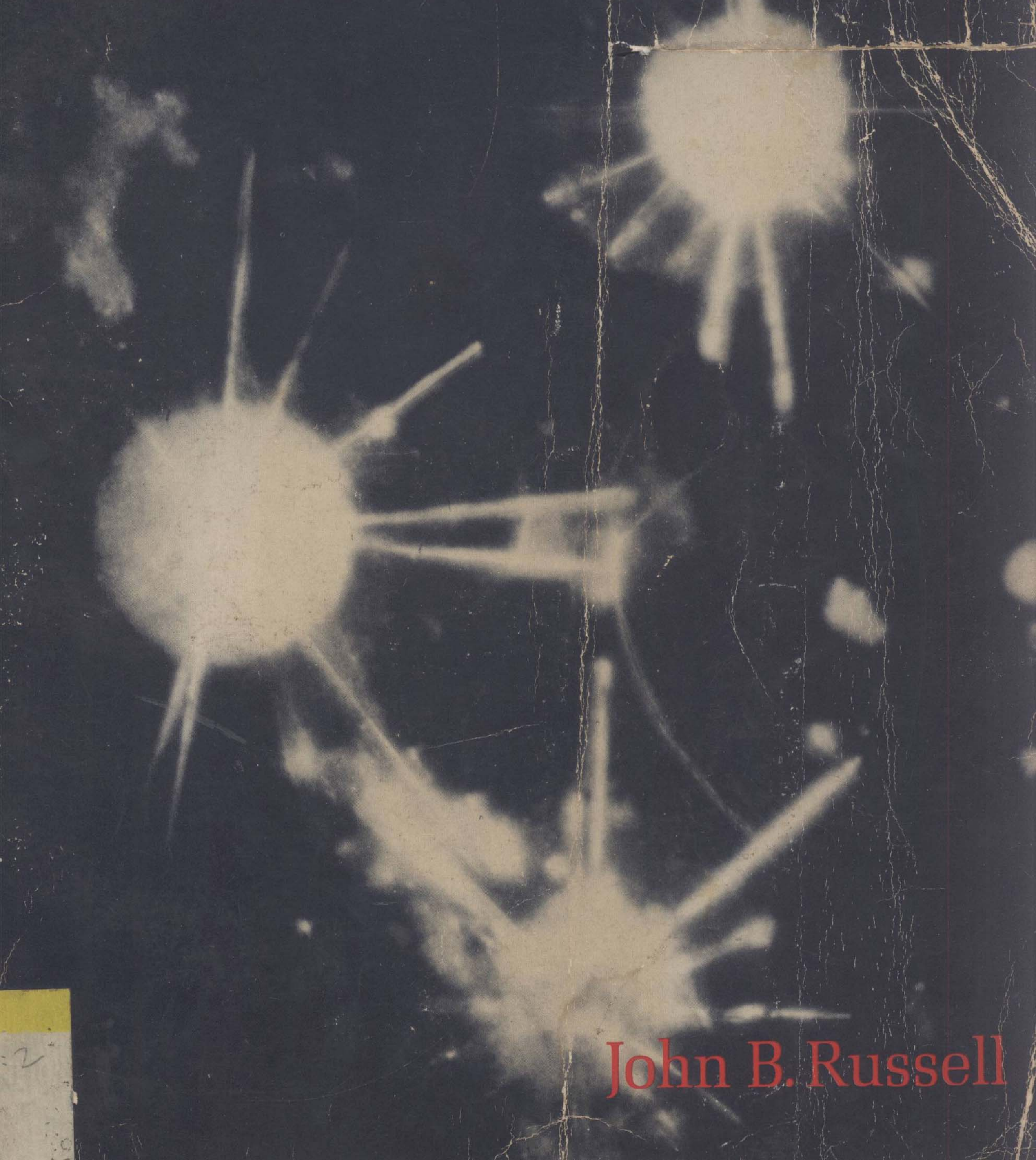
# CHEMISTRY

Study Guide for Sienko and Plane / *Fifth Edition*



John B. Russell

# Study Guide for Sienko and Plane

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*Fifth Edition*

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# Preface

Students taking freshman chemistry typically form a rather heterogeneous group; they tend to vary widely in their backgrounds, aptitudes, and motivation. In writing this Study Guide I have tried to keep these variations in mind, and my hope is that it will be useful to all who use the parent text. I should point out that this book is designed to aid the student and only indirectly assist his professor. By this I mean that it is designed not so much to teach the student as to help him learn the material in the text. It should also be noted that most of the self-test questions at the conclusion of each chapter of this Study Guide would be inappropriate on an examination; they are not intended for that purpose. Rather, they are designed to help the student make a periodic evaluation of his progress and to identify areas of difficulty.

