

2002 Advanced Placement Chemistry Exam

Section I: Multiple Choice

Time — 1 hour and 30 minutes

NO CALCULATORS 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	m	= molal
P	= pressure	L, mL	= liter(s), milliliter(s)
V	= volume	g	= gram(s)
S	= entropy	nm	= nanometer(s)
H	= enthalpy	atm	= atmosphere(s)
G	= free energy	J, kJ	= joule(s), kilojoule(s)
R	= molar gas constant	V	= volt(s)
n	= number of moles	mol	= mole(s)
M	= molar		

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 1–2

Consider atoms of the following elements. Assume that the atoms are in the ground state.

(A) S (B) Ca (C) Ga (D) Sb (E) Br

1. The atom that contains exactly two unpaired electrons
2. The atom that contains only one electron in the highest occupied energy sublevel

Questions 3–5 refer to the following molecules.

(A) CO₂ (B) H₂O (C) CH₄ (D) C₂H₄ (E) PH₃

3. The molecule with only one double bond
4. The molecule with the largest dipole moment
5. The molecule that has trigonal pyramidal geometry

Questions 6–7 refer to the following solid compounds.

- (A) PbSO_4 (B) CuO (C) KMnO_4 (D) KCl (E) FeCl_3

6. Is purple in aqueous solution
7. Is white and very soluble in water

Questions 8–10 refer to the following gases at 0°C and 1 atm.

- (A) Ne (B) Xe (C) O_2 (D) CO (E) NO

8. Has an average atomic or molecular speed closest to that of N_2 molecules at 0°C and 1 atm
9. Has the greatest density
10. Has the greatest rate of effusion through a pinhole

Questions 11–14 refer to the reactions represented below.

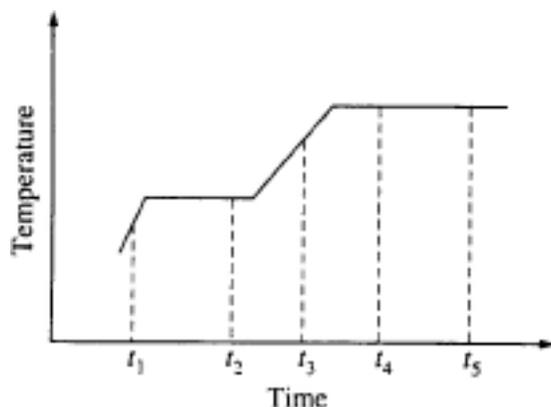
- (A) $\text{H}_2\text{SeO}_4(\text{aq}) + 2 \text{Cl}^-(\text{aq}) + 2 \text{H}^+(\text{aq}) \rightarrow \text{H}_2\text{SeO}_3(\text{aq}) + \text{Cl}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$
(B) $\text{S}_8(\text{s}) + 8 \text{O}_2(\text{g}) \rightarrow 8 \text{SO}_2(\text{g})$
(C) $3 \text{Br}_2(\text{aq}) + 6 \text{OH}^-(\text{aq}) \rightarrow 5 \text{Br}^-(\text{aq}) + \text{BrO}_3^-(\text{aq}) + 3 \text{H}_2\text{O}(\text{l})$
(D) $\text{Ca}^{2+}(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) \rightarrow \text{CaSO}_4(\text{s})$
(E) $\text{PtCl}_4(\text{s}) + 2 \text{Cl}^-(\text{aq}) \rightarrow \text{PtCl}_6^{2-}(\text{aq})$

11. A precipitation reaction
12. A reaction that produces a coordination complex
13. A reaction in which the same reactant undergoes both oxidation and reduction
14. A combustion reaction
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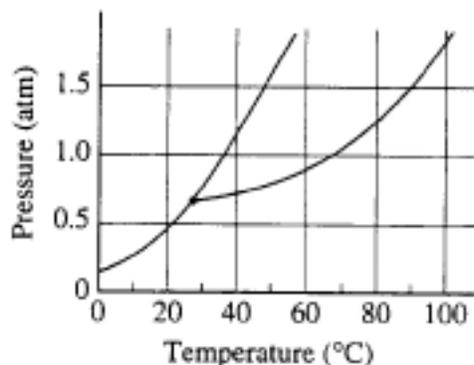
Part B

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.

