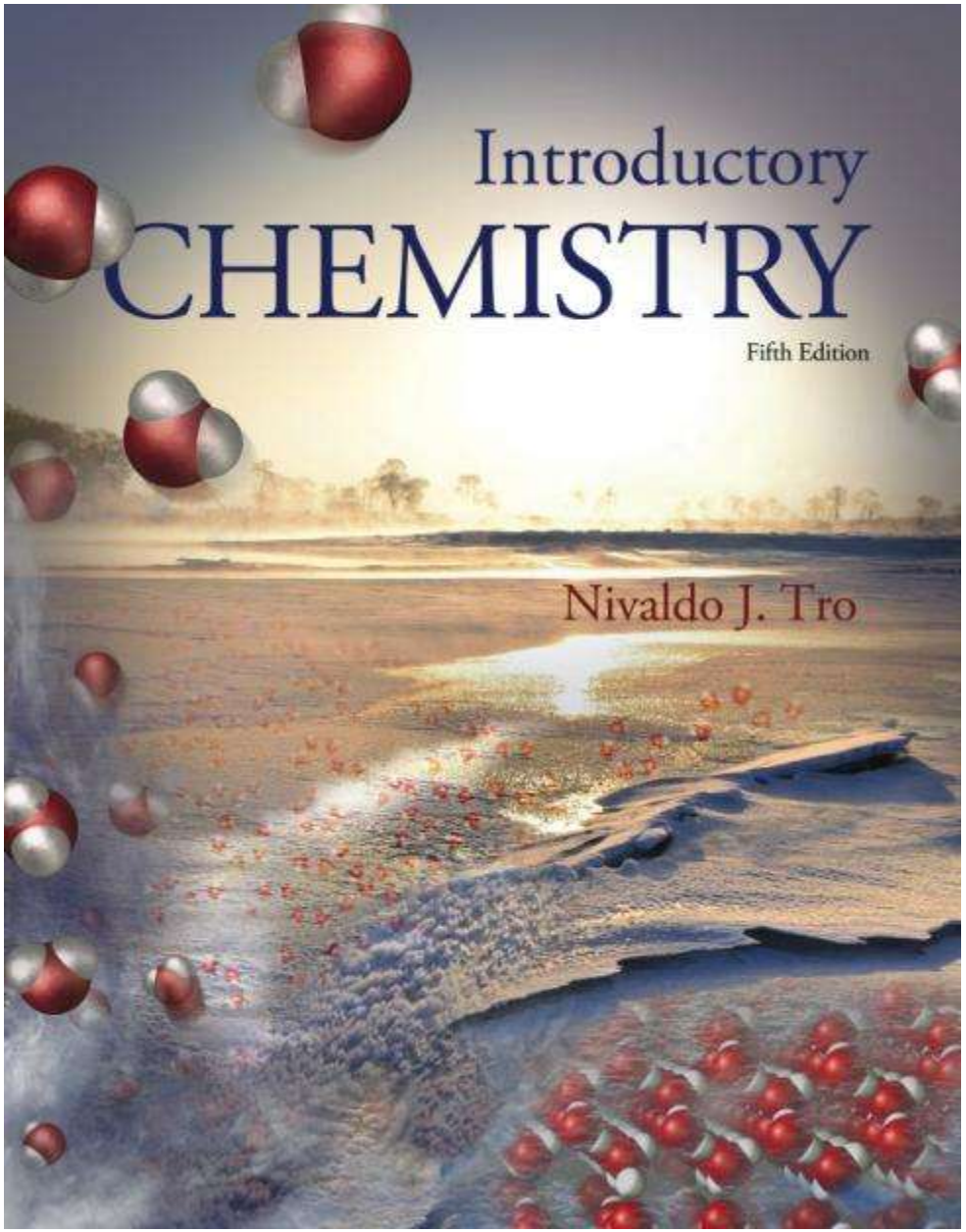

Introductory Chemistry

Fifth Edition

Nivaldo J. Tro

Chapter 1

The Chemical World

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The Chemical World

Chemistry:
The science that seeks
to understand **what matter does**
by studying **what atoms and molecules do.**
Virtually everything around you is composed of chemicals.

