Pearson Education

Test Prep Series

For

AP® CHEMISTRY

EDWARD L. WATERMAN

To accompany:

CHEMISTRY: THE CENTRAL SCIENCE
THIRTEENTH EDITION
AP® EDITION

BROWN LeMAY BURSTEN MURPHY
WOODWARD STOLTZFUS

PEARSON

Boston Columbus Indianapolis New York San Francisco Upper Saddle River
Amsterdam Cape Town Dubai London Madrid Milan Munich Paris Montréal Toronto
Delhi Mexico City São Paulo Sydney Hong Kong Seoul Singapore Taipei Tokyo

Editor in Chief: Adam Jaworski
Senior Acquisitions Editor: Terry Haugen
Acquisitions Editor: Chris Hess Ph.D.
Senior Marketing Manager: Jonathan Cottrell
Associate Team Lead, Program Management, Chemistry and Geosciences: Jessica Moro
Team Lead, Project Management, Chemistry and Geosciences: Gina M. Cheselka
Project Manager: Erin Kneuer
Editorial Production Service: PreMediaGlobal
Operations Specialist: Christy Hall
Supplement Cover Designer: Seventeenth Street Studios

Cover Image Credit: Graphene by Dr. Jannik C. Meyer of the University of Ulm, Germany Credits and acknowledgments borrowed from other sources and reproduced, with permission, in this textbook appear on the appropriate page within the text.

Library of Congress Cataloging-in-Publication Data

1 2 3 4 5 6 7 8 9 10—EB—15 14 13 12 11

PEARSON

PearsonSchool.com/Advanced

ISBN-10: 0-13-359802-0
ISBN-13: 978-0-13-359802-5

About the Author

Ed Waterman is a writer, a public speaker, and a retired high school chemistry teacher. He taught chemistry and Advanced Placement Chemistry from 1976 to 2007 at Rocky Mountain High School in Fort Collins, Colorado. From 1971 to 1976, he taught general, organic, and analytical chemistry at Colorado State University.

Mr. Waterman is the author or coauthor of five high school chemistry textbooks. His publications include *Pearson Chemistry*, a popular text for first-year high school chemistry, and *Small-Scale Chemistry Laboratory*, also published by Pearson. In addition, he has published numerous professional papers in peer-reviewed journals including the *Journal of the American Chemical Society*, the *Journal of Organic Chemistry*, and the *Journal of Chemical Education*.

Mr. Waterman holds a Bachelor of Science degree in chemistry from Montana State University and a Master of Science degree in synthetic organic chemistry from Colorado State University. In his free time, he enjoys exploring wild places by hiking, kayaking, and cross-country skiing in the Rocky Mountains and on the Colorado Plateau. He also presents photo-essay lectures about the natural history of molecules, engaging the general public in an appreciation for and an understanding of chemistry.

This book is dedicated to all the hard-working teachers of Advanced Placement Chemistry across the United States and Canada. Your important contributions to chemical education, your dedication to your students, and the significant and beneficial effects you continue to build into the fabric of our society can never be measured, only acknowledged. The students who take up the challenge of Advanced Placement Chemistry are indeed fortunate to have you as a teacher, a coach, and a mentor. I hope that you will continue to find only the greatest satisfaction in helping young people reach for their dreams. Please accept my heartfelt thanks for your efforts and my best wishes for your continued success.

Ed Waterman
Rocky Mountain High School (retired)
Fort Collins, Colorado

Table of Contents

To the Teacher

The *Pearson Education Test Prep Workbook for AP® Chemistry* is designed especially for student success on the Advanced Placement® Chemistry examination. Thoroughly revised and redesigned, this *Test Prep Workbook for AP® Chemistry* correlates to the new *AP® Chemistry Curriculum Framework* (CF) launched in the 2013–2014 school year.

The new *Pearson Education AP® Test Prep Series: Chemistry*:

- Is designed to accompany the 13th edition of Pearson's *Chemistry: The Central Science* by Brown & LeMay
- Concisely summarizes all the important content in the 6 Big Ideas and the 117 Learning Objectives of the new CF
- Clearly explains and provides questions and problems for new content including photoelectron spectroscopy (PES), mass spectrometry, chromatography, UV–VIS spectrophotometry, and Coulomb's law
- Outlines the structure and content of the new AP® Chemistry Exam
- Offers many useful test-taking strategies for students to practice while they study AP chemistry throughout the year
- Includes hundreds of revised multiple choice and free response practice questions, formatted for the new curriculum and aligned to the 117 Learning Objectives, with complete answers and explanations
- Contains many new and revised Your Turn conceptual questions designed to allow students to connect to content, analyze data, and write clear, concise, focused answers in the way that the new AP® Exam requires
- Identifies many common misconceptions and corrects them with clear and concise explanations

- Includes two complete practice tests with thorough answers and explanations, and a unique scoring guide
- Gives students control of the required content and provides them with ample practice to master the material
- Is suitable for use with any AP chemistry text

Many AP chemistry teachers use this book as the primary source to guide them through the new Curriculum Framework and direct them to the important course topics. Teachers find that students command a significant competitive advantage when taking the AP® Chemistry Exam. When teaching AP chemistry, I found that if each of my students used a personal copy to review, their scores increased significantly. With this book, my role changed from chemistry teacher to chemistry coach. It made a challenging job much easier.