Questions 15-16 relate to the graph below. The graph shows the temperature of a pure substance as it is heated at a constant rate in an open vessel at 1.0 atm pressure. The substance changes from the solid to the liquid to the gas phase.



15. The substance is at its normal freezing point at time
 (A) t_1 (B) t_2 (C) t_3 (D) t_4 (E) t_5
16. Which of the following best describes what happens to the substance between t_4 and t_5 ?
- (A) The molecules are leaving the liquid phase.
 (B) The solid and liquid phases coexist in equilibrium.
 (C) The vapor pressure of the substance is decreasing.
 (D) The average intermolecular distance is decreasing.
 (E) The temperature of the substance is increasing.
17. In which of the following groups are the three species isoelectronic; i.e., have the same number of electrons?
- (A) S^{2-} , K^+ , Ca^{2+} (B) Sc , Ti , V^{2+} (C) O^{2-} , S^{2-} , Cl^-
 (D) Mg^{2+} , Ca^{2+} , Sr^{2+} (E) Cs , Ba^{2+} , La^{3+}



18. The phase diagram for the pure substance X is shown above. The temperature of a sample of pure solid X is slowly raised from $10^\circ C$ to $100^\circ C$ at a constant pressure of 0.5 atm. What is the expected behavior of the substance?
- (A) It first melts to a liquid and then boils at about $70^\circ C$.

- (B) It first melts to a liquid and then boils at about 30°C.
 (C) It melts to a liquid at a temperature of about 20°C and remains a liquid until the temperature is greater than 100°C.
 (D) It sublimes to vapor at an equilibrium temperature of about 20°C.
 (E) It remains a solid until the temperature is greater than 100°C.

19. In which of the following species does sulfur have the same oxidation number as it does in H₂SO₄?
 (A) H₂SO₃ (B) S₂O₃²⁻ (C) S²⁻ (D) S₈ (E) SO₂Cl₂

20. A flask contains 0.25 mole of SO_{2(g)}, 0.50 mole of CH_{4(g)}, and 0.50 mole of O_{2(g)}. The total pressure of the gases in the flask is 800 mm Hg. What is the partial pressure of the SO_{2(g)} in the flask?

- (A) 800 mm Hg (B) 600 mm Hg (C) 250 mm Hg (D) 200 mm Hg (E) 160 mm Hg

21. In the laboratory, H_{2(g)} can be produced by adding which of the following to 1 M HCl(aq)?

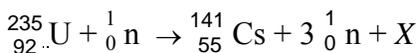
- I. 1 M NH_{3(aq)} II. Zn(s) III. NaHCO_{3(s)}

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



22. In liquid ammonia, the reaction represented above occurs. In the reaction NH₄⁺ acts as

- (A) a catalyst (B) both an acid and a base
 (C) the conjugate acid of NH₃ (D) the reducing agent
 (E) the oxidizing agent

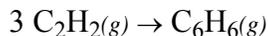


23. Neutron bombardment of uranium can induce the reaction represented above. Nuclide X is which of the following?

- (A) ${}_{35}^{92}\text{Br}$ (B) ${}_{35}^{94}\text{Br}$ (C) ${}_{37}^{91}\text{Rb}$ (D) ${}_{37}^{92}\text{Rb}$ (E) ${}_{37}^{94}\text{Rb}$

24. A compound contains 1.10 mol of K, 0.55 mol of Te, and 1.65 mol of O. What is the simplest formula of this compound?

- (A) KTeO (B) KTe₂O (C) K₂TeO₃ (D) K₂TeO₆ (E) K₄TeO₆

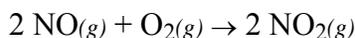


25. What is the standard enthalpy change, ΔH°, for the reaction represented above? (ΔH_f° of C₂H_{2(g)} is 230 kJ mol⁻¹; ΔH_f° of C₆H_{6(g)} is 83 kJ mol⁻¹.)

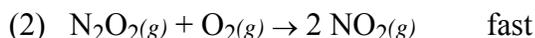
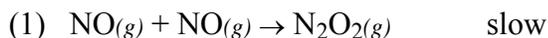
- (A) -607 kJ (B) -147 kJ (C) -19 kJ (D) +19 kJ (E) +773 kJ

26. Approximately what mass of CuSO₄·5H₂O (250 g mol⁻¹) is required to prepare 250 mL of 0.10 M copper(II) sulfate solution?

