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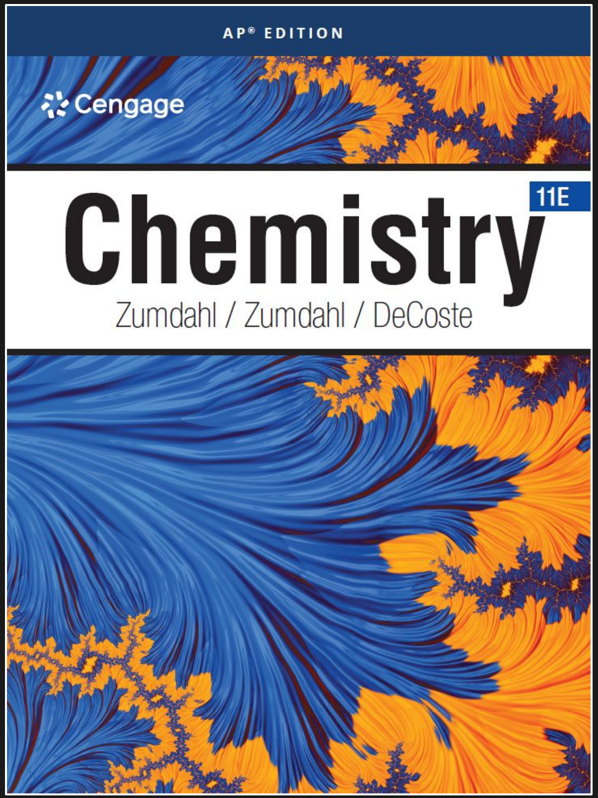
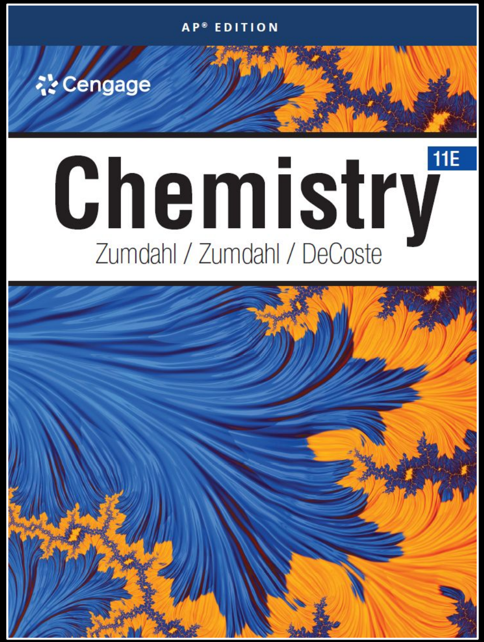


Chemistry, 11th Edition, AP® Edition

Zumdahl/Zumdahl/DeCoste

Cengage OWLv2

- **Build problem-solving skills** with conceptual understanding and critical thinking
- **Ensure all students succeed** with varied problem types and adaptive technology
- **Prepare students for AP® success** with teacher support and student test prep



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Up-to-Date AP® Resources

- Fast Track to a 5: Preparing for the AP® Chemistry Exam
- AP® Teacher Resource Guide and Correlation
- AP® Lab Manual & Teacher's Guide for Lab Manual
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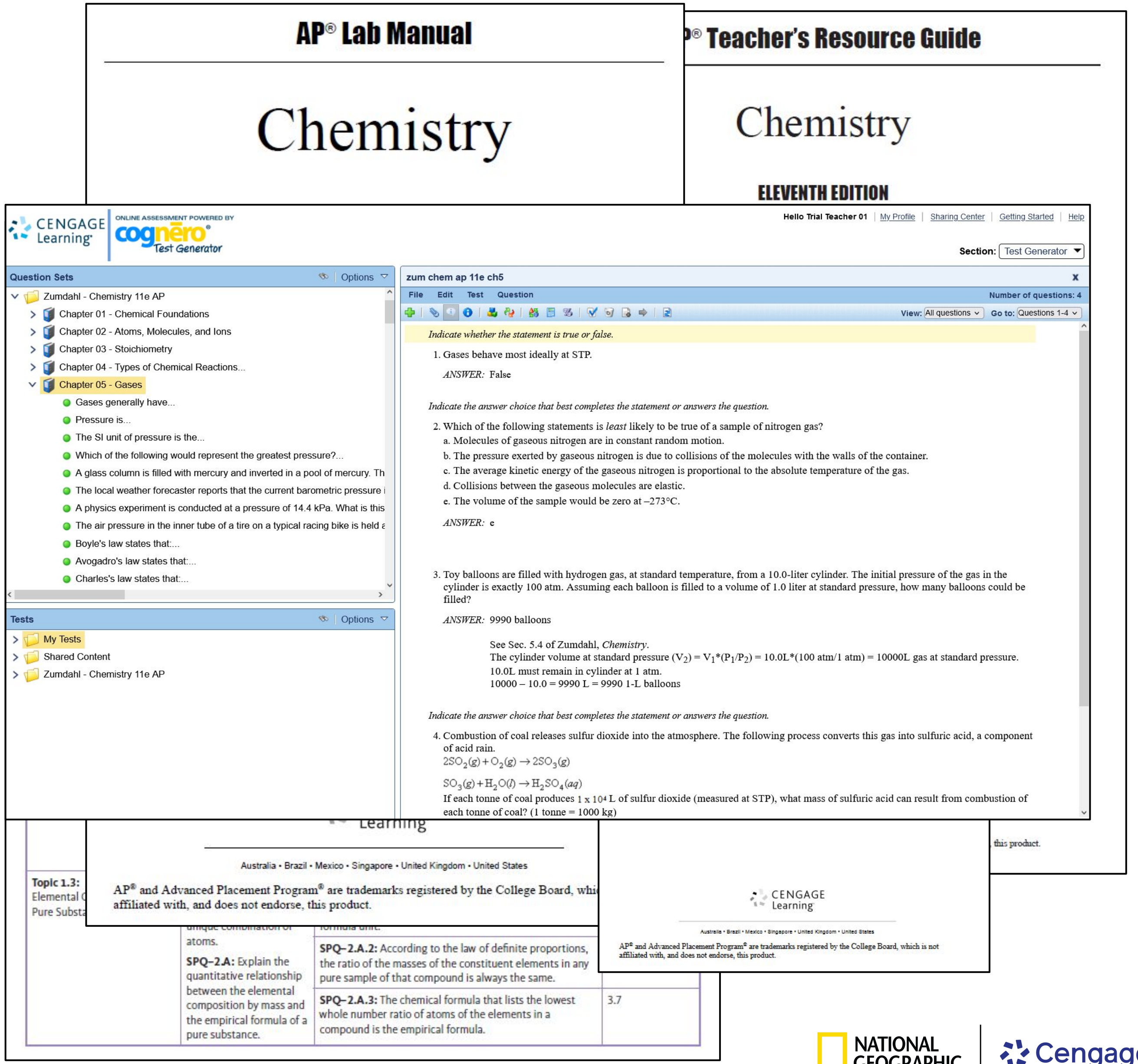

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Interactive Example 5.2

An interactive version of this example with a step-by-step approach is available online.

Boyle's Law I

Sulfur dioxide (SO_2), a gas that plays a central role in the formation of acid rain, is found in the exhaust of automobiles and power plants. Consider a 1.53-L sample of gaseous SO_2 at a pressure of 5.6×10^3 Pa. If the pressure is changed to 1.5×10^4 Pa at a constant temperature, what will be the new volume of the gas?

Solution

Where are we going?

To calculate the new volume of gas

What do we know?

- $P_1 = 5.6 \times 10^3$ Pa
- $P_2 = 1.5 \times 10^4$ Pa
- $V_1 = 1.53$ L
- $V_2 = ?$

What information do we need?

