CollegeBoard

AP Chemistry Practice Exam

From the 2012 Administration

Contents

Note: This publication shows the page numbers that appeared in the *2011–12 AP Exam Instructions* book and in the actual exam. This publication was not repaginated to begin with page 1.

Exam Instructions

The following contains instructions taken from the ***2011–12 AP Exam Instructions*** book.

AP® Chemistry Exam

Regularly Scheduled Exam Date: Monday morning, May 7, 2012

Late-Testing Exam Date: Thursday afternoon, May 24, 2012

Section I: At a Glance

Total Time:
1 hour, 30 minutes
Number of Questions:
75
Percent of Total Score:
50%
Writing Instrument:
Pencil required
Electronic Device:
None allowed

Section II: At a Glance

Total Time:
1 hour, 35 minutes
Number of Questions:
6
Percent of Total Score:
50%
Writing Instrument:
Either pencil or pen with black or dark blue ink

Part A:

Number of Questions:
3
Time:
55 minutes
Electronic Device:
Calculator allowed
Percent of Section II Score:
Question 1 20%
Question 2 20%
Question 3 20%

Part B:

Number of Questions:
3
Time:
40 minutes
Electronic Device:
None allowed
Percent of Section II Score:
Question 4 10%
Question 5 15%
Question 6 15%

Section I: Multiple Choice Booklet Instructions

Section I of this exam contains 75 multiple-choice questions. Fill in only the circles for numbers 1 through 75 of the answer sheet.

Indicate all of your answers to the multiple-choice questions on the answer sheet. No credit will be given for anything written in this exam booklet, but you may use the booklet for notes or scratch work. After you have decided which of the suggested answers is best, completely fill in the corresponding circle on the answer sheet. Give only one answer to each question. If you change an answer, be sure that the previous mark is erased completely.

Use your time effectively, working as quickly as you can without losing accuracy. Do not spend too much time on any one question. Go on to other questions and come back to the ones you have not answered if you have time. It is not expected that everyone will know the answers to all of the multiple-choice questions.

Your total score on the multiple-choice section is based only on the number of questions answered correctly. Points are not deducted for incorrect answers or unanswered questions.

Section II: Free Response Booklet Instructions

The questions for Part A and Part B are printed in this booklet. Pages containing a periodic table, reduction potentials, and lists containing equations and constants are also printed in this booklet.

The proctor will announce the times for Part A and Part B; you may not begin working on Part B until the proctor tells you to do so. However, you may proceed freely from one question to the next within each part.

You may use the pages that the questions are printed on to organize your answers or for scratch work, but you must write your answers in the areas designated for each response.

Write clearly and legibly. Cross out any errors you make; erased or crossed-out work will not be scored. Manage your time carefully. Do not spend too much time on any one question. If you finish Part B before time is called, you may go back to Part A, but you may NOT use a calculator.

What Proctors Need to Bring to This Exam

- Exam packets
- Answer sheets
- AP Student Packs
- *2011-12 AP Coordinator's Manual*
- This book — *AP Exam Instructions*
- School Code and Home-School/Self-Study Codes
- Extra calculators
- Pencil sharpener
- Extra No. 2 pencils with erasers
- Extra pens with black or dark blue ink
- Extra paper
- Stapler
- Watch
- Signs for the door to the testing room
  - "Exam in Progress"
  - "Cell phones are prohibited in the testing room"

Students are permitted to use calculators to answer some of the questions in Section II of the AP Chemistry Exam. Before starting the exam, refer to the calculator policy for Chemistry on pages 40–42 of the *2011-12 AP Coordinator's Manual*. If a student does not have an appropriate calculator, you may provide one from your supply. If the student does not want to use the calculator you provide, or does not want to use a calculator at all, he or she must hand copy, date, and sign the release statement on page 41 of the *2011-12 AP Coordinator's Manual*.

During the administration of Section II, Part A only, students may have no more than two calculators on their desks; calculators may not be shared. Calculator memories do not need to be cleared before or after the exam. Calculators with QWERTY keyboards are prohibited.

SECTION I: Multiple Choice

Do not begin the exam instructions below until you have completed the appropriate General Instructions for your group.

Make sure you begin the exam at the designated time.

If you are giving the regularly scheduled exam, say:

It is Monday morning, May 7, and you will be taking the AP Chemistry Exam.

If you are giving the alternate exam for late testing, say:

It is Thursday afternoon, May 24, and you will be taking the AP Chemistry Exam.

In a moment, you will open the packet that contains your exam materials. By opening this packet, you agree to all of the AP Program's policies and procedures outlined in the *2011-12 Bulletin for AP Students and Parents*. You may now remove the shrinkwrap from your exam packet and take out the Section I booklet, but do not open the booklet or the shrinkwrapped Section II materials. Put the white seals aside. . . .

Look at page 1 of your answer sheet and locate the dark blue box near the top right-hand corner that states, "Take the AP Exam label from your Section I booklet and place the label here.". . .

Now look at the front cover of your exam booklet and locate the AP Exam label near the top left of the cover. . . .

Carefully peel off the AP Exam label and place it on your answer sheet on the dark blue box that we just identified. . . .

Now read the statements on the front cover of Section I and look up when you have finished. . . .

Sign your name, and write today's date. Look up when you have finished. . . .

Now print your full legal name where indicated. Are there any questions? . . .

Turn to the back cover and read it completely. Look up when you have finished. . . .

Are there any questions? . . .

Section I is the multiple-choice portion of the exam. You may never discuss these specific multiple-choice questions at any time in any form with anyone, including your teacher and other students. If you disclose these questions through any means, your AP Exam score will be canceled. Are there any questions? . . .

You must complete the answer sheet using a No. 2 pencil only. Mark all of your responses on your answer sheet, one response per question. Completely fill in the circles. If you need to erase, do so carefully and completely. No credit will be given for anything written in the exam booklet. Scratch paper is not allowed, but you may use the margins or any blank space in the exam booklet for scratch work. Calculators are not allowed for this section. Please put your calculators under your chair. Are there any questions? . . .

You have 1 hour and 30 minutes for this section. Open your Section I booklet and begin.

 Note Start Time here _____. Note Stop Time here _____. Check that students are marking their answers in pencil on their answer sheets, and that they are not looking at their shrinkwrapped Section II booklets. After 1 hour and 30 minutes, say:

Stop working. Close your booklet and put your answer sheet on your desk, face up. Make sure you have your AP number label and an AP Exam label on page 1 of your answer sheet. I will now collect your answer sheet.

Collect an answer sheet from each student. Check that each answer sheet has an AP number label and an AP Exam label. Then say:

Now you must seal your exam booklet. Remove the white seals from the backing and press one on each area of your exam booklet cover marked "PLACE SEAL HERE." Fold each seal over the back cover. When you have

finished, place the booklet on your desk, face up. I will now collect your Section I booklet. . . .

Check that each student has signed the front cover of the sealed Section I booklet. There is a 10-minute break between Sections I and II. When all Section I materials have been collected and accounted for and you are ready for the break, say:

Please listen carefully to these instructions before we take a 10-minute break. Everything you placed under your chair at the beginning of the exam must stay there. Leave your shrinkwrapped Section II packet on top of your desk during the break. You are not allowed to consult teachers, other students, or textbooks about the exam during the break. You may not make phone calls, send text messages, check email, use a social networking site, or access any electronic or communication device. Remember, you are not allowed to discuss the multiple-choice section of this exam. Failure to adhere to any of these rules could result in cancellation of your score. Are there any questions? . . .

You may begin your break. Testing will resume at _____.

SECTION II: Free Response

After the break, say:

May I have everyone's attention? Place your Student Pack on your desk. . . .

You may now remove the shrinkwrap from the Section II packet, but do not open the exam booklet until you are told to do so. . . .

Read the bulleted statements on the front cover of the exam booklet. Look up when you have finished. . . .

Now place an AP number label on the shaded box. If you don't have any AP number labels, write your AP number in the box. Look up when you have finished. . . .

Read the last statement. . . .

Using your pen, print the first, middle and last initials of your legal name in the boxes and print today's date where indicated. This constitutes your signature and your agreement to the statements on the front cover. . . .

Turn to the back cover and read Item 1 under "Important Identification Information." Print the first two letters of your last name and the first letter of your first name in the boxes. Look up when you have finished. . . .

In Item 2, print your date of birth in the boxes. . . .

In Item 3, write the school code you printed on the front of your Student Pack in the boxes. . . .

Read Item 4. . . .

Are there any questions? . . .

I need to collect the Student Pack from anyone who will be taking another AP Exam. You may keep it only if you are not taking any other AP Exams this year. If you have no other AP Exams to take, place your Student Pack under your chair now. . . .

While Student Packs are being collected, read the information on the back cover of the exam booklet. Do not open the exam booklet until you are told to do so. Look up when you have finished. . . .

Collect the Student Packs. Then say:

Are there any questions? . . .

Section II has two parts. You are responsible for pacing yourself, and may proceed freely from one question to the next within each part. Write your answers legibly using either a pen with black or dark blue ink or a No. 2 pencil. If you use a pencil, be sure that your writing is dark enough to be easily read. Do not begin Part B until you are told to do so. Calculators are allowed for Part A. You may get your calculators from under your chair and place them on your desk. . . .

You have 55 minutes to complete Part A. You must answer Questions 1, 2, and 3. If you need more paper during the exam, raise your hand. At the top of each extra piece of paper you use, be sure to write only your AP number and the number of the question you are working on. Do not write your name. Do not begin Part B at this time. Are there any questions? . . .

Open the exam booklet and begin Part A.

 Note Start Time here _____. Note Stop Time here _____. Check that students are writing their answers in their exam booklets and that they are not working on Part B. Pages in Part B are easily identifiable by a row of large bold letter B's at the top of each page. Proctors should also make sure that calculators' infrared ports are not facing each other and that students are not sharing calculators. After 45 minutes, say:

There are 10 minutes remaining in Part A.

After 10 minutes, say:

Stop working on Part A. Calculators are not allowed for Part B. Please put your calculators under your chair. . . .

You have 40 minutes to complete Part B. You must answer Questions 4, 5, and 6. If you finish Part B before time is called, you may go back to Part A, but you may <u>not</u> use your calculators. You must write your answers in the exam booklet using a pen or a No. 2 pencil. If you use a pencil, be sure that your writing is dark enough to be easily read. Are there any questions? . . .

You may begin Part B.

Note Start Time here _____. Note Stop Time here _____. Check that students are writing their answers in their exam booklets and that they are not using calculators. After 30 minutes, say:

There are 10 minutes remaining in Part B.

After 10 minutes, say:

Stop working and close your exam booklet. Place it on your desk, face up. . . .

If any students used extra paper for the free-response section, have those students staple the extra sheet/s to the first page corresponding to that question in their exam booklets. Then say:

Remain in your seat, without talking, while the exam materials are collected. . . .

Collect a Section II booklet from each student. Check for the following:

- Exam booklet front cover: The student placed an AP number label on the shaded box, and printed his or her initials and today's date.
- Exam booklet back cover: The student completed the "Important Identification Information" area.

When all exam materials have been collected and accounted for, return to students any electronic devices you may have collected before the start of the exam.

If you are giving the regularly scheduled exam, say:

You may not discuss these specific free-response questions with anyone unless they are released on the College Board website in about two days. You should receive your score report in the mail about the third week of July.

If you are giving the alternate exam for late testing, say:

None of the questions in this exam may ever be discussed or shared in any way at any time. You should receive your score report in the mail about the third week of July.

If any students completed the AP number card at the beginning of this exam, say:

Please remember to take your AP number card with you.

Then say:

You are now dismissed.

All exam materials should be put in secure storage until they are returned to the AP Program after your school's last administration. Before storing materials, check the "School Use Only" section on page 1 of the answer sheet and:

- Fill in the appropriate section number circle in order to view a separate AP Instructional Planning Report (for regularly scheduled exams only) or Subject Score Roster at the class section or teacher level. See "Post-Exam Activities" in the *2011-12 AP Coordinator's Manual*.
- Check your list of students who are eligible for fee reductions and fill in the appropriate circle on their registration answer sheets.

Student Answer Sheet for the Multiple-Choice Section

Use this section to capture student responses. (Note that the following answer sheet is a sample, and may differ from one used in an actual exam.)

2012 Answer Sheet

Take an AP Number label from your AP Student Pack and place the label here.

B123456789T

Take the AP Exam label from your Section I booklet and place the label here.

CollegeBoard

NAME AND EXAM AREA — COMPLETE THIS AREA AT EVERY EXAM.

USE NO. 2 PENCIL ONLY

To maintain the security of the exam and the validity of my AP score, I will allow no one else to see the multiple-choice questions. I will seal the multiple-choice booklet when asked to do so, and I will not discuss these questions with anyone at any time after the completion of the section. I am aware of and agree to the AP Program's policies and procedures as outlined in the *2011-12 Bulletin for AP Students and Parents*, including using testing accommodations (e.g., extended time, computer, etc.) only if I have been preapproved by College Board Services for Students with Disabilities.

A. SIGNATURE Sign your legal name as it will appear on your college applications. Date

B. LEGAL NAME Omit apostrophes, Jr., II.

Legal Last Name — First 15 Letters | Legal First Name — First 12 Letters | MI

C. YOUR AP NUMBER

D. EXAM DATE Month

E. EXAM START TIME AM PM

F. MULTIPLE-CHOICE BOOKLET SERIAL NUMBER S

G. ONLINE PROVIDER CODE

H. AP EXAM I AM TAKING USING THIS ANSWER SHEET Print Exam Name: Print Form: Print Form Code:

STUDENT INFORMATION AREA — COMPLETE THIS AREA ONLY ONCE.

I. DATE OF BIRTH Month Day Year

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

J. SEX

- Female
- Male

K. CURRENT GRADE LEVEL

- Pre-9th
- 9th
- 10th
- 11th
- 12th
- Post-12th

L. SOCIAL SECURITY NUMBER (Optional)

M. EXPECTED DATE OF COLLEGE ENTRANCE

- Fall
- Winter/Spring
- Summer
- Undecided
- 2012
- 2013
- 2014
- 2015

N. STUDENT SEARCH SERVICE®

I want the College Board to send information about me to colleges, universities and government scholarship programs interested in students like me.

Yes No

O. WHICH LANGUAGE DO YOU KNOW BEST?

- English
- English and another language about the same
- Another language

P. ETHNICITY/RACE

- American Indian or Alaska Native
- Asian, Asian American or Pacific Islander
- Black or African American
- Mexican or Mexican American
- Puerto Rican
- Other Hispanic, Latino or Latin American
- White
- Other

Q. PARENTAL EDUCATION LEVEL

Father/ Male Guardian	Mother/ Female Guardian	
○	○	Grade school
○	○	Some high school
○	○	High school diploma or equivalent
○	○	Business or trade school
○	○	Some college
○	○	Associate or two-year degree
○	○	Bachelor's or four-year degree
○	○	Some graduate or professional school
○	○	Graduate or professional degree

SCHOOL USE ONLY

Section Number: 1 2 3 4 5 6 7 8 9

Fee Reduction Granted: 1 Option 1 2 Option 2

ETS USE ONLY

Exam: 0 1 2 3 4 5 6 7 8 9

Exam: 0 1 2 3 4 5 6 7 8 9

762000

PAGE 2

R. SURVEY QUESTIONS — Answer the survey questions in the AP Student Pack. Do not put responses to exam questions in this section.

