Instructional Design of the Program

This Teacher's Edition provides robust support for the program. We believe in teaching chemistry by DOING chemistry, so our Lab Investigation Manual contains over 60 labs and project-based investigations, and we often recommend that the first experience in a new chapter comes from doing a lab investigation. This Introduction to the Teacher's Edition opens with a course overview, followed by a detailed treatment of new updates and support for the Next Generation Science Standards (NGSS), and finally, support for teaching the program day-by-day.

The "toolbox" for *A Natural Approach to Chemistry* provides tools for students (Student Book, Lab Investigations Manual), tools for teachers (Teacher Edition) and online tools for both teachers and students, as follows:

Tools for Students

The primary student resources include the Student Book and the Lab Investigation Manual (LIM).

The Student Book contains 21 chapters, each divided into 2-5 smaller sections. Each chapter begins with a two-page Getting Started section to set forth the main learning goals, to elicit what students already know about the content, and to capture student questions for further investigation. This section contains a short investigation, which can be done in class if desired, that relates to the phenomena explored in the chapter. Each chapter concludes with the Chemical Connections to show the connections to the nature of science and NGSS crosscutting concepts – how the chemistry core ideas connect with the real world, often incorporating the Earth and Life sciences.

The Lab Investigation Manual contains more than 60 lab investigations, aligned to each chapter, and includes project-based, design-oriented, open investigations to help support the Engineering, Technology and Applications of Science (ETS) standards in NGSS. Students will need to use both resources to make satisfactory progress toward the Performance Expectations outlined in NGSS. Assessment practices vary from the Student Book and LIM and will be described in detail later in this section.

Tools for Teachers

The Teacher's Edition provides detailed support for using each of the resources. Each chapter begins with an Overview of learning content and resources available for student use.

These are followed by tables that describe how content from the Student Book and Lab Investigation Manual is introduced, developed, and assessed, and how it aligns to NGSS. The Getting Started section uses a novel investigation, which can be read and discussed, viewed as a demonstration video, or actually done in class. It introduces an investigative phenomena to focus student attention and drive student questions and observations leading to the lab investigations and Student Book content for the chapter.

The Lab Investigations section for each TE chapter includes:

- NGSS alignment and support
- Scope and sequence
- Detailed materials and setup information
- Sample answers to all the formative assessments
- Sample data for all student measurements.
- Detailed example—lesson dialogs packed with experienced insight on teaching each investigation
- Useful techniques for using the required equipment

The Student Book section of each chapter includes:

- NGSS alignment and support
- Scope and sequence
- Concise tables that organize instructional techniques and resources for each chapter, with differentiation strategies, skill sheets, and assessment.
- Advice for recognizing and using the many assessment tools and strategies
- Answers with worked-out solutions to all the problems in the text

The learning needs of individual students, or those working in groups or in classes, varies widely as does the experience and preference of teachers who teach them. The Teacher's Edition contains suggested pacing instructions to help with lesson planning. The authors have suggested Learning Sequences for all chapters that provide a suggested sequence of student resources that should also be helpful in lesson planning. Each learning sequence combines Student Book and LIM content. This course was developed with reference to the 5E model (Bybee, et. al.) which is also described in detail for each chapter. The "A" labs in the LIM have been written to be used without a great deal of prior knowledge and can generally be used to engage students in the chapter content, as has previously been mentioned.

Online Tools for Teachers and Students

The Online Teacher Portal contains digital versions of all the available printed material plus many digital-only teaching materials, as shown in the list below. The Digital Resources include:

- Full text of the Student Book, Laboratory Investigations Manual, and Teacher's Edition
- Slide decks to support the Student Book and LIM
- Teacher Prep videos for the LIM
- Video Podcasts to support the Student Book
- Assessments
- Skill Sheets
- Additional web content

The online portal always contains the latest version of the printed materials.

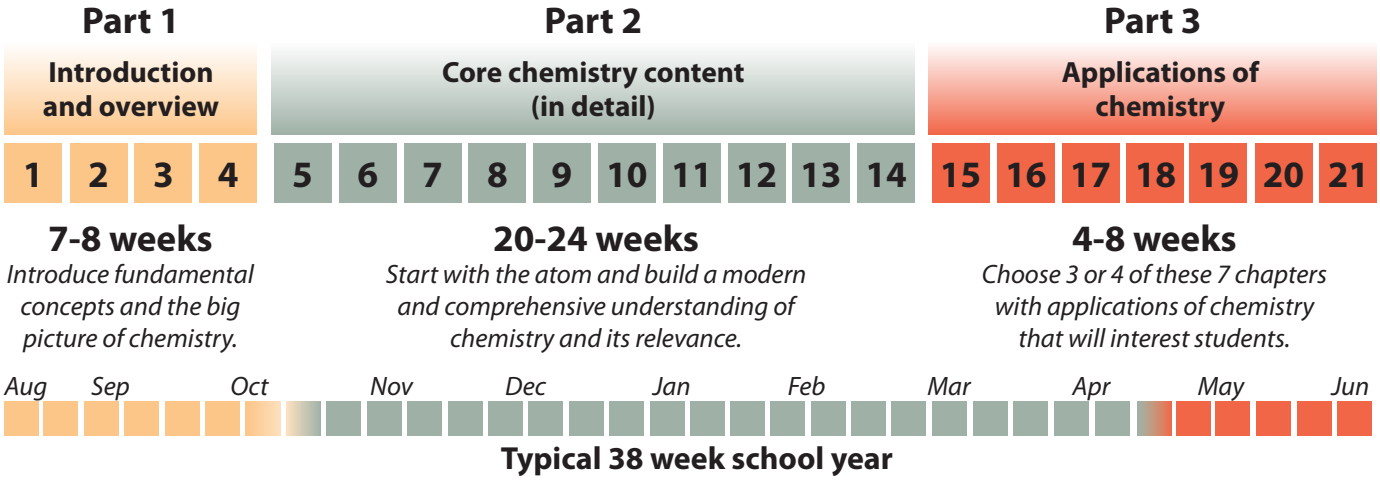
Using a Spiral Approach

The concept of *spiraling* means students are exposed to similar content in greater depth as their understanding and mathematical skills increase. A good example is the idea of matter. In elementary school matter is taught as "stuff" with properties like weight, color, texture, and hardness. In middle school, matter becomes solid, liquid, or gas and intrinsic properties such as density are investigated. In high school, the full atomic and molecular understanding of matter is developed along with more detailed explanations of chemical and physical properties.

Vertical spiraling curriculum
(grade to grade)

High school	Matter is made of atoms, elements and copounds.
Middle school	Matter has mass and can be solid, liquid, or gas.
Elementary school	Matter is "stuff" with color, shape, weight, etc.