To order, use ISBN: 0-13-359802-0 / 978-0-13-359802-5 at Pearsonschool.com or call 1-800-848-9500.

For more information, please contact your Pearson General Account Manager at Pearsonschool.com.

Best wishes for continued success teaching Advanced Placement® Chemistry and good luck to your students on the upcoming exam.

Ed Waterman
Rocky Mountain High School (Retired)
Fort Collins, Colorado

Introduction

Advanced Placement® Chemistry is more than just a course in first-year college general chemistry. Whether or not your AP® Exam score qualifies you for college credit, there are many advantages of taking Advanced Placement® Chemistry. It is an opportunity to prepare for college by challenging yourself with rigorous college-level work while you are still in high school. Your classmates will be some of the best and brightest students at your school and the peer group you study with will enhance your own abilities as a student. Likely your teacher will be among the best at your school and he or she will have invaluable knowledge and insight. Besides acquiring advanced knowledge of chemistry, the science central to all other scientific disciplines, you will develop your skills in analytical thinking, abstract reasoning, problem solving, and effective communication. You will enhance your study skills, both as an individual and within a group, and you will increase your own ability to learn how to learn. A second year of chemistry in high school will give you a decided competitive advantage over your future college classmates who have not taken Advanced Placement® classes in high school. Advanced Placement® Chemistry can serve as a measure of "survival insurance" for that upcoming pivotal year in life: the first year of college.

Advanced Placement® Chemistry and College Credit

By taking the Advanced Placement® Exam, you could qualify for college chemistry credit. Many public colleges and universities grant credit for scores of 3 or higher. More competitive public institutions and many private colleges have higher standards. Generally, the higher your score, the more potential credit you receive. Because all colleges set their own standards, be sure to check the website of any college you are considering attending or call or write the office of admissions for details about how that institution grants credit for Advanced Placement® scores. To expedite the process, go to the College Board website at http://collegesearch.collegeboard.com/apcreditpolicy/index.jsp/, type in the name of the college or university you are interested in, and the site will take you directly to that institution's credit policy for Advanced Placement®.

How to Use This Book?

This book is designed to help you score well on the Advanced Placement® Examination in Chemistry. Each numbered topic is a chapter summary and correlates directly with the chapter of the same number in *Chemistry: The Central Science* published by Pearson. Because many other college chemistry texts are suitable for Advanced Placement® Chemistry, you can use this book even if you do not have access to *Chemistry: The Central Science*.

During the first half of your Advanced Placement® course, focus on the course work your teacher emphasizes and what is in your text. Especially focus on solving the challenging quantitative problems and writing short, concise, directed answers to qualitative questions based on chemical principles. **Be sure you are able to interpret data tables, graphs, and charts and atomic and molecular representations of matter.**

Halfway through the course, in about December or January, as you continue with your class work, begin reviewing about two topics a week using this book. Read each topic summary and answer each Your Turn question as you come across it. The Your Turn questions, while not always at the AP level, are designed to focus your attention on one specific point and provide you with practice in writing clear, concise, directed responses, much as the AP® Exam requires. At the end of each topic summary, you will find multiple choice and free response questions. Answer these questions and check your answers with the detailed answers at the end of each topic. If you do not know how to do a problem or if you get a question wrong, go back and review the topic summary and/or the corresponding chapter in *Chemistry: The Central Science*. Be sure to read the explanation for each question, even if you answered it correctly the first time.

In February, ask your teacher about the procedure for ordering and paying for the Advanced Placement® Exam. This needs to be done well before the exam and different high schools have different procedures.

In February and March, continue working through your review, two topics per week.

Finally, about a month before the exam, work through Practice Test 1 within the suggested time limits, check your answers, and calculate your score. This will give you a measure of your progress in mastering the twenty topics. Go back and review the material you have not yet mastered. Be sure to read the explanations for each question. When you are ready to try again, work Practice Test 2. These two practice tests are designed to simulate the Advanced Placement® Exam, each emphasizing different topics. Be sure to download and work some of the past Advanced Placement® Exams posted on the College Board website at http://www.collegeboard.com/student/testing/ap/chemistry/samp.html?chem.

A week before the exam, read through the equations list that you will use on exam day. Do not memorize what is on the equation sheet because you will have it to refer to during the exam. The point is to know what is on the equation sheet and where to find specific information as you work the exam. Look at each item and ask yourself, "What would I use this for?"

