CHAPTER 2

ATOMIC STRUCTURE AND INTERATOMIC BONDING

PROBLEM SOLUTIONS

Fundamental Concepts

Electrons in Atoms

2.1 *Cite the difference between atomic mass and atomic weight.*

Solution

Atomic mass is the mass of an individual atom, whereas atomic weight is the average (weighted) of the atomic masses of an atom's naturally occurring isotopes.

2.2 *Chromium has four naturally-occurring isotopes: 4.34% of* ^{50}*Cr, with an atomic weight of 49.9460 amu, 83.79% of* ^{52}*Cr, with an atomic weight of 51.9405 amu, 9.50% of* ^{53}*Cr, with an atomic weight of 52.9407 amu, and 2.37% of* ^{54}*Cr, with an atomic weight of 53.9389 amu. On the basis of these data, confirm that the average atomic weight of Cr is 51.9963 amu.*

Solution

The average atomic weight of silicon $(\overline{A}_{\mathrm{Cr}})$ is computed by adding fraction-of-occurrence/atomic weight products for the three isotopes. Thus

$$\overline{A}_{\mathrm{Cr}} = f_{^{50}\mathrm{Cr}} A_{^{50}\mathrm{Cr}} + f_{^{52}\mathrm{Cr}} A_{^{52}\mathrm{Cr}} + f_{^{53}\mathrm{Cr}} A_{^{53}\mathrm{Cr}} + f_{^{54}\mathrm{Cr}} A_{^{54}\mathrm{Cr}}$$

$$= (0.0434)(49.9460 \text{ amu}) + (0.8379)(51.9405 \text{ amu}) + (0.0950)(52.9407 \text{ amu}) + (0.0237)(53.9389 \text{ amu}) = 51.9963 \text{ amu}$$

2.3 *(a) How many grams are there in one amu of a material?*

(b) Mole, in the context of this book, is taken in units of gram-mole. On this basis, how many atoms are there in a pound-mole of a substance?

Solution

(a) In order to determine the number of grams in one amu of material, appropriate manipulation of the amu/atom, g/mol, and atom/mol relationships is all that is necessary, as

$$\# \text{ g/amu} = \left(\frac{1 \text{ mol}}{6.022 \times 10^{23} \text{ atoms}}\right)\left(\frac{1 \text{ g/mol}}{1 \text{ amu/atom}}\right)$$

$$= 1.66 \times 10^{-24} \text{ g/amu}$$

(b) Since there are 453.6 g/lb$_m$,

$$1 \text{ lb-mol} = (453.6 \text{ g/lb}_m)(6.022 \times 10^{23} \text{ atoms/g-mol})$$

$$= 2.73 \times 10^{26} \text{ atoms/lb-mol}$$

2.4 *(a) Cite two important quantum-mechanical concepts associated with the Bohr model of the atom.*

(b) Cite two important additional refinements that resulted from the wave-mechanical atomic model.

Solution

(a) Two important quantum-mechanical concepts associated with the Bohr model of the atom are (1) that electrons are particles moving in discrete orbitals, and (2) electron energy is quantized into shells.

(b) Two important refinements resulting from the wave-mechanical atomic model are (1) that electron position is described in terms of a probability distribution, and (2) electron energy is quantized into both shells and subshells--each electron is characterized by four quantum numbers.

2.5 *Relative to electrons and electron states, what does each of the four quantum numbers specify?*

Solution

The n quantum number designates the electron shell.

The l quantum number designates the electron subshell.

The m_l quantum number designates the number of electron states in each electron subshell.

The m_s quantum number designates the spin moment on each electron.

