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Setting a Policy for AP[®] Chemistry

The purpose of this guide is to provide college faculty and administrators with research data, participation and performance data of AP[®] Chemistry students, curricular content, and sample exam questions to facilitate the establishment of appropriate credit and placement policies for AP Chemistry.

The Advanced Placement Program[®] (AP) provides motivated students with the opportunity to take college-level courses while still in high school. Students demonstrate their mastery of the curriculum by taking AP Exams—35 exams are available in 20 subject areas. In 2005, more than 1.2 million students took AP Exams worldwide. Of the 2.1 million AP Exams taken in 2005, about 80,000 were in Chemistry. More than 3,000 colleges and universities, including many international institutions, accept qualifying AP Exam scores for credit, placement, or both.

Throughout its 50-year history, the AP Program has maintained high standards of rigor in its courses and exams. Since its inception, AP has been a respected force in American education due to the critical involvement of college and university faculty members.

Chemistry Faculty Involvement in AP

College and university faculty members play a vital role in every stage of development and scoring of an AP course and exam, helping to ensure their high quality. Each AP discipline has its own Development Committee—composed of college and university professors and experienced AP teachers—that is responsible for creating the course guidelines and exam questions. College and university faculty members also serve as the Chief Readers, responsible for establishing the exam-scoring guidelines and overseeing the annual AP Reading of the free-response section for their academic discipline.

“The AP Exam in Chemistry reflects current practices in college courses as determined by surveys of the first-year college chemistry course. The exam covers a sufficient breadth and width of subject areas to ensure that students who do well on the exam are well grounded in chemistry. However, as new pedagogical methods in chemistry increasingly focus on conceptual understanding, AP is committed to the redesign of the curriculum and exam to remain consistent with these new approaches to instruction in accordance with the National Science Education Standards. In this respect the AP Program is ahead of many college curricula in complying with an emphasis on conceptual understanding as urged by the National Research Council. In particular the AP Chemistry Exam is moving toward more emphasis on laboratory and inquiry-based learning. The AP Development Committees, consisting of teaching faculty at both high schools and colleges, are focused on how the course uplifts the instruction, learning, and interest in the subject area. Thus AP is taking a leading position in the movement toward more effective teaching.”

—James N. Spencer, AP Chemistry Development Committee Chair
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The College Board publication *AP and Higher Education* discusses the following topics at greater length: how to set an AP policy, AP research studies, the development of AP courses and exams, and the AP Exam scoring. For more information or to request a copy of this publication, please go to apcentral.collegeboard.com/highered.

How to Set an AP Policy

The College Board encourages higher education institutions to base their AP policy decisions on data and research, and recognizes that different institutions and departments will set different policies, based upon factors unique to their institution, student body, and academic discipline. The best way for colleges and universities to determine their AP credit and placement policies is to conduct their own research on the performance of AP and non-AP students at their own institution and in their own department.

Research on AP Chemistry Student Performance

Research studies show that students who do well on an AP Exam are academically prepared to place out of a corresponding college course and move on to the next higher-level course in the discipline. See Table 1 for data from a research study comparing AP and non-AP student performance in second- and third-level college chemistry courses.

Table 1: Student Performance in Second- and Third-Level Chemistry Courses
AP Chemistry Students Versus Non-AP Students

	AP EXAM GRADE	SECOND-LEVEL COURSES		THIRD-LEVEL COURSES	
		GPA	PERCENT OF STUDENTS SCORING AN A OR B	GPA	PERCENT OF STUDENTS SCORING AN A OR B
AP Students Who Place Out of Intro. Course	AP 5	3.38	86	3.43	88
	AP 4	3.29	84	3.05	76
	AP 3	3.10	82	3.02	74
Students Who Complete Intro. Course	Non-AP	2.71	60	2.76	65

Taking the AP course and exam stimulates further interest in the subject area and encourages deeper disciplinary knowledge.

Research studies show that students who take the AP Chemistry Exam are significantly more likely to take further course work in chemistry than students who do not take the AP Exam. See Table 2 for data from this research study.