Also, skim through the answers you wrote for the Your Turn questions and the multiple choice and free response questions at the end of each topic. Gather your thoughts and prepare to go into the Advanced Placement® Exam, recognizing that you will not know everything, but confident that you will score high because you have worked hard and prepared well.

What to Do on Exam Day?

- Be sure to get a couple of good nights' sleep before the exam.
- Eat a healthy breakfast the day of the exam.
- Bring a calculator with fresh batteries and a spare calculator, just in case. Know how to use the spare calculator!
- Bring at least six sharpened number two pencils with good erasers.
- Bring a water bottle and a nutritious energy snack to consume during the short break.
- Bring a photo ID and an admission ticket, if required.
- Bring a watch to keep track of the time. Be sure to turn off the alarm, if it has one.
- Arrive at the examination site at least 20 minutes early. If the door closes before you arrive, you will not be allowed to take the exam.
- Be prepared for poor working conditions—some rooms provide only arm-chair desks with little room to work. Sometimes right-handed students will be assigned left-handed desks and vice versa!
- Dress in layers. Some rooms are unnecessarily air-conditioned; others are not air-conditioned at all.
- Leave backpacks and personal belongings at home. All you need is a photo ID, two reliable calculators, a sharp pencil, and a mind to match.

Calculator Use

You can use a calculator only for Section II, the free response section. Most silent types of scientific, programmable, and graphing calculators are permitted, if they do not have typewriter-style (QWERTY) keyboards. You need not clear your calculator memory. You may not share a calculator with another student during the exam. You may not use a calculator on Section I, the multiple choice section of the exam.

The Content and Nature of the AP® Exam in Chemistry

The Advanced Placement® Examination in Chemistry is a comprehensive evaluation of knowledge of all areas of general chemistry at the first-year college level. It consists of two equally weighted 90-minute sessions. Section I contains 60 multiple choice questions worth 50% of the total score. Three long and four short free response questions, counting for another 50%, compose Section II. Use of calculators is allowed only on the free response section. A periodic table and a list of pertinent equations and constants are available for the entire exam. Please refer to the end of this section for a periodic table and a list of equations and constants similar to what will be provided for use on the exam.

For more information and published examples of recent exams, please refer to the College Board's Advanced Placement website at http://apcentral.collegeboard.com/. Also two complete practice exams, similar to the Advanced Placement® Examination in Chemistry, are included at the end of this book. You will also find a scoring guide and complete answers and explanations. *Be cautious about studying older exams or guidebooks because the format and content of the exam changed in 2014.*

Tips for Writing the Multiple Choice Section

- Make a note of the start time at the top of the question page. Add 90 minutes to define the stop time. Remember, you have 90 minutes to answer 60 questions. Pace yourself accordingly.
- Read each question carefully. Do not assume you know what it asks without a careful reading.
- Pay close attention to words such as EXCEPT and DOES NOT and look for the response that does not belong.
- When simple math is involved (remember, no calculators!), pay attention to factors of 2 and 3.
- Eliminate answers you know are wrong. There is no penalty for guessing, so it is to your advantage to answer every question.
- Never assume a question has two valid answers unless there is an "all of these" response. Closely analyze the two responses you think might be correct. How do they differ? Does the question include words such as EXCEPT or DOES NOT?
- Keep track of answers by marking the correct answer on both the test questions and the answer sheet to expedite a self-check later.
- Periodically check that you are marking the answer sheet correctly and check your watch to monitor your progress.
- Give yourself time to answer all the questions you know how to answer. The last question is worth the same number of points as the first question. Do not spend too much time on the harder or more time-consuming questions at the expense of not having enough time to answer the ones you can.

- As you read through and answer the questions, consider using the "answer/plus/minus" method. It works like this:

Answer: Answer any question you immediately know the answer to.

Plus: Mark a "+" (on the exam, not on the answer, sheet!) next to any question you know how to answer but feel will take too much time to work. Be sure to skip the corresponding number on the answer sheet. You can come back to the questions marked "+" when you have finished reading all the questions and answering as many as you know.

Minus: Mark a "–" next to any question you really do not understand. After you have finished the other questions, including the ones you have marked with a "+," use the time remaining to reconsider the "–" questions. Often a second reading will give you fresh insights.

- Be sure to answer every question. There is no penalty for guessing. The more difficult questions tend to be toward the end of the exam, so do not panic if, after your best effort, you do not finish.

- Finally, if there is still time, skim through all the questions, comparing the answers you have marked on the exam with those you have marked on the answer sheet. Correct any obvious errors, both in accurately marking the answer sheet and in choosing the best answer. Be sure to make any changes to the answer sheet by first erasing cleanly and leaving no stray marks.

- When your watch shows that there are 10 minutes left, make a decision about how you can finish the question(s) that will score the most points. Be sure to stop when time is called.