2.6 *Allowed values for the quantum numbers of electrons are as follows:*

$$n = 1, 2, 3, \ldots$$

$$l = 0, 1, 2, 3, \ldots, n-1$$

$$m_l = 0, \pm 1, \pm 2, \pm 3, \ldots, \pm l$$

$$m_s = \pm\frac{1}{2}$$

The relationships between n and the shell designations are noted in Table 2.1. Relative to the subshells,

l = 0 corresponds to an s subshell

l = 1 corresponds to a p subshell

l = 2 corresponds to a d subshell

l = 3 corresponds to an f subshell

For the K shell, the four quantum numbers for each of the two electrons in the 1s state, in the order of nlm_lm_s*, are* $100(\frac{1}{2})$ *and* $100(-\frac{1}{2})$*. Write the four quantum numbers for all of the electrons in the L and M shells, and note which correspond to the s, p, and d subshells.*

<u>Solution</u>

For the *L* state, $n = 2$, and eight electron states are possible. Possible l values are 0 and 1, while possible m_l values are 0 and ±1; and possible m_s values are $\pm\frac{1}{2}$. Therefore, for the *s* states, the quantum numbers are $200(\frac{1}{2})$ and $200(-\frac{1}{2})$. For the *p* states, the quantum numbers are $210(\frac{1}{2})$, $210(-\frac{1}{2})$, $211(\frac{1}{2})$, $211(-\frac{1}{2})$, $21(-1)(\frac{1}{2})$, and $21(-1)(-\frac{1}{2})$.

For the *M* state, $n = 3$, and 18 states are possible. Possible l values are 0, 1, and 2; possible m_l values are 0, ±1, and ±2; and possible m_s values are $\pm\frac{1}{2}$. Therefore, for the *s* states, the quantum numbers are $300(\frac{1}{2})$, $300(-\frac{1}{2})$, for the *p* states they are $310(\frac{1}{2})$, $310(-\frac{1}{2})$, $311(\frac{1}{2})$, $311(-\frac{1}{2})$, $31(-1)(\frac{1}{2})$, and $31(-1)(-\frac{1}{2})$; for the *d* states they are $320(\frac{1}{2})$, $320(-\frac{1}{2})$, $321(\frac{1}{2})$, $321(-\frac{1}{2})$, $32(-1)(\frac{1}{2})$, $32(-1)(-\frac{1}{2})$, $322(\frac{1}{2})$, $322(-\frac{1}{2})$, $32(-2)(\frac{1}{2})$, and $32(-2)(-\frac{1}{2})$.

2.7 *Give the electron configurations for the following ions:* Fe^{3+}, Ga^{3+}, Cr^{+}, Ca^{2+}, Na^{-}, *and* S^{2-}.

Solution

The electron configurations for the ions are determined using Table 2.2 (and Figure 2.6).

Fe^{3+}: From Table 2.2, the electron configuration for an atom of iron is $1s^22s^22p^63s^23p^63d^64s^2$. In order to become an ion with a plus three charge, it must lose three electrons—in this case the two 4*s* and one 3d. Thus, the electron configuration for an Fe^{3+} ion is $1s^22s^22p^63s^23p^63d^5$.

Ga^{3+}: From Table 2.2, the electron configuration for an atom of gallium is $1s^22s^22p^63s^23p^63d^{10}4s^24p^1$. In order to become an ion with a plus three charge, it must lose three electrons—in this case two 4*s* and the one 4*p*. Thus, the electron configuration for an Ga^{3+} ion is $1s^22s^22p^63s^23p^63d^{10}$.

Cr^{+}: From Table 2.2, the electron configuration for an atom of chromium is $1s^22s^22p^63s^23p^63d^54s^1$. In order to become an ion with a plus one charge, it must lose one electron—in this case the 4*s*. Thus, the electron configuration for a Cr^{+} ion is $1s^22s^22p^63s^23p^63d^5$.

Ca^{2+}: From Table 2.2, the electron configuration for an atom of calcium is $1s^22s^22p^63s^23p^64s^2$. In order to become an ion with a plus two charge, it must lose two electrons—in this case the two 4*s*. Thus, the electron configuration for a Ca^{2+} ion is $1s^22s^22p^63s^23p^6$.

Na^{-}: From Table 2.2, the electron configuration for an atom of sodium is $1s^22s^22p^63s^1$. In order to become an ion with a minus one charge, it must acquire one electron—in this case another 3s. Thus, the electron configuration for a Na^{-} ion is $1s^22s^22p^63s^2$.

