AP CHEMISTRY

UNIT 4

Chemical Reactions

7–9%
AP EXAM WEIGHTING

~14–15
CLASS PERIODS

Remember to go to **AP Classroom** to assign students the online **Personal Progress Check** for this unit.

Whether assigned as homework or completed in class, the **Personal Progress Check** provides each student with immediate feedback related to this unit's topics and skills.

Personal Progress Check 4

Multiple-choice: ~20 questions
Free-response: 1 question

- Long-answer

UNIT 4

7–9% AP EXAM WEIGHTING | **~14–15** CLASS PERIODS

Chemical Reactions

BIG IDEA 1
Scale, Proportion, and Quantity SPQ
- What makes fireworks explode?

BIG IDEA 3
Transformations TRA
- Why is the mass of a raw egg different than a boiled egg?
- What are the processes related to changes in a substance?

Developing Understanding

This unit explores chemical transformations of matter by building on the physical transformations studied in Unit 3. Chemical changes involve the making and breaking of chemical bonds. Many properties of a chemical system can be understood using the concepts of varying strengths of chemical bonds and weaker intermolecular interactions. When chemical changes occur, the new substances formed have properties that are distinguishable from the initial substance or substances. Chemical reactions are the primary means by which transformations in matter occur. Chemical equations are a representation of the rearrangement of atoms that occur during a chemical reaction. In subsequent units, students will explore rates at which chemical changes occur.

Building the Science Practices

1.B 2.B 5.C 5.E 6.B

In Unit 3, students constructed particulate-level representations of compounds and molecules and explained the forces that come into play when particles interact. In Unit 4, students will describe and construct equations of chemical systems and learn to balance those equations. Students should be able to identify and effectively represent types of reactions (e.g., acid-base, redox, precipitation) and then use that knowledge to make hypotheses or predictions about the outcome of a reaction. Additionally, students should be able to support their claims about the identity and amount of product yield through evidence gained with both experimentation and the principles of stoichiometry. Further, students should be able to determine the output of a reaction when the number of moles of reactants change or are in limited/excess supply. This practice of effectively representing balanced chemical equations and using stoichiometry to calculate outcomes of such reactions is critical to student success in the remainder of the course.

Preparing for the AP Exam

On the AP Exam, students must be able to demonstrate proficiency in writing and balancing chemical equations (molecular, complete, net ionic) and calculating quantities in multiple contexts using more than just 1:1 stoichiometric ratios. Students often struggle with questions that require them to justify their identification of a particular type of reaction using an equation. They also struggle with determining the limiting reactant using stoichiometry. For example, with stoichiometric calculations, students often make the mistake of comparing mass to mass instead of mole to mole when determining the limiting reactant. Teacher can ensure that students practice writing balanced equations (for net ionic and molecular) and that they develop a strong understanding of the mole concept and gain proficiency with dimensional analysis. This will help them correctly calculate required quantities using stoichiometric ratios.

UNIT AT A GLANCE

Enduring Understanding	Topic	Suggested Skill	Class Periods
			~14–15 CLASS PERIODS
TRA-1	**4.1 Introduction for Reactions**	2.B Formulate a hypothesis or predict the results of an experiment.	
	4.2 Net Ionic Equations	5.E Determine a balanced chemical equation for a given chemical phenomena.	
	4.3 Representations of Reactions	3.B Represent chemical substances or phenomena with appropriate diagrams or models (e.g., electron configuration).	
	4.4 Physical and Chemical Changes	6.B Support a claim with evidence from experimental data.	
SPQ-4	**4.5 Stoichiometry**	5.C Explain the relationship between variables within an equation when one variable changes.	
	4.6 Introduction to Titration	3.A Represent chemical phenomena using appropriate graphing techniques, including correct scale and units.	
TRA-2	**4.7 Types of Chemical Reactions**	1.B Describe the components of and quantitative information from models and representations that illustrate both particulate-level and macroscopic-level properties.	
	4.8 Introduction to Acid-Base Reactions	1.B Describe the components of and quantitative information from models and representations that illustrate both particulate-level and macroscopic-level properties.	
	4.9 Oxidation-Reduction (Redox) Reactions	5.E Determine a balanced chemical equation for a given chemical phenomena.	