A *Natural Approach to Chemistry* spirals the content *within the course,* as well as building on knowledge and skills from prior grades. This is consistent with research on learning that shows students need multiple exposures and varied contexts before they effectively retain new knowledge and skills. The course has three major parts. **Part 1** (Chapters 1-4) presents an overview of chemistry painted with a broad brush. This gives students an introduction to the subject and an overview of major concepts. Part 1 is short so students quickly get the big picture and see how major ideas, such as atoms and temperature, fit together in a comprehensive understanding of the material universe. Except for Chapter 3, each of the concepts covered in Part 1 is treated in much greater detail later in the book. Avoid a tendency to spend too much time teaching this part of the course.



Part 2 begins with the structure of the atom and builds upward in scale through bonding, molecules, and reactions. All major chemistry standards in the NGSS, and for most states, are covered in detail in Part 2—which is the major section of the book. Major concepts from Part 1, such as molecules, are the subject of an entire chapter in Part 2. **Part 3** provides additional chapters that extend chemistry to interesting applications, such as the chemistry of Earth.

Typical Horizontal spiraling curriculum *(within the same year)*

Overarching concepts and basic principles | **Detailed, quantitative, contextual understanding of each core concept** | **Interesting extensions to the real world**

Part 1 Summary

Chapters 1 and 2

Research on learning tells us that most students need to be exposed to a new concept at least three times before they really learn it. This means key ideas and concepts must be introduced three or more times for the majority of students to learn and retain the knowledge. That is why important concepts such as the chemical formula are introduced in Chapter 2 and repeated again in subsequent chapters.

The overview chapters also allow you to quickly establish or review basic foundational concepts. Many students need to see the big picture, such as the existence of elements, before they can become engaged with details such reactivity and electron configurations.

Chapter 1 provides introductory material to the study and the science of chemistry, what chemistry is about, the nature of science and scientific creativity, matter and energy, and the tools and mathematics of chemistry. This is all done using examples to show the chemistry of the human body and natural environment.

Chapter 2 is the necessary start of the learning cycle and not a treatment-in-depth. Do not expect your students to master everything in this chapter before moving on or you will become very frustrated.

We recommend you devote no more than four weeks to Chapters 1 and 2, particularly Chapter 2. For example, we strongly suggest you fight the urge to teach all of solutions in Chapter 2. Chapter 9 is a whole chapter on solutions. The more limited goal of Chapter 2 is for students to mix easy solutions and learn the basic ideas:

- A solution is a mixture of at least two substances.
- One substance is dissolved in the other.
- The concentration tells you the ratio of the substances.

You will teach a lot more about solutions in Chapter 9, including the concepts of solubility, liquid-liquid solutions, alloys, temperature dependence, and reactions in solution.

A powerful argument for the starting with a broad overview is *engagement.* Students want to know *why* they need to learn details like the chemical formula before they fully engage in learning. Many chemistry texts go straight to teaching details, and then more details. If the student survives to the end of the course *then* they might see how all the details fit together. Of course, by then many have sworn never to take chemistry again for the rest of their lives! Instilling dislike of chemistry is *not* the intent of teaching the subject and to get students engaged with chemistry, Chapters 1–4 include many hands-on, "big-idea" intuitive investigations. Depth comes later.

Chapter 3

Chapter 3 is the core treatment of heat and temperature. Unlike Chapter 2, we recommend that Chapter 3 be taught in depth and not as an overview. Understanding temperature is a key to understanding why chemistry works and how the atomic model of matter explains macroscopic properties such as solid, liquid, and gas phases. Energy is a fundamental theme. We want students doing quantitative work with energy and matter.

Chapter 4

Chapter 4 is more like Chapter 2—a broad-brush overview of the concepts of physical and chemical change. Like Chapter 2, we recommend you use Chapter 4 as an introductory overview of the concept of chemical reactions. Later in the text are whole chapters on reactions, acids and bases, and electrochemistry. The goal for Chapter 4 is to make the conceptual point that reactions rearrange the same atoms into different compounds. That is the fundamental explanation for chemical change. An important corollary is that the observable properties of matter depend on the compound and not the elements that are in the compound.

A second motivation for Chapter 4 is to set the intellectual stage for the molecular understanding of chemistry that begins in Chapter 5. Why do some compounds react while other compounds do nothing when mixed? Why does one oxygen atom combine with exactly two hydrogen atoms to make water, why not four or five? These questions are answered by the details of how the atomic model of matter and the structure of the atom influence chemical bonding.

Part 2 Summary

Chapters 5–14

Part 2 of the text starts with the atom and builds up the science of chemistry from the microscopic world of atoms to the macroscopic world of chemical and physical properties. The structure of the atom is the subject of Chapter 5. The different types of atoms (elements) and the periodic table are the subject of Chapter 6 and bonds between atoms are the subject of Chapter 7. Chapters 8-14 rigorously cover the remaining core content in chemistry.

Part 3 Summary

Chapters 15–21

Part 3 of the text includes Chapters 15-21. We hope you teach as much of Part 3 as you have time for because the subject matter is interesting and relevant; *however, these chapters are optional and can be taught in any order.* One or even all of them, may be omitted. Chapter 15 is focused on electrochemistry and batteries. Chapter 16 is an introduction to the chemistry of materials science. Organic chemistry and biochemistry are the subject of Chapters 17 and 18. Chapter 19 introduces environmental chemistry, the chemistry of planet Earth. Nuclear chemistry and nuclear reactions are covered in Chapter 20. Finally, Chapter 21 takes a peek at some of the fascinating chemistry on the other planets and moons of the Solar System and the stars beyond.

Concept Mapping the Spiral Approach

A Natural Approach to Chemistry spirals the concepts within the course, as well as building on knowledge and skills from prior grades. This is consistent with learning research that shows students need multiple exposures and varied contexts to retain new knowledge and skills effectively.

The following tables provide more detail on how the spiral approach presents and connects key concepts in the Student Book.