S^{2-}: From Table 2.2, the electron configuration for an atom of sulfur is $1s^22s^22p^63s^23p^4$. In order to become an ion with a minus two charge, it must acquire two electrons—in this case another two 3*p*. Thus, the electron configuration for an S^{2-} ion is $1s^22s^22p^63s^23p^6$.

2.8 *Sodium chloride (NaCl) exhibits predominantly ionic bonding. The* Na^+ *and* Cl^- *ions have electron structures that are identical to which two inert gases?*

Solution

The Na^+ ion is just a sodium atom that has lost one electron; therefore, it has an electron configuration the same as neon (Figure 2.6).

The Cl^- ion is a chlorine atom that has acquired one extra electron; therefore, it has an electron configuration the same as argon.

The Periodic Table

2.9 *With regard to electron configuration, what do all the elements in Group VIIA of the periodic table have in common?*

Solution

Each of the elements in Group VIIA has five *p* electrons.

2.10 *To what group in the periodic table would an element with atomic number 114 belong?*

Solution

From the periodic table (Figure 2.6) the element having atomic number 114 would belong to group IVA. According to Figure 2.6, Ds, having an atomic number of 110 lies below Pt in the periodic table and in the right-most column of group VIII. Moving four columns to the right puts element 114 under Pb and in group IVA.

2.11 *Without consulting Figure 2.6 or Table 2.2, determine whether each of the electron configurations given below is an inert gas, a halogen, an alkali metal, an alkaline earth metal, or a transition metal. Justify your choices.*

(a) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7 4s^2$

(b) $1s^2 2s^2 2p^6 3s^2 3p^6$

(c) $1s^2 2s^2 2p^5$

(d) $1s^2 2s^2 2p^6 3s^2$

(e) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^2$

(f) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

Solution

(a) The $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7 4s^2$ electron configuration is that of a transition metal because of an incomplete *d* subshell.

(b) The $1s^2 2s^2 2p^6 3s^2 3p^6$ electron configuration is that of an inert gas because of filled 3*s* and 3*p* subshells.

(c) The $1s^2 2s^2 2p^5$ electron configuration is that of a halogen because it is one electron deficient from having a filled *L* shell.

(d) The $1s^2 2s^2 2p^6 3s^2$ electron configuration is that of an alkaline earth metal because of two *s* electrons.

(e) The $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^2$ electron configuration is that of a transition metal because of an incomplete *d* subshell.

(f) The $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$ electron configuration is that of an alkali metal because of a single *s* electron.

2.12 *(a) What electron subshell is being filled for the rare earth series of elements on the periodic table?*

(b) What electron subshell is being filled for the actinide series?

Solution

(a) The 4*f* subshell is being filled for the rare earth series of elements.

(b) The 5*f* subshell is being filled for the actinide series of elements.

Bonding Forces and Energies

2.13 *Calculate the force of attraction between a* K^+ *and an* O^{2-} *ion the centers of which are separated by a distance of 1.5 nm.*

Solution

The attractive force between two ions F_A is just the derivative with respect to the interatomic separation of the attractive energy expression, Equation 2.8, which is just

$$F_A = \frac{dE_A}{dr} = \frac{d\left(-\frac{A}{r}\right)}{dr} = \frac{A}{r^2}$$

The constant A in this expression is defined in footnote 3. Since the valences of the K^+ and O^{2-} ions (Z_1 and Z_2) are +1 and -2, respectively, $Z_1 = 1$ and $Z_2 = 2$, then

$$F_A = \frac{(Z_1 e)(Z_2 e)}{4\pi\varepsilon_0 r^2}$$

$$= \frac{(1)(2)\left(1.602 \times 10^{-19}\ \mathrm{C}\right)^2}{(4)(\pi)\left(8.85 \times 10^{-12}\ \mathrm{F/m}\right)\left(1.5 \times 10^{-9}\ \mathrm{m}\right)^2}$$

$$= 2.05 \times 10^{-10}\ \mathrm{N}$$

2.14 *The net potential energy between two adjacent ions,* E_N*, may be represented by the sum of Equations 2.8 and 2.9; that is,*

$$E_N = -\frac{A}{r} + \frac{B}{r^n}$$

Calculate the bonding energy E_0 *in terms of the parameters A, B, and n using the following procedure:*

