

## The Exam

AP<sup>®</sup> Chemistry Exam

## SECTION I: Multiple-Choice Questions

2008

**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 Grade**

50%

**Writing Instrument**

Pencil required

**Electronic Device**

None allowed

**Instructions**

Section I of this exam contains 75 multiple-choice questions. Fill in only the ovals 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 oval 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) ● (C) (D) (E)

(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.

**About Guessing**

Many students wonder whether or not to guess the answers to questions about which they are not certain. In this section of the exam, as a correction for random guessing, one-fourth of the number of questions you answer incorrectly will be subtracted from the number of questions you answer correctly. If you are not sure of the best answer but have some knowledge of the question and are able to eliminate one or more of the answer choices, your chance of answering correctly is improved, and it may be to your advantage to answer such a question.

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	<b>H</b> 1.008																	2	<b>He</b> 4.00																
3	<b>Li</b> 6.94	4	<b>Be</b> 9.01																	9	<b>F</b> 19.00	10	<b>Ne</b> 20.18												
11	<b>Na</b> 22.99	12	<b>Mg</b> 24.30																	17	<b>Cl</b> 35.45	18	<b>Ar</b> 39.95												
19	<b>K</b> 39.10	20	<b>Ca</b> 40.08	21	<b>Sc</b> 44.96	22	<b>Ti</b> 47.90	23	<b>V</b> 50.94	24	<b>Cr</b> 52.00	25	<b>Mn</b> 54.94	26	<b>Fe</b> 55.85	27	<b>Co</b> 58.93	28	<b>Ni</b> 58.69	29	<b>Cu</b> 63.55	30	<b>Zn</b> 65.39	31	<b>Ga</b> 69.72	32	<b>Ge</b> 72.59	33	<b>As</b> 74.92	34	<b>Se</b> 78.96	35	<b>Br</b> 79.90	36	<b>Kr</b> 83.80
37	<b>Rb</b> 85.47	38	<b>Sr</b> 87.62	39	<b>Y</b> 88.91	40	<b>Zr</b> 91.22	41	<b>Nb</b> 92.91	42	<b>Mo</b> 95.94	43	<b>Tc</b> (98)	44	<b>Ru</b> 101.1	45	<b>Rh</b> 102.91	46	<b>Pd</b> 106.42	47	<b>Ag</b> 107.87	48	<b>Cd</b> 112.41	49	<b>In</b> 114.82	50	<b>Sn</b> 118.71	51	<b>Sb</b> 121.75	52	<b>Te</b> 127.60	53	<b>I</b> 126.91	54	<b>Xe</b> 131.29
55	<b>Cs</b> 132.91	56	<b>Ba</b> 137.33	57	<b>*La</b> 138.91	72	<b>Hf</b> 178.49	73	<b>Ta</b> 180.95	74	<b>W</b> 183.85	75	<b>Re</b> 186.21	76	<b>Os</b> 190.2	77	<b>Ir</b> 192.2	78	<b>Pt</b> 195.08	79	<b>Au</b> 196.97	80	<b>Hg</b> 200.59	81	<b>Tl</b> 204.38	82	<b>Pb</b> 207.2	83	<b>Bi</b> 208.98	84	<b>Po</b> (209)	85	<b>At</b> (210)	86	<b>Rn</b> (222)
87	<b>Fr</b> (223)	88	<b>Ra</b> 226.02	89	<b>†Ac</b> 227.03	104	<b>Rf</b> (261)	105	<b>Db</b> (262)	106	<b>Sg</b> (266)	107	<b>Bh</b> (264)	108	<b>Hs</b> (277)	109	<b>Mt</b> (268)	110	<b>Ds</b> (271)	111	<b>Rg</b> (272)	200.59	207.2	208.98	209)	210)	(210)	(222)							
				*Lanthanide Series																66	<b>Dy</b> 162.50	67	<b>Ho</b> 164.93	68	<b>Er</b> 167.26	69	<b>Tm</b> 168.93	70	<b>Yb</b> 173.04	71	<b>Lu</b> 174.97				
				†Actinide Series																98	<b>Cf</b> 285.10	99	<b>Es</b> (287)	100	<b>Fm</b> (289)	101	<b>Md</b> (291)	102	<b>No</b> (293)	103	<b>Lr</b> (262)				

## 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 oval 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 types of elements in the periodic table.