Go to **AP Classroom** to assign the **Personal Progress Check** for Unit 4. Review the results in class to identify and address any student misunderstandings.

SAMPLE INSTRUCTIONAL ACTIVITIES

The sample activities on this page are optional and are offered to provide possible ways to incorporate various instructional approaches into the classroom. Teachers do not need to use these activities or instructional approaches and are free to alter or edit them. The examples below were developed in partnership with teachers from the AP community to share ways that they approach teaching some of the topics in this unit. Please refer to the Instructional Approaches section beginning on p. 197 for more examples of activities and strategies.

Activity	Topic	Sample Activity
1	4.2 4.3	**Explore Representations** Have students work through an online simulation of particulate-level representations of various single-displacement reactions. Then have them translate these particle-level views into net ionic equations.
2	4.5	**Simulations** Have students view a simulated reaction pertaining to a limiting reagent problem. Each iteration of the simulation provides students with different unknown concentrations of the reactants from which students calculate the amount of product that is dissolved. Then have them check their answers upon completion of the simulation.
3	4.6	**Think-Pair-Share** Ask students to connect four different particulate representations with a strong acid-strong base titration curve between HCl + NaOH. The representations depict the acid before base has been added, the half equivalence point of the titration, the equivalence point of the titration, and some point beyond the equivalence point (excess base). Have students defend their choices with a partner.
4	4.7	**Critique Reasoning** After a review of different types of chemical reactions (acid-base, redox, precipitation), give students a series of 10 reactions (both the equation and a short demo of the reaction taking place). Have them identify what type of reaction is taking place and justify that claim with evidence. Then have them pair up and evaluate the strength of each other's claims.
5	4.9	**Simulations** After viewing a simulation on metal/metal ion reactions, provide students with several 1 molar solutions and a piece of aluminum and ask them to select a solution that would react to coat the Al. Students who select incorrect solutions should go back and revisit the simulation.

SUGGESTED SKILL

Question and Method

2.B

Formulate a hypothesis or predict the results of an experiment.

AVAILABLE RESOURCES

- Classroom Resource > **Guided Inquiry Activities for the Classroom: Lesson 1**

TOPIC 4.1
Introduction for Reactions

Required Course Content

ENDURING UNDERSTANDING

TRA-1

A substance that changes its properties, or that changes into a different substance, can be represented by chemical equations.

LEARNING OBJECTIVE

TRA-1.A

Identify evidence of chemical and physical changes in matter.

ESSENTIAL KNOWLEDGE

TRA-1.A.1

A physical change occurs when a substance undergoes a change in properties but not a change in composition. Changes in the phase of a substance (solid, liquid, gas) or formation/separation of mixtures of substances are common physical changes.

TRA-1.A.2

A chemical change occurs when substances are transformed into new substances, typically with different compositions. Production of heat or light, formation of a gas, formation of a precipitate, and/or color change provide possible evidence that a chemical change has occurred.

TOPIC 4.2
Net Ionic Equations

Required Course Content

ENDURING UNDERSTANDING

TRA-1

A substance that changes its properties, or that changes into a different substance, can be represented by chemical equations.

LEARNING OBJECTIVE

TRA-1.B

Represent changes in matter with a balanced chemical or net ionic equation:

a. For physical changes.

b. For given information about the identity of the reactants and/or product.

c. For ions in a given chemical reaction.

ESSENTIAL KNOWLEDGE

TRA-1.B.1

All physical and chemical processes can be represented symbolically by balanced equations.

TRA-1.B.2

Chemical equations represent chemical changes. These changes are the result of a rearrangement of atoms into new combinations; thus, any representation of a chemical change must contain equal numbers of atoms of every element before and after the change occurred. Equations thus demonstrate that mass is conserved in chemical reactions.

TRA-1.B.3

Balanced molecular, complete ionic, and net ionic equations are differing symbolic forms used to represent a chemical reaction. The form used to represent the reaction depends on the context in which it is to be used.

SUGGESTED SKILL

Mathematical Routines

5.E

Determine a balanced chemical equation for a given chemical phenomena.

AVAILABLE RESOURCES

- AP Chemistry Lab Manual > **Investigation 8: How Can We Determine the Actual Percentage of H2O2 in a Drugstore Bottle of Hydrogen Peroxide?**

SUGGESTED SKILL

Representing Data and Phenomena

3.B

Represent chemical substances or phenomena with appropriate diagrams or models (e.g., electron configuration).