STUDENT BOOK CONTENT	SPIRAL TREATMENT
Part 1	
1.1 The World is Chemistry Chemistry plays key roles in the... • Biosphere • Geosphere • Hydrosphere • Atmosphere	**Prior knowledge:** This is a broad introduction to these connections between chemistry and the world we live in. **More depth:** The interlay between chemistry and the world around us is explored in more depth in each subsequent chapter.
1.2 Chemistry is Matter and Energy • States of matter • Conservation of energy	**Prior knowledge:** This is the first introduction to these concepts. **More depth:** Phase changes (Sec 3.3), systems and surroundings (Sec 3.2, 4.2), first law of thermodynamics (Sec 3.2), intermolecular forces (Sec 8.3), gases (Chap 14), condensed matter (Sec 16.2)
1.3 Who are Scientists and What is Science? • Scientific Creativity and Inquiry • Scientific evidence • Experiments and hypotheses • Variables and experimental design • Analyzing data and drawing conclusions	**Prior knowledge**: This is the first introduction to these concepts. **More depth:** Discovering the structure of the atom (Sec 5.1), possibility of life elsewhere (Sec 21.3)
1.4 Making and Working With Measurements • Pressure • Accuracy and precision • Scientific notation • Unit conversion	**Prior knowledge:** This is the first introduction to these concepts. **More depth:** Celsius–Fahrenheit–Kelvin conversion (Sec 3.1), effect of pressure on chemical equilibria (Sec 12.2), pressure and kinetic theory (Sec 14.1) **Additional coverage:** Using exponents to express pH (Sec 13.2)
2.1 Matter and the Elements • Substances and mixtures • Physical and chemical properties • Physical and chemical changes • Macro- and microscopic scales	**Prior knowledge:** This is the first introduction to these concepts. **More depth:** Mixtures and solutions (Sec 2.3), specific heat (Sec 3.2), phase changes (Sec 3.3), physical and chemical changes (Chap 4), water and solutions (Chap 9), properties of gases (Sec 14.1), physical properties of solids and liquids (Chap 16)
• Atoms and elements • The periodic table • The mole	**Prior knowledge**: This is the first introduction to these concepts. **More depth:** Structure of the atom (Chap 5), elements and the periodic table (Chap 6), solving problems with moles (Sec 2.2)

STUDENT BOOK CONTENT	SPIRAL TREATMENT
2.2 Molecules and Compounds • The chemical formula • Molecules and compounds	**Prior knowledge:** This is the first introduction to these concepts. **More depth:** Geometry and structure (Sec 7.3), covalent bonds (Sec 4.1, 7.1, 7.2), molecular formulas (Sec 8.4)
• Ionic compounds • The formula mass • Solving problems with moles • Avogadro's number	**Prior knowledge:** This is the first introduction to these concepts. **More depth:** Ionic formulas (Sec 7.2, 8.1), ionic and metallic bonds (Sec 7.1), formula masses (Sec 8.4), stoichiometry (Sec 11.1), chemistry of the atmosphere (Sec 19.1)
2.3 Mixtures and Solutions • Mixtures and solutions • Concentration	**Prior knowledge:** This is the first introduction to these concepts. **More depth:** Solutes, solvents, and water (Sec 9.1), concentration and solubility (Sec 9.2), gas–gas stoichiometry calculations (Sec 14.3), pressure and kinetic theory (Sec 14.1), chemistry of the oceans (Sec 19.2)
• Concentration • Solubility • Molarity • Mixtures of gases • Partial pressures	**Prior knowledge:** This is the first introduction to these concepts. **More depth:** Solutes, solvents, and water (Sec 9.1), concentration and solubility (Sec 9.2), gas–gas stoichiometry calculations (Sec 14.3), pressure and kinetic theory (Sec 14.1), chemistry of the oceans (Sec 19.2)
3.1 Temperature and Particle Motion • Temperature and energy • Temperature scales • Celsius and Fahrenheit • Temperature measurement	**Prior knowledge:** Unit conversion (Sec 1.1), matter and energy (Sec 1.3)
• Temperature scales • Celsius and Fahrenheit • Absolute zero	**Prior knowledge:** Unit conversion (Sec 1.1), matter and energy (Sec 1.3) **Additional coverage:** Kelvin scale and the gas laws (Sec 14.2)
3.2 Heat and Thermal Energy • Heat and energy • Systems	**Prior knowledge:** Matter and energy (Sec 1.3), temperature and energy (Sec 3.1) **More depth:** Calorimetry (Sec 9.3)
• Systems • Thermal equilibrium • Conservation of energy	**Prior knowledge:** Matter and energy (Sec 1.3), temperature and energy (Sec 3.1) **More depth:** Calorimetry (Sec 9.3)
• Specific heat • Heat transfer • Calculating temperature and heat	**Prior knowledge:** Physical properties (Sec 2.1) **Additional knowledge:** Properties of solids (Sec 16.1)
3.3 Phase Changes • Phase changes • Heat of vaporization	**Prior knowledge:** Matter and energy (Sec 1.3) **More depth:** Intermolecular forces (Sec 8.3), the special case of water (Sec 9.1), solids and liquids(Chap 16)
• Heat of fusion • Solving phase-change problems	**Prior knowledge:** Conservation of energy (Sec 1.3, 3.2) **Additional coverage:** Colligative properties (Sec 9.3)
• Evaporation • Condensation • Effect of pressure • Relative humidity	**Prior knowledge:** This is the first introduction to these concepts. **More depth:** Intermolecular forces (Sec 8.3), gases (Chap 14)

STUDENT BOOK CONTENT	SPIRAL TREATMENT
4.1 Understanding Chemical Changes • Chemical change • Interatomic and intermolecular forces • Chemical bonds	**Prior knowledge:** Chemical properties (Sec 2.1) **More depth:** Forces in the atom (Sec 5.2), structure of the atom (Chap 5), chemical bonds (Sec 7.1), single/double/triple bonds (Sec 7.2), intermolecular forces (Sec 8.3), saturated and unsaturated hydrocarbons (Sec 17.1)
• Electric charge • Covalent bonds • Ionic bonds • Reactivity	**Prior knowledge:** Ionic compounds (Sec 2.2) **More depth:** Electric charge in the atom (Sec 5.2), covalent bonds (Sec 4.1, 7.1, 7.2), ionic bonds (Sec 7.1), electron configuration of ions (Sec 7.2), octet rule (Sec 7.2), ionic compounds (Sec 8.1), molecular compounds (Sec 8.2), electric charge and current (Sec 15.1)
4.2 Chemical Reactions • Chemical reactions • The chemical equation • Conservation of mass	**Prior knowledge:** Chemical change (Sec 4.1) **More depth:** Chemical equations (Sec 10.1), balancing equations (Sec 10.2), analyzing a chemical equation/ stoichiometry (Sec 11.1)
• Endothermic reactions • Exothermic reactions • Activation energy	**Prior knowledge:** This is the first introduction to these concepts. **More depth:** Chemical reactions and energy (Sec 10.4), energy diagrams (Sec 12.1), reaction profile (Sec 12.3), catalysts (Sec 12.4), photosynthesis and respiration (Sec 18.2), enzymes (Sec 18.3)
4.3 Chemical Reactions in the Lab • Aqueous solution • Notation: s, l, g, and aq • Oxidation and reduction reactions • Acids and bases	**Prior knowledge:** Water (Sec 1.1) **More depth:** Water and solutions (Chap 9), types of chemical reactions (Sec 10.3), chemical reactions and energy (Sec 10.4), oxidation–reduction reactions (Sec 15.2, 15.3), acids and bases (Chap 13), electron transport chain (Sec 18.2)