- (A) Noble gases
- (B) Alkali metals
- (C) Halogens
- (D) Transition elements
- (E) Actinides

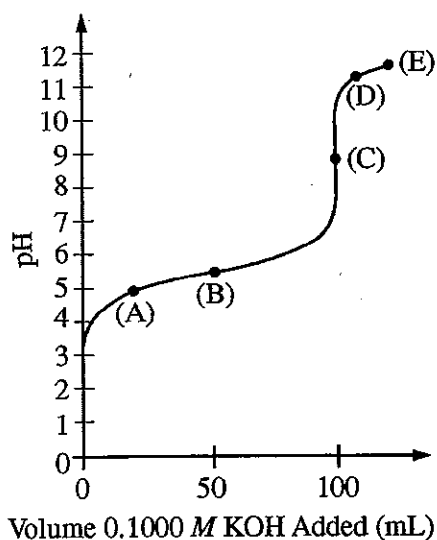
1. Are the most difficult to oxidize in a given period of the periodic table
2. Are always radioactive
3. Are the most likely to form anions

## Section I

## Part A

## Questions 4-6

A solution of a weak monoprotic acid is titrated with a solution of a strong base, KOH. Consider the points labeled (A) through (E) on the titration curve that results, as shown below.



- The point at which the moles of the added strong base are equal to the moles of the weak acid initially present
- The point at which the pH is closest to that of the strong base being added
- The point at which the concentrations of the weak acid and its conjugate base are approximately equal

Questions 7-9 refer to the following pure substances, which are gases at 25°C and 1 atmosphere.

- $\text{NH}_3(g)$
- $\text{BH}_3(g)$
- $\text{H}_2(g)$
- $\text{H}_2\text{S}(g)$
- $\text{HBr}(g)$

- Has molecules with a pyramidal shape
- Is a strong electrolyte in aqueous solution
- Is the slowest to effuse through a small opening at 25°C and 1 atm

Questions 10-11 refer to the following.

- Activation energy
- Enthalpy of formation
- Entropy
- Gibbs free energy
- Lattice energy

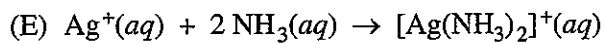
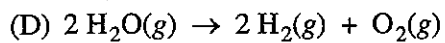
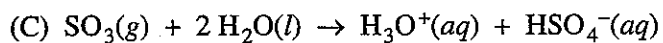
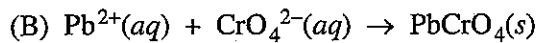
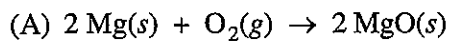
- Quantity that would be zero for a pure, perfect crystal at 0 K
- Quantity typically determined by measuring the rate of a reaction at two or more different temperatures

Questions 12-14 refer to the following combinations of enthalpy changes ( $\Delta H$ ) and entropy changes ( $\Delta S$ ) for chemical reactions.

- $\Delta H > 0, \Delta S > 0$
- $\Delta H > 0, \Delta S < 0$
- $\Delta H < 0, \Delta S > 0$
- $\Delta H < 0, \Delta S < 0$
- $\Delta H = 0, \Delta S < 0$

- Must be true for a reaction that is spontaneous at all temperatures
- True for the evaporation of water at 25°C and 1 atm
- True for the combustion of liquid pentane,  $\text{C}_5\text{H}_{12}(l)$ , to form  $\text{H}_2\text{O}(g)$  and  $\text{CO}_2(g)$  at 1 atm

Questions 15-17 refer to the following reactions.



15. A precipitation reaction

16. A Lewis acid-base reaction that produces a coordination complex

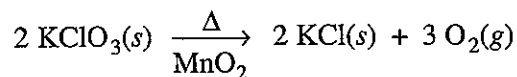
17. An oxidation-reduction reaction that is also a synthesis reaction

## Section I

## Part B

## 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 oval on the answer sheet.



18. According to the equation above, how many moles of potassium chlorate,  $\text{KClO}_3$ , must be decomposed to generate 1.0 L of  $\text{O}_2$  gas at standard temperature and pressure?
- (A)  $\frac{1}{3} \left( \frac{1}{22.4} \right)$  mol  
 (B)  $\frac{1}{2} \left( \frac{1}{22.4} \right)$  mol  
 (C)  $\frac{2}{3} \left( \frac{1}{22.4} \right)$  mol  
 (D)  $\frac{3}{2} \left( \frac{1}{22.4} \right)$  mol  
 (E)  $2 \left( \frac{1}{22.4} \right)$  mol
19. Which of the following ions has the same number of electrons as  $\text{Br}^-$ ?
- (A)  $\text{Ca}^{2+}$   
 (B)  $\text{K}^+$   
 (C)  $\text{Sr}^{2+}$   
 (D)  $\text{I}^-$   
 (E)  $\text{Cl}^-$
20. In solid methane, the forces between neighboring  $\text{CH}_4$  molecules are best characterized as
- (A) ionic bonds  
 (B) covalent bonds  
 (C) hydrogen bonds  
 (D) ion-dipole forces  
 (E) London (dispersion) forces
21. Of the following electron configurations of neutral atoms, which represents an atom in an excited state?
- (A)  $1s^2 2s^2 2p^5$   
 (B)  $1s^2 2s^2 2p^5 3s^2$   
 (C)  $1s^2 2s^2 2p^6 3s^1$   
 (D)  $1s^2 2s^2 2p^6 3s^2 3p^2$   
 (E)  $1s^2 2s^2 2p^6 3s^2 3p^5$
22. Which of the following is a nonpolar molecule that contains polar bonds?
- (A)  $\text{F}_2$   
 (B)  $\text{CHF}_3$   
 (C)  $\text{CO}_2$   
 (D)  $\text{HCl}$   
 (E)  $\text{NH}_3$
23. The oxidation state that is common to aqueous ions of Fe, Mn, and Zn is
- (A) +1  
 (B) +2  
 (C) +3  
 (D) +4  
 (E) +5
24. Which of the following shows the correct number of protons, neutrons, and electrons in a neutral cesium-134 atom?
- |     | Protons | Neutrons | Electrons |
|-----|---------|----------|-----------|
| (A) | 55      | 55       | 55        |
| (B) | 55      | 79       | 55        |
| (C) | 55      | 79       | 79        |
| (D) | 79      | 55       | 79        |
| (E) | 134     | 55       | 134       |

