Assignment 10 – Solutions
Chapter 12: Quantum Mechanics and Atomic Theory
Chapter 13: Bonding General Concepts

Chapter 12: 86, 100, 118, 120

Chapter 12: 88, 94, 96, 122, 124; Chapter 13: 15, 22, 27

Chapter 13: 52, 54, 72, 74, 98

The Periodic Table and Periodic Properties

86. The ionization energy trend is the opposite of the radius trend; ionization energy (IE), in general, increases left to right across the periodic table and decreases from top to bottom of the periodic table.

a. Te < Se < S b. K < Ni < Br c. Ba < Si < F

d. Rb < Na < Be e. Sr < Se < Ne f. Fe < P < O

All follow the general ionization energy (IE) trend.

100. a. More favorable EA: C, Br, K, and Cl; the electron affinity trend is very erratic. N, Ar, and Mg have positive EA values (unfavorable) due to their electron configurations (see text for detailed explanation). F has a more positive EA value than expected from its position in the periodic table.

b. Higher IE: N, Ar, Mg, and F (follows the IE trend)

c. Larger size: C , Br, K, and Cl (follows the radius trend)

Additional Exercises

118. The general ionization energy trend says that ionization energy increases going left to right across the periodic table. However, one of the exceptions to this trend occurs between Groups 2A and 3A. Between these two groups, Group 3A elements usually have a lower ionization energy than Group 2A elements. Therefore, Al should have the lowest first ionization energy value, followed by Mg, with Si having the largest ionization energy. Looking at the values for the first ionization energy in the graph, the green plot is Al, the blue plot is Mg, and the red plot is Si.

Mg (the blue plot) is the element with the huge jump between I_2 and I_3. Mg has two valence electrons, so the third electron removed is an inner core electron. Inner core electrons are always much more difficult to remove than valence electrons since they are closer to the nucleus, on average, than the valence electrons.

120. a. $Se^{3+}(g) \rightarrow Se^{4+}(g) + e^-$ b. $S^-(g) + e^- \rightarrow S^{2-}(g)$ c. $Fe^{3+}(g) + e^- \rightarrow Fe^{2+}(g)$

d. $Mg(g) \rightarrow Mg^+(g) + e^-$ e. $Mg(s) \rightarrow Mg^+(s) + e^-$

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The Periodic Table and Periodic Properties

88. a. He b. Cl

c. Element 117 is the next halogen to be discovered (under At), element 119 is the next alkali metal to be discovered (under Fr), and element 120 is the next alkaline earth metal to be discovered (under Ra). From the general radius trend, the halogen (element 117) will be the smallest.

d. Si

e. Na^+; this ion has the fewest electrons compared to the other sodium species present. Na^+ has the smallest number of electron-electron repulsions, which makes it the smallest ion with the largest ionization energy.

94. The electron affinity trend is very erratic. In general, EA becomes more positive in going down a group, and EA becomes more negative from left to right across a period (with many exceptions).

a. I < Br < F < Cl; Cl is most exothermic (F is an exception).

b. N < O < F, F is most exothermic.

96. O; the electron-electron repulsions will be much more severe for $O^- + e^- \rightarrow O^{2-}$ than for $O + e^- \rightarrow O^-$.

Additional Exercises

122. All oxygen family elements have ns^2np^4 valence electron configurations, so this nonmetal is from the oxygen family.

a. 2 + 4 = 6 valence electrons.

b. O, S, Se, and Te are the nonmetals from the oxygen family (Po is a metal).

c. Because oxygen family nonmetals form -2 charged ions in ionic compounds, K_2X would be the predicted formula, where X is the unknown nonmetal.

d. From the size trend, this element would have a smaller radius than barium.

e. From the ionization energy trend, this element would have a smaller ionization energy than fluorine.

124. a. As we remove succeeding electrons, the electron being removed is closer to the nucleus, and there are fewer electrons left repelling it. The remaining electrons are more strongly attracted to the nucleus, and it takes more energy to remove these electrons.

b. Al: $1s^2 2s^2 2p^6 3s^2 3p^1$; for I_4, we begin removing an electron with $n = 2$. For I_3, we remove an electron with $n = 3$ (the last valence electron). In going from $n = 3$ to $n = 2$ there is a big jump in ionization energy because the $n = 2$ electrons are much closer to the nucleus on average than the $n = 3$ electrons. Since the $n = 2$ electrons are closer to the nucleus, they are held more tightly and require a much larger amount of energy to remove compared to the $n = 3$ electrons. In general, valence electrons are much easier to remove than inner core electrons.

c. Al^{4+}; The electron affinity for Al^{4+} is ΔH for the reaction:

$$Al^{4+}(g) + e^- \rightarrow Al^{3+}(g) \quad \Delta H = -I_4 = -11{,}600 \text{ kJ/mol}$$

d. The greater the number of electrons, the greater the size.

