Unit 7: Solutions

Prepare to mix it up! In this unit, we’ll explore the dynamic interplay of solutes and solvents.

- Explore properties of aqueous solutions, and explain how water’s polarity allows it to dissolve a wide range of solutes.
- Analyze solubility curves to understand how temperature affects solubility for solids and gases.
- Investigate the effects of temperature, agitation, and surface area of solids on dissolution rate.
- Predict products of double replacement reactions, and use solubility rules to determine their states.
- Apply molarity to calculate and describe changes in concentration for aqueous solutions.

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| CHEM.11A | Describe the unique role of water in solutions in terms of polarity.  

Why does a soda eventually go flat when the can is opened?  
The bubbles found in carbonated soft drinks come from carbon dioxide gas that is dissolved into the aqueous solution at a low temperature and a high pressure. When a soda can is opened, the pressure inside the can decreases until it is equal to the atmospheric pressure outside the can. As pressure above the surface of the liquid decreases, the solubility of carbon dioxide in the solution decreases, and bubbles begin to rise to the surface. If this occurs quickly, it is often accompanied by a hissing sound as gas moves through the opening of the can, and foaming at the surface of the liquid as groups of gas bubbles escape together. If the open can of soda is left out and allowed to warm to room temperature, the solubility of carbon dioxide in the aqueous solution will decrease further. As more and more gas comes out of solution and escapes into the air around the can, the soda will go flat.  

Prompts for students to consider:
- How is water able to act as a solvent to dissolve carbon dioxide?
- How would you calculate the maximum mass of carbon dioxide that is able to dissolve in a 355 mL can of soda at 8 °C and 1 atm?
- Why is the solubility of other compounds dissolved in soft drinks, such as sugar and phosphoric acid, greater than that of carbon dioxide at a given temperature and pressure?
- Why does a soda go flat when left out, and how do temperature and pressure affect this process?
agitation, and surface area.

How do phosphates and nitrates from agricultural fertilizers end up in our waterways, and what is their impact on aquatic ecosystems?

Agricultural fertilizers are applied to soil to provide plants with necessary sources of nitrogen and phosphorus. This widespread practice enhances crop yields, but the nitrates and phosphates found in fertilizers can make their way into groundwater, rivers, lakes, and coastal waters by leaching or runoff. When the concentrations of these water-soluble compounds reach critical levels, they throw off the balance of ecosystems by overpromoting the growth of algae. Algal blooms decrease oxygen concentration in the water and block sunlight from underwater plants, leading to “dead zones” where fish and other aquatic life cannot survive. The largest dead zone in the United States is 6000-7000 square miles at the mouth of the Mississippi River in the Gulf of Mexico, including along parts of the Texas coast.

Prompts for students to consider:

- How does the polarity of water molecules aid in dissolving ionic compounds like nitrates and phosphates found in fertilizers?
- As climate change leads to higher average temperatures and more extreme storm events, how might these factors affect dissolution rates for nitrates and phosphates and impact agricultural runoff?
- How would you calculate the molarities of phosphates and nitrates in a waterway, and why is understanding these concentrations important for assessing environmental impact?
- What are some of the short and long-term environmental impacts of increased concentrations of phosphates and nitrates in our waterways?
- What are some approaches to addressing the problem of agricultural runoff and pollution of our waterways?

### 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: Aqueous solutions** | Describe the properties of aqueous solutions, and explain how water’s polarity contributes to its ability to dissolve a wide range of substances. Classify solutions based on their relative concentrations and their strength as electrolytes or as nonelectrolytes. | • After reviewing bond polarity and intermolecular forces from Unit 3, ask students to draw diagrams showing hydrogen bonding interactions between water molecules. Then, ask students to consider what they think happens on a particle level when sodium chloride crystals dissolve in water.  
• Allow students to explore the concept of water as “the universal solvent” by mixing water with table salt, sugar, and oil. Ask students to hypothesize why not all substances dissolve in water.  
• Ask students to draw and interpret particle level diagrams showing solutions with different relative concentrations (more/less concentrated or more/less dilute). Emphasize that concentration depends on both the amount of solute particles present and the total volume of the solution.  
• The PhET Sugar and Salt Solutions simulation is a useful tool to help students explore the difference between electrolytes and nonelectrolytes in solution and the effect of ion concentration on electrical conductivity.  
• Set up dilute solutions of sodium chloride and sucrose with a conductivity meter in each solution. Gradually add solute to each solution to increase concentration, and discuss what students observe. Ask students to draw particle level diagrams representing an electrolyte and a nonelectrolyte dissolved in water. Challenge students to explain why the electrolyte conducts electricity more effectively as more solute is added and why the nonelectrolyte solution never conducts electricity, no matter how much solute is added. |
| **Lesson 2: Solubility of solids and gases** | Explain how the relative strengths of attractions between solute and solvent particles affect solubility. Analyze solubility curves to understand the | • Help students unpack the concept of “like dissolves like” by emphasizing that solubility depends on the relative strengths of solute-solute attractions, solvent-solvent attractions, and solute-solvent attractions. If attractions between the solute particles or the solvent particles are significantly |
The relationship between temperature and solubility for solids and gases. Explore how rates of dissolution are affected by changes in temperature, agitation, and surface area of a solid solute.

