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Polymer Hybrid Materials and Nanocomposites

Fundamentals and Applications

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Tawfik Abdo Saleh
King Fahd University of Petroleum and Minerals, Saudi Arabia

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Preface

The expansion of chemical structures is the focal point of research and technology that is mostly related to chemistry, physics, applied sciences, petroleum, and engineering. Research on nanotechnology and hybrid materials has mainly focused on the aspects of synthesis of novel materials that have unique chemical, thermal, and mechanical properties applicable to a wide range of applications. A variety of properties and phenomena have been investigated, and many of the studies have been directed toward understanding the properties and applications of nanomaterials. This becomes more interesting when nanomaterials are combined with polymers.

Owing to their enhanced chemical and mechanical properties, the hybrid materials play promising roles in several applications. Nanomaterials have properties that are useful for enhancing surface-to-volume ratio, reactivity, strength, and durability. In pursuit of the same goal, this book offers detailed, up-to-date chapters on the synthesis, properties, and technological developments of polymer hybrid materials and nanocomposites, as well as their applications in several fields including water and energy.

The book has been developed as a consequence of significant advances in the materials science community. In the excitement surrounding these materials and technologies, however, their potential has been, frequently overhyped. The book explores these kinds of materials and their forward-looking potential applications. The book is organized in a good way and makes extensive use of illustrations.

In this book, we have tried to cover many aspects of hybrid materials and nanocomposites, which is of current interest. This book is written for a large readership, including university students and researchers from diverse backgrounds such as chemistry, petroleum, materials science, physics, and engineering. It can be used not only as a textbook for both undergraduate and graduate students but also as a review and reference book for researchers in these fields. We hope that the chapters of this book will provide the readers with valuable insight into the state-of-the-art advanced and functional hybrid nanomaterials and technologies.

However, it is possible that some topics have been left out owing to constraints on the size of the book and possible errors in judgment. We trust that the preface will be useful to students, teachers, and researchers.

I welcome suggestions from readers toward improvements that can be incorporated in future editions of this book.

I hope that you enjoy the book!

Tawfik A. Saleh
Department of Chemistry,
King Fahd University of Petroleum & Minerals,
Saudi Arabia

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Many thanks.
Tawfik Abdo Saleh
Department of Chemistry, and
Interdisciplinary Research Center for Advanced Materials,
King Fahd University of Petroleum & Minerals,
Saudi Arabia

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Chapter 1

Introduction to materials: fundamentals and interactions

1. Introduction

Materials are the matters that objects are made from. In other words, a material is a matter; it is a substance or a mixture of substances that constitute an object. The general classification of matter can be presented as in Fig. 1.1. Matter can be classified depending on the characteristics of the substance. Broadly speaking, it can be classified as chemical and pure substances. A chemical substance is a form of matter that has a constant chemical composition and characteristic properties. Matter can be defined as anything that has mass and occupies space. Mass is a measure of the quantity of matter in a sample of any material. Pure substances can be elements of the periodic table or molecules such as ethanol, water, and benzene. The most common classifications of materials will be discussed in the following sections.

1.1 Elements and compounds

An element is a material that is the same throughout, such as gold or silver. Elements can be classified into metals, nonmetals (most are gases at room temperature), and metalloids (elements that are in between metals and nonmetals or elements that exhibit properties of both metals and nonmetals) based on the following:

- physical properties, such as color, texture, melting and boiling points, density, and hardness;
- chemical properties, such as flammability and reactivity to other reagents including oxygen and acids.

Metals are solids except for liquid mercury. They are good conductors of heat and electricity. Metalloids, on the other hand, are solids that can conduct electricity but are poor conductors of heat. Nonmetals, however, are poor conductors of both heat and electricity (Pletsch et al., 2015).

A compound is a substance made of molecules, each of which is made up of two or more different atoms. A compound contains two or more elements

