High School Chemistry

Unit 4: Chemical reactions

SCIENCE: CHEM.9A | CHEM.9B

Change is coming! In this unit, we’ll delve into different types of chemical reactions and learn how to represent, analyze, and predict their outcomes.

- Interpret and write balanced chemical equations to represent reactions.
- Recognize patterns in chemical reactions and classify them as synthesis, decomposition, single replacement, or combustion.
- Explain and analyze the transfer of electrons between substances in oxidation-reduction reactions.
- Apply knowledge of chemical bonding and reaction patterns to predict the products of single replacement reactions and simple synthesis and decomposition reactions.

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<th>TEKS standards</th>
<th>Example phenomena</th>
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<td>CHEM.9A Interpret, write, and balance chemical equations, including synthesis, decomposition, single replacement, double replacement,* and combustion reactions using the law of conservation of mass.</td>
<td>What strategies can we use to prevent or mitigate the impacts of metal corrosion on machinery and infrastructure, such as bridges and pipelines? Corrosion is a chemical process by which pure metals become oxidized to more stable compounds as they interact with other substances in the environment. This causes the metal to deteriorate and lose its structural integrity, leading to safety concerns and significant economic costs. In order to address these issues, engineers have developed a number of corrosion prevention strategies, such as applying paint or polyurethane to provide a physical barrier between the metal and the environment or coating it with a layer of zinc in a process called “galvanizing.”</td>
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| CHEM.9B Differentiate among acid-base reactions,* precipitation reactions,* and oxidation-reduction reactions. | Prompts for students to consider:
- What substances in the environment are involved in the chemical reactions that lead to metal corrosion, and what role do they play?
- How can an understanding of oxidation-reduction reactions aid in developing anti-corrosion strategies?
- How does galvanizing iron or steel with a layer of zinc protect it from oxidation, and what role does the reactivity series play?
- What factors make oil and gas pipelines susceptible to corrosion, and why is effective corrosion prevention so critical in this industry? |

*These concepts are covered in Units 7 & 8.

How does chemistry contribute to and help us address climate change?
Since the Industrial Revolution, human activities have been driving climate change and leading to long-term shifts in temperature and weather patterns.
on Earth. Combustion of fossil fuels like coal, gasoline, and oil to generate electricity, heat homes, drive cars, and for other applications produces large amounts of carbon dioxide gas. Carbon dioxide and other greenhouse gases impact climate by trapping heat in our atmosphere, rather than allowing it to radiate out into space. Key strategies to address climate change include reducing reliance on combustion of fossil fuels, developing alternative energy sources like wind and solar, and carbon sequestration methods, whereby carbon dioxide is captured and removed from the atmosphere.

Prompts for students to consider:

- How does burning fossil fuels contribute to climate change, and what are some of its impacts on your community or state?
- How does reforestation aid in carbon capture, and why is photosynthesis important in combating climate change?
- How can changing agricultural practices lead to carbon capture?
- How is carbon dioxide removed from the atmosphere through the process of "mineralization?"

Unit resources

- For the videos in this unit, use the Learning summary video notetaking guide
- For the articles in this unit, use the Article notetaking guide
- For the exercises in this unit, use the Blank workspace template
- Vocabulary and notation notetaker

Lesson overview

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| Lesson 1: Representing chemical reactions | Interpret the meaning of symbols and numbers in chemical equations, and identify the reactants and products. Explain the difference in meaning between subscripts and coefficients in a balanced chemical equation. Use subscripts and coefficients to determine the number of each kind of atom present in the reactants and products of | - Introduce a balanced chemical equation and ask students to "diagram" it by labeling/desccribing all of the components using a given list of vocabulary words (e.g., reactants, products, coefficient, subscript, solid, liquid, gas, aqueous, atom, molecule, formula unit, yields).  
- Ask students to translate a few balanced chemical equations into words as complete sentences. This provides practice interpreting the symbols in chemical equations and emphasizes the value of using the equation notation as effective shorthand.  
- Having students translate reactions from words to chemical equations is also valuable and reinforces |
## Lesson 2: Balancing chemical equations

**TEKS standard:**
CHEM.9A

- Explain why the law of conservation of mass requires chemical equations to be balanced with coefficients.
- Use coefficients to balance chemical equations for synthesis, decomposition, single replacement, and combustion reactions.