25. The pressure, in atm, exerted by 1.85 mol of an ideal gas placed in a 3.00 L container at 35.0°C is given by which of the following expressions?

(A)  $\frac{(1.85)(0.0821)(308)}{3.00}$  atm

(B)  $\frac{(1.85)(35.0)}{(0.0821)(3.00)}$  atm

(C)  $\frac{3.00}{(1.85)(0.0821)(308)}$  atm

(D)  $\frac{(1.85)(8.314)(308)}{3.00}$  atm

(E)  $\frac{(3.00)(1.85)}{(0.0821)(35.0)}$  atm

Experiment	[X] <sub>0</sub>	[Y] <sub>0</sub>	Initial Rate of Formation of Z (mol L <sup>-1</sup> sec <sup>-1</sup> )
1	0.40	0.10	R
2	0.20	0.20	?

26. The table above shows the results from a rate study of the reaction  $X + Y \rightarrow Z$ . Starting with known concentrations of X and Y in experiment 1, the rate of formation of Z was measured. If the reaction was first order with respect to X and second order with respect to Y, the initial rate of formation of Z in experiment 2 would be

(A)  $\frac{R}{4}$

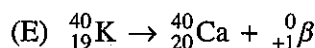
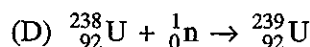
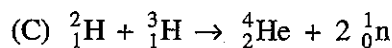
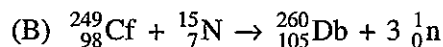
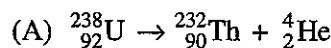
(B)  $\frac{R}{2}$

(C) R

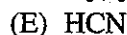
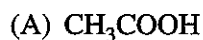
(D) 2R

(E) 4R

27. Which of the following is a correctly balanced nuclear reaction?



28. Which of the following molecules contains only single bonds?



29. What is the molality of a solution of phosphoric acid, H<sub>3</sub>PO<sub>4</sub>, that contains 24.5 g of phosphoric acid (molar mass 98.0 g) in 100. g of H<sub>2</sub>O?

(A) 0.245 m

(B) 2.50 m

(C) 4.00 m

(D) 25.0 m

(E) 40.0 m

**Section I****Part B**

	Mass (g)
Empty flask	18.990
Flask + liquid	39.493

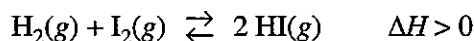
30. The density of a pure liquid at 25°C was calculated by determining the mass and volume of a sample of the liquid. A student measured the mass of a clean, dry 25.00 mL volumetric flask, filled the flask to its calibration mark with the liquid, and then measured the mass of the flask and liquid. The recorded measurements are shown in the table above. On the basis of this information, to how many significant figures should the density of the liquid be reported?
- (A) 3  
(B) 4  
(C) 5  
(D) 6  
(E) 8
31. A compound contains 30. percent sulfur and 70. percent fluorine by mass. The empirical formula of the compound is
- (A) SF  
(B) SF<sub>2</sub>  
(C) SF<sub>4</sub>  
(D) SF<sub>6</sub>  
(E) S<sub>2</sub>F
32. Gaseous cyclobutene undergoes a first-order reaction to form gaseous butadiene. At a particular temperature, the partial pressure of cyclobutene in the reaction vessel drops to one-eighth its original value in 124 seconds. What is the half-life for this reaction at this temperature?
- (A) 15.5 sec  
(B) 31.0 sec  
(C) 41.3 sec  
(D) 62.0 sec  
(E) 124 sec
33. If 0.40 mol of H<sub>2</sub> and 0.15 mol of O<sub>2</sub> were to react as completely as possible to produce H<sub>2</sub>O, what mass of reactant would remain?
- (A) 0.20 g of H<sub>2</sub>  
(B) 0.40 g of H<sub>2</sub>  
(C) 3.2 g of O<sub>2</sub>  
(D) 4.0 g of O<sub>2</sub>  
(E) 4.4 g of O<sub>2</sub>





34. When the equation above is balanced and all coefficients are reduced to lowest whole-number terms, what is the coefficient for  $\text{H}_3\text{PO}_4(l)$  ?