Tips for Writing the Free Response Section

- Make a note of the start time at the top of the question page. Add 90 minutes to define the stop time. Remember, you have 90 minutes to answer all seven free response questions. Pace yourself accordingly.

- Be sure to read each question carefully.

- Read all the questions once before you decide which question to answer first.

- You need not answer the questions in order, but be sure to clearly label your answers in the answer booklet with the number and letter of each part.

- Fight off fear and apprehension. It is not likely that you are going to know everything! Remember, scoring well is a numbers game. You can make up for not knowing how to do one question by scoring well on another.

- Reread the question that seems easiest to you. Determine what is asked and answer the question directly and specifically.
- With numerical problems, show your work clearly and logically. You need not show any arithmetic, but the grader is looking for a logical progression of your ideas. Circle any numerical final answer.
- In written responses, be clear and concise.
- Write in complete sentences or bulleted phrases. Do not assume the reader knows what you are trying to say. Avoid one-word answers.
- Do not be afraid to state the obvious. What is obvious to you might be exactly what the grader is looking for.
- Avoid pronouns, especially the word, "it," even if your writing seems redundant.
- Underline and define key terms to make them stand out, if appropriate, but do not overdo it.
- Write what you know and stop. Two sentences often fully express an answer to any one part of a question. These are not essay questions. They are more like short answer questions, requiring clear and concise answers with justifications. The grader does not want to see any more than what is specifically asked for.
- Do not hesitate to use a picture, a diagram, or an equation to illustrate your answer, if appropriate.
- Review your writing. Does it make sense to you? Will it make sense to the grader? Does it specifically answer the question that is asked? Have you used chemical terminology correctly?
- Keep in mind that partial credit is often given, so make sure you put something down for every part.
- If you are not clear about an answer, rewrite the question in your own words. Often this practice will jump-start your thinking and allow you to arrive at the answer. What you write, even if it only partially answers the question, might score partial credit.
- When your watch shows that there are 10 minutes left, make a decision about how you can finish the question(s) that will score the most points. Be sure to stop when time is called.

Equations and Constants

The following pages contain a list of equations and constants and a periodic table similar to those provided by the Advanced Placement® Chemistry Exam, which you can use during the entire test. Do not memorize this information. Rather, know that it will be available to you as you take the test and refer to it often as you study Advance Placement® Chemistry.

Common units

L, mL = liter, milliliter	*atm* = atmosphere
g = gram	*mm Hg* = millimeter of mercury
nm = nanometer	*J, kJ* = joule, kilojoule
mol = mole	*V* = volt

Light and Atomic Structure

$E = h\nu$ — E = energy of a photon or quantum state

$\nu = c/\lambda$ — ν = frequency of light

λ = wavelength of light

$c =$ speed of light $= 3.00 \times 10^8$ m/s $= 3.00 \times 10^{17}$ nm/s
$h =$ Planck's constant $= 6.63 \times 10^{-34}$ J-s
$N =$ Avogadro's number $= 6.02 \times 10^{23}$ molecules/mol
$e =$ electric charge $= -1.60 \times 10^{-19}$ coul/electron

Equilibrium

Law of mass action for $a\mathrm{A} + b\mathrm{B} \rightleftharpoons c\mathrm{C} + d\mathrm{D}$,

$K_{eq} = ([C]^c[D]^d)/([A]^a[B]^b)$	$K_{eq} =$ equilibrium constant
$Q = ([C]^c[D]^d)/([A]^a[B]^b)$	$Q =$ reaction quotient
$K_a = [H^+][A^-]/[HA]$	$K_a =$ weak acid ionization constant
$K_b = [OH^-][HB^+]/[B]$	$K_b =$ weak base ionization constant
$K_w = [H^+][OH^-] = 1.0 \times 10^{-14}$ at 25 °C	$K_w =$ autoionization constant for water
$K_w = K_a \times K_b$	$K_p =$ gas pressure equilibrium constant
$\mathrm{pH} = -\log[H^+]$	$K_c =$ molar concentration constant
$\mathrm{pOH} = -\log[OH^-]$	$K_{sp} =$ solubility product constant
$\mathrm{pH} = \mathrm{p}K_a + \log([A^-]/[HA])$	$R =$ gas constant $= 8.31$ J/mol-K
$\mathrm{p}K_a = -\log K_a$	
$\mathrm{p}K_b = -\log K_b$	
$K_p = K_c(RT)^{\Delta n}$	

$\Delta n =$ mol gaseous products $-$ mol gaseous reactants

Thermodynamics

$\Delta H^\circ_{rxn} = \sum \Delta H^\circ_{f\ products} - \sum \Delta H^\circ_{f\ reactants}$

$\Delta G^\circ_{rxn} = \sum \Delta G^\circ_{f\ products} - \sum \Delta G^\circ_{f\ reactants}$

