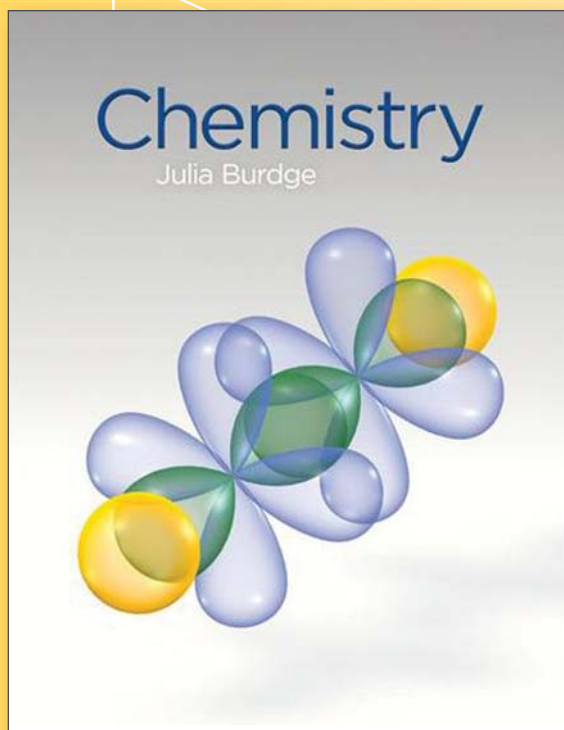




CASE STUDY:

# BURDGE CHEMISTRY

PRECISION



### MISSION

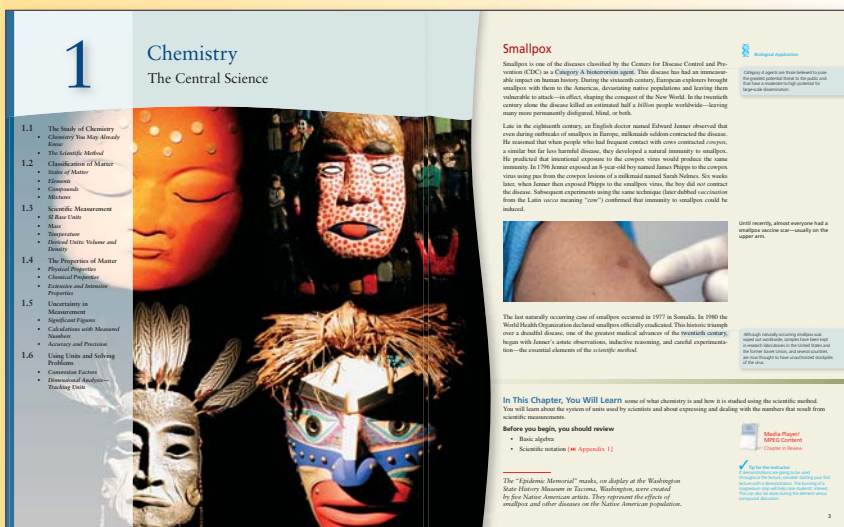
Create a visually dynamic first-edition book and 3-D media program.

Author Julia Burdge had collaborated on textbooks before beginning work on *Chemistry*, and she had definite ideas about the look and feel of her first solo project. Precision Graphics took the initiative in taking the author's preferred art style and making it our own. By creating a detailed style sheet that began with the general design of the art, we were able to ensure that the unique and complex style would be successfully implemented throughout the entire project.

While the usual workflow means sending project communications through project managers, Precision's lead artist for *Chemistry* was encouraged to communicate directly with the author. We took full advantage of this, leading not only to email and phone conversations, but to several working meetings in our office. This allowed for valuable interaction in the early stages of art production that ensured we were meeting the author's expectations before we were very far into the process.

“We’ve built a strong relationship with the author that will serve as a foundation for future editions.”

