bond Energy; Bond Length; Polyatomic Ion; Localized Electron Model; Electronegativity; Polar Covalent Bond

Questions

1. For each of the following diatomic molecules, (1) draw the Lewis structure, (2) identify the bond order of the bond in each molecule, (3) rank each molecule from lowest to highest bond energy, and (4) rank each bond from shortest to longest bond length:
   (a) P₂  (b) S₂  (c) Cl₂

2. Draw Lewis structures that obey the octet rule for each of the following molecules or ions, and identify the bond order of the bonds in each:
   (a) SiO₂  (b) PO₃⁻  (c) NO₂⁻

3. Predict which element in each of the following groups will have the highest electronegativity:
   (a) C, N  (b) Ge, Sn

4. Predict which bond will be the most polar: As–O or Sb–O

HOMEWORK 2C

Definitions

Formal Charge, Resonance

Questions

1. Draw Lewis structures that obey the octet rule for each of the following molecules or ions, and give the formal charge for each atom.
   (a) PF₃  (b) NH₂⁻  (c) CN⁻

2. Draw the best Lewis structures for each of the following molecules or ions by minimizing formal charges:
   (a) COF⁻ (C central)  (b) CO₂

3. Draw Lewis structures for each of the following molecules which have central atoms that do not obey the octet rule:
   (a) BeCl₂  (b) SeF₄

4. Draw the best Lewis structures for each of the following molecules or ions by minimizing formal charges:
   (a) PO₄³⁻  (b) ClO₃⁻  (c) NO₄³⁻

5. Have access to Handout 3 from the Class Web Site.
HOMEWORK 2D

Definitions

VSEPR Model

Questions

1. Draw the best Lewis structure for each of the following, and predict their shapes:
   (a) BeH$_2^{2-}$
   (b) SeCl$_2$
   (c) XeF$_2$
   (d) BrF$_5$

2. Although the VSEPR theory is correct in predicting that CH$_4$ is tetrahedral, NH$_3$ is trigonal pyramidal, and H$_2$O is bent, the HNH angle in NH$_3$ is only 107.3° and the HOH angle in H$_2$O is only 104.5°. Explain these deviations from the expected tetrahedral angle of 109.5°.

3. Have access to Handout 4 from the Class Web Site.

HOMEWORK 2E

Definitions

Dipolar

Questions

1. Draw the best Lewis structure for each of the following, predict the shape of each, and predict whether each is polar or nonpolar:
   (a) HCl
   (b) Br$_2$
   (c) CF$_4$
   (d) CHCl$_3$
   (e) SCl$_4$
   (f) XeF$_4$

HOMEWORK 2F

Definitions

Hybridization

Questions

1. A silicon atom can react with hydrogen to form silane, SiH$_4$.
   (a) Explain how the electrons must be arranged in the outer shell orbitals of silicon to make 4 bonds.
   (b) What type of hybrid orbitals must the silicon atom create to achieve this electron arrangement?
   (c) Name the bonds in the silane molecule.
**HOMEWORK 2G**

*Definitions*

Sigma Bond; Pi Bond

*Questions*

1. Draw the best Lewis structure for each of the following, give the hybridization of the central atom, predict the shape of each, and predict whether each is polar or nonpolar:
   
   (a) \( \text{OF}_2 \)  
   (b) \( \text{SO}_2 \)  
   (c) \( \text{BrF}_3 \)  
   (d) \( \text{KrOF}_4 \) (Kr central)

**HOMEWORK 2H**

*Definitions*

Hydrocarbon; Saturated; Unsaturated; Alkanes; Alkenes; Alkynes

*Questions*

1. For atoms with the following hybridizations, (1) sketch the geometry of the valence atomic orbitals of each atom, and (2) sketch the valence atomic orbitals of each atom, using lines to represent each orbital, as you would in a bond orbital model:
   