Table 2: Additional College Chemistry Course Work
AP Chemistry Students Versus Non-AP Students

	AP EXAM GRADE	PERCENT TAKING ADDITIONAL CHEMISTRY COURSES	AVERAGE NUMBER OF COLLEGE CHEMISTRY COURSES TAKEN
AP Chemistry Students	AP 5	63	3.7
	AP 4	63	3.2
	AP 3	71	3.3
	AP 2	74	3.0
	AP 1	68	2.4
Non-AP Students	Non-AP	46	1.5

PDF copies of these and other research studies can be found at apcentral.collegeboard.com/colleges/research.

In addition to research studies on AP student performance, the College Board conducts college comparability studies to measure the degree to which the AP courses and exams are equivalent in content and difficulty to corresponding college courses. The AP Exam scoring rubric is established so that the lowest composite score that earns an AP grade of 5 is equivalent to the average score earned by college students who received grades of A in a comparable course. The lowest score that earns an AP grade of 4 is equivalent to the average B, and the lowest score that earns an AP grade of 3 is equivalent to the average C.

The research that the College Board conducts is intended to help institutions and academic departments as they establish appropriate AP policies. AP Central® (apcentral.collegeboard.com), the College Board's online home for AP professionals, contains other resources that may assist in this process, including the Course Description, released exam questions, and sample student responses at different levels of ability.

For more information go to:
apcentral.collegeboard.com/chemistry/exam

AP Credit Policy Info on the Web

Information about AP credit and placement policies at more than 1,000 colleges and universities is available on the College Board's Web site at www.collegeboard.com/ap/creditpolicy.

AP Chemistry Students, Course, and Exam

Participation and Performance Data for AP Chemistry Students in 2005

Total Number of Schools Offering AP Chemistry: 6,150

Table 3: AP Chemistry Exam Score Distribution, 2005

EXAM GRADE	NUMBER OF EXAMINEES	% AT
Score of 5	11,796	15.0%
Score of 4	14,340	18.3%
Score of 3	17,775	22.7%
Score of 2	15,493	19.7%
Score of 1	19,049	24.3%
	78,453	100.0%

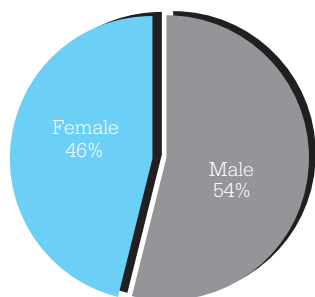
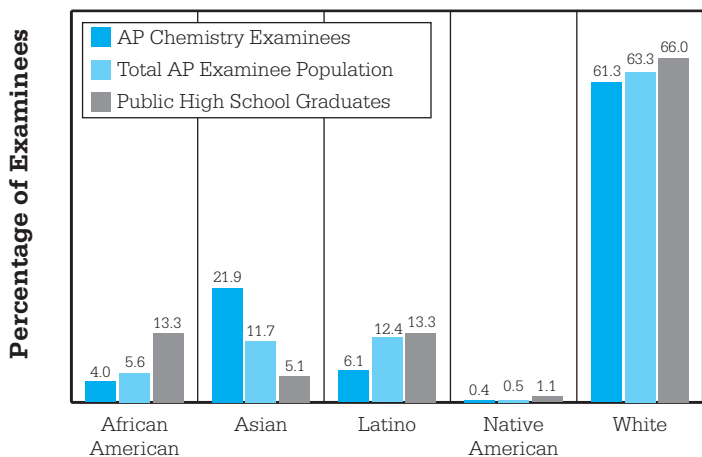


Figure 1: AP Chemistry Examinees by Gender, 2005

Figure 2: AP Chemistry Examinees by Race and Ethnicity, 2005



The AP Chemistry Course

The AP Chemistry course is designed to be the equivalent of the general chemistry course usually taken during the first college year. The AP Chemistry course requires the use of a college-level textbook and significant laboratory experience. The course covers topics such as the structure of matter, kinetic theory of gases, chemical equilibria, chemical kinetics, and the basic concepts of thermodynamics. The course should contribute to the development of the students' abilities to think clearly and to express their ideas, orally and in writing, with clarity and logic.