Atoms and Molecules in Matter

Atoms are very small.
Atoms and molecules are tiny particles that compose all common matter.

The **atoms** are bound together to form several different types of **molecules.**

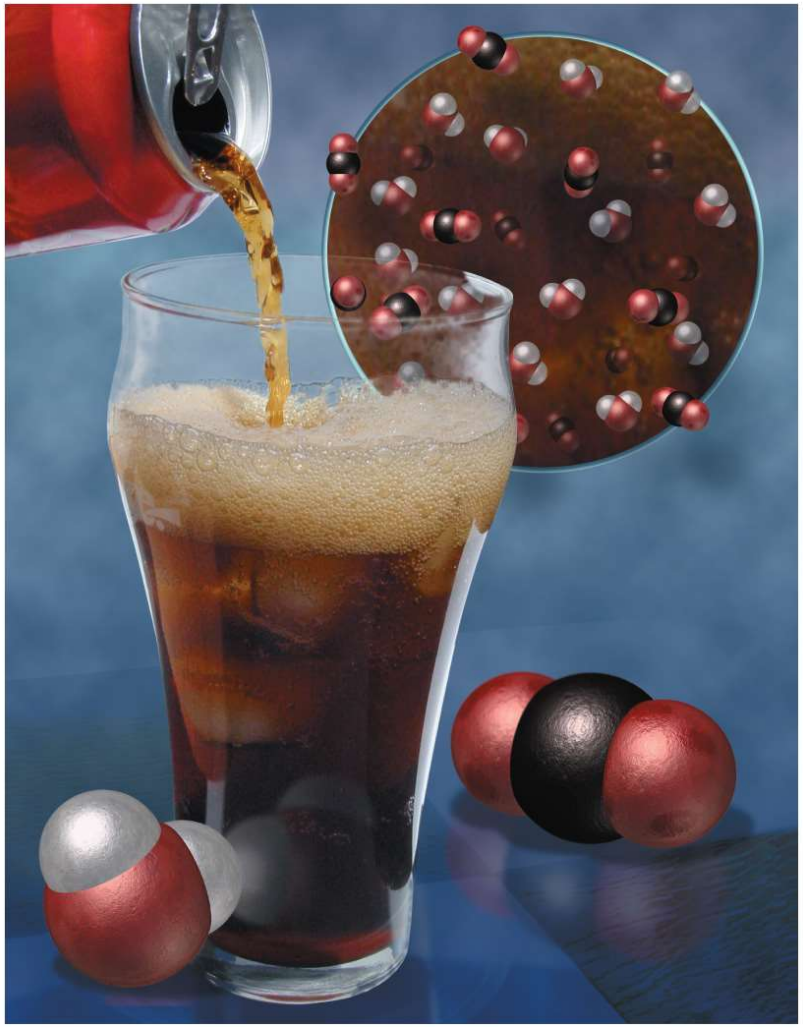
Chemical bonds are the attachments that hold atoms together.

Atoms and Molecules in Soda Pop

- Soda pop is composed of tiny particles called *atoms.*
- A single drop of soda pop contains about one billion trillion $(1 \times 10^9 \times 10^{12})$ atoms.
- Soda pop is a mixture: carbon dioxide molecules, water molecules, and other substances that contribute flavor and color.

Atoms and Molecules in Soda Pop Fizz

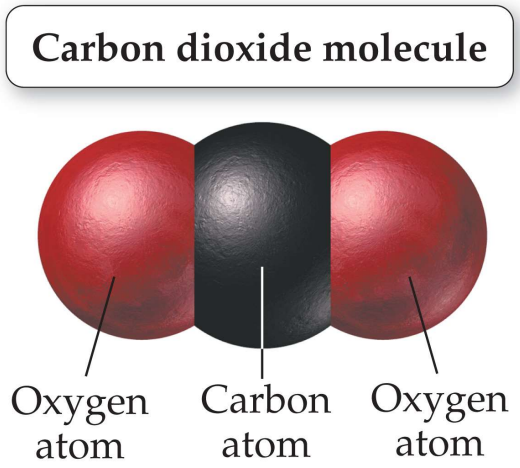
- Identify the two molecules.
- Identify each of the atoms within each molecule.
- From a molecular point of view, can we explain why soda pop fizzes?
- What molecules are inside the bubbles in a glass of soda pop?