I wish to thank all my colleagues for their suggestions and assistance. I am especially grateful for the inspiration I have received from Roger Weiss of Humboldt State University and, of course, from Mike Sienko of Cornell University and Bob Plane of Clarkson College.

**John B. Russell**

# To the Student

How should you use this Study Guide? The answer depends, in part, on your own study habits. It is important to understand that this book is not a substitute for your text, your instructor, or—most important—your own mental effort. You will not find this Study Guide to be a "magic formula" for success. I hope that you will find it of use as a guide as you work your way through the text. Sometimes students think they understand important chemical ideas better than they really do, only to have a rude awakening in an examination. This Study Guide is intended to help you recognize those points which need more study—before the examination!

You will find in each chapter a first section labelled "Ideas to Remember." I don't think you will find a need to study this section intensively, but I do think you should read it, because in it I have attempted to say a few things a little differently from the way they are stated in the text. (Sometimes a slightly different perspective helps.) Also in each chapter is a listing of "Important Terms." Here I have tried to define, explain, or comment on the important terms in the chapter. In some chapters you will find supplementary "Sample Calculations" which are meant to augment those given in your text, so that you will have still more examples to learn from. Some of the later chapters contain "Checklists of Descriptive Chemistry." These can be used to help organize, and hence remember, the properties and reactions of many elements and compounds. (Try using the items as main headings in an outline, the subheadings of which you should try to fill in.) Lastly, you will find a "Self-Test" in each chapter. Try to answer these questions without constantly referring back to your text. By the time you're through, you will either have convinced yourself that you understand most of the text chapter, or you will have identified the major areas of confusion, at least.

If what you read in a chapter in this Study Guide "makes sense," and if you do well on the self-test, you are probably in good shape. If, on the other hand, the Study Guide chapter raises questions in your mind, if it suggests that maybe you don't understand the material very well after all, or if it points out ideas which seem vague, then it's "back to the drawing board," or, in this case, to your text.

I hope you find the study of chemistry as exciting as I have, and I wish you success!

**John B. Russell**

# Contents

# 1 Study of Matter

## Ideas to Remember

You have undoubtedly noticed that this chapter contains a liberal sprinkling of definitions. Because words are used to communicate ideas, it is very important to understand just how those words are defined. As you study this and subsequent chapters in your text, you will find that it has been often useful to give a very exact and special meaning to a common, everyday word in order to make the word useful in a precise, scientific way. For example, to many people the word *work* means doing anything difficult or tedious. The scientific definition of work is much less general; it refers to the moving of an object against an opposing force. We may speak, for example, of doing work when we lift up a book against the opposing force of gravity. But when we push very hard against an unyielding object such as a wall, we do no work (scientific definition) at all, although if we push long and hard enough, we might be tempted to exclaim, "That's work!" The point of all this is that the loose definition of work (and of many other common words as well) is not particularly useful for some scientific purposes, and it is consequently necessary to use a more restrictive definition. Study the terms and their definitions in this chapter carefully. Make special note where the scientific definition differs from the one which you are used to. This will pay off for you later.

This chapter includes a description of the methods of science. As you study chemistry, watch for laws and theories and try always to distinguish between the two. Sometimes this is not so easy, surprisingly enough. When a theory has seemingly stood the test of time, there is a human tendency to regard the model upon which the theory is based as a directly observable phenomenon or object. For example, although few scientists in the world today would care to question the existence of atoms, strictly speaking these particles are only theoretical constructs invented by people to help explain the behavior of matter. Atomic theory has proved to be so useful for so many years that one tends not to question it as one would a new, less familiar theory. It is true, however, that any theory is only an attempt to understand some aspects of our environment in terms of a "thought model" which may at some later date prove inappropriate. Many spectacular discoveries have been made by investigators who refused to accept some well-established theory. You, too, are invited to be skeptical. Do not feel that you must accept every word in the text, in this Study Guide, or from your instructor as the unchangeable truth. It is wise, of course, to be diplomatic in the expression of your skepticism. It is also wise to combine it with good measures of open-mindedness and scientific curiosity.

