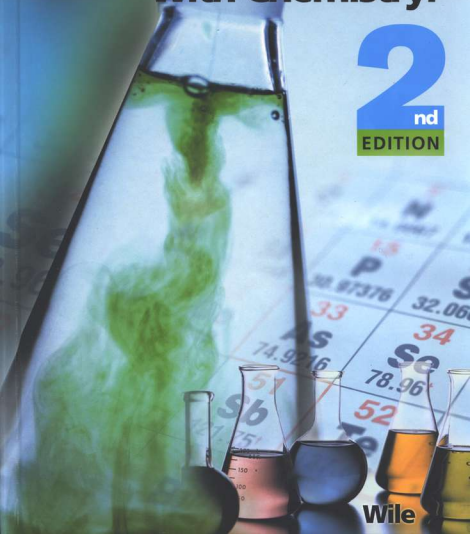


Exploring Creation With Chemistry:

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Exploring Creation With Chemistry

Table of Contents

MODULE #1: Measurement and Units	1
Introduction	1
Experiment 1.1: Air Has Mass	1
Experiment 1.2: Air Takes Up Space	2
Units of Measurement	3
The Metric System	4
Manipulating Units	6
Converting Between Units	7
Converting Between Unit Systems	10
More Complex Unit Conversions	11
Derived Units	13
Making Measurements	17
Accuracy, Precision, and Significant Figures	19
Scientific Notation	23
Using Significant Figures in Mathematical Problems	25
Experiment 1.3: Comparing Conversions to Measurements	27
Density	28
Experiment 1.4: The Density of Liquids	29
Answers to the "On Your Own" Problems	32
Review Questions	35
Practice Problems	36
MODULE #2: Energy, Heat, and Temperature	37
Introduction	37
Energy and Heat	37
The Nature of a Scientific Law	39
The First Law of Thermodynamics	40
Units for Measuring Heat and Energy	40
Experiment 2.1: Calibrating Your Thermometer	43
The Calorie Unit	48
Measuring Heat	49
Calorimetry	53
Experiment 2.2: Measuring the Specific Heat of a Metal	58
Answers to the "On Your Own" Problems	61
Review Questions	67
Practice Problems	68

MODULE #3: Atoms and Molecules	69
Introduction	69
Early Attempts to Understand Matter	69
The Law of Mass Conservation	70
Experiment 3.1: The Conservation of Mass	71
Elements: The Basic Building Blocks of Matter	74
The Periodic Table of Elements	75
Compounds	78
The Law of Multiple Proportions	82
Dalton's Atomic Theory	83
Molecules: The Basic Building Blocks of Compounds	85
Abbreviating and Classifying Compounds	86
Classifying Matter as Ionic or Covalent	87
Experiment 3.2: Electrical Conductivity of Compounds Dissolved in Water	88
Naming Compounds	90
Answers to the "On Your Own" Problems	94
Review Questions	97
Practice Problems	98

MODULE #4: Classifying Matter and Its Changes	99
Introduction	99
Classifying Matter	99
Experiment 4.1: Separating a Mixture of Sand and Salt	101
Classifying Changes That Occur in Matter	106
Experiment 4.2: Distinguishing Between Chemical and Physical Change	107
Phase Changes	109
Experiment 4.3: Condensing Steam in an Enclosed Vessel	110
The Kinetic Theory of Matter	111
Experiment 4.4: The Kinetic Theory of Matter	113
Phase Changes in Water	114
Chemical Reactions and Chemical Equations	115
Determining Whether or Not a Chemical Equation is Balanced	120
Balancing Chemical Equations	122
Answers to the "On Your Own" Problems	126
Review Questions	131
Practice Problems	132

MODULE #5: Counting Molecules and Atoms in Chemical Equations	133
Introduction	133
Three Basic Types of Chemical Reactions	133
Decomposition Reactions	133
Formation Reactions	137
Complete Combustion Reactions	138
Incomplete Combustion Reactions	140
Molecular Mass	144
The Mole Concept	145
Experiment 5.1: Measuring the Width of a Molecule	149
Using the Mole Concept in Chemical Equations	153
Answers to the "On Your Own" Problems	157
Review Questions	161
Practice Problems	162
 MODULE #6: Stoichiometry	 163
Introduction	163
Mole Relationships in Chemical Equations	164
Limiting Reactants and Excess Components	165
Experiment 6.1: Limiting Reactants	166
Fully Analyzing Chemical Equations	168
Relating Products to Reactants in Chemical Equations	170
Using Chemical Equations When the Limiting Reactant Is Identified	171
Volume Relationships for Gases in Chemical Equations	174
Mass Relationships in Chemical Equations	176
Using Stoichiometry to Determine Chemical Formulas	183
Empirical and Molecular Formulas	185
More Complicated Experiments for Determining Chemical Formulas	189
Answers to the "On Your Own" Problems	191
Review Questions	198
Practice Problems	199