(A) 1  
(B) 2  
(C) 3  
(D) 4  
(E) 5



35. Which of the following changes to the equilibrium system represented above will increase the quantity of  $\text{HI}(g)$  in the equilibrium mixture?

I. Adding  $\text{H}_2(g)$   
II. Increasing the temperature  
III. Decreasing the pressure

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

36. How many carbon atoms are contained in 2.8 g of  $\text{C}_2\text{H}_4$  ?

(A)  $1.2 \times 10^{23}$   
(B)  $3.0 \times 10^{23}$   
(C)  $6.0 \times 10^{23}$   
(D)  $1.2 \times 10^{24}$   
(E)  $6.0 \times 10^{24}$

37. Which of the following elements combines with oxygen to form a covalent network solid?

(A) Si  
(B) S  
(C) C  
(D) Mg  
(E) Cs

38. How many mL of 10.0 M HCl are needed to prepare 500. mL of 2.00 M HCl ?

(A) 1.00 mL  
(B) 10.0 mL  
(C) 20.0 mL  
(D) 100. mL  
(E) 200. mL

39. A student mixes equal volumes of 1.0 M solutions of tin(II) chloride and copper(II) sulfate and observes that no precipitate forms. Then the student mixes equal volumes of 1.0 M solutions of zinc(II) sulfate and tin(II) fluoride and observes the formation of a precipitate. The formula of the precipitate must be

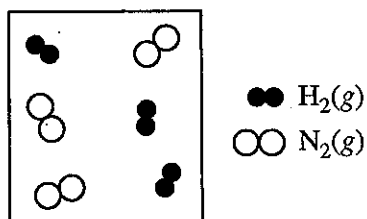
(A)  $\text{SnF}_2$   
(B)  $\text{SnSO}_4$   
(C)  $\text{Sn}(\text{SO}_4)_2$   
(D)  $\text{ZnF}$   
(E)  $\text{ZnF}_2$

40. On the basis of strength of intermolecular forces, which of the following elements would be expected to have the highest melting point?

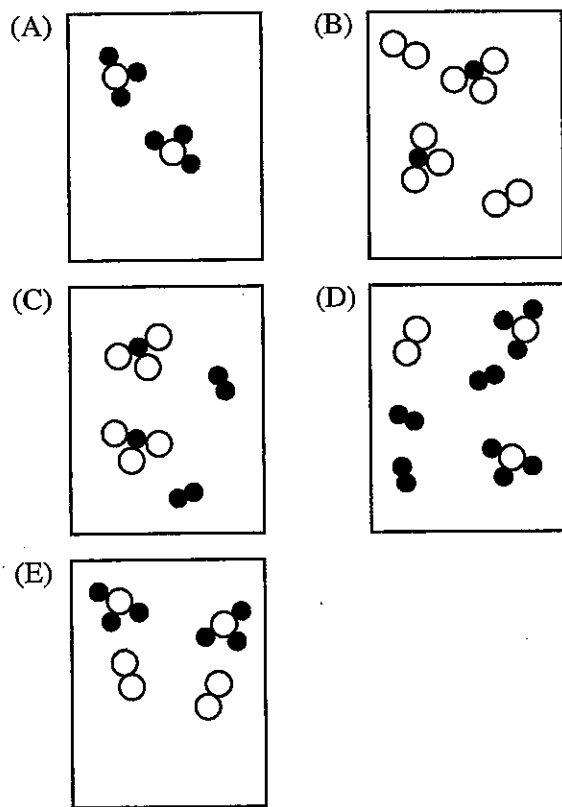
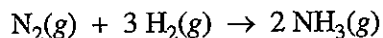
(A)  $\text{Br}_2$   
(B)  $\text{Cl}_2$   
(C)  $\text{F}_2$   
(D) Kr  
(E)  $\text{N}_2$

**Section I**

**Part B**



41. The diagram above represents  $\text{H}_2(g)$  and  $\text{N}_2(g)$  in a closed container. Which of the following diagrams would represent the results if the reaction shown below were to proceed as far as possible?

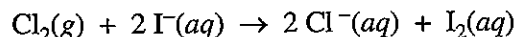


42. Equal masses of He and Ne are placed in a sealed container. What is the partial pressure of He if the total pressure in the container is 6 atm?

- (A) 1 atm  
 (B) 2 atm  
 (C) 3 atm  
 (D) 4 atm  
 (E) 5 atm

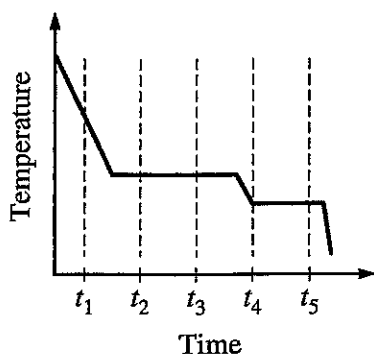
43. A pure liquid in an open vessel boils at the temperature at which the

- (A) molar entropy of the liquid becomes equal to that of the gas  
 (B) vapor pressure of the liquid becomes equal to the equilibrium pressure at the triple point  
 (C) vapor pressure of the liquid becomes equal to the atmospheric pressure on the surface of the liquid  
 (D) molar heat capacity of the liquid becomes equal to that of the gas  
 (E) average kinetic energy of the liquid molecules becomes equal to that of the gas molecules



44. Which of the following best accounts for the fact that a galvanic cell based on the reaction represented above will generate electricity?