$\Delta S^\circ_{rxn} = \sum S^\circ_{products} - \sum S^\circ_{reactants}$

$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$

$\Delta G^\circ = -RT \ln K$

$\Delta G^\circ = -nFE^\circ$

$\Delta G = \Delta G^\circ + RT \ln Q$

$C_p = \Delta H/\Delta T$

$q = mc\Delta T$

c = specific heat capacity in J/g K

H° = standard enthalpy

G° = standard free energy

S° = standard entropy

T = Kelvin temperature

K = equilibrium constant

E° = standard cell potential

Q = reaction quotient

C_p = molar heat capacity in J/K

q = heat in J, m = mass in g

n = moles of electrons

F = Faraday's constant, the charge on a mole of electrons = 96,500 C/mol e^-

1 amp = 1 coul/sec 1 volt = 1 joul/coul

Gases

$PV = nRT$ P = pressure, V = volume

R = gas constant = 0.0821 L-atm/mol-K = 8.31 J/mol-K = 62.4 L torr/mol-K

$P_a = P_t \times X_a$ P_a = partial pressure of gas a

$P_t = P_a + P_b + P_c + \ldots$ P_t = total pressure

K = °C + 273 X_a = mole fraction of gas = mol a/total moles

$KE_{molecule} = \frac{1}{2}mv^2$ T = Kelvin temperature

1 atm = 760 mmHg = 760 torr KE = kinetic energy

Solutions

M = moles solute/liters of solution M = molarity

$A = abc$ A = *absorbance*, a = molar absorptivity, b = path length, c = concentration

Electrochemistry

Amperes = coulombs per second $E^\circ_{cell} = E^\circ_{red} + E^\circ_{ox}$

n = moles of electrons

$\Delta G^\circ = -nFE^\circ = -RT \ln K$ K = equilibrium constant

F = Faraday's constant = 96,500 C per mole of electrons

E° is the standard cell potential in volts

Kinetics

$\ln[A]_t - \ln[A]_o = -kt$ k = rate constant

$1/[A]_t - 1/[A]_o = kt$ t = time

$t_{1/2} = 0.693/k$ $t_{1/2}$ = half life

	Main groups 1A[a] 1	2A 2	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	9	10	1B 11	2B 12	Main groups 3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1	1 **H** 1.00794																	2 **He** 4.002602
2	3 **Li** 6.941	4 **Be** 9.012182											5 **B** 10.811	6 **C** 12.0107	7 **N** 14.0067	8 **O** 15.9994	9 **F** 18.998403	10 **Ne** 20.1797
3	11 **Na** 22.989770	12 **Mg** 24.3050											13 **Al** 26.981538	14 **Si** 28.0855	15 **P** 30.973761	16 **S** 32.065	17 **Cl** 35.453	18 **Ar** 39.948
4	19 **K** 39.0983	20 **Ca** 40.078	21 **Sc** 44.955910	22 **Ti** 47.867	23 **V** 50.9415	24 **Cr** 51.9961	25 **Mn** 54.938049	26 **Fe** 55.845	27 **Co** 58.933200	28 **Ni** 58.6934	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.64	33 **As** 74.92160	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
5	37 **Rb** 85.4678	38 **Sr** 87.62	39 **Y** 88.90585	40 **Zr** 91.224	41 **Nb** 92.90638	42 **Mo** 95.94	43 **Tc** [98]	44 **Ru** 101.07	45 **Rh** 102.90550	46 **Pd** 106.42	47 **Ag** 107.8682	48 **Cd** 112.411	49 **In** 114.818	50 **Sn** 118.710	51 **Sb** 121.760	52 **Te** 127.60	53 **I** 126.90447	54 **Xe** 131.293
6	55 **Cs** 132.90545	56 **Ba** 137.327	71 **Lu** 174.967	72 **Hf** 178.49	73 **Ta** 180.9479	74 **W** 183.84	75 **Re** 186.207	76 **Os** 190.23	77 **Ir** 192.217	78 **Pt** 195.078	79 **Au** 196.96655	80 **Hg** 200.59	81 **Tl** 204.3833	82 **Pb** 207.2	83 **Bi** 208.98038	84 **Po** [208.98]	85 **At** [209.99]	86 **Rn** [222.02]
7	87 **Fr** [223.02]	88 **Ra** [226.03]	103 **Lr** [262.11]	104 **Rf** [261.11]	105 **Db** [262.11]	106 **Sg** [266.12]	107 **Bh** [264.12]	108 **Hs** [269.13]	109 **Mt** [268.14]	110 **Ds** [281.15]	111 **Rg** [272.15]	112 **Cn** [285]	113 [284]	114 **Fl** [289]	115 [288]	116 **Lv** [292]	117 [294]	118 [294]

Transition metals: groups 3B–2B (3–12).