1 (A) (B) (C) (D) (E) (F) (G) (H) (I)	4 (A) (B) (C) (D) (E) (F) (G) (H) (I)	7 (A) (B) (C) (D) (E) (F) (G) (H) (I)
2 (A) (B) (C) (D) (E) (F) (G) (H) (I)	5 (A) (B) (C) (D) (E) (F) (G) (H) (I)	8 (A) (B) (C) (D) (E) (F) (G) (H) (I)
3 (A) (B) (C) (D) (E) (F) (G) (H) (I)	6 (A) (B) (C) (D) (E) (F) (G) (H) (I)	9 (A) (B) (C) (D) (E) (F) (G) (H) (I)

S. LANGUAGE — Do not complete this section unless instructed to do so.

If this answer sheet is for the French Language and Culture, German Language and Culture, Italian Language and Culture, Spanish Language, or Spanish Literature Exam, please answer the following questions. Your responses will not affect your score.

1. Have you lived or studied for one month or more in a country where the language of the exam you are now taking is spoken?

◯ Yes ◯ No

2. Do you regularly speak or hear the language at home?

◯ Yes ◯ No

Indicate your answers to the exam questions in this section. If a question has only four answer options, do not mark option E. Your answer sheet will be scored by machine. Use only No. 2 pencils to mark your answers on pages 2 and 3 (one response per question). After you have determined your response, be sure to completely fill in the corresponding circle next to the number of the question you are answering. Stray marks and smudges could be read as answers, so erase carefully and completely. Any improper gridding may affect your score. Answers written in the multiple-choice booklet will not be scored.

1 (A) (B) (C) (D) (E)	26 (A) (B) (C) (D) (E)	51 (A) (B) (C) (D) (E)
2 (A) (B) (C) (D) (E)	27 (A) (B) (C) (D) (E)	52 (A) (B) (C) (D) (E)
3 (A) (B) (C) (D) (E)	28 (A) (B) (C) (D) (E)	53 (A) (B) (C) (D) (E)
4 (A) (B) (C) (D) (E)	29 (A) (B) (C) (D) (E)	54 (A) (B) (C) (D) (E)
5 (A) (B) (C) (D) (E)	30 (A) (B) (C) (D) (E)	55 (A) (B) (C) (D) (E)
6 (A) (B) (C) (D) (E)	31 (A) (B) (C) (D) (E)	56 (A) (B) (C) (D) (E)
7 (A) (B) (C) (D) (E)	32 (A) (B) (C) (D) (E)	57 (A) (B) (C) (D) (E)
8 (A) (B) (C) (D) (E)	33 (A) (B) (C) (D) (E)	58 (A) (B) (C) (D) (E)
9 (A) (B) (C) (D) (E)	34 (A) (B) (C) (D) (E)	59 (A) (B) (C) (D) (E)
10 (A) (B) (C) (D) (E)	35 (A) (B) (C) (D) (E)	60 (A) (B) (C) (D) (E)
11 (A) (B) (C) (D) (E)	36 (A) (B) (C) (D) (E)	61 (A) (B) (C) (D) (E)
12 (A) (B) (C) (D) (E)	37 (A) (B) (C) (D) (E)	62 (A) (B) (C) (D) (E)
13 (A) (B) (C) (D) (E)	38 (A) (B) (C) (D) (E)	63 (A) (B) (C) (D) (E)
14 (A) (B) (C) (D) (E)	39 (A) (B) (C) (D) (E)	64 (A) (B) (C) (D) (E)
15 (A) (B) (C) (D) (E)	40 (A) (B) (C) (D) (E)	65 (A) (B) (C) (D) (E)
16 (A) (B) (C) (D) (E)	41 (A) (B) (C) (D) (E)	66 (A) (B) (C) (D) (E)
17 (A) (B) (C) (D) (E)	42 (A) (B) (C) (D) (E)	67 (A) (B) (C) (D) (E)
18 (A) (B) (C) (D) (E)	43 (A) (B) (C) (D) (E)	68 (A) (B) (C) (D) (E)
19 (A) (B) (C) (D) (E)	44 (A) (B) (C) (D) (E)	69 (A) (B) (C) (D) (E)
20 (A) (B) (C) (D) (E)	45 (A) (B) (C) (D) (E)	70 (A) (B) (C) (D) (E)
21 (A) (B) (C) (D) (E)	46 (A) (B) (C) (D) (E)	71 (A) (B) (C) (D) (E)
22 (A) (B) (C) (D) (E)	47 (A) (B) (C) (D) (E)	72 (A) (B) (C) (D) (E)
23 (A) (B) (C) (D) (E)	48 (A) (B) (C) (D) (E)	73 (A) (B) (C) (D) (E)
24 (A) (B) (C) (D) (E)	49 (A) (B) (C) (D) (E)	74 (A) (B) (C) (D) (E)
25 (A) (B) (C) (D) (E)	50 (A) (B) (C) (D) (E)	75 (A) (B) (C) (D) (E)

ETS USE ONLY	48, 55, 62, 75, 87		R	W	O	OTHER		R	W	O
		PT02					TOTAL			
		PT03								
		PT04								

DO NOT WRITE IN THIS AREA

QUESTIONS 76–120

Be sure each mark is dark and completely fills the circle. If a question has only four answer options, do not mark option E.

76	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	91	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	106	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
77	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	92	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	107	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
78	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	93	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	108	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
79	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	94	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	109	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
80	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	95	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	110	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
81	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	96	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	111	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
82	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	97	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	112	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
83	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	98	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	113	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
84	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	99	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	114	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
85	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	100	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	115	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
86	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	101	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	116	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
87	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	102	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	117	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
88	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	103	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	118	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
89	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	104	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	119	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
90	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	105	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ	120	Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ

DO NOT WRITE IN THIS AREA

HOME ADDRESS AND SCHOOL AREA — COMPLETE THIS AREA ONLY ONCE.

T. YOUR MAILING ADDRESS

Use the address abbreviations from your AP Student Pack. Fill in only one circle per column. Indicate a space in your address by leaving a blank box; do not grid that column.

STREET ADDRESS (include street number, street name, apartment number, etc.)

CITY

ZIP OR POSTAL CODE

COUNTRY CODE

STATE

AK	HI	MI	NV	UT
AL	IA	MN	NY	VA
AR	ID	MO	OH	VT
AZ	IL	MS	OK	WA
CA	IN	MT	OR	WI
CO	KS	NC	PA	WV
CT	KY	ND	RI	WY
DC	LA	NE	SC	Puerto Rico
DE	MA	NH	SD	
FL	MD	NJ	TN	Other
GA	ME	NM	TX	

U. AREA CODE AND PHONE NUMBER

INTERNATIONAL PHONE

V. SCHOOL YOU ATTEND

SCHOOL CODE

School Name

City

State

Country

W. COLLEGE TO RECEIVE YOUR AP SCORE REPORT

COLLEGE CODE

Using the college code listed in the AP Student Pack, indicate the **ONE** college that you want to receive your AP score report.

College Name

City

State

Country

X. FOR STUDENTS OUTSIDE THE UNITED STATES ONLY

If the address gridded above is not complete enough for delivery of your score report, please fill in this circle and print your complete address below. ◯

Address	City	State or Province	Country	ZIP or Postal Code

Y. EMAIL ADDRESS

By providing your email address, you are granting the College Board permission to use your email in accordance with the policies in the *2011-12 Bulletin for AP Students and Parents*.

GO ON TO THE NEXT PAGE.

Section I: Multiple-Choice Questions

This is the multiple-choice section of the 2012 AP exam. It includes cover material and other administrative instructions to help familiarize students with the mechanics of the exam. (Note that future exams may differ in look from the following content.)

PLACE SEAL HERE

AP® Chemistry Exam

SECTION I: Multiple Choice

2012

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

At a Glance

Total Time
1 hour, 30 minutes
Number of Questions
75
Percent of Total Score
50%
Writing Instrument
Pencil required
Electronic Device
None allowed

Instructions

Section I of this exam contains 75 multiple-choice questions. Fill in only the circles for numbers 1 through 75 of the answer sheet.

Indicate all of your answers to the multiple-choice questions on the answer sheet. No credit will be given for anything written in this exam booklet, but you may use the booklet for notes or scratch work. After you have decided which of the suggested answers is best, completely fill in the corresponding circle on the answer sheet. Give only one answer to each question. If you change an answer, be sure that the previous mark is erased completely. Here is a sample question and answer.

Sample Question	Sample Answer
Chicago is a (A) state (B) city (C) country (D) continent (E) village	Ⓐ ● Ⓒ Ⓓ Ⓔ

Use your time effectively, working as quickly as you can without losing accuracy. Do not spend too much time on any one question. Go on to other questions and come back to the ones you have not answered if you have time. It is not expected that everyone will know the answers to all of the multiple-choice questions.

Your total score on the multiple-choice section is based only on the number of questions answered correctly. Points are not deducted for incorrect answers or unanswered questions.

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Minimum 20% post-consumer waste

Form I
Form Code 4IBP4-S

PLACE SEAL HERE
DO NOT seal answer sheet inside

MATERIAL IN THE FOLLOWING TABLE MAY BE USEFUL IN ANSWERING THE QUESTIONS IN THIS SECTION OF THE EXAMINATION.

DO NOT DETACH FROM BOOK.

PERIODIC TABLE OF THE ELEMENTS

1																	2
H																	**He**
1.008																	4.00
3	4											5	6	7	8	9	10
Li	**Be**											**B**	**C**	**N**	**O**	**F**	**Ne**
6.94	9.01											10.81	12.01	14.01	16.00	19.00	20.18
11	12											13	14	15	16	17	18
Na	**Mg**											**Al**	**Si**	**P**	**S**	**Cl**	**Ar**
22.99	24.30											26.98	28.09	30.97	32.06	35.45	39.95
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K	**Ca**	**Sc**	**Ti**	**V**	**Cr**	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**Ga**	**Ge**	**As**	**Se**	**Br**	**Kr**
39.10	40.08	44.96	47.90	50.94	52.00	54.94	55.85	58.93	58.69	63.55	65.39	69.72	72.59	74.92	78.96	79.90	83.80
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	**Sr**	**Y**	**Zr**	**Nb**	**Mo**	**Tc**	**Ru**	**Rh**	**Pd**	**Ag**	**Cd**	**In**	**Sn**	**Sb**	**Te**	**I**	**Xe**
85.47	87.62	88.91	91.22	92.91	95.94	(98)	101.1	102.91	106.42	107.87	112.41	114.82	118.71	121.75	127.60	126.91	131.29
55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs	**Ba**	***La**	**Hf**	**Ta**	**W**	**Re**	**Os**	**Ir**	**Pt**	**Au**	**Hg**	**Tl**	**Pb**	**Bi**	**Po**	**At**	**Rn**
132.91	137.33	138.91	178.49	180.95	183.85	186.21	190.2	192.2	195.08	196.97	200.59	204.38	207.2	208.98	(209)	(210)	(222)
87	88	89	104	105	106	107	108	109	110	111							
Fr	**Ra**	**†Ac**	**Rf**	**Db**	**Sg**	**Bh**	**Hs**	**Mt**	**Ds**	**Rg**							
(223)	226.02	227.03	(261)	(262)	(266)	(264)	(277)	(268)	(271)	(272)							

	58	59	60	61	62	63	64	65	66	67	68	69	70	71
*Lanthanide Series	**Ce**	**Pr**	**Nd**	**Pm**	**Sm**	**Eu**	**Gd**	**Tb**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**
	140.12	140.91	144.24	(145)	150.4	151.97	157.25	158.93	162.50	164.93	167.26	168.93	173.04	174.97
	90	91	92	93	94	95	96	97	98	99	100	101	102	103
†Actinide Series	**Th**	**Pa**	**U**	**Np**	**Pu**	**Am**	**Cm**	**Bk**	**Cf**	**Es**	**Fm**	**Md**	**No**	**Lr**
	232.04	231.04	238.03	(237)	(244)	(243)	(247)	(247)	(251)	(252)	(257)	(258)	(259)	(262)

GO ON TO THE NEXT PAGE.

CHEMISTRY

Section I

Time—1 hour and 30 minutes

NO CALCULATOR MAY BE USED WITH SECTION I.

Note: For all questions, assume that the temperature is 298 K, the pressure is 1.00 atmosphere, and solutions are aqueous unless otherwise specified.

Throughout the test the following symbols have the definitions specified unless otherwise noted.

T	= temperature	L, mL	= liter(s), milliliter(s)
P	= pressure	g	= gram(s)
V	= volume	nm	= nanometer(s)
S	= entropy	atm	= atmosphere(s)
H	= enthalpy	mm Hg	= millimeters of mercury
G	= Gibbs free energy	J, kJ	= joule(s), kilojoule(s)
R	= molar gas constant	V	= volt(s)
n	= number of moles	mol	= mole(s)
M	= molar		
m	= molal		

Part A

Directions: Each set of lettered choices below refers to the numbered statements immediately following it. Select the one lettered choice that best fits each statement and then fill in the corresponding circle on the answer sheet. A choice may be used once, more than once, or not at all in each set.

Questions 1-3 refer to the following gaseous molecules.

(A) $BeCl_2$
(B) SO_2
(C) N_2
(D) O_2
(E) F_2

1. Is a polar molecule

2. Is best represented by two or more resonance forms

3. Is the molecule in which the <u>intramolecular</u> forces are strongest

GO ON TO THE NEXT PAGE.

Questions 4-5

(A) Alpha-particle emission
(B) Beta-particle emission
(C) Electron capture
(D) Gamma-ray emission
(E) Nuclear fission

4. Is the major process by which nuclei lose excess energy without a change in atomic number

5. Accounts for the transformation of $^{207}_{81}\mathrm{T1}$ into $^{207}_{82}\mathrm{Pb}$

Questions 6-8 refer to the following types of chemical or physical changes.

(A) Oxidation-reduction reaction
(B) Brønsted-Lowry acid-base reaction
(C) Sublimation
(D) Dehydration
(E) Precipitation

6. Occurs when aqueous solutions of ammonia and vinegar are mixed

7. Occurs when $\mathrm{Al}(s)$ and $\mathrm{CuCl_2}(aq)$ are mixed

8. Occurs when solid sodium acetate, $\mathrm{NaC_2H_3O_2}(s)$, is added to water

GO ON TO THE NEXT PAGE.

Questions 9-10 refer to the following gas molecules at the conditions indicated.

