The Advanced Placement Program®

AP Chemistry: An Overview of Course Revisions

CollegeBoard
inspiring minds™

Why We Are Changing AP® Chemistry and Other AP® Science Courses?

To Respond to changes recommended by the National Research Council and the National Science Foundation

To Reduce the emphasis on broad content coverage and focus on depth of understanding

To Emphasize scientific inquiry and reasoning

To Support teachers in their efforts to foster students' deep understanding of science

Goals of the *AP® Chemistry* Revision

Working Directly With Experts From Colleges and High Schools, the College Board Has Created a Revised AP® Chemistry Course that:

- Reduces and defines the breadth of the required content so that teachers have more time to develop students' deep conceptual understanding and to engage in inquiry-based lab experiences
- Provides learning objectives to guide teachers in their development of instructional strategies for teaching key concepts in ways that are meaningful to their own strengths and preferences and to their students' interests
- Makes knowing what will be on the AP® Chemistry Exam completely transparent

Goals of the *AP® Chemistry* Revision

(continued)

Working Directly With Experts From Colleges and High Schools, the College Board Has Created a Revised AP® Chemistry Course That:

- Meets colleges' expectations for what students should learn and do in an introductory college-level chemistry course.
- Supports the awarding of college credit/placement for qualifying student exam performance

The New Course Was Created in Collaboration With College Faculty & AP® Chemistry Teachers

Jim Spencer
Franklin and Marshall College

Sean Decatur
Mt. Holyoke College

John Gelder
Oklahoma State University

Carlos Gutierrez
California State University

Angelica Stacy
University of California, Berkeley

Thomas Holme
University of Wisconsin

Jennifer Lewis
University of South Florida

Carlos Ayala
Sonoma State University

Mark Reckase
Michigan State University

Becki Williams
Richland College

John Hutchinson
Rice University

David Yaron
Carnegie Mellon University

Melanie Cooper
Clemson University

Rick Moog
Franklin and Marshall College

Donald Wink
University of Illinois, Chicago

Brian Coppola
University of Michigan

Jim Pellegrino
University of Illinois, Chicago

Jeanne Pemberton
University of Arizona

John Hnatow
Emmaus High School

Reen Gibb
Westwood High School

Annis Hapkiewicz
Okemos High School

Jennifer Kennison
North Country Union High School

Dana Krejcarek
Kohler High School

Luisa Marcos
Union Hill High School

Trinna McKay
Dunwoody High School

Carol Brown
St. Mary's Hall High School

Jamie Benigna
The Roeper School

What Has Changed?

Current Course

- Teachers have only a general topic outline in the AP® Course Description and released exams to determine what to teach
- Teachers feel the need to march through all textbook chapters associated with the general topics because no specific guidance was given

What Has Changed?