- Boyle's law

$$PV = k$$

Boyle's law also can be written as

$$P_1V_1 = P_2V_2$$

How do we get there?

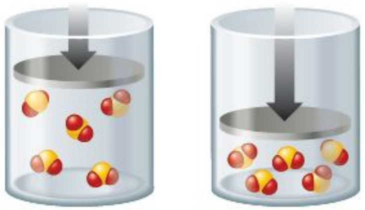
What is Boyle's law (in a form useful with our knowns)?

$$P_1V_1 = P_2V_2$$

What is V_2?

$$V_2 = \frac{P_1V_1}{P_2} = \frac{5.6 \times 10^3 \text{ Pa} \times 1.53 \text{ L}}{1.5 \times 10^4 \text{ Pa}} = 0.57 \text{ L}$$

■ The new volume will be 0.57 L.



▲ As pressure increases, the volume of SO_2 decreases.

Reality Check The new volume (0.57 L) is smaller than the original volume. As pressure increases, the volume should decrease, so our answer is reasonable.

See Exercise 5.49

Where are we going?
What do we know?

What info do we need?
How do we get there?

Reality Check

Problem-Solving Strategy

Solving Acid–Base Problems

- *Think chemistry.* Focus on the solution components and their reactions. It is almost always possible to choose one reaction that is most important.
- *Be systematic.* Acid–base problems require a step-by-step approach.
- *Be flexible.* Although all acid–base problems are similar in many ways, important differences do occur. Treat each problem as a separate force a given problem into matching any you have solved b both the similarities and the differences.
- *Be patient.* The complete solution to a complicated probler immediately in all its detail. Pick the problem apart into its
- *Be confident.* Look within the problem for the solution, an guide you. Assume that you can think it out. Do not rely o tions to problems. In fact, memorizing solutions is usually you tend to try to force a new problem to be the same as o before. *Understand and think; don't just memorize.*

Problem-Solving Strategy

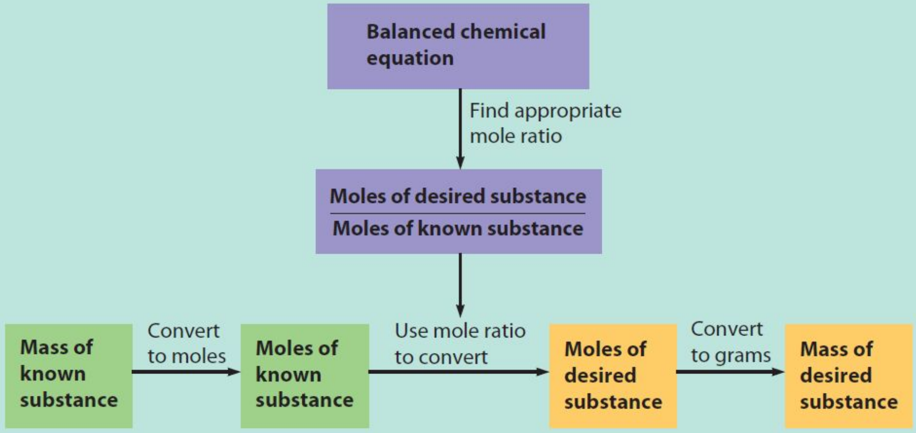
Steps to Apply the VSEPR Model

1. Draw the Lewis structure for the molecule.
2. Count the electron pairs and arrange them in the way that minimizes repulsion (that is, put the pairs as far apart as possible).
3. Determine the positions of the atoms from the *way the electron pairs are shared.*
4. Determine the name of the molecular structure from the *positions of the atoms.*

Problem-Solving Strategy

Calculating Masses of Reactants and Products in Chemical Reactions

1. Balance the equation for the reaction.
2. Convert the known mass of the reactant or product to moles of that substance.
3. Use the balanced equation to set up the appropriate mole ratios.
4. Use the appropriate mole ratios to calculate the number of moles of the desired reactant or product.
5. Convert from moles back to grams if required by the problem.



- Emphasis on Modeling
- Let's Review

Models: An Overview

The framework of chemistry, like that of any science, consists of *models*—attempts to explain how nature operates on the microscopic level based on experiences in the macroscopic world. To understand chemistry, one must understand its models and how they are used. We will use the concept of bonding to reemphasize the important characteristics of models, including their origin, structure, and uses.

Models originate from our observations of the properties of nature. For example, the concept of

8.13 Molecular Structure: The VSEPR Model

The structures of molecules play a very important role in determining their chemical properties. As we will see later, this is particularly important for biological molecules; a slight change in the structure of a large biomolecule can completely destroy its usefulness to a cell or may even change the cell from a normal one to a cancerous one.

LET'S REVIEW Fundamental Properties of Models

- Models are human inventions, always based on an incomplete understanding of how nature works. *A model does not equal reality.*
- Models are often wrong. This property derives from the first property. Models are based on speculation and are always oversimplifications.
- Models tend to become more complicated as they age. As flaws are discovered in our models, we "patch" them and thus add more detail.
- It is very important to understand the assumptions inherent in a particular model before you use it to interpret observations or to make predictions. Simple models usually involve very restrictive assumptions and can be expected to yield only qualitative information. Asking for a sophisticated explanation from a simple model is like expecting to get an accurate mass for a diamond using a bathroom scale.

  For a model to be used effectively, we must understand its strengths and weaknesses and ask only appropriate questions. An illustration of this point is the simple aufbau principle used to account for the electron configurations of the elements. Although this model correctly predicts the configuration for most atoms, chromium and copper, for example, do not agree with the predictions. Detailed studies show that the configurations of chromium and copper result from complex electron interactions that are not taken into account in the simple model. However, this does not mean that we should discard the simple model that is so useful for most atoms. Instead, we must apply it with caution and not expect it to be correct in every case.
- When a model is wrong, we often learn much more than when it is right. If a model makes a wrong prediction, it usually means we do not understand some fundamental characteristics of nature. We often learn by making mistakes. (Try to remember this when you get back your next chemistry test.)

LET'S REVIEW Lewis Structures: Comments About the Octet Rule

- The second-row elements C, N, O, and F should always be assumed to obey the octet rule.
- The second-row elements B and Be often have fewer than eight electrons around them in their compounds. These electron-deficient compounds are very reactive.
- The second-row elements never exceed the octet rule, since their valence orbitals (2*s* and 2*p*) can accommodate only eight electrons.
- Third-row and heavier elements often satisfy the octet rule but can exceed the octet rule by using their empty valence *d* orbitals.
- When writing the Lewis structure for a molecule, satisfy the octet rule for the atoms first. If electrons remain after the octet rule has been satisfied, then place them on the elements having available *d* orbitals (elements in Period 3 or beyond).

Active Learning Questions

These questions are designed to be used by groups of students in class.

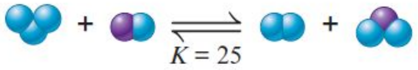
1. Consider an equilibrium mixture of four chemicals (A, B, C, and D, all gases) reacting in a closed flask according to the equation:

$$A(g) + B(g) \rightleftharpoons C(g) + D(g)$$

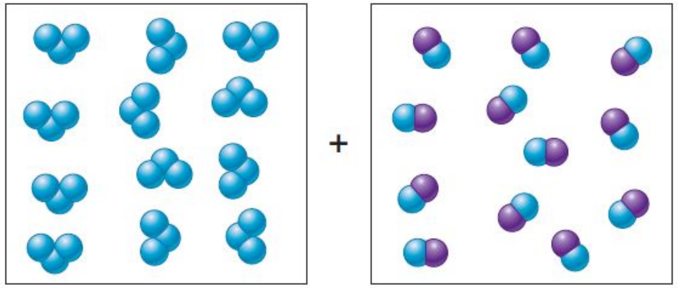
   a. You add more A to the flask. How does the concentration of each chemical compare to its original concentration after equilibrium is reestablished? Justify your answer.

   b. You have the original setup at equilibrium, and you add more D to the flask. How does the concentration of each chemical compare to its original concentration after equilibrium is reestablished? Justify your answer.

