AP Chemistry Practice Exam 1

Section I	**Total Time:** 1 hour and 30 minutes **Percent of Total Score:** 50%	**Number of Questions:** 50 *On operational exams, there are 60 multiple-choice questions.* Calculators allowed for all of Section I.	**Writing Instrument:** Pencil required
Section II	**Total Time:** 1 hour and 45 minutes **Percent of Total Score:** 50%	**Number of Questions:** 7 *(3 ten-point and 4 four-point questions)* Calculators allowed for all of Section II	**Writing Instrument:** Either pencil or pen with black or dark blue ink

Note: Tables of equations and constants are provided for both sections of the exam.

Students are permitted to use scientific or graphing calculators to answer questions in Section I and Section II of the AP Chemistry Exam. Four-function calculators are also permitted, but are not recommended. Before starting the exam administration, make sure that each student has an appropriate calculator and that any student with a graphing calculator has a model from the approved list found in the *AP Coordinator's Manual*.

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. Students with Hewlett-Packard 48–50 Series and Casio FX-9860 graphing calculators may use cards designed for use with these calculators. Proctors should make sure infrared ports (Hewlett-Packard) are not facing each other. **Since graphing calculators can be used to store data, including text, proctors should monitor that students are using their calculators appropriately. Attempts by students to use the calculator to remove exam questions and/or answers from the room may result in the cancellation of AP Exam scores.**

Students will be allowed to use the table of equations and constants on both sections of the exam.

NOTE: The Periodic Table of the Elements and the AP Chemistry Equations and Constants must not be removed from the exam books.

SECTION I: Multiple Choice

Look at your exam packet and confirm that the exam title is "AP Chemistry."

You will now take the multiple-choice portion of the exam. You should have in front of you the multiple-choice booklet and your answer sheet. You may never discuss the multiple-choice exam content at any time in any form with anyone, including your teacher and other students. If you disclose the multiple-choice exam content through any means, your AP Exam score will be canceled.

Open your answer sheet to page 2. The answer sheet has circles A–E for each question. For Chemistry, you will use only the circles marked A–D. You must complete the answer sheet using a No. 2 pencil only. Mark all of your responses beginning on page 2 of 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 _____. Note Stop Time _____.

Check that students are marking their answers in pencil on their answer sheets and that they have not opened their shrinkwrapped Section II booklets.

After 1 hour and 20 minutes, say:

There are 10 minutes remaining.

After 10 minutes, say:

Stop working. Close your booklet and put your answer sheet on your desk, faceup. Make sure you have your AP number label and an AP Exam label on page 1 of your answer sheet. Sit quietly while I collect your answer sheets.

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

There is a 10-minute break between Sections I and II.

When you are ready for the break, say:

Please listen carefully to these instructions before we take a 10-minute break. All items you placed under your chair at the beginning of this exam, including your Student Pack, must stay there, and you are not permitted to open or access them in any way. Leave your shrinkwrapped Section II packet on top of your desk during the break. You are not allowed to consult teachers, other students, notes, textbooks, or any other resources 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. You may not leave the designated break area. Remember, you may never discuss the multiple-choice exam content with anyone, and if you disclose the content through any means, your AP Exam score will be canceled. Are there any questions? . . .

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

SECTION II: Free Response

After the break, say:

Calculators may be used for Section II. You may get your calculators from under your chair and place them on your desk. . . .

You have 1 hour and 45 minutes to complete Section II. You are responsible for pacing yourself, and you may proceed freely from one question to the next. You must write your answers in the exam booklet using 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. If you need more paper to complete your responses, raise your hand. At the top of each extra sheet of paper you use, write only:

- **your AP number,**
- **the exam title, and**
- **the question number you are working on.**

Do not write your name. Are there any questions? . . .

You may begin.

Note Start Time _____. Note Stop Time _____.

Proctors should also make sure that Hewlett-Packard calculators' infrared ports are not facing each other and that students are not sharing calculators.

After 1 hour and 35 minutes, say:

There are 10 minutes remaining.

After 10 minutes, say:

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

If any students used extra paper for a question in the free-response section, have those students staple the extra sheet(s) to the first page corresponding to that question in their free-response exam booklets. Complete an Incident Report after the exam and return these free-response booklets with the extra sheets attached in the Incident Report return envelope (see page 68 of the *2018-19 AP Coordinator's Manual* for complete details).

Then say:

You are now dismissed.

Name:_____

Answer Sheet for AP Chemistry Practice Exam 1, Section I

No.	Answer
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
21	
22	
23	
24	
25	

No.	Answer
26	
27	
28	
29	
30	
31	
32	
33	
34	
35	
36	
37	
38	
39	
40	
41	
42	
43	
44	
45	
46	
47	
48	
49	
50	

AP® Chemistry Exam

SECTION I: Multiple Choice

2019

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

Instructions

Section I of this exam contains 50 multiple-choice questions. Fill in only the circles for numbers 1 through 50 on your answer sheet. Pages containing a periodic table and lists containing equations and constants are also printed in this booklet.

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.

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 Section I is based only on the number of questions answered correctly. Points are not deducted for incorrect answers or unanswered questions.

At a Glance

Total Time
1 hour and 30 minutes
Number of Questions
50
Percent of Total Score
50%
Writing Instrument
Pencil required
Electronic Device
Calculator allowed

Form I
Form Code 4PBP4-S
25

DO NOT DETACH FROM BOOK.