(A) $H_2(g)$ molecules at 10^{-3} atm and 200°C
(B) $O_2(g)$ molecules at 20 atm and 200°C
(C) $SO_2(g)$ molecules at 20 atm and 200°C
(D) $NH_3(g)$ molecules at 20 atm and 200°C
(E) $NH_3(g)$ molecules at 20 atm and 300°C

9. Behave most like an ideal gas

10. Have lowest root-mean-square speed

Questions 11-13

(A) Cs
(B) Ag
(C) Pb
(D) Br
(E) Se

11. Has the highest electronegativity

12. Has the lowest first-ionization energy

13. Has the largest atomic radius

GO ON TO THE NEXT PAGE.

Questions 14-16 refer to the following compounds.

(A) $CH_3CH_2CH_2CH_3$
(B) $CH_3CH_2CH_2OH$
(C) CH_3COCH_3
(D) CH_3COOH
(E) $CH_3CH_2CH_2NH_2$

14. Is isomeric with CH_3CH_2CHO

15. Dissolves in water to form an acidic solution

16. Is the LEAST soluble in water

GO ON TO THE NEXT PAGE.

Part B

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and then fill in the corresponding circle on the answer sheet.

17. A certain crystalline substance that has a low melting point does not conduct electricity in solution or when melted. This substance is likely to be

    (A) a covalent network solid
    (B) a metallic solid
    (C) a polymer
    (D) an ionic solid
    (E) a molecular solid

18. Solid $Al(NO_3)_3$ is added to distilled water to produce a solution in which the concentration of nitrate, $[NO_3^-]$, is 0.10 *M*. What is the concentration of aluminum ion, $[Al^{3+}]$, in this solution?

    (A) 0.010 *M*
    (B) 0.033 *M*
    (C) 0.066 *M*
    (D) 0.10 *M*
    (E) 0.30 *M*

19. Which of the following is a weak acid in aqueous solution?

    (A) HCl
    (B) $HClO_4$
    (C) HNO_3
    (D) H_2S
    (E) H_2SO_4

20. In 1.00 mol of potassium zirconium sulfate trihydrate, $K_4Zr(SO_4)_4 \cdot 3\ H_2O$, there are

    (A) $3 \times 6.02 \times 10^{23}$ hydrogen atoms
    (B) 6.02×10^{23} sulfur atoms
    (C) $4 \times 6.02 \times 10^{23}$ potassium atoms
    (D) 4 moles of oxygen atoms
    (E) 4 moles of zirconium atoms

$$X + 2\,Y \rightarrow Z + 3\,Q$$

21. For the reaction represented above, the initial rate of decrease in [X] was 2.8×10^{-3} mol L^{-1} s^{-1}. What was the initial rate of decrease in [Y] ?

    (A) 7.0×10^{-4} mol L^{-1} s^{-1}
    (B) 1.4×10^{-3} mol L^{-1} s^{-1}
    (C) 2.8×10^{-3} mol L^{-1} s^{-1}
    (D) 5.6×10^{-3} mol L^{-1} s^{-1}
    (E) 1.1×10^{-2} mol L^{-1} s^{-1}

22. To determine the percentage of water in a hydrated salt, a student heated a 1.2346 g sample of the salt for 30 minutes; when cooled to room temperature, the sample weighed 1.1857 g. After the sample was heated for an additional 10 minutes and again cooled to room temperature, the sample weighed 1.1632 g. Which of the following should the student do next?

    (A) Use the smallest mass value to calculate the percentage of water in the hydrated salt.
    (B) Repeat the experiment with a new sample of the same mass and average the results.
    (C) Repeat the experiment with a new sample that has a different mass.
    (D) Reheat the sample until its mass is constant.
    (E) Use the average of the mass values obtained after the two heatings to calculate the percentage of water in the hydrated salt.

GO ON TO THE NEXT PAGE.

23. Which of the following statements about atoms is NOT correct?

(A) Atoms are electrically neutral because they have the same number of protons and electrons.
(B) All atoms of a given element must have the same number of protons, neutrons, and electrons.
(C) Most of the volume of an atom contains only electrons.
(D) The nucleus is positively charged.
(E) Almost all of the mass of an atom is in the nucleus.

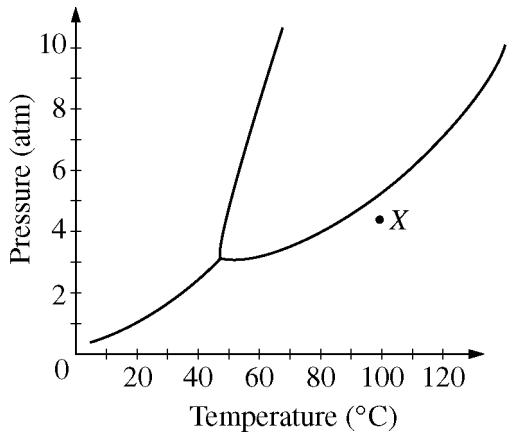
$$NH_3(aq) + HCl(aq) \rightleftarrows NH_4^+(aq) + Cl^-(aq)$$

24. The Brønsted-Lowry bases in the reaction represented above are

(A) $NH_3(aq)$ and $NH_4^+(aq)$
(B) $NH_3(aq)$ and $Cl^-(aq)$
(C) $NH_3(aq)$ and $HCl(aq)$
(D) $HCl(aq)$ and $NH_4^+(aq)$
(E) $HCl(aq)$ and $Cl^-(aq)$

25. When 6.0 L of $He(g)$ and 10. L of $N_2(g)$, both at 0°C and 1.0 atm, are pumped into an evacuated 4.0 L rigid container, the final pressure in the container at 0°C is

(A) 2.0 atm
(B) 4.0 atm
(C) 6.4 atm
(D) 8.8 atm
(E) 16 atm



26. Shown above is the phase diagram of a pure substance. The substance under the conditions corresponding to point X on the diagram is cooled to 40°C while the pressure remains constant. As the substance cools, the phase of the substance changes from

(A) gas to liquid to solid
(B) gas to solid to liquid
(C) solid to liquid to gas
(D) liquid to solid to gas
(E) liquid to gas to solid

27. Oxygen is acting as an oxidizing agent in all of the following reactions EXCEPT

(A) $2\,C(s) + O_2(g) \rightarrow 2\,CO(g)$
(B) $S(s) + O_2(g) \rightarrow SO_2(g)$
(C) $2\,F_2(g) + O_2(g) \rightarrow 2\,OF_2(g)$
(D) $2\,Na(s) + O_2(g) \rightarrow Na_2O_2(s)$
(E) $2\,Mg(s) + O_2(g) \rightarrow 2\,MgO(s)$

28. What is the maximum number of moles of Al_2O_3 that can be produced by the reaction of 0.40 mol of Al with 0.40 mol of O_2 ?

(A) 0.10 mol
(B) 0.20 mol
(C) 0.27 mol
(D) 0.33 mol
(E) 0.40 mol

GO ON TO THE NEXT PAGE.

$\ldots C_3H_8(g) + \ldots O_2(g) \rightarrow \ldots H_2O(g) + \ldots CO_2(g)$

29. When the equation for the reaction represented above is balanced and all coefficients are reduced to the lowest whole-number terms, the coefficient for $O_2(g)$ is

    (A) 1
    (B) 2
    (C) 3
    (D) 5
    (E) 6

30. A 0.1 *M* solution of which of the following is colorless?

    (A) $MgCl_2$
    (B) $Ni(NO_3)_2$
    (C) Na_2CrO_4
    (D) $KMnO_4$
    (E) $CuSO_4$

31. Under which of the following conditions can an endothermic reaction be thermodynamically favorable?

    (A) ΔG is positive
    (B) ΔS is negative
    (C) $T\Delta S > \Delta H$
    (D) $T\Delta S = 0$
    (E) There are no conditions under which an endothermic reaction can be thermodynamically favorable.

32. The vapor pressure of pure water at 25°C is 24.0 mm Hg. What is the expected vapor pressure at 25°C of an ideal solution of a nonvolatile nonelectrolyte in which the mole fraction of water is 0.900 ?

    (A) 1.48 mm Hg
    (B) 2.40 mm Hg
    (C) 21.6 mm Hg
    (D) 24.0 mm Hg
    (E) 26.7 mm Hg

33. Which of the following salts is LEAST soluble in water?

    (A) NiS
    (B) $MgCl_2$
    (C) K_2CrO_4
    (D) $Al_2(SO_4)_3$
    (E) $Pb(NO_3)_2$

34. Which of the following is the best piece of laboratory glassware for preparing 500.0 mL of an aqueous solution of a solid?

    (A) Volumetric flask
    (B) Erlenmeyer flask
    (C) Test tube
    (D) Graduated beaker
    (E) Graduated cylinder

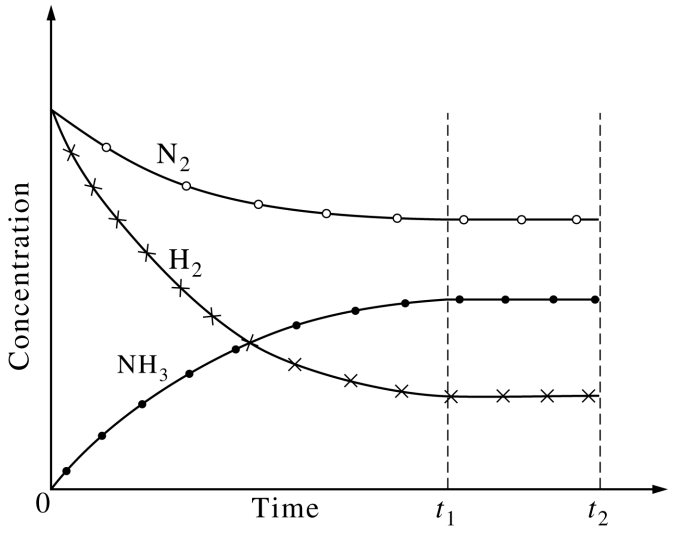
GO ON TO THE NEXT PAGE.

Questions 35-36 refer to the experiment described below.

H_2 gas and N_2 gas were placed in a rigid vessel and allowed to reach equilibrium in the presence of a catalyst according to the following equation.

$$3\ H_2(g) + N_2(g) \rightleftarrows 2\ NH_3(g) \qquad \Delta H^\circ = -92\ \text{kJ/mol}_{rxn}$$

The diagram below shows how the concentrations of H_2, N_2, and NH_3 in this system changed over time.



35. Which of the following was true for the system between time t_1 and time t_2 ?

(A) The concentration of N_2 decreased.
(B) The temperature of the system decreased.
(C) The number of effective collisions between H_2 and N_2 was zero.
(D) The rates of the forward and reverse reactions were equal.
(E) The rate of formation of NH_3 molecules was equal to the rate of disappearance of H_2 molecules.

36. More NH_3 gas is added to the system at time t_2 while the temperature is held constant. Which of the following will most likely occur?

(A) The value of the equilibrium constant will increase.
(B) The value of the equilibrium constant will decrease.
(C) The total pressure in the container will decrease.
(D) The amount of N_2 will increase.
(E) The amount of H_2 will decrease.

GO ON TO THE NEXT PAGE.

37. When heated, metallic carbonates generally produce

(A) metallic peroxide + CO
(B) metal + CO + O_2
(C) metallic hydroxide + CO_2
(D) metallic oxalate + O_2
(E) metallic oxide + CO_2

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftarrows Fe(SCN)^{2+}(aq)$$

38. For the reaction represented above, the value of the equilibrium constant, K_{eq}, is 240 at 25°C. From this information, correct deductions about the reaction at 25°C include which of the following?

I. The reaction is quite rapid.
II. The product is favored over the reactants at equilibrium.
III. The reaction is endothermic.

(A) I only
(B) II only
(C) I and II only
(D) II and III only
(E) I, II, and III

39. The volume of water that must be added in order to dilute 40 mL of 9.0 *M* HCl to a concentration of 6.0 *M* is closest to

(A) 10 mL
(B) 20 mL
(C) 30 mL
(D) 40 mL
(E) 60 mL

40. Which of the following statements best explains why an increase in temperature of 5-10 Celsius degrees can substantially increase the rate of a chemical reaction?

(A) The activation energy for the reaction is lowered.
(B) The number of effective collisions between reactant particles is increased.
(C) The rate of the reverse reaction is increased.
(D) ΔH for the reaction is lowered.
(E) ΔG for the reaction becomes more positive.

$$2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)$$

41. What is the percentage yield of O_2 if 12.3 g of $KClO_3$ (molar mass 123 g) is decomposed to produce 3.2 g of O_2 (molar mass 32 g) according to the equation above?

(A) 100%
(B) 67%
(C) 50%
(D) 33%
(E) 10%

42. When a strong acid is titrated with a strong base using phenolphthalein as an indicator, the color changes abruptly at the endpoint of the titration and can be switched back and forth by the addition of only one drop of acid or base. The reason for the abruptness of this color change is that

(A) a large change in pH occurs near the endpoint of the titration
(B) a buffer solution exists at the endpoint of the titration
(C) phenolphthalein is a strong proton donor
(D) the pH of water is very resistant to change
(E) phenolphthalein is much more sensitive to the pH of a solution than most other indicators

GO ON TO THE NEXT PAGE.

43. A 1 mol sample of zinc can reduce the greatest number of moles of which of the following ions?

(A) Al^{3+}
(B) Pb^{2+}
(C) Ag^{+}
(D) Cl^{-}
(E) N^{3-}

44. At 298 K and 1 atm, bromine is a liquid with a high vapor pressure, whereas chlorine is a gas. This provides evidence that, under these conditions, the

(A) forces among Br_2 molecules are greater than those among Cl_2 molecules
(B) forces among Br_2 molecules are weaker than the Br–Br bond
(C) forces among Cl_2 molecules are stronger than the Cl–Cl bond
(D) Br–Br bond is stronger than the Cl–Cl bond
(E) Br–Br bond is weaker than the Cl–Cl bond

45. The value of K_{sp} for $PbCl_2$ is 1.6×10^{-5}. What is the lowest concentration of $Cl^{-}(aq)$ that would be needed to begin precipitation of $PbCl_2(s)$ in 0.010 *M* $Pb(NO_3)_2$?

(A) 1.6×10^{-7} *M*
(B) 4.0×10^{-4} *M*
(C) 1.6×10^{-3} *M*
(D) 2.6×10^{-3} *M*
(E) 4.0×10^{-2} *M*

46. Which of the following aqueous solutions has the lowest freezing point?

(A) 0.2 *m* NaCl
(B) 0.2 *m* $CaCl_2$
(C) 0.2 *m* H_2SO_4
(D) 0.2 *m* NH_3
(E) 0.2 *m* $Al(NO_3)_3$

Step 1: $NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$
Step 2: $NO_2(g) + O(g) \rightarrow NO(g) + O_2(g)$

47. A reaction mechanism for the destruction of ozone, $O_3(g)$, is represented above. In the overall reaction, $NO(g)$ is best described as

(A) an inhibitor
(B) a catalyst
(C) a reactant
(D) an intermediate
(E) a product

48. When a buret is rinsed before a titration, which of the techniques below is the best procedure?

(A) Rinse the buret one time with some of the titrant solution.
(B) Rinse the buret one time with some of the titrant solution and then dry the buret in an oven.
(C) Rinse the buret two times: once with some of the titrant solution, then once with distilled water.
(D) Rinse the buret two times: each time with some of the titrant solution.
(E) Rinse the buret two times: each time with distilled water.