- Before getting into the mechanics of balancing chemical equations, introduce the law of conservation of mass and connect it to Dalton’s postulate from Unit 1 that chemical reactions involve the rearrangement of atoms, not their destruction or creation.
- Have students analyze an unbalanced chemical equation to determine the number of each kind of atom in the reactants and products. Ask them to consider how they could adjust the equation to be consistent with the law of conservation of mass. Discuss why changing subscripts is not an acceptable solution.
- Emphasize that the process of “balancing” a chemical equation is simply a way of representing on paper what actually occurs in a reaction. Adding coefficients to a chemical equation does not add to or change the chemical reaction. Rather, it adjusts the equation to correctly reflect the ratios in which the substances react.
- Use the [PhET Balancing Chemical Equations](https://phet.colorado.edu/) simulation to help students visualize what is changing and not changing about the components of a chemical reaction when they adjust coefficients. Challenge students to practice their balancing skills with the "game" section.

## Lesson 3: Types of reactions

**TEKS standards:**
CHEM.9A; 9B

- Classify reactions into types, including synthesis, decomposition, combustion, and single replacement, based on how the reactants rearrange to form products.
- Explain the concepts of oxidation and reduction in chemical formula writing skills from Unit 3.

- Promote student engagement by providing many opportunities to observe and analyze exciting chemical reactions through videos, live demonstrations, and hands-on experiments. Not only does this generate excitement, it gives students visual and tangible frames of reference for understanding reaction patterns.
terms of electron transfer, and identify elements that are oxidized or reduced in a chemical reaction.

Apply knowledge of chemical bonding and reaction patterns to predict the products of single replacement reactions and simple synthesis and decomposition reactions.

Use the relative reactivities of elements to determine if a given single replacement reaction will occur.

- Give students a set of 12-16 index cards, each with an example of a synthesis, decomposition, single replacement, or combustion reaction on it. Have students work in pairs or small groups to organize the reactions into categories based on patterns that they notice. Have them share their categories and reasoning with the class, and use this as a segue into the four types of reactions.

- Diagram oxidation-reduction reactions by having students identify the charges on atoms in the reactants and products and use arrows to indicate the number of electrons gained or lost. Introduce mnemonic devices, such as “OIL RIG” (Oxidation Is Loss, Reduction Is Gain), to help students remember that oxidation occurs when an atom loses electrons, and reduction is when an atom gains electrons.

- Writing a balanced chemical equation for a reaction from a given set of reactants is a complex process involving a number of layered skills. Students must recognize reaction patterns, analyze relative reactivity, correctly write chemical formulas, and balance with coefficients. In the beginning, provide scaffolded worksheets that break the process down into discrete steps. Before removing this scaffolding, have students generate their own lists of steps and questions to consider when approaching these problems.

**Best practices**

**COMMON MISCONCEPTIONS AND HOW TO ADDRESS THEM**

"It's okay to change subscripts in order to 'balance' a chemical equation."

Students may think that it is acceptable to reconcile the number of each kind of atom in the reactants and products of a chemical equation by changing the subscripts in chemical formulas. This misconception may arise because students do not fully understand the different meanings of subscripts and coefficients.

**How to address this misconception**

Emphasize that subscripts indicate the number of atoms of an element within a molecule or formula unit of a substance. If these numbers change, then the identity of the substance changes. Introduce examples like water (H$_2$O) and hydrogen peroxide (H$_2$O$_2$) to show that chemical formulas with the same kinds of atoms and different subscripts represent different substances with different properties. Have students represent balanced chemical equations with molecular diagrams to show...
how coefficients change the number of molecules or formula units involved in the reaction without changing the identities of the reactants or products.

“Pure elements always appear as individual atoms in chemical equations.”
Students often forget about the existence of diatomic elements that naturally form stable bonded pairs. Alternatively, students may think that diatomic elements must always have a subscript of 2, even in a compound. Both of these misconceptions may lead to errors in writing balanced chemical equations.

How to address this misconception
Address early on that the elements H, N, O, F, Cl, Br, and I, are always diatomic in their pure elemental forms. It can be helpful to note that these elements are all "gens"—hydrogen, nitrogen, oxygen, and the halogens (fluorine, chlorine, bromine, and iodine). Use Lewis dot diagrams to help students understand why these elements are more stable as diatomic molecules. Emphasize that these elements will bond with other elements in different ratios that depend on valence electrons and the octet rule. Provide example problems where diatomic elements are reactants or products, so that students practice recognizing and writing the correct formulas for diatomic elements.