## Important Terms

**Matter** Matter is anything that has mass and occupies space: an ice cube, a piece of copper wire, a wooden box, the air we breathe, a cupful of DDT, a cloud of smoke, a speck of dust, the moon, the printer's ink in the period at the end of this sentence. What things are not matter? A ray of light, a clap of thunder, the *color* of an object, an idea, motion, emotion, force, heat; none of these has mass and occupies space, hence, none is matter. In a word, matter is simply "stuff."

**Mass** Mass is a measure of the *amount* of "stuff" in a sample or piece of matter; in other words, the more "stuff" in the piece, the higher is its mass. Experimentally the mass of an object can be determined by measuring the resistance which an object shows to being set in motion or to having its motion changed or stopped. In other words, the inertia of the object is measured. (Kick a table-tennis ball and then a cannonball. Which one hurt your foot more? Which one has the higher mass?) Another much more common and convenient way to measure mass is by comparison with an object of known mass, using a chemical balance. (See text, Section 1.2.)

**Weight** The *force* with which an object is attracted to earth is called its weight. (If the earth is not nearby, the moon or some other large, handy object may be used.) Objects with identical masses will generally have identical weights only if the weights are measured at the same location. Since mass does not depend on the place of measurement, it is generally a more useful quantity than weight.

It should not be necessary to say more about the distinction between mass and weight. Unfortunately it is. For years the word *weight* has been used by people (including scientists) to mean mass. This is a state of affairs which at first seems very unfortunate but turns out not to be so bad in actual practice. For example, a set of known comparison masses for use with a two-pan chemical balance is known as a *set of weights*. To make matters worse, although the verb *to weigh* implies a weight determination, it is the only English verb available for the purpose of indicating a mass determination! Because of the dilemma of the missing verb, and because of common usage, we will frequently refer to the *weight* of an object, even though *mass* is a technically better term.

**Kinetic Energy** An object which has the capacity to do work is said to possess energy. If an object has this capacity *because* it is moving, its energy is kinetic energy.

**Potential Energy** The potential energy of an object is that energy which the object possesses because of its position. But position alone is not enough to define potential energy; it is also necessary that a force be acting on the object. Consequently a piece of iron with no force acting upon it has no potential energy. If, on the other hand, the piece of iron is acted upon by the force of the earth's gravity, then it has potential energy, for it can now fall to the floor (or to some lower level) and do work. Other forces which we might use in order to give the piece of iron potential energy are the force applied to the iron by a long, stretched spring attached to the wall, or the attractive force produced by a large magnet. In each example the iron is potentially able to do work; in other words, it has "stored" or potential energy.

The choice of arrangement that corresponds to zero potential energy is arbitrary. For example, consider a book held above the floor. When the book is dropped to the floor, work is done. We say that the initial system (book above the floor) has higher potential energy than the final system (book on the floor) because it has more capacity to do work. If we arbitrarily label the final system as having zero potential energy, then the initial system has a positive value of potential energy. However, we must appreciate that we have set an arbitrary zero. We can get more work out of the book by dropping it through a hole cut in the floor. It will reach a position of lower potential energy, a position of negative potential energy on the scale that assigns the zero point to the book-on-the-floor position.

**Heat and Temperature** These two terms need not be confusing. All substances in the world, even very cold ones, contain heat. The *amount* of heat may be measured in joules or any other energy unit. But the *hotness* of a substance is measured by its temperature. The difference becomes clear if we consider what happens when we add 4000 joules of heat to 100 g of each of three substances: iron at a temperature of 25°C, liquid water at 25°C, and ice at 0°C. Although each now contains 4000 joules more heat energy than it had originally, the temperature change for each is different! The final temperature of the iron will be about 114°C and that of the water, about 35°C; but the temperature of the ice will not change at all. Clearly the temperature of an object depends on more factors than the amount of heat it contains.

