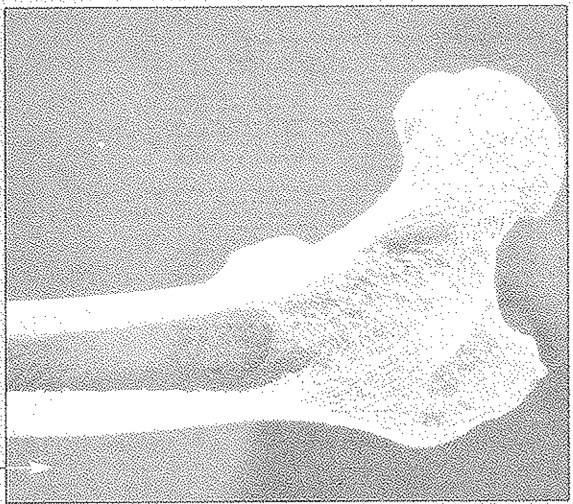
GUIDED TOUR

Modern materials science topics have been added throughout the text including:

- Smart materials/devices, MEMs and nanomaterials
- Biomedical applications
- Chapter 4 has been split into two chapters to allow diffusion to be covered alone
- Three new sections devoted to advanced alloys and their application in biomedical engineering
- Ceramics coverage has been expanded to include nanotechnology and ceramics

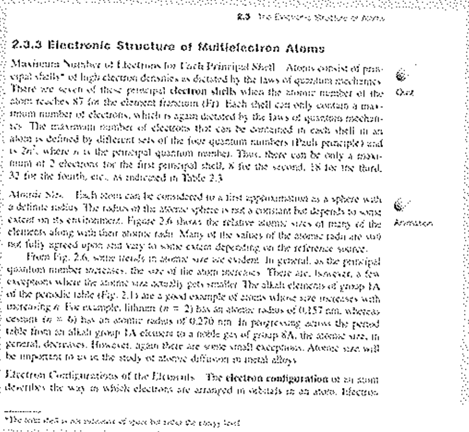


Materials selection and design problems follow the end-of-chapter problems. These problems challenge students to create engineering solutions through materials selection and process design.

198 CHAPTER 5 Thermally Activated Processes and Diffusion in Solids

5.8 MATERIALS SELECTION AND DESIGN PROBLEMS

1. In integrated circuits, dissimilar metal wires such as gold and aluminum are joined at the cross section to form a bonded interface. At elevated temperatures, the interface starts to move or shift in the direction of one of the metals, called the Kirkendall effect. (*a*) Can you explain this phenomenon? (*b*) Is the direction of the shift random? (*c*) What are the negative effects of this process?
2. (*a*) Design a process that would be used to make a solid steel component out of fine steel powder. The density of the formed solid should be very close to the density of the physical metal. (*b*) Explain how this process works at both macro and micro levels. (*c*) What are some of the obstacles that you may encounter in your process?
3. Explain what happens if carbon steel is exposed to an oxygen-rich atmosphere at elevated temperatures inside a furnace.
4. Based on the data in Table 5.2, is it easier for carbon atoms to diffuse in the structure of BCC iron or FCC iron? What is the physical reason for this?
5. Classify the mechanism of diffusion in all 12 solute/solvent pairs given in Table 5.2 (interstitial or substitutional). Compare the diffusivity values and draw a conclusion.
6. The activation energy for the diffusion of hydrogen in steel at room temperature is 3600 cal/mol, which is significantly lower than that of, for example, carbon at 20,900 cal/mol. Investigate the effect of diffused hydrogen on the mechanical behavior of steel.
7. Investigate the role of solid state diffusion in manufacturing of ceramic components using the powder metallurgy process.



2.3 The Electronic Structure of Atoms

2.3.3 Electronic Structure of Multielectron Atoms

Maximum Number of Electrons for Each Principal Shell   Atoms consist of principal shells* of high electron densities as dictated by the laws of quantum mechanics. There are seven of these principal **electron shells** when the atomic number of the atom reaches 87 for the element francium (Fr). Each shell can only contain a maximum number of electrons, which is again dictated by the laws of quantum mechanics. The maximum number of electrons that can be contained in each shell in an atom is defined by different sets of the four quantum numbers (Pauli principle) and is $2n^2$, where n is the principal quantum number. Thus, there can be only a maximum of 2 electrons for the first principal shell, 8 for the second, 18 for the third, 32 for the fourth, etc., as indicated in Table 2.3.

Quiz

Atomic Size   Each atom can be considered to a first approximation as a sphere with a definite radius. The radius of the atomic sphere is not a constant but depends to some extent on its environment. Figure 2.6 shows the relative atomic sizes of many of the elements along with their atomic radii. Many of the values of the atomic radii are still not fully agreed upon and vary to some extent depending on the reference source.

Animation

From Fig. 2.6, some trends in atomic size are evident. In general, as the principal quantum number increases, the size of the atom increases. There are, however, a few exceptions where the atomic size actually gets smaller. The alkali elements of group 1A of the periodic table (Fig. 2.1) are a good example of atoms whose size increases with increasing n. For example, lithium ($n = 2$) has an atomic radius of 0.157 nm, whereas cesium ($n = 6$) has an atomic radius of 0.270 nm. In progressing across the period table from an alkali group 1A element to a noble gas of group 8A, the atomic size, in general, decreases. However, again there are some small exceptions. Atomic size will be important to us in the study of atomic diffusion in metal alloys.

Electron Configurations of the Elements   The **electron configuration** of an atom describes the way in which electrons are arranged in orbitals in an atom. Electron

*The term shell is not a volume of space but rather the energy level.

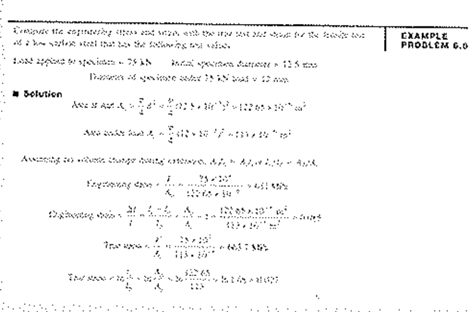
Icons have been added to highlight the media supplement resources.

LEARNING OBJECTIVES

By the end of this chapter, students will be able to. . .

1. Describe what crystalline and noncrystalline (amorphous) materials are.
2. Learn how atoms and ions in solids are arranged in space and identify the basic building blocks of solids.
3. Describe the difference between atomic structure and crystal structure for solid material.
4. Distinguish between crystal structure and crystal system.
5. Explain why plastics cannot be 100% crystalline in structure.
6. Explain polymorphism or allotropy in materials.
7. Compute the densities for metals having body-centered, and face-centered cubic structures.
8. Describe how to use the x-ray diffraction method for material characterization.
9. Write the designation for atom position, direction indices, and Miller indices for cubic crystals. Specify what are the three densely packed structures for most metals. Determine Miller-Bravais indices for hexagonal-closed packed structure. Be able to draw directions and planes in cubic and hexagonal crystals.

Learning Objectives have been added to each chapter to guide students' comprehension of the material.



6.4 Hardness and Hardness Testing   227

hardness tests, a known load is applied slowly by pressing the indenter at 90° into the metal surface being tested [Fig. 6.27b (2)]. After the indentation has been made, the indenter is withdrawn from the surface [Fig. 6.27b (3)]. An empirical hardness

EXAMPLE PROBLEM

■ Solution

SI Units have been used throughout the book.