1. Differentiate E_N *with respect to r, and then set the resulting expression equal to zero, since the curve of* E_N *versus r is a minimum at* E_0*.*

2. Solve for r in terms of A, B, and n, which yields r_0*, the equilibrium interionic spacing.*

3. Determine the expression for E_0 *by substitution of* r_0 *into Equation 2.11.*

Solution

(a) Differentiation of Equation 2.11 yields

$$\frac{dE_N}{dr} = \frac{d\left(-\frac{A}{r}\right)}{dr} + \frac{d\left(\frac{B}{r^n}\right)}{dr}$$

$$= \frac{A}{r^{(1+1)}} - \frac{nB}{r^{(n+1)}} = 0$$

(b) Now, solving for r (= r_0)

$$\frac{A}{r_0^2} = \frac{nB}{r_0^{(n+1)}}$$

or

$$r_0 = \left(\frac{A}{nB}\right)^{1/(1-n)}$$

(c) Substitution for r_0 into Equation 2.11 and solving for E (= E_0)

$$E_0 = -\frac{A}{r_0} + \frac{B}{r_0^n}$$

$$= -\frac{A}{\left(\frac{A}{nB}\right)^{1/(1-n)}} + \frac{B}{\left(\frac{A}{nB}\right)^{n/(1-n)}}$$

2.15 *For a* K^+*–*Cl^- *ion pair, attractive and repulsive energies* E_A *and* E_R*, respectively, depend on the distance between the ions r, according to*

$$E_A = -\frac{1.436}{r}$$

$$E_R = \frac{5.8 \times 10^{-6}}{r^9}$$

For these expressions, energies are expressed in electron volts per K^+*–*Cl^- *pair, and r is the distance in nanometers. The net energy* E_N *is just the sum of the two expressions above.*

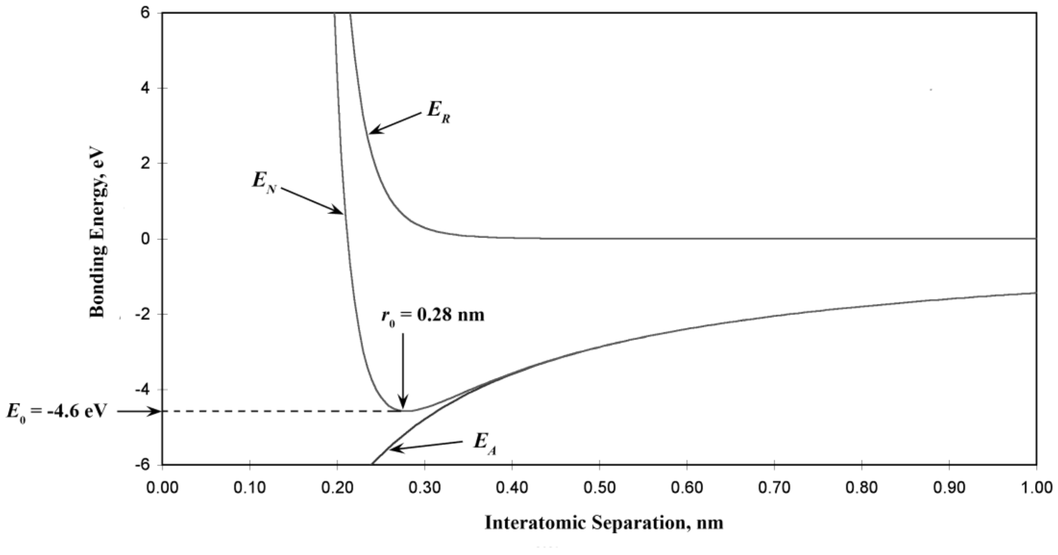
(a) Superimpose on a single plot E_N*,* E_R*, and* E_A *versus r up to 1.0 nm.*

(b) On the basis of this plot, determine (i) the equilibrium spacing r_0 *between the* K^+ *and* Cl^- *ions, and (ii) the magnitude of the bonding energy* E_0 *between the two ions.*

(c) Mathematically determine the r_0 *and* E_0 *values using the solutions to Problem 2.14, and compare these with the graphical results from part (b).*

Solution

(a) Curves of E_A, E_R, and E_N are shown on the plot below.