PERIODIC TABLE OF THE ELEMENTS

1												13	14	15	16	17	18
1 **H** 1.008	2																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	3	4	5	6	7	8	9	10	11	12	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** 47.87	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** 65.38	31 **Ga** 69.72	32 **Ge** 72.63	33 **As** 74.92	34 **Se** 78.97	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** 95.95	43 **Tc**	44 **Ru** 101.07	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** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	57–71 *	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	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**	85 **At**	86 **Rn**
87 **Fr**	88 **Ra**	89–103 †	104 **Rf**	105 **Db**	106 **Sg**	107 **Bh**	108 **Hs**	109 **Mt**	110 **Ds**	111 **Rg**	112 **Cn**	113 **Nh**	114 **Fl**	115 **Mc**	116 **Lv**	117 **Ts**	118 **Og**

*Lanthanoids	57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm**	62 **Sm** 150.36	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** 173.05	71 **Lu** 174.97
†Actinoids	89 **Ac**	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np**	94 **Pu**	95 **Am**	96 **Cm**	97 **Bk**	98 **Cf**	99 **Es**	100 **Fm**	101 **Md**	102 **No**	103 **Lr**

AP® CHEMISTRY EQUATIONS AND CONSTANTS

UNIT SYMBOLS	
gram,	g
mole,	mol
liter,	L
meter,	m
second,	s
hertz,	Hz
atmosphere,	atm
millimeter of mercury,	mm Hg
degree Celsius,	°C
kelvin,	K
joule,	J
volt,	V
coulomb,	C
ampere,	A

UNIT CONVERSIONS
1 hertz = 1 s^{-1}
1 atm = 760 mm Hg = 760 torr
K = °C + 273.15
1 volt = $\frac{1 \text{ joule}}{1 \text{ coulomb}}$
1 ampere = $\frac{1 \text{ coulomb}}{1 \text{ second}}$

METRIC PREFIXES		
Factor	Prefix	Symbol
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

ATOMIC STRUCTURE

$$E = h\nu$$

$$c = \lambda\nu$$

$$F_{coulombic} \propto \frac{q_1 q_2}{r^2}$$

E = energy
ν = frequency
λ = wavelength
F = force
q = charge
r = separation
Planck's constant, $h = 6.626 \times 10^{-34}$ J s
Speed of light, $c = 2.998 \times 10^{8}$ m s^{-1}
Avogadro's number = 6.022×10^{23} mol^{-1}

GASES, LIQUIDS, AND SOLUTIONS

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

$$PV = nRT$$

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

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

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

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

$$KE = \frac{1}{2}mv^2$$

$$M = \frac{n_{solute}}{\text{L}_{solution}}$$

$$A = \varepsilon bc$$

P = pressure
V = volume
T = temperature
n = number of moles
X = mole fraction
m = mass
$\boldsymbol{M}$ = molar mass
D = density
KE = kinetic energy
v = velocity
M = molarity
A = absorbance
ε = molar absorptivity
b = path length
c = concentration
Gas constant, $R = 8.314$ J mol^{-1} K^{-1}
$= 0.08206$ L atm K^{-1} mol^{-1}
STP = 273.15 K and 1.0 atm
Ideal gas at STP = 22.4 L mol^{-1}

KINETICS

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

$$\ln[\mathrm{A}]_t - \ln[\mathrm{A}]_0 = -kt$$

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

$$t_{1/2} = \frac{0.693}{k}$$

k = rate constant
t = time
$t_{1/2}$ = half-life

EQUILIBRIUM

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

$$K_p = \frac{(P_\mathrm{C})^c(P_\mathrm{D})^d}{(P_\mathrm{A})^a(P_\mathrm{B})^b}$$

$$K_w = [\mathrm{H_3O^+}][\mathrm{OH^-}] = 1.0 \times 10^{-14} \text{ at } 25^\circ\mathrm{C}$$

$$\mathrm{p}K_w = 14 = \mathrm{pH} + \mathrm{pOH} \text{ at } 25^\circ\mathrm{C}$$

$$\mathrm{pH} = -\log[\mathrm{H_3O^+}], \qquad \mathrm{pOH} = -\log[\mathrm{OH^-}]$$

$$K_a = \frac{[\mathrm{H_3O^+}][\mathrm{A^-}]}{[\mathrm{HA}]}, \qquad K_b = \frac{[\mathrm{OH^-}][\mathrm{HB^+}]}{[\mathrm{B}]}$$

$$\mathrm{p}K_a = -\log K_a, \qquad \mathrm{p}K_b = -\log K_b$$

$$K_w = K_a \times K_b, \qquad \mathrm{p}K_w = \mathrm{p}K_a + \mathrm{p}K_b$$

$$\mathrm{pH} = \mathrm{p}K_a + \log\frac{[\mathrm{A^-}]}{[\mathrm{HA}]}$$

Equilibrium Constants

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

THERMODYNAMICS/ELECTROCHEMISTRY

$$q = mc\Delta T$$

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

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

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

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$
$$= -RT\ln K$$
$$= -nFE^\circ$$

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

$$E_{cell} = E^\circ_{cell} - \frac{RT}{nF}\ln Q$$

q = heat
m = mass
c = specific heat capacity
T = temperature
S° = standard entropy
H° = standard enthalpy
G° = standard Gibbs free energy
R = gas constant
K = equilibrium constant
n = number of moles of electrons
E° = standard potential
I = current (amperes)
q = charge (coulombs)
t = time (seconds)
Q = reaction quotient
Faraday's constant, F = 96,485 coulombs / 1 mol e^-

CHEMISTRY

Section I

Time—1 hour and 30 minutes

50 Questions

CALCULATORS ARE ALLOWED FOR SECTION I.

Note: For all questions, assume that the temperature is 298 K, the pressure is 1.0 atm, and solutions are aqueous unless otherwise specified.

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

1. In which of the following processes will $\Delta S°$ be negative?

(A) $C_2H_5OH(l) \rightarrow C_2H_5OH(g)$

(B) $NaCl(s) \rightarrow NaCl(l)$

(C) $CO_2(s) \rightarrow CO_2(g)$

(D) $Cl_2(g) \rightarrow Cl_2(l)$

Solution
0.1 *M* $HC_2H_3O_2(aq)$
0.1 *M* $KI(aq)$
0.1 *M* $CH_3OH(aq)$

2. Of the three solutions listed in the table above, which one, if any, has the greatest electrical conductivity and why?

(A) 0.1 *M* $HC_2H_3O_2(aq)$ because its molecules have the most atoms.

(B) 0.1 *M* $KI(aq)$ because KI completely dissociates in water to produce ions.

(C) 0.1 *M* $CH_3OH(aq)$ because its molecules can form hydrogen bonds.

(D) All three solutions have the same electrical conductivity because the concentrations are the same.