**Heat Capacity** When heat is added to an object, as long as no phase change such as melting or boiling occurs, there will be an increase in temperature. The extent of this increase depends on (1) the amount of heat added, (2) the weight (mass) of the object, and (3) the heat capacity of the substance of which the object is composed. The heat capacity of a substance is equal to the amount of heat which must be added to one gram of the substance in order to raise the temperature one degree Celsius.

**Element** An element is a pure substance which cannot be decomposed (separated by chemical reaction) into simpler substances.

**Compound** A compound is a pure substance which is a chemical combination of two or more elements. Note that both elements and compounds are pure substances, not solutions or heterogeneous mixtures.

**Solution** A solution is a homogeneous mixture. Solutions can have various compositions. A martini (without the olive) is a solution and can have many different compositions depending on how much water (from the melted ice) is present, how much gin and vermouth were used, and what gin and vermouth were used. (Gin and vermouth are solutions themselves, too.)

**Phase** A phase is a physically distinct region with a uniform set of properties throughout.

**Homogeneous** A homogeneous substance is one consisting of only one phase. Examples of homogeneous substances are water, air, salt, sugar, iron, salt water, glass, praseodymium, and maple syrup.

**Heterogeneous** A heterogeneous substance is one which consists of more than one phase. Sometimes a microscope is necessary to observe the different phases in a heterogeneous substance. Examples of heterogeneous substances are granite, muddy water, a mixture of ice and water, peanut butter, smoky air, beer foam, wood, and milk.

**Definite Composition** The law of definite composition is one of the laws of chemical change. One way of stating it is to say that each compound has its own characteristic composition. Let's look at table salt, for example. Table salt is a compound which has the chemical name sodium chloride. It is always composed of the elements sodium (Na) and chlorine (Cl), and its composition is always the same, 39% sodium and 61% chlorine by weight. (This means that of 100 g of table salt, 39 g is sodium and 61 g is chlorine.) It is an intrinsic property of table salt that it always has this composition.

## Sample Calculations

**Example 1** The heat capacity of gold is 0.128 joule/g · deg. 10.0 g of gold at a temperature of 90.0°C is added to 10.0 g of water at 25.0°C. What is the final temperature of the mixture?

We start by recognizing that when the gold comes into contact with the water it loses heat to the water. (It is a natural law that a hotter object in contact with a colder one will spontaneously lose heat to the colder object. As this happens, the temperature of the colder object rises, and that of the hotter object falls, until the two reach the same temperature.) Now let's use a little algebra:

Let $x$ = final temperature (in °C)
Temperature decrease of gold = $90.0 - x$
Temperature increase of water = $x - 25.0$
Heat lost by 1 g of gold = $(90.0 - x)(0.128)$
Heat gained by 1 g of water = $(x - 25.0)(4.184)$ (text, p. 10)
Heat lost by 10.0 g of gold = $(90.0 - x)(0.128)(10.0)$
Heat gained by 10.0 g of water = $(x - 25.0)(4.184)(10.0)$
Heat lost by the gold = heat gained by the water
$(90.0 - x)(0.128)(10.0) = (x - 25.0)(4.184)(10.0)$
Solving for $x$ we get $x = 26.9$
Final temperature is 26.9°C.

**Example 2** Water is a compound which consists of 88.9% oxygen and 11.1% hydrogen by weight. How much water can be made from 10.0 g of oxygen and 10.0 g of hydrogen?

From the given composition we can see that 88.9 g of oxygen will combine chemically with 11.1 g of hydrogen (to form 100.0 g of water).

Weight of hydrogen which will combine with 1.00 g of oxygen = $\frac{11.1}{88.9}$

Weight of hydrogen which will combine with 10.0 g of oxygen = $\left(\frac{11.1}{88.9}\right)(10.0)$ = 1.25 g

Weight of water formed = weight of oxygen + weight of hydrogen = 10.0 + 1.25 = 11.2 g
(10.0 − 1.25 = 8.8 g of hydrogen is left over in excess.)

## SELF-TEST

### Fill in the Blanks

*1* Complex substances having an unvarying composition are called ________.

*2* A system consisting of two or more phases is said to be ________.

*3* A statement which summarizes the results of many observations is sometimes called a ________.

*4* The primary constituents of the gaseous solutions which we usually call "air" are nitrogen and ________.