(b) From this plot

r_0 = 0.28 nm

E_0 = – 4.6 eV

(c) From Equation 2.11 for E_N

$A = 1.436$

$B = 5.86 \times 10^{-6}$

$n = 9$

Thus,

$$r_0 = \left(\frac{A}{nB}\right)^{1/(1\,-\,n)}$$

$$= \left[\frac{1.436}{(8)(5.86\ \times\ 10^{-6})}\right]^{1/(1\,-\,9)} = 0.279\ \text{nm}$$

and

$$E_0 = -\frac{A}{\left(\frac{A}{nB}\right)^{1/(1\,-\,n)}} + \frac{B}{\left(\frac{A}{nB}\right)^{n/(1\,-\,n)}}$$

$$= -\frac{1.436}{\left[\frac{1.436}{(9)(5.86\times10^{-6})}\right]^{1/(1\,-\,9)}} + \frac{5.86\ \times\ 10^{-6}}{\left[\frac{1.436}{(9)(5.86\times10^{-6})}\right]^{9/(1\,-\,9)}}$$

$$= -\,4.57\ \text{eV}$$

2.16 *Consider a hypothetical* X^+-Y^- *ion pair for which the equilibrium interionic spacing and bonding energy values are 0.35 nm and -6.13 eV, respectively. If it is known that n in Equation 2.11 has a value of 10, using the results of Problem 2.14, determine explicit expressions for attractive and repulsive energies* E_A *and* E_R *of Equations 2.8 and 2.9.*

Solution

This problem gives us, for a hypothetical X^+-Y^- ion pair, values for r_0 (0.35 nm), E_0 (– 6.13 eV), and *n* (10), and asks that we determine explicit expressions for attractive and repulsive energies of Equations 2.8 and 2.9. In essence, it is necessary to compute the values of *A* and *B* in these equations. Expressions for r_0 and E_0 in terms of *n*, *A*, and *B* were determined in Problem 2.14, which are as follows:

$$r_0 = \left(\frac{A}{nB}\right)^{1/(1\ -\ n)}$$

$$E_0 = -\frac{A}{\left(\frac{A}{nB}\right)^{1/(1\ -\ n)}} + \frac{B}{\left(\frac{A}{nB}\right)^{n/(1\ -\ n)}}$$

Thus, we have two simultaneous equations with two unknowns (viz. *A* and *B*). Upon substitution of values for r_0 and E_0 in terms of *n*, these equations take the forms

$$0.35\text{ nm} = \left(\frac{A}{10B}\right)^{1/(1\ -\ 10)} = \left(\frac{A}{10B}\right)^{-1/9}$$

and

$$-6.13\text{ eV} = -\frac{A}{\left(\frac{A}{10B}\right)^{1/(1-10)}} + \frac{B}{\left(\frac{A}{10B}\right)^{10/(1-10)}}$$

$$= -\frac{A}{\left(\frac{A}{10B}\right)^{-1/9}} + \frac{B}{\left(\frac{A}{10B}\right)^{-10/9}}$$