   (a) \( \text{sp} \)  
   (b) \( \text{sp}^2 \)  
   (c) \( \text{sp}^2 \) (rotated \( 90^\circ \) from your sketch in b)  
   (d) \( \text{sp}^3 \)  
   (e) \( \text{sp}^3 \text{d} \)  
   (f) \( \text{sp}^3 \text{d}^2 \)

2. Draw the bond orbital model and label all of the bonds in the following molecules:
   
   (a) \( \text{CH}_2\text{O} \)  
   (b) \( \text{HCN} \)  
   (c) \( \text{O}_3 \)

3. Give the number of sigma and pi bonds in the following molecule:

\[
\begin{array}{c}
\text{H} \\
\text{C=}
\end{array}
\begin{array}{c}
\text{H} \\
\text{H} \\
\text{H}
\end{array}
\begin{array}{c}
\text{C} \\
\text{=}
\end{array}
\begin{array}{c}
\text{N}.
\end{array}
\]
HOMEWORK 2I

Definitions

Molecular Orbitals; Sigma Molecular Orbitals; Bonding Molecular Orbitals; Antibonding Molecular Orbitals; Bond Order

Questions

1. Draw a picture of the molecular orbital that would be formed from the following combinations of atomic orbitals:
   (a) 1s + 1s
   (b) 1s − 1s

2. For each of the following diatomic species, (1) draw a molecular orbital energy level diagram, (2) write the electron configuration notation, (3) determine the bond order, and (4) determine if the species is paramagnetic or diamagnetic:
   (a) H₂⁺  
   (b) H₂  
   (c) H₂⁻

HOMEWORK 2J

Definitions

Pi Molecular Orbitals; Paramagnetism; Diamagnetism; Delocalized Pi System

Questions

1. For each of the following molecular orbitals, identify whether they are (1) bonding or antibonding molecular orbitals, (2) sigma or pi molecular orbitals, and (3) tell what atomic orbitals may have combined to form them:
   (a)  
   (b)  
   (c)  
   (d) 

2. Draw a molecular orbital energy level diagram for O₂.

3. For each of the following diatomic species, (1) write the electron configuration notation, (2) determine the bond order, (3) determine if the species is paramagnetic or diamagnetic, (4) indicate which one has the highest bond energy and which one has the lowest bond energy, and (5) indicate which one has the longest bond length and which one has the shortest bond length:
   (a) O₂  
   (b) O₂⁻  
   (c) O₂²⁻

4. You drew a bond orbital model for O₃ in Homework 2H that was incorrect. O₃ possesses resonance, therefore it must have a delocalized pi system. Redraw the correct bond orbital model for O₃ and label all of the bonds.
HOMEWORK 2K

Definitions

Empirical Formula; Molecular Formula

Questions

1. Determine the empirical formula of a compound of cobalt and oxygen that is 71.1% cobalt by mass.

2. A sample of urea contains 1.121 g of nitrogen, 0.161 g of hydrogen, 0.480 g of carbon, and 0.640 g of oxygen. Determine the empirical formula of urea.

3. A compound containing only sulfur and nitrogen is 69.9% sulfur by mass, and has a molar mass of 184 g/mol. Determine the empirical and molecular formulas of the compound.

4. A hydrocarbon is 85.6% carbon and 14.4% hydrogen by mass. If the molar mass of the compound is 85 ± 5 g/mol, determine its empirical and molecular formulas.

HOMEWORK 2R

1. Predict whether each of the following will be bonded with ionic, covalent, or metallic bonds:
   (a) Co          (b) CoS          (c) COS          (d) H₃AsO₄

2. Arrange the following sets of atoms in order of increasing electronegativities:
   (a) B, O, Ga    (b) S, O, F    (c) Tl, S, Ge

3. Predict which bond in each of the following pairs will be the most polar (the highest percentage ionic character):
   (a) C–F, Si–F  (b) As–F, Se–F