GO ON TO THE NEXT PAGE.

$$H_2(g) + I_2(g) \rightleftarrows 2\ HI(g)$$

3. Hydrogen gas reacts with iodine gas at constant temperature in a sealed rigid container. The gases are allowed to reach equilibrium according to the equation above. Which of the following best describes what will happen to the reaction immediately after additional iodine gas is added to the system?

(A) The rates of both the forward and reverse reactions decrease.

(B) The rates of both the forward and reverse reactions do not change.

(C) The rate of the forward reaction becomes greater than the rate of the reverse reaction.

(D) The rate of the forward reaction becomes less than the rate of the reverse reaction.

	Ionization Energy (kJ/mol)
First	578
Second	1,817
Third	2,745
Fourth	11,577
Fifth	14,842

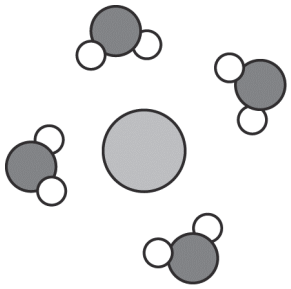
4. The first five ionization energies of an unknown element are listed in the table above. Which of the following statements correctly identifies the element and cites the evidence supporting the identification?

(A) Na, because of the large difference between the first and the second ionization energies

(B) Al, because of the large difference between the third and fourth ionization energies

(C) Si, because the fifth ionization energy has the greatest value

(D) P, because a neutral atom of P has five valence electrons



5. The diagram above represents a particle in aqueous solution. Which of the following statements about the particle is correct?

(A) The particle must be a cation because the negative end of each water molecule is pointed toward it.

(B) The particle must be an anion because the positive end of each water molecule is pointed toward it.

(C) The charge of the particle cannot be determined because water molecules have no net charge.

(D) The charge of the particle cannot be determined because the water molecules are arranged symmetrically and their partial charges cancel.

Compound	Formula	Boiling Point (°C)	Density (g/mL)
Hexane	C_6H_{14}	69	0.66
Octane	C_8H_{18}	126	0.70

6. A student obtains a mixture of the liquids hexane and octane, which are miscible in all proportions. Which of the following techniques would be best for separating the two components of the mixture, and why?

(A) Filtration, because the different densities of the liquids would allow one to pass through the filter paper while the other would not.

(B) Paper chromatography, because the liquids would move along the stationary phase at different rates owing to the difference in polarity of their molecules.

(C) Column chromatography, because the higher molar mass of octane would cause it to move down the column faster than hexane.

(D) Distillation, because the liquids would boil at different temperatures owing to the difference in strength of their intermolecular forces.

GO ON TO THE NEXT PAGE.

$$Ge(g) + 2\ Cl_2(g) \rightleftarrows GeCl_4(g)$$

7. The value of the equilibrium constant for the reaction represented above is 1×10^{10}. What is the value of the equilibrium constant for the following reaction?

$$2\ GeCl_4(g) \rightleftarrows 2\ Ge(g) + 4\ Cl_2(g)$$

(A) 1×10^{-20}

(B) 1×10^{-10}

(C) 1×10^{10}

(D) 1×10^{20}

8. To catalyze a biochemical reaction, an enzyme typically

(A) drives the reaction to completion by consuming byproducts of the reaction

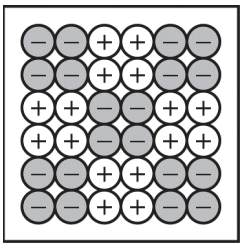
(B) binds temporarily to reactant molecules to lower the activation energy of the reaction

(C) dissociates into additional reactant molecules, thereby increasing the reaction rate

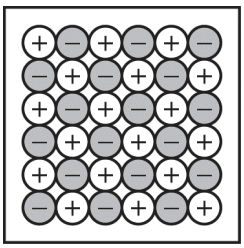
(D) decomposes and releases energy to increase the number of successful collisions between reactant molecules

9. Of the following diagrams, which best represents the structure of solid KF ?

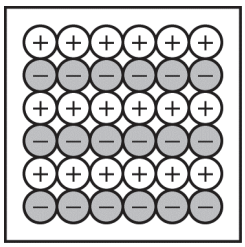
(A)



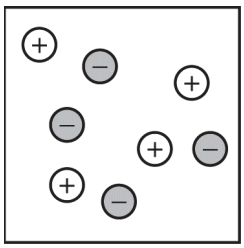
(B)



(C)

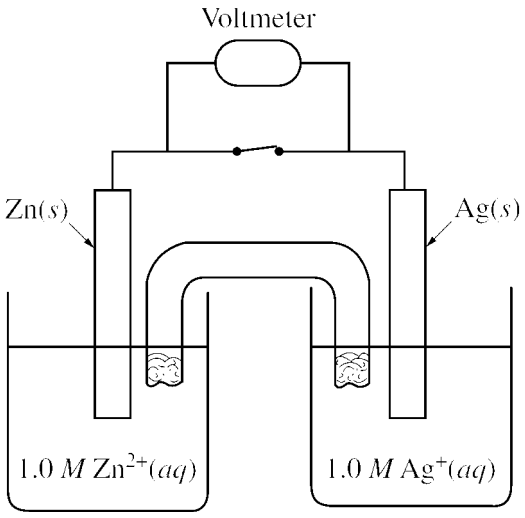


(D)



GO ON TO THE NEXT PAGE.

Questions 10-11 refer to the following information.



Standard reduction potentials for the half-reactions associated with the electrochemical cell shown above are given in the table below.

Half-Reaction	$E°$ (V)
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+ 0.80
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	− 0.76

10. Which of the following is the net ionic equation for the overall reaction that occurs as the cell operates?

(A) $Ag(s) + Zn^{2+}(aq) \rightarrow Ag^{2+}(aq) + Zn(s)$

(B) $Ag^+(aq) + Zn^{2+}(aq) + 3\ e^- \rightarrow AgZn(s)$

(C) $Ag^+(aq) + Zn(s) \rightarrow Ag(s) + Zn^{2+}(aq) + e^-$

(D) $2\ Ag^+(aq) + Zn(s) \rightarrow 2\ Ag(s) + Zn^{2+}(aq)$

11. What is the value of $E°$ for the cell?

(A) 0.04 V

(B) 0.84 V

(C) 1.56 V

(D) 2.36 V

GO ON TO THE NEXT PAGE.

$$CO_2(g) + 2\ LiOH(s) \rightarrow Li_2CO_3(aq) + H_2O(l)$$

12. In a one-person spacecraft, an astronaut exhales 880 g of $CO_2(g)$ (molar mass 44 g/mol) per day. To prevent the buildup of $CO_2(g)$ in the spacecraft, a device containing LiOH(s) is used to remove the $CO_2(g)$, as represented by the equation above. What mass of LiOH(s) (molar mass 24 g/mol) is needed to react with all of the $CO_2(g)$ produced by an astronaut in one day?