2. The boxes shown below represent a set of initial conditions for the reaction:



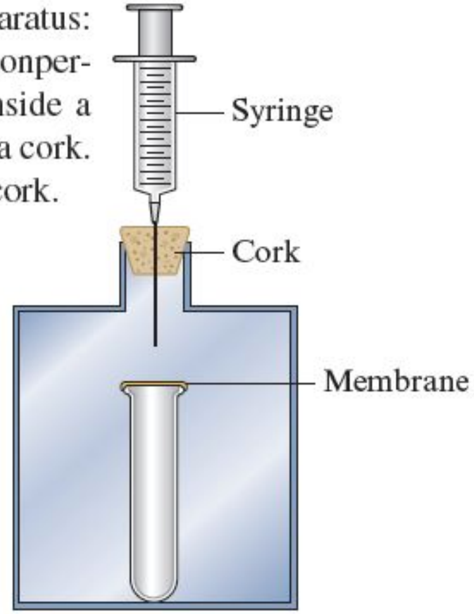
Draw a quantitative molecular picture that shows what this system looks like after the reactants are mixed in one of the boxes and the system reaches equilibrium. Support your answer with calculations.



Active Learning Questions

These questions are designed to be used by groups of students in class.

1. Consider the following apparatus: a test tube covered with a nonpermeable elastic membrane inside a container that is closed with a cork. A syringe goes through the cork.



   a. As you push down on the syringe, how does the membrane covering the test tube change?

   b. You stop pushing the syringe but continue to hold it down. In a few seconds, what happens to the membrane?

2. Figure 5.2 shows a picture of a barometer. Which of the following statements is the best explanation of how this barometer works?

   a. Air pressure outside the tube causes the mercury to move

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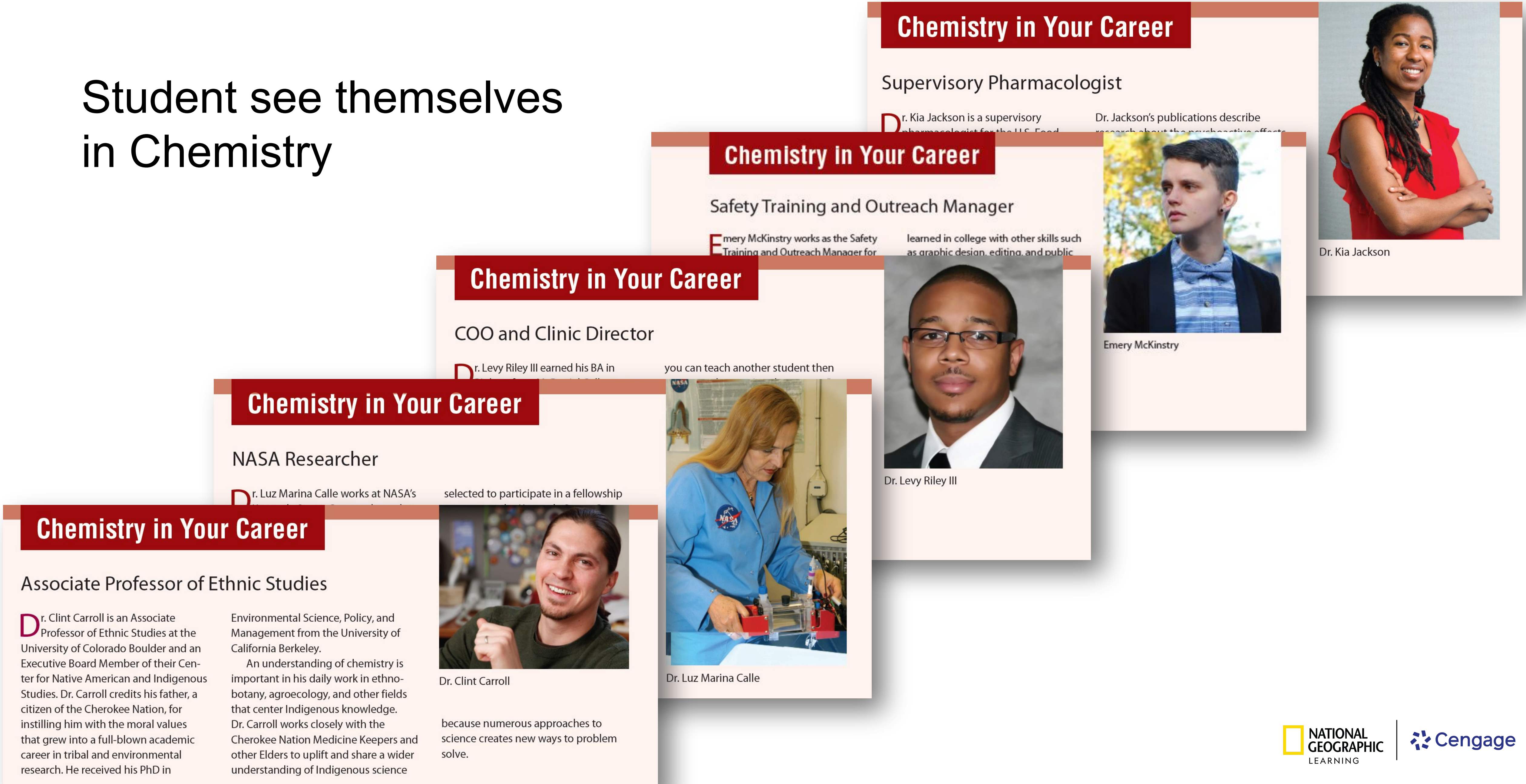
Student see themselves in Chemistry