- (A)  $\text{Cl}_2$  can easily lose two electrons.  
 (B)  $\text{Cl}_2$  is a stronger oxidizing agent than  $\text{I}_2$ .  
 (C) I atoms have more electrons than do atoms of Cl.  
 (D)  $\text{I}^-$  is a more stable species than  $\text{I}_2$ .  
 (E)  $\text{I}_2(s)$  is more soluble than  $\text{Cl}_2(g)$ .



45. The cooling curve above shows how the temperature of a sample varies with time as the sample goes through phase changes. The sample starts as a gas, and heat is removed at a constant rate. At which time does the sample contain the most liquid?

- (A)  $t_1$
- (B)  $t_2$
- (C)  $t_3$
- (D)  $t_4$
- (E)  $t_5$

46. A solution is prepared by adding 16 g of  $\text{CH}_3\text{OH}$  (molar mass 32 g) to 90. g of  $\text{H}_2\text{O}$  (molar mass 18 g). The mole fraction of  $\text{CH}_3\text{OH}$  in this solution is closest to which of the following?

- (A) 0.1
- (B) 0.2
- (C) 0.3
- (D) 0.4
- (E) 0.6

47. When diluting concentrated  $\text{H}_2\text{SO}_4$ , one should slowly add acid to a beaker of water rather than add water to a beaker of acid. The reason for this precaution is to ensure that

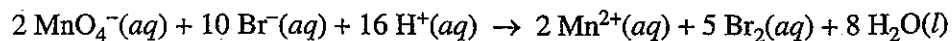
- (A) there is complete ionization of the  $\text{H}_2\text{SO}_4$
- (B) there is a sufficient volume of water to absorb the heat released
- (C) the water does not sink beneath the acid and remain unmixed
- (D) the acid does not react with impurities in the dry beaker
- (E) any  $\text{SO}_2$  released quickly redissolves in the water

48. Which of the following is the conjugate acid of  $\text{NH}_2^-$ ?

- (A)  $\text{NH}_2^-$
- (B)  $\text{NH}_3$
- (C)  $\text{H}^+$
- (D)  $\text{NH}_4^+$
- (E)  $\text{H}_2\text{O}$

49. Salts containing which of the following ions are generally insoluble in cold water?

- (A) Acetate
- (B) Ammonium
- (C) Potassium
- (D) Nitrate
- (E) Phosphate

**Section I****Part B**

50. How many electrons are transferred in the reaction represented by the balanced equation above?

- (A) 2
- (B) 4
- (C) 5
- (D) 8
- (E) 10

51. Under which of the following conditions of temperature and pressure would 1.0 mol of the real gas  $\text{CO}_2(g)$  behave most like an ideal gas?

	Temperature (K)	Pressure (atm)
(A)	100	0.1
(B)	100	100
(C)	800	0.1
(D)	800	1
(E)	800	100

52. Which of the following measures of concentration changes with temperature?

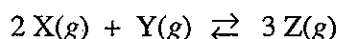
- (A) Mass percentage
- (B) Mole fraction
- (C) Molarity
- (D) Molality
- (E) Parts per million by mass

53. A sample of 10.0 mol of butyric acid,  $\text{HC}_4\text{H}_7\text{O}_2$ , a weak acid, is dissolved in 1000. g of water to make a 10.0-molal solution. Which of the following would be the best method to determine the molarity of the solution? (In each case, assume that no additional information is available.)

- (A) Titration of the solution with standard acid
- (B) Measurement of the pH with a pH meter
- (C) Determination of the freezing point of the solution
- (D) Measurement of the total volume of the solution
- (E) Measurement of the electrical conductivity of the solution

54. The nonvolatile compound ethylene glycol,  $\text{C}_2\text{H}_6\text{O}_2$ , forms nearly ideal solutions with water. What is the vapor pressure of a solution made from 1.00 mole of  $\text{C}_2\text{H}_6\text{O}_2$  and 9.00 moles of  $\text{H}_2\text{O}$  if the vapor pressure of pure water at the same temperature is 25.0 mm Hg?

- (A) 2.50 mm Hg
- (B) 7.50 mm Hg
- (C) 12.5 mm Hg
- (D) 22.5 mm Hg
- (E) 27.5 mm Hg



55. The reaction mixture represented above is at equilibrium at 298 K, and the molar concentrations are  $[\text{X}] = 2.0 \text{ M}$ ,  $[\text{Y}] = 0.5 \text{ M}$ , and  $[\text{Z}] = 4.0 \text{ M}$ . What is the value of the equilibrium constant for the reaction at 298 K?