(A) 40. g

(B) 240 g

(C) 480 g

(D) 960 g

GO ON TO THE NEXT PAGE.

Time (s)	$[NO_2]$ (mol/L)	$\ln [NO_2]$	$\frac{1}{[NO_2]}$ (L/mol)
0	0.500	–0.693	2.00
100	0.364	–1.01	2.75
200	0.286	–1.25	3.50
300	0.235	–1.45	4.25

13. The data from a study of the decomposition of $NO_2(g)$ to form $NO(g)$ and $O_2(g)$ are given in the table above. Which of the following rate laws is consistent with the data?

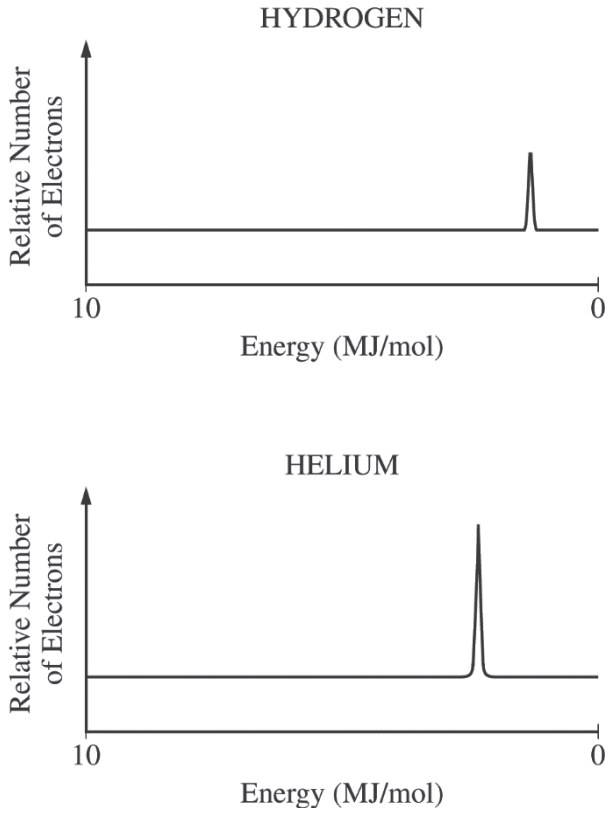
(A) Rate $= k\ [NO_2]$

(B) Rate $= k\ [NO_2]^2$

(C) Rate $= k\ \frac{1}{[NO_2]}$

(D) Rate $= k\ \frac{1}{[NO_2]^2}$

GO ON TO THE NEXT PAGE.



14. The photoelectron spectra for H and He are represented above. Which of the following statements best accounts for the fact that the peak on the He spectrum is farther to the left and higher than the peak on the H spectrum?

(A) He has an additional valence electron in a higher energy level than the valence electron in H.

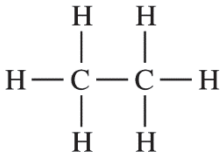
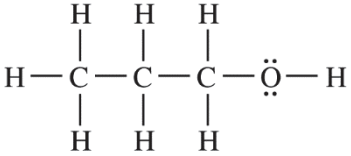
(B) He has a greater nuclear charge than H and an additional electron in the same energy level.

(C) He has a completely filled valence shell in which the electrons are a greater distance from the nucleus than the distance between the H nucleus and its electron.

(D) It takes longer for the electrons in He to be removed due to the higher nuclear mass of He.

GO ON TO THE NEXT PAGE.

Questions 15-19 are based on the information in the table below.

Compound	Molar Mass	Balanced Equation for the Combustion of One Mole of the Compound	ΔH_{comb} (kJ/mol$_{rxn}$)
 Ethane	30. g/mol	$C_2H_6(g) + \frac{7}{2}O_2(g) \rightarrow 2\ CO_2(g) + 3\ H_2O(l)$	−1560
 Propanol	60. g/mol	$C_3H_8O(l) + \frac{9}{2}O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(l)$	−2020
Unknown	?	$? + 5\ O_2(g) \rightarrow 4\ CO_2(g) + 4\ H_2O(l)$	−2240

15. Which of the following is the molecular formula of the unknown compound?

(A) C_4H_8

(B) C_4H_8O

(C) $C_4H_4O_2$

(D) $C_4H_8O_2$

16. Which of the following best explains why the combustion reactions represented in the table are exothermic?

(A) The number of bonds in the reactant molecules is greater than the number of bonds in the product molecules.

(B) The number of bonds in the reactant molecules is less than the number of bonds in the product molecules.

(C) The energy required to break the bonds in the reactants is greater than the energy released in forming the bonds in the products.

(D) The energy required to break the bonds in the reactants is less than the energy released in forming the bonds in the products.

GO ON TO THE NEXT PAGE.

17. Based on the structural formulas, which of the following identifies the compound that is more soluble in water and best helps to explain why?

(A) Ethane, because the electron clouds of its molecules are more polarizable than those of propanol.

(B) Ethane, because its molecules can fit into the spaces between water molecules more easily than those of propanol can.

(C) Propanol, because its molecules have a greater mass than the molecules of ethane have.

(D) Propanol, because its molecules can form hydrogen bonds with water molecules but those of ethane cannot.

18. In an experiment, 30.0 g of ethane and 30.0 g of propanol are placed in separate reaction vessels. Each compound undergoes complete combustion with excess $O_2(g)$. Which of the following best compares the quantity of heat released in each combustion reaction?

(A) $q_{ethane} < q_{propanol}$

(B) $q_{ethane} = q_{propanol}$

(C) $q_{ethane} > q_{propanol}$

(D) The quantities of heat released in the combustions of ethane and propanol cannot be compared without knowing the specific heat capacity of the compounds.