Chemistry in Your Career

Supervisory Pharmacologist

Dr. Kia Jackson is a supervisory

Dr. Jackson's publications describe

Dr. Kia Jackson

Chemistry in Your Career

Safety Training and Outreach Manager

Emery McKinstry works as the Safety

learned in college with other skills such

Emery McKinstry

Chemistry in Your Career

COO and Clinic Director

Dr. Levy Riley III earned his BA in

you can teach another student then

Dr. Levy Riley III

Chemistry in Your Career

NASA Researcher

Dr. Luz Marina Calle works at NASA's

selected to participate in a fellowship

Dr. Luz Marina Calle

Chemistry in Your Career

Associate Professor of Ethnic Studies

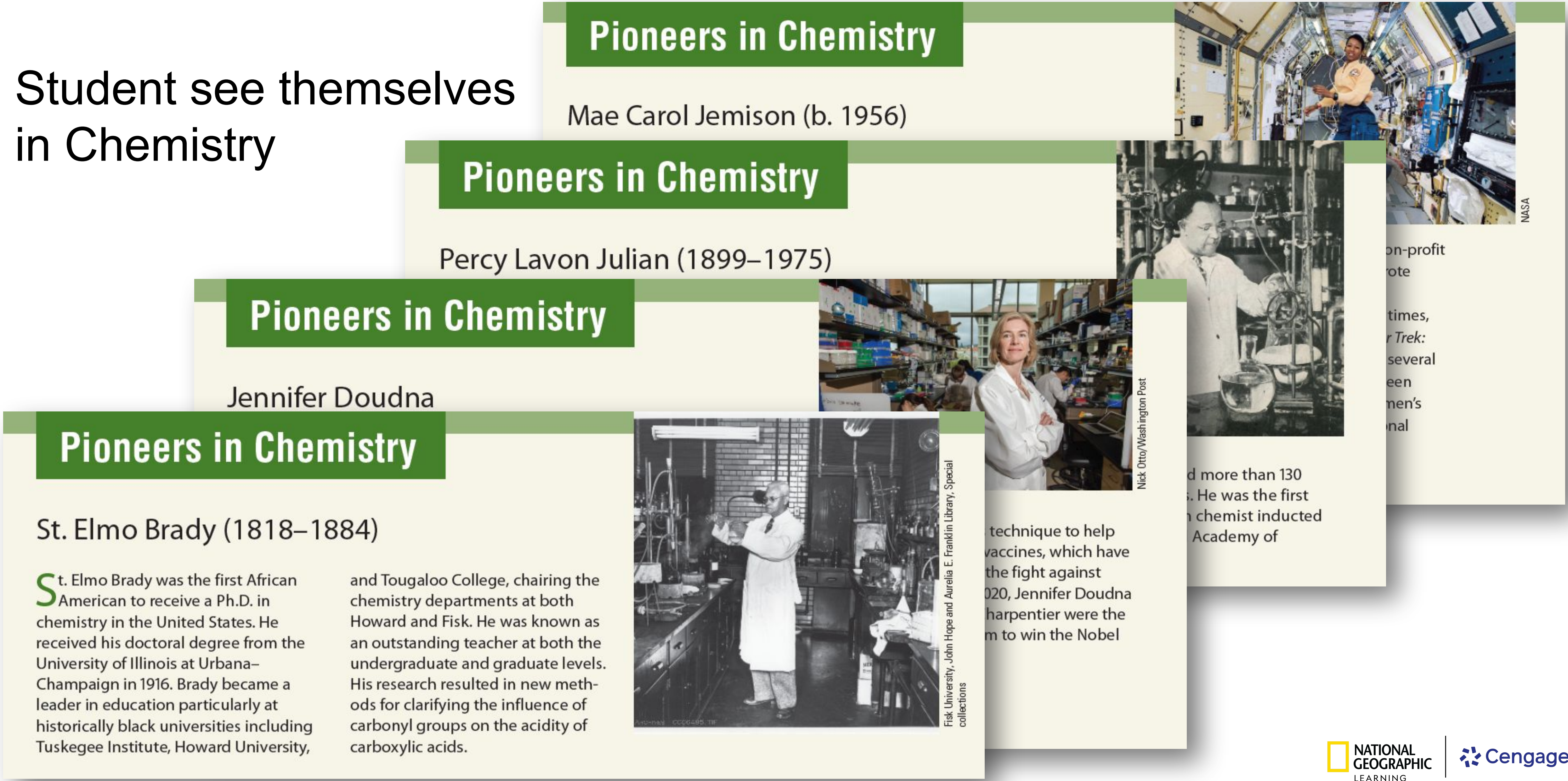
Dr. Clint Carroll is an Associate Professor of Ethnic Studies at the University of Colorado Boulder and an Executive Board Member of their Center for Native American and Indigenous Studies. Dr. Carroll credits his father, a citizen of the Cherokee Nation, for instilling him with the moral values that grew into a full-blown academic career in tribal and environmental research. He received his PhD in Environmental Science, Policy, and Management from the University of California Berkeley.

An understanding of chemistry is important in his daily work in ethnobotany, agroecology, and other fields that center Indigenous knowledge. Dr. Carroll works closely with the Cherokee Nation Medicine Keepers and other Elders to uplift and share a wider understanding of Indigenous science

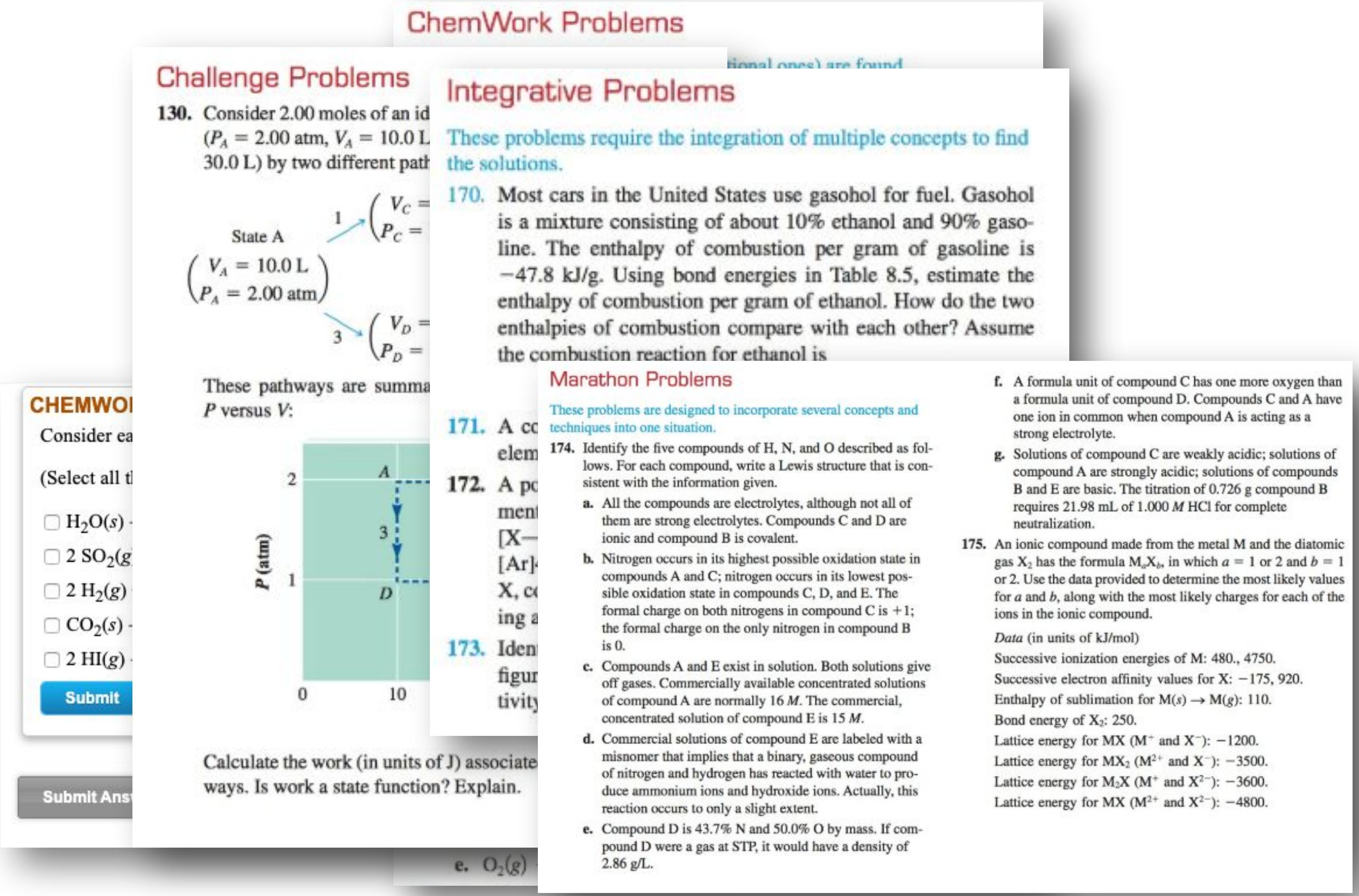
Dr. Clint Carroll

because numerous approaches to science creates new ways to problem solve.

Student see themselves in Chemistry



- ChemWork
- Challenge Problems
- Integrative Problems
- Marathon Problems



Chemical Connections

The Chemistry of Air Bags

The inclusion of air bags in modern automobiles has led to a significant reduction in the number of injuries as a result of car crashes. Air bags are stored in the steering wheel and dashboard of all cars, and many autos now have additional air bags that protect the occupant's knees, head, and shoulders. In fact, some auto manufacturers now include air bags in the seat belts. Also, because deployment of an air bag can severely injure a child, all new cars now have "smart" air bags that deploy with an inflation force that is proportional to the seat occupant's weight.