Revised Course

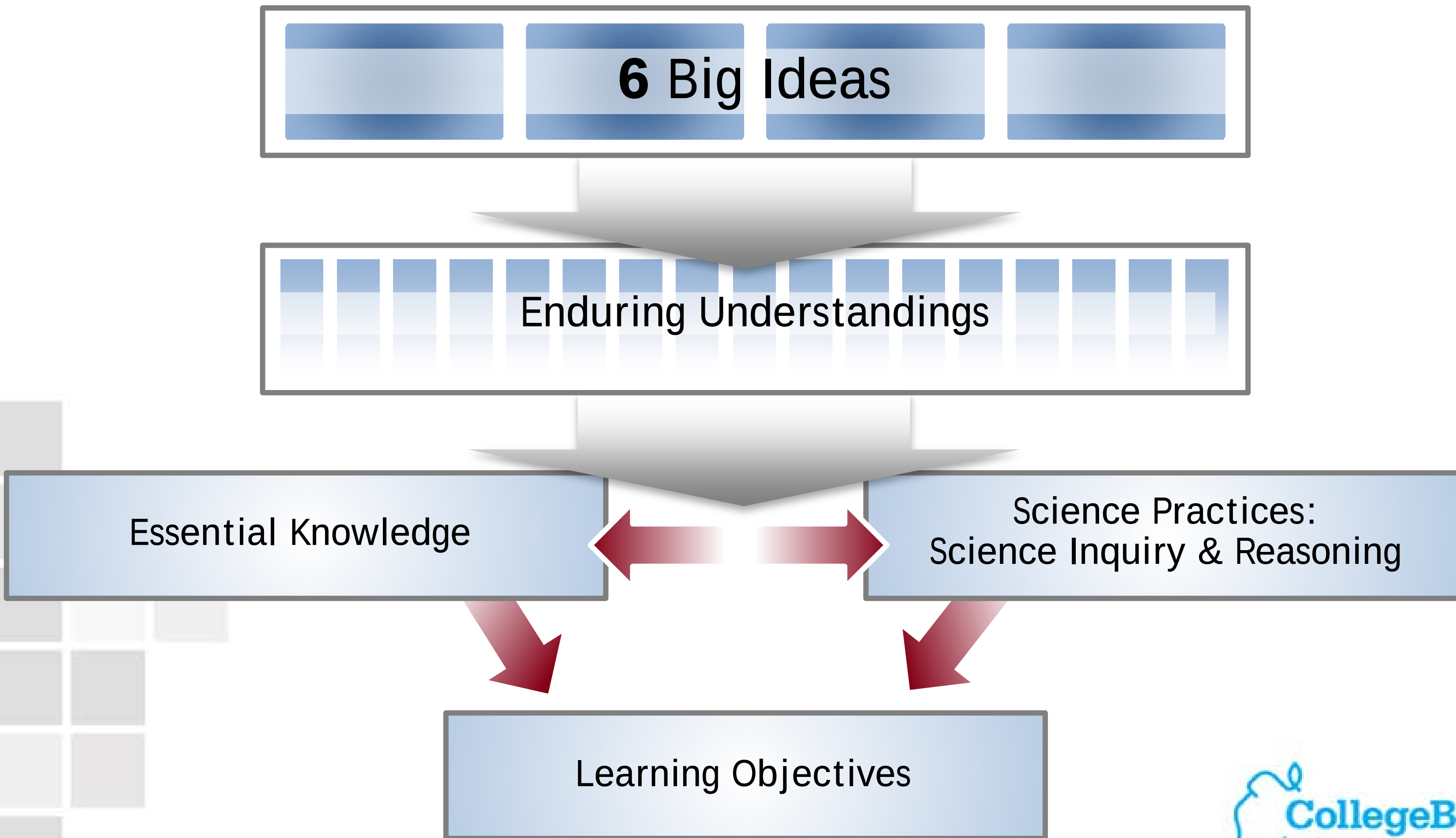
- A detailed curriculum framework defines and articulates the scope of the course. Clear guidance is provided on what concepts, content and skills should be taught and will be assessed on the AP® Exam

- "Exclusion Statements" — clear indications in curriculum as to what teachers don't have to teach

- New emphasis on integrating inquiry and reasoning throughout the course and on critical thinking skills

CollegeBoard inspiring minds™

The New Curriculum Framework Supports and Furthers Conceptual Knowledge



AP® Chemistry Curriculum Is Framed Around Six Big Ideas

BIG IDEA 1	The chemical elements are fundamental building materials of matter, and all matter can be understood in terms of arrangements of atoms. These atoms retain their identity in chemical reactions.
BIG IDEA 2	Chemical and physical properties of materials can be explained by the structure and the arrangement of atoms, ions, or molecules and the forces between them.
BIG IDEA 3	Changes in matter involve the rearrangement and/or reorganization of atoms and/or the transfer of electrons.
BIG IDEA 4	Rates of chemical reactions are determined by details of the molecular collisions.

Curriculum Framework: Big Ideas

BIG IDEA 5

The laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter.