STUDENT BOOK CONTENT	SPIRAL TREATMENT
Part 2	
5.1 The Atom Has a Structure • Atomic theory • Discovery of the nucleus • Structure of an atom	**Prior knowledge:** Microscopic scale (Sec 2.1), elements or types of atoms (Sec 2.1), periodic table (Chap 2.1) **More depth:** Atoms and chemical bonds (Sec 4.1) **Additional coverage:** Fission and fusion reactions (Sec 20.4), Chemistry in the Sun and other stars (Sec 21.1)
• Atomic number and atomic mass • Electron cloud • Forces in the atom • Ions	**Prior knowledge:** Elements or types of atoms (Sec 2.1) **More depth:** Atoms and chemical bonds (Sec 4.1), electric charge (Sec 4.1), ionic bonds (Sec 4.1), electron configurations (Sec 5.3, 6.2), unpaired electrons (Sec 7.2), valence electrons (Sec 7.2) **Additional coverage:** Carbon-14 and radiometric dating (Sec 20.3), binding energy (Sec 20.4), nuclear equations (Sec 21.1)
5.2 The Quantum Atom • Quantum theory • Waves and particles • Quantum states	**Prior knowledge:** This is the first introduction to these concepts. **More depth:** Electron configurations (Sec 5.3, 6.2), energy levels and the periodic table (Sec 5.3), orbitals and the periodic table (Sec 6.1)
• Quantum states • Orbitals • Energy levels • Orbitals and the periodic table	**Prior knowledge:** This is the first introduction to these concepts. **More depth:** Electron configurations (Sec 5.3, 6.2), energy levels and the periodic table (Sec 5.3), orbitals and the periodic table (Sec 6.1)

STUDENT BOOK CONTENT	SPIRAL TREATMENT
5.3 Electron Configurations • Filling energy levels • Electron configuration	**Prior knowledge:** Energy levels (Sec 5.2) **Additional coverage:** Noble gases (Sec 6.2), compound formation (Sec 6.3), valence electrons (Sec 6.3), octet rule (Sec 7.2)
• Principal quantum numbers • Filling energy levels	**Prior knowledge:** Energy levels (Sec 5.2) **Additional coverage:** Noble gases (Sec 6.2), compound formation (Sec 6.3), valence electrons (Sec 6.3), octet rule (Sec 7.2)
5.4 Light and Spectroscopy • Visible spectrum • Electromagnetic spectrum	**Prior knowledge:** Wavelength and frequency (Sec 5.2) **Additional coverage:** photodissociation and photoionization (Sec 19.1), electromagnetic radiation (Sec 20.2), biological effects of radiation (Sec 20.5)
• Speed of light • Light and matter • Spectroscopy	**Prior knowledge:** Wavelength and frequency (Sec 5.2) **Additional coverage:** Chemistry of the Solar System (Chap 21)
6.1 The Periodic Table • The periodic table • Periodic trends	**Prior knowledge:** Introduction to the periodic table (Sec 2.1), element symbol, atomic number, period, group (Sec 2.1), reactivity (Sec 4.1) **Additional coverage:** Electronegativity and predicting bond types (Sec 7.1)
• The first periodic table • The modern periodic table	**Prior knowledge:** Rows and energy levels (Sec 5.2), electron configurations (Sec 5.3) **More depth:** Reactivity, valence (Sec 6.2, 6.3)
• Orbitals	**Prior knowledge:** Electron configurations (Sec 5.3, 6.2)
6.2 Properties of Groups of Elements • Alkali metals • Alkaline earth metals • Transition metals	**Prior knowledge:** Elements (Sec 2.1), electron configuration (Sec 5.3) **Additional coverage:** Ionic compounds (Sec 8.1), molecular compounds (Sec 8.2)
• Carbon, oxygen, nitrogen • Halogens	**Prior knowledge:** Elements and the periodic table (Sec 2.1), Molecules and compounds (Sec 2.2) **Additional coverage:** Bonding (Chap 7)
• Noble gases • Formation of compounds	**Prior knowledge:** Reactivity patterns (Sec 4.1), electron configurations (Sec 5.3) **Additional coverage:** Octet rule and noble gas electron configuration (Sec 7.2)
6.3 Valence • Valence electrons	**Prior knowledge:** Structural diagrams (Sec 2.2), electrons (Sec 5.1), energy levels and configurations (Sec 5.3, 6.2) **Additional coverage:** Molecular geometry and VSEPR (Sec 7.3)
• Lewis dot structure • Properties of elements	**Prior knowledge:** Formation of compounds (Sec 6.2) **Additional coverage:** Molecular geometry and Lewis dot structures Section (7.3)
7.1 What Is a Chemical Bond? • Bond formation • Molecular models	**Prior knowledge:** Introduction to molecular compounds (Sec 2.2), Electric charge (Sec 4.1)
• Covalent bonds • Ionic and metallic bonds	**Prior knowledge:** Introduction to ionic compounds (Sec 2.2), Electric charge (Sec 4.1) **Additional coverage:** Electrolyte solutions (Sec 8.1, 9.3), deionized water (Sec 9.1), electrochemical cells (Sec 15.4)
• Electronegativity • Polarity	**Prior knowledge:** Electronegativity and periodic trends (Sec 6.1) **Additional coverage:** Polarity and intermolecular forces (Sec 8.3)