19. A sealed 10.0 L flask at 400 K contains equimolar amounts of ethane and propanol in gaseous form. Which of the following statements concerning the average molecular speed of ethane and propanol is true?

(A) The average molecular speed of ethane is less than the average molecular speed of propanol.

(B) The average molecular speed of ethane is greater than the average molecular speed of propanol.

(C) The average molecular speed of ethane is equal to the average molecular speed of propanol.

(D) The average molecular speeds of ethane and propanol cannot be compared without knowing the total pressure of the gas mixture.

GO ON TO THE NEXT PAGE.

20. As a sample of $KNO_3(s)$ is stirred into water at 25°C, the compound dissolves endothermically. Which of the following best helps to explain why the process is thermodynamically favorable at 25°C?

(A) All endothermic processes are thermodynamically favorable.

(B) Stirring the solution during dissolution adds the energy needed to drive an endothermic process.

(C) Dissolving the salt decreases the enthalpy of the system.

(D) Dissolving the salt increases the entropy of the system.

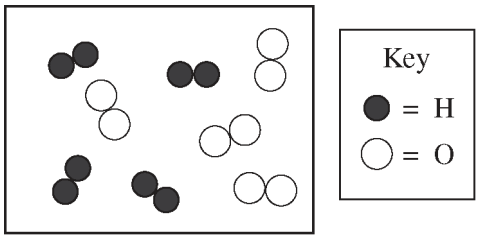
21. A solution is prepared by mixing equal volumes of 0.20 *M* $HC_2H_3O_2$ and 0.40 *M* $NaC_2H_3O_2$. Which of the following correctly describes what occurs if a small amount of HCl(*aq*) or NaOH(*aq*) is added?

(A) If HCl(*aq*) is added, the pH will increase only slightly because the Cl^- ions will react with $C_2H_3O_2^-$ ions.

(B) If HCl(*aq*) is added, the pH will decrease only slightly because the H^+ ions will react with $C_2H_3O_2^-$ ions.

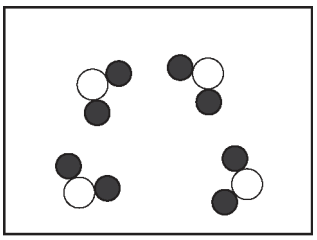
(C) If NaOH(*aq*) is added, the pH will increase only slightly because the OH^- ions will react with $C_2H_3O_2^-$ ions.

(D) If NaOH(*aq*) is added, the pH will decrease only slightly because the OH^- ions will react with $HC_2H_3O_2$ molecules.

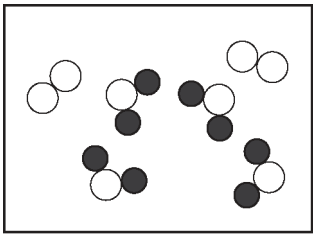


22. A mixture of $H_2(g)$ and $O_2(g)$ is placed in a container as represented above. The $H_2(g)$ and $O_2(g)$ react to form $H_2O(g)$. Which of the following best represents the container after the reaction has gone to completion?

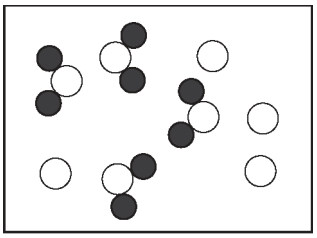
(A)



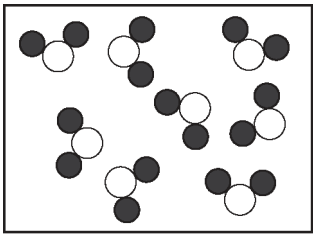
(B)



(C)



(D)



GO ON TO THE NEXT PAGE.

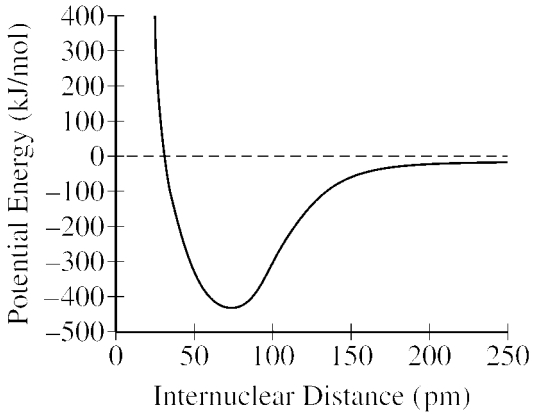
23. After a certain pesticide compound is applied to crops, its decomposition is a first-order reaction with a half-life of 56 days. What is the rate constant, k, for the decomposition reaction?

(A) $0.012\ \text{day}^{-1}$

(B) $0.018\ \text{day}^{-1}$

(C) $56\ \text{day}^{-1}$

(D) $81\ \text{day}^{-1}$



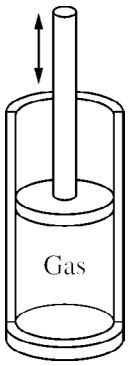
24. Which of the following can be inferred from the diagram above that shows the dependence of potential energy on the internuclear distance between two atoms?

(A) The atoms form a bond with a bond length of 25 pm.

(B) The atoms form a bond with a bond length of 75 pm.

(C) The net force between the atoms is attractive at 25 pm.

(D) The net force between the atoms is attractive at 75 pm.



25. A mixture of two gases, 0.01 mol of $C_4H_{10}(g)$ and 0.065 mol of $O_2(g)$, is pumped into a cylinder with a movable piston, as shown above. The mixture, originally at 200°C and 1.0 atm, is sparked and the reaction represented below occurs.

$$2\ C_4H_{10}(g) + 13\ O_2(g) \rightarrow 8\ CO_2(g) + 10\ H_2O(g)$$

Which of the following is true after the product gases return to the original temperature and pressure, and why will the change occur? (Assume all gases behave ideally.)

(A) The piston will be higher than its original position, because the cylinder will contain a greater number of gas molecules.

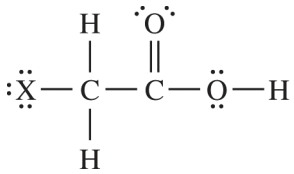
(B) The position of the piston will be unchanged, because the total mass of the gases in the cylinder does not change.