AVAILABLE RESOURCES

- Classroom Resource > **Guided Inquiry Activities for the Classroom: Lesson 1**

TOPIC 4.3
Representations of Reactions

Required Course Content

ENDURING UNDERSTANDING

TRA-1

A substance that changes its properties, or that changes into a different substance, can be represented by chemical equations.

LEARNING OBJECTIVE

TRA-1.C

Represent a given chemical reaction or physical process with a consistent particulate model.

ESSENTIAL KNOWLEDGE

TRA-1.C.1

Balanced chemical equations in their various forms can be translated into symbolic particulate representations.

TOPIC 4.4
Physical and Chemical Changes

Required Course Content

ENDURING UNDERSTANDING

TRA-1

A substance that changes its properties, or that changes into a different substance, can be represented by chemical equations.

LEARNING OBJECTIVE

TRA-1.D

Explain the relationship between macroscopic characteristics and bond interactions for:

a. Chemical processes.

b. Physical processes.

ESSENTIAL KNOWLEDGE

TRA-1.D.1

Processes that involve the breaking and/or formation of chemical bonds are typically classified as chemical processes. Processes that involve only changes in intermolecular interactions, such as phase changes, are typically classified as physical processes.

TRA-1.D.2

Sometimes physical processes involve the breaking of chemical bonds. For example, plausible arguments could be made for the dissolution of a salt in water, as either a physical or chemical process, involves breaking of ionic bonds, and the formation of ion-dipole interactions between ions and solvent.

SUGGESTED SKILL

Argumentation

6.B

Support a claim with evidence from experimental data.

AVAILABLE RESOURCES

- AP Chemistry Lab Manual > **Investigation 9: Can the Individual Components of Quick Ache Relief Be Used to Resolve Consumer Complaint?**

SUGGESTED SKILL

Mathematical Routines

5.C

Explain the relationship between variables within an equation when one variable changes.

AVAILABLE RESOURCES

- AP Chemistry Lab Manual > **Investigation 7: Using the Principle That Each Substance Has Unique Properties to Purify a Mixture: An Experiment in Applying Green Chemistry to Purification**

TOPIC 4.5
Stoichiometry

Required Course Content

ENDURING UNDERSTANDING

SPQ-4

When a substance changes into a new substance, or when its properties change, no mass is lost or gained.

LEARNING OBJECTIVE

SPQ-4.A

Explain changes in the amounts of reactants and products based on the balanced reaction equation for a chemical process.

ESSENTIAL KNOWLEDGE

SPQ-4.A.1

Because atoms must be conserved during a chemical process, it is possible to calculate product amounts by using known reactant amounts, or to calculate reactant amounts given known product amounts.

SPQ-4.A.2

Coefficients of balanced chemical equations contain information regarding the proportionality of the amounts of substances involved in the reaction. These values can be used in chemical calculations involving the mole concept.

SPQ-4.A.3

Stoichiometric calculations can be combined with the ideal gas law and calculations involving molarity to quantitatively study gases and solutions.

TOPIC 4.6
Introduction to Titration

Required Course Content

ENDURING UNDERSTANDING

SPQ-4

When a substance changes into a new substance, or when its properties change, no mass is lost or gained.

LEARNING OBJECTIVE

SPQ-4.B

Identify the equivalence point in a titration based on the amounts of the titrant and analyte, assuming the titration reaction goes to completion.

ESSENTIAL KNOWLEDGE

SPQ-4.B.1

Titrations may be used to determine the concentration of an analyte in solution. The titrant has a known concentration of a species that reacts specifically and quantitatively with the analyte. The equivalence point of the titration occurs when the analyte is totally consumed by the reacting species in the titrant. The equivalence point is often indicated by a change in a property (such as color) that occurs when the equivalence point is reached. This observable event is called the endpoint of the titration.

SUGGESTED SKILL

Representing Data and Phenomena

3.A

Represent chemical phenomena using appropriate graphing techniques, including correct scale and units.