Atoms and Molecules in Soda Pop Fizz

- A can of soda pop is a chemical mixture.
- Soda pop consists primarily of sugar, water, and carbon dioxide.
- The characteristics of sugar molecules produce the sensation of sweetness on our taste buds.
- The molecules important to fizzing are carbon dioxide and water.

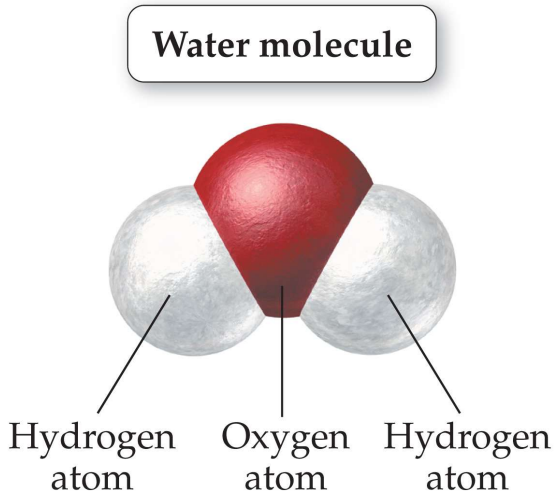
Carbon Dioxide Molecules



Carbon dioxide molecules consist of three atoms—one carbon and two oxygen—held together in a straight line by chemical bonds.

The characteristics of carbon dioxide molecules make carbon dioxide **a gas** at room temperature.

Water Molecules



Water molecules consist of three atoms—one oxygen and two hydrogen—bonded together, but rather than being linear like the carbon dioxide molecule, the water molecule is bent.

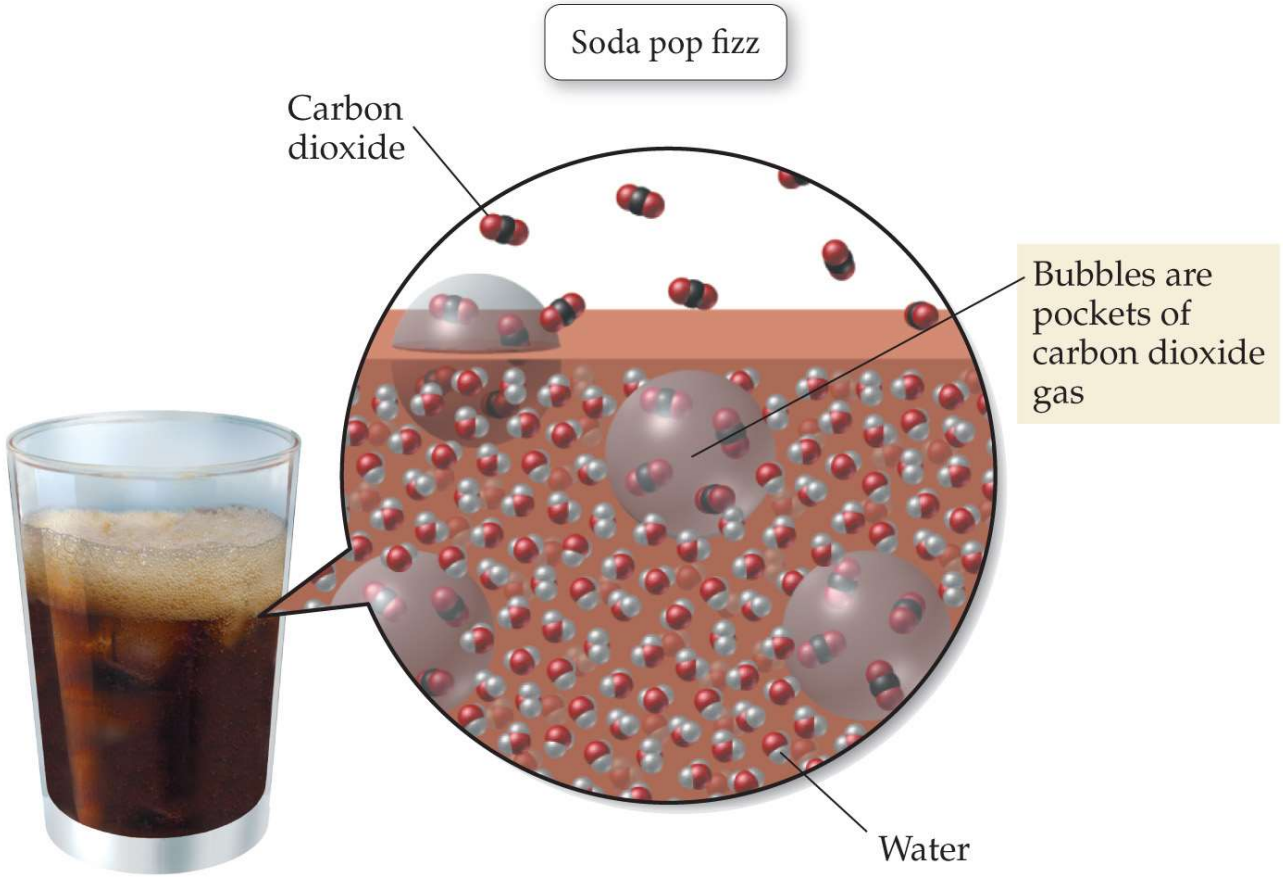
The characteristics of water molecules make water **a liquid** at room temperature.

