AP CHEMISTRY

UNIT 4

Chemical Reactions

7–9%
AP EXAM WEIGHTING

~14–15
CLASS PERIODS

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Chemical Reactions

ESSENTIAL QUESTIONS

- What makes fireworks explode?
- In what ways can a chemical change be described and documented?
- How can you predict that a chemical reaction will generate enough product?

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 encounter difficulty 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.

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

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
4.1.A Identify evidence of chemical and physical changes in matter.	**4.1.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.
	4.1.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

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
4.2.A Represent changes in matter with a balanced chemical or net ionic equation: i. For physical changes. ii. For given information about the identity of the reactants and/or product. iii. For ions in a given chemical reaction.	**4.2.A.1** All physical and chemical processes can be represented symbolically by balanced equations. **4.2.A.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 and charge are conserved in chemical reactions. **4.2.A.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?**
- The Exam > **2023 Chief Reader Report**

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**
- The Exam > **2022 Chief Reader Report**

TOPIC 4.3
Representations of Reactions

Required Course Content

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
4.3.A Represent a given chemical reaction or physical process with a consistent particulate model.	**4.3.A.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

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
4.4.A Explain the relationship between macroscopic characteristics and bond interactions for: i. Chemical processes. ii. Physical processes.	**4.4.A.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. **4.4.A.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

LEARNING OBJECTIVE

4.5.A

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

ESSENTIAL KNOWLEDGE

4.5.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.

4.5.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.

4.5.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

LEARNING OBJECTIVE

4.6.A

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

4.6.A.1

Titrations may be used to determine the amount 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?**
- The Exam > **2018 Chief Reader Report**

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

LEARNING OBJECTIVE

4.7.A

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

ESSENTIAL KNOWLEDGE

4.7.A.1

Acid-base reactions involve transfer of one or more protons (H^+ ions) between chemical species.

4.7.A.2

Oxidation-reduction (redox) 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.

4.7.A.3

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

> ***Exclusion Statement:*** *The meaning of the terms "reducing agent" and "oxidizing agent" will not be assessed on the AP Exam.*

4.7.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.

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LEARNING OBJECTIVE

4.7.A

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

ESSENTIAL KNOWLEDGE

4.7.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.

Exclusion Statement: *Rote memorization of "solubility rules" other than those implied in 4.7.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

LEARNING OBJECTIVE

4.8.A

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

ESSENTIAL KNOWLEDGE

4.8.A.1

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

4.8.A.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.

4.8.A.3

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

Exclusion Statement: *Lewis acid-base concepts will not be assessed on the AP Exam. The emphasis in AP Chemistry is on reactions in aqueous solution.*

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

LEARNING OBJECTIVE	ESSENTIAL KNOWLEDGE
4.9.A Represent a balanced redox reaction equation using half-reactions.	**4.9.A.1** Balanced chemical equations for redox reactions can be constructed from half-reactions.