- (A) 0.50
- (B) 2.0
- (C) 4.0
- (D) 16
- (E) 32

56. The London (dispersion) forces are weakest for which of the following gases under the same conditions of temperature and pressure?

- (A)  $\text{H}_2$
- (B)  $\text{O}_2$
- (C) Xe
- (D)  $\text{F}_2$
- (E)  $\text{N}_2$



57. What is the hybridization of the carbon atoms in a molecule of ethyne, represented above?

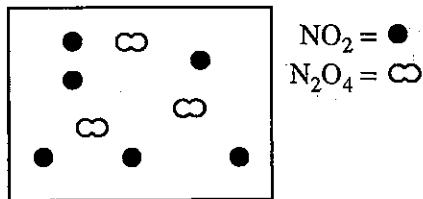
- (A)  $sp$
- (B)  $sp^2$
- (C)  $sp^3$
- (D)  $dsp^2$
- (E)  $d^2sp$

58. A 360. mg sample of aspirin,  $\text{C}_9\text{H}_8\text{O}_4$ , (molar mass 180. g), is dissolved in enough water to produce 200. mL of solution. What is the molarity of aspirin in a 50. mL sample of this solution?

- (A) 0.0800 M
- (B) 0.0400 M
- (C) 0.0200 M
- (D) 0.0100 M
- (E) 0.00250 M

## Section I

## Part B

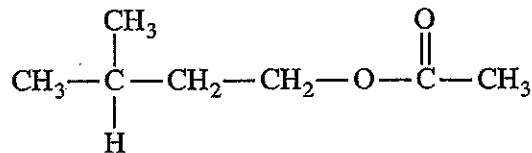


59. The diagram above represents a mixture of  $\text{NO}_2(g)$  and  $\text{N}_2\text{O}_4(g)$  in a 1.0 L container at a given temperature. The two gases are in equilibrium according to the equation  $2 \text{NO}_2(g) \rightleftharpoons \text{N}_2\text{O}_4(g)$ . Which of the following must be true about the value of the equilibrium constant for the reaction at this temperature?

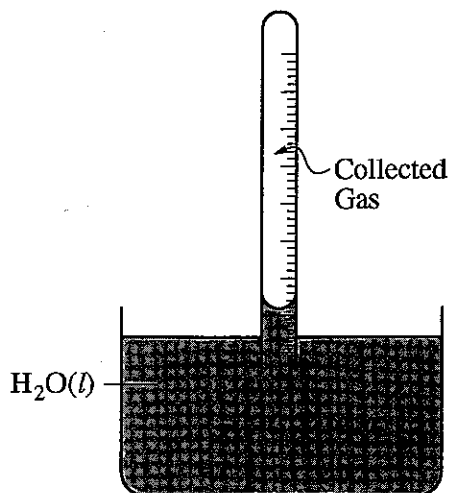
- (A)  $K = 0$   
 (B)  $0 < K < 1$   
 (C)  $K = 1$   
 (D)  $K > 1$   
 (E) There is not enough information to determine the relative value of  $K$ .

60. When aqueous  $\text{NH}_3$  is first added to a solution containing  $\text{Ni}^{2+}$ , a precipitate forms, but when an excess of aqueous  $\text{NH}_3$  is added, the precipitate dissolves. Which of the following best explains why the precipitate dissolves?

- (A)  $\text{Ni}^{2+}$  forms hydrogen bonds with  $\text{NH}_3$ .  
 (B)  $\text{Ni}^{2+}$  forms a complex ion with  $\text{NH}_3$ .  
 (C)  $\text{Ni}^{2+}$  acts as a Brønsted-Lowry base.  
 (D)  $\text{Ni}^{2+}$  is oxidized to  $\text{Ni}^{3+}$ .  
 (E)  $\text{Ni}^{2+}$  is reduced to  $\text{Ni}^+$ .



61. The structure of a molecule of "banana oil" is shown above. This organic compound is an example of
- (A) an alcohol  
 (B) an amine  
 (C) a carboxylic acid  
 (D) an ester  
 (E) a ketone
62. Which of the following pieces of laboratory glassware should be used to most accurately measure out a 25.00 mL sample of a solution?
- (A) 5 mL pipet  
 (B) 25 mL pipet  
 (C) 25 mL beaker  
 (D) 25 mL Erlenmeyer flask  
 (E) 50 mL graduated cylinder
63. Which of the following best helps to account for the fact that the  $\text{F}^-$  ion is smaller than the  $\text{O}^{2-}$  ion?
- (A)  $\text{F}^-$  has a larger nuclear mass than  $\text{O}^{2-}$  has.  
 (B)  $\text{F}^-$  has a larger nuclear charge than  $\text{O}^{2-}$  has.  
 (C)  $\text{F}^-$  has more electrons than  $\text{O}^{2-}$  has.  
 (D)  $\text{F}^-$  is more electronegative than  $\text{O}^{2-}$  is.  
 (E)  $\text{F}^-$  is more polarizable than  $\text{O}^{2-}$  is.
64. Which of the following solutions has a pH greater than 7.0?
- (A) 0.10 M KBr  
 (B) 0.10 M  $\text{NH}_4\text{Cl}$   
 (C) 0.10 M  $\text{HC}_2\text{H}_3\text{O}_2$   
 (D) 0.10 M NaF  
 (E) 0.10 M HI



