Chapter 1

1. Chapter 1: The Chemical World
2. 1.1: The Scope of Chemistry
3. 1.2: Chemicals Compose Ordinary Things
4. 1.3: Hypothesis, Theories, and Laws
5. 1.4: The Scientific Method: How Chemists Think
6. 1.5: A Beginning Chemist: How to Succeed

• Chapter 2

1. Chapter 2: Measurement and Problem Solving
2. 2.1: Taking Measurements
3. 2.2: Scientific Notation: Writing Large and Small Numbers
4. 2.3: Significant Figures: Writing Numbers to Reflect Precision
5. 2.4: Significant Figures in Calculations
6. 2.5: The Basic Units of Measurement
7. 2.6: Problem Solving and Unit Conversions
8. 2.7: Solving Multistep Conversion Problems
9. 2.8: Units Raised to a Power
10. 2.9: Density
11. 2.10: Numerical Problem-Solving Strategies and the Solution Map
12. 2.E: Measurement and Problem Solving (Exercises)

• Chapter 3

1. Chapter 3: Matter and Energy
2. 3.1: In Your Room
3. 3.2: What is Matter?
4. 3.3: Classifying Matter According to Its State: Solid, Liquid, and Gas
5. 3.4: Classifying Matter According to Its Composition
6. 3.5: Differences in Matter: Physical and Chemical Properties
7. 3.6: Changes in Matter: Physical and Chemical Changes
8. 3.7: Conservation of Mass: There is No New Matter
9. 3.8: Energy
10. 3.9: Energy and Chemical and Physical Change
11. 3.10: Temperature: Random Motion of Molecules and Atoms
12. 3.11: Temperature Changes: Heat Capacity
13. 3.12: Energy and Heat Capacity Calculations
14. 3.E: Exercises
• Chapter 4
  1. Chapter 4: Atoms and Elements
  2. 4.1: Experiencing Atoms at Tiburon
  3. 4.2: Indivisible: The Atomic Theory
  4. 4.3: The Nuclear Atom
  5. 4.4: The Properties of Protons, Neutrons, and Electrons
  6. 4.5: Elements: Defined by Their Numbers of Protons
  7. 4.6: Looking for Patterns: The Periodic Law and the Periodic Table
  8. 4.7: Ions: Losing and Gaining Electrons
  9. 4.8: Isotopes: When the Number of Neutrons Varies
  10. 4.9: Atomic Mass: The Average Mass of an Element’s Atoms

• Chapter 5
  1. Chapter 5: Molecules and Compounds
  2. 5.1: Sugar and Salt
  3. 5.2: Compounds Display Constant Composition
  4. 5.3: Chemical Formulas: How to Represent Compounds
  5. 5.4: A Molecular View of Elements and Compounds
  6. 5.5: Writing Formulas for Ionic Compounds
  7. 5.6: Nomenclature: Naming Compounds
  8. 5.7: Naming Ionic Compounds
  9. 5.8: Naming Molecular Compounds
  10. 5.9: Naming Acids
  11. 5.10: Nomenclature Summary
  12. 5.11: Formula Mass: The Mass of a Molecule or Formula Unit

• Chapter 6
  1. Chapter 6: Chemical Composition
  2. 6.1: How Much Sodium?
  3. 6.2: Counting Nails by the Pound
  4. 6.3: Counting Atoms by the Gram
  5. 6.4: Counting Molecules by the Gram
  6. 6.5: Chemical Formulas as Conversion Factors
  7. 6.6: Mass Percent Composition of Compounds
  8. 6.7: Mass Percent Composition from a Chemical Formula
  9. 6.8: Calculating Empirical Formulas for Compounds
  10. 6.9: Calculating Molecular Formulas for Compounds

• Chapter 7
Chapter 7: Chemical Reactions

1. **Chapter 7: Chemical Reactions**
2. **7.1: Grade School Volcanoes, Automobiles, and Laundry Detergents**
3. **7.2: Evidence of a Chemical Reaction**
4. **7.3: The Chemical Equation**
5. **7.4: How to Write Balanced Chemical Equations**
6. **7.5: Aqueous Solutions and Solubility: Compounds Dissolved in Water**
7. **7.6: Precipitation Reactions: Reactions in Aqueous Solution That Form a Solid**
8. **7.7: Writing Chemical Equations for Reactions in Solution: Molecular, Complete Ionic, and Net Ionic Equations**
9. **7.8: Acid–Base and Gas Evolution Reactions**
10. **7.9: Oxidation–Reduction Reactions**
11. **7.10: Classifying Chemical Reactions**
12. **7.11: The Activity Series**