- (A) 4.0 g (B) 6.2 g (C) 34 g (D) 85 g (E) 140 g



27. A possible mechanism for the overall reaction represented above is the following.



Which of the following rate expressions agrees best with this possible mechanism?

(A) Rate = $k[\text{NO}]^2$

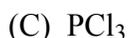
(B) Rate = $k \frac{[\text{NO}]}{[\text{O}_2]}$

(C) Rate = $k \frac{[\text{NO}]^2}{[\text{O}_2]}$

(D) Rate = $k[\text{NO}]^2[\text{O}_2]$

(E) Rate = $k[\text{N}_2\text{O}_2][\text{O}_2]$

28. Of the following compounds, which is the most ionic?



29. The best explanation for the fact that diamond is extremely hard is that diamond crystals

(A) are made up of atoms that are intrinsically hard because of their electronic structures

(B) consist of positive and negative ions that are strongly attracted to each other

(C) are giant molecules in which each atom forms strong covalent bonds with all of its neighboring atoms

(D) are formed under extreme conditions of temperature and pressure

(E) contain orbitals or bands of delocalized electrons that belong not to single atoms but to each crystal as a whole

30. At 25°C aqueous solutions with a pH of 8 have a hydroxide ion concentration, $[\text{OH}^-]$, of

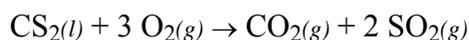
(A) $1 \times 10^{-14} \text{ M}$

(B) $1 \times 10^{-8} \text{ M}$

(C) $1 \times 10^{-6} \text{ M}$

(D) 1 M

(E) 8 M



31. What volume of $\text{O}_2(g)$ is required to react with excess $\text{CS}_2(l)$ to produce 4.0 L of $\text{CO}_2(g)$? (Assume all gases are measured at 0°C and 1 atm.)

(A) 12 L

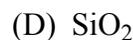
(B) 22.4 L

(C) $\frac{1}{3} \times 22.4 \text{ L}$

(D) $2 \times 22.4 \text{ L}$

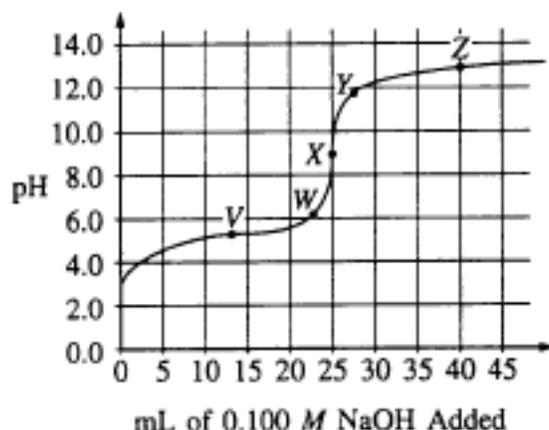
(E) $3 \times 22.4 \text{ L}$

32. Which of the following oxides is a gas at 25°C and 1 atm?



Questions 33-34

The graph below shows the titration curve that results when 100. mL of 0.0250 M acetic acid is titrated with 0.100 M NaOH.



33. Which of the following indicators is the best choice for this titration?

<u>Indicator</u>	<u>pH Range of Color Change</u>
(A) Methyl orange	3.2 - 4.4
(B) Methyl red	4.8 - 6.0
(C) Bromothymol blue	6.1 - 7.6
(D) Phenolphthalein	8.2 - 10.0
(E) Alizarin	11.0 - 12.4

34. What part of the curve corresponds to the optimum buffer action for the acetic acid/acetate ion pair?

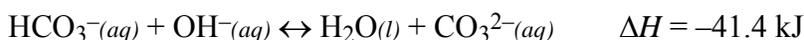
- (A) Point V (B) Point X
 (C) Point Z (D) Along all of section WY
 (E) Along all of section YZ