*Lanthanide series	57 ***La** 138.9055	58 **Ce** 140.116	59 **Pr** 140.90765	60 **Nd** 144.24	61 **Pm** [145]	62 **Sm** 150.36	63 **Eu** 151.964	64 **Gd** 157.25	65 **Tb** 158.92534	66 **Dy** 162.50	67 **Ho** 164.93032	68 **Er** 167.259	69 **Tm** 168.93421	70 **Yb** 173.04
†Actinide series	89 **†Ac** [227.03]	90 **Th** 232.0381	91 **Pa** 231.03588	92 **U** 238.02891	93 **Np** [237.05]	94 **Pu** [244.06]	95 **Am** [243.06]	96 **Cm** [247.07]	97 **Bk** [247.07]	98 **Cf** [251.08]	99 **Es** [252.08]	100 **Fm** [257.10]	101 **Md** [258.10]	102 **No** [259.10]

[a] The labels on top (1A, 2A, etc.) are common American usage. The labels below these (1, 2, etc.) are those recommended by the International Union of Pure and Applied Chemistry.
Except for elements 114 and 116, the names and symbols for elements above 113 have not yet been decided.
Atomic weights in brackets are the masses of the longest-lived or most important isotope of radioactive elements.
Further information is available at http://www.webelements.com
The production of element 116 was reported in May 1999 by scientists at Lawrence Berkeley National Laboratory.

The 6 Big Ideas and 117 Learning Objectives of the AP® Chemistry Curriculum Framework

Big Idea 1. All matter is composed of atoms.

Learning Objectives

1.1 Justify that the elemental mass ratio in any pure compound is always identical using atomic molecular theory.

1.2 Identify or infer from mass data the quantitative compositions of pure substances and mixtures.

1.3 Use calculations of mass data to determine the identity or purity of a substance.

1.4 Interconvert quantities of substances: number of particles, moles, masses, and volumes.

1.5 Use data to explain electron distributions in atoms or ions.

1.6 Analyze data of electron energies for patterns and relationships.

1.7 Describe atomic electronic structure using Coulomb's law, ionization energy, and data from photoelectron spectroscopy.

1.8 Analyze measured energies to explain electron configurations using Coulomb's law.

1.9 Predict atomic properties and explain their trends using the shell model and atomic placement on the periodic table.

1.10 Use experimental evidence to explain the arrangement of the periodic table and apply periodic properties to chemical reactivity.

1.11 Analyze and identify patterns in data for binary compounds to predict properties of related compounds.

1.12 Explain how data sets support the classical shell atomic model or the quantum mechanical model.

1.13 Justify that an atomic model is consistent with a given set of data.

1.14 Use mass spectral data to identify elements and the masses of isotopes.

1.15 Explain why different types of spectroscopy are used to measure vibration and electronic motions of molecules.

1.16 Design and interpret an experiment that uses spectrophotometry to determine the concentration of a substance in solution.

1.17 Use both symbols and particle drawings in balanced chemical equations to quantitatively and qualitatively express the law of conservation of mass.

1.18 Apply conservation of atoms to particle views of balanced chemical reactions and physical changes.

1.19 Design and interpret data from a gravimetric analysis experiment to determine the concentration of a substance in solution.

1.20 Design and interpret data from a titration experiment to determine the concentration of a substance in solution.

Big Idea 2. Chemical bonding and intermolecular forces explain the chemical and physical properties of matter.

Learning Objectives

2.1 Predict properties based on chemical formulas and explain properties using particle views.

2.2 Explain the relative strengths of acids and bases using molecular structure, intermolecular forces, and solution equilibrium.

2.3 Use particulate models and energy considerations to explain the differences between solids and liquids.

2.4 Use kinetic molecular theory and intermolecular forces to predict and explain the macroscopic properties of real and ideal gases.

2.5 Use particle representations, mathematical models, and macroscopic observations to explain the effect of changes in the macroscopic properties of gases.

2.6 Use data to calculate temperature, pressure, volume, and moles for an ideal gas.

2.7 Use intermolecular forces to explain how solutes separate by chromatography.

2.8 Draw and interpret particle representations of solutions showing interactions between the solute and solvent particles.

2.9 Create and use particle views to interpret molar concentrations of solutions.

2.10 Design an experiment to separate substances using filtration, paper chromatography, column chromatography, or distillation and explain how substances separate citing intermolecular interactions.

2.11 Use London dispersion forces to predict properties and explain trends for nonpolar substances.

2.12 Analyze data for real gases to identify deviations from ideal behavior and explain using molecular interactions.

2.13 Explain how the structural features of polar molecules affect the forces of attraction between them.

2.14 Using particle views, qualitatively apply Coulomb's law to explain how the solubility of ionic compounds is affected by interactions between ions, and attractions between ions and solvents.

2.15 Explain the solubility of ionic solids and molecules in water and other solvents using entropy and particle views to show intermolecular forces.