4. Arrange each of the following groups of atoms and/or ions in order of increasing size:
   (a) Ni²⁺, Pd²⁺, Pt²⁺  (b) Eu³⁺, Gd³⁺, Yb³⁺  (c) Cu, Cu⁺, Cu²⁺  (d) Te²⁻, I⁻, Cs⁺, Ba²⁺

5. Write the electron dot notation for each ionic compound:
   (a) Li₃N          (b) Ga₂O₃        (c) BaS          (d) RbOH

6. Draw Lewis structures for each of the following molecules or ions:
   (a) OCl₂         (b) CF₄           (c) NO₂⁻          (d) SF₆
   (e) BeH₂         (f) PF₅           (g) BH₃           (h) Br₃⁻
   (i) ClO₂⁻        (j) IF₃           (k) SO₃           (l) NF₃
   (m) SF₄          (n) XeF₄          (o) ClF₅          (p) OCN⁻ (C is central)

(continued on next page)
7. Give the formal charge for each atom from the molecules and ions in question 6 (a) to 6 (d).

8. Predict (1) the shape, (2) the polarity, and (3) the hybridization of the central atom, for each molecule or ion in question 6.

9. Draw Lewis structures that obey the octet rule for each of the following molecules or ions:
   (a) CO    (b) CO₂    (c) CO₃²⁻    (d) CH₃OH

10. For the carbon-oxygen bonds in the four species from question 9:
    (a) give their bond orders
    (b) arrange them from longest to shortest bond length
    (c) arrange them from highest to lowest bond energy

11. Draw bond-orbital-models for the four species from question 9, labeling all of the bonds

12. Give the number of σ and π bonds in the biacetyl molecule:

```
    H :O: :O: H
   /        \
H—C—C—C—C—H
  /        \
H     H
```

13. For each of the following diatomic molecules, (1) draw a molecular orbital energy level diagram, (2) write the electron configuration notation, (3) determine the bond order, and (4) predict if it is paramagnetic or diamagnetic:
   (a) H₂    (b) B₂    (c) O₂

14. For the molecules from question 13:
    (a) indicate which one has the highest bond energy and which one has the lowest bond energy
    (b) indicate which one has the longest bond length and which one has the shortest bond length

15. Draw a molecular orbital energy level diagram for BO.

16. For each of the following diatomic species, (1) write the electron configuration notation, (2) determine the bond order, (3) determine if the species is paramagnetic or diamagnetic, (4) indicate which one has the highest bond energy and which one has the lowest bond energy, and (5) indicate which one has the longest bond length and which one has the shortest bond length:
   (a) BO    (b) BO⁺    (c) BO⁻

17. Analysis of the active ingredient in photographic fixer shows that it contains 0.979 g sodium, 1.365 g sulfur and 1.021 g oxygen. Determine the empirical formula of the substance.

18. A compound that contains only nitrogen and oxygen is 30.4 % nitrogen by mass. If the molar mass of the compound is 92 g/mol, determine its empirical and molecular formulas.

19. Glucose is 40.0% carbon, 6.7% hydrogen, and 53.3% oxygen by mass. If glucose has a molar mass of about 180 g/mol, determine its molecular formula.

(continued on next page)
20. A mixture of 80. grams of potassium iodide and 10. grams of potassium chlorate is to be separated by crystallization. The solubility curves of the two compounds are shown below.

(a) The mixture is dissolved in 100 g of water and the temperature raised to 90°C. What are the solubilities of the two components at this temperature?

(b) Do both substances dissolve completely in the 100 g of water at 90°C?

(c) The mixture is cooled to 0°C. What are the solubilities of the two components at this temperature?

(d) Are the crystals that are formed at 0°C pure potassium iodide?

(e) What percentage of the potassium iodide from the original mixture have been collected as crystals?

21. A mixture of 80. grams of potassium iodide and 10. grams of potassium chlorate is to be separated by crystallization.

(a) The mixture is dissolved in 50. g of water and the temperature raised to 90°C. What are the solubilities of the two components at this temperature?

(b) Do both substances dissolve completely in the 50. g of water at 90°C?