MODULE #7: Atomic Structure	201
Introduction	201
Historical Overview	201
Electrical Charge	203
Experiment 7.1: Electrical Charge	203
Electrical Charge and Atomic Structure	205
Determining the Number of Protons and Electrons in an Atom	205
Determining the Number of Neutrons in an Atom	206
Isotopes and Nuclear Bombs	208
Atomic Structure in More Detail	209
The Nature of Light	213
The Electromagnetic Spectrum	219
The Relationship Between Frequency and Energy	221
How the Eye Detects Color	223
Experiment 7.2: How the Eye Detects Color	223
The Bohr Model of the Atom	224
The Quantum Mechanical Model of the Atom	228
Building Atoms in the Quantum Mechanical Model (Electron Configurations)	231
Abbreviated Electron Configurations	237
The Amazing Design of Atoms	238
Answers to the "On Your Own" Problems	241
Review Questions	245
Practice Problems	246
 MODULE #8: Molecular Structure	 247
Introduction	247
Electron Configurations and the Periodic Chart	247
Lewis Structures	249
Lewis Structures for Ionic Compounds	251
Handling the Exceptions in Ionic Compounds	257
Ionization Potential and Periodic Properties	258
Electronegativity: Another Periodic Property	261
Atomic Radius: Another Periodic Property	262
Lewis Structures of Covalent Compounds	263
More Complicated Lewis Structures	269
An Application of Lewis Structures	272
Answers to the "On Your Own" Problems	277
Review Questions	283
Practice Problems	284

MODULE #9: Polyatomic Ions and Molecular Geometry	285
Introduction	285
Polyatomic Ions	285
Molecular Geometry: The VSEPR Theory	289
Purely Covalent and Polar Covalent Bonds	298
Experiment 9.1: Polar Covalent Versus Purely Covalent Compounds	300
Purely Covalent and Polar Covalent Molecules	303
The Practical Consequence of Whether or Not a Molecule Is Polar Covalent	307
Experiment 9.2: Solubility of Ionic Compounds	307
Answers to the "On Your Own" Problems	309
Review Questions	317
Practice Problems	318
 MODULE #10: Acid/Base Chemistry	 319
Introduction	319
Acids and Bases	319
Experiment 10.1: Common Household Examples of Acids and Bases	320
The Chemical Definitions of Acids and Bases	322
The Behavior of Ionic Compounds in Aqueous Solutions	324
Identifying Acids and Bases in Chemical Reactions	325
Recognizing Acids and Bases From Their Chemical Formulas	327
Predicting the Reactions That Occur Between Acids and Bases	329
The Reactions Between Acids and Covalent Bases	332
Molarity	334
The Dilution Equation	336
The Importance of Concentration in Chemistry	338
Using Concentration in Stoichiometry	339
Acid/Base Titrations	341
Experiment 10.2: Acid/Base Titration	342
Answers to the "On Your Own" Problems	346
Review Questions	351
Practice Problems	352

MODULE #11: The Chemistry of Solutions 353

Introduction	353
How Solutes Dissolve in Solvents	353
Solubility	358
Experiment 11.1: The Effect of Temperature on the Solubility of Solid Solutes	359
Experiment 11.2: The Effect of Temperature on the Solubility of a Gas	361
Energy Changes That Occur When Making a Solution	363
Experiment 11.3: Investigation of a Solute That Releases Heat When Dissolved	363
Applying Stoichiometry to Solutions	365
Molality	367
Experiment 11.4: Freezing-Point Depression	369
Boiling-Point Elevation	374
Answers to the "On Your Own" Problems	376
Review Questions	381
Practice Problems	382

MODULE #12: The Gas Phase..... 383

Introduction	383
The Definition of Pressure	383
Boyle's Law	384
Charles's Law	387
The Combined Gas Law	391
Ideal Gases	394
Dalton's Law of Partial Pressures	395
An Alternative Statement of Dalton's Law	399
The Ideal Gas Law	403
Using the Ideal Gas Law in Stoichiometry	404
Experiment 12.1: Using the Ideal Gas Equation	404
Answers to the "On Your Own" Problems	409
Review Questions	415
Practice Problems	416

