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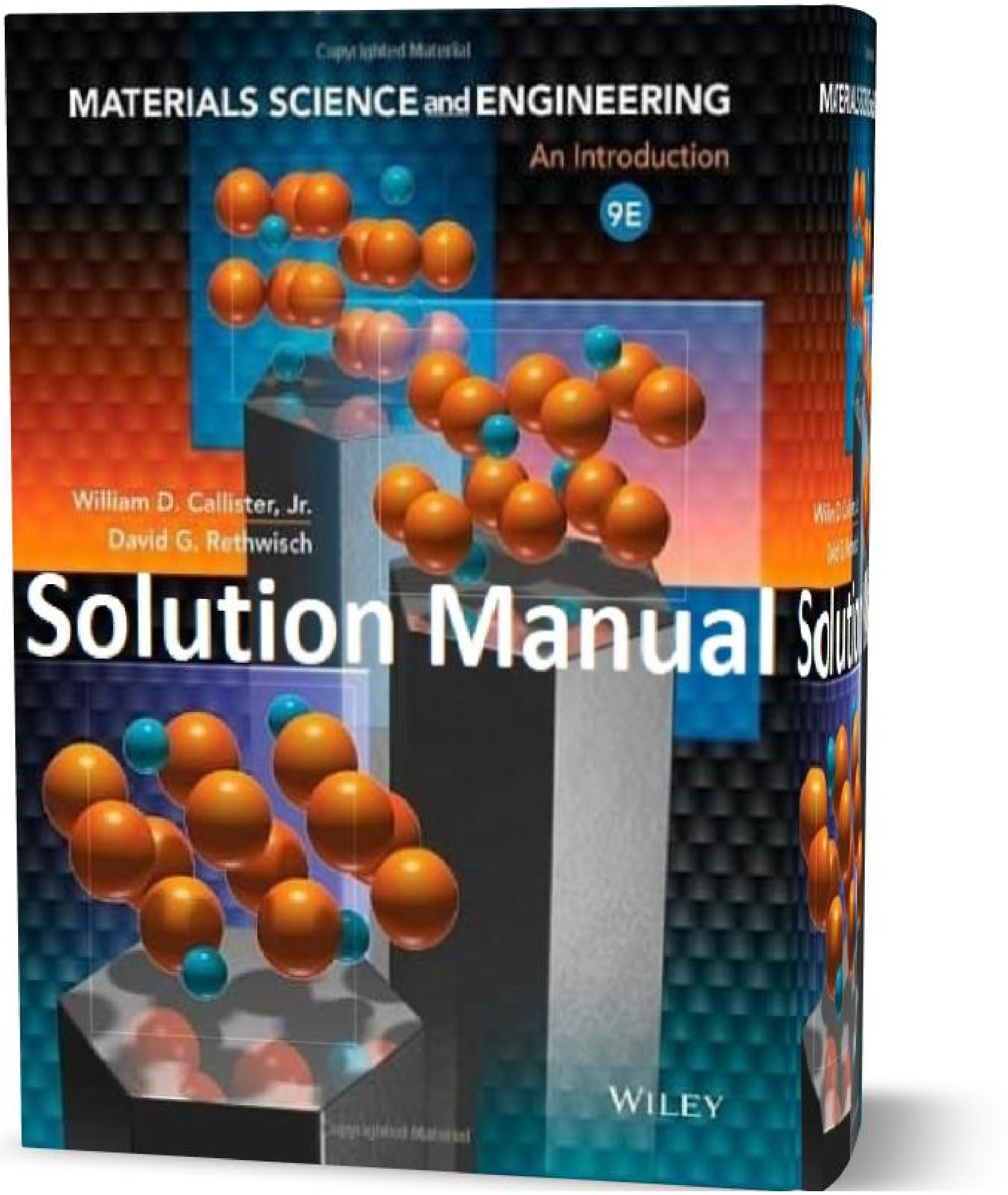

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CHAPTER 2

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.