Carbon Dioxide Molecules in Soda Pop Fizz

Under pressure, gaseous carbon dioxide molecules are forced to remain mixed with liquid water molecules in a sealed container. When the can is opened and the **pressure is released,** carbon dioxide molecules escape out of the soda mixture, creating bubbles.

Soda Pop Fizz

Bubbles in Soda Pop:
Pockets of carbon dioxide gas molecules escaping out of liquid water

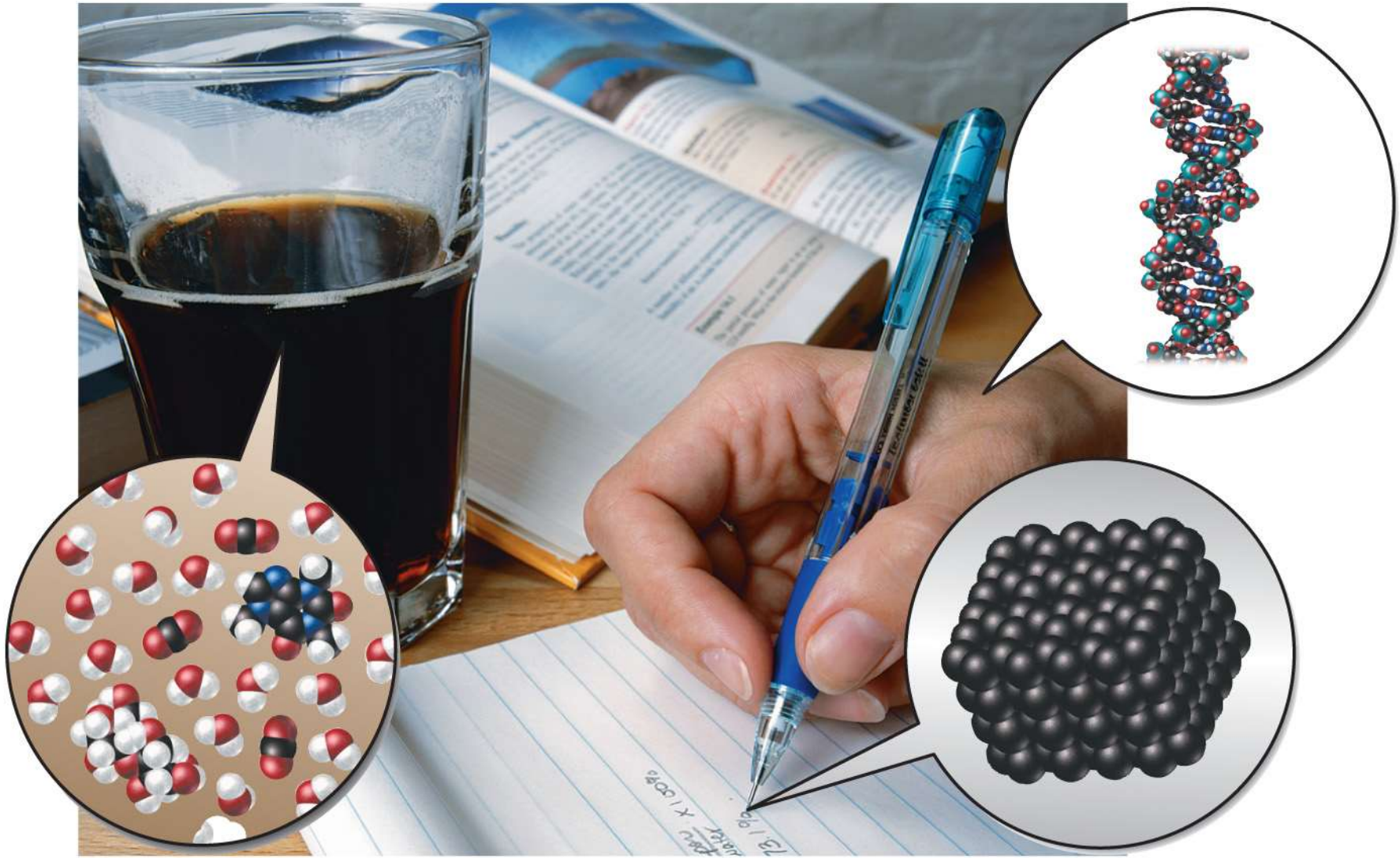


Chemicals Compose Ordinary Things

There is nothing you can hold or touch that is *not made of chemicals.*

Chemicals make up virtually everything we come into contact with.

Chemicals Compose Ordinary Things



Chemicals Compose Ordinary Things

People often have a very narrow view of chemicals, thinking of them only as dangerous poisons or pollutants.

Chemicals Compose Ordinary Things

Chemicals compose ordinary things, too.

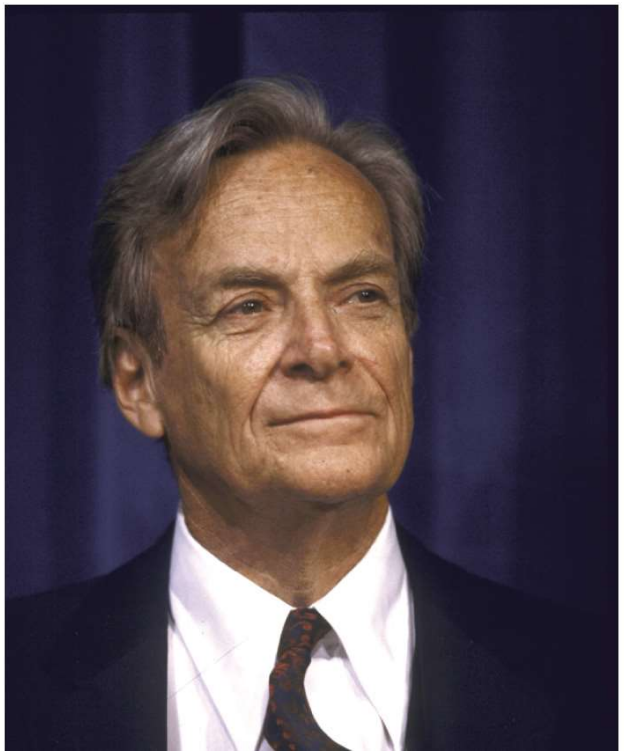
- The air we breathe
- The water we drink
- Toothpaste, Tylenol, toilet paper

Chemicals Compose Ordinary Things

Chemistry explains the properties and behavior of chemicals by helping us understand the molecules that compose them.

All Things Are Made of Atoms and Molecules

- The most important idea in all of human knowledge: *All things are made of atoms.*
- Richard Feynman (1918–1988), Nobel Prize–winning physicist and popular professor at California Institute of Technology



A Definition of Chemistry

- A good, simple definition of **chemistry** is *the science that tries to understand how matter behaves by studying how atoms and molecules behave.*

The Scientific Method: How Chemists Think

Ways to Understand the World:
Chemists use the **scientific method**

—a way of learning that emphasizes observation and experimentation—

to produce knowledge as the result of the senses.