GO ON TO THE NEXT PAGE.

$$Sr^{2+}(aq) + F^{-}(aq) \rightleftarrows SrF^{+}(aq)$$

49. At 25°C, the equilibrium constant for the reaction represented above has a value of 1.3. At 50°C, the value of the equilibrium constant is less than 1.3. Based on this information, which of the following must be correct?

(A) The reaction rate decreases as the temperature is increased.
(B) The reaction is thermodynamically favorable only at temperatures above 25°C.
(C) At 25°C, ΔG° for the reaction is positive.
(D) At 25°C, ΔS° for the reaction is positive.
(E) At 25°C, ΔH° for the reaction is negative.

$$Ni^{2+}(aq) + 6\,NH_3(aq) \rightarrow [Ni(NH_3)_6]^{2+}(aq)$$

50. The reaction represented above is best classified as

(A) a Lewis acid-base reaction
(B) a Brønsted-Lowry acid-base reaction
(C) an Arrhenius acid-base reaction
(D) an oxidation-reduction reaction
(E) a precipitation reaction

GO ON TO THE NEXT PAGE.

$$Cu^{2+}(aq) + 2\,e^- \rightarrow Cu(s) \qquad E^\circ = 0.34\ V$$
$$Cr^{3+}(aq) + e^- \rightarrow Cr^{2+}(aq) \qquad E^\circ = -0.41\ V$$

51. According to the half-reactions represented above, which of the following occurs in aqueous solutions under standard conditions?

(A) $Cu^{2+}(aq) + Cr^{3+}(aq) \rightarrow Cu(s) + Cr^{2+}(aq)$
(B) $Cu^{2+}(aq) + 2\,Cr^{2+}(aq) \rightarrow Cu(s) + 2\,Cr^{3+}(aq)$
(C) $Cu(s) + 2\,Cr^{3+}(aq) \rightarrow Cu^{2+}(aq) + 2\,Cr^{2+}(aq)$
(D) $Cu(s) + Cr^{3+}(aq) \rightarrow Cu^{2+}(aq) + Cr^{2+}(aq)$
(E) $2\,Cu^{2+}(aq) + Cr^{3+}(aq) \rightarrow 2\,Cu(s) + Cr^{2+}(aq)$

$$\ldots Zn(s) + \ldots H^+(aq) + \ldots NO_3^-(aq) \rightarrow \ldots Zn^{2+}(aq) + \ldots NH_4^+(aq) + \ldots H_2O(l)$$

52. When the equation above is balanced and all coefficients are reduced to lowest whole number terms, the coefficient for $Zn(s)$ is

(A) 2
(B) 4
(C) 6
(D) 10
(E) 14

$$4\ NH_3(g)\ +\ 3\ O_2(g)\ \rightarrow\ 2\ N_2(g)\ +\ 6\ H_2O(g)$$

53. If the standard molar heats of formation of ammonia, $NH_3(g)$, and gaseous water, $H_2O(g)$, are −46 kJ/mol and −242 kJ/mol, respectively, what is the value of ΔH°_{298} for the reaction represented above?

(A) $-190\ kJ/mol_{rxn}$
(B) $-290\ kJ/mol_{rxn}$
(C) $-580\ kJ/mol_{rxn}$
(D) $-1{,}270\ kJ/mol_{rxn}$
(E) $-1{,}640\ kJ/mol_{rxn}$

54. When a magnesium wire is dipped into a solution of lead(II) nitrate, a black deposit forms on the wire. Which of the following can be concluded from this observation?

(A) The standard reduction potential, E°, for $Pb^{2+}(aq)$ is greater than that for $Mg^{2+}(aq)$.
(B) $Mg(s)$ is less easily oxidized than $Pb(s)$.
(C) An external source of potential must have been supplied.
(D) The magnesium wire will be the cathode of a Mg/Pb cell.
(E) $Pb(s)$ can spontaneously displace $Mg^{2+}(aq)$ from solution.

55. Which of the molecules represented below contains carbon with sp^2 hybridization?

(A) CH_4
(B) CH_2Cl_2
(C) C_2H_6
(D) $C_2H_2Cl_2$
(E) $C_2H_4Cl_2$

56. A chemical supply company sells a concentrated solution of aqueous H_2SO_4 (molar mass 98 g mol^{-1}) that is 50. percent H_2SO_4 by mass. At 25°C, the density of the solution is 1.4 g mL^{-1}. What is the molarity of the H_2SO_4 solution at 25°C?

(A) 1.8 *M*
(B) 3.6 *M*
(C) 5.1 *M*
(D) 7.1 *M*
(E) 14 *M*

57. A reaction produces a colorless gas, which is collected by water displacement. A glowing splint inserted into a bottle full of the gas is extinguished. The gas could be

(A) N_2
(B) NO_2
(C) O_2
(D) Br_2
(E) Cl_2

58. A solution of methanol, CH_3OH, in water is prepared by mixing together 128 g of methanol and 108 g of water. The mole fraction of methanol in the solution is closest to

(A) 0.80
(B) 0.60
(C) 0.50
(D) 0.40
(E) 0.20

59. A sample of a compound contains 3.21 g of sulfur and 11.4 g of fluorine. Which of the following represents the empirical formula of the compound?

(A) SF_2
(B) SF_3
(C) SF_4
(D) SF_5
(E) SF_6

GO ON TO THE NEXT PAGE.

60. Of the following, the best explanation for the fact that most gases are easily compressed is that the molecules in a gas

(A) are in constant motion
(B) are relatively far apart
(C) have relatively small masses
(D) have a real, nonzero volume
(E) move slower as temperature decreases

61. Given that the density of $Hg(l)$ at 0°C is about 14 g mL^{-1}, which of the following is closest to the volume of one mole of $Hg(l)$ at this temperature?

(A) 0.070 mL
(B) 0.14 mL
(C) 1.4 mL
(D) 14 mL
(E) 28 mL

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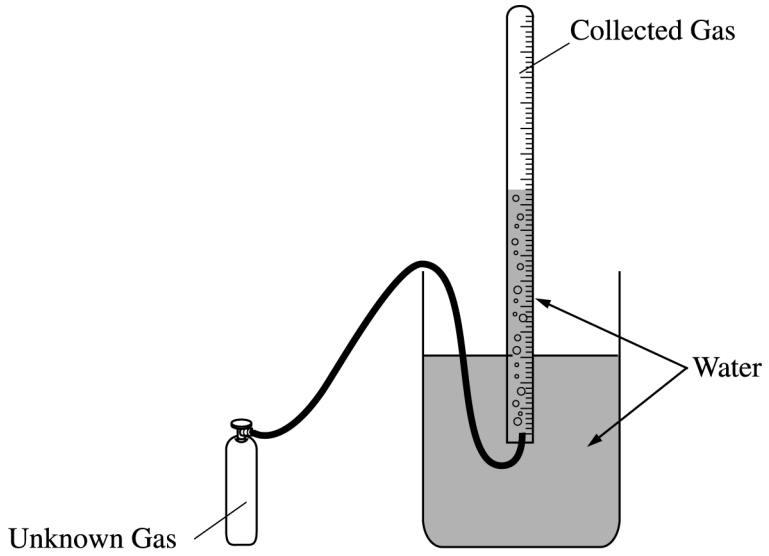


62. A sample of an unknown gas from a cylinder is collected over water in the apparatus shown above. After all the gas sample has been collected, the water levels inside and outside the gas collection tube are made the same. Measurements that must be made to calculate the molar mass of the gas include all of the following EXCEPT

(A) atmospheric pressure
(B) temperature of the water
(C) volume of gas in the gas-collection tube
(D) initial and final mass of the gas cylinder
(E) mass of the water in the apparatus

63. Addition of sulfurous acid (a weak acid) to barium hydroxide (a strong base) results in the formation of a precipitate. The net ionic equation for this reaction is

(A) $2\ H^+(aq) + 2\ OH^-(aq) \rightleftarrows 2\ H_2O(l)$

(B) $H_2SO_3(aq) + Ba^{2+}(aq) + 2\ OH^-(aq) \rightleftarrows BaSO_3(s) + 2\ H_2O(l)$

(C) $2\ H^+(aq) + SO_3{}^{2-}(aq) + Ba^{2+}(aq) + 2\ OH^-(aq) \rightleftarrows BaSO_3(s) + 2\ H_2O(l)$

(D) $H_2SO_3(aq) + Ba^{2+}(aq) + 2\ OH^-(aq) \rightleftarrows Ba^{2+}(aq) + SO_3{}^{2-}(aq) + 2\ H_2O(l)$

(E) $H_2SO_3(aq) + Ba(OH)_2(aq) \rightleftarrows BaSO_3(s) + 2\ H_2O(l)$

GO ON TO THE NEXT PAGE.

$\frac{1}{2}\ H_2(g) + \frac{1}{2}\ I_2(s) \rightarrow HI(g) \quad \Delta H = 26\ kJ/mol_{rxn}$

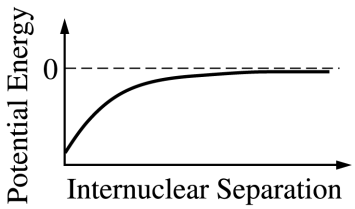
$\frac{1}{2}\ H_2(g) + \frac{1}{2}\ I_2(g) \rightarrow HI(g) \quad \Delta H = -5.0\ kJ/mol_{rxn}$

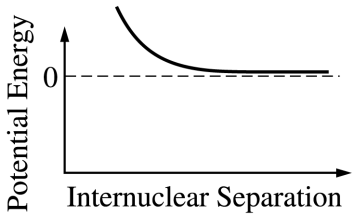
64. Based on the information above, what is the enthalpy change for the sublimation of iodine, represented below?

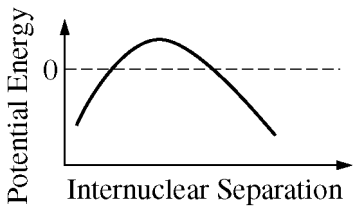
$$I_2(s) \rightarrow I_2(g)$$

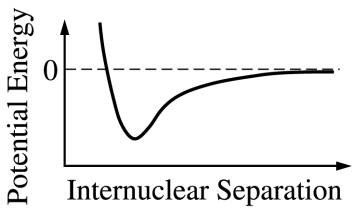
(A) 15 kJ/mol_{rxn}
(B) 21 kJ/mol_{rxn}
(C) 31 kJ/mol_{rxn}
(D) 42 kJ/mol_{rxn}
(E) 62 kJ/mol_{rxn}

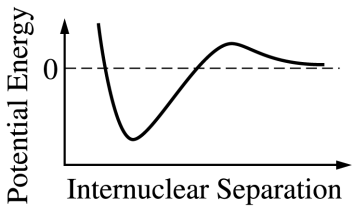
65. Which of the following graphs correctly shows the relationship between potential energy and internuclear separation for two hydrogen atoms?

(A)


(B)


(C)


(D)


(E)


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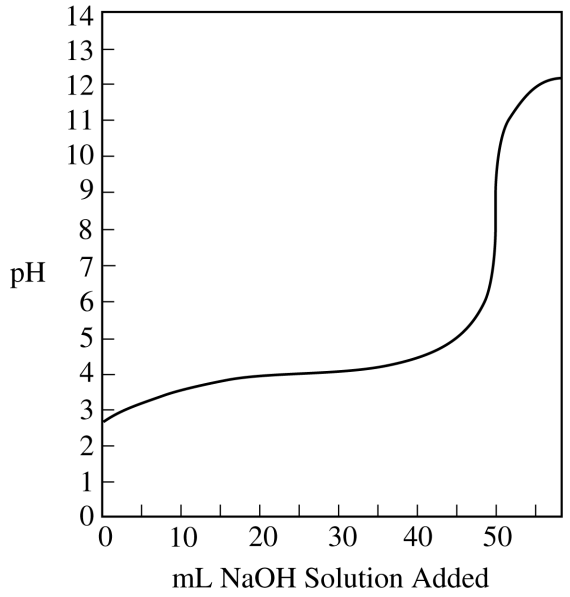
66. Which of the following compounds is LEAST likely to exist?

(A) PCl_5
(B) PBr_3
(C) NF_3
(D) NI_5
(E) SbF_5



67. The graph above shows the titration curve that resulted when a sample of 0.1 *M* monoprotic acid was titrated with a solution of NaOH. Based on the graph, the pK_a of the acid is closest to

(A) 3.0
(B) 4.0
(C) 6.0
(D) 8.0
(E) 12.0

68. The rate law for the reaction of nitrogen dioxide and chlorine is found to be rate = $k\,[NO_2]^2[Cl_2]$. By what factor does the rate of the reaction change when the concentrations of both NO_2 and Cl_2 are doubled?

(A) 2
(B) 3
(C) 4
(D) 6
(E) 8

69. When a student prepares an aqueous solution containing the five cations $Ag^+(aq)$, $Hg_2^{2+}(aq)$, $Cu^{2+}(aq)$, $Mn^{2+}(aq)$, and $Ba^{2+}(aq)$, the student observes that no precipitates form in the solution. Which of the following could be the identity of the anion in the solution?

(A) $Cl^-(aq)$
(B) $CO_3^{2-}(aq)$
(C) $CrO_4^{2-}(aq)$
(D) $NO_3^-(aq)$
(E) $SO_4^{2-}(aq)$

70. What is the molarity of $I^-(aq)$ in a solution that contains 34 g of SrI_2 (molar mass 341 g) in 1.0 L of the solution?

(A) 0.034 *M*
(B) 0.068 *M*
(C) 0.10 *M*
(D) 0.20 *M*
(E) 0.68 *M*

GO ON TO THE NEXT PAGE.

71. Which of the following compounds contains both ionic and covalent bonds?

(A) SO_3
(B) C_2H_5OH
(C) MgF_2
(D) H_2S
(E) NH_4Cl

72. Some pollutant gases in the atmosphere act as contributors to the formation of acid rain, a serious environmental problem. An example of such a gas is

(A) N_2
(B) O_2
(C) H_2O
(D) NO_2
(E) CH_4

$$2\ S(s) + 2\ O_2(g) \rightleftarrows 2\ SO_2(g) \quad K_1 = 2 \times 10^{105}$$

$$2\ SO_2(g) + O_2(g) \rightleftarrows 2\ SO_3(g) \quad K_2 = 7 \times 10^{24}$$

73. Given the value of the equilibrium constants K_1 and K_2 for the reactions represented above, what is the value of the equilibrium constant, K_3, for the following reaction?

$$2\ S(s) + 3\ O_2(g) \rightleftarrows 2\ SO_3(g) \quad K_3 = ?$$

(A) 1×10^{130}
(B) 3×10^{80}
(C) 1×10^{65}
(D) 2×10^{40}
(E) 7×10^{24}

GO ON TO THE NEXT PAGE.