The term "air bag" is really a misnomer because air is not involved in the inflation process. Rather, an air bag inflates rapidly (in about 30 ms) due to the explosive production of N_2 gas. Originally, sodium azide, which decomposes to produce N_2,

$$2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$$

was used, but it has now been replaced by less toxic materials.

The sensing devices that trigger the air bags must react very rapidly. For example, consider a car hitting a concrete bridge abutment. When this happens, an internal accelerometer sends a message to the control module that a collision possibly is occurring. The microprocessor then analyzes the measured deceleration from several accelerometers and door pressure sensors and decides whether air bag deployment is appropriate. All this happens within 8 to 40 ms of the initial impact.

Because an air bag must provide the appropriate cushioning effect, the bag begins to vent even as it is being filled. In fact, the maximum pressure in the bag is 5 pounds per square inch (psi), even in the middle of a collision event. Air bags represent a case where an explosive chemical reaction saves lives rather than the reverse.

Courtesy, Chrysler

Inflated air bags.

Chemical Connections

Nature Has Hot Plants

The voodoo lily is a beautiful, seductive—and foul-smelling— ... lily features an ... echanism— ... ach nearly ... aked by a ... ch to the plant ... ells terrible! ... odor, this putrid ... ogists for many ... y to generate ... etabolic activ- ... an be as much ... temperature. ... eat, the meta- ... st be close to ... bird! ... this intense ... ant faced with ... e very com- ... here it grows, ... ke a great waste ... this mystery is ... linated mainly ... Thus, the lily ... ixture of chem- ... ing meat, which ... surrounding ... beetles and flies. Then, once the insects enter the pollination chamber, the high temperatures there (as high as 110°F) cause the insects to remain very active to better carry out their pollination duties.

The voodoo lily is only one of many such thermogenic (heat-producing) plants. Another interesting example is the eastern skunk cabbage, which produces enough heat to bloom inside of a snow bank by creating its own ice caves. These plants are of special interest to biologists because they provide opportunities to study metabolic reactions that are quite subtle in "normal" plants. For example, recent studies have shown that salicylic acid, the active form of aspirin, is probably very important in producing the metabolic bursts in thermogenic plants.

Besides studying the dramatic heat effects in thermogenic plants, biologists are also interested in calorimetric studies of regular plants. For example, very precise calorimeters have been designed that can be used to study the heat produced, and thus the metabolic activities, of clumps of cells no larger than a bread crumb. Several scientists have suggested that a single calorimetric measurement taking just a few minutes on a tiny plant might be useful in predicting the growth rate of the mature plant throughout its lifetime. If true, this would provide a very efficient method for selecting the plants most likely to thrive as adults.

Because the study of the heat production by plants is an excellent way to learn about plant metabolism, this continues to be a "hot" area of research.

United States Botanic Garden

The voodoo lily attracts pollinating insects with its foul odor.

Chemical Connections

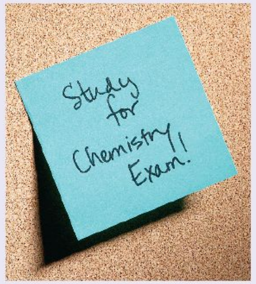
A Note-able Achievement

Post-it Notes, a product of the 3M Corporation, revolutionized casual written communications and personal ...

he spread the word of his discovery to his fellow employees at 3M to see if anyone had an application for it. In addition, over the next several years, development was carried out to improve the adhesive's properties. It was not until 1974 that the idea for Post-it Notes popped up. One Sunday, Art Fry, a chemical engineer for 3M, was singing in his church choir when he became annoyed that the bookmark in his hymnal kept falling out. He thought to himself that it would be nice if the bookmark were sticky enough to stay in place but not so sticky that it couldn't be moved. Luckily, he remembered Silver's glue—and the Post-it Note was born.

For the next three years, Fry worked to overcome the manufacturing obstacles associated with the product. By 1977, enough Post-it Notes were being produced to supply 3M's corporate headquarters, where the employees quickly became addicted to their many uses.

In the years since the introduction of Post-it Notes, 3M has heard some remarkable stories connected to the use of these notes. For example, a Post-it Note was applied to the nose of a corporate jet, where it was intended



to be read by the plane's Las Vegas ground crew. Someone forgot to remove it, however. The note was still on the nose of the plane when it landed in Minneapolis, having survived a takeoff, a landing, and speeds of 500 miles per hour at temperatures as low as −56°F. Stories describe how a Post-it Note on the front door of a home survived the 140-mile-per-hour winds of Hurricane Hugo and how a foreign official accepted Post-it Notes in lieu of cash when a small bribe was needed to cut through bureaucratic hassles.

Post-it Notes have definitely changed the way we communicate and remember things.

705

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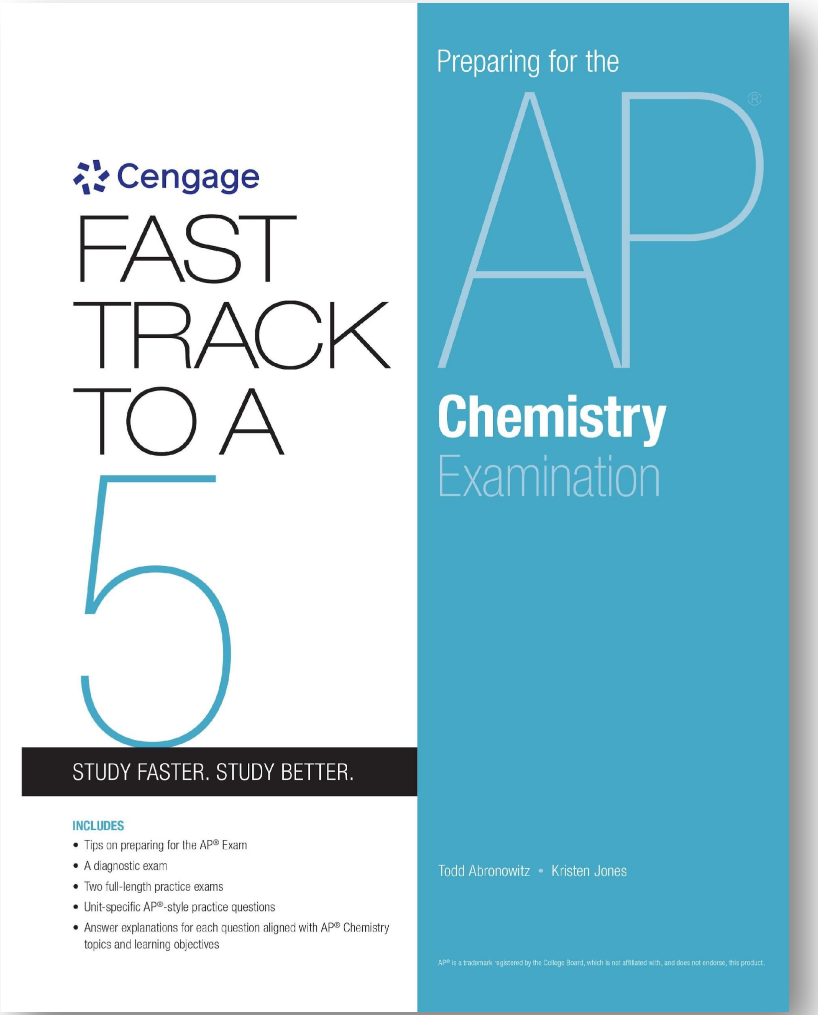

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AP® Multiple-Choice Review Questions