Ancient Philosophy and Medieval Applications

- The scientific method stands in contrast to ancient Greek philosophies and medieval applications of them that emphasized *reason* **to produce knowledge as the result of thoughts.**

The Scientific Method: How Chemists Think

Knowledge as a Result of the Senses:

- **Observations** involve measuring or observing some aspect of nature.
- **Hypotheses** are tentative interpretations of the observations.
- **Laws** summarize the results of a large number of observations.
- **Theories** are models that explain and give the underlying causes for observations and laws.

The Scientific Method: Experiments

- Hypotheses, laws, and theories must be tested and validated by experiment.
- If hypotheses are not confirmed, they are revised and tested through further experimentation.

The Scientific Method: Observation

- Some observations can be made with the naked eye.
- Other observations emerge from experiments that rely on the use of sensitive instrumentation.
- Observation usually involves the measurement or description of some aspect of the physical world.

Observation of Combustion

Antoine Lavoisier (1743–1794), a French chemist, made an *observation* about the physical world.

- Lavoisier measured the property of mass in the process of combustion (Combustion means burning).
- The mass of an object is a measure of the quantity of matter within it.

Observation of Combustion Experiments

- Lavoisier burned substances in closed containers.
- He measured the mass of each container and its contents before and after burning the substance inside.
- He noted that there was no change in the mass during combustion.

The Scientific Method: Hypothesis

Observations lead scientists to formulate a **hypothesis,** a tentative interpretation or explanation of the observations.

- A good hypothesis is *falsifiable (it is possible to test it and it is possible that the test will fail),* which means that further testing has the potential to prove it wrong.
- Hypotheses are tested by **experiments,** highly controlled observations designed to validate or invalidate hypotheses.
- The results of an experiment may confirm a hypothesis or show it to be mistaken in some way.
- The hypothesis may have to be modified or discarded and replaced by an alternative.
- The new or revised hypothesis must also be tested through further experimentation.

Law of Conservation of Mass

A number of similar observations lead to the development of a **scientific law,** a brief statement that synthesizes past observations and predicts future ones.

Lavoisier developed the **law of conservation of mass,** which states,

"In a chemical reaction, matter is neither created nor destroyed."

The Scientific Method: Scientific Theory

One or more well-established hypotheses may form the basis for a **scientific theory.**

- Theories provide a broader and deeper explanation for observations and laws.
- Theories are models of the way nature is.
- Theories often predict behavior that extends well beyond the observations and laws on which they are founded.

The Scientific Method: Observation, Law, Theory

Classify each statement as an observation, a law, or a theory.

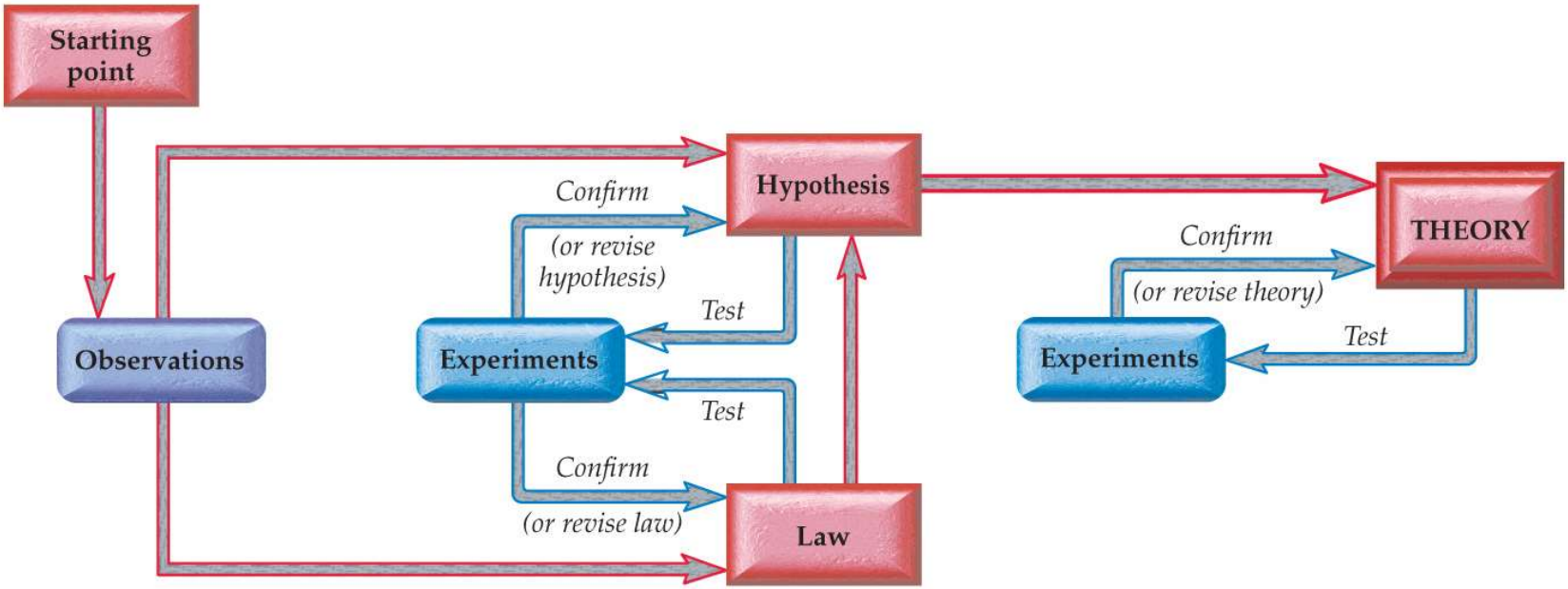
(a) When a metal is burned in a closed container, the mass of the container and its contents does not change.