74. Which of the following molecules is nonpolar but has polar covalent bonds?

(A) N_2
(B) H_2O_2
(C) H_2O
(D) CCl_4
(E) CH_2Cl_2

75. A 0.10 *M* solution of which of the following salts is most basic?

(A) $LiNO_3$
(B) Na_2SO_4
(C) $CaCl_2$
(D) $Al(NO_3)_3$
(E) K_2CO_3

END OF SECTION I

**IF YOU FINISH BEFORE TIME IS CALLED,
YOU MAY CHECK YOUR WORK ON THIS SECTION.**

DO NOT GO ON TO SECTION II UNTIL YOU ARE TOLD TO DO SO.

MAKE SURE YOU HAVE DONE THE FOLLOWING.

- **PLACED YOUR AP NUMBER LABEL ON YOUR ANSWER SHEET**
- **WRITTEN AND GRIDDED YOUR AP NUMBER CORRECTLY ON YOUR ANSWER SHEET**
- **TAKEN THE AP EXAM LABEL FROM THE FRONT OF THIS BOOKLET AND PLACED IT ON YOUR ANSWER SHEET**

GO ON TO THE NEXT PAGE.

Section II: Free-Response Questions

This is the free-response section of the 2012 AP exam. It includes cover material and other administrative instructions to help familiarize students with the mechanics of the exam. (Note that future exams may differ in look from the following content.)

AP® Chemistry Exam

SECTION II: Free Response

2012

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.

At a Glance

Total Time
1 hour, 35 minutes
Number of Questions
6
Percent of Total Score
50%
Writing Instrument
Either pencil or pen with black or dark blue ink

Part A

Number of Questions
3
Time
55 minutes
Electronic Device
Calculator allowed
Percent of Section II Score
Question 1 — 20%
Question 2 — 20%
Question 3 — 20%

Part B

Number of Questions
3
Time
40 minutes
Electronic Device
None allowed
Percent of Section II Score
Question 4 — 10%
Question 5 — 15%
Question 6 — 15%

IMPORTANT Identification Information

PLEASE PRINT WITH PEN:

1. First two letters of your last name ☐☐
   First letter of your first name ☐
2. Date of birth
   ☐☐ Month ☐☐ Day ☐☐☐☐ Year
3. Six-digit school code
   ☐☐☐☐☐☐
4. Unless I check the box below, I grant the College Board the unlimited right to use, reproduce, and publish my free-response materials, both written and oral, for educational research and instructional purposes. My name and the name of my school will not be used in any way in connection with my free-response materials. I understand that I am free to mark "No" with no effect on my score or its reporting.
   No, I do not grant the College Board these rights. ☐

Instructions

The questions for Part A and Part B are printed in this booklet. Pages containing a periodic table, reduction potentials, and lists containing equations and constants are also printed in this booklet.

The proctor will announce the times for Part A and Part B; you may not begin working on Part B until the proctor tells you to do so. However, you may proceed freely from one question to the next within each part.

You may use the pages that the questions are printed on to organize your answers or for scratch work, but you must write your answers in the areas designated for each response.

Write clearly and legibly. Cross out any errors you make; erased or crossed-out work will not be scored. Manage your time carefully. Do not spend too much time on any one question. If you finish Part B before time is called, you may go back to Part A, but you may NOT use a calculator.

INFORMATION IN THE TABLE BELOW AND IN THE TABLES ON PAGES 3-5 MAY BE USEFUL IN ANSWERING THE QUESTIONS IN THIS SECTION OF THE EXAMINATION.

DO NOT DETACH FROM BOOK.

PERIODIC TABLE OF THE ELEMENTS

1 **H** 1.008																	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.30											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.91	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57 ***La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.02	89 **†Ac** 227.03	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (271)	111 **Rg** (272)							

*Lanthanide Series	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
†Actinide Series	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

GO ON TO THE NEXT PAGE.

STANDARD REDUCTION POTENTIALS IN AQUEOUS SOLUTION AT 25°C

Half-reaction			$E°$(V)
$F_2(g) + 2e^-$	→	$2F^-$	2.87
$Co^{3+} + e^-$	→	Co^{2+}	1.82
$Au^{3+} + 3e^-$	→	$Au(s)$	1.50
$Cl_2(g) + 2e^-$	→	$2Cl^-$	1.36
$O_2(g) + 4H^+ + 4e^-$	→	$2H_2O(l)$	1.23
$Br_2(l) + 2e^-$	→	$2Br^-$	1.07
$2Hg^{2+} + 2e^-$	→	Hg_2^{2+}	0.92
$Hg^{2+} + 2e^-$	→	$Hg(l)$	0.85
$Ag^+ + e^-$	→	$Ag(s)$	0.80
$Hg_2^{2+} + 2e^-$	→	$2Hg(l)$	0.79
$Fe^{3+} + e^-$	→	Fe^{2+}	0.77
$I_2(s) + 2e^-$	→	$2I^-$	0.53
$Cu^+ + e^-$	→	$Cu(s)$	0.52
$Cu^{2+} + 2e^-$	→	$Cu(s)$	0.34
$Cu^{2+} + e^-$	→	Cu^+	0.15
$Sn^{4+} + 2e^-$	→	Sn^{2+}	0.15
$S(s) + 2H^+ + 2e^-$	→	$H_2S(g)$	0.14
$2H^+ + 2e^-$	→	$H_2(g)$	0.00
$Pb^{2+} + 2e^-$	→	$Pb(s)$	−0.13
$Sn^{2+} + 2e^-$	→	$Sn(s)$	−0.14
$Ni^{2+} + 2e^-$	→	$Ni(s)$	−0.25
$Co^{2+} + 2e^-$	→	$Co(s)$	−0.28
$Cd^{2+} + 2e^-$	→	$Cd(s)$	−0.40
$Cr^{3+} + e^-$	→	Cr^{2+}	−0.41
$Fe^{2+} + 2e^-$	→	$Fe(s)$	−0.44
$Cr^{3+} + 3e^-$	→	$Cr(s)$	−0.74
$Zn^{2+} + 2e^-$	→	$Zn(s)$	−0.76
$2H_2O(l) + 2e^-$	→	$H_2(g) + 2OH^-$	−0.83
$Mn^{2+} + 2e^-$	→	$Mn(s)$	−1.18
$Al^{3+} + 3e^-$	→	$Al(s)$	−1.66
$Be^{2+} + 2e^-$	→	$Be(s)$	−1.70
$Mg^{2+} + 2e^-$	→	$Mg(s)$	−2.37
$Na^+ + e^-$	→	$Na(s)$	−2.71
$Ca^{2+} + 2e^-$	→	$Ca(s)$	−2.87
$Sr^{2+} + 2e^-$	→	$Sr(s)$	−2.89
$Ba^{2+} + 2e^-$	→	$Ba(s)$	−2.90
$Rb^+ + e^-$	→	$Rb(s)$	−2.92
$K^+ + e^-$	→	$K(s)$	−2.92
$Cs^+ + e^-$	→	$Cs(s)$	−2.92
$Li^+ + e^-$	→	$Li(s)$	−3.05

GO ON TO THE NEXT PAGE.

ATOMIC STRUCTURE

$$E = h\nu \qquad c = \lambda\nu$$

$$\lambda = \frac{h}{m\upsilon} \qquad p = m\upsilon$$

$$E_n = \frac{-2.178 \times 10^{-18}}{n^2} \text{ joule}$$

EQUILIBRIUM

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

$$K_b = \frac{[OH^-][HB^+]}{[B]}$$

$$K_w = [OH^-][H^+] = 1.0 \times 10^{-14} \text{ @ } 25^\circ\text{C}$$
$$= K_a \times K_b$$

$$pH = -\log[H^+], \; pOH = -\log[OH^-]$$

$$14 = pH + pOH$$

$$pH = pK_a + \log\frac{[A^-]}{[HA]}$$

$$pOH = pK_b + \log\frac{[HB^+]}{[B]}$$

$$pK_a = -\log K_a, \; pK_b = -\log K_b$$

$$K_p = K_c(RT)^{\Delta n},$$

where Δn = moles product gas − moles reactant gas

THERMOCHEMISTRY/KINETICS

$$\Delta S^\circ = \sum S^\circ \text{ products} - \sum S^\circ \text{ reactants}$$

$$\Delta H^\circ = \sum \Delta H_f^\circ \text{ products} - \sum \Delta H_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \sum \Delta G_f^\circ \text{ products} - \sum \Delta G_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$
$$= -RT\ln K = -2.303RT\log K$$
$$= -n\mathcal{F}E^\circ$$

$$\Delta G = \Delta G^\circ + RT\ln Q = \Delta G^\circ + 2.303RT\log Q$$

$$q = mc\Delta T$$

$$C_p = \frac{\Delta H}{\Delta T}$$

$$\ln[A]_t - \ln[A]_0 = -kt$$

$$\frac{1}{[A]_t} - \frac{1}{[A]_0} = kt$$

$$\ln k = \frac{-E_a}{R}\left(\frac{1}{T}\right) + \ln A$$

E = energy
υ = velocity
ν = frequency
n = principal quantum number
λ = wavelength
m = mass
p = momentum

Speed of light, $c = 3.0 \times 10^8$ m s^{-1}

Planck's constant, $h = 6.63 \times 10^{-34}$ J s

Boltzmann's constant, $k = 1.38 \times 10^{-23}$ J K^{-1}

Avogadro's number $= 6.022 \times 10^{23}$ mol^{-1}

Electron charge, $e = -1.602 \times 10^{-19}$ coulomb

1 electron volt per atom = 96.5 kJ mol^{-1}

Equilibrium Constants

K_a (weak acid)
K_b (weak base)
K_w (water)
K_p (gas pressure)
K_c (molar concentrations)

S° = standard entropy
H° = standard enthalpy
G° = standard free energy
E° = standard reduction potential
T = temperature
n = moles
m = mass
q = heat
c = specific heat capacity
C_p = molar heat capacity at constant pressure
E_a = activation energy
k = rate constant
A = frequency factor

Faraday's constant, $\mathcal{F}$ = 96,500 coulombs per mole of electrons

Gas constant, R = 8.31 J mol^{-1} K^{-1}
= 0.0821 L atm mol^{-1} K^{-1}
= 62.4 L torr mol^{-1} K^{-1}
= 8.31 volt coulomb mol^{-1} K^{-1}

GO ON TO THE NEXT PAGE.

GASES, LIQUIDS, AND SOLUTIONS

$$PV = nRT$$

$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

$$P_A = P_{total} \times X_A, \text{where } X_A = \frac{\text{moles A}}{\text{total moles}}$$

$$P_{total} = P_A + P_B + P_C + \ldots$$

$$n = \frac{m}{\boldsymbol{M}}$$

$$\text{K} = {}^\circ\text{C} + 273$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$D = \frac{m}{V}$$

$$u_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{\boldsymbol{M}}}$$

$$KE \text{ per molecule} = \frac{1}{2} m\upsilon^2$$

$$KE \text{ per mole} = \frac{3}{2} RT$$

$$\frac{r_1}{r_2} = \sqrt{\frac{\boldsymbol{M}_2}{\boldsymbol{M}_1}}$$

molarity, M = moles solute per liter solution

molality = moles solute per kilogram solvent

$$\Delta T_f = iK_f \times \text{molality}$$

$$\Delta T_b = iK_b \times \text{molality}$$

$$\pi = iMRT$$

$$A = abc$$

OXIDATION-REDUCTION; ELECTROCHEMISTRY

$$Q = \frac{[\text{C}]^c\,[\text{D}]^d}{[\text{A}]^a\,[\text{B}]^b}, \text{ where } a\,\text{A} + b\,\text{B} \rightarrow c\,\text{C} + d\,\text{D}$$

$$I = \frac{q}{t}$$

$$E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{RT}{n\mathcal{F}} \ln Q = E^\circ_{\text{cell}} - \frac{0.0592}{n} \log Q \ @\ 25^\circ\text{C}$$

$$\log K = \frac{nE^\circ}{0.0592}$$

P = pressure
V = volume
T = temperature
n = number of moles
D = density
m = mass
υ = velocity

u_{rms} = root-mean-square speed
KE = kinetic energy
r = rate of effusion
$\boldsymbol{M}$ = molar mass
π = osmotic pressure
i = van't Hoff factor
K_f = molal freezing-point depression constant
K_b = molal boiling-point elevation constant
A = absorbance
a = molar absorptivity
b = path length
c = concentration
Q = reaction quotient
I = current (amperes)
q = charge (coulombs)
t = time (seconds)
E° = standard reduction potential
K = equilibrium constant

Gas constant, R = 8.31 J mol^{-1} K^{-1}
= 0.0821 L atm mol^{-1} K^{-1}
= 62.4 L torr mol^{-1} K^{-1}
= 8.31 volt coulomb mol^{-1} K^{-1}

Boltzmann's constant, k = 1.38×10^{-23} J K^{-1}

K_f for H_2O = 1.86 K kg mol^{-1}

K_b for H_2O = 0.512 K kg mol^{-1}

1 atm = 760 mm Hg
= 760 torr

STP = 0.00 °C and 1.0 atm

Faraday's constant, $\mathcal{F}$ = 96,500 coulombs per mole of electrons

GO ON TO THE NEXT PAGE.

CHEMISTRY

Section II

(Total time—95 minutes)

Part A

Time—55 minutes

YOU MAY USE YOUR CALCULATOR FOR PART A.

CLEARLY SHOW THE METHOD USED AND THE STEPS INVOLVED IN ARRIVING AT YOUR ANSWERS. It is to your advantage to do this, since you may obtain partial credit if you do and you will receive little or no credit if you do not. Attention should be paid to significant figures. Be sure to write all your answers to the questions on the lined pages following each question in this booklet.

Answer Questions 1, 2, and 3. The Section II score weighting for each question is 20 percent.

$$CH_3NH_2(aq) + H_2O(l) \rightleftarrows CH_3NH_3^+(aq) + OH^-(aq) \qquad K_b = 4.4 \times 10^{-4}$$

1. Methylamine, CH_3NH_2, is a weak base that reacts with water according to the equation above. A student obtains a 50.0 mL sample of a methylamine solution and determines the pH of the solution to be 11.77.

   (a) Write the expression for the equilibrium constant, K_b, for methylamine.

   (b) Calculate the molar concentration of OH^- in the 50.0 mL sample of the methylamine solution.

   (c) Calculate the initial molar concentration of $CH_3NH_2(aq)$ in the solution before it reacted with water and equilibrium was established.

