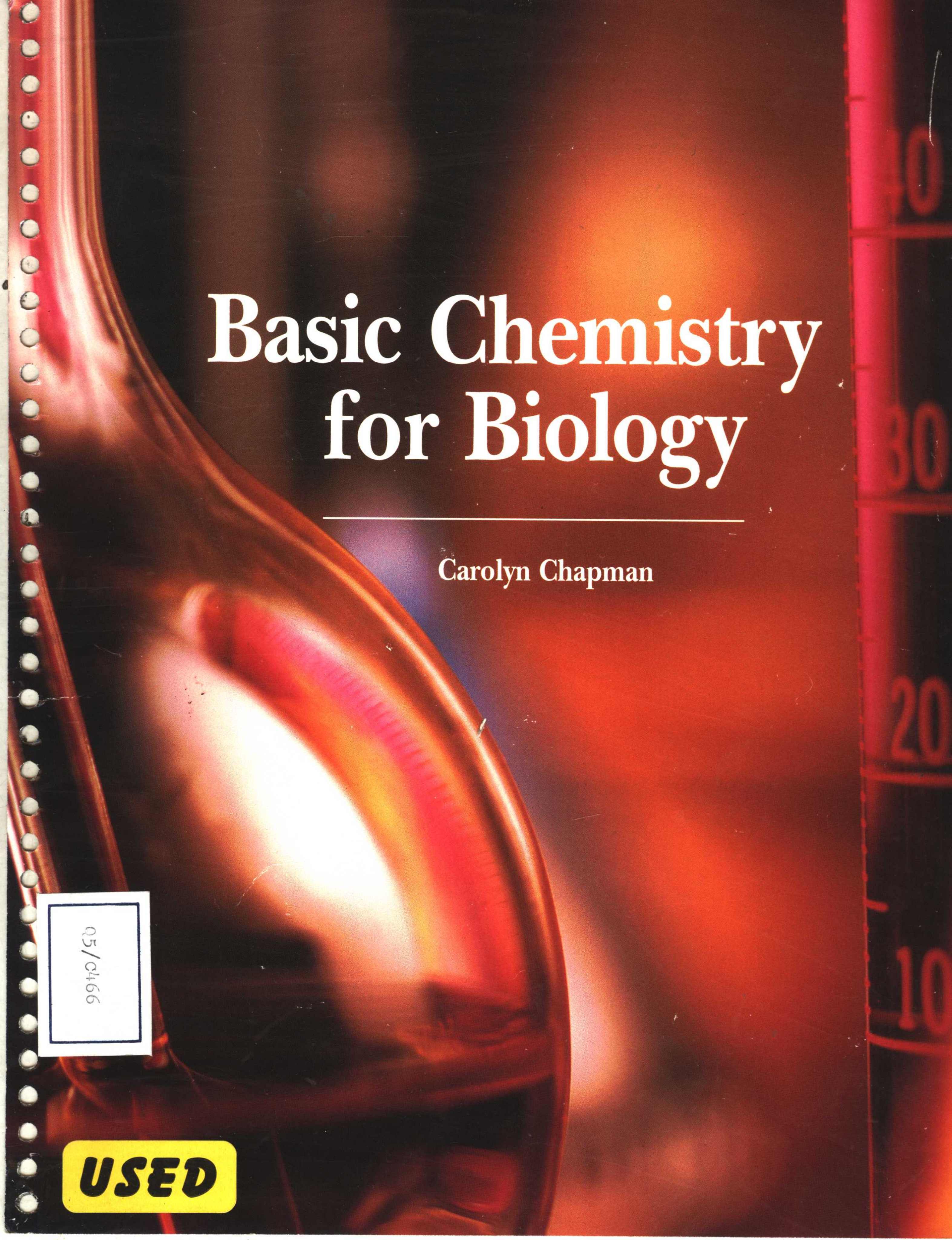

Basic Chemistry for Biology

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INTRODUCTION

Welcome to *Basic Chemistry for Biology*. Chemistry is a subject that is important in many other areas of science. Students of biology, medicine, geology, and astronomy need a working knowledge of chemistry to succeed in their fields. The goal of this book is to provide you with an introduction or review of the basic principles of chemistry that are most useful in other areas of science.

As a beginning science student, you may wonder why you need to know about chemistry if your direct goal is to learn a field such as anatomy and physiology or geology. Some examples will illustrate why chemistry is so fundamental. The human body, like that of all living organisms, is composed of chemicals. The composition of the body will not make sense unless a basic knowledge of chemistry is available to help you understand the body's structure. Living organisms are based on chemical activity. When the liver responds to hormones and regulates blood sugar levels, chemical reactions are responsible. When you think and learn, chemical interactions in the neurons of the brain play an essential role. These examples show that physiology is the study of how the body regulates its internal chemistry. Clearly, a knowledge of chemistry will greatly increase your chances of success in physiology. Similar examples from other areas of science would lead to the same conclusion.