(b) Matter is made of atoms.

(c) Matter is conserved in chemical reactions.

(d) When wood is burned in a closed container, its mass does not change.

The Scientific Method: Overview



The Scientific Method: Experiments

Scientific theories are tested and validated by experiments.

- If a law, hypothesis, or theory is inconsistent with the findings of an experiment, it must be revised and new experiments must be conducted to test the revisions.
- Over time, poor theories are eliminated and good theories—those consistent with experiments—remain.

Example: The Scientific Method

The **atomic theory** of John Dalton (1766–1844)

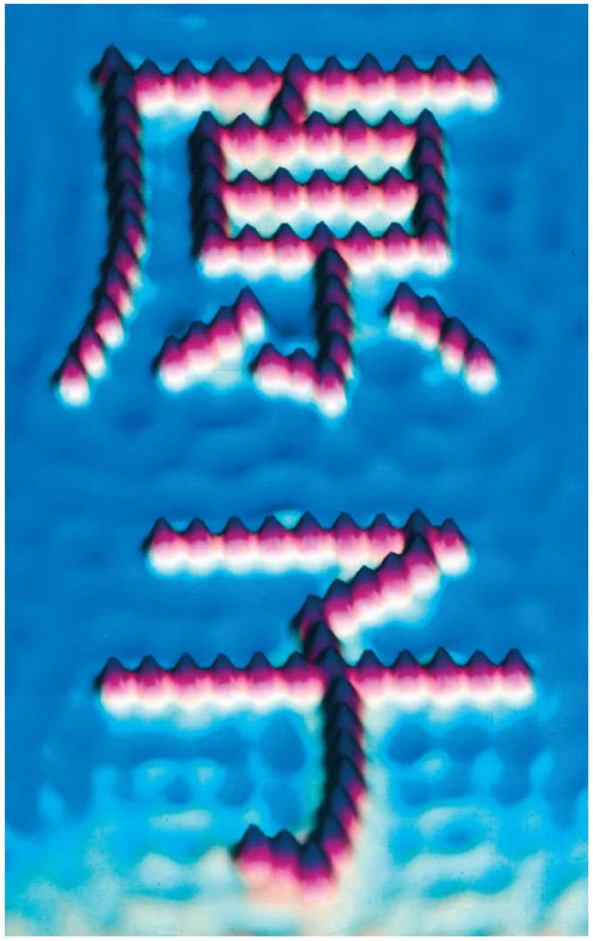
- Dalton explained the law of conservation of mass by proposing that all matter was composed of small, indestructible particles called atoms.
- Dalton's theory was a model of the physical world—it went beyond the laws and observations of the time to **explain** these laws and observations.