5 Careful investigation for the purpose of acquiring knowledge is called ________.

6 The symbol for the element iodine is ________.

7 The symbol for the element sodium is ________.

8 A reaction which liberates energy in the form of heat is said to be ________.

9 Table salt is a compound composed of the elements sodium and ________. *(If you do not know the answer to this one, look at the first letters of the answers to Questions 1 to 8.)*

*Which of the following statements might be called laws? Which sound like theories? Which are examples of experimental data? (Pay no attention to whether or not the statements are true.)*

*10* Mr. Lavoisier's wine bottle, when dropped down the well, bounced back up.

*11* All wine bottles, except for yellow ones, burn brightly when bounced.

*12* The behavior of wine bottles may be explained by assuming that they are very much like puppies.

*13* The behavior of matter undergoing a chemical change may be explained by assuming that it is composed of tiny, indivisible, indestructible particles.

*14* All orange wastebaskets have gentle mufflers.

*15* Any two objects, no matter how far apart, are attracted toward each other.

*Indicate the number of phases in each of the following chemical systems. (Do not forget the container, if one is specified.)*

*16* A glass fishbowl filled with leaded gasoline

*17* An aluminum teakettle filled with champagne

*18* An ice cube floating in gin

*19* An ice cube floating in water

*20* A well-mixed mixture of sand, salt, sugar, and lots of water

*21* A copper jug containing water, alcohol, lubricating oil, lead shot, an ice cube, and air

*Classify each of the following chemical systems as either homogeneous or heterogeneous:*

*22* Liquid water

*23* Liquid water plus gaseous water (steam)

*24* Milk

*25* The air above a typical large city

*26* Transparent window glass

*27* A sterling silver spoon

*28* An apple

*29* A chip of granite rock

*30* A woman

Multiple Choice

*31* The density of aluminum is 2.70 g/cm$^3$. How much does 47.0 cm$^3$ of aluminum weigh?
(*a*) 127 g (*b*) 17.4 g (*c*) 0.0574 g (*d*) 49.7 g

*32* 25.0 cm$^3$ of gold weighs 482 g. The density of gold in g/cm$^3$ is:
(*a*) 0.0519 (*b*) 19.3 (*c*) 12.1 (*d*) 1.93

*33* The density of chromium is 7.20 g/cm$^3$. 15.0 g of chromium occupies a volume of:
(*a*) 2.08 cm$^3$ (*b*) 0.480 cm$^3$ (*c*) 108 cm$^3$ (*d*) 4.80 cm$^3$

*34* Ammonia is a compound consisting of 82.4% nitrogen and 17.6% hydrogen by weight. The weight of nitrogen combined in 59.0 g of ammonia is:
(*a*) 10.4 g (*b*) 20.5 g (*c*) 17.6 g (*d*) 48.6 g

*35* The mineral quartz consists of 46.8% silicon and 53.2% oxygen by weight. A piece of quartz which contains 25.0 g of silicon also contains how many grams of oxygen?
(*a*) 11.7 (*b*) 13.3 (*c*) 22.0 (*d*) 28.4

*36* The freezing point of water is:
(*a*) 32°C (*b*) 16°C (*c*) 8°C (*d*) 0°C

*37* Comfortable room temperature is about:
(*a*) 10°C (*b*) 23°C (*c*) 38°C (*d*) 70°C

*38* 225 joules of heat is added to 10.0 g of water, initially at 25.0°C. The final temperature is:
(*a*) 5.4°C (*b*) 30.4°C (*c*) 75.4°C (*d*) 90.1°C

*39* In order to raise the temperature of 1.00 g of water from 25.0°C to 47.5°C, the quantity of heat required is:
(*a*) 22.5 joules (*b*) 68.9 joules (*c*) 94.1 joules (*d*) 198 joules

*40* In order to raise the temperature of 6.80 g of water from 25.0°C to 47.5°C, the quantity of heat required is:
(*a*) 319 joules (*b*) 640 joules (*c*) 719 joules (*d*) 821 joules

*41* In order to lower the temperature of 6.80 g of water from 47.5°C to 25.0°C, the quantity of heat which must be removed from the water is:
(*a*) 319 joules (*b*) 640 joules (*c*) 719 joules (*d*) 821 joules