(c) The mixture is cooled to 0°C. What are the solubilities of the two components at this temperature?

(d) Are the crystals that are formed at 0°C pure potassium iodide?

(e) What percentage of the potassium iodide from the original mixture have been collected as crystals?

(continued on next page)
22. The concentration of the yellow substance potassium chromate in an unknown solution was to be determined.

(a) What color wavelength will be the best to analyze the concentration of the potassium chromate?

(b) The absorbances of a series of standard potassium chromate solutions were measured with a wavelength of 457 nm in a 1.00 cm cuvet, and a calibration line was created using LoggerPro, which is showed below. If the absorbance of the unknown solution was found to be 0.375, determine the concentration of potassium chromate in the unknown solution.

(c) Calculate the extinction coefficient for potassium chromate at a wavelength of 457 nm.

(continued on next page)
23. Brilliant Blue FCF is often found in ice cream, canned processed peas, packet soups, bottled food colorings, icings, ice pops, blue raspberry flavored products, dairy products, sweets, and drinks, especially the liqueur blue curaçao. The concentration of Brilliant Blue FCF in blue curaçao was to be determined.

(a) What color wavelength will be the best to analyze the concentration of the Brilliant Blue FCF?

(b) The absorbances of a series of standard Brilliant Blue FCF solutions were measured with a wavelength of 627 nm in a 1.00 cm cuvet, and a calibration line was created using LoggerPro, which is showed below. If the absorbance of a sample of blue curaçao was found to be 0.441, determine the concentration of Brilliant Blue FCF in blue curaçao.

(c) The Acceptable Daily Intake (ADI) of Brilliant Blue FCF is 2.5 mg/kg of body weight/day. Use this information to calculate the number of shots a 60. kg person would need to ingest to receive the ADI of Brilliant Blue FCF. A shot is 1.0 fluid ounce.
HOMEWORK 2R ANSWERS

1. (a) metallic  (b) ionic  (c) covalent  (d) covalent

2. (a) Ga < B < O  (b) S < O < F  (c) Tl < Ge < S  (b) As–F

3. (a) Si–F

4. (a) Ni²⁺ < Pd²⁺ < Pt²⁺  (b) Yb³⁺ < Gd³⁺ < Eu³⁺  (c) Cu²⁺ < Cu⁺ < Cu  (d) Ba²⁺ < Cs⁺ < I⁻ < Te²⁻

5. (a)

\[ \text{Li}^+ \quad \text{Li}^+ \quad \text{Li}^+ \quad \text{N}^{-3} \]

(c)

\[ \text{Ba}^{2+} \quad \text{S}^{-2} \]

(b)

\[ \text{Ga}^{3+} \quad \text{Ga}^{3+} \quad \text{O}^{2-} \quad \text{O}^{2-} \quad \text{O}^{2-} \]

(d)

\[ \text{Rb}^+ \quad \text{O} \quad \text{H}^- \]

6. (a)

\[ \text{Cl}^- \quad \text{O} \quad \text{Cl}^- \]

(b)

\[ \text{F}^- \quad \text{C} \quad \text{F} \quad \text{F} \]

(c)

\[ \text{O} \quad \text{N} \quad \text{O}^- \quad \text{O}^- \]

(d)

\[ \text{S} \quad \text{O} \quad \text{F} \quad \text{F} \quad \text{F} \]

(e)

\[ \text{H} \quad \text{Be} \quad \text{H} \]

(f)

\[ \text{H} \quad \text{B} \quad \text{H} \]

(g)

\[ \text{Br} \quad \text{Br} \quad \text{Br} \quad \text{Br} \]

(h)

(i)

\[ \text{O} \quad \text{Cl} \quad \text{O}^- \quad \text{O} \]

(j)

\[ \text{F}^- \quad \text{F} \quad \text{F} \]

(k)

\[ \text{O} \quad \text{S} \quad \text{O} \quad \text{O} \]

(l)

\[ \text{F} \quad \text{N} \quad \text{F} \]