(C) The position of the piston will be unchanged, because the temperature and pressure of the contents of the cylinder remain the same.

(D) The piston will be lower than its original position, because the product molecules are smaller than the reactant molecules.

GO ON TO THE NEXT PAGE.

Questions 26-28 are based on the following information.



The structure of haloacetic acids, XCH_2COOH (where X is either F, Cl, Br, or I), is shown above. The dissociation constants and molar masses of four haloacetic acids are listed in the table below.

Acid	pK_a	K_a	Molar Mass (g/mol)
Fluoroacetic acid	2.59	2.57×10^{-3}	78.0
Chloroacetic acid	2.87	1.35×10^{-3}	94.5
Bromoacetic acid	2.90	1.26×10^{-3}	138.9
Iodoacetic acid	3.18	6.61×10^{-4}	185.9

26. Which compound, chloroacetic acid or iodoacetic acid, most likely has the lower boiling point, and why?

(A) Chloroacetic acid, because the London dispersion forces among its molecules are weaker.

(B) Chloroacetic acid, because the dipole-dipole forces among its molecules are weaker.

(C) Iodoacetic acid, because the London dispersion forces among its molecules are stronger.

(D) Iodoacetic acid, because the dipole-dipole forces among its molecules are stronger.

27. An aqueous solution contains small but equal concentrations of both chloroacetic and fluoroacetic acids. Which statement comparing the percent ionizations of the two acids in the solution is true?

(A) The percent ionization of chloroacetic acid is greater than that of fluoroacetic acid.

(B) The percent ionization of chloroacetic acid is less than that of fluoroacetic acid.

(C) The percent ionizations cannot be compared without knowing the concentrations of the two acids.

(D) The percent ionizations cannot be compared without knowing the pH of the solution.

28. A student titrates 10.0 mL samples of 1.0 *M* solutions of each of the haloacetic acids with a standard solution of NaOH. Which of the following statements correctly predicts the volume of NaOH(*aq*) needed to reach the equivalence point?

(A) Fluoroacetic acid will need the smallest volume of NaOH(*aq*) to reach the equivalence point.

(B) Iodoacetic acid will need the smallest volume of NaOH(*aq*) to reach the equivalence point.

(C) All of the acids will need the same volume of NaOH(*aq*) to reach the equivalence point.

(D) All of the haloacetic acids are weak; therefore none will reach an equivalence point.

GO ON TO THE NEXT PAGE.

29. The value of K_w at 40°C is 3.0×10^{-14}. What is the pH of pure water at 40°C?

(A) 3.0

(B) 6.8

(C) 7.0

(D) 7.2

30. A 1.0 mol sample of He(g) at 25°C is mixed with a 1.0 mol sample of Xe(g) at 50°C. Which of the following correctly predicts the changes in average kinetic energy and the average speed of the Xe(g) atoms that will occur as the mixture approaches thermal equilibrium?

	Average Kinetic Energy of Xe Atoms	Average Speed of Xe Atoms
(A)	Will increase	Will increase
(B)	Will increase	Will decrease
(C)	Will decrease	Will increase
(D)	Will decrease	Will decrease

31. Which of the following best helps to explain why Na(s) is more reactive with water than Mg(s) is?

(A) Na(s) is softer than Mg(s).

(B) The atomic mass of Na is less than that of Mg.

(C) The Na^+ ion has weaker Coulombic attraction to an anion than the Mg^{2+} ion has.

(D) The first ionization energy of Na is less than that of Mg.

32. At 25°C, enough distilled water is added to a 30.0 mL sample of $HNO_3(aq)$ with a pH of 4.20 so that the final pH of the diluted solution is 5.20. The volume of distilled water added to the original solution is closest to

(A) 30.0 mL

(B) 60.0 mL

(C) 270. mL

(D) 300. mL

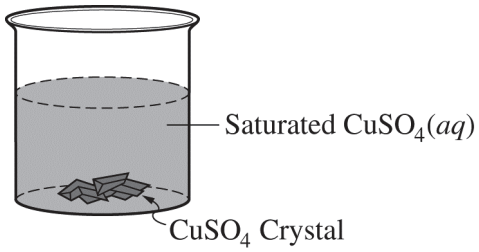
33. A student observes that the equilibrium constant for a reaction is greater than 1.0 at temperatures below 500 K but less than 1.0 at temperatures above 500 K. What can the student conclude about the values of $\Delta H°$ and $\Delta S°$ for the reaction? (Assume that $\Delta H°$ and $\Delta S°$ are independent of temperature.)

(A) $\Delta H° > 0$ and $\Delta S° > 0$

(B) $\Delta H° > 0$ and $\Delta S° < 0$

(C) $\Delta H° < 0$ and $\Delta S° > 0$

(D) $\Delta H° < 0$ and $\Delta S° < 0$



34. The saturated $CuSO_4(aq)$ shown above is left uncovered on a lab bench at a constant temperature. As the solution evaporates, 1.0 mL samples of the solution are removed every three days and the $[SO_4^{2-}]$ in the samples is measured. It is observed that the $[SO_4^{2-}]$ in the solution did not change over time. Which of the following best helps to explain the observation?

(A) As the solution evaporates, $Cu^{2+}(aq)$ and $SO_4^{2-}(aq)$ leave the beaker along with the water molecules.

(B) As the solution evaporates, the dissolution of $CuSO_4(s)$ in the beaker decreases.