The College Board recently began a major long-term initiative, in conjunction with the National Science Foundation, aimed at improving the quality of learning and teaching in AP science courses. This was undertaken in response to a 2002 report on advanced studies in mathematics and science by the National Research Council that recommended specific changes in advanced high school studies in the sciences. A special task force is currently evaluating the AP Chemistry course and will draft recommendations to be presented to the Development Committee, which creates the course guidelines and designs the AP Exam.

The Development Committee has created a topic outline that covers the main subject areas that should be taught, along with the relative weight to be assigned to each topic.

- I. Structure of Matter.....20%
 - A. Atomic theory and atomic structure
 - B. Chemical bonding
 - C. Nuclear chemistry
- II. States of Matter20%
 - A. Gases
 - B. Liquids and solids
 - C. Solutions
- III. Reactions.....35–40%
 - A. Reaction types
 - B. Stoichiometry
 - C. Equilibrium
 - D. Kinetics
 - E. Thermodynamics

IV. Descriptive Chemistry..... 10–15%

The descriptive facts of chemistry should be taught throughout the course to illustrate and illuminate the principles. The following areas should be covered:

Chemical reactivity and products of chemical reactions

Relationships in the periodic table

Introduction to organic chemistry

V. Laboratory..... 5–10%

The following experiences and skills should be acquired through laboratory work:

Making observations of chemical reactions and substances

Recording data

Calculating and interpreting results based on the quantitative data obtained

Communicating effectively the results of experimental work

Beginning in fall 2006, AP Chemistry teachers and principals of schools where AP Chemistry is taught must certify that their 2007–08 courses follow all the requirements stipulated by the Development Committee, including using a college-level textbook and providing the class time and equipment to complete the required laboratories, in order to ensure that the AP course reflects college-level standards. By completing this AP Course Audit, high schools will receive individual licenses to label their chemistry courses “AP.” In fall 2007, colleges and universities will receive a list of all high schools authorized to use the “AP” designation for their chemistry courses.

The AP Chemistry Exam

The AP Chemistry Exam consists of two equally weighted sections: a multiple-choice section and a free-response section. The multiple-choice section includes 75 questions with broad coverage of topics to be answered in 90 minutes. Students are not permitted to use calculators during the multiple-choice section of the exam. The free-response section, also to be completed in 90 minutes, is divided into two parts. In the first part (40 minutes) the students will be permitted to use their calculators as they work on several comprehensive problems. For the remaining 50 minutes—without their calculators—students will answer a question requiring the determination of products of chemical reactions and several essay questions. The essays give the student an opportunity to demonstrate the ability to think clearly and to present ideas in a logical and coherent fashion. During the free-response section (but not the multiple-choice section) students will be provided with tables containing equations commonly used in chemistry.

AP Chemistry free-response questions from recent exam years are listed below.

Question 1



In a study of the kinetics of the reaction represented above, the following data were obtained at 298 K.

Experiment	Initial [Br ⁻] (mol L ⁻¹)	Initial [BrO ₃ ⁻] (mol L ⁻¹)	Initial [H ⁺] (mol L ⁻¹)	Rate of Disappearance of BrO ₃ ⁻ (mol L ⁻¹ s ⁻¹)
1	0.00100	0.00500	0.100	2.50 × 10 ⁻⁴
2	0.00200	0.00500	0.100	5.00 × 10 ⁻⁴
3	0.00100	0.00750	0.100	3.75 × 10 ⁻⁴
4	0.00100	0.01500	0.200	3.00 × 10 ⁻³

- From the data given above, determine the order of the reaction for each reactant listed below. Show your reasoning.
 - Br⁻
 - BrO₃⁻
 - H⁺
- Write the rate law for the overall reaction.
- Determine the value of the specific rate constant for the reaction at 298 K. Include the correct units.
- Calculate the value of the standard cell potential, E° , for the reaction using the information in the table below.