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2.2 *Silicon has three naturally occurring isotopes: 92.23% of* ^{28}Si*, with an atomic weight of 27.9769 amu, 4.68% of* ^{29}Si*, with an atomic weight of 28.9765 amu, and 3.09% of* ^{30}Si*, with an atomic weight of 29.9738 amu. On the basis of these data, confirm that the average atomic weight of Si is 28.0854 amu.*

Solution

The average atomic weight of silicon $(\bar{A}_{\mathrm{Si}})$ is computed by adding fraction-of-occurrence/atomic weight products for the three isotopes—i.e., using Equation 2.2. (Remember: fraction of occurrence is equal to the percent of occurrence divided by 100.) Thus

$$\bar{A}_{\mathrm{Si}} = f_{^{28}\mathrm{Si}} A_{^{28}\mathrm{Si}} + f_{^{29}\mathrm{Si}} A_{^{29}\mathrm{Si}} + f_{^{30}\mathrm{Si}} A_{^{30}\mathrm{Si}}$$

$$= (0.9223)(27.9769) + (0.0468)(28.9765) + (0.0309)(29.9738) = 28.0854$$

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2.3 *Zinc has five naturally occurring isotopes: 48.63% of* ^{64}*Zn with an atomic weight of 63.929 amu; 27.90% of* ^{66}*Zn with an atomic weight of 65.926 amu; 4.10% of* ^{67}*Zn with an atomic weight of 66.927 amu; 18.75% of* ^{68}*Zn with an atomic weight of 67.925 amu; and 0.62% of* ^{70}*Zn with an atomic weight of 69.925 amu. Calculate the average atomic weight of Zn.*

Solution

The average atomic weight of zinc $\bar{A}_{\mathrm{Zn}}$ is computed by adding fraction-of-occurrence—atomic weight products for the five isotopes—i.e., using Equation 2.2. (Remember: fraction of occurrence is equal to the percent of occurrence divided by 100.) Thus

$$\bar{A}_{\mathrm{Zn}} = f_{^{64}\mathrm{Zn}} A_{^{64}\mathrm{Zn}} + f_{^{66}\mathrm{Zn}} A_{^{66}\mathrm{Zn}} + f_{^{67}\mathrm{Zn}} A_{^{67}\mathrm{Zn}} + f_{^{68}\mathrm{Zn}} A_{^{68}\mathrm{Zn}} + f_{^{70}\mathrm{Zn}} A_{^{70}\mathrm{Zn}}$$

Including data provided in the problem statement we solve for $\bar{A}_{\mathrm{Zn}}$ as

$$\bar{A}_{\mathrm{Zn}} = (0.4863)(63.929\text{ amu}) + (0.2790)(65.926\text{ amu})$$

$$+ (0.0410)(66.927\text{ amu}) + (0.1875)(67.925\text{ amu}) + (0.0062)(69.925)$$

$$= 65.400\text{ amu}$$

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2.4 *Indium has two naturally occurring isotopes:* ^{113}*In with an atomic weight of 112.904 amu, and* ^{115}*In with an atomic weight of 114.904 amu. If the average atomic weight for In is 114.818 amu, calculate the fraction-of-occurrences of these two isotopes.*

Solution

The average atomic weight of indium $(\bar{A}_{\mathrm{In}})$ is computed by adding fraction-of-occurrence—atomic weight products for the two isotopes—i.e., using Equation 2.2, or

$$\bar{A}_{\mathrm{In}} = f_{^{113}\mathrm{In}} A_{^{113}\mathrm{In}} + f_{^{115}\mathrm{In}} A_{^{115}\mathrm{In}}$$