1. Magnesium reacts with hydrochloric acid to produce hydrogen gas. An experiment was set up to determine the rate of production of the hydrogen gas by measuring its change in volume over the first 60 seconds of the reaction. Magnesium ribbon was cut into squares of 0.5 cm^2 and 1.0 cm^2. The volume of hydrochloric acid solution and the total mass of magnesium were held constant in each trial. Which set of conditions would produce the highest rate of production of hydrogen gas?
   (A) 1 *M* HCl, 0.5-cm^2 pieces of magnesium
   (B) 1 *M* HCl, 1.0-cm^2 pieces of magnesium
   (C) 3 *M* HCl, 1.0-cm^2 pieces of magnesium
   (D) 3 *M* HCl, 0.5-cm^2 pieces of magnesium

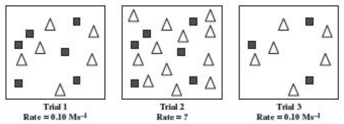
Trial #	$[A]_0$ (mol L^{-1})	$[B]_0$ (mol L^{-1})	Rate of formation of C (mol L^{-1} s^{-1})
1	1.2×10^{-2}	1.2×10^{-2}	1.8×10^{-4}
2	1.2×10^{-2}	2.4×10^{-2}	7.2×10^{-4}
3	2.4×10^{-2}	1.2×10^{-2}	3.6×10^{-4}

2. Based on the experimental data given in the table above and the reaction $A + 2B \rightarrow C$, what is the complete rate law?
   (A) Rate = k[A]
   (B) Rate = k[A][B]
   (C) Rate = $k[A]^2[B]$
   (D) Rate = $k[A][B]^2$

Questions 3 and 4 use the following information:

Shown below are the initial concentrations of reactants for three different trials of the reaction $3X + Y \rightarrow Z$.

X = △ Y = ■



3. If the reaction is determined to be first order in X, what will be the rate for trial 2?
   (A) 0.10 Ms^{-1}, because the rate constant of a specific reaction is constant at a given temperature.
   (B) 0.10 Ms^{-1}, because Y is now a limiting reagent and adding more X can't increase the rate.
   (C) 0.20 Ms^{-1}, because doubling the concentration of X will double the rate.
   (D) 0.60 Ms^{-1} because the coefficient of X in the balanced equation is 3 and the concentration of X is doubled, so $3 \times 2 = 6$.

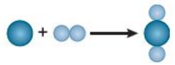
4. What is the order of reaction with respect to Y?
   (A) 0
   (B) ½
   (C) 1
   (D) 2

5. What is the value of k for a first-order reaction with a half-life of 23.1 s?
   (A) 16.0 s^{-1}
   (B) 16.0 s
   (C) 0.0300 s^{-1}
   (D) 0.0300 s

6. In a chemical reaction that has first-order kinetics, which is true at constant temperature?
   (A) Half-life and k are both constant.
   (B) Neither half-life nor k is constant.
   (C) Half-life is constant, but k changes.
   (D) Half-life changes, but k is constant.

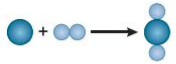
7. The reaction $Q + R_2 \rightarrow R_2Q$ is found to be first order in R_2 and zero order in Q. Which of these mechanisms is most likely for this reaction?
   (A) $Q + R_2 \rightarrow R_2Q$ (slow)
   (B) $2Q \rightarrow Q_2$ (slow)
   $Q_2 + R_2 \rightarrow R_2Q + Q$ (fast)
   (C) $Q + Z \rightarrow QZ$ (slow)
   $QZ + R \rightarrow QR + Z$ (fast)
   $QR + R \rightarrow R_2Q$ (fast)
   (D) $R_2 \rightarrow 2R$ (slow)
   $R + Q \rightarrow RQ$ (fast)
   $RQ + R \rightarrow R_2Q$ (fast)

8. Which of the following is the most likely sequence and orientation of the collisions of the reactants that would result in the following overall reaction?

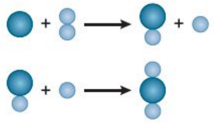


Step or steps

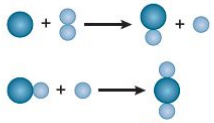
(A)



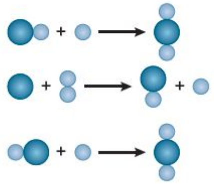
(B)



(C)



(D)



9. Which is a correct explanation for why the rate of a chemical reaction increases with increasing temperature?
   (A) The reaction becomes more exothermic.
   (B) The enthalpy change of the reaction increases.
   (C) The activation energy of the reaction decreases.
   (D) More of the colliding particles have the activation energy.

10. How would the net-ionic equation written for a catalyzed reaction differ from the net-ionic equation written for the same reaction without a catalyst?
   (A) The net-ionic equation would be different because an additional reactant is needed.
   (B) The net-ionic equation would be different because the catalyst should be shown on both the reactant and product side.
   (C) The net-ionic equation would be the same because the catalyst is a spectator ion and would be left out of a net ionic equation.
   (D) The net-ionic equation would be the same because a catalyst is neither a reactant nor a product.

11. The following reaction was determined to be elementary:

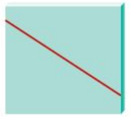
$$A + B \rightarrow C$$

What is the overall order of the reaction and the units of the rate constant, k?
   (A) first order, $time^{-1}$
   (B) second order, $time^{-1}$
   (C) second order, L/(mol × time)
   (D) cannot determine the order and units of k without experimental data

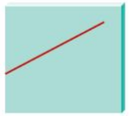
12. The concentration of reactant versus time data were measured and plotted for a reaction with the rate law: Rate = $k[A]^2$. Which graph would result?

(A)

(B)



(C)



(D)

13. Many organic reactions, such as the two-step conversion of 2-butene to 1-butene as shown in the mechanism below, proceed at higher rates in the presence of an acid. What is the role of the H_3O^+ in this mechanism?

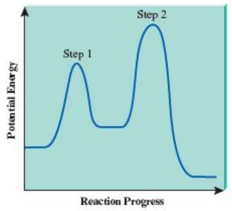
$$CH_3CH{=}CHCH_3 + H_3O^+ \rightleftharpoons CH_3CH_2\overset{+}{C}HCH_3 + H_2O$$
$$CH_3CH_2\overset{+}{C}HCH_3 + H_2O \rightleftharpoons CH_3CH_2CH{=}CH_2 + H_3O^+$$

   (A) reactant
   (B) catalyst
   (C) inhibitor
   (D) intermediate

14. A proposed mechanism for the reaction $W_2 + X_2 \rightarrow 2WX$ is:
   Step 1: $W_2 \rightleftharpoons 2W$ (fast)
   Step 2: $W + X_2 \rightarrow WX + X$ (slow)
   Step 3: $X + W \rightarrow WX$ (fast)

   What rate law is supported by this mechanism?
   (A) rate = $k[W_2]$
   (B) rate = $k[W][X_2]$
   (C) rate = $k[W_2][X_2]$
   (D) rate = $k[W_2]^{1/2}[X_2]$

15. An energy profile for a reaction is shown below.



Which statement correctly describes this process?
   (A) Step 1 is the rate-determining step, and the overall process is exothermic.
   (B) Step 2 is the rate-determining step, and the overall process is exothermic.
   (C) Step 1 is the rate-determining step, and the overall process is endothermic.
   (D) Step 2 is the rate-determining step, and the overall process is endothermic.

AP® Free-Response Questions

Question Format: Short

There are four common types of solids: ionic, network covalent, metallic, and molecular.

(a) For each of these types of solids, identify the forces between the particles in the blue shaded areas of the table.

	Particles	Binding Forces
Ionic	Cations and anions	
Metallic	Cations and electrons	
Covalent network	Atoms	
Molecular	Molecules	

(b) A student conducts an experiment to determine the type of bonding found in various solids. The laboratory results are shown below. For each of solids one through four below, identify its type based on the laboratory data.