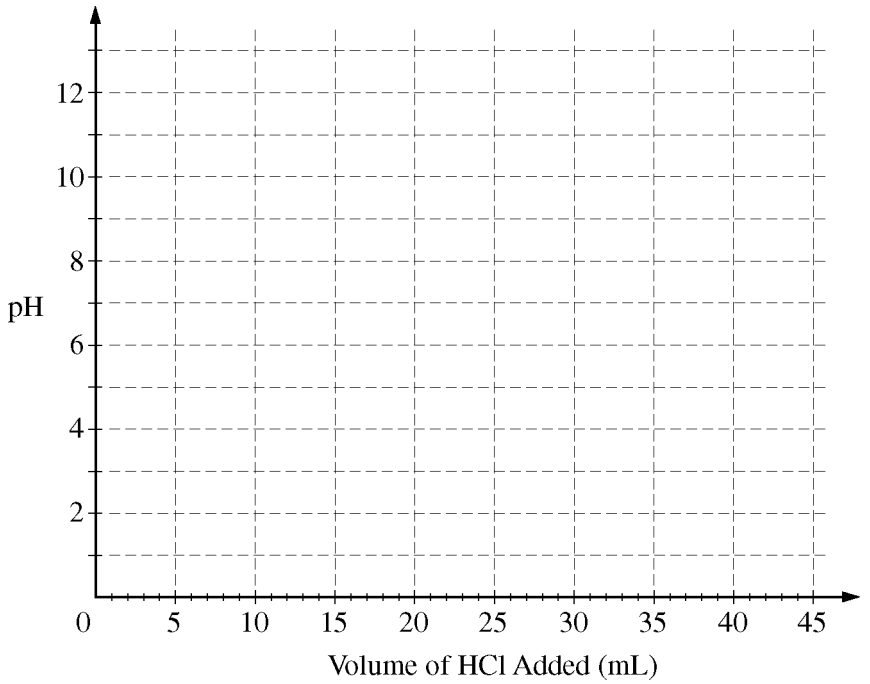
   The 50.0 mL sample of the methylamine solution is titrated with an HCl solution of unknown concentration. The equivalence point of the titration is reached after a volume of 36.0 mL of the HCl solution is added. The pH of the solution at the equivalence point is 5.98.

   (d) Write the net-ionic equation that represents the reaction that takes place during the titration.

   (e) Calculate the concentration of the HCl solution used to titrate the methylamine.

   (f) Using the axes provided, sketch the titration curve that results from the titration described above. On the graph, clearly label the equivalence point of the titration.

GO ON TO THE NEXT PAGE.



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ADDITIONAL PAGE FOR ANSWERING QUESTION 1

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ADDITIONAL PAGE FOR ANSWERING QUESTION 1

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$$Mg(s) + 2\ H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$$

2. A student performs an experiment to determine the volume of hydrogen gas produced when a given mass of magnesium reacts with excess $HCl(aq)$, as represented by the net ionic equation above. The student begins with a 0.0360 g sample of pure magnesium and a solution of 2.0 *M* $HCl(aq)$.

   (a) Calculate the number of moles of magnesium in the 0.0360 g sample.

   (b) Calculate the number of moles of $HCl(aq)$ needed to react completely with the sample of magnesium.

   As the magnesium reacts, the hydrogen gas produced is collected by water displacement at 23.0°C. The pressure of the gas in the collection tube is measured to be 749 torr.

   (c) Given that the equilibrium vapor pressure of water is 21 torr at 23.0°C, calculate the pressure that the $H_2(g)$ produced in the reaction would have if it were dry.

   (d) Calculate the volume, in liters measured at the conditions in the laboratory, that the $H_2(g)$ produced in the reaction would have if it were dry.

   (e) The laboratory procedure specified that the concentration of the HCl solution be 2.0 *M*, but only 12.3 *M* HCl solution was available. Describe the steps for safely preparing 50.0 mL of 2.0 *M* $HCl(aq)$ using 12.3 *M* HCl solution and materials selected from the list below. Show any necessary calculation(s).

10.0 mL graduated cylinder	Distilled water
250 mL beakers	Balance
50.00 mL volumetric flask	Dropper

ADDITIONAL PAGE FOR ANSWERING QUESTION 2

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ADDITIONAL PAGE FOR ANSWERING QUESTION 2

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ADDITIONAL PAGE FOR ANSWERING QUESTION 2

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$$CaSO_4 \cdot 2H_2O(s) \rightleftarrows CaSO_4(s) + 2\,H_2O(g)$$

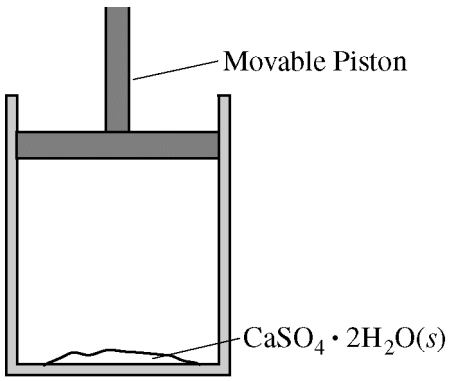
3. The hydrate $CaSO_4 \cdot 2H_2O(s)$ can be heated to form the anhydrous salt, $CaSO_4(s)$, as shown by the reaction represented above.

   (a) Using the data in the table below, calculate the value of $\Delta G°$, in kJ/mol_{rxn}, for the reaction at 298 K.

Substance	ΔG_f° at 298 K (kJ/mol)
$CaSO_4 \cdot 2H_2O(s)$	−1795.70
$CaSO_4(s)$	−1320.30
$H_2O(g)$	−228.59

   (b) Given that the value of $\Delta H°$ for the reaction at 298 K is +105 kJ/mol_{rxn}, calculate the value of $\Delta S°$ for the reaction at 298 K. Include units with your answer.

A sample of $CaSO_4 \cdot 2H_2O(s)$ is placed in a cylinder with a movable piston as shown in the diagram below. The air above the solid is at 1.00 atm and is initially dry (partial pressure of $H_2O(g)$ = 0 atm).



   (c) Write the expression for the equilibrium constant, K_p, for the reaction.

   (d) Given that the equilibrium constant, K_p, is 6.4×10^{-4} at 298 K, determine the partial pressure, in atm, of water vapor in the cylinder at equilibrium at 298 K.

   (e) If the volume of the system is reduced to one-half of its original volume and the system is allowed to reestablish equilibrium at 298 K, what will be the pressure, in atm, of the water vapor at the new volume? Justify your answer.

In the laboratory, the hydrate $CaSO_4 \cdot 2H_2O(s)$ can be heated in a crucible to completely drive off the water of hydration to form the anhydrous salt, $CaSO_4(s)$.

   (f) A 2.49 g sample of pure $CaSO_4 \cdot 2H_2O(s)$ is heated several times until the mass is constant. Calculate the mass, in grams, of the solid that remains after the dehydration reaction is complete.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 3

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ADDITIONAL PAGE FOR ANSWERING QUESTION 3

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ADDITIONAL PAGE FOR ANSWERING QUESTION 3

S T O P

If you finish before time is called, you may check your work on this part only.
Do not turn to the other part of the test until you are told to do so.

CHEMISTRY

Part B

Time—40 minutes

NO CALCULATORS MAY BE USED FOR PART B.

Answer Question 4 below. The Section II score weighting for this question is 10 percent.

4. For each of the following three reactions, in part (i) write a balanced equation for the reaction and in part (ii) answer the question about the reaction. In part (i), coefficients should be in terms of lowest whole numbers. Assume that solutions are aqueous unless otherwise indicated. Represent substances in solutions as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. You may use the empty space at the bottom of the next page for scratch work, but only equations that are written in the answer boxes provided will be scored.

EXAMPLE:

A strip of magnesium metal is added to a solution of silver(I) nitrate.

(i) Balanced equation:

$$Mg + 2\,Ag^{+} \longrightarrow Mg^{2+} + 2\,Ag$$

(ii) Which substance is oxidized in the reaction?

Mg is oxidized.

(a) Solutions of ethanoic (acetic) acid and lithium hydroxide are combined.

(i) Balanced equation:

(ii) If the ethanoic acid is titrated with the lithium hydroxide, is the pH at the equivalence point equal to 7, less than 7, or greater than 7? Explain.

(b) Solutions of iron(III) chloride and tin(II) chloride are combined.

(i) Balanced equation:

(ii) Identify the species that is reduced in the reaction.

_____

_____

(c) Solutions of silver(I) nitrate and sodium phosphate are combined, forming a precipitate.

(i) Balanced equation:

(ii) If 5 mol of silver(I) nitrate and 3 mol of sodium phosphate react as completely as possible, which reactant, if any, is present in excess? Justify your answer.

_____

_____

_____

YOU MAY USE THE SPACE BELOW FOR SCRATCH WORK, BUT ONLY EQUATIONS THAT ARE WRITTEN IN THE ANSWER BOXES PROVIDED WILL BE SCORED.

Answer Question 5 and Question 6. The Section II score weighting for these questions is 15 percent each.

Your responses to these questions will be scored on the basis of the accuracy and relevance of the information cited. Explanations should be clear and well organized. Examples and equations may be included in your responses where appropriate. Specific answers are preferable to broad, diffuse responses.

$$2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(g)$$

5. The decomposition of hydrogen peroxide to form water and oxygen gas is represented by the equation above. A proposed mechanism for the reaction, which involves the free radicals $HO\bullet$ and $HOO\bullet$, is represented by the three equations below.

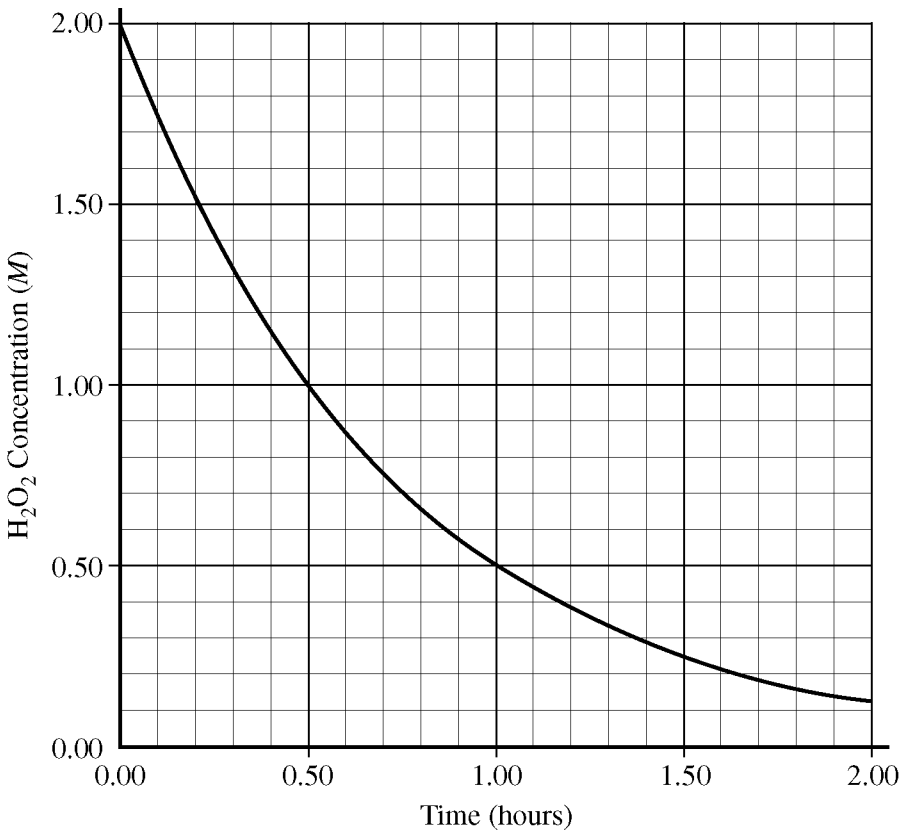
$$H_2O_2 \rightarrow 2\ HO\bullet \qquad (slow)$$

$$H_2O_2 + HO\bullet \rightarrow H_2O + HOO\bullet \qquad (fast)$$

$$HOO\bullet + HO\bullet \rightarrow H_2O + O_2 \qquad (fast)$$

(a) Write the rate law consistent with the proposed mechanism above.

(b) The rate of the decomposition reaction was studied in an experiment, and the resulting data were plotted in the graph below.



Using the graph, determine the time, in hours, needed for the concentration of H_2O_2 to change from

(i) 1.50 *M* to 0.75 *M*

(ii) 0.80 *M* to 0.40 *M*

(c) The experimental data are consistent with the proposed mechanism. Explain.

An electrochemical cell based on the decomposition of H_2O_2 can be constructed based on the half-reactions in the table below.

Half-Reaction	Standard Reduction Potential, $E°$
$H_2O_2 + 2\,e^- \rightarrow 2\,OH^-$	0.88 V
$O_2 + 2\,H_2O + 2\,e^- \rightarrow H_2O_2 + 2\,OH^-$	–0.15 V

(d) Calculate the value of the standard cell potential, $E°$, for the cell.

(e) Indicate whether $\Delta G°$ for the decomposition reaction is greater than 0, less than 0, or equal to 0. Justify your answer.

(f) The decomposition of $H_2O_2(aq)$ is slow at 298 K, but a suitable catalyst greatly increases the rate of the decomposition reaction.

(i) Draw a circle around each of the quantities below that has a different value for the catalyzed reaction than for the uncatalyzed reaction.

K_{eq} $\Delta G°$ $\Delta H°$ E_a

(ii) For any quantity that you circled above, indicate whether its value is greater or less for the catalyzed reaction than for the uncatalyzed reaction. Explain why.

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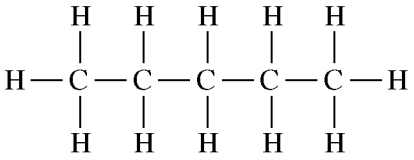
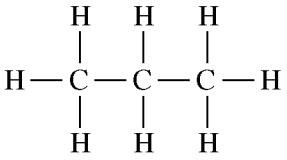
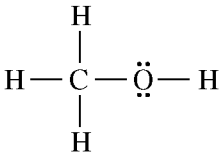
6. Answer the following questions in terms of principles of chemical bonding and intermolecular forces. In each explanation where a comparison is to be made, a complete answer must include a discussion of both substances. The following complete Lewis electron-dot diagrams may be useful in answering parts of this question.



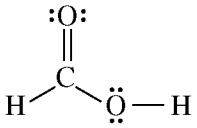
Pentane



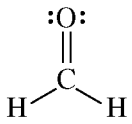
Propane



Methanol



Methanoic (formic) acid



Methanal (formaldehyde)

(a) At 1 atm and 298 K, pentane is a liquid whereas propane is a gas. Explain.

(b) At 1 atm and 298 K, methanol is a liquid whereas propane is a gas. Explain.