2.16 Use the strengths and types of intermolecular forces to explain the properties of molecules such as phase, vapor pressure, viscosity, melting point, and boiling point.

2.17 Predict the type of bonding in a binary compound based on electronegativity of the elements and their locations on the periodic table.

2.18 Rank and justify bond polarity using location of atoms on the periodic table.

2.19 Use particle views of ionic compounds to explain the effect of microscopic structure on macroscopic properties such as boiling point, solubility, hardness, brittleness, low volatility, and the lack of malleability, ductility, and conductivity.

2.20 Explain how the electron-sea model of delocalized electrons affects the macroscopic properties of metals such as electrical and thermal conductivity, malleability, ductility, and low volatility.

2.21 Use Lewis diagrams and VSEPR to predict geometry and polarity of molecules and identify hybridization.

2.22 Design and evaluate an experimental plan to collect and interpret data to deduce the types of bonding in solids.

2.23 Create a visual representation of an ionic solid showing its structure and particle interactions.

2.24 Use a visual representation of an ionic solid to explain its structure and particle interactions.

2.25 Compare properties of alloys and metals, identify alloy types, and explain properties at the atomic level.

2.26 Use the electron-sea model to explain the macroscopic properties of metals and alloys.

2.27 Create a visual representation of a metallic solid showing its structure and particle interactions.

2.28 Use a visual representation of a metallic solid to explain its structure and particle interactions.

2.29 Create a visual representation of a covalent solid showing its structure and particle interactions.

2.30 Use a visual representation of a covalent solid to explain its structure and particle interactions.

2.31 Create a visual representation of a molecular solid showing its structure and particle interactions.

2.32 Use a visual representation of a molecular solid to explain its structure and particle interactions.

Big Idea 3. Chemical reactions involve the rearrangement of atoms and describe how matter changes.

Learning Objectives

3.1 Interpret macroscopic observations of change using symbols, chemical equations, and particle views.

3.2 Interpret an observed chemical change using a balanced molecular (complete), ionic, or net ionic equation and justify why each is used in a given situation.

3.3 Use stoichiometry calculations to model laboratory chemical reactions and analyze deviations from the expected results.

3.4 Apply stoichiometry calculations to convert measured quantities such as masses, solution volumes, or volumes and pressures of gases to other quantities in chemical reactions, including reactions with limiting reactants or unreacted products.

3.5 Design an experiment and analyze its data for the synthesis or decomposition of a compound to confirm the conservation of mass and the law of definite proportions.

3.6 Use data from synthesis or decomposition of a compound to confirm the conservation of mass and the law of definite proportions.

3.7 Use proton-transfer reactions to identify compounds such as Brønsted–Lowry acids and bases and conjugate acid–base pairs.

3.8 Use electron transfer to identify redox reactions.

3.9 Design or interpret the results of a redox titration experiment.

3.10 Classify a process as a physical change, a chemical change, or an ambiguous change using macroscopic observations and the formation or breaking of chemical bonds or intermolecular forces.

3.11 Create symbolic and graphical representations to describe energy changes associated with a chemical or physical change.

3.12 Use half-cell reactions, potentials, and Faraday's laws to make quantitative predictions about voltaic (galvanic) or electrolytic reactions.

3.13 Analyze voltaic (galvanic) or electrolytic cell data to identify properties of redox reactions.

Big Idea 4. Molecular collisions determine the rates of chemical reactions.

Learning Objectives

4.1 Design and interpret an experiment to determine the factors that affect reaction rate such as temperature, concentration, and surface area.

4.2 Analyze concentration versus time data to determine the rate law for a zeroth-, first-, and second-order reaction.

4.3 Determine half-life from the rate constant of a first-order reaction and explain the relationship between half-life and reaction order.

4.4 Explain how rate law, order, and rate constant for an elementary reaction relate to the frequency and success of molecular collisions.

4.5 Explain effective and ineffective reactant collisions using energy distributions and molecular orientation.

4.6 Make qualitative predictions about the temperature dependence of reaction rate using an energy profile for an elementary reaction showing reactants, transition state, and products.

4.7 Evaluate alternative reaction mechanisms to determine which are consistent with rate data, and infer the presence of intermediates.

4.8 Use various representations including energy profiles, particle views, and chemical equations to describe chemical reactions that occur with and without catalysts.

4.9 Explain rate changes due to acid–base, surface, and enzyme catalysts, and select appropriate mechanisms with or without catalysts.

Big Idea 5. Thermodynamics describes the role energy plays in physical and chemical changes.

Learning Objectives

5.1 Create and interpret graphical representations that show the dependence of potential energy on the distance between atoms to explain bond order, bond length, bond strength, and the relative magnitudes of intermolecular forces between polar molecules.

5.2 Explain how temperature relates to molecular motion using particle views of moving molecules and plots of Maxwell–Boltzmann distributions.