Half-reaction	E° (V)
$\text{Br}_2(l) + 2 e^- \rightarrow 2 \text{ Br}^-(aq)$	+1.065
$\text{BrO}_3^-(aq) + 6 \text{ H}^+(aq) + 5 e^- \rightarrow \frac{1}{2} \text{ Br}_2(l) + 3 \text{ H}_2\text{O}(l)$	+1.52

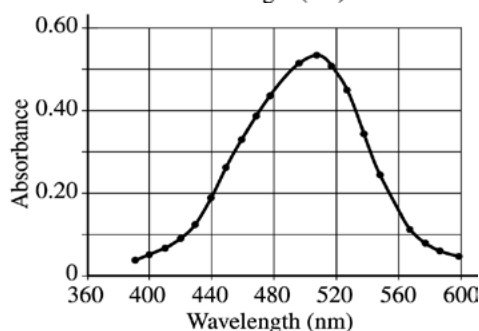
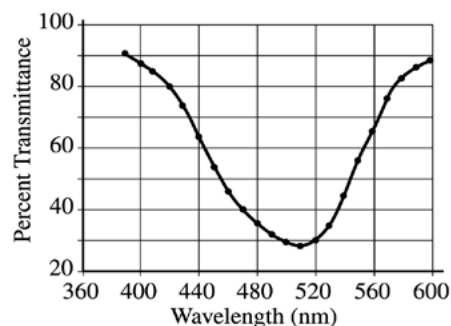
- Determine the total number of electrons transferred in the overall reaction.

Question 2

A student is instructed to determine the concentration of a solution of CoCl₂ based on absorption of light (spectrometric/colorimetric method). The student is provided with a 0.10 M solution of CoCl₂ with which to prepare standard solutions with concentrations of 0.020 M, 0.040 M, 0.060 M, and 0.080 M.

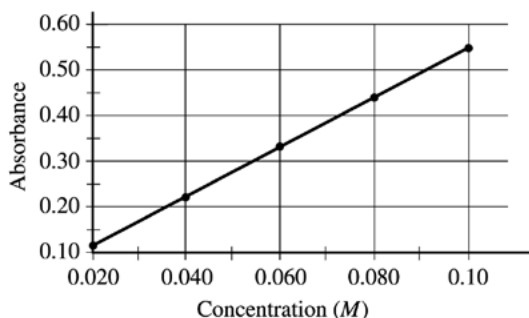
- Describe the procedure for diluting the 0.10 M solution to a concentration of 0.020 M using distilled water, a 100 mL volumetric flask, and a pipet or buret. Include specific amounts where appropriate.

The student takes the 0.10 M solution and determines the percent transmittance and the absorbance at various wavelengths. The two graphs below represent the data.



- (b) Identify the optimum wavelength for the analysis.

The student measures the absorbance of the 0.020 M, 0.040 M, 0.060 M, 0.080 M, and 0.10 M solutions. The data are plotted below.

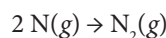


- (c) The absorbance of the unknown solution is 0.275. What is the concentration of the solution?
- (d) Beer's Law is an expression that includes three factors that determine the amount of light that passes through a solution. Identify two of these factors.
- (e) The student handles the sample container (e.g., test tube or cuvette) that holds the unknown solution and leaves fingerprints in the path of the light beam. How will this affect the calculated concentration of the unknown? Explain your answer.
- (f) Why is this method of determining the concentration of CoCl_2 solution appropriate, whereas using the same method for measuring the concentration of NaCl solution would not be appropriate?

Question 3

Answer the following questions that relate to the chemistry of nitrogen.

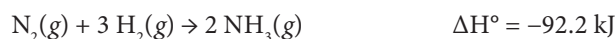
- (a) Two nitrogen atoms combine to form a nitrogen molecule, as represented by the following equation.



Using the table of average bond energies below, determine the enthalpy change, ΔH , for the reaction.

Bond	Average Bond Energy (kJ mol ⁻¹)
N—N	160
N=N	420
N≡N	950

- (b) The reaction between nitrogen and hydrogen to form ammonia is represented below.



Predict the sign of the standard entropy change, ΔS° , for the reaction. Justify your answer.

- (c) The value of ΔG° for the reaction represented in part (b) is negative at low temperatures but positive at high temperatures. Explain.
- (d) When $\text{N}_2(g)$ and $\text{H}_2(g)$ are placed in a sealed container at a low temperature, no measurable amount of $\text{NH}_3(g)$ is produced. Explain.