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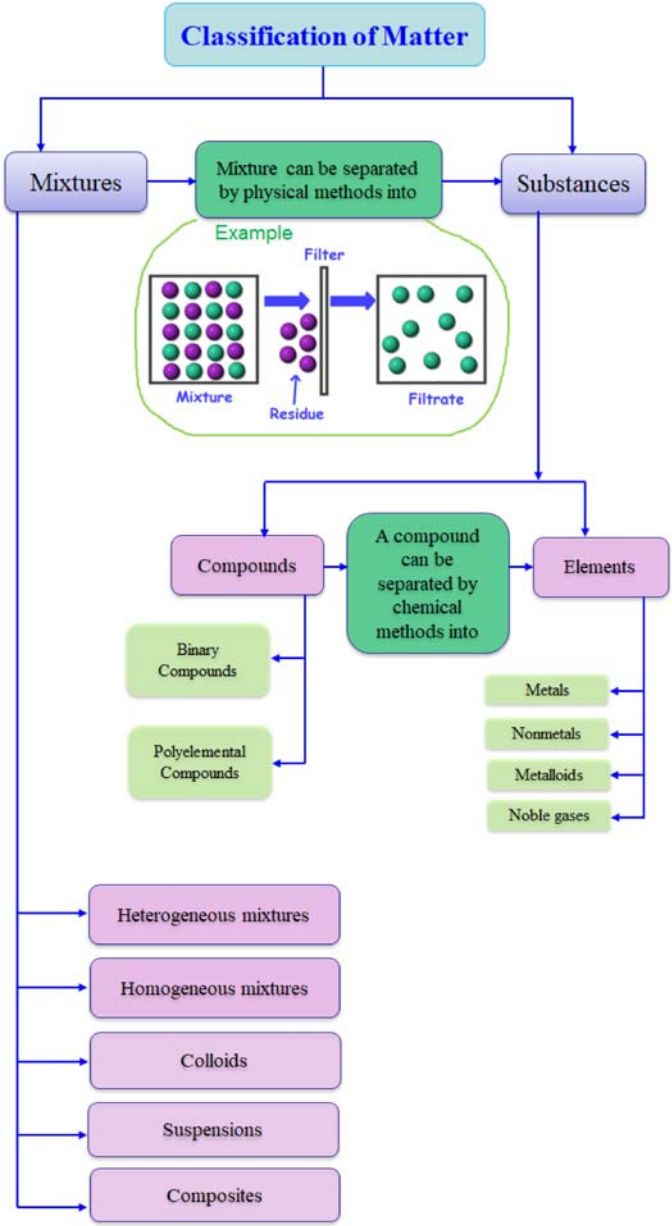

FIGURE 1.1 The general classification of matter.

combined in definite proportions. For example, sodium chloride salt is a compound, while sodium is an element. Chemical compounds can be categorized based on their chemical reactions, the types of bonds, and the types of elements present. Chemical compounds include oxide compounds containing oxygen atoms, hydrides containing hydrogen atoms, and halides containing halogen atoms (F, Cl, Br, I). Compounds are mostly classified as inorganic. However, those with a backbone of carbon atoms are classified as organic compounds. Organometallic compounds are organic compounds that are bonded to metal atoms. As per the types of bonds, compounds can be ionic, formed by attractive forces among oppositely charged ions (ionic bonding; e.g., NaCl). Molecular compounds, on the other hand, are formed by covalent bonding, holding different atoms such as methane, hydrogen fluoride, and water.

1.2 Mixtures

A combination of two or more pure substances, such as NaCl and water, is called a mixture. Mixtures can be categorized as in Fig. 1.1. They can be separated into pure substances. The composition may remain constant while changing phases from solid to liquid to gas. A heterogeneous mixture is a mixture with a nonuniform composition, and its components can be distinguished and separated by physical methods such as heating. The composition of a heterogeneous mixture differs from one area to another, with at least two phases remaining separate from each other and with identifiable properties.

A homogeneous substance is a matter that contains one type of compound or one element, or a mixture with uniform composition. Examples of a homogeneous substance include metals containing only one type of atoms such as Ni, Al, Fe, Si; compounds such as solid salts; and liquid solutions such as ethanol and methanol. A homogeneous mixture can also be a combination of two or more pure substances, where the substances present no change in properties. The components of homogeneous mixtures are indistinguishable; however, their composition can vary.

To go deep into the atomic level, anything that has mass and occupies space is a matter that mainly consists of particles. The particles can be molecules, atoms, or subatomic bits, such as protons, electrons, and leptons. To understand matter, the atomic level should be understood. Fig. 1.2 depicts the formation of atoms, elements, and compounds. Atoms are mainly made up of protons, neutrons, and electrons. Atoms are the basic units of matter, defining the structure of elements. They are also the building blocks of all materials, simple and complicated. Compounds are made up of a combination of different types of element atoms. An element is made up of only one type of atom. The atomic number is the number of protons in the atom nucleus. The number of protons defines the identity of an element (i.e., an element with six protons is a carbon atom, irrespective of the number of neutrons present).