—Lead Artist, Gary Hunt



## 1

### Chemistry The Central Science

- 1.1 The Study of Chemistry
  - Chemistry You May Already Know
  - The Scientific Method
- 1.2 Classification of Matter
  - States of Matter
  - Elements
  - Compounds
  - Mixtures
- 1.3 Scientific Measurement
  - SI Base Units
  - Mass
  - Temperature
  - Physical Units Volume and Density
- 1.4 The Properties of Matter
  - Physical Properties
  - Chemical Properties
  - Extensive and Intensive Properties
- 1.5 Uncertainty in Measurement
  - Significant Figures
  - Calculation with Measured Quantities
  - Accuracy and Precision
- 1.6 Using Units and Solving Problems
  - Conversion Factors
  - Dimensional Analysis—Thinking Like a Chemist



**Smallpox**

Smallpox is one of the diseases classified by the Centers for Disease Control and Prevention (CDC) as a Category A bioterrorism agent. This disease has had an immeasurable impact on human history. During the sixteenth century, European explorers brought smallpox with them to the Americas, decimating native populations and leaving them vulnerable to attack—in effect, shaping the conquest of the New World. In the twentieth century alone, the disease killed an estimated half a billion people worldwide—leaving many more permanently disfigured, blind, or deaf.

Late in the eighteenth century, an English doctor named Edward Jenner observed that over long outbreaks of smallpox in Europe, milkmaids seldom contracted the disease. He reasoned that when people who had frequent contact with cows contracted cowpox, a similar but far less harmful disease, they developed a natural immunity to smallpox. He postulated that intentional exposure to the cowpox virus would produce the same immunity. In 1796 Jenner exposed an 8-year-old boy named James Phipps to the cowpox virus using pus from the cowpox lesions of a milkmaid named Sarah Nelmes. Six weeks later, when Jenner then exposed Phipps to the smallpox virus, the boy did not contract the disease. Subsequent experiments using the same technique (later dubbed vaccination from the Latin *vacca* meaning “cow”) confirmed that immunity to smallpox could be induced.

Until recently, almost everyone had a smallpox vaccine scar—usually on the upper arm.

Although smallpox-vaccinating needles are now so readily available that they are used by the World Health Organization and the United States military, and smallpox is no longer a threat to most populations of the world.

**In This Chapter, You Will Learn** some of what chemistry is and how it is studied using the scientific method. You will learn about the systems of units used by scientists and about expressing and dealing with the numbers that result from scientific measurements.

**Before you begin, you should review**

- Basic algebra
- Scientific notation (see Appendix 1)

**Make It Real!**  
Chapter 5: Matter

**Go to the Website!**  
Visit the website for more information and resources on the scientific method and the history of chemistry.

The “Epidemic Memorial” masks, on display at the Washington State History Museum in Tacoma, Washington, were created by the Native American artist. They represent the effects of smallpox and other diseases on the Native American population.

474 CHAPTER 12 Intermolecular Forces and the Physical Properties of Liquids and Solids

Figure 12.15 Arrangement of identical spheres in a simple cubic cell. (a) Top view of one layer of spheres. (b) Delimitation of a simple cubic cell.

Figure 12.16 Three types of cubic cells. The top view makes it easier to see the location of the lattice points, but the bottom view is more realistic, with the spheres touching one another.

Figure 12.17 In the body-centered cubic arrangement, the spheres in each layer sit in the depression between spheres in the previous layer.

The other types of cubic cells, shown in Figure 12.16, are the **body-centered cubic cell** (bcc) and the **face-centered cubic cell** (fcc). Unlike the simple cubic, the second layer of atoms in the body-centered cubic arrangement fits into the depression of the first layer and the third layer fits into the depression of the second layer (Figure 12.17).

The coordination number of each atom in the bcc structure is 8; each sphere is in contact with four others in the layer above and four others in the layer below. In the face-centered cubic cell, there are atoms at the center of each of the six faces of the cube, in addition to the eight corner atoms. The coordination number in the face-centered cubic cell is 12; each sphere is in contact with four others in its own layer, four others in the layer above, and four others in the layer below.