This book can be used as an introduction to chemistry or as a review of the subject. Those topics from high school chemistry (or an entry-level college course) that are most essential to an understanding of other science areas are included here. This book is not intended to replace an entire chemistry course. If you master the subject matter of this book, you will learn (or relearn) the principles of chemistry used in introductory science courses. If you decide to pursue the study of science seriously, however, you will need to take several chemistry courses as you progress.

All fields of science are based on experimentation. The goal of this book is to help you acquire a basic knowledge of the concepts of chemistry as quickly as possible. Therefore, the concepts of chemistry are presented without their experimental basis. It is important to remember that these concepts are not arbitrary but were developed to explain and be compatible with experimental findings. A full chemistry course will include the experimental basis of the field.

A scientific model is a description and explanation of experimental observations. Models can be of varying complexity. In general, simpler models are utilized in this book. The octet rule, used to predict chemical reactions, would be an example. Such models are compatible with many experimental findings and can be used to predict a wide array of chemical reactions. Typically, they do not explain everything, and exceptions are known. This does not mean that such models are incorrect, but rather that they represent incomplete and simplified descriptions of the natural world. As your knowledge of chemistry increases, more complex models can be added to those presented here.

HOW TO USE THIS BOOK

Objectives

Each chapter in this book covers the major topic stated in its title. The first page of each chapter gives a list of learning objectives for the chapter. These objectives list the things you should be able to do when you have mastered the material in the chapter.

Some of these objectives are basic and must be mastered before you can continue on to more advanced topics. This is because much of the subject matter of chemistry is cumulative and later topics build on what has gone before. Other objectives are intermediate or advanced. These objectives are indicated with an asterisk. Frequently, these topics can be omitted without impeding your progress through future chapters. You should customize your chemistry study by choosing which of these to include. Your prior knowledge of chemistry and the requirements of your current academic program are prime factors to consider. One effective strategy is to work through the book two or more times. The first time through, the basic objectives are covered. This provides a good start to the beginning student without introducing difficult subject matter. Then, during subsequent readings, intermediate and advanced topics are added.

Study and Self-testing

Each section of text includes a short paragraph about a new topic. Read the paragraph carefully. The paragraph will be followed by a series of questions that test your understanding of the material and ask you to apply it. Answer the questions as completely as you can.

The answers to the questions are on the facing page. Conceal the answer page while you work on the questions. (The wire coil spine makes it easy to fold your book to accomplish this.) When you have completed the questions on a page, check your responses against the answers. Explanations are often included with the answers. If you did not answer the question correctly, the explanation may be sufficient to help you get back on track. The answer pages also can be removed and used as study sheets.

If you understood the paragraph and answered all the questions correctly, you are ready to continue to the next section. If you are uncertain about your understanding and missed questions, the same section should be repeated. Read the paragraph again. When you understand it, retry the questions.

Repetition is essential to the learning process. Working through the questions in this book more than once provides such repetition and is strongly recommended. A longer and more complete test is included at the end of each chapter. This test enables you to evaluate your mastery of the entire chapter. The chapter test is also a learning experience since it provides more repetition of the subjects that have been covered.

TABLE OF CONTENTS

Chapter 1
THE ATOM

How to Use the Objectives

The objectives for chapter 1 are stated below. All are tasks you should be able to complete successfully once the material in this chapter has been mastered. These are general objectives. The questions in chapter 1 specifically apply to these objectives. Correct answers to the questions in chapter 1 provide good evidence that the objectives have been achieved. A full chapter test at the end of this unit is available for you to take when you are ready. It includes questions designed to evaluate all of the objectives. Your score on the chapter test provides you with an overall assessment of your mastery of the chapter objectives.

Objectives that cover more advanced material are indicated with an asterisk (*). Include the optional objectives appropriate for your academic program. Progress through the remaining chapters of this book does not require mastery of the optional topics.

Objectives

1 . Define the following terms and apply the definitions correctly:
matter, element, atom, atomic number, mass number, atomic mass (weight), and isotope.

2 . List the elementary particles, their properties, and locations in an atom.

3 . State the interactions of like and unlike electrical charges.

4 . Given the atomic number and mass number, calculate the number of protons, neutrons, and electrons in an atom.

5 . Use the periodic table of the elements to find information such as an element's name, atomic number, atomic mass (weight), and symbol.

6 . List the symbols for the elements that are significant in living things.

7 . Know and use the appropriate formula to calculate the number of electrons in an electron shell.