AVAILABLE RESOURCES

- AP Chemistry Lab Manual > **Investigation 4: How Much Acid Is in Fruit Juice and Soft Drinks?**

SUGGESTED SKILL

Models and Representations

1.B

Describe the components of and quantitative information from models and representations that illustrate both particulate-level and macroscopic-level properties.

TOPIC 4.7
Types of Chemical Reactions

Required Course Content

ENDURING UNDERSTANDING

TRA-2

A substance can change into another substance through different processes, and the change itself can be classified by the sort of processes that produced it.

LEARNING OBJECTIVE

TRA-2.A

Identify a reaction as acid-base, oxidation-reduction, or precipitation.

ESSENTIAL KNOWLEDGE

TRA-2.A.1

Acid-base reactions involve transfer of one or more protons between chemical species.

TRA-2.A.2

Oxidation-reduction reactions involve transfer of one or more electrons between chemical species, as indicated by changes in oxidation numbers of the involved species. Combustion is an important subclass of oxidation-reduction reactions, in which a species reacts with oxygen gas. In the case of hydrocarbons, carbon dioxide and water are products of complete combustion.

TRA-2.A.3

In a redox reaction, electrons are transferred from the species that is oxidized to the species that is reduced.

X THE MEANING OF THE TERMS "REDUCING AGENT" AND "OXIDIZING AGENT" WILL NOT BE ASSESSED ON THE AP EXAM.

Rationale: *Understanding this terminology is not necessary for reasoning about redox chemistry.*

continued on next page

LEARNING OBJECTIVE

TRA-2.A

Identify a reaction as acid-base, oxidation-reduction, or precipitation.

ESSENTIAL KNOWLEDGE

TRA-2.A.4

Oxidation numbers may be assigned to each of the atoms in the reactants and products; this is often an effective way to identify the oxidized and reduced species in a redox reaction.

TRA-2.A.5

Precipitation reactions frequently involve mixing ions in aqueous solution to produce an insoluble or sparingly soluble ionic compound. All sodium, potassium, ammonium, and nitrate salts are soluble in water.

ROTE MEMORIZATION OF "SOLUBILITY RULES" OTHER THAN THOSE IMPLIED IN TRA-2.A.5 WILL NOT BE ASSESSED ON THE AP EXAM.

SUGGESTED SKILL

Models and Representations

1.B

Describe the components of and quantitative information from models and representations that illustrate both particulate-level and macroscopic-level properties.

AVAILABLE RESOURCES

- Classroom Resource > **Guided Inquiry Activities for the Classroom: Lesson 2**

TOPIC 4.8
Introduction to Acid-Base Reactions

Required Course Content

ENDURING UNDERSTANDING

TRA-2

A substance can change into another substance through different processes, and the change itself can be classified by the sort of processes that produced it.

LEARNING OBJECTIVE

TRA-2.B

Identify species as Brønsted-Lowry acids, bases, and/or conjugate acid-base pairs, based on proton-transfer involving those species.

ESSENTIAL KNOWLEDGE

TRA-2.B.1

By definition, a Brønsted-Lowry acid is a proton donor and a Brønsted-Lowry base is a proton acceptor.

TRA-2.B.2

Only in aqueous solutions, water plays an important role in many acid-base reactions, as its molecular structure allows it to accept protons from and donate protons to dissolved species.

TRA-2.B.3

When an acid or base ionizes in water, the conjugate acid-base pairs can be identified and their relative strengths compared.

X LEWIS ACID-BASE CONCEPTS WILL NOT BE ASSESSED ON THE AP EXAM.

Rationale: *Lewis acid-base concepts are important ideas for organic chemistry. However, as the emphasis in AP Chemistry is on reactions in aqueous solution, these concepts will not be examined.*

TOPIC 4.9
Oxidation-Reduction (Redox) Reactions

SUGGESTED SKILL

Mathematical Routines

5.E

Determine a balanced chemical equation for a given chemical phenomena.

Required Course Content

ENDURING UNDERSTANDING

TRA-2

A substance can change into another substance through different processes, and the change itself can be classified by the sort of processes that produced it.

LEARNING OBJECTIVE

TRA-2.C

Represent a balanced redox reaction equation using half-reactions.

ESSENTIAL KNOWLEDGE

TRA-2.C.1

Balanced chemical equations for redox reactions can be constructed from half-reactions.