BIG IDEA 6

Any bond or intermolecular attraction that can be formed can be broken. These two processes are in a dynamic competition, sensitive to initial conditions and external perturbations.

EXAMPLE

Building Enduring Understandings

For each of the six Big Ideas, there is a set of Enduring Understandings which incorporates core concepts that students should retain from these learning experiences

BIG IDEA 2

Chemical and physical properties of materials can be explained by the structure and the arrangement of atoms, ions, or molecules and the forces between them.

- Enduring Understanding 2.A: Matter can be described by its physical properties. The physical properties of a substance generally depend on the spacing between the particles (atoms, molecules, ions) that make up the substance and the forces of attraction among them.
- Enduring Understanding 2.B: Forces of attraction between particles (including the noble gases and also different parts of some large molecules) are important in determining many macroscopic properties of a substance, including how the observable physical state changes with temperature.
- Enduring Understanding 2.C: The strong electrostatic forces of attraction holding atoms together in a unit are called chemical bonds.
- Enduring Understanding 2.D: The type of bonding in the solid state can be deduced from the properties of the solid state.

EXAMPLE

Building Essential Knowledge

Each Enduring Understanding is followed by statements of the Essential Knowledge students must develop in the course

BIG IDEA 2

Chemical and physical properties of materials can be explained by the structure and the arrangement of atoms, ions, or molecules and the forces between them.

- **Enduring Understanding 2.B**: Forces of attraction between particles (including the noble gases and also different parts of some large molecules) are important in determining many macroscopic properties of a substance, including how the observable physical state changes with temperature.
  - Essential Knowledge 2.B.1: London dispersion forces are attractive forces present between all atoms and molecules. London dispersion forces are often the strongest net intermolecular force between large molecules.
    - a. A temporary, instantaneous dipole may be created by an uneven distribution of electrons around the nucleu s (nuclei) of an atom (molecule).
    - b. London dispersion forces arise due to the coulombic interaction of the temporary dipole with the electron distribution in neighboring atoms and molecules.
    - c. Dispersion forces increase with contact area between molecules and with increasing polarizability of the molecules. The polarizability of a molecule increases with the number of electrons in the molecule, and is enhanced by the presence of pi bonding.

Emphasis on Science Practices

The science practices enable students to establish lines of evidence and use them to develop and refine testable explanations and predictions of natural phenomena

SCIENCE PRACTICES

- **1.0** The student can use representations and models to communicate scientific phenomena and solve scientific problems.
- **2.0** The student can use mathematics appropriately.
- **3.0** The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.
- **4.0** Student can plan and implement data collection strategies in relation to a particular scientific question.
- **5.0** The student can perform data analysis and evaluation of evidence.
- **6.0** The student can work with scientific explanations and theories.
- **7.0** The student can connect and relate knowledge across various scales, concepts, and representations in and across domains.

EXAMPLE

Clearly Articulated Science Practices Underpin the Entire Course

SCIENCE PRACTICES **5.0**

The student can perform data analysis and evaluation of evidence.

- **5.1** The student can analyze data to identify patterns or relationships.
- **5.2** The student can refine observations and measurements based on data analysis.
- **5.3** The student can evaluate the evidence provided by data sets in relation to a particular scientific question.

CollegeBoard inspiring minds™

An Example of Integrating the Concept, Content and the Science Practice

Content

Essential Knowledge 3.C.3
Electrochemistry shows the interconversion between chemical and electrical energy in galvanic and electrolytic cells.

Science + Practice

Science Practice 5.1
The student can analyze data to identify patterns or relationships.

Learning Objective

Learning Objective (3.C.3 & 5.1)
The student can analyze data regarding galvanic or electrolytic cells to identify properties of the underlying redox reactions.

The Purpose of Learning Objectives in the Curriculum Framework

Learning Objectives are provided to

- Guide teachers' development of instructional strategies
- Strengthen students' understanding of the skills needed to be successful in the course
- Illuminate a pathway of learning which integrates content with context and provides an opportunity for students to transfer knowledge and skills to non-routine problem solving.