MODULE #13: Thermodynamics	417
Introduction	417
Enthalpy	417
Determining ΔH for a Chemical Reaction by Experiment.....	420
Experiment 13.1: Determining the ΔH of a Chemical Reaction	421
Determining the ΔH of a Chemical Reaction Using Bond Energies	423
Hess's Law	428
Applying Enthalpy to Stoichiometry.....	434
Energy Diagrams	436
The Second Law of Thermodynamics.....	439
The Proper Application of the Second Law of Thermodynamics	444
Gibbs Free Energy	446
Answers to the "On Your Own" Problems	450
Review Questions	456
Practice Problems	457
 MODULE #14: Kinetics.....	 459
Introduction	459
Reaction Kinetics	459
Factors That Affect the Kinetics of a Chemical Reaction	460
Experiment 14.1: Factors That Affect Chemical Reaction Rates	460
The Rate Equation	464
Using Experiments to Determine the Details of the Rate Equation	466
Rate Orders	472
Using Rate Equations	474
Temperature Dependence in the Rate Equation	477
Catalysts and Reaction Rate	479
Experiment 14.2: The Effect of a Catalyst on the Decomposition of Hydrogen Peroxide	480
Answers to the "On Your Own" Problems	485
Review Questions	488
Practice Problems	489

MODULE #15: Chemical Equilibrium	491
Introduction	491
The Definition of Chemical Equilibrium	491
Experiment 15.1: A Demonstration of Equilibrium	493
The Equilibrium Constant	495
A Few More Details Concerning the Equilibrium Constant	499
Using the Equilibrium Constant to Predict the Progress of a Reaction	501
Le Chatelier's Principle	504
Pressure and Le Chatelier's Principle	507
Temperature and Le Chatelier's Principle	510
Experiment 15.2: Temperature and Le Chatelier's Principle	510
Acid/Base Equilibria	513
The pH Scale	516
Acid Rain	517
Answers to the "On Your Own" Problems	519
Review Questions	522
Practice Problems	523
MODULE #16: Reduction/Oxidation Reactions	525
Introduction	525
Oxidation Numbers	525
Determining Oxidation Numbers	527
Oxidation and Reduction	531
Recognizing Reduction/Oxidation Reactions	533
An Important Characteristic of Reduction/Oxidation Reactions	534
Experiment 16.1: Invisible Writing	535
How Batteries Work	536
Real Batteries	542
Corrosion	545
A Few Final Words	545
Answers to the "On Your Own" Problems	546
Review Questions	549
Practice Problems	550
Glossary	551
Appendix A	563
Appendix B	569
Appendix C	585
Index	593

MODULE #1: Measurement and Units

Introduction

What is chemistry? That's a very good question. Chemistry is, quite simply, the study of **matter**. Of course, this definition doesn't do us much good unless we know what matter is. So, in order to understand what chemistry is, we first need to define matter. A good working definition for matter is:

Matter - Anything that has mass and takes up space

If you have a problem with the word "mass," don't worry about it. We will discuss this concept in a little while. For right now, you can replace the word "mass" with the word "weight." As we will see later, this isn't quite right, but it will be okay for now.

If matter is defined in this way, almost *everything* around us is matter. Your family car has a lot of mass. That's why it's so heavy. It also takes up a lot of space sitting in the driveway or in the garage. Thus, your car must be made of matter. The food you eat isn't as heavy as a car, but it still has some mass. It also takes up space. So food must be made up of matter as well. Indeed, almost everything you see around you is made up of matter because nearly everything has mass and takes up space. There is one thing, however, that has no mass and takes up no space. It's all around you right now. Can you think of what it might be? What very common thing that is surrounding you right now has no mass and takes up no space?

You might think that the answer is "air." Unfortunately, that's not the right answer. Perform the following experiments to see what I mean:

EXPERIMENT 1.1

Air Has Mass

Supplies:

- A meterstick (A yardstick will work as well; a 12-inch ruler is not long enough.)
 - Two 8-inch or larger balloons
 - Two pieces of string long enough to tie the balloons to the meterstick
 - Tape
 - Safety goggles
1. Without blowing them up, tie the balloons to the strings. Be sure to make the knots loose so that you can untie one of the balloons later in the experiment.
 2. Tie the other end of each string to each end of the meterstick. Try to attach the strings as close to the ends of the meterstick as possible.
 3. Once the strings have been tied to the meterstick, tape them down so that they cannot move.
 4. Go into your bathroom and pull back the shower curtain so that a large portion of the curtain rod is bare. Balance the meterstick (with the balloons attached) on the bare part of the shower curtain rod. You should be able to balance it very well. If you don't have a shower curtain rod or you are having trouble using yours, you can use any surface that is adequate for delicate balancing.