STUDENT BOOK CONTENT	SPIRAL TREATMENT
7.2 Valence Electrons and Bonding Patterns • Bonding patterns • Octet rule	**Prior knowledge:** Electron configurations and compound formation (Sec 5.3, 6.2)
• Ion formation • Simple ionic formulas	**Prior knowledge:** Introduction to ionic compounds (Sec 2.2), imbalance of protons and electrons (Sec 5.1), ionic bonds (Sec 7.1), electronegativity (Sec 7.1) **Additional coverage:** Naming polyatomic ions (Sec 7.3), naming molecular compounds (Sec 8.2)
• Covalent bonds • Unpaired electrons	**Prior knowledge:** Introduction to molecular compounds (Sec 2.2), electron configurations (Sec 5.3, 6.2), electronegativity (Sec 6.1, 7.1), Lewis dot structures (Sec 6.3) **Additional coverage:** Valence electrons (Sec 7.3)
7.3 Molecular Geometry and Lewis Dot Structures • Bonding patterns • Isomers • Double and triple bonds	**Prior knowledge:** Formulas, models and diagrams of molecules (Sec 2.2), intro to structural isomers (Sec 2.2), double and triple bonds (Sec 4.1) **Additional coverage:** Saturated and unsaturated hydrocarbons (Sec 17.1)
• VSEPR • Molecular geometry • Electron density	**Prior knowledge:** Molecules and compounds (Sec 2.2), electron cloud (Sec 5.1), Lewis dot structures (Sec 6.3), unpaired and valence electrons (Sec 7.2) **Additional coverage:** Intermolecular forces (Sec 8.3), properties of solids and liquids (Chap 16), isomers (Sec 17.1), chirality (Sec 18.3)
8.1 Ionic Compounds • Ionic compounds • Structure and properties • Polyatomic ions • Ionic formulas	**Prior knowledge:** Electric charge and ionic bonds (Sec 4.1), Electronegativity and types of bonds (Sec 7.1) **Additional coverage:** Electrolyte solutions (Sec 9.3), electrochemical cells (Sec 15.4), crystal structures and Bravais lattices (Sec 16.2)
• Polyatomic ions • Ionic formulas • Naming ionic compounds	**Prior knowledge:** Electric charge and ionic bonds (Sec 4.1), Simple ionic formulas (Sec 7.1), naming polyatomic ions (Sec 7.2) **Additional coverage:** Naming molecular compounds (Sec 8.2), crystals and Bravais lattices (Sec 16.2)
8.2 Molecular Compounds • Molecular compounds • Small molecules	**Prior knowledge:** Molecules and compounds (Sec 2.2), covalent bonds (Sec 4.1, 7.1, 7.2), valence (Sec 6.3), polarity (Sec 7.1) **Additional coverage:** Intermolecular forces (Sec 8.3), water (Sec 9.1), properties of liquids (Sec 16.4), organic molecules (Chap 17)
• Medium-sized molecules • Polymers • Network covalent molecules	**Prior knowledge:** Covalent bonds (Sec 4.1, 7.1, 7.2), small molecules (Sec 8.2) **Additional coverage:** Addition and condensation polymerization (Sec 17.3), polysaccharides (Sec 18.1), proteins and amino acids (Sec 18.3), DNA and RNA (Sec 18.4)
• Empirical and molecular formulas • Naming molecular compounds	**Prior knowledge:** The formula mass (Sec 2.2), ionic formulas (Sec 8.1) **Additional coverage:** Naming organic molecules (Sec 17.1, 17.2)

STUDENT BOOK CONTENT	SPIRAL TREATMENT
8.3 Intermolecular Forces • Intermolecular forces • Dipole–dipole attractions • Hydrogen bonding	**Prior knowledge:** Physical properties (Sec 2.1), electronegativity (Sec 6.1, 7.1), polarity(Sec 6.1, 7.1) **Additional coverage:** Special case of water (Sec 9.1), surface tension, adhesion and cohesion (Sec 16.4), protein structure and protein folding (Sec 18.3)
• Hydrogen bonding • London dispersion • Intermolecular forces and boiling points	**Prior knowledge:** Physical properties (Sec 2.1), electronegativity (Sec 6.1, 7.1), polarity (Sec 6.1, 7.1) **Additional coverage:** Properties of liquids (Sec 16.4), Hydrocarbons (Sec 17.1), lipids (Sec 18.1), structure and protein folding (Sec 18.3), DNA and RNA (Sec 18.4)
8.4 Formula Masses • Molar mass • Percent composition	**Prior knowledge:** Mass in chemistry (Sec 1.1), the mole and calculations with moles (Sec 2.2), atomic mass (Sec 5.1), empirical formula (8.2)
• Percent composition	**Prior knowledge:** Mass in chemistry (Sec 1.1), the mole and calculations with moles (Sec 2.2), atomic mass (Sec 5.1), empirical formula (8.2)
• Empirical formula • Molecular formula	**Prior knowledge:** Atomic mass (Sec 5.1), introduction to empirical and molecular formulas (Sec 8.2)
9.1 Solutes, Solvents, and Water • Solutions • The water molecule	**Prior knowledge:** Concentration and molarity (Sec 2.3), calorimetry (Chap 3), electronegativity (Sec 6.1), valence and bonding patterns (Sec 7.2, 7.3), molecular compounds (Sec 8.2), polarity and intermolecular forces (Sec 8.3) **Additional coverage:** Properties of liquids (Sec 16.4)
• Water as a solvent • Reactions in aqueous solutions • Other solvents	**Prior knowledge:** Concentration and molarity (Sec 2.3), calorimetry (Chap 3), electronegativity (Sec 6.1), valence and bonding patterns (Sec 7.2, 7.3), molecular compounds (Sec 8.2), polarity and intermolecular forces (Sec 8.3) **Additional coverage:** Properties of liquids (Sec 16.4)
9.2 Concentration and Solubility • Concentration	**Prior knowledge:** Concentration and molarity (Sec 2.3), solubility (Sec 2.3), solutions (Sec 9.1)
• Saturation and equilibrium • Affecting solubility	**Prior knowledge:** Concentration and molarity (Sec 2.3), solubility (Sec 2.3), solutions (Sec 9.1) **Additional coverage:** Reaction rates and equilibrium (Chap 12)
• Affecting solubility • Preparing a solution	**Prior knowledge:** Concentration and molarity (Sec 2.3), solubility (Sec 2.3), solutions (Sec 9.1) **Additional coverage:** Reaction rates and equilibrium (Chap 12)
9.3 Properties of Solutions • Affecting reaction rates • Heat of solution • Calorimetry	**Prior knowledge:** Solubility (Sec 2.3), specific heat of solution (Sec 3.2), enthalpy (Sec 4.2) **Additional coverage:** Reaction rates and equilibrium (Chap 12), enthalpy calculations (Sec 10.4)
• Calorimetry	**Prior knowledge:** Conservation of energy (Sec 1.3), specific heat of solution (Sec 3.2), enthalpy (Sec 4.2), chemical reactions (Chap 4) **Additional coverage:** Reaction rates and equilibrium (Chap 12), enthalpy calculations (Sec 10.4)
• Density of a solution • Colligative properties • Electrolyte solutions	**Prior knowledge:** Physical properties (Sec 1.1, 2.1), mixtures and solutions (Sec 2.3, 9.1), ions (Sec 5.1, 7.1, 8.1) **Additional coverage:** Electrochemical cells (Sec 15.4), salinity and ocean currents (Sec 19.2)