CollegeBoard
inspiring minds™

Learning Objectives Addressing Student-Directed Laboratory, Field, and In-Class Learning Experiences

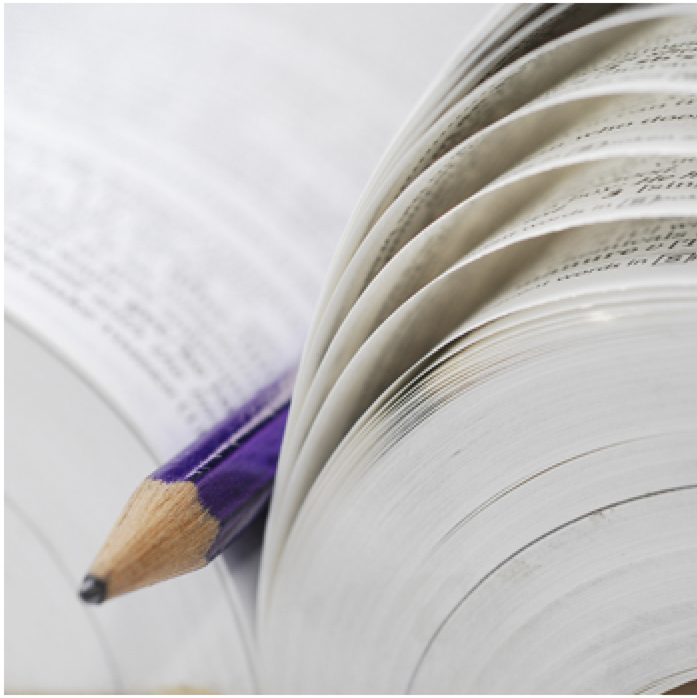
- The Learning Objectives will guide teachers in choosing which physical laboratory and student-directed activities in order to build students' proficiency with:
  - deriving knowledge and concepts through data analysis
  - designing and refining experimental procedures
  - working with and developing models based on experimental data (self-collected or already established).
- In addition, experience in the physical laboratory component of the redesigned course will continue to be on par with that of a college chemistry course.
- Moreover, the revised exam will assess students' proficiency with the learning objectives addressed by performing the labs and participating in student-directed investigations.

CollegeBoard inspiring minds™

How the Curriculum Framework Helps you Focus and Constrain Breadth

- **Exclusion Statements** define the type and level of content that is excluded from the AP® Chemistry course and exam or represents knowledge students should have acquired prior to participating in this course.

- **Concept and Content Connections** are indicated with the addition of *[connects to]* at the end of the learning objective. Drawing connections between the essential knowledge components is an important aspect of learning chemistry. For this reason, the Learning Objectives may occur at the level of Big Ideas, Enduring Understandings, or Essential Knowledge.



CollegeBoard inspiring minds™

Breadth Reduction in the Curriculum Framework

1.C.1 **Many properties of atoms exhibit periodic trends that are reflective of the periodicity of electronic structure.**

a. The structure of the Periodic Table is a consequence of the pattern of electron configurations and the presence of shells (and subshells) of electrons in atoms.
b. Ignoring the few exceptions, the electron configuration for an atom can be deduced from the element's position in the Periodic Table.

LO 1.9 The student is able to predict and/or justify trends in atomic properties based on location on the periodic table and/or the shell model. **[***See* **SP 6.4]**

LO 1.10 Students can justify with evidence the arrangement of the periodic table and can apply periodic properties to chemical reactivity. [*See* **SP 6.1]**

EXCLUSION STATEMENT

✘ *Memorization of exceptions to the Aufbau principle is beyond the scope of this course and the AP® exam.*

Reducing Breadth of the AP® Chemistry Course:

Student memorization of ubiquitous factoids out of the context of application is no longer a part of the AP® Chemistry curriculum framework.

Instead, the AP® Chemistry framework focuses on increasing students' depth of understanding of enduring principles for the purpose of application of skills to solve non- routine problems.