5. Once you have the meterstick balanced, stand back and look at it. The meterstick balances right now because the total mass on one side of the meterstick equals the total mass on the other side of the meterstick. In order to knock it off balance, you would need to move the meterstick or add more mass to one side. You will do the latter.
6. Have someone else hold the meterstick so that it does not move. In order for this experiment to work properly, the meterstick must stay stationary.
7. While the meterstick is held stationary, remove one of the balloons from its string (do not untie the string from the meterstick), and blow up the balloon.
8. Tie the balloon closed so that the air does not escape, then reattach it to its string.
9. Have the person holding the meterstick let go. If the meterstick was not moved while you were blowing up the balloon, it will tilt toward the side with the inflated balloon as soon as the person lets it go. This is because you added air to the balloon. Since air has mass, it knocks the meterstick off balance. Thus, air does have mass!
10. Clean up your mess.

EXPERIMENT 1.2

Air Takes Up Space

Supplies:

- A tall glass
- A paper towel
- A sink full of water
- Safety goggles

1. Fill your sink with water until the water level is high enough to submerge the entire glass.
2. Make sure the inside of the glass is dry.
3. Wad up the paper towel and shove it down into the bottom of the glass.
4. Turn the glass upside down and be sure that the paper towel does not fall out of the glass.
5. Submerge the glass upside down in the water, being careful not to tip the glass at any time.
6. Wait a few seconds and remove the glass, still being careful not to tilt it.
7. Pull the paper towel out of the glass. You will find that the paper towel is completely dry. Even though the glass was submerged in water, the paper towel never got wet. Why? When you tipped the glass upside down, there was air inside the glass. When you submerged it in the water, the air could not escape the glass. Thus, the glass was still full of air. Since air takes up space, there was no room for water to enter the glass, so the paper towel stayed dry.
8. Repeat the experiment, but this time be sure to tip the glass while it is underwater. You will see large bubbles rise to the surface of the water, and when you pull the glass out, you will find that it has water in it and that the paper towel is wet. This is because you allowed the air trapped inside the glass to escape when you tilted the glass. Once the air escaped, there was room for the water to come into the glass.
9. Clean up your mess.

Now that you see that air does have mass and does take up space, have you figured out the correct answer to my original question? What very common thing that is surrounding you right now has no mass and takes up no space? The answer is *light*. As far as scientists can tell, light does not have any mass and takes up no space. Thus, light is not considered matter. Instead, it is pure energy. Everything else that you see around you, however, is considered matter. Chemistry, then, is the study of nearly everything! As you can imagine, studying nearly everything can be a very daunting task. However, chemists have found that even though there are many forms of matter, they all behave according to a few fundamental laws. If we can clearly understand these laws, then we can clearly understand the nature of the matter that exists in God's creation.

Before we start trying to understand these laws, however, we must first step back and ask a more fundamental question. *How* do we study matter? Well, the first thing we have to be able to do in order to study matter is to measure it. If I want to study an object, I first must learn things like how big it is, how heavy it is, and how old it is. In order to learn these things, I have to make some measurements. The rest of this module explains how scientists measure things and what those measurements mean.

Units of Measurement

Let's suppose I'm making curtains for a friend's windows. I ask him to measure the window and give me the dimensions so that I can make the curtains the right size. My friend tells me that his windows are 50 by 60, so that's how big I make the curtains. When I go over to his house, it turns out that my curtains are more than twice as big as his windows! My friend tells me that he's certain he measured the windows correctly, and I tell my friend that I'm certain I measured the curtains correctly. How can this be? The answer is quite simple. My friend measured the windows in *centimeters*. I, on the other hand, measured the curtains in *inches*. Our problem was not caused by one of us measuring incorrectly. Instead, our problem was the result of measuring with different **units**.

When we are making measurements, the units we use are just as important as the numbers that we get. If my friend had told me that his windows were 50 centimeters by 60 centimeters, then there would have been no problem. I would have known exactly how big to make the curtains. Since he failed to do this, the numbers that he gave me (50 by 60) were essentially useless. Please note that a failure to indicate the units involved in measurements can lead to serious problems. For example, the Mars Climate Orbiter, a NASA (National Aeronautics and Space Administration) spacecraft built for the exploration of Mars, vanished during an attempt to put the craft into orbit around the planet. In an investigation that followed, NASA determined that a units mix-up had caused the disaster. One team of engineers had used metric units in its designs, while another team had used English units. The teams did not indicate the units they were using, and as a result, the designs were incompatible.