STUDENT BOOK CONTENT	SPIRAL TREATMENT
10.1 Chemical Equations • Chemical equations • Conservation of mass • Balancing chemical equations	**Prior knowledge:** Chemical properties and chemical change (Sec 2.1, 4.2), oxidation–reduction and acid–base reactions (Sec 4.3), conservation of mass (Sec 4.2) **Additional knowledge:** Balancing redox equations (Sec 15.3), conservation of mass in nuclear reactions, $E = mc^2$ (Sec 20.4)
10.2 Methods for Balancing Chemical Equations • Balancing pure elements • Checking Steps in balancing chemical equations	**Prior knowledge:** Chemical properties and chemical change (Sec 2.1, 4.2), oxidation–reduction and acid–base reactions (Sec 4.3), conservation of mass (Sec 4.2) **Additional knowledge:** Balancing redox equations (Sec 15.3)
10.3 Types of Chemical Reactions • Synthesis • Decomposition	**Prior knowledge:** Chemical change (Sec 4.1), types of chemical reactions (Sec 4.3) **Additional coverage:** Acid–base reactions (Sec 13.4), redox reactions (Sec 15.2), addition and condensation polymerization (Sec 17.3), nuclear reactions (Sec 20.2)
• Single replacement • Double replacement	**Prior knowledge:** Chemical change (Sec 4.1), types of chemical reactions (Sec 4.3) **Additional coverage:** Acid–base reactions (Sec 13.4), redox reactions (Sec 15.2), addition and condensation polymerization (Sec 17.3), nuclear reactions (Sec 20.2)
• Precipitate reaction • Polymerization	**Prior knowledge:** Chemical change (Sec 4.1), types of chemical reactions (Sec 4.3) **Additional coverage:** Addition and condensation polymerization (Sec 17.3), polysaccharides (Sec 18.1), proteins and amino acids (Sec 18.3), DNA and RNA (Sec 18.4)
10.4 Chemical Reactions and Energy • Exothermic and endothermic reactions • Enthalpy calculations	**Prior knowledge:** Conservation of energy (Sec 1.3), enthalpy (Sec 4.2), calorimetry (Sec 3.2, 9.3) **Additional coverage:** Energy diagrams (Sec 12.1), reaction profile (Sec 12.3), catalysts (Sec 12.4), photosynthesis and respiration (Sec 18.2), enzymes (Sec 18.3)
• Energy profile • Energy barrier • Hess's law	**Prior knowledge:** Conservation of energy (Sec 1.3), enthalpy (Sec 4.2), calorimetry (Sec 3.2, 9.3) **Additional coverage:** Energy diagrams (Sec 12.1), reaction profile (Sec 12.3), catalysts (Sec 12.4), photosynthesis and respiration (Sec 18.2), enzymes (Sec 18.3)
• Hess's law	**Prior knowledge:** Conservation of energy (Sec 1.3), enthalpy (Sec 4.2), calorimetry (Sec 3.2, 9.3)
11.1 Analyzing a Chemical Reaction • Stoichiometry • Mole ratio	**Prior knowledge:** The mole and calculations with moles (Sec 2.2), conservation of mass (Sec 4.2), balancing equations (Sec 10.2) **Additional coverage:** Percent yield (Sec 11.2), stoichiometry and gases (Sec 14.3)
• Stoichiometry • Mole ratio	**Prior knowledge:** The mole and calculations with moles (Sec 2.2), conservation of mass (Sec 4.2), balancing equations (Sec 10.2) **Additional coverage:** Percent yield (Sec 11.2), stoichiometry and gases (Sec 14.3)

STUDENT BOOK CONTENT	SPIRAL TREATMENT
11.2 Percent Yield and Concentration • Theoretical and actual yield • Percent yield	**Prior knowledge:** The mole and calculations with moles (Sec 2.2), conservation of mass (Sec 4.2), balancing equations (Sec 10.2)
• Percent yield • Stoichiometry with solutions	**Prior knowledge:** The mole and calculations with moles (Sec 2.2), concentration and molarity (Sec 2.3), conservation of mass (Sec 4.2), balancing equations (Sec 10.2)
11.3 Limiting Reactants • Limiting and excess reactants • Identifying the limiting reactants	**Prior knowledge:** The mole and calculations with moles (Sec 2.2), conservation of mass (Sec 4.2), balancing equations (Sec 10.2)
11.4 Solving Stoichiometric Problems • Limiting reactant • Theoretical yield • Percent yield	**Prior knowledge:** The mole and calculations with moles (Sec 2.2), conservation of mass (Sec 4.2), molar mass (Sec 8.2), balancing equations (Sec 10.2)
• Percent yield • Reactions in aqueous solutions	**Prior knowledge:** The mole and calculations with moles (Sec 2.2), concentration and molarity (Sec 2.3), conservation of mass (Sec 4.2), molar mass (Sec 8.2), balancing equations (Sec 10.2)
12.1 Reaction Rates • Collision theory • Energy change and reaction profile	**Prior knowledge:** Energy (Sec 1.3), concentration and molarity (Sec 2.3), Brownian motion (Sec 3.1), chemical changes (Chap 4), chemical reactions and energy (Sec 10.4), stoichiometry (Chap 11) **Additional coverage:** Pressure and molecular kinetic theory (Sec 14.1)
• Energy change and reaction profile • Factors affecting rate	**Prior knowledge:** Energy (Sec 1.3), concentration and molarity (Sec 2.3), Brownian motion (Sec 3.1), chemical changes (Chap 4), chemical reactions and energy (Sec 10.4), stoichiometry (Chap 11)
12.2 Chemical Equilibrium • Physical equilibrium • Chemical equilibrium	**Prior knowledge:** Evaporation of water (Sec 3.3), thermal equilibrium (Sec 3.2), reactants and products (Sec 4.2, 10.1), solubility, saturation, and equilibrium (Sec 9.2) **Additional coverage:** Acid–base equilibria (Sec 13.3), metals and alloys, binary phase diagram (Sec 16.3)
• Chemical equilibrium • Le Châtelier's principle	**Prior knowledge:** Equilibrium (Sec 3.2), reactants and products (Sec 4.2, 10.1), solubility, saturation, and equilibrium (Sec 9.2) **Additional coverage:** Acid–base equilibria (Sec 13.3), metals and alloys, binary phase diagram (Sec 16.3), chemistry of the atmosphere (Sec 19.1), chemistry of the oceans (Sec 19.2)
• Effects from temperature • Effects from concentration • Effects from pressure • *Equilibrium expression (AP)* • *Equilibrium constant (AP)*	**Prior knowledge:** Concentration and molarity (Sec 2.3), evaporation of water (Sec 3.3), thermal equilibrium (Sec 3.2), reactants and products (Sec 4.2, 10.1), solubility, saturation, and equilibrium (Sec 9.2), factors that affect solubility (Sec 9.2)