We now want to solve these two equations simultaneously for values of *A* and *B*. From the first of these two equations, solving for *A*/8*B* leads to

$$\frac{A}{10B} = (0.35 \text{ nm})^{-9}$$

Furthermore, from the above equation the *A* is equal to

$$A = 10B(0.35 \text{ nm})^{-9}$$

When the above two expressions for *A*/10*B* and *A* are substituted into the above expression for E_0 (- 6.13 eV), the following results

$$-6.13 \text{ eV} = = -\frac{A}{\left(\dfrac{A}{10B}\right)^{-1/9}} + \frac{B}{\left(\dfrac{A}{10B}\right)^{-10/9}}$$

$$= -\frac{10B(0.35 \text{ nm})^{-9}}{\left[(0.35 \text{ nm})^{-9}\right]^{-1/9}} + \frac{B}{\left[(0.35 \text{ nm})^{-9}\right]^{-10/9}}$$

$$= -\frac{10B(0.35 \text{ nm})^{-9}}{0.35 \text{ nm}} + \frac{B}{(0.35 \text{ nm})^{10}}$$

Or

$$-6.13 \text{ eV} = = -\frac{10B}{(0.35 \text{ nm})^{10}} + \frac{B}{(0.35 \text{ nm})^{10}} = -\frac{9B}{(0.35 \text{ nm})^{10}}$$

Solving for *B* from this equation yields

$$B = 1.88 \times 10^{-5} \text{ eV-nm}^{10}$$

Furthermore, the value of *A* is determined from one of the previous equations, as follows:

$$A = 10B(0.35 \text{ nm})^{-9} = (10)\left(1.88 \times 10^{-5} \text{ eV-nm}^{10}\right)(0.35 \text{ nm})^{-9}$$

$$= 2.39 \text{ eV-nm}$$

Thus, Equations 2.8 and 2.9 become

$$E_A = -\frac{2.39}{r}$$

$$E_R = \frac{1.88 \times 10^{-5}}{r^{10}}$$

Of course these expressions are valid for r and E in units of nanometers and electron volts, respectively.

2.17 *The net potential energy E_N between two adjacent ions is sometimes represented by the expression*

$$E_N = -\frac{C}{r} + D\exp\left(-\frac{r}{\rho}\right) \tag{2.12}$$

in which r is the interionic separation and C, D, and ρ are constants whose values depend on the specific material.

(a) Derive an expression for the bonding energy E_0 in terms of the equilibrium interionic separation r_0 and the constants D and ρ using the following procedure:

1. Differentiate E_N with respect to r, and set the resulting expression equal to zero.

2. Solve for C in terms of D, ρ, and r_0.

3. Determine the expression for E_0 by substitution for C in Equation 2.12.

(b) Derive another expression for E_0 in terms of r_0, C, and ρ using a procedure analogous to the one outlined in part (a).

Solution

(a) Differentiating Equation 2.12 with respect to *r* yields

$$\frac{dE}{dr} = \frac{d\left(-\frac{C}{r}\right)}{dr} - \frac{d\left[D\ \exp\left(-\frac{r}{\rho}\right)\right]}{dr}$$

$$= \frac{C}{r^2} - \frac{De^{-r/\rho}}{\rho}$$

At $r = r_0$, $dE/dr = 0$, and

$$\frac{C}{r_0^2} = \frac{De^{-(r_0/\rho)}}{\rho} \tag{2.12b}$$

Solving for *C* and substitution into Equation 2.12 yields an expression for E_0 as

$$E_0 = De^{-(r_0/\rho)}\left(1 - \frac{r_0}{\rho}\right)$$

(b) Now solving for *D* from Equation 2.12b above yields

$$D = \frac{C\rho\ e^{(r_0/\rho)}}{r_0^2}$$

Substitution of this expression for D into Equation 2.12 yields an expression for E_0 as

$$E_0 = \frac{C}{r_0}\left(\frac{\rho}{r_0} - 1\right)$$

Primary Interatomic Bonds

2.18 *(a) Briefly cite the main differences between ionic, covalent, and metallic bonding.*

(b) State the Pauli exclusion principle.

Solution

(a) The main differences between the various forms of primary bonding are:

Ionic--there is electrostatic attraction between oppositely charged ions.

Covalent--there is electron sharing between two adjacent atoms such that each atom assumes a stable electron configuration.

Metallic--the positively charged ion cores are shielded from one another, and also "glued" together by the sea of valence electrons.

(b) The Pauli exclusion principle states that each electron state can hold no more than two electrons, which must have opposite spins.