Because every unit cell in a crystalline solid is adjacent to other unit cells, most of a cell's atoms are shared by neighboring cells. (The atoms at the center of the body-centered

SECTION 12.3 Crystal Structure 475

Figure 12.18 (a) A corner atom in any cell is shared by eight unit cells. (b) An edge atom is shared by four unit cells. (c) A face-centered atom in cubic cells is shared by two unit cells.

Figure 12.19 Because each sphere is shared by eight unit cells and there are eight corners in a cube, there is the equivalent of one complete sphere inside a simple cubic unit cell.

Figure 12.20 (a) In a close-packed layer, each second layer sits in the depression between the atoms, such that each layer of atoms is directly over a hole in the layer below. (b) In a face-centered cubic cell, there are four complete atoms—three from the six face-centered atoms and one from the eight corner atoms.

Figure 12.21 (a) In all types of cubic cells, for example, each corner atom belongs to eight unit cells whose corners all touch (Figure 12.18(a)). An atom that lies on an edge, on the other hand, is shared by four unit cells (Figure 12.18(b)), and a face-centered atom is shared by two unit cells (Figure 12.18(c)). Because a simple cubic cell has lattice points only at each of the eight corners and because each corner atom is shared by eight unit cells, there will be the equivalent of only one complete atom contained within a simple cubic unit cell (Figure 12.19). A body-centered cubic cell contains the equivalent of two complete atoms, one in the center and eight shared corner atoms. A face-centered cubic cell contains the equivalent of four complete atoms—three from the six face-centered atoms and one from the eight shared corner atoms.

**Closest Packing**

There is one empty space in the simple cubic and body-centered cubic cells than in the face-centered cubic cell. Closest packing, the most efficient arrangement of atoms, starts with the atoms shown in Figure 12.20(a), which we call layer A. Because of the only atom that is surrounded completely by other atoms, we see that it has six immediate neighbors in its own layer. In the second layer, which we call layer B, atoms are packed into the depression between the atoms in the first layer so that all the atoms are as close together as possible (Figure 12.20(b)).

There are two ways that a third layer of atoms can be arranged. They may sit in the depression between second layer atoms such that the third layer atoms fit directly over atoms in the first layer (Figure 12.20(c)). In this case, the third layer is also labeled A. Alternatively, atoms in the third layer may sit in a different set of depressions such that they do not fit directly over atoms in the first layer (Figure 12.20(d)). In this case, we label the third layer C.

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“Meeting the author really helped personalize our work on this book. I feel like this book is not just hers, but *ours*.”  
—Lead Composer, Karen Hawk

**Common Ion Effect**

We prepare a saturated solution by adding  $\text{AgCl}$  to water and stirring.

In the resulting saturated solution, the concentrations of  $\text{Ag}^+$  and  $\text{Cl}^-$  are equal and the product of their concentrations is constant,  $K_{sp}$ .

$$[\text{Ag}^+][\text{Cl}^-] = 1.6 \times 10^{-10}$$

Therefore, the concentrations are  $[\text{Ag}^+] = 1.3 \times 10^{-5} \text{ M}$  and  $[\text{Cl}^-] = 1.3 \times 10^{-5} \text{ M}$ .

When  $\text{AgCl}$  is added to a saturated solution of  $\text{AgCl}$  a precipitate forms. The solution has become saturated with respect to the precipitate to which the process.

Notice that the concentration of  $\text{Ag}^+$  is now higher, the product of  $\text{Ag}^+$  and  $\text{Cl}^-$  concentrations is no longer equal to  $K_{sp}$ .

$$[\text{Ag}^+][\text{Cl}^-] = (2.3 \times 10^{-5} \text{ M})(1.3 \times 10^{-5} \text{ M}) = 3.0 \times 10^{-10}$$

In any solution saturated with  $\text{AgCl}$  at  $25^\circ\text{C}$ , the product of  $[\text{Ag}^+]$  and  $[\text{Cl}^-]$  is equal to the  $K_{sp}$  of  $\text{AgCl}$ . Therefore,  $[\text{Ag}^+][\text{Cl}^-]$  will precipitate until the product of ion concentrations is again  $1.6 \times 10^{-10}$ .