STUDENT BOOK CONTENT	SPIRAL TREATMENT
12.3 Chemical Pathways • Reaction mechanism • Elementary step • Intermediate • Molecularity	**Prior knowledge:** Brownian motion (Sec 3.1), chemical change (Sec 4.1), activation energy (Sec 4.2), chemical reactions (Sec 4.3, 10.3), reaction profile (Sec 10.4), collision theory (Sec 12.1) **Additional coverage:** Catalysts and enzymes (Sec 12.4), photosynthesis and respiration (Sec 18.2), enzymes (Sec 18.3)
• Reaction rates • Reaction profile • Rate-determining step	**Prior knowledge:** Brownian motion (Sec 3.1), chemical change (Sec 4.1), activation energy (Sec 4.2), chemical reactions (Sec 4.3, 10.3), reaction profile (Sec 10.4), collision theory (Sec 12.1)
12.4 Catalysts • Catalyst • Enzyme • Importance of catalysts	**Prior knowledge:** Brownian motion (Sec 3.1), chemical change (Sec 4.1), activation energy (Sec 4.2), chemical reactions (Sec 4.3, 10.3), reaction profile (Sec 10.4), collision theory (Sec 12.1) **Additional coverage:** Catalytic converters (Chap 15 Chemical Connections), enzymes (Sec 18.3)
13.1 The Chemical Nature of Acids and Bases • The hydronium ion • Brønsted–Lowry acids and bases	**Prior knowledge:** Introduction to acids, bases and the pH scale (Sec 4.3), chemical reactions in the lab (Sec 4.3), types of chemical reactions (Sec 10.3) **Additional coverage:** Electrochemical cells (Sec 15.4), functional groups in organic chemistry (Sec 17.2)
• Acid–base pairs • Acid and base strengths	**Prior knowledge:** Introduction to acids, bases and the pH scale (Sec 4.3), chemical reactions in the lab (Sec 4.3), types of chemical reactions (Sec 10.3) **Additional coverage:** Functional groups in organic chemistry (Sec 17.2), amino acids (Sec 18.3), chemistry of the oceans (Sec 19.1), chemistry of the oceans (Sec 19.2)
13.2 The pH Scale • The pH scale • Concentration and logarithm	**Prior knowledge:** Use of exponents (Sec 1.1), concentration and molarity (Sec 2.3), introduction to the pH scale (Sec 4.3), the hydronium ion (Sec 13.1) **Additional coverage:** Titration curves and equivalence point (Sec 13.4)
• Calculating pH • pH indicators	**Prior knowledge:** Use of exponents (Sec 1.1), concentration and molarity (Sec 2.3), introduction to the pH scale (Sec 4.3), the hydronium ion (Sec 13.1) **Additional coverage:** Titration curves and equivalence point (Sec 13.4)
13.3 Acid–Base Equilibria • *Polyprotic acids (AP)* • *pH of weak bases (AP)*	**Prior knowledge:** Introduction to acids, bases, and the pH scale (Sec 4.3), definitions of acids and bases (Sec 13.1), physical and chemical equilibria (Sec 12.2)
13.4 Acid–Base Reactions • Corrosion	**Prior knowledge:** Acids and bases (Sec 4.3, Sec 13.1), chemical reactions (Chap 4, 10), reactivity (Sec 4.1), properties of metals (Sec 6.2)
• Electrolysis • Neutralization • Salts	**Prior knowledge:** Acids and bases (Sec 4.3, Sec 13.1), chemical reactions (Chap 4, 10), reactivity (Sec 4.1) **Additional coverage:** Electrochemical cells (Sec 15.4)
• Neutralization • Titration • Buffers	**Prior knowledge:** Acids and bases (Sec 4.3, Sec 13.1), chemical reactions (Chap 4, 10), reactivity (Sec 4.1) **Additional coverage:** Chemistry of the oceans (Sec 19.2)

STUDENT BOOK CONTENT	SPIRAL TREATMENT
14.1 Pressure and Kinetic Theory • Kinetic molecular theory • Brownian motion	**Prior knowledge:** Matter and mass (Sec 1.1), Brownian motion and thermal energy (Sec 3.1), collision theory (Sec 12.1)
• Pressure • Measuring pressure • Atmospheric pressure	**Prior knowledge:** Brownian motion and thermal energy (Sec 3.1), units of pressure (Sec 1.1), collision theory (Sec 12.1) **Additional coverage:** Chemistry of the atmosphere (Sec 19.1), chemistry of the land (Sec 19.3)
• Kinetic theory of pressure	**Prior knowledge:** Matter and mass (Sec 1.1), Brownian motion and thermal energy (Sec 3.1), collision theory (Sec 12.1)
• Diffusion • *Boltzmann's constant (AP)*	**Prior knowledge:** Matter and mass (Sec 1.1), Brownian motion and thermal energy (Sec 3.1), entropy (Sec 9.3), collision theory (Sec 12.1) **Additional coverage:** Chemistry of the oceans (Sec 19.2)
14.2 The Gas Laws • Boyle's law • Equalizing pressure	**Prior knowledge:** Pressure, volume, and temperature (Sec 1.1), moles (Sec 2.1), Kelvin scale (Sec 3.1), measuring pressure (Sec 4.1), molar mass (Sec 8.4) **Additional coverage:** Chemistry of the atmosphere (Sec 19.1), Atmosphere of planets in the Solar System (Sec 21.2)
• Charles's law • Combined gas law	**Prior knowledge:** Pressure, volume, and temperature (Sec 1.1), moles (Sec 2.1), Kelvin scale (Sec 3.1), measuring pressure (Sec 4.1), molar mass (Sec 8.4) **Additional coverage:** Chemistry of the atmosphere (Sec 19.1), Atmosphere of planets in the Solar System (Sec 21.2)
• Avogadro's law • Ideal gas law	**Prior knowledge:** Pressure, volume, and temperature (Sec 1.1), moles (Sec 2.1), Kelvin scale (Sec 3.1), measuring pressure (Sec 4.1), molar mass (Sec 8.4)
14.3 Stoichiometry and Gases • Gas–solid stoichiometry	**Prior knowledge:** Pressure, volume, and temperature (Sec 1.1), moles (Sec 2.1), calculations with moles (Sec 2.2), Kelvin scale (Sec 3.1), measuring pressure (Sec 4.1), molar mass (Sec 8.4), stoichiometry (Chap 11)
• Gas–solution stoichiometry • Gas–gas stoichiometry	**Prior knowledge:** Pressure, volume, and temperature (Sec 1.1), moles (Sec 2.1), calculations with moles (Sec 2.2), molarity (Sec 2.3), Kelvin scale (Sec 3.1), measuring pressure (Sec 4.1), molar mass (Sec 8.4), stoichiometry (Chap 11)

Note: Concept mapping is not provided for Part 3 (Advanced Topics) as the use of Part 3 concepts will vary from teacher to teacher.