Chapter 8: Quantities in Chemical Reactions

1. **Chapter 8: Quantities in Chemical Reactions**
2. **8.1: Climate Change: Too Much Carbon Dioxide**
3. **8.2: Stoichiometry**
4. **8.3: Making Molecules: Mole-to-Mole Conversions**
5. **8.4: Making Molecules: Mass-to-Mass Conversions**
6. **8.5: Limiting Reactant, Theoretical Yield, and Percent Yield**
7. **8.6: Limiting Reactant, Theoretical Yield, and Percent Yield from Initial Masses of Reactants**
8. **8.7: Enthalpy: A Measure of the Heat Evolved or Absorbed in a Reaction**

Chapter 9: Electrons in Atoms and the Periodic Table

1. **Chapter 9: Electrons in Atoms and the Periodic Table**
2. **9.1: Blimps, Balloons, and Models of the Atom**
3. **9.2: Light: Electromagnetic Radiation**
4. **9.3: The Electromagnetic Spectrum**
5. **9.4: The Bohr Model: Atoms with Orbits**
6. **9.5: The Quantum-Mechanical Model: Atoms with Orbitals**
7. **9.6: Quantum-Mechanical Orbitals and Electron Configurations**
8. **9.7: Electron Configurations and the Periodic Table**
9. **9.8: The Explanatory Power of the Quantum-Mechanical Model**

Chapter 10: Chemical Bonding

1. **Chapter 10: Chemical Bonding**
2. **10.1: Bonding Models and AIDS Drugs**
3. **10.2: Representing Valence Electrons with Dots**
4. **10.3: Lewis Structures of Ionic Compounds: Electrons Transferred**
5. **10.4: Covalent Lewis Structures: Electrons Shared**
6. **10.5: Writing Lewis Structures for Covalent Compounds**
7. **10.6: Resonance: Equivalent Lewis Structures for the Same Molecule**
8. **10.7: Predicting the Shapes of Molecules**
9. **10.8: Electronegativity and Polarity: Why Oil and Water Don’t Mix**

   • **Chapter 11**
   1. Chapter 11: Gases
   2. **11.1: Extra-Long Straws**
   3. **11.2: Kinetic Molecular Theory: A Model for Gases**
   4. **11.3: Pressure: The Result of Constant Molecular Collisions**
      5. **11.4: Boyle’s Law: Pressure and Volume**
      6. **11.5: Charles’s Law: Volume and Temperature**
      7. **11.6: Gay-Lussac’s Law: Temperature and Pressure**
   8. **11.7: The Combined Gas Law: Pressure, Volume, and Temperature**
   9. **11.8: Avogadro’s Law: Volume and Moles**
10. **11.9: The Ideal Gas Law: Pressure, Volume, Temperature, and Moles**
11. **11.10: Mixtures of Gases: Why Deep-Sea Divers Breathe a Mixture of Helium and Oxygen**
12. **11.11: Gases in Chemical Reactions**

   • **Chapter 12**
   1. Chapter 12: Liquids, Solids, and Intermolecular Forces
   2. **12.1: Interactions between Molecules**
   3. **12.2: Properties of Liquids and Solids**
   4. **12.3: Intermolecular Forces in Action: Surface Tension and Viscosity**
      5. **12.4: Evaporation and Condensation**
      6. **12.5: Melting, Freezing, and Sublimation**
   7. **12.6: Types of Intermolecular Forces: Dispersion, Dipole–Dipole, Hydrogen Bonding, and Ion-Dipole**
   8. **12.7: Types of Crystalline Solids: Molecular, Ionic, and Atomic**
   9. **12.8: Water: A Remarkable Molecule**

   • **Chapter 13**
   1. Chapter 13: Solutions
   2. **13.1: Prelude - Tragedy in Cameroon**
   3. **13.2: Solutions: Homogeneous Mixtures**
   5. **13.4: Solutions of Gases in Water: How Soda Pop Gets Its Fizz**
   6. **13.5: Solution Concentration: Mass Percent**
Learning Objectives

- To identify the components of the scientific method

Scientists search for answers to questions and solutions to problems by using a procedure called the scientific method. This procedure consists of making observations, formulating hypotheses, and designing experiments, which in turn lead to additional observations, hypotheses, and experiments in repeated cycles (Figure \(PageIndex{1})).
Step 1: Make observations

Observations can be qualitative or quantitative. **Qualitative observations** describe properties or occurrences in ways that do not rely on numbers. Examples of qualitative observations include the following: the outside air temperature is cooler during the winter season, table salt is a crystalline solid, sulfur crystals are yellow, and dissolving a penny in dilute nitric acid forms a blue solution and a brown gas. **Quantitative observations** are measurements, which by definition consist of both a number and a unit. Examples of quantitative observations include the following: the melting point of crystalline sulfur is 115.21° Celsius, and 35.9 grams of table salt—whose chemical name is sodium chloride—dissolve in 100 grams of water at 20° Celsius. For the question of the dinosaurs’ extinction, the initial observation was quantitative: iridium concentrations in sediments dating to 66 million years ago were 20–160 times higher than normal.