2.19 *Compute the percents ionic character of the interatomic bonds for the following compounds:* TiO_2*, ZnTe, CsCl, InSb, and* $MgCl_2$*.*

Solution

The percent ionic character is a function of the electron negativities of the ions X_A and X_B according to Equation 2.10. The electronegativities of the elements are found in Figure 2.7.

For TiO_2, X_{Ti} = 1.5 and X_O = 3.5, and therefore,

$$\%IC = \left[1 - e^{(-0.25)(3.5-1.5)^2}\right] \times 100 = 63.2\%$$

For ZnTe, X_{Zn} = 1.6 and X_{Te} = 2.1, and therefore,

$$\%IC = \left[1 - e^{(-0.25)(2.1-1.6)^2}\right] \times 100 = 6.1\%$$

For CsCl, X_{Cs} = 0.7 and X_{Cl} = 3.0, and therefore,

$$\%IC = \left[1 - e^{(-0.25)(3.0-0.7)^2}\right] \times 100 = 73.4\%$$

For InSb, X_{In} = 1.7 and X_{Sb} = 1.9, and therefore,

$$\%IC = \left[1 - e^{(-0.25)(1.9-1.7)^2}\right] \times 100 = 1.0\%$$

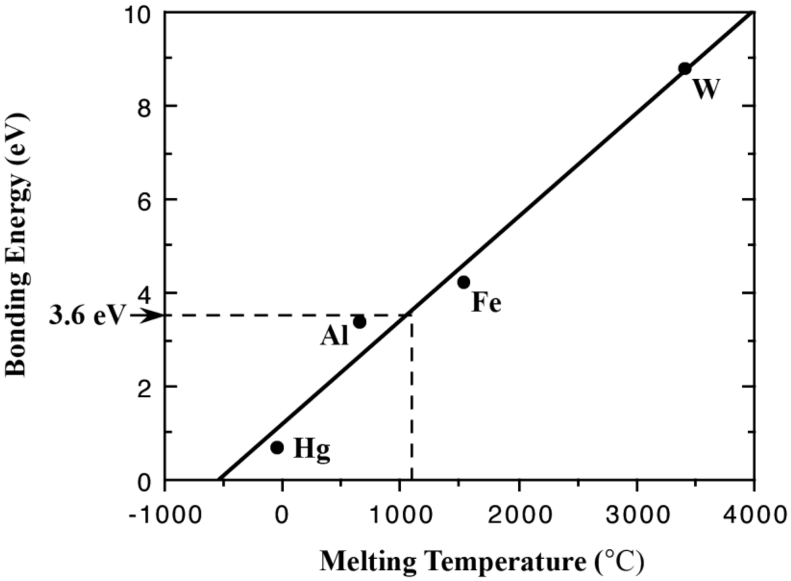
For $MgCl_2$, X_{Mg} = 1.2 and X_{Cl} = 3.0, and therefore,

$$\%IC = \left[1 - e^{(-0.25)(3.0-1.2)^2}\right] \times 100 = 55.5\%$$

2.20 *Make a plot of bonding energy versus melting temperature for the metals listed in Table 2.3. Using this plot, approximate the bonding energy for copper, which has a melting temperature of 1084°C.*

Solution

Below is plotted the bonding energy versus melting temperature for these four metals. From this plot, the bonding energy for copper (melting temperature of 1084°C) should be approximately 3.6 eV. The experimental value is 3.5 eV.



2.21 *Using Table 2.2, determine the number of covalent bonds that are possible for atoms of the following elements: germanium, phosphorus, selenium, and chlorine.*

Solution

For germanium, having the valence electron structure $4s^2 4p^2$, N' = 4; thus, there are 8 – N' = 4 covalent bonds per atom.

For phosphorus, having the valence electron structure $3s^2 3p^3$, N' = 5; thus, there is 8 – N' = 3 covalent bonds per atom.

For selenium, having the valence electron structure $4s^2 4p^4$, N' = 6; thus, there are 8 – N' = 2 covalent bonds per atom.