65. In a laboratory experiment,  $\text{H}_2(\text{g})$  is collected over water in a gas-collection tube as shown in the diagram above. The temperature of the water is  $21^\circ\text{C}$  and the atmospheric pressure in the laboratory is measured to be 772 torr. Before measuring the volume of gas collected in the tube, what step, if any, must be taken to make it possible to determine the total gas pressure inside the tube?

- (A) Tilt the tube to the side enough to let some air in to break the partial vacuum in the tube.
- (B) Lift the tube upward until it is just barely immersed in the water.
- (C) Move the tube downward until the water level is the same inside and outside the tube.
- (D) Adjust the temperature of the water to  $25^\circ\text{C}$ .
- (E) No further steps need to be taken as long as the temperature of the water is known.

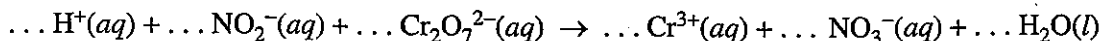
66. Factors that affect the rate of a chemical reaction include which of the following?

- I. Frequency of collisions of reactant particles
- II. Kinetic energy of collisions of reactant particles
- III. Orientation of reactant particles during collisions

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

## Section I

## Part B



67. When the equation above is balanced and all coefficients are reduced to lowest whole-number terms, the coefficient for  $\text{H}_2\text{O}(l)$  is

- (A) 2
- (B) 4
- (C) 5
- (D) 6
- (E) 8

68. The pH of a solution prepared by the addition of 10. mL of 0.002 M  $\text{KOH}(aq)$  to 10. mL of distilled water is closest to

- (A) 12
- (B) 11
- (C) 10
- (D) 4
- (E) 3

69. At standard temperature and pressure, a 0.50 mol sample of  $\text{H}_2$  gas and a separate 1.0 mol sample of  $\text{O}_2$  gas have the same

- (A) average molecular kinetic energy
- (B) average molecular speed
- (C) volume
- (D) effusion rate
- (E) density

70. Naturally produced amino acids typically contain all of the following elements EXCEPT

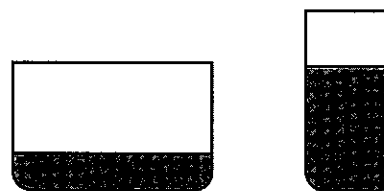
- (A) nitrogen
- (B) chlorine
- (C) oxygen
- (D) hydrogen
- (E) carbon

71. Of the following single bonds, which is the LEAST polar?

- (A) N-H
- (B) H-F
- (C) O-F
- (D) I-F
- (E) O-H

72. When mixed, each of the following pairs of reactants gives visible evidence of a chemical reaction EXCEPT

- (A)  $\text{Na}_2\text{CO}_3(s) + \text{HCl}(aq)$
- (B)  $\text{Zn}(s) + \text{HCl}(aq)$
- (C)  $\text{Ba}(\text{NO}_3)_2(aq) + \text{Na}_2\text{SO}_4(aq)$
- (D)  $\text{FeCl}_3(aq) + \text{KOH}(aq)$
- (E)  $\text{NH}_4\text{Cl}(aq) + \text{HCl}(aq)$



Container 1

Container 2

73. The figure above shows two closed containers. Each contains the same volume of acetone in equilibrium with its vapor at the same temperature. The vapor pressure of the acetone is

- (A) higher in container 1 because the surface area of the liquid is greater
- (B) higher in container 1 because the volume of vapor is greater
- (C) lower in container 1 because the level of the liquid is lower
- (D) the same in both containers because the volume of the liquid is the same
- (E) the same in both containers because the temperature is the same



74. An electric current of 1.00 ampere is passed through an aqueous solution of  $\text{Ni}(\text{NO}_3)_2$ . How long will it take to plate out exactly 1.00 mol of nickel metal, assuming 100 percent current efficiency?

(1 faraday = 96,500 coulombs =  $6.02 \times 10^{23}$  electrons)

- (A) 386,000 sec
  - (B) 193,000 sec
  - (C) 96,500 sec
  - (D) 48,200 sec
  - (E) 24,100 sec
- 

75. Which of the following molecules has an angular (bent) geometry that is commonly represented as a resonance hybrid of two or more electron-dot structures?