- Use graphic organizers to help students categorize substances as ionic, polar, or nonpolar and predict the likelihood that they will be soluble in water.
- Provide students with solubility curves for ionic solids and for gases. Ask students to analyze and compare the general trends they observe in the two graphs. Challenge them to consider the curve for one compound on the solids graph and describe a solution that falls below the curve (unsaturated), on the curve (saturated), and above the curve (saturated with solid solute left over).
- Encourage students to connect the concepts of temperature, kinetic energy, and particle collisions from earlier units to the topic of solubility. Ask students to use these concepts to explain why increasing temperature increases solubility of solids and decreases solubility of gases.
- Allow students to investigate the effects of temperature, agitation, and surface area of a solid solute on the rate of dissolution using granulated sugar and sugar cubes in water at different temperatures and with different levels of stirring. Emphasize that the rate at which a solute dissolves is not the same as the amount of solute that dissolves in a given amount of solvent at a specific temperature (solubility).

Lesson 3: Solubility rules

**TEKS standard:** CHEM.11D; 9A

Apply general solubility rules to predict the solubility of products in double replacement reactions.

- To help students become comfortable using solubility tables, start by giving them examples of ionic compounds and asking them to determine if each compound will be soluble in water. Note that substances soluble in water will be designated as aqueous (aq) in chemical equations and those that are not soluble will be designated as solid (s).
- Introduce double replacement reactions with a quick demonstration of a precipitate reaction, such as silver nitrate reacting with sodium chloride. Ask students to write the reactants as their constituent ions dissociated in solution, then have them predict the identities of the products if the ions “trade partners.” Lastly, have students write the reaction equations.
as a balanced chemical equation with appropriate state symbols, based on solubility rules.

- Students may need help remembering how to balance charges when writing formulas for ionic compounds. Emphasize that the subscripts in the reactant formulas do not need to be the same as those in the product formulas. Any inequality in the number of each kind of atom in the reactants and products will be addressed using coefficients to balance the chemical equation as a final step.

Lesson 4: Molarity

TEKS standards: CHEM.11E; 11F

Define molarity as the number of moles of solute per liter of solution.

Calculate solution concentration in units of molarity.

Determine how the molarity of a solution changes as the amount of solute or solvent changes.

- After introducing the concept of molarity, allow students to explore the PhET Concentration and/or PhET Molarity simulations to gain a better understanding of how changes in the amount of solute and solvent affect molarity.

- Before asking students to calculate the molarity of a solution, review the concept of molar mass from Unit 5, and give students practice using molar mass to convert between grams and moles.

- Emphasize that the “M” for molarity represents a compound unit of “moles solute/liters solution.”

- Challenge students to come up with procedures for making an aqueous solution of a specific volume and molarity (e.g., 100 mL of 0.05 M NaCl) both from the solid solute and from a more concentrated stock solution (e.g., 0.1 M NaCl). After reaching consensus about appropriate procedures, allow students to reinforce their understanding by carrying out the processes.

Best practices

COMMON MISCONCEPTIONS AND HOW TO ADDRESS THEM

“Solubility and rate of dissolution are the same.”

Students may confuse solubility (how much of a substance can dissolve in a given volume of solution) with the rate of dissolution (how quickly a substance dissolves). Students may believe that if a substance dissolves quickly, it must also have a high solubility. This misconception is often reinforced when discussing the impacts of temperature on solubility and rate of dissolution, as higher temperature will lead to higher solubility for solids and also will increase rate of dissolution.
How to address this misconception
Emphasize that the extent to which a solute dissolves in a given volume of solvent at a specific temperature depends on the relative strengths of the attractions between the solute and solvent particles. The rate of dissolution depends on the frequency and force of collisions between solute and solvent particles. One way to demonstrate this distinction is by adding drops of food coloring to beakers of water at different temperatures. The color will diffuse much more quickly in the water above room temperature and much more slowly in the water below room temperature, but after sufficient time has passed, the color will have spread out evenly in all of the beakers.

“All ionic compounds dissolve in water.”
Based on their experience with common ionic compounds that readily dissolve in water, such as table salt, students may assume that all ionic compounds are soluble in water. This may lead to confusion when talking about precipitate formation in double replacement reactions.

How to address this misconception
Explain that, while many ionic compounds are soluble in water, some do not dissolve due to strong ionic bonds and lattice structures that cannot be overcome by attractions to polar water molecules. Allow students to observe this by testing the solubility of various ionic compounds, like sodium chloride and potassium bromide (soluble) and calcium carbonate and barium sulfate (insoluble).

CLASSROOM ACTIVITY
Predict and balance precipitate reactions.
In this activity, students will predict and observe precipitate formation in double replacement reactions.

Materials: Each group will need a solubility chart, 0.1 M solutions of sodium chloride, potassium nitrate, silver nitrate, and calcium sulfate, droppers, a small multi-well plate, safety goggles, and gloves. You also may wish to provide a graphic organizer for students to use in recording predictions and data.

☐ Predict the possible products for each of the six different combinations of solutions. Use a solubility table to predict which of those possible products will be an insoluble salt (precipitate).
☐ Test all six possible reactant combinations by adding a few drops of the solutions to different wells in the multi-well plate. Note and record the formation of any precipitates.
☐ Write balanced chemical equations for the reactant combinations that produced precipitates.

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.