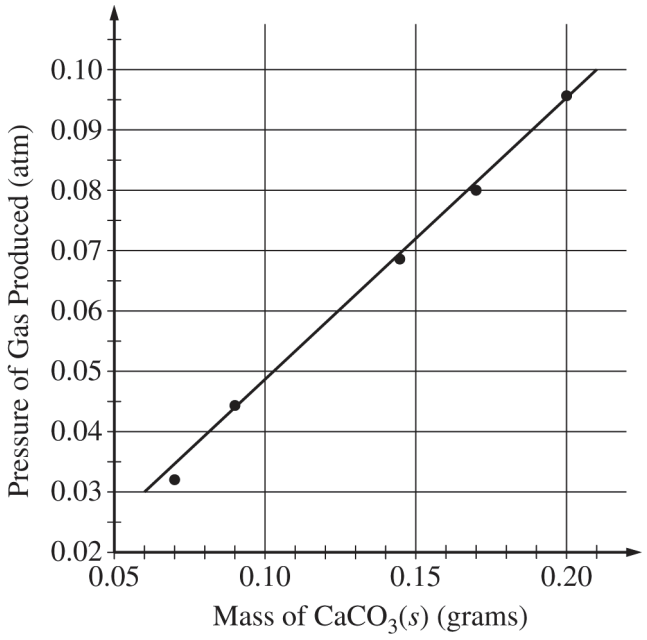
(C) The evaporation of water is endothermic, so more $CuSO_4(s)$ dissolves exothermically in the solution, which increases the $[SO_4^{2-}]$.

(D) As water evaporates, more $CuSO_4(s)$ precipitates out of the solution in the beaker.

GO ON TO THE NEXT PAGE.

Questions 35-38 refer to the following information.

An experiment is performed to measure the mass percent of $CaCO_3(s)$ in eggshells. Five different samples of $CaCO_3(s)$ of known mass react with an excess of 2.0 *M* HCl(*aq*) in identical sealed, rigid reaction vessels. The pressure of the gas produced is measured with a pressure gauge attached to the reaction vessel. Since the reaction is exothermic, the reaction system is cooled to its original temperature before the pressure is recorded. The experimental data are used to create the calibration line below.



The experiment is repeated with an eggshell sample, and the experimental data are recorded in the table below.

Mass of eggshell sample	0.200 g
Pressure prior to reaction	0.800 atm
Pressure at completion of reaction	0.870 atm

GO ON TO THE NEXT PAGE.

35. Which of the following equations best represents the species that react and the species that are produced when $CaCO_3(s)$ and $HCl(aq)$ are combined?

(A) $2\ H^+(aq) + CaCO_3(s) \rightarrow Ca^{2+}(aq) + CO_3^{2-}(aq) + H_2(g)$

(B) $2\ H^+(aq) + CaCO_3(s) \rightarrow Ca^{2+}(aq) + H_2O(l) + CO_2(g)$

(C) $2\ H^+(aq) + CaCO_3(s) \rightarrow Ca^{2+}(aq) + 2\ OH^-(aq) + CO(g)$

(D) $2\ HCl(aq) + CaCO_3(s) \rightarrow Ca^{2+}(aq) + H_2O(l) + CO_2(g) + 2\ Cl^-(aq)$

36. The mass percent of $CaCO_3(s)$ in the eggshell sample is closest to

(A) 30%

(B) 45%

(C) 60%

(D) 75%

37. Another sample of eggshell reacts completely with 4.0 mL of an $HCl(aq)$ solution of unknown concentration. If the reaction produced 0.095 atm of gas, the concentration of the $HCl(aq)$ solution was at least

(A) 0.0020 *M*

(B) 0.050 *M*

(C) 0.50 *M*

(D) 1.0 *M*

38. Which of the following modifications will increase the rate of the reaction the most?

(A) Using 2.0 *M* $CH_3COOH(aq)$ instead of 2.0 *M* $HCl(aq)$

(B) Cooling the $HCl(aq)$ to a lower temperature than it was in the original experiment

(C) Reducing the volume of the reaction vessel

(D) Using eggshells that are more finely powdered than those used in the original experiment

GO ON TO THE NEXT PAGE.

39. Samples of $NaF(s)$ and $NH_4Cl(s)$ are dissolved in separate beakers that each contain 100 mL of water. One of the salts produces a slightly acidic solution. Which of the following equations best represents the formation of the slightly acidic solution?

(A) $Na^+(aq) + 2\ H_2O(l) \rightleftarrows NaOH(aq) + H_3O^+(aq)$

(B) $F^-(aq) + H_2O(l) \rightleftarrows HF(aq) + OH^-(aq)$

(C) $NH_4^+(aq) + H_2O(l) \rightleftarrows NH_3(aq) + H_3O^+(aq)$

(D) $Cl^-(aq) + H_2O(l) \rightleftarrows HCl(aq) + OH^-(aq)$

GO ON TO THE NEXT PAGE.

$$\text{C(diamond)} \rightarrow \text{C(graphite)} \qquad \Delta G^\circ = -2.9 \text{ kJ/mol}_{rxn}$$

40. Which of the following best explains why the reaction represented above is not observed to occur at room temperature?

(A) The rate of the reaction is extremely slow because of the relatively small value of ΔG° for the reaction.

(B) The entropy of the system decreases because the carbon atoms in graphite are less ordered than those in diamond.

(C) The reaction has an extremely large activation energy due to strong three-dimensional bonding among carbon atoms in diamond.

(D) The reaction does not occur because it is not thermodynamically favorable.

$$C_9H_8O_4(aq) + NaOH(aq) \rightleftarrows C_9H_7O_4^-(aq) + Na^+(aq) + H_2O(l)$$

41. The reaction represented above occurs when 2.00×10^{-4} mol of pure acetylsalicylic acid, $C_9H_8O_4$, is completely dissolved in 15.00 mL of water in a flask and titrated to the equivalence point with 0.100 *M* NaOH(*aq*). Which of the following statements about the titration is true at the equivalence point?

(A) $[C_9H_8O_4]$ is greater than $[C_9H_7O_4^-]$.

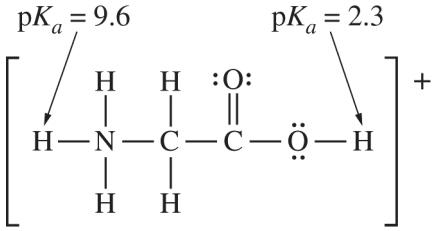
(B) $[C_9H_8O_4]$ is less than $[C_9H_7O_4^-]$.

(C) $[C_9H_8O_4]$ is equal to $[C_9H_7O_4^-]$.

(D) The relationship between $[C_9H_8O_4]$ and $[C_9H_7O_4^-]$ cannot be determined without additional information.

GO ON TO THE NEXT PAGE.

Questions 42-44 refer to the following.