8 . Sketch the structure of any atom up to an atomic number of 18, showing the correct number of electrons in each electron shell.

9 . Represent the isotopic variants of an element with standard chemical notation.

10.* Sketch the electron structure of any atom up to atomic number 38, showing the correct number of electrons in each electron shell.

11.* Accurately describe the size of an atom and the spatial relationships within it.

MATTER, ELEMENTS, AND ATOMS

All physical objects, including all living organisms, are made of matter. Matter is defined as anything that occupies space and has mass. The space an object occupies can be measured and is the volume of that object. Under the circumstances we usually encounter (on earth in a gravitational field), having mass is detected as weighing a finite amount.

Questions

1. Is your body composed of matter? How would you demonstrate the validity of your answer?

Yes ☐ No ☐

____

____

2. Is a classroom desk composed of matter? How can you tell?

Yes ☐ No ☐

____

____

3. A tank appears to be empty. It is weighed. Then it is connected to a vacuum pump, which is operated for ten minutes. The tank is weighed again and now weighs less. Did it contain matter? How did the information provided permit you to answer the question?

Yes ☐ No ☐

____

____

How could you determine whether the tank still contains some matter after being pumped?

____

____

Answers

1. Is your body composed of matter? How would you demonstrate the validity of your answer?

Yes ☒ No ☐

Every person's body occupies a certain amount of space. Since body shape is irregular, the volume of the body is most easily determined by water displacement. A measured amount of water is placed in a calibrated tank. The irregular object (such as the human body) is immersed in the water, causing the water level to rise. The increase in water level is measured to determine the volume of the immersed body. The weight of the body can be determined on a bathroom scale. Thus, the body occupies space, has mass, and is therefore composed of matter.

2. Is a classroom desk composed of matter? How can you tell?

Yes ☒ No ☐

The desk takes up some room and this is the space it occupies. Its actual volume could be measured by water displacement. Weighing the desk would determine its mass. The desk occupies space, has mass, and is therefore composed of matter.

3. A tank appears to be empty. It is weighed. Then it is connected to a vacuum pump, which is operated for ten minutes. The tank is weighed again and now weighs less. Did it contain matter? How did the information provided permit you to answer the question?

Yes ☒ No ☐

Although the matter contained in the tank was apparently invisible, as are gases, it did occupy the space of the tank. The fact that the tank weighed less after the vacuum pump was operated demonstrates that the tank was filled with something that had mass, probably some type of gas.

How could you determine whether the tank still contains some matter after being pumped?

You could then use a higher-quality, more efficient vacuum pump for a longer time. If it succeeded in decreasing the weight of the tank still further, that would demonstrate that the tank had contained some residual matter after the first pump was used. Some of that residual matter was then removed by the second, more efficient pump.

Matter has been extensively analyzed by chemists. This experimental work has identified simple forms of matter called elements. The elements are the basic building blocks of more complex forms of matter. Elements *cannot* be converted to less complex substances by chemical reactions.

Questions

4. Samples of four pure gases were put through testing procedures that attempted to decompose them into simpler substances using chemical reactions. The following results were obtained: oxygen, nitrogen, and neon could not be decomposed into simpler substances. Carbon dioxide did decompose, releasing carbon and oxygen. Based on these results, which gases are elements? Explain.

____

____

5. An electrical current is used to decompose a sample of water. As the electrolysis procedure progresses, both hydrogen gas and oxygen gas are released. Is water an element? What evidence supports your answer?

Yes ☐ No ☐

____

____

6. A pure sample of sugar is burned in oxygen. The products of combustion are carbon dioxide and water. Is sugar an element? Explain your reasons for answering as you did.

Yes ☐ No ☐

____

____

____

Answers

4. Samples of four pure gases were put through testing procedures that attempted to decompose them into simpler substances using chemical reactions. The following results were obtained: oxygen, nitrogen, and neon could not be decomposed into simpler substances. Carbon dioxide did decompose, releasing carbon and oxygen. Based on these results, which gases are elements? Explain.

Carbon, nitrogen, and neon are elements because they did not decompose into simpler substances. Carbon dioxide is not an element because it decomposed into two components, carbon and oxygen. (Carbon and oxygen are themselves elements.) Therefore, carbon dioxide could not be one of the most simple building blocks and is not an element.

5. An electrical current is used to decompose a sample of water. As the electrolysis procedure progresses, both hydrogen gas and oxygen gas are released. Is water an element? What evidence supports your answer?

Yes ☐ No ☒

Water is decomposed into two simpler substances during the course of this chemical reaction. Therefore, water is not an element.

6. A pure sample of sugar is burned in oxygen. The products of combustion are carbon dioxide and water. Is sugar an element? Explain your reasons for answering as you did.