Question 4



Hypobromous acid, HOBr , is a weak acid that dissociates in water, as represented by the equation above.

- (a) Calculate the value of $[\text{H}^+]$ in an HOBr solution that has a pH of 4.95.
- (b) Write the equilibrium constant expression for the ionization of HOBr in water, then calculate the concentration of $\text{HOBr}(aq)$ in an HOBr solution that has $[\text{H}^+]$ equal to $1.8 \times 10^{-5} \text{ M}$.
- (c) A solution of $\text{Ba}(\text{OH})_2$ is titrated into a solution of HOBr .
- Calculate the volume of 0.115 M $\text{Ba}(\text{OH})_2(aq)$ needed to reach the equivalence point when titrated into a 65.0 mL sample of 0.146 M $\text{HOBr}(aq)$.
 - Indicate whether the pH at the equivalence point is less than 7, equal to 7, or greater than 7. Explain.
- (d) Calculate the number of moles of $\text{NaOBr}(s)$ that would have to be added to 125 mL of 0.160 M HOBr to produce a buffer solution with $[\text{H}^+] = 5.00 \times 10^{-9} \text{ M}$. Assume that volume change is negligible.
- (e) HOBr is a weaker acid than HBrO_3 . Account for this fact in terms of molecular structure.

Question 5

Use principles of atomic structure, bonding, and/or intermolecular forces to respond to each of the following. Your responses must include specific information about all substances referred to in each question.

- (a) At a pressure of 1 atm, the boiling point of $\text{NH}_3(l)$ is 240 K, whereas the boiling point of $\text{NF}_3(l)$ is 144 K.
- Identify the intermolecular force(s) in each substance.
 - Account for the difference in the boiling points of the substances.
- (b) The melting point of $\text{KCl}(s)$ is 776°C , whereas the melting point of $\text{NaCl}(s)$ is 801°C .
- Identify the type of bonding in each substance.
 - Account for the difference in the melting points of the substances.
- (c) As shown in the table below, the first ionization energies of Si, P, and Cl show a trend.

Element	First Ionization Energy (kJ mol^{-1})
Si	786
P	1,012
Cl	1,251

- For each of the three elements, identify the quantum level (e.g., $n = 1$, $n = 2$, etc.) of the valence electrons in the atom.
 - Explain the reasons for the trend in first ionization energies.
- (d) A certain element has two stable isotopes. The mass of one of the isotopes is 62.93 amu and the mass of the other isotope is 64.93 amu.
- Identify the element. Justify your answer.
 - Which isotope is more abundant? Justify your answer.

Question 6

Answer the following questions about a pure compound that contains only carbon, hydrogen, and oxygen.

- (a) A 0.7549 g sample of the compound burns in $\text{O}_2(g)$ to produce 1.9061 g of $\text{CO}_2(g)$ and 0.3370 g of $\text{H}_2\text{O}(g)$.
- Calculate the individual masses of C, H, and O in the 0.7549 g sample.
 - Determine the empirical formula for the compound.
- (b) A 0.5246 g sample of the compound was dissolved in 10.0012 g of lauric acid, and it was determined that the freezing point of the lauric acid was lowered by 1.68°C . The value of K_f of lauric acid is $3.90^\circ\text{C } m^{-1}$. Assume that the compound does not dissociate in lauric acid.
- Calculate the molality of the compound dissolved in the lauric acid.
 - Calculate the molar mass of the compound from the information provided.
- (c) Without doing any calculations, explain how to determine the molecular formula of the compound based on the answers to parts (a)(ii) and (b)(ii).
- (d) Further tests indicate that a 0.10 M aqueous solution of the compound has a pH of 2.6. Identify the organic functional group that accounts for this pH.

How to Get Involved

There are many ways college and university faculty members can help maintain the high standards of the AP Program:

- Participate in a college comparability study
- Be an AP Reader
- Contribute multiple-choice test items for the AP Exam
- Become an AP Faculty Consultant

For more information, please go to: apcentral.collegeboard.com/highered/getinvolved

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The College Board: Connecting Students to College Success

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