The structural formula of the glycinium cation is shown above. Arrows indicate the pK_a values for the labile protons in the molecule.

42. What is the approximate H−O−C bond angle in the glycinium cation?

(A) 180°

(B) 120°

(C) 105°

(D) 90°

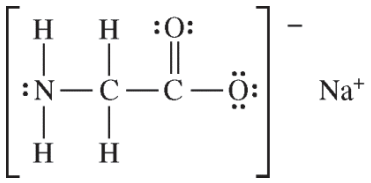
43. Which of the following is true about the geometry of the glycinium cation?

(A) The leftmost C atom and all the atoms directly bonded to it lie in the same plane.

(B) Both C atoms and both O atoms lie in the same plane.

(C) The N−C−C bond angle is 180°.

(D) The geometry around the N atom is planar.



44. Which of the following statements is true about sodium glycinate, represented above?

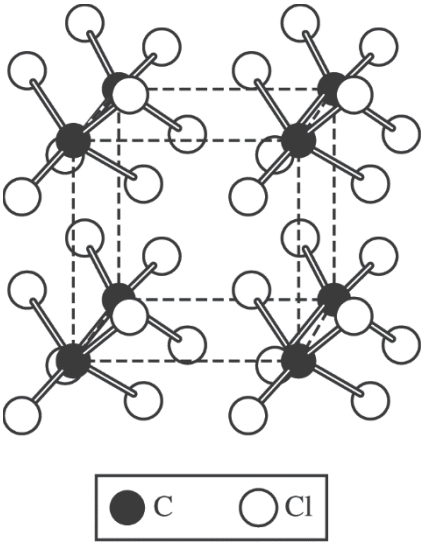
(A) It is an ionic solid at room temperature.

(B) It is not soluble in water.

(C) It evaporates easily because of the lack of hydrogen bonding.

(D) It dissolves in water to form an acidic solution.

GO ON TO THE NEXT PAGE.



45. Solid carbon tetrachloride, $CCl_4(s)$, is represented by the diagram above. The attractions between the CCl_4 molecules that hold the molecules together in the solid state are best identified as

(A) polar covalent bonds

(B) nonpolar covalent bonds

(C) intermolecular attractions resulting from temporary dipoles

(D) intermolecular attractions resulting from permanent dipoles

46. Which of the following is a list of the minimum amount of data needed for determining the molar enthalpy of solution of KCl(*s*) in pure $H_2O(l)$? (Assume that the KCl(*aq*) has the same specific heat capacity as pure water and that the initial temperatures of the KCl(*s*) and the water are the same.)

(A) Mass of KCl(*s*), initial temperature of the water, and final temperature of the solution

(B) Mass of H_2O, initial temperature of the water, and final temperature of the solution

(C) Mass of KCl(*s*), mass of H_2O, initial temperature of the water, and final temperature of the solution

(D) Mass of KCl(*s*), mass of H_2O, initial temperature of the water, final temperature of the solution, and atmospheric pressure.

$$X_2(g) + Y_2(g) \rightleftarrows 2\ XY(g) \qquad K_c = 3.0$$

47. A mixture of $X_2(g)$, $Y_2(g)$, and XY(g) is placed in a previously evacuated, rigid container and allowed to reach equilibrium at a constant temperature, as shown above. Which of the following sets of initial concentrations would lead to the formation of more product as the system moves toward equilibrium?

	$[X_2]_{initial}$	$[Y_2]_{initial}$	$[XY]_{initial}$
(A)	0.40 *M*	0.40 *M*	0.20 *M*
(B)	0.30 *M*	0.30 *M*	0.90 *M*
(C)	0.15 *M*	0.15 *M*	0.30 *M*
(D)	0.10 *M*	0.10 *M*	0.20 *M*

GO ON TO THE NEXT PAGE.

cis-isomer *trans*-isomer

48. The structural formulas for two isomers of 1,2-dichloroethene are shown above. Which of the two liquids has the higher equilibrium vapor pressure at 20°C, and why?

(A) The *cis*-isomer, because it has dipole-dipole interactions, whereas the *trans*-isomer has only London dispersion forces

(B) The *cis*-isomer, because it has only London dispersion forces, whereas the *trans*-isomer also has dipole-dipole interactions

(C) The trans-isomer, because it has dipole-dipole interactions, whereas the *cis*-isomer has only London dispersion forces

(D) The *trans*-isomer, because it has only London dispersion forces, whereas the *cis*-isomer also has dipole-dipole interactions

---

$$CaF_2(s) \rightleftarrows Ca^{2+}(aq) + 2\ F^-(aq) \qquad K_{sp} = 4.0 \times 10^{-11}$$

49. The concentration of $F^-(aq)$ in drinking water that is considered to be ideal for promoting dental health is $4.0\times10^{-5}\,M$. Based on the information above, the maximum concentration of $Ca^{2+}(aq)$ that can be present in drinking water without lowering the concentration of $F^-(aq)$ below the ideal level is closest to

(A) 0.25 M

(B) 0.025 M

(C) $1.6\times10^{-6}\,M$

(D) $1.6\times10^{-15}\,M$

GO ON TO THE NEXT PAGE.

$$2\ FeO(s) \rightleftarrows 2\ Fe(s) + O_2(g) \qquad K_{eq} = 1 \times 10^{-6} \text{ at } 1000\ K$$

$$CO_2(g) \rightleftarrows C(s) + O_2(g) \qquad K_{eq} = 1 \times 10^{-32} \text{ at } 1000\ K$$

50. The formation of Fe(*s*) and $O_2(g)$ from FeO(*s*) is not thermodynamically favorable at room temperature. In an effort to make the process favorable, C(*s*) is added to the FeO(*s*) at elevated temperatures. Based on the information above, which of the following gives the value of K_{eq} and the sign of $\Delta G°$ for the reaction represented by the equation below at 1000 K?

$$2\ FeO(s) + C(s) \rightleftarrows 2\ Fe(s) + CO_2(g)$$

	K_{eq}	$\Delta G°$
(A)	1×10^{-38}	Positive
(B)	1×10^{-38}	Negative
(C)	1×10^{26}	Positive
(D)	1×10^{26}	Negative

GO ON TO THE NEXT PAGE.

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**