Yes ☐ No ☒

Sugar is not an element because it decomposed into two other substances. Therefore, sugar could not be one of the simple building block substances. Carbon dioxide and water were produced when sugar was burned. Information presented in previous questions showed that carbon dioxide and water are themselves not elements because they can also be decomposed further.

Experimental investigation has demonstrated that matter is particulate in nature. An atom is the smallest particle of an element that still retains the properties of that element. Atoms are extremely tiny. Between one million and two million atoms could line up side by side across the diameter of one of the printed periods on this page.

Questions

7. Carbon is an element that is very important in organic molecules. (Organic molecules are synthesized by living cells and are always based on carbon. Organic molecules are central to the structure and function of all forms of life.) An atom of carbon is one _________ of carbon.

8. Experimentation shows that atoms can be broken up, though not by chemical means. Atoms have internal structure and contain still smaller particles. Would the smaller particles within the carbon atom have the properties of carbon? Explain.

Yes ☐ No ☐

____

____

9. Would one particle of sugar be an atom? Explain your answer.

Yes ☐ No ☐

____

____

10. The smallest particle of nitrogen that still has the properties of nitrogen is one __________ of nitrogen. Would this single particle of nitrogen be visible to the unaided eye? Explain your answer.

Yes ☐ No ☐

____

____

Answers

7. Carbon is an element that is very important in organic molecules. (Organic molecules are synthesized by living cells and are always based on carbon. Organic molecules are central to the structure and function of all forms of life.) An atom of carbon is one particle of carbon.

8. Experimentation shows that atoms can be broken up, though not by chemical means. Atoms have internal structure and contain still smaller particles. Would the smaller particles within the carbon atom have the properties of carbon? Explain.

Yes ☐ No ☒

The atom is defined as the smallest portion of an element that still retains the properties of the element. The smaller particles within an atom do not have the properties of the entire atom.

9. Would one particle of sugar be an atom? Explain your answer.

Yes ☐ No ☒

Sugar is not an element (refer to question 6 if you have forgotten this). Since sugar is not an element, one particle of sugar cannot be an atom. An atom is defined as the smallest particle of an element that still has the properties of the element.

10. The smallest particle of nitrogen that still has the properties of nitrogen is one atom of nitrogen. This is true because nitrogen is an element (see question 4). Would this single particle of nitrogen be visible to the unaided eye? Explain your answer.

Yes ☐ No ☒

Atoms are too tiny to see with the naked eye. Since one to two million atoms can fit across the diameter of a period, the size of one atom would be less than one-millionth of the diameter. This is far too small to see even for a person with excellent vision.

ELEMENTARY PARTICLES

The simplified model of atomic structure presented here considers the atom to be composed of three types of elementary particles (subatomic particles): the proton, the neutron, and the electron. Each particle is characterized by a weight (or mass) and an electrical charge.

Particle	Symbol	Mass*	Charge
Proton	p	1	+1
Neutron	n	1	0
Electron	e^-	0**	-1

* The units of mass are atomic mass units (amu) or daltons.

** The mass of the electron is not exactly zero, but is so small that it is negligible for most purposes.

Questions

11. Which elementary particles have a charge?

____

12. Which elementary particle is not charged?

____

13. Which elementary particles account for nearly all the weight of the atom?

____

14. Which elementary particle has a charge that is equal in magnitude, but opposite in sign, to the proton?

____

15. Which elementary particle contributes very little to the weight of the atom?

____

Answers

11. Which elementary particles have a charge?

    The electron and the proton have an electrical charge. (Any positive or negative value indicates a charge.)

12. Which elementary particle is not charged?

    The neutron is not charged. As its name implies, it is neutral and the charge is 0.

13. Which elementary particles account for nearly all the weight of the atom?

    The proton and the neutron contribute nearly all the weight of the atom. The weight of the electron is not significant.

14. Which elementary particle has a charge that is equal in magnitude, but opposite in sign, to the proton?

    The electron. The electron's charge of -1 is opposite in sign to the proton's charge of +1. The charges are the same magnitude or size.

15. Which elementary particle contributes very little to the weight of the atom?

    The electron contributes very little to the weight of the atom. Its weight is about 1/2000 that of a proton; therefore, electrons make a negligible contribution to the weight of the atom.

Electrical charges that are opposite in sign are attracted to each other. Electrical charges that have the same sign are repelled from each other. Uncharged matter is neither repelled nor attracted.

Questions

For the pairs of particles listed, state whether the particles would be attracted to each other, repelled from each other, or would not interact.

16. Proton and neutron.

___

17. Proton and electron.

___

18. Electron and neutron.

___

19. Neutron and neutron.

___

20. Electron and electron.

___

21. Electron and proton.

___