The Scientific Method: Scientific Theories

- Established theories with strong experimental support are the most powerful pieces of scientific knowledge.
- People unfamiliar with science sometimes say, “That is just a theory,” as if theories were mere speculations.
- Well-tested theories are as close to truth as we get in science.

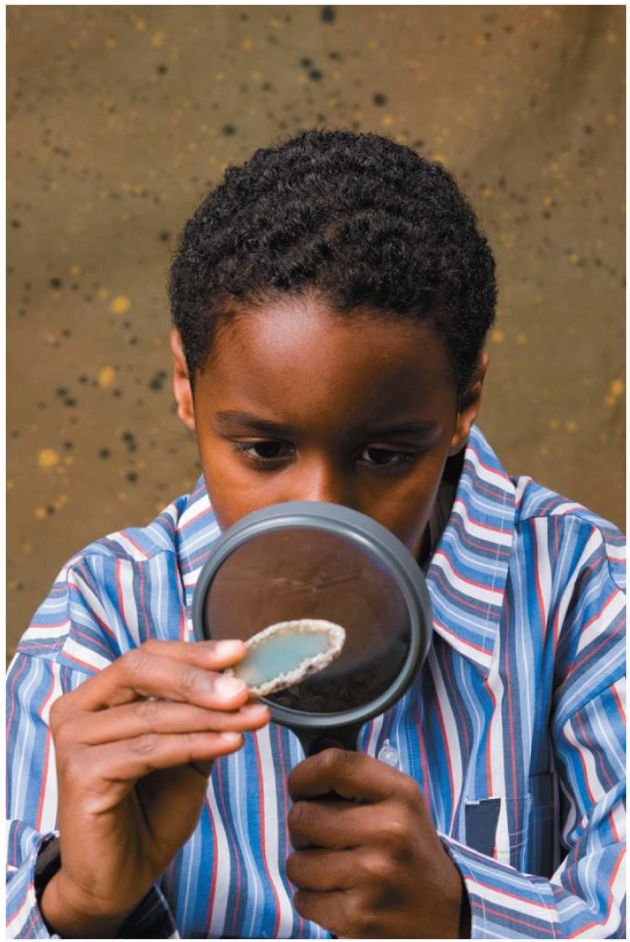
The Scientific Method: Atomic Theory

- The idea that all matter is made of atoms is a theory with two hundred years of experimental evidence to support it.
- Modern technology provides recent images, such as this one, of atoms themselves.
- This image shows the Kanji characters for “atom” written with individual iron atoms on top of a copper surface.



A Beginning Chemist: How to Succeed

- Chemistry requires curiosity and imagination.
- *You must want to know the why of things.*



Chemistry Requires Calculation

- *Quantification* involves measurement as part of observation—it is one of the most important tools in science.
- Quantification allows you to specify the difference precisely.
- For example, two samples of water may feel equally hot to your hand, but when you measure their temperatures, you may find that one is 40 °C and the other is 44 °C.

Chemistry Requires Commitment

- You must do your work regularly and carefully.
- If you do, you will succeed.
- You will be rewarded by seeing a whole new world—the world of molecules and atoms.

A Note About the Text

- Questions: *Answers to all questions numbered in blue appear in the Answers section at the back of the book.*
- Problems: *The exercises in the Problems section are paired, and the answers to the odd-numbered exercises (numbered in blue) appear in the Answers section at the back of the book.*

Success as a Beginning Chemist

- You must be curious and imaginative.
- You must be willing to do calculations.
- You must be committed to learning the material
- Practice plenty on your own.

Chapter 1 in Review

Matter and Molecules:

- **Chemistry is the science that tries to understand what matter does by understanding what molecules do.**

The Scientific Method:

- **Chemists employ the scientific method, which makes use of observations, hypotheses, laws, theories, and experiments.**

Law of Conservation of Mass

Atomic Theory

Chemical Skills Learning Objectives

1. LO: Recognize that chemicals make up virtually everything we come into contact with in our world.
2. LO: Recognize that all things are made of atoms and molecules.
3. LO: Identify and understand the key characteristics of the scientific method: observation, the formulation of hypotheses, the testing of hypotheses by experiment, and the formulation of laws and theories.