5.3 Use molecular collisions to explain or predict the transfer of heat between systems.

5.4 Use conservation of energy to explain energy transfer between systems including the quantity of energy transferred, the direction of energy flow, and the type of energy (heat or work).

5.5 Use conservation of energy to calculate and explain the quantity of energy change that occurs when two substances of different temperatures interact.

5.6 Calculate or estimate energy changes associated with a chemical reaction (heat of reaction), a temperature change (heat capacity), or a phase change (heat of fusion or vaporization), and relate energy changes to $P\Delta V$ work.

5.7 Design and interpret a constant pressure calorimetry experiment to determine change in enthalpy of a chemical or physical process.

5.8 Use bond energies to calculate or estimate enthalpies of reaction.

5.9 Explain and predict the relative strengths and types of intermolecular forces acting between molecules using molecular electron density distributions.

5.10 Classify and justify physical and chemical changes using intermolecular forces and changes in chemical bonds.

5.11 Identify the intermolecular forces, such as hydrogen bonds and London dispersions, to explain the shapes and functions of large molecules.

5.12 Use particle views and models to predict the signs and relative magnitudes of the entropy changes associated with chemical or physical processes.

5.13 Use the signs of both $\Delta H°$ and $\Delta S°$ for calculation or estimation of $\Delta G°$, to predict the thermodynamic favorability of a physical or chemical change.

5.14 Calculate the change in standard Gibbs free energy to determine the thermodynamic favorability of a chemical or physical change.

5.15 Explain how nonthermodynamically favored processes can be made favorable by coupling them with thermodynamically favored reactions.

5.16 Use Le Châtelier's principle to predict direction of reaction for a system in which coupled reactions share a common intermediate.

5.17 Use the equilibrium constant for combined reactions to make predictions for a system involving coupled reactions sharing a common intermediate.

5.18 Explain how initial conditions can greatly affect product formation for both thermodynamically favored and unfavored reactions using thermodynamic and kinetic arguments.

Big Idea 6. Equilibrium represents a balance between enthalpy and entropy for reversible physical and chemical changes.

Learning Objectives

6.1 Given a set of experimental observations, explain on the molecular level, the reversibility of a chemical, biological, or environmental process.

6.2 Predict how manipulating a chemical equation by reversing it, doubling its coefficients, or adding it to another equation affects the value of Q or K.

6.3 Predict the change in relative rates of forward and reverse reactions using Le Châtelier's principle and principles of kinetics.

6.4 Given initial conditions, use the relative values of Q and K to predict the direction a reaction will progress toward equilibrium.

6.5 Calculate the equilibrium constant, K, given the appropriate tabular or graphical data for a system at equilibrium.

6.6 Given initial conditions and the equilibrium constant, K, use stoichiometry and the law of mass action to determine equilibrium concentrations or partial pressures.

6.7 Determine which chemical species will have relatively large and small concentrations given an equilibrium system with a large or small K.

6.8 Use Le Châtelier's principle to predict the direction a reaction at equilibrium will progress when a change is applied such as concentration, pressure, or temperature.

6.9 Design a set of conditions that will optimize a desired result using Le Chatelier's principle.

6.10 Use Le Châtelier's principle to explain the effect a change will have on Q or K for a reversible reaction.

6.11 Construct a particle representation for a strong or weak acid or base to illustrate which species will have large and small concentrations at equilibrium.

6.12 Compare and contrast pH, percentage ionization, concentrations, and the amount of titrant required to reach an equivalence point for solutions of strong and weak acids.

6.13 Interpret titration data to determine concentration of a weak acid or base and its pK_a or pK_b.

6.14 Explain why a neutral solution requires $[H^+] = [OH^-]$ rather than pH $= 7$, using the dependence of K_w on temperature.

6.15 Calculate or estimate the pH and the concentrations of all species in a mixture of strong acid or base.

6.16 Identify a solution as a weak acid or base, calculate its pH and the concentrations of all species in the solution, and infer its relative strength.

6.17 Given a mixture of weak and strong acids and bases, identify the chemical reaction and tell which species are present in large concentrations at equilibrium.

6.18 Select an appropriate conjugate acid–base pair to design a buffer solution with a target pH and estimate the concentrations needed to achieve a desired buffer capacity.

6.19 Given the pK_a, predict the predominant form of a weak acid in a solution of a given pH.

6.20 Identify a buffer solution and explain how it behaves upon addition of acid or base.

6.21 Predict and rank the solubilities of various salts, given their K_{sp} values.

6.22 Interpret solubility data for various salts to determine or rank K_{sp} values.

6.23 Use data to predict the influence of pH and common ions on the relative solubilities of salts.

6.24 Use particle representations to explain changes in enthalpy and entropy associated with the dissolution of a salt.

6.25 Use the relationship between ΔG° and K ($\Delta G^\circ = -RT \ln K$) to estimate the magnitude of K and the thermodynamic favorability of a process.