35. A solution is made by dissolving a nonvolatile solute in a pure solvent. Compared to the pure solvent, the solution

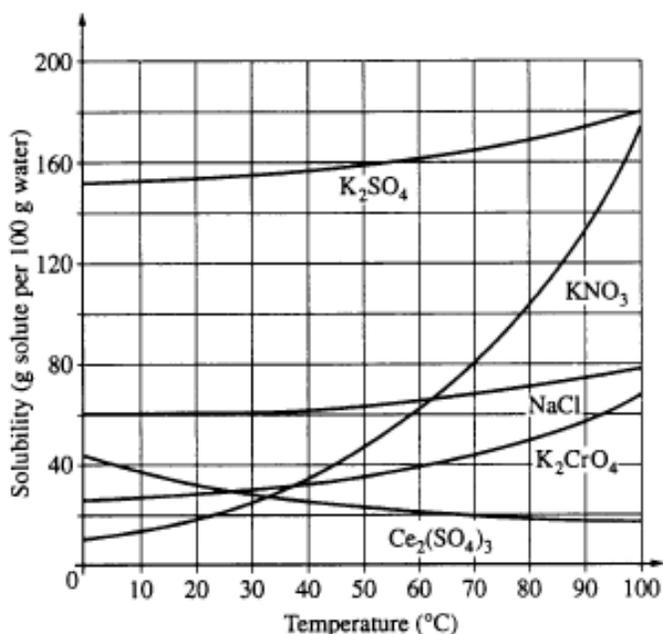
- (A) has a higher normal boiling point (B) has a higher vapor pressure
 (C) has the same vapor pressure (D) has a higher freezing point
 (E) is more nearly ideal

36. A sample of a solution of an unknown was treated with dilute hydrochloric acid. The white precipitate formed was filtered and washed with hot water. A few drops of potassium iodide solution were added to the hot water filtrate and a bright yellow precipitate was produced. The white precipitate remaining on the filter paper was readily soluble in ammonia solution. What two ions could have been present in the unknown?

- (A) $\text{Ag}^+(aq)$ and $\text{Hg}_2^{2+}(aq)$ (B) $\text{Ag}^+(aq)$ and $\text{Pb}^{2+}(aq)$
 (C) $\text{Ba}^{2+}(aq)$ and $\text{Ag}^+(aq)$ (D) $\text{Ba}^{2+}(aq)$ and $\text{Hg}_2^{2+}(aq)$
 (E) $\text{Ba}^{2+}(aq)$ and $\text{Pb}^{2+}(aq)$

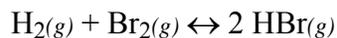


37. When the reaction represented by the equation above is at equilibrium at 1 atm and 25°C, the ratio $\frac{[\text{CO}_3^{2-}]}{[\text{HCO}_3^-]}$ can be increased by doing which of the following?
- (A) Decreasing the temperature
 (B) Adding acid
 (C) Adding a catalyst
 (D) diluting the solution with distilled water
 (E) Bubbling neon gas through the solution
38. A 0.10 M aqueous solution of sodium sulfate, Na_2SO_4 , is a better conductor of electricity than 0.10 M aqueous solution of sodium chloride, NaCl . Which of the following best explains this observation?
- (A) Na_2SO_4 is more soluble water than NaCl is.
 (B) Na_2SO_4 has a higher molar mass than NaCl has.
 (C) To prepare a given volume of 0.10 M solution, the mass of Na_2SO_4 needed is more than twice the mass of NaCl needed.
 (D) More moles of ions are present in a given volume of 0.10 M Na_2SO_4 than in the same volume of 0.10 M NaCl .
 (E) The degree of dissociation of Na_2SO_4 in solution is significantly greater than that of NaCl .



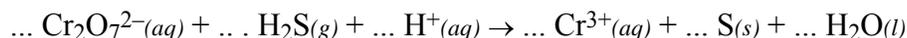
39. On the basis of the solubility curves shown above, the greatest percentage of which compound can be recovered by cooling a saturated solution of that compound from 90°C to 30°C?
- (A) NaCl (B) KNO_3 (C) K_2CrO_4 (D) K_2SO_4 (E) $\text{Ce}_2(\text{SO}_4)_3$
40. An excess of $\text{Mg}_{(s)}$ is added to 100. mL of 0.400 M HCl . At 0°C and 1 atm pressure, what volume of H_2 gas can be obtained?
- (A) 22.4 mL (B) 44.8 mL (C) 224 mL (D) 448 mL (E) 896 mL
41. When solid NH_4SCN is mixed with solid $\text{Ba}(\text{OH})_2$ in a closed container, the temperature drops and a gas is produced. Which of the following indicates the correct signs for ΔG , ΔH , and ΔS for the process?