(c) Indicate the hybridization of the carbon atom in each of the following:

(i) Methanol

(ii) Methanoic (formic) acid

(d) Draw the complete Lewis electron-dot diagram for a molecule of propanoic acid, $HC_3H_5O_2$.

(e) Explain the following observations about the two carbon-oxygen bonds in the methanoate (formate) anion, HCO_2^-. You may draw a Lewis electron-dot diagram (or diagrams) of the methanoate ion as part of your explanations.

(i) The two carbon-oxygen bonds in the methanoate (formate) anion, HCO_2^-, have the same length.

(ii) The length of the carbon-oxygen bonds in the methanoate (formate) anion, HCO_2^-, is intermediate between the length of the carbon-oxygen bond in methanol and the length of the carbon-oxygen bond in methanal.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 6

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STOP

END OF EXAM

IF YOU FINISH PART B OF SECTION II BEFORE TIME IS CALLED, YOU MAY RETURN TO PART A OF SECTION II IF YOU WISH, BUT YOU MAY NOT USE A CALCULATOR.

THE FOLLOWING INSTRUCTIONS APPLY TO THE COVERS OF THE SECTION II BOOKLET.

- **MAKE SURE YOU HAVE COMPLETED THE IDENTIFICATION INFORMATION AS REQUESTED ON THE FRONT AND BACK COVERS OF THE SECTION II BOOKLET.**
- **CHECK TO SEE THAT YOUR AP NUMBER LABEL APPEARS IN THE BOX(ES) ON THE COVER(S).**
- **MAKE SURE YOU HAVE USED THE SAME SET OF AP NUMBER LABELS ON ALL AP EXAMS YOU HAVE TAKEN THIS YEAR.**

GO ON TO THE NEXT PAGE.

Multiple-Choice Answer Key

The following contains the answers to the multiple-choice questions in this exam.

Answer Key for AP Chemistry
Practice Exam, Section I

Multiple-Choice Questions	
Question #	**Key**
1	B
2	B
3	C
4	D
5	B
6	B
7	A
8	B
9	A
10	C
11	D
12	A
13	A
14	C
15	D
16	A
17	E
18	B
19	D
20	C
21	D
22	D
23	B
24	B
25	B
26	A
27	C
28	B
29	D
30	A
31	C
32	C
33	A
34	A
35	D
36	D
37	E
38	B
39	B
40	B
41	B
42	A
43	C
44	A
45	E
46	E
47	B
48	D
49	E
50	A
51	B
52	B
53	D
54	A
55	D
56	D
57	A
58	D
59	E
60	B
61	D
62	E
63	B
64	E
65	D
66	D
67	B
68	E
69	D
70	D
71	E
72	D
73	A
74	D
75	E

Free-Response Scoring Guidelines

The following contains the scoring guidelines for the free-response questions in this exam.

AP® CHEMISTRY 2012 SCORING GUIDELINES (INTERNATIONAL)

Question 1

$$CH_3NH_2(aq) + H_2O(l) \rightleftarrows CH_3NH_3^+(aq) + OH^-(aq) \qquad K_b = 4.4 \times 10^{-4}$$

Methylamine, CH_3NH_2, is a weak base that reacts with water according to the equation above. A student obtains a 50.0 mL sample of a methylamine solution and determines the pH of the solution to be 11.77.

(a) Write the expression for the equilibrium constant, K_b, for methylamine.

$K_b = \dfrac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2]}$	One point is earned for the correct expression.

(b) Calculate the molar concentration of OH^- in the 50.0 mL sample of the methylamine solution.

pH = 11.77 $[H^+] = 10^{-11.77} = 1.7 \times 10^{-12}$ $[OH^-] = \dfrac{K_w}{[H^+]} = \dfrac{1.0 \times 10^{-14}}{1.7 \times 10^{-12}} = 5.9 \times 10^{-3}$ ***OR*** pOH = 14 – pH = 2.23 $[OH^-] = 10^{-2.23} = 5.9 \times 10^{-3}$	One point is earned for correct $[OH^-]$.

(c) Calculate the initial molar concentration of $CH_3NH_2(aq)$ in the solution before it reacted with water and equilibrium was established.

$K_b = \dfrac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2]}$ $4.4 \times 10^{-4} = \dfrac{(5.9 \times 10^{-3})(5.9 \times 10^{-3})}{(x - 5.9 \times 10^{-3})}$ $x =$ **0.085 *M***	One point is earned for $[CH_3NH_3^+] = [OH^-]$. One point is earned for the correct initial molar concentration. Note: An approximated molar concentration does *not* earn the second point.

Question 1 (continued)

The 50.0 mL sample of the methylamine solution is titrated with an HCl solution of unknown concentration. The equivalence point of the titration is reached after a volume of 36.0 mL of the HCl solution is added. The pH of the solution at the equivalence point is 5.98.

(d) Write the net-ionic equation that represents the reaction that takes place during the titration.

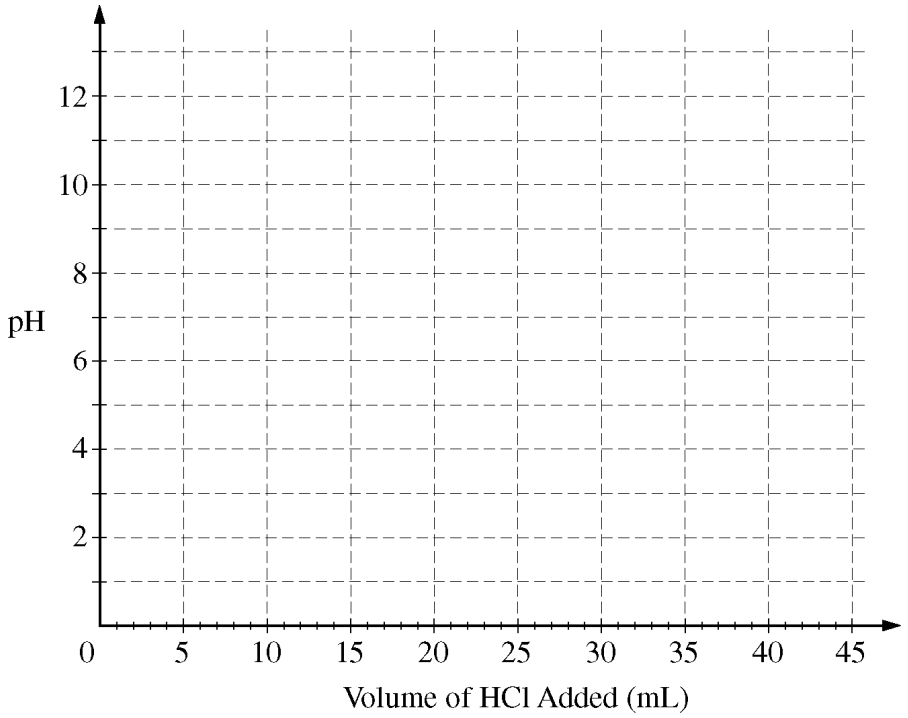
$CH_3NH_2 + H_3O^+ \rightarrow CH_3NH_3^+ + H_2O$ ***OR*** $CH_3NH_2 + H^+ \rightarrow CH_3NH_3^+$	One point is earned for a correct equation.

(e) Calculate the concentration of the HCl solution used to titrate the methylamine.

$\frac{0.085 \text{ mol}}{1000. \text{ mL}} \times 50.0 \text{ mL} = 0.00425 \text{ mol } CH_3NH_2$ $\frac{0.00425 \text{ mol HCl}}{36.0 \text{ mL}} \times \frac{1000. \text{ mL}}{1.000 \text{ L}} =$ **0.12 *M***	One point is earned for equal moles of acid and base. One point is earned for the correct concentration.

Question 1 (continued)

(f) Using the axes provided, sketch the titration curve that results from the titration described above. On the graph, clearly label the equivalence point of the titration.



One point is earned for a curve starting at a pH between 11 and 12.

One point is earned for labeling the equivalence point at V = ~36.0 mL HCl and a pH of ~5.98 .

One point is earned for general shape of the curve for a weak acid/strong base titration.

Question 2

$$Mg(s) + 2\ H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$$

A student performs an experiment to determine the volume of hydrogen gas produced when a given mass of magnesium reacts with excess $HCl(aq)$, as represented by the net ionic equation above. The student begins with a 0.0360 g sample of pure magnesium and a solution of 2.0 M $HCl(aq)$.

(a) Calculate the number of moles of magnesium in the 0.0360 g sample.

$\frac{1 \text{ mol Mg}}{24.30 \text{ g Mg}} \times 0.0360 \text{ g} = 0.00148 \text{ mol Mg}$	One point is earned for the correct number of moles of Mg. Note: For errors in significant figures or mathematics, there is a 1 point deduction; For the entire question, only 1 point total can be deducted for each type of error.

(b) Calculate the number of moles of $HCl(aq)$ needed to react completely with the sample of magnesium.

$0.00148 \text{ mol Mg} \times \frac{2 \text{ mol H}^+}{1 \text{ mol Mg}} = 0.00296 \text{ mol HCl}$	One point is earned for the correct number of moles of HCl.

As the magnesium reacts, the hydrogen gas produced is collected by water displacement at 23.0°C. The barometric pressure in the lab is measured to be 749 torr.

(c) Given that the equilibrium vapor pressure of water is 21 torr at 23.0°C, calculate the pressure that the $H_2(g)$ produced in the reaction would have if it were dry.

$P = 749 \text{ torr} - 21 \text{ torr} = 728 \text{ torr}$	One point is earned for the correct pressure.

(d) Calculate the volume, in liters measured at the conditions in the laboratory, that the $H_2(g)$ produced in the reaction would have if it were dry.

$PV = nRT \Rightarrow V = \frac{nRT}{P}$ $728 \text{ torr} \times \frac{1 \text{ atm}}{760 \text{ torr}} = 0.958 \text{ atm}$ $V = \frac{(0.00148 \text{ mol H}_2)(0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1})(296 \text{ K})}{0.958 \text{ atm}}$ $= 0.0375 \text{ L}$	One point is earned for the correct moles of $H_2(g)$. One point is earned for agreement of units of P (from part(c)) and R. One point is earned for the correct temperature substitution and calculated volume.

Question 2 (continued)

(e) The laboratory procedure specified that the concentration of the HCl solution be 2.0 *M*, but only 12.3 *M* HCl solution was available. Describe the steps for safely preparing 50.0 mL of 2.0 *M* HCl(*aq*) using 12.3 *M* HCl solution and materials selected from the list below. Show any necessary calculation(s).

10.0 mL graduated cylinder	Distilled water
250 mL beakers	Balance
50.00 mL volumetric flask	Dropper

$\frac{2.0 \text{ mol HCl}}{1000. \text{ mL}} \times 50.0 \text{ mL} = 0.10 \text{ mol HCl}$ $\frac{1000. \text{ mL}}{12.3 \text{ mol HCl}} \times 0.10 \text{ mol HCl} = 8.1 \text{ mL}$ Pour some distilled water into the volumetric flask so it is about half full. Use the graduated cylinder to measure 8.1 mL of 12.3 *M* HCl and pour it into the volumetric flask. Add a few mL of distilled water to the graduated cylinder, swirl, and add the liquid to the volumetric flask. Swirl the flask to mix. Carefully add more distilled water to the flask, using the dropper for the last few mL to fill the flask to the mark with distilled water.	One point is earned for calculating the correct volume of 12.3 *M* HCl. One point is earned for adding acid to water in the dilution process. One point is earned for filling the volumetric to the 50.00 mL mark with distilled water.

Question 3

$$CaSO_4 \cdot 2H_2O(s) \rightleftarrows CaSO_4(s) + 2\ H_2O(g)$$

The hydrate $CaSO_4 \cdot 2H_2O(s)$ can be heated to form the anhydrous salt, $CaSO_4(s)$, as shown by the reaction represented above.

(a) Using the data in the table below, calculate the value of $\Delta G°$, in kJ mol^{-1}, for the reaction at 298 K.

Substance	ΔG_f° at 298 K (kJ mol^{-1})
$CaSO_4 \cdot 2H_2O(s)$	–1795.70
$CaSO_4(s)$	–1320.30
$H_2O(g)$	–228.59

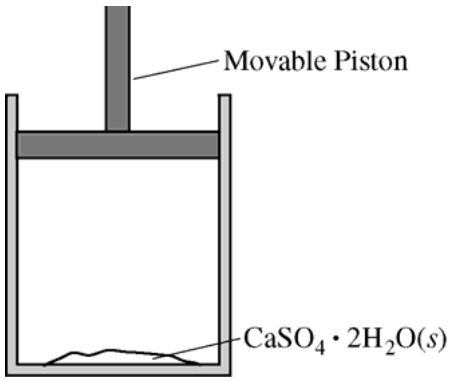
$\Delta G° = \Sigma \Delta G_{f\ products}^\circ - \Sigma \Delta G_{f\ reactants}^\circ$ $= -1320.30 + (2 \times -228.59) - (-1795.70 \text{ kJ mol}^{-1})$ $=$ **18.22 kJ mol^{-1}**	One point is earned for the mole factor for water. One point is earned for answer (units are optional)

(b) Given that the value of $\Delta H°$ for the reaction at 298 K is +105 kJ mol^{-1}, calculate the value of $\Delta S°$ for the reaction at 298 K. Include units with your answer.

$\Delta G° = \Delta H° - T\Delta S°$ $\Delta S° = \frac{\Delta H° - \Delta G°}{T} = \frac{(105 - 18.22) \text{ kJ mol}^{-1}}{298 \text{ K}}$ $=$ **0.29 kJ K^{-1} mol^{-1}** ***OR*** **290 J K^{-1} mol^{-1}**	One point is earned for the correct substitution of $\Delta G°$, $\Delta H°$, and T. One point is earned for the correct answer *with correct units*.

Question 3 (continued)

A sample of $CaSO_4 \cdot 2H_2O(s)$ is placed in a cylinder with a movable piston as shown in the diagram below. The air above the solid is at 1.00 atm and is initially dry (partial pressure of $H_2O(g) = 0$ atm).



(c) Write the expression for the equilibrium constant, K_p, for the reaction.

$K_p = (p_{H_2O})^2$	One point is earned for the correct expression (use of partial pressure only).

(d) Given that the equilibrium constant, K_p, is 6.4×10^{-4} at 298 K, determine the partial pressure, in atm, of water vapor in the cylinder at equilibrium at 298 K.

$K_p = (p_{H_2O})^2 \Rightarrow 6.4 \times 10^{-4}$ $p_{H_2O} = \sqrt{6.4 \times 10^{-4}} =$ **0.025 atm**	One point is earned for the correct partial pressure (units are not required).

(e) If the volume of the system is reduced to one-half of its original volume and the system is allowed to reestablish equilibrium at 298 K, what will be the pressure, in atm, of the water vapor at the new volume? Justify your answer.