Now that the concentration of  $\text{Ag}^+$  is higher,  $\text{AgCl}$  will precipitate until the product of  $[\text{Ag}^+]$  and  $[\text{Cl}^-]$  is again equal to  $K_{sp}$ .

$$[\text{Ag}^+][\text{Cl}^-] = 1.6 \times 10^{-10}$$

Resulting  $[\text{Ag}^+] = 1.0 \times 10^{-5} \text{ M}$

**What's the point?**

When two salts contain the same ion, the one they both contain is called the "common ion." The solubility of a slightly soluble salt such as  $\text{AgCl}$  can be decreased by the addition of a soluble salt with a common ion. In this example,  $\text{AgCl}$  is precipitated by adding  $\text{NaCl}$ .  $\text{AgCl}$  could also be precipitated by adding a soluble salt containing the  $\text{Ag}^+$  ion, such as  $\text{AgNO}_3$ .

370 CHAPTER 10 Organic Chemistry

Acetone Methylamine Toluene

The functional groups in the types of compounds shown in Table 10.2 are the **hydroxy** group (in alcohols), the **carboxy** group (in carboxylic acids), the **carboxyl** group (in carboxylic acids), the **carboxyl** group (in carboxylic acids), the **amino** group (in amines), and the **amide** group (in amides). Functional groups determine many of the properties of a compound, including what types of reactions it is likely to undergo. Figure 10.1 shows ball-and-stick models and electrostatic potential maps of the hydroxy, carboxy, carbonyl, amino, and amide functional groups.

A compound consisting of an alkyl group and the functional group  $-\text{OH}$  is an **alcohol**. The identity of an individual alcohol depends on the identity of R, the alkyl group. For example, when R is the **methyl** group, we have  $\text{CH}_3\text{OH}$ . This is methyl alcohol or methanol, also known as wood alcohol. It is highly toxic and can cause blindness or even death in relatively small doses. When R is the **ethyl** group, we have  $\text{CH}_3\text{CH}_2\text{OH}$ . This is ethyl alcohol or ethanol. Ethanol is the alcohol in alcoholic beverages. When R is the **isopropyl** group, we have  $(\text{CH}_3)_2\text{CHOH}$ . This is isopropyl alcohol. Isopropyl alcohol, which we commonly call "rubbing alcohol," is widely used as a disinfectant.

Methanol Ethanol Isopropyl alcohol

Many compounds contain more than one functional group. An **amino acid**, for example, contains both the amino group and the carboxy group.

Alanine

Hydroxy group Carboxy group Carbonyl group Amino group Amide group

Figure 10.1 Models and electrostatic potential maps of the hydroxy, carboxy, carbonyl, amino, and amide functional groups.

Much of the art for this book was rendered initially using 3D software, which can be time-consuming and expensive. By initiating early and direct author collaboration, we were able to ensure that we stayed within the budget. Further, when the client saw what Precision was creating, they added media elements to the package. What began as an art and composition project expanded to include high-end animations and the cover illustration.

In addition to our contact with the author, the PG team stayed in close touch with the client's book team. We were able to stay on top of the client's many marketing goals and deadlines, which helped make Burdge *Chemistry* a successful book for the publisher as well.

Finally, the early collaboration with the author enhanced personal ownership in the project on the part of Precision's book team. We were not just working with a name on the spine. Dr. Burdge became a valued colleague, and it became important to each member of PG's book team to make her proud of what we created. Every member of the book team, from the author to the proofreader to the illustrators, can claim this project as a personal success.

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