In the end, then, scientists should never simply report numbers. They must always include units with those numbers so that everyone knows exactly what those numbers mean. That will be the rule in this chemistry course. If you answer a question or a problem and do not list units with the numbers, your answer will be considered incorrect. In science, numbers mean nothing unless there are units attached to them.

Window illustration by
Megan Whitaker

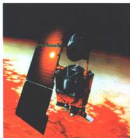
FIGURE 1.1

Two Consequences of Not Using Units Properly

Mars Climate Orbiter image
Courtesy of NASA/JPL/Caleech



These curtains are too long for this window because the window was measured in centimeters, but the curtains were made assuming the measurements were in inches.



The Mars Climate Orbiter did not successfully make it into orbit because two of the engineering teams involved used different units in their designs.

Since scientists use units in all of their measurements, it is convenient to define a standard set of units that will be used by everyone. This system of standard units is called the **metric system**. If you do not fully understand the metric system, don't worry. By the end of this module, you will be an expert at using it. If you do fully understand the metric system, you can probably skip ahead to the section labeled "Converting Between Units."

The Metric System

There are many different things that we need to measure when studying nature. First, we must determine how much matter exists in the object that we want to study. We know that there is a lot more matter in a car than there is in a feather, since a car is heavier. In order to study an object precisely, however, we need to know *exactly* how much matter is in the object. To accomplish this, we measure the object's **mass**. In the metric system, the unit for mass is the **gram**. If an object has a mass of 10 grams, we know that it has 10 times the matter that is in an object with a mass of 1 gram. To give you an idea of the size of a gram, the average mass of a housefly is just about 1 gram. Based on this fact, we can say that a gram is a rather small unit. Most of the things that we will measure will have masses of 10 to 10,000 grams. For example, this book has a mass of about 2,300 grams.

Now that we know what the metric unit for mass is, we need to know a little bit more about the concept itself. I said in the beginning that we could think of mass as weight. That's not exactly true. Mass and weight are two different things. Mass measures how much matter exists in an object. Weight, on the other hand, measures how hard gravity pulls on that object.

For example, if I were to get on my bathroom scale and weigh myself, I would find that I weigh 170 pounds. However, if I were to take that scale to the moon and weigh myself, I would find that I weighed only 28 pounds there. Does that mean I'm thinner on the moon than I am at home? Of course not. It means that on the moon, gravity is not as strong as it is in my house.

On the other hand, if I were to measure my mass at home, I would find it to be 77,000 grams. If I were to measure my mass on the moon, it would still be 77,000 grams. That's the difference between mass and weight. Since weight is a measure of how hard gravity pulls, an object weighs different amounts depending on where that object is. Mass, on the other hand, is a measure of how much matter is in an object and does not depend on where that object is.

Unfortunately, there are many other unit systems in use today besides the metric system. In fact, the metric system is probably not the system with which you are most familiar. You are probably most familiar with the English system. The unit of pounds comes from the English system. However, pounds are not a measure of mass; they are a measure of weight. The metric unit for weight is called the **Newton**. The English unit for mass is (believe it or not) called the **slug**. Although we will not use the slug often, it is important to understand what it means, especially when you study physics.

There is more to measurement than just grams, however. We might also want to measure how big an object is. For this, we must use the metric system's unit for distance, which is the **meter**. You are probably familiar with a yardstick. Well, a meter is just slightly longer than a yardstick. The English unit for distance is the **foot**. What about inches, yards, and miles? We'll talk about those a little later.

We also need to be able to measure how much space an object occupies. This measurement is commonly called "volume" and is measured in the metric system with the unit called the **liter**. The main unit for measuring volume in the English system is the **gallon**. To give you an idea of the size of a liter, it takes just under four liters to make a gallon.

Finally, we have to be able to measure the passage of time. When studying matter, we will see that it has the ability to change. The shape, size, and chemical properties of certain substances change over time, so it is important to be able to measure time so that we can determine how quickly the changes take place. In both the English and metric systems, time is measured in **seconds**.

Since it is very important for you to be able to recognize which units correspond to which measurements, Table 1.1 summarizes what you have just read. The letters in parentheses are the commonly used abbreviations for the units listed.

TABLE 1.1
Physical Quantities and Their Base Units

Physical Quantity	Base Metric Unit	Base English Unit
Mass	gram (g)	slug (sl)
Distance	meter (m)	foot (ft)
Volume	liter (L)	gallon (gal)
Time	second (s)	second (s)

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