The p_{H_2O} at equilibrium at the new volume will be 0.025 atm. Equilibrium vapor pressure is dependent on K_p, which in turn is a function of temperature, not volume. Because the temperature is still 298 K, the vapor pressure of H_2O remains 0.025 atm in the new volume.	One point is earned for the correct answer with justification.

Question 3 (continued)

In the laboratory, the hydrate $CaSO_4 \cdot 2H_2O(s)$ can be heated in a crucible to completely drive off the water of hydration to form the anhydrous salt, $CaSO_4(s)$.

(f) A 2.49 g sample of pure $CaSO_4 \cdot 2H_2O(s)$ is heated several times until the mass is constant. Calculate the mass, in grams, of the solid that remains after the dehydration reaction is complete.

molar mass of $CaSO_4 \cdot 2H_2O(s) = 172.172 \text{ g mol}^{-1}$ molar mass of $CaSO_4(s) = 136.14 \text{ g mol}^{-1}$ $2.49 \text{ g } CaSO_4 \cdot 2H_2O \times \frac{136.14 \text{ g } CaSO_4}{172.172 \text{ g } CaSO_4 \cdot 2H_2O} = 1.97 \text{ g } CaSO_4$	One point is earned for the (rounded) correct molar masses. One point is earned for an answer consistent with the molar masses.

Question 4

For each of the following three reactions, in part (i) write a balanced equation for the reaction and in part (ii) answer the question about the reaction. In part (i), coefficients should be in terms of lowest whole numbers. Assume that solutions are aqueous unless otherwise indicated. Represent substances in solutions as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. You may use the empty space at the bottom of the next page for scratch work, but only equations that are written in the answer boxes provided will be graded.

(a) Solutions of ethanoic (acetic) acid and lithium hydroxide are combined.

(i) Balanced equation: $HC_2H_3O_2 + OH^- \rightarrow C_2H_3O_2^- + H_2O$	One point is earned for the correct reactants. Two points are earned for the correct products. One point is earned for balancing the equation for mass and charge.

(ii) If the ethanoic acid is titrated with the lithium hydroxide, is the pH at the equivalence point equal to 7, less than 7, or greater than 7? Explain.

The pH will be greater than 7. $HC_2H_3O_2$ is a weak acid and LiOH is a strong base. At the equivalence point, the $C_2H_3O_2^-$ is the pH-determining species because of the reaction, $C_2H_3O_2^- + H_2O \rightleftarrows HC_2H_3O_2 + OH^-$.	One point is earned for the correct answer with an explanation.

(b) Solutions of iron(III) chloride and tin(II) chloride are combined.

(i) Balanced equation: $2\ Fe^{3+} + Sn^{2+} \rightarrow 2\ Fe^{2+} + Sn^{4+}$ ***OR*** $2\ Fe^{3+} + 3\ Sn^{2+} \rightarrow 2\ Fe + 3\ Sn^{4+}$	One point is earned for the correct reactants. Two points are earned for the correct products. One point is earned for balancing the equation for both mass and charge.

(ii) Identify the species that is reduced in the reaction.

Fe^{3+} is reduced.	One point is earned for correct answer.

Question 4 (continued)

(c) Solutions of silver(I) nitrate and sodium phosphate are combined, forming a precipitate.

(i) Balanced equation: $3\ Ag^+ + PO_4^{3-} \rightarrow Ag_3PO_4$	Two points are earned for the correct reactants. One point is earned for the correct product. One point is earned for balancing the equation for both mass and charge.

(ii) If 5 mol of silver(I) nitrate and 3 mol of sodium phosphate react as completely as possible, which reactant, if any, is present in excess? Justify your answer.

Nine moles of Ag^+ would be needed to react completely with the three moles of PO_4^{3-}, so sodium phosphate is present in excess.	One point is earned for a correct answer with reference to reactant data.

Question 5

$$2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(g)$$

The decomposition of hydrogen peroxide to form water and oxygen gas is represented by the equation above. A proposed mechanism for the reaction, which involves the free radicals $HO\cdot$ and $HOO\cdot$, is represented by the three equations below.

$$H_2O_2 \rightarrow 2\ HO\cdot \qquad (slow)$$

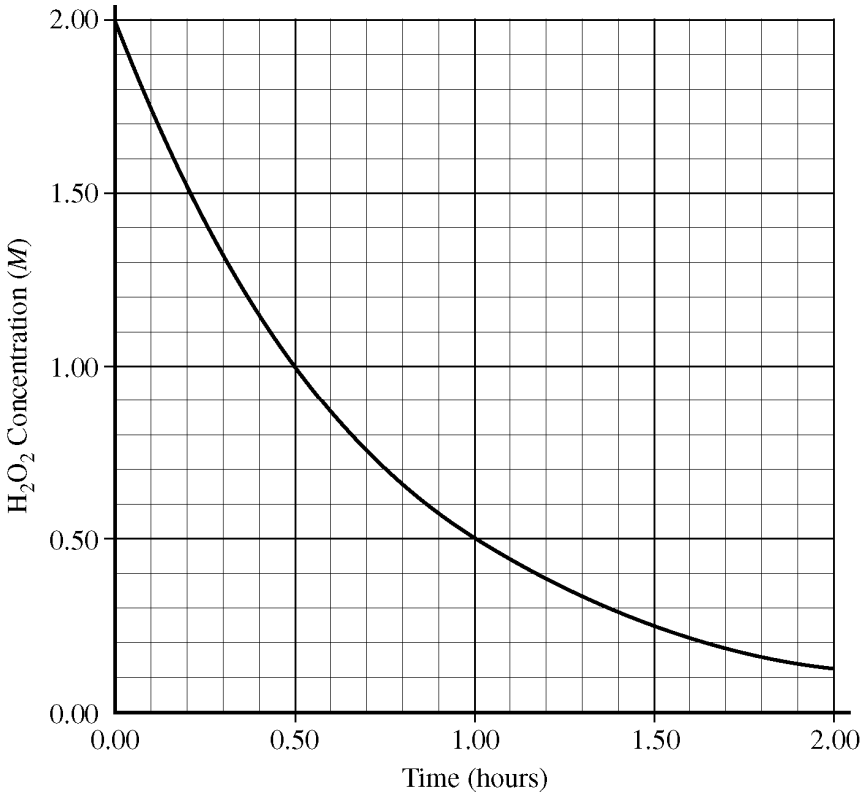
$$H_2O_2 + HO\cdot \rightarrow H_2O + HOO\cdot \qquad (fast)$$

$$HOO\cdot + HO\cdot \rightarrow H_2O + O_2 \qquad (fast)$$

(a) Write the rate law consistent with the proposed mechanism above.

rate = $k\ [H_2O_2]$	One point is earned for the correct rate law.

(b) The rate of the decomposition reaction was studied in an experiment, and the resulting data were plotted in the graph below.



Question 5 (continued)

Using the graph, determine the time, in hours, needed for the concentration of H_2O_2 to change from

(i) 1.50 *M* to 0.75 *M*

Time = 0.71 – 0.21 = 0.50 ± 0.05 hour	One point is earned for the correct time.

(ii) 0.80 *M* to 0.40 *M*

Time = 1.17 – 0.66 = 0.51 ± 0.05 hour	One point is earned for the correct time.

(c) The experimental data are consistent with the proposed mechanism. Explain.

The data show that the time remains constant when the concentration of the reactant decreases by one-half, indicating that the reaction is first order. The rate law for the proposed mechanism has $[H_2O_2]$ to the first power, indicating a first-order reaction.	One point is earned for a correct explanation.

An electrochemical cell based on the decomposition of H_2O_2 can be constructed based on the half-reactions in the table below.

Half-Reaction	**Standard Reduction Potential, $E°$**
$H_2O_2 + 2\,e^- \rightarrow 2\,OH^-$	0.88 V
$O_2 + 2\,H_2O + 2\,e^- \rightarrow H_2O_2 + 2\,OH^-$	–0.15 V

(d) Calculate the value of the standard cell potential, $E°$, for the cell.

$H_2O_2 + 2\,OH^- \rightarrow O_2 + 2\,H_2O + 2\,e^-$ 0.15 V $H_2O_2 + 2\,e^- \rightarrow 2\,OH^-$ 0.88 V ——————————— $2\,H_2O_2 \rightarrow 2\,H_2O + O_2$ 1.03 V	One point is earned for the correct value of $E°$.

Question 5 (continued)

(e) Indicate whether $\Delta G°$ for the decomposition reaction is greater than 0, less than 0, or equal to 0. Justify your answer.

$\Delta G°$ is less than 0. $\Delta G° = -nFE°$. Because $E°$ is positive, $\Delta G°$ must be negative. ***OR*** $E°$ is positive, thus the reaction is spontaneous. For spontaneous reactions, $\Delta G°$ is always negative.	One point is earned for the correct answer with justification.

(f) The decomposition of $H_2O_2(aq)$ is slow at 298 K, but a suitable catalyst greatly increases the rate of the decomposition reaction.

(i) Draw a circle around each of the quantities below that has a different value for the catalyzed reaction than for the uncatalyzed reaction.

K_{eq} $\Delta G°$ $\Delta H°$ E_a

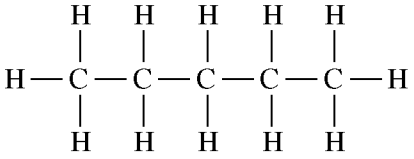
Only E_a should be circled.	One point is earned for circling E_a and none of the other quantities.

(ii) For any quantity that you circled above, indicate whether its value is greater or less for the catalyzed reaction than for the uncatalyzed reaction. Explain why.

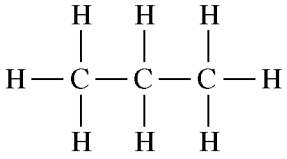
E_a, the activation energy, is less for the catalyzed reaction than for the uncatalyzed reaction. A catalyst provides a new reaction mechanism that requires a lower minimum required potential energy for the reaction to occur. Thus the activation energy is lowered. Note: reference to other circled quantities is ignored.	One point is earned for a correct answer with reference to an altered mechanism.

Question 6

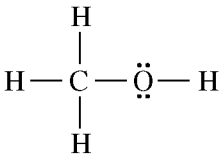
Answer the following questions in terms of principles of chemical bonding and intermolecular forces. In each explanation where a comparison is to be made, a complete answer must include a discussion of both substances. The following complete Lewis electron-dot diagrams may be useful in answering parts of this question.



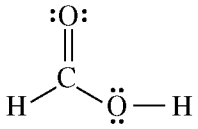
Pentane



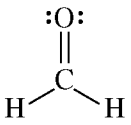
Propane



Methanol



Methanoic (formic) acid



Methanal (formaldehyde)

(a) At 1 atm and 298 K, pentane is a liquid whereas propane is a gas. Explain.

Both molecules are nonpolar, and the only intermolecular forces in each are London dispersion forces. However, pentane is larger than propane and has a more extensive electron cloud that can be involved in a greater number of London interactions, leading to stronger intermolecular attractions overall. Thus it takes a higher temperature for pentane molecules to have enough kinetic energy (on average) to overcome their stronger intermolecular attractions, thus pentane has the higher boiling point.	One point is earned for recognizing that pentane and propane *both* have only LDF's. One point is earned for recognizing that pentane has a larger electron cloud with greater IMF's and higher BP (reference to state of matter).

(b) At 1 atm and 298 K, methanol is a liquid whereas propane is a gas. Explain.

Propane molecules are nonpolar and only interact with one another via London dispersion forces. Methanol molecules are polar and hydrogen bonds (as well as London forces) can form among them. Because hydrogen bonds are stronger than London forces, methanol has greater intermolecular attractions. Thus it takes a higher temperature for methanol molecules to have enough kinetic energy (on average) to overcome their stronger intermolecular attractions, thus methanol has the higher boiling point.	One point is earned for recognizing that methanol has hydrogen-bonding IMF's and propane has LDF's. One point is earned for recognizing that hydrogen-bonding results in a greater IMF causing methanol to be a liquid.

Question 6 (continued)

(c) Indicate the hybridization of the carbon atom in each of the following:

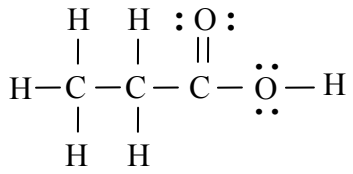
(i) Methanol

sp^3	One point is earned for the correct hybridization.

(ii) Methanoic (formic) acid

sp^2	One point is earned for the correct hybridization.

(d) Draw the complete Lewis electron-dot diagram for a molecule of propanoic acid, $HC_3H_5O_2$.

	One point is earned for the correct diagram (all electron pairs must be included).

(e) Explain the following observations about the two carbon-oxygen bonds in the methanoate (formate) anion, HCO_2^-. You may draw a Lewis electron-dot diagram (or diagrams) of the methanoate ion as part of your explanations.

(i) The two carbon-oxygen bonds in the methanoate (formate) anion, HCO_2^-, have the same length.

Resonance structures can be drawn for the methanoate anion, with one carbon-oxygen bond as a single bond and the other as a double bond (and the opposite in the other structure). The electrons are shared equally between the two carbon-oxygen bonds in the methanoate anion, resulting in two bonds with the same length.	One point is earned for the correct explanation.

(ii) The length of the carbon-oxygen bonds in the methanoate (formate) anion, HCO_2^-, is intermediate between the length of the carbon-oxygen bond in methanol and the length of the carbon-oxygen bond in methanal.

The two identical carbon-oxygen bonds in the methanoate anion each have a bond order of 1.5. The carbon-oxygen bond in methanol is a single bond, and the carbon-oxygen bond in methanal is a double bond. Single bonds between atoms of the same two elements are longer than double bonds, and a bond with a bond order of 1.5 would have a bond length between that of a single bond and that of a double bond.	One point is earned for the correct explanation comparing the single, double *and* resonating bonds of the respective molecules.

Scoring Worksheet

The following provides a worksheet and conversion table used for calculating a composite score of the exam.

2012 AP Chemistry Scoring Worksheet

Section I: Multiple Choice

_____	× 1.0000 =	_____
Number Correct (out of 75)		Weighted Section I Score (Do not round)

Section II: Free Response

Question 1	_____ (out of 10)	× 1.5000 =	_____ (Do not round)
Question 2	_____ (out of 9)	× 1.6666 =	_____ (Do not round)
Question 3	_____ (out of 9)	× 1.6666 =	_____ (Do not round)
Question 4	_____ (out of 15)	× 0.5000 =	_____ (Do not round)
Question 5	_____ (out of 8)	× 1.4062 =	_____ (Do not round)
Question 6	_____ (out of 9)	× 1.2500 =	_____ (Do not round)

Sum = _____
Weighted Section II Score (Do not round)

Composite Score

_____	+	_____	=	_____
Weighted Section I Score		Weighted Section II Score		Composite Score (Round to nearest whole number)

AP Score Conversion Chart
Chemistry

Composite Score Range	AP Score
110-150	5
92-109	4
73-91	3
58-72	2
0-57	1

AP Chemistry

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