	ΔG	ΔH	ΔS
(A)	—	—	—
(B)	—	+	—
(C)	—	+	+
(D)	+	—	+
(E)	+	—	—



42. At a certain temperature, the value of the equilibrium constant, K , for the reaction represented above is 2.0×10^5 . What is the value of K for the reverse reaction at the same temperature?
 (A) -2.0×10^{-5} (B) 5.0×10^{-6} (C) 2.0×10^{-5} (D) 5.0×10^{-5} (E) 5.0×10^{-4}
43. The atomic mass of copper is 63.55. Given that there are only two naturally occurring isotopes of copper, ^{63}Cu and ^{65}Cu , the natural abundance of the ^{65}Cu isotope must be approximately
 (A) 90% (B) 70% (C) 50% (D) 25% (E) 10%
44. Which of the following properties generally decreases across the periodic table from sodium to chlorine?
 (A) First ionization energy (B) Atomic mass
 (C) Electronegativity (D) Maximum value of oxidation number
 (E) Atomic radius
45. What is the mole fraction of ethanol, $\text{C}_2\text{H}_5\text{OH}$, in an aqueous solution that is 46 percent ethanol by mass? (The molar mass of $\text{C}_2\text{H}_5\text{OH}$ is 46 g; the molar mass of H_2O is 18 g.)
 (A) 0.25 (B) 0.46 (C) 0.54 (D) 0.67 (E) 0.75
46. The effective nuclear charge experienced by the outermost electron of Na is different than the effective nuclear charge experienced by the outermost electron of Ne. This difference best accounts for which of the following?
 (A) Na has a greater density at standard conditions than Ne.
 (B) Na has a lower first ionization energy than Ne.
 (C) Na has a higher melting point than Ne.
 (D) Na has a higher neutron-to-proton ratio than Ne.
 (E) Na has fewer naturally occurring isotopes than Ne.
47. Which of the following is a correct statement about reaction order?
 (A) Reaction order can only be a whole number.
 (B) Reaction order can be determined only from the coefficients of the balanced equation for the reaction.
 (C) Reaction order can be determined only by experiment.
 (D) Reaction order increases with increasing temperature.
 (E) A second-order reaction must involve at least two different compounds as reactants.

48. Sodium chloride is LEAST soluble in which of the following liquids?
(A) H₂O (B) CCl₄ (C) HF (D) CH₃OH (E) CH₃COOH



49. When the equation above is correctly balanced and all coefficients are reduced to lowest whole-number terms, the coefficient for H⁺(aq) is
(A) 2 (B) 4 (C) 6 (D) 8 (E) 14

50. Which of the following represents acceptable laboratory practice?
(A) Placing a hot object on a balance pan
(B) Using distilled water for the final rinse of a buret before filling it with standardized solution
(C) Adding a weighed quantity of solid acid to a titration flask wet with distilled water
(D) Using 10 mL of standard strength phenolphthalein indicator solution for titration of 25 mL of acid solution
(E) Diluting a solution in a volumetric flask to its final concentration with hot water



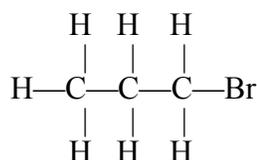
51. True statements about the reaction represented above include which of the following?
I. Cu(s) acts as an oxidizing agent.
II. The oxidation state of nitrogen changes from +5 to +2.
III. Hydrogen ions are oxidized to form H₂O(l).
(A) I only (B) II only (C) III only (D) I and II (E) II and III

52. Propane gas, C₃H₈, burns in excess oxygen gas. When the equation for this reaction is correctly balanced and all coefficients are reduced to their lowest whole-number terms, the coefficient for O₂ is
(A) 4 (B) 5 (C) 7 (D) 10 (E) 22

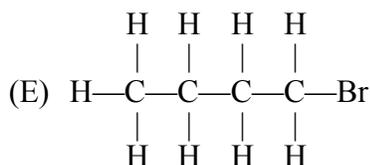
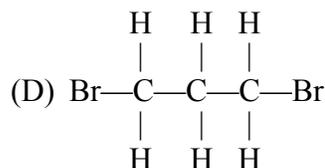