For chlorine, having the valence electron structure $3s^2 3p^5$, N' = 7; thus, there are 8 – N' = 1 covalent bond per atom.

2.22 *What type(s) of bonding would be expected for each of the following materials: brass (a copper-zinc alloy), rubber, barium sulfide (BaS), solid xenon, bronze, nylon, and aluminum phosphide (AlP)?*

Solution

For brass, the bonding is metallic since it is a metal alloy.

For rubber, the bonding is covalent with some van der Waals. (Rubber is composed primarily of carbon and hydrogen atoms.)

For BaS, the bonding is predominantly ionic (but with some covalent character) on the basis of the relative positions of Ba and S in the periodic table.

For solid xenon, the bonding is van der Waals since xenon is an inert gas.

For bronze, the bonding is metallic since it is a metal alloy (composed of copper and tin).

For nylon, the bonding is covalent with perhaps some van der Waals. (Nylon is composed primarily of carbon and hydrogen.)

For AlP the bonding is predominantly covalent (but with some ionic character) on the basis of the relative positions of Al and P in the periodic table.

Secondary Bonding or van der Waals Bonding

2.23 *Explain why hydrogen fluoride (HF) has a higher boiling temperature than hydrogen chloride (HCl) (19.4 vs. –85°C), even though HF has a lower molecular weight.*

Solution

The intermolecular bonding for HF is hydrogen, whereas for HCl, the intermolecular bonding is van der Waals. Since the hydrogen bond is stronger than van der Waals, HF will have a higher melting temperature.

Fundamentals of Engineering Questions and Problems

2.1FE *The chemical composition of the repeat unit for nylon 6,6 is given by the formula* $C_{12}H_{22}N_2O_2$. *Atomic weights for the constituent elements are* $A_C = 12$, $A_H = 1$, $A_N = 14$, *and* $A_O = 16$. *According to this chemical formula (for nylon 6,6), the percent (by weight) of carbon in nylon 6,6 is most nearly:*

(A) 31.6%

(B) 4.3%

(C) 14.2%

(D) 63.7%

Solution

The total atomic weight of one repeat unit of nylon 6,6, A_{total}, is calculated as

$$A_{\text{total}} = (12\text{ atoms})(A_C) + (22\text{ atoms})(A_H) + (2\text{ atoms})(A_N) + (2\text{ atoms})(A_O)$$

$$= (12\text{ atoms})(12\text{ g/mol}) + (22\text{ atoms})(1\text{ g/mol}) + (2\text{ atoms})(14\text{ g/mol}) + (2\text{ atoms})(16\text{ g/mol}) = 226\text{ g/mol}$$

Therefore the percent by weight of carbon is calculated as

$$\text{C(wt\%)} = \frac{(12\text{ atoms})(A_C)}{A_{\text{total}}} \times 100$$

$$= \frac{(12\text{ atoms})(12\text{ g/mol})}{226\text{ g/mol}} \times 100 = 63.7\%$$

which is answer D.

2.2FE *Which of the following electron configurations is for an inert gas?*

(A) $1s^2 2s^2 2p^6 3s^2 3p^6$
(B) $1s^2 2s^2 2p^6 3s^2$
(C) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
(D) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^2$

Solution

The correct answer is A. The $1s^2 2s^2 2p^6 3s^2 3p^6$ electron configuration is that of an inert gas because of filled $3s$ and $3p$ subshells.

2.3FE *What type(s) of bonding would be expected for bronze (a copper-tin alloy)?*

(A) ionic bonding

(B) metallic bonding

(C) covalent bonding with some van der Waals bonding

(D) van der Waals bonding

Solution

The correct answer is B. For bronze, the bonding is metallic since it is a metal alloy.

2.4FE *What type(s) of bonding would be expected for rubber?*

(A) ionic bonding

(B) metallic bonding

(C) covalent bonding with some van der Waals bonding

(D) van der Waals bonding

Solution

The correct answer is C. For rubber, the bonding is covalent with some van der Waals bonding. (Rubber is composed primarily of carbon and hydrogen atoms.)