Size trend: $Al^{4+} < Al^{3+} < Al^{2+} < Al^+ < Al$

Chapter 13: 15, 22, 27

Chemical Bonds and Electronegativity

15. The general trends in electronegativity used in Exercises 13.13 and 13.14 are only rules of thumb. In this exercise we use experimental values of electronegativities and can begin to see several exceptions. The order of EN using Figure 13.3 is:

a. C (2.6) < N (3.0) < O (3.4) same as predicted

b. Se (2.6) = S (2.6) < Cl (3.2) different

c. Si (1.9) < Ge (2.0) = Sn (2.0) different

d. Tl (2.0) = Ge (2.0) < S (2.6) different

e. Rb (0.8) = K (0.8) < Na (0.9) different

f. Ga (1.8) < B (2.0) < O (3.4) same

Most polar bonds using actual EN values:

a. Si–F (Ge–F predicted)

b. P–Cl (same as predicted)

c. S–F (same as predicted)

d. Ti–Cl (same as predicted)

e. C–H (Sn–H predicted)

f. Al–Br (Tl–Br predicted)

Ionic Compounds

22. a. Mg^{2+}: $1s^2 2s^2 2p^6$

Sn^{2+}: $[Kr]5s^2 4d^{10}$

K^+: $1s^2 2s^2 2p^6 3s^2 3p^6$

Al^{3+}: $1s^2 2s^2 2p^6$

Tl^+: $[Xe]6s^2 4f^{14} 5d^{10}$

As^{3+}: $[Ar]4s^2 3d^{10}$

b. N^{3-}, O^{2-} and F^-: $1s^2 2s^2 2p^6$

Te^{2-}: $[Kr]5s^2 4d^{10} 5p^6$

c. Be^{2+}: $1s^2$

Rb^+: $[Ar]4s^2 3d^{10} 4p^6$

Ba^{2+}: $[Kr]5s^2 4d^{10} 5p^6$

Se^{2-}: $[Ar]4s^2 3d^{10} 4p^6$

I^-: $[Kr]5s^2 4d^{10} 5p^6$

27. a. Al^{3+} and S^{2-} are the expected ions. The formula of the compound would be Al_2S_3 (aluminum sulfide).

b. K^+ and N^{3-}; K_3N, potassium nitride

c. Mg^{2+} and Cl^-; $MgCl_2$, magnesium chloride

d. Cs^+ and Br^-; CsBr, cesium bromide

Challenge problem

a. The Pauli Principle states that each electron in a multi-electron atom must be described by a unique set of quantum numbers. Thus, for this alternative universe, the Pauli Exclusion Principle states that each orbital (*i.e.*, that which is defined by a given set of n, l, and m_l values) can contain a maximum of 3 electrons (*i.e.*, one with each possible value of m_s).

b.

H 1	He 2																									Li 3
Be 4	B 5	C 6																N 7	O 8	F 9	Ne 10	Na 11	Mg 12	Al 13	Si 14	P 15
S 16	Cl 17	Ar 18																K 19	Ca 20	Sc 21	Ti 22	V 23	Cr 24	Mn 25	Fe 26	Co 27
Ni 28	Cu 29	Zn 30	Ga 31	Ge 32	As 33	Se 34	Br 35	Kr 36	Rb 37	Sr 38	Y 39	Zr 40	Nb 41	Mo 42	Tc 43	Ru 44	Rh 45	Pd 46	Ag 47	Cd 48	In 49	Sn 50				

c. Sn: $1s^3\ 2s^3\ 2p^9\ 3s^3\ 3p^9\ 4s^3\ 3d^{15}\ 4p^5$

d i. Ga (Z = 31)

ii. Si (Z = 14)

iii. For a compound of formula $(X^{2+})(Y^-)_2$, possible cations include He^{2+}, B^{2+}, Cl^{2+}, and Cu^{2+}, and possible anions include Si^- and Fe^-. For a compound of formula $(X^{4+})(Y^{2-})_2$, possible cations include N^{4+}, K^{4+}, and Pd^{4+}, and possible anions include Al^{2-} and Mn^{2-}.

iv. Li, P, Co