- (A)  $\text{CO}_2$
- (B)  $\text{O}_3$
- (C)  $\text{CH}_4$
- (D)  $\text{BeF}_2$
- (E)  $\text{OF}_2$

END OF SECTION I

# Chapter III: Answers to the 2008 AP Chemistry Exam

## ■ Section I: Multiple Choice

- Section I Answer Key and Percent Answering Correctly
- Analyzing Your Students' Performance on the Multiple-Choice Section
- Diagnostic Guide for the 2008 AP Chemistry Exam

## ■ Section II: Free Response

- Comments from the Chief Reader
- Scoring Guidelines, Sample Student Responses, and Commentary

## Section I: Multiple Choice

Listed below are the correct answers to the multiple-choice questions, the percent of AP students who answered each question correctly by AP score, and the total percent answering correctly.

### Section I Answer Key and Percent Answering Correctly

Item No.	Correct Answer	Percent Correct by Score					Total Percent Correct
		5	4	3	2	1	
1	A	87	82	77	70	54	72
2	E	94	85	75	65	45	70
3	C	89	81	69	58	37	63
4	C	91	76	66	58	46	65
5	E	95	86	76	65	42	69
6	B	74	45	32	25	22	38
7	A	91	79	69	62	51	68
8	E	85	67	51	38	25	50
9	E	90	79	67	55	35	62
10	C	69	52	41	33	21	41
11	A	56	36	29	26	23	33
12	C	93	79	62	45	25	57
13	A	81	57	39	26	16	41
14	C	71	47	32	21	13	34
15	B	99	96	91	83	52	80
16	E	87	72	58	47	37	58
17	A	91	75	56	40	24	54
18	C	85	72	63	57	43	62
19	C	99	95	89	78	48	78
20	E	87	66	48	33	16	46
21	B	95	88	79	68	42	71
22	C	75	50	36	26	19	39
23	B	97	92	87	80	64	82
24	B	98	94	89	80	60	82
25	A	98	95	93	89	71	87

Item No.	Correct Answer	Percent Correct by Score					Total Percent Correct
		5	4	3	2	1	
26	D	87	65	45	31	21	47
27	D	91	81	73	64	48	69
28	C	96	91	84	76	52	77
29	B	82	65	48	31	18	46
30	B	77	63	54	48	37	54
31	C	90	81	70	59	39	65
32	C	73	53	37	26	14	38
33	A	93	77	58	41	26	56
34	D	94	89	85	80	61	80
35	C	86	71	57	46	33	56
36	A	71	45	29	22	17	35
37	A	81	61	45	32	17	44
38	D	96	90	81	70	47	73
39	E	82	71	64	54	35	58
40	A	67	40	27	22	19	33
41	E	84	66	53	43	29	52
42	E	69	44	25	13	5	29
43	C	83	67	54	41	28	52
44	B	82	61	46	36	25	48
45	D	90	75	61	48	30	57
46	A	93	84	71	55	26	61
47	B	49	34	27	23	18	29
48	B	91	80	70	59	38	64
49	E	81	66	53	41	24	50
50	E	80	50	30	17	8	34

*continued on the next page*

## Section I Answer Key and Percent Answering Correctly (continued)

Item No.	Correct Answer	Percent Correct by Score					Total Percent Correct
		5	4	3	2	1	
51	C	73	51	37	25	15	37
52	C	69	51	39	30	23	40
53	D	88	77	67	58	42	64
54	D	54	26	15	10	9	21
55	E	94	87	80	68	35	69
56	A	78	52	38	29	21	41
57	A	74	51	35	22	11	36
58	D	67	42	30	22	14	33
59	B	63	43	31	22	14	32
60	B	68	42	28	21	15	33
61	D	58	39	30	24	19	32
62	B	47	38	32	29	22	32
63	B	80	55	36	23	12	38

Item No.	Correct Answer	Percent Correct by Score					Total Percent Correct
		5	4	3	2	1	
64	D	72	44	28	20	13	33
65	C	62	52	45	39	29	43
66	E	80	64	53	44	32	52
67	B	49	22	13	10	11	20
68	B	56	30	18	14	11	24
69	A	81	63	47	36	23	47
70	B	92	85	78	73	60	76
71	C	75	59	47	35	23	45
72	E	74	57	46	37	24	45
73	E	44	24	19	17	14	23
74	B	69	33	13	7	9	24
75	B	79	56	40	29	16	41

### Analyzing Your Students' Performance on the Multiple-Choice Section

If you give your students the 2008 exam for practice, you may want to analyze the results to find overall strengths and weaknesses in their understanding of AP Chemistry. The following diagnostic worksheet will help you do this. You are permitted to photocopy and distribute it to your students for completion.

1. In each section, students should insert a check mark for each correct answer.
2. Add together the total number of correct answers for each section.

3. To compare the student's number of correct answers for each section with the average number correct for that section, copy the number of correct answers to the "Number Correct" table at the end of the Diagnostic Guide.

In addition, under each item, the percent of AP students who answered correctly is shown, so students can analyze their performance on individual items. This information will be helpful in deciding how students should plan their study time. Please note that one item may appear in several different categories, as questions can cover different topics.