Because there are just two isotopes, the sum of the fracture-of-occurrences will be 1.000; or

$$f_{^{113}\mathrm{In}} + f_{^{115}\mathrm{In}} = 1.000$$

which means that

$$f_{^{113}\mathrm{In}} = 1.000 - f_{^{115}\mathrm{In}}$$

Substituting into this expression the one noted above for $f_{^{113}\mathrm{In}}$, and incorporating the atomic weight values provided in the problem statement yields

$$114.818 \text{ amu} = f_{^{113}\mathrm{In}} A_{^{113}\mathrm{In}} + f_{^{115}\mathrm{In}} A_{^{115}\mathrm{In}}$$

$$114.818 \text{ amu} = (1.000 - f_{^{113}\mathrm{In}}) A_{^{113}\mathrm{In}} + f_{^{115}\mathrm{In}} A_{^{115}\mathrm{In}}$$

$$114.818 \text{ amu} = (1.000 - f_{^{115}\mathrm{In}})(112.904 \text{ amu}) + f_{^{115}\mathrm{In}}(114.904 \text{ amu})$$

$$114.818 \text{ amu} = 112.904 \text{ amu} - f_{^{115}\mathrm{In}}(112.904 \text{ amu}) + f_{^{115}\mathrm{In}}(114.904 \text{ amu})$$

Solving this expression for $f_{^{115}\mathrm{In}}$ yields $f_{^{115}\mathrm{In}} = 0.957$. Furthermore, because

$$f_{^{113}\mathrm{In}} = 1.000 - f_{^{115}\mathrm{In}}$$

then

$$f_{^{113}\mathrm{In}} = 1.000 - 0.957 = 0.043$$

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2.5 *(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,

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

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

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2.6 *(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.

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2.7 *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.

2.8 *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.*

Answer

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 $32(-2)(-\frac{1}{2})$.

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2.9 *Give the electron configurations for the following ions:* P^{5+}, P^{3-}, Sn^{4+}, Se^{2-}, I^{-}, *and* Ni^{2+}.

Solution

The electron configurations for the ions are determined using Table 2.2 (and Figure 2.8).

P^{5+}: From Table 2.2, the electron configuration for an atom of phosphorus is $1s^22s^22p^63s^23p^3$. In order to become an ion with a plus five charge, it must lose five electrons—in this case the three 3*p* and the two 3*s*. Thus, the electron configuration for a P^{5+} ion is $1s^22s^22p^6$.

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

Sn^{4+}: From the periodic table, Figure 2.8, the atomic number for tin is 50, which means that it has fifty electrons and an electron configuration of $1s^22s^22p^63s^23p^63d^{10}4s^24p^64d^{10}5s^25p^2$. In order to become an ion with a plus four charge, it must lose four electrons—in this case the two 4*s* and two 5*p*. Thus, the electron configuration for an Sn^{4+} ion is $1s^22s^22p^63s^23p^63d^{10}4s^24p^64d^{10}$.

Se^{2-}: From Table 2.2, the electron configuration for an atom of selenium is $1s^22s^22p^63s^23p^63d^{10}4s^24p^4$. In order to become an ion with a minus two charge, it must acquire two electrons—in this case another two 4*p*. Thus, the electron configuration for an Se^{2-} ion is $1s^22s^22p^63s^23p^63d^{10}4s^24p^6$.

I^{-}: From the periodic table, Figure 2.8, the atomic number for iodine is 53, which means that it has fifty three electrons and an electron configuration of $1s^22s^22p^63s^23p^63d^{10}4s^24p^64d^{10}5s^25p^5$. In order to become an ion with a minus one charge, it must acquire one electron—in this case another 5*p*. Thus, the electron configuration for an I^{-} ion is $1s^22s^22p^63s^23p^63d^{10}4s^24p^64d^{10}5s^25p^6$.

Ni^{2+}: From Table 2.2, the electron configuration for an atom of nickel is $1s^22s^22p^63s^23p^63d^84s^2$. 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 Ni^{2+} ion is $1s^22s^22p^63s^23p^63d^8$.

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2.10 *Potassium iodide (KI) exhibits predominantly ionic bonding. The* K^+ *and* I^- *ions have electron structures that are identical to which two inert gases?*

Solution

The K^+ ion is just a potassium atom that has lost one electron; therefore, it has an electron configuration the same as argon (Figure 2.8).

The I^- ion is a iodine atom that has acquired one extra electron; therefore, it has an electron configuration the same as xenon.

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

Solution

Each of the elements in Group IIA has two *s* electrons.