CLASSROOM ACTIVITIES
Investigate types of reactions.
In this series of demonstrations, students will observe chemical reactions and apply their understanding of bonding and reactivity patterns to identify reaction types, predict products, and write balanced equations.

For each demonstration:
☐ Provide the chemical formulas of the reactant(s), and give a brief overview of the procedure.
☐ Ensure students are wearing safety goggles and located a safe distance from the demonstration.
☐ Encourage students to record observations about the substances before, during, and after the reaction, taking particular note of changes in properties.
☐ Ask students to work in small groups to predict the product(s), write a balanced chemical equation, and identify the type of reaction as synthesis, decomposition, single replacement, or combustion.
☐ Ask students to analyze reactions 1 and 3 in terms of oxidation and reduction.

Note: Videos of each of these reactions can be found online. If you do not have the necessary materials or are not able to take appropriate safety precautions, consider having students observe and take notes from videos.

Demo Reaction 1 | Synthesis
Iron and sulfur react to form iron(II) sulfide.

Materials: iron filings, sulfur powder, test tube, magnet, test tube holder, hot mitt, Bunsen burner, striker, safety goggles, and gloves.

☐ Combine iron filings with sulfur powder in a test tube. Move a magnet up and down along the outside of the tube to show that the iron filings are attracted to it, while the sulfur is not.
☐ Heat the tube with a Bunsen burner until reaction occurs. This is best carried out in a fume hood.
☐ Once the test tube cools, use the magnet on the outside of the test tube to demonstrate that the new substance is not magnetic.
Demo Reaction 2 | Decomposition
Hydrogen peroxide breaks down into water and oxygen gas in the presence of a potassium iodide catalyst.

**Materials:** 30% hydrogen peroxide, dish soap, 2 M potassium iodide, 100-mL graduated cylinder, plastic tray 8-10 cm deep, wood splint, lighter, safety goggles, and gloves.

- Add 20 mL of 30% hydrogen peroxide and 10 mL dish soap to a 100-mL graduated cylinder placed in the center of a plastic tray.
- After allowing students to observe for a few minutes, add 5 mL of 2M potassium iodide solution to the graduated cylinder.
- Light a wood splint and gently blow it out. While the splint is still glowing, bring it close to the foam being produced by the reaction. The splint should relight, providing evidence for the presence of oxygen gas as a product of the reaction.
- This demonstration provides an opportunity to talk about the role of catalysts and how to represent them in balanced chemical equations. Note that the dish soap is not part of the chemical reaction and is used only to make the gas product more visible.

Demo Reaction 3 | Single replacement
Magnesium metal reacts with hydrochloric acid to produce aqueous magnesium chloride and hydrogen gas.

**Materials:** 1 M hydrochloric acid, magnesium, test tube, wood splint, lighter, safety goggles, and gloves.

- Add about 1 cm of magnesium ribbon to a test tube containing 20 mL of 1 M hydrochloric acid.
- While the reaction is going, conduct a pop test with a lit wood splint. Place the lit splint just inside the mouth of the test tube to show the explosive property of the gas produced in the reaction.

Demo Reaction 4 | Combustion
Methane gas reacts with oxygen gas to produce carbon dioxide gas and water vapor.

**Materials:** dish soap, water, trough, methane gas source, flexible tubing, taper (e.g., long fireplace match or a candle taped to a meter stick), lighter, and safety goggles.

- Fill a trough with soapy water in a well-ventilated area near a laboratory gas jet.
- Connect a length of flexible tubing to a laboratory gas jet, then turn on the valve and gently blow methane into the solution to create methane-filled soap bubbles.
- After ensuring that the gas valve is closed, use a taper to carefully ignite the methane-filled bubbles.

**GENERAL CLASSROOM IMPLEMENTATION RESOURCES:**

- **Weekly Khan Academy Quick Planning Guide:** Use this template to easily plan your week using Khan Academy.
- **Student Learning Templates:** Choose a template for students to record their learning. There are templates for watching videos, reading articles, and doing exercises.
- **Using Khan Academy in the Classroom:** Learn about teaching strategies and structures to support your students in their learning with Khan Academy.
- **Differentiation Strategies for the Classroom:** Read about strategies to support the learning of all students.