(m)

\[ \text{S} \quad \text{F} \quad \text{F} \]

(n)

\[ \text{Xe} \quad \text{F} \quad \text{F} \quad \text{F} \]

(o)

\[ \text{Cl} \quad \text{F} \quad \text{F} \quad \text{F} \]

(p)

\[ \text{O} \quad \text{C} \quad \text{N}^- \]

(continued on next page)
7. (a) \( O = 0, \text{Cl} = 0 \)  
   (c) \( N = 0, O = 0, -1 \)  
   (b) \( C = 0, F = 0 \)  
   (d) \( S = 0, F = 0 \)

8. (a) bent, 109.5°  
   (b) tetrahedral  
   (c) linear  
   (d) octahedral  
   (e) trigonal planar  
   (f) trigonal bipyramidal  
   (g) bent, 120°  
   (h) linear  
   (i) bent, 109.5°  
   (j) T-shape  
   (k) trigonal planar  
   (l) trigonal pyramidal  
   (m) see-saw  
   (n) square planar  
   (o) square pyramidal  
   (p) linear

9. (a)  
   (b)  
   (c)  
   (d)  
   (continued on next page)

10. (a) \( \text{CO} = 3, \text{CO}_2 = 2, \text{CO}_3^{2-} = 1/3, \text{CH}_3\text{OH} = 1 \)  
    (b) \( \text{CH}_3\text{OH} > \text{CO}_3^{2-} > \text{CO}_2 > \text{CO} \)  
    (c) \( \text{CO} > \text{CO}_2 > \text{CO}_3^{2-} > \text{CH}_3\text{OH} \)

11. (a)  
   (b)  
   (c)  
   (d)  
   (continued on next page)
12. there are 11 $\sigma$ bonds and 2 $\pi$ bonds

13. (a) $\sigma_{1s}^2$, $\sigma_{2s}^2$, $\sigma_{2p}^2$, $\pi_{2p}^4$, $\sigma_{2s}^*$, $\sigma_{2s}^*$

B.O. = 1

diamagnetic

(b) $\sigma_{2s}^2(\sigma_{2s}^*)^2(\pi_{2p}^4)^4(\sigma_{2p}^*^2)$

B.O. = 1

paramagnetic

(c) $\sigma_{2s}^2(\sigma_{2s}^*)^2(\pi_{2p}^4)^4(\sigma_{2p}^*^2)$

B.O. = 2

paramagnetic

14. (a) highest bond energy: $O_2$

(b) longest bond length: $B_2$

(lowest bond energy: $B_2$

(shortest bond length: $H_2$

(continued on next page)

15. 

16. (a) $\sigma_{2s}^h^2(\sigma_{2s}^*)^2(\pi_{2p}^h^4)(\sigma_{2p}^h)^1$

B.O. = $2\frac{1}{2}$

paramagnetic

(b) $\sigma_{2s}^h^2(\sigma_{2s}^*)^2(\pi_{2p}^h^4)$

B.O. = 2

diamagnetic

(lowest B.E.

(longest B.L.

(c) $\sigma_{2s}^h^2(\sigma_{2s}^*)^2(\pi_{2p}^h^4)(\sigma_{2p}^h)^2$

B.O. = 3

diamagnetic

(highest B.E.

(shortest B.L.

17. $Na_2S_2O_3$

18. $N_2O_4$

19. $C_6H_{12}O_6$

(continued on next page)
20. (a) 190. g KI, 70. g KClO₃ (b) yes
    (c) 40. g KI, 25 g KClO₃ (d) yes
    (e) 50% KI

21. (a) 95. g KI, 35. g KClO₃ (b) yes
    (c) 20. g KI, 12.5 g KClO₃ (d) yes
    (e) 75% KI

22. (a) violet (b) 27.0 mg/L (c) 0.0140 Lmg⁻¹cm⁻¹

23. (a) orange (b) 1.6 mg/oz (c) 94 shots per day