The 5E Instructional Model

A Natural Approach to Chemistry was designed around the instructional model. Extensive learning research since the 1960s supports the conclusion that learning does not take place all at once, but occurs in stages that are part of a *learning cycle.* The cycle that begins with some kind of *engagement* experience in which the learner cognitively connects with the content being taught. The learning experience is shaped through reflective and cognitive processes until it leads to real and retained learning. In 1989, Roger Bybee and colleagues suggested five steps that could serve as a model for developing instructional materials that explicitly made use of learning cycles. The five steps were called *engage, explore, explain, extend,* and *evaluate*. The 5E model is a proven, well-used, and successful curriculum design philosophy that has been used over and over again in lesson plans in the past three decades. While there have been many refinements, the core idea is as powerful today as when it was first published.

Engage. The first step in learning occurs when the student engages with the content. Engagement means consciously focusing on the task, problem, experiment, or lecture. Without engagement, a lesson has no chance at creating any real learning. Effective lessons often begin with engaging elements that are active, paradoxical, funny, or even shocking. These elements break student attention away from texting their friends, chatting, or whatever they were doing and get them to focus on the task at hand. The engage stage of the learning cycle

- initiates the learning activity and focuses attention on it,
- may make connections to past, present and future knowledge, and
- establishes a need-to-know level of interest that motivates the next stage of learning.

Each chapter of *A Natural Approach to Chemistry* begins with a short reading—designed to engage the student. The second page of each chapter shows an unusual or paradoxical experiment. Most importantly, each chapter begins with an "A" investigation. The "A" investigation is designed to be the primary engagement activity for the content of the chapter and therefore we ask that it usually be taught *before* the student has formal exposure to the content through lessons or readings. This keeps curiosity as a motivating factor because the students does not know *a priori* what is going to happen.

Explore. Engagement only lasts a short time and the exploration phase of a lesson provides common, concrete experiences that students can discuss and share as they dig-in to a new concept. In a good exploration activity, students observe interesting aspects of a new idea, talk about them, and may start suggesting ideas of their own.

- Provide the class with shared, concrete experiences involving the new ideas.
- Stimulate student exploration of important aspects of a topic.

Students explore what they are interested in. By concentrating on the chemistry of the human body and the chemistry of the environment, examples throughout the text encourage exploration by making each new concept immediately relevant. This exploration is further developed through the investigations.

Explain. You have watched students try to explain something in their own words to you or another student. The very act of explaining to someone else is a crucial, and often necessary part of learning. Research confirms that until students can put a new idea correctly in their own words, they do not yet understand it. Focus on one aspect of a new idea.

- Form and demonstrate a conceptual understanding of the idea.
- Communicate the idea to others.

Almost all of the Investigations in *A Natural Approach to Chemistry* provide opportunities for students to form and express explanations for real observations they make. In the text, more than 400 conceptual questions challenge students to apply the content of each chapter to explain something real that they might encounter in their lives, in the news, or even in movies.

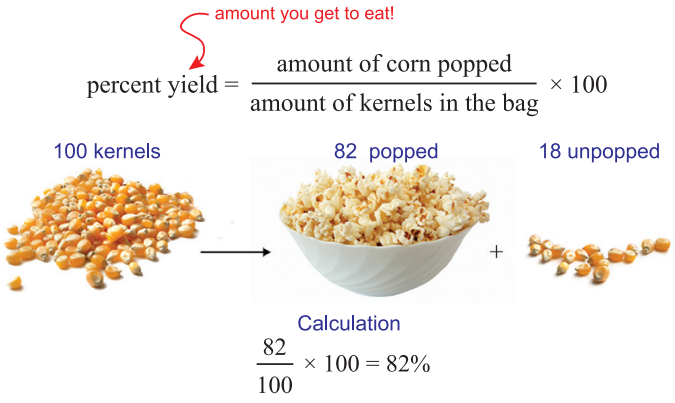
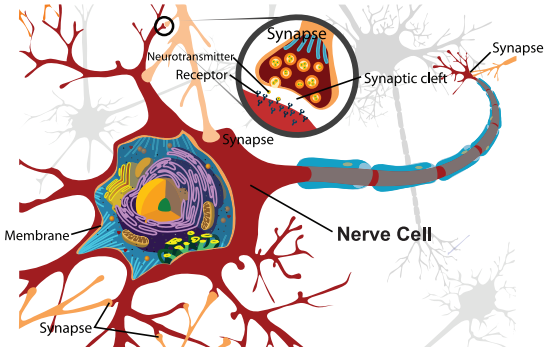


FIGURE 11.14 *Process for calculating percent yield for popcorn*



Extend. Once an idea has made it into working memory, the brain needs to connect it with more experiences and prior knowledge to make the transition to long-term, retained knowledge or skills. Extension broadens and deepens student experience with the new idea by applying it or identifying it in more and different applications, contexts, or experiences.

- Extend ideas to more contexts, skills and applications
- Provide multiple and meaningful ties for recall and use.
- Deepen and broaden understanding.

Evaluate. The traditional 5E model uses evaluate to mean assessment—has the idea really been learned and can it be applied? Self-evaluation is particularly powerful since it often leads to more engagement. External evaluation in the form of homework, quizzes, and tests is also part of the equation.

There is another aspect to evaluation that is also important in *A Natural Approach to Chemistry.* At the top of Bloom's Taxonomy is the cognitive task of evaluation. Evaluation means using the new knowledge or skills to make a decision or compare one or more options. We believe the practical value in knowing chemistry is that the knowledge can be used to evaluate situations and make rational decisions based on knowledge and data rather than on marketing propaganda or less reliable information.

Part 3: How much vitamin C is there in different fruits and juices?

Here we will determine the vitamin C content of a food of your choice. You may use citrus fruits, fresh squeezed or prepared, apple juice, or any drink containing ascorbic acid. Real lemon juice also makes a nice sample to test, and the amount of vitamin C is on the label.

1. To begin you may use fresh or prepared juice. You will need about 25 mL of juice to have enough vitamin C for a good measurement. If you use freshly squeezed juice, it is helpful to strain out the pulp with cheesecloth. An easy way to strain out the pulp is to use a funnel lined with two or three layers of cheesecloth. Pour the sample of juice through the cheesecloth and collect the juice. Record the exact volume of juice you will titrate.
2. Add your juice to a 250 mL Erlenmeyer flask.

FIGURE 13.13

- Assess gain in knowledge and skills
- Use new information and skills to make critically evaluate alternatives