Concepts no longer tested in revised course:
Memorization of the exceptions in electron configuration of atoms and solubility rules
Assigning quantum numbers
Writing nuclear reactions
Deriving the Henderson-Hasselbalch equation
Computations of solubility as a function of pH
Memorizing specific types of crystal structures
Using standard enthalpies of formation to calculate the overall energy change in a reaction
Lewis Acid-Base Theory

CollegeBoard inspiring minds™

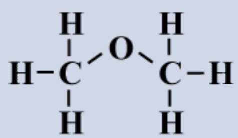
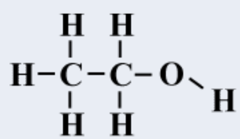
AP® Chemistry New Exam Design: Assessing the Learning Objectives

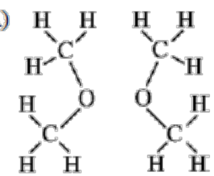
<table>
<tr><th>Section Information:
Item Types & Weight</th><th>Question Types and Distribution</th><th colspan="2">Timing</th></tr>
<tr><td>Multiple Choice-representing all Big ideas (50% of exam weight)</td><td>60 multiple choice</td><td colspan="2">90 min</td></tr>
<tr><td colspan="4">Five Minutes Required Reading Time in Advance of the Free-Response Section</td></tr>
<tr><td rowspan="3">Free Response-representing all Big Ideas (50% of exam weight)</td><td>3 multipart questions</td><td>20-25 min per question</td><td rowspan="3">90 min</td></tr>
<tr><td>4 single-part questions</td><td>3-10 min per question</td></tr>
<tr><td colspan="2">Types of questions to be distributed among the single and multi-part questions:
• Lab 1: Experimental design
• Lab 2: Patterns/analysis/selection of authentic data/observations
• Representations 1: Translation between representations
• Representations 2: Atomic/molecular view to explain observation
• Quantitative: Following a logical/analytical pathway</td></tr>
</table>

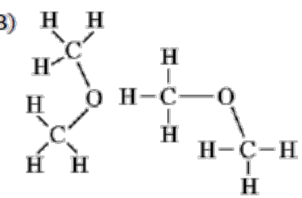
EXAMPLE

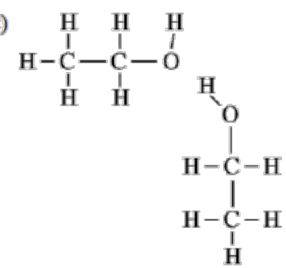
Particulate View

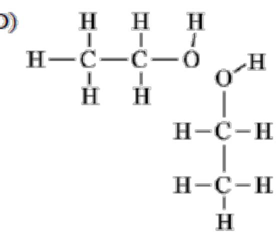
Multiple Choice

Compound	Molecular Structure	Normal Boiling Point
Dimethyl ether		250 K
Ethanol		351 K

(A)


(B)


(C)


(D)


The structures and normal boiling points of dimethyl ether and ethanol are given in the table above. Which of the following diagrams best helps to explain the difference in boiling point of the two compounds?

Real-World Application

Multiple Choice

Of the following metals, which would be the most appropriate choice for lining the inside of a railroad tank car used for transporting 1.0 *M* hydrochloric acid?

	Metal	Half-Reaction	E^o
a)	Al	$Al^{3+} + 3\ e^- \rightarrow Al$	–1.66 V
b)	Cd	$Cd^{2+} + 2\ e^- \rightarrow Cd$	–0.40 V
c)	Cu	$Cu^{2+} + 2\ e^- \rightarrow Cu$	0.34 V
d)	Zn	$Zn^{2+} + 2\ e^- \rightarrow Zn$	–0.76 V