Step 2: Formulate a hypothesis

After deciding to learn more about an observation or a set of observations, scientists generally begin an investigation by forming a hypothesis, a tentative explanation for the observation(s). The hypothesis may not be correct, but it puts the scientist’s understanding of the system being studied into a form that can be tested. For example, the observation that
we experience alternating periods of light and darkness corresponding to observed movements of the sun, moon, clouds, and shadows is consistent with either of two hypotheses:

a. Earth rotates on its axis every 24 hours, alternately exposing one side to the sun, or
b. the sun revolves around Earth every 24 hours.

Suitable experiments can be designed to choose between these two alternatives. For the disappearance of the dinosaurs, the hypothesis was that the impact of a large extraterrestrial object caused their extinction. Unfortunately (or perhaps fortunately), this hypothesis does not lend itself to direct testing by any obvious experiment, but scientists can collect additional data that either support or refute it.

**Step 3: Design and perform experiments**

After a hypothesis has been formed, scientists conduct experiments to test its validity. Experiments are systematic observations or measurements, preferably made under controlled conditions—that is, under conditions in which a single variable changes.

**Step 4: Accept or modify the hypothesis**

A properly designed and executed experiment enables a scientist to determine whether the original hypothesis is valid. In which case he can proceed to step 5. In other cases, experiments often demonstrate that the hypothesis is incorrect or that it must be modified thus requiring further experimentation.

**Step 5: Development into a law and/or theory**

More experimental data are then collected and analyzed, at which point a scientist may begin to think that the results are sufficiently reproducible (i.e., dependable) to merit being summarized in a law, a verbal or mathematical description of a phenomenon that allows for general predictions. A law simply says what happens; it does not address the question of why.

One example of a law, the law of definite proportions, which was discovered by the French scientist Joseph Proust (1754–1826), states that a chemical substance always contains the same proportions of elements by mass. Thus, sodium chloride (table salt) always contains the same proportion by mass of sodium to chlorine, in this case 39.34% sodium and 60.66% chlorine by mass, and sucrose (table sugar) is always 42.11% carbon, 6.48% hydrogen, and 51.41% oxygen by mass.

Whereas a law states only what happens, a theory attempts to explain why nature behaves as it does. Laws are unlikely to change greatly over time unless a major experimental error is discovered. In contrast, a theory, by definition, is incomplete and imperfect, evolving with time to explain new facts as they are discovered.

Because scientists can enter the cycle shown in Figure \(\PageIndex{1}\) at any point, the actual application of the scientific method to different topics can take many different forms. For example, a scientist may start with a hypothesis formed by reading about work done by others in the field, rather than by making direct observations.
Example (PageIndex{1})

Classify each statement as a law, a theory, an experiment, a hypothesis, an observation.

a. Ice always floats on liquid water.
b. Birds evolved from dinosaurs.
c. Hot air is less dense than cold air, probably because the components of hot air are moving more rapidly.
d. When 10 g of ice were added to 100 mL of water at 25°C, the temperature of the water decreased to 15.5°C after the ice melted.
e. The ingredients of Ivory soap were analyzed to see whether it really is 99.44% pure, as advertised.

Solution

a. This is a general statement of a relationship between the properties of liquid and solid water, so it is a law.
b. This is a possible explanation for the origin of birds, so it is a hypothesis.
c. This is a statement that tries to explain the relationship between the temperature and the density of air based on fundamental principles, so it is a theory.
d. The temperature is measured before and after a change is made in a system, so these are observations.
e. This is an analysis designed to test a hypothesis (in this case, the manufacturer's claim of purity), so it is an experiment.

Exercise (PageIndex{1})

Classify each statement as a law, a theory, an experiment, a hypothesis, a qualitative observation, or a quantitative observation.

a. Measured amounts of acid were added to a Rolaids tablet to see whether it really "consumes 47 times its weight in excess stomach acid."
b. Heat always flows from hot objects to cooler ones, not in the opposite direction.
c. The universe was formed by a massive explosion that propelled matter into a vacuum.
d. Michael Jordan is the greatest pure shooter ever to play professional basketball.
e. Limestone is relatively insoluble in water but dissolves readily in dilute acid with the evolution of a gas.

Answer a: experiment

Answer b: law

Answer c: theory

Answer d: hypothesis

Answer e: observation
Summary

The scientific method is a method of investigation involving experimentation and observation to acquire new knowledge, solve problems, and answer questions. The key steps in the scientific method include the following:

- Step 1: Make observations.
- Step 2: Formulate a hypothesis.
- Step 3: Test the hypothesis through experimentation.
- Step 4: Accept or modify the hypothesis.
- Step 5: Development into a law and/or a theory.

Contributions & Attributions

This page was constructed from content via the following contributor(s) and edited (topically or extensively) by the LibreTexts development team to meet platform style, presentation, and quality:

- CK-12 Foundation by Sharon Bewick, Richard Parsons, Therese Forsythe, Shonna Robinson, and Jean Dupon.
- Wikipedia
- Marisa Alviar-Agnew (Sacramento City College)
- Henry Agnew (UC Davis)