Experimental Test	Solid One	Solid Two	Solid Three	Solid Four
Conductivity of solid	No	No	No	Yes
Melting point	High	Low	High	High
Hardness	High	Soft	High	High
Dissolve in water	Yes	Yes	No	No
Conduct electricity in solution	Yes	No	Not tested	Not tested

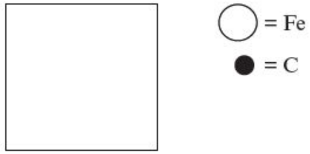
Question Format: Long

Three common ores of iron are FeO, Fe_2O_3, and Fe_3O_4. Iron ores are often reduced to elemental iron by heating in the presence of carbon monoxide. These iron ores are all brittle and do not conduct electricity in their solid form.

(a) Identify the oxidation number of the iron atoms in each of the three ores.
(b) Choose one of the iron ores and write a balanced chemical equation to show its reduction reaction with carbon monoxide.
(c) Considering the types of bonding involved, how and why do the properties of the ores differ from those of pure iron?

Carbon steel is an interstitial alloy of iron with a small amount of carbon which has greater strength and density than pure iron but maintains the metallic properties of iron.

(d) Is the combination of iron with carbon to form steel a chemical or physical change? Explain your answer.
(e) In a box like the one shown here, draw a representation of the structure of this alloy. Use 10–20 iron atoms and 4–6 carbon atoms in your structure.



(f) As the percent carbon increases in steel, the ductility of the steel decreases. Explain why this might occur.

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What's in the *Chemistry* Textbook That Will Help Your Preparation

As you work your way through the textbook, there are some features that will assist you in getting the most out of it:

- Make use of the Conceptual Problem-Solving Method introduced in Chapter 3 in which you break the problem down into three parts: (1) Where are we going? (2) How do we get there? and (3) Reality Check.
- Make certain you carefully study the Sample Exercises with solutions in each chapter. These will often guide you in developing your problem-solving skills and tailoring them for the type(s) of problems covered in that chapter.
- Read the For Review section that highlights the material presented in the chapter as a way to double-check your understandi
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Strategies for Answering the Multiple-Choice Questions

- **Read the question carefully.** Pressured for time, many students make the mistake of reading the questions too quickly or merely skimming them. By reading a question carefully, you may already have some idea about the correct answer. You can then look for it in the responses. Look for key terms in the stem of the question.
- **Eliminate any answer you know is wrong.** You can write on the multiple-choice questions in the test book. As you read through the responses, draw a line through any answer you know is wrong.
- **With a little bit of content knowledge, the majority of multiple-choice answers can be narrowed down to two choices.** Many questions have the answers set up in the format of two sets [(A) and (B) as a set followed by (C) and (D)], and they follow the pattern: answer – reason. Choices A and B have the same answer and different reasons, and Choices C and D have the opposite answer and the same reasons. So if you know the answer or the reason, you can narrow your choice to two possible answers.

Preparing For The AP® Chemistry Examination

Whether you are taking an AP® course at your school or you are working on AP® independently, the stage is set for a great intellectual experience.

But sometime in January, when the examination begins to loom on a very real horizon, Advanced Placement® can seem downright intimidating. If you are nervous about taking the exam, that is only normal.

The best way to deal with an AP® examination is to master it, not let it master you. If you can think of these examinations as a way to show off how much chemistry you know, you have a leg up. Attitude and confidence *do* help. If you are not one of those students, there is still a great deal you can do to sideline your anxiety.

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- Read the For Review section that highlights the material presented in the chapter as a way to double-check your understanding before you proceed.
- Answer the Review Questions at the end of each chapter as a measure of your understanding. This will give you instant feedback as to how much of the chapter you may need to study again.
- Complete the multiple-choice AP® assessment items at the end of each chapter as well as those in the AP® Practice Exam at the end of the text. They are a good representation of the multiple-choice questions on the exam and are tied to the AP® Learning Objectives that are the basis for all questions on the exam.
- Carefully work out the free-response AP® assessment items at the end of each chapter as well as those in the AP® Practice Exam at the end of the text. They will give you a good idea of the length and variety of questions involved and are good examples of how these in-depth questions combine ideas from different areas of chemistry.
- Working in small groups, answer the Active Learning Questions at the end of each chapter. This is an excellent opportunity to gauge your level of understanding and to receive assistance from your classmates.
- Do as many Challenge and Marathon Problems as you can. These problems are intended to incorporate many different concepts into the solution. Problems like this are particularly good practice for the free-response portion of the AP® exam.

Being successful in chemistry usually involves careful reading of the textbook and working as many different types of problems as possible. The successful student is not one who memorizes a bunch of facts but one who is able to synthesize and analyze the problem. Chemistry is like a lot of subjects in that an understanding of new material often depends on an understanding of previous concepts.

Before the Examination

You should be signed up for MyAP® Classroom. This is where you will sign up for taking the exam. Many schools take care of the paperwork and handle the fees for their AP® students, but check with your teacher or the AP® coordinator to make sure that you are on the list. This is especially important if you have a documented disability and need test accommodations. If you are studying independently, call AP® Services at the College Board for the name of the local coordinator, who will help you through the registration process.

The evening before the exam is not a great time for cramming. If you like, look over class notes or drift through your textbook, concentrating on the broad outlines, not the small details, of the course.

The evening before the exam *is* a great time to get your things organized for the next day. Sharpen a fistful of no. 2 pencils with good erasers; bring a scientific calculator with fresh batteries. Certain types of calculators are not allowed, so be sure to verify with your teacher or the College Board that your model is acceptable. For example, you cannot use a calculator with a typewriter-style keyboard. Also, there are common items such as cell phones and other personal electronics that you must be sure to leave at home. Check with your teacher if you have questions about what items are and aren't allowed in the testing room. You will need a simple watch for tracking your time (without Internet connections—no smartwatches) and be certain to turn off the alarm if it has one. Bring a piece of fruit or a power bar and a bottle of water for the break. Make sure you have your Social Security number and whatever photo identification and admission ticket are required. Then relax. And get a good night's sleep.

On the day of the examination, plan to arrive early. It is wise not to skip breakfast—studies show that students who eat a hot breakfast before testing earn higher grades. Be

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careful not to drink a lot of liquids, necessitating a trip to the bathroom during the exam. Breakfast will give you the energy to power through the exam—and more. You will spend some time waiting while everyone is seated in the right room for the right exam before the test has even begun. With a short break between Sections I and II, the AP® Chemistry exam lasts for more than three and a half hours. So be prepared for a long morning. You do not want to be distracted by a growling stomach or hunger pangs.

Be sure to wear comfortable clothes, taking along a sweater in case the heating or air conditioning is erratic. Be sure, too, to wear clothes you like—everyone performs better when they think they look better—and by all means wear your lucky socks!

Now roll up your sleeves and get ready to earn a 5!

Taking The AP® Chemistry Examination

The AP® Chemistry curriculum emphasizes the importance of inquiry and reasoning in science, and requires depth of understanding more than memorization of facts. On the exam, you may be asked to perform a range of tasks, such as interpreting lab data or making predictions based on your knowledge of chemical principles.

Some content in your text will not be tested in the examination, although your teacher may choose to include that material in your course.

The AP® Chemistry exam will consist of two sections. The sections are described below.

Section I: The main features of the multiple-choice section are given in the following table.

	Format
Number of questions	60
Time to complete	90 minutes
Number of choices	4
Calculator	Yes
Periodic table and formula chart	Yes
Weighting	50%

The questions will often refer to "real world" situations and will contain several sets of questions. Some sample questions are given in the "Types of Multiple-Choice Questions" section that follows here.

Section II: After Section I is collected, you will have a short break. The main features of the free-response section are given in the following table.

	Format
Number of questions	7 The questions are made up of three long questions [with between four and eight main parts, designated with letters, (a), (b), etc., and often with subparts designated (i), (ii), etc.] and four short questions (with up to four parts/subparts).
Point value	This section is worth up to 46 points. Each long question is worth 10 points. Each short question is worth 4 points.
Time to complete	105 minutes
Calculator	Yes
Periodic table and formula chart	Yes
Weighting	50%

In this section, you may be asked to:

- Design an experiment to test a hypothesis, given a specific set of laboratory equipment.
- Interpret and draw conclusions from data.
- Use models to describe physical phenomena.
- Follow a logical or analytical pathway to solve a problem.

When answering these questions, you will need to be able to explain what is happening at the atomic or molecular level and you may be asked to draw diagrams of the particle level to demonstrate that you can make models of systems and understand concepts.

The focus on laboratory work as a tool of scientific inquiry means that you will need to practice writing laboratory procedures, understand the correct use of laboratory equipment to gather data, and incorporate safe practices.

Plan of Attack for the Multiple-Choice Section

Each question in the multiple-choice section is worth one point—whether it takes you 5 minutes or 15 seconds, it counts the same. Your goal is to first answer 45 questions and feel confident that you have those 45 questions correct. That will generally give you a 3 on the exam just from the multiple-choice questions. Here are some ideas for attacking this section of the exam.

- Go through the test completely once, answering the questions that are easy for you to answer.
- When you run into a problem that you know you can do, but that will take you several minutes, put a star (★) next to the problem number and move on.
- If you are a slow test taker, especially when mathematical calculations are involved, mark these questions with a star in the margin and go back after finishing the rest of the questions.

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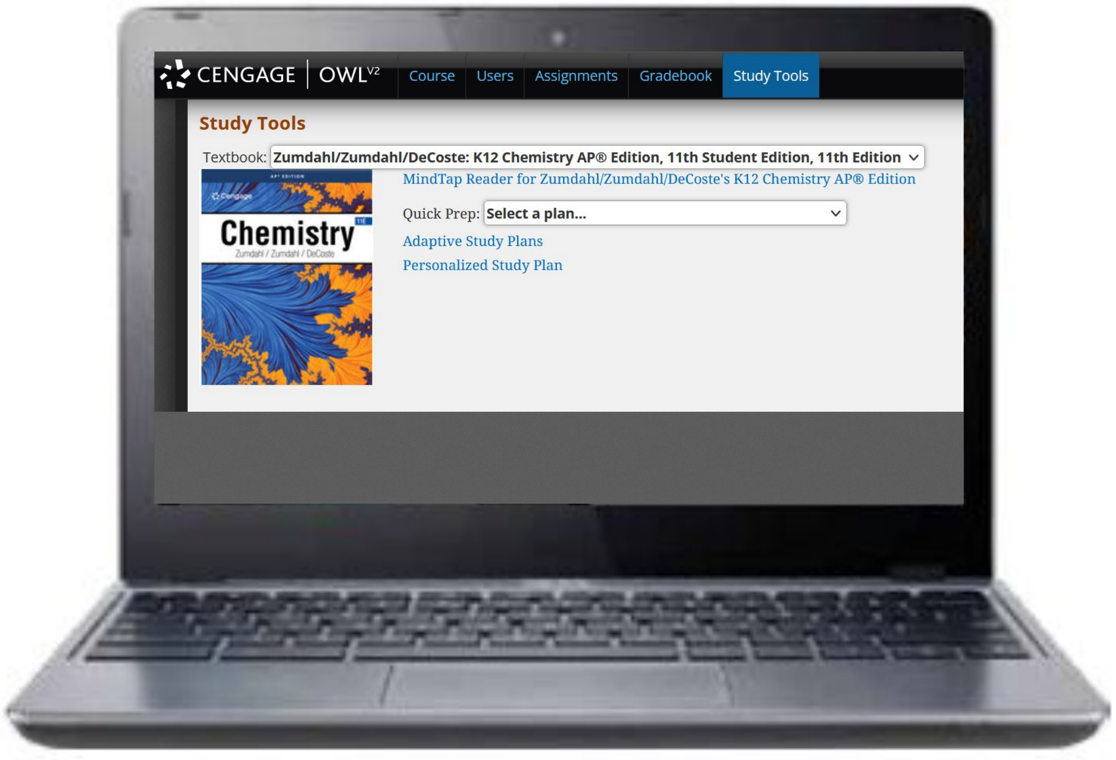
RESOURCES

- **Student Book**
- **OWLv2 Digital Solution**
- **Instructor Companion Site**
  - PowerPoint Lecture Presentations
  - Inquiry-Based Learning Guide
  - Student Solution Manual
- **AP Resources**
  - Fast Track to a 5 Test Prep
  - AP Teacher's Resource Guide
  - AP Lab Manual (with Teacher's Guide)

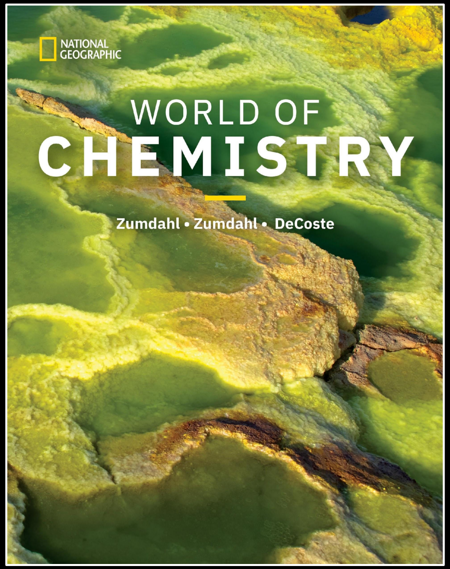
LET'S GO LIVE!

Teacher View

- Adaptive Study Plan in OWLv2
- ChemDoodle in OWLv2
- Mastery problem sets
- Dynamically created homework to eliminate cheating/Googling answers

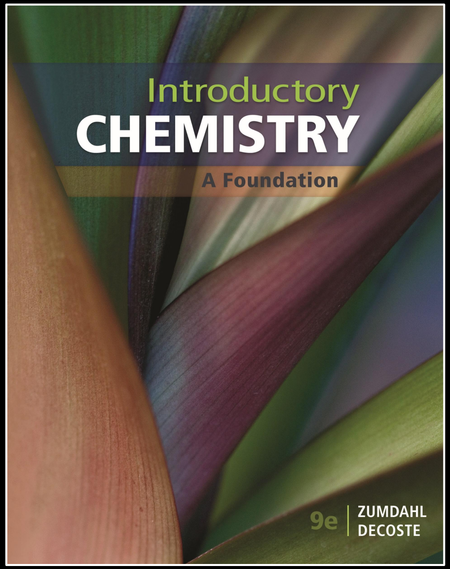


Cengage OWLv2



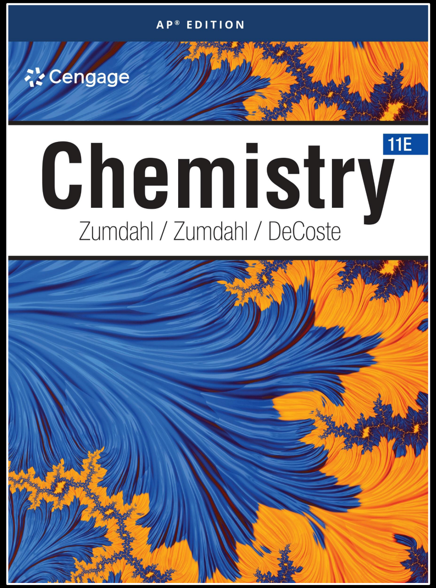
On-level

World of Chemistry



Honors

Introductory Chemistry:
A Foundation



AP

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