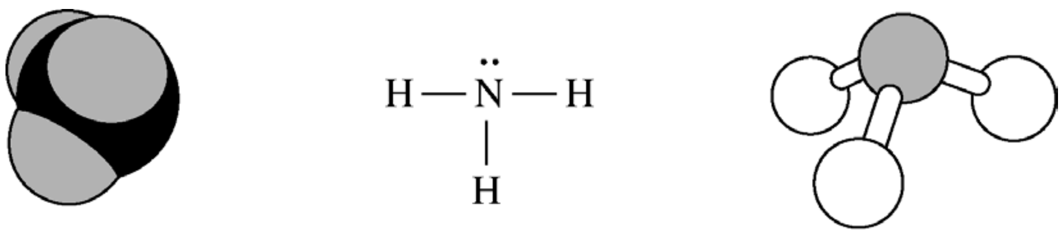
Free-Response Section of the Exam

- Types of Free-Response Questions:
  - Lab I: Engaging in experimental design
  - Lab II: Selection and analysis of authentic data/observations to identify patterns or explain phenomena
  - Representations I: Translation between representations
  - Representations II: Creating or analyzing atomic/molecular views to explain observations
  - Quantitative: Following a logical/analytical pathway to solve a problem

Short Part/Representation II

Free Response

Shown below are three models that can be used to represent a molecule of ammonia.



1 2 3

Select one of the models. Indicate clearly which model you selected, and describe:

a) one aspect of the ammonia molecule that the model represents accurately/well, and …

b) one aspect of the ammonia molecule that the model does not represent accurately/well.

Multipart/Lab I (Experimental Design)

Free Response

Design an experiment to collect data that supports the claim that a 1.0 *M* NaCl solution is a ***homogeneous*** mixture. Describe the steps, the data you would collect, and how the data support the claim. Laboratory equipment for your experiment should be taken from the list below. (You may not need all of the equipment.)

50-mL beakers	Drying oven
Volumetric pipets (5 mL, 10 mL and 25 mL)	Hot plate
Stirring rod	Balance
100 mL of 1.0 M NaCl(aq)	Fume hood

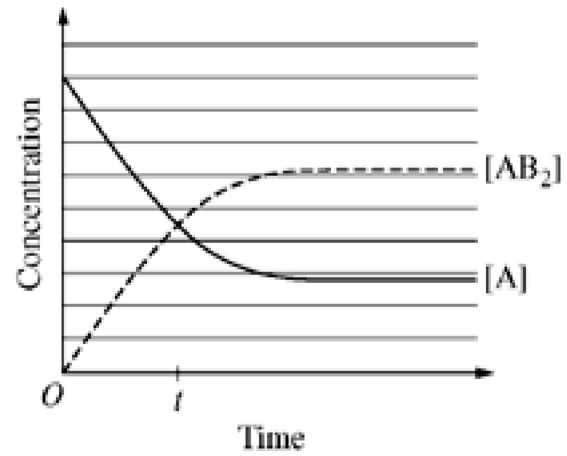
EXAMPLE

Multipart/Quantitative

Free Response

$A + 2B \leftrightarrows AB_2$

The following diagram shows the change in concentration of the reactant A and product AB_2 for the reaction represented by the equation above. The species A, B, and AB_2 are gases.



a) Indicate on the diagram where the reaction reaches equilibrium.

b) At time *t*, what is the relationship between *Q* (the reaction quotient), and *K* (the equilibrium constant)?

c) At equilibrium, what is the relationship between the rate of decomposition of AB_2 and the rate of consumption of B for the reaction?

d) For the same reaction at a different temperature, 6 moles of A and 9 moles of B are combined in a rigid 1.0 L container, and the system reaches equilibrium. If there are 3 moles of AB_2 present at equilibrium, what is the value of *K* for the reaction at this temperature?

Preparing for the New Course

- Visit Advances in AP®
  advancesinap.collegeboard.org
  - Updates on all AP® course and exam revisions
  - Answers to any questions that you may have

Thank You!

On behalf of the Advanced Placement Program®, thank you very much for your time to learn more about the upcoming changes to AP® Chemistry.

We look forward to partnering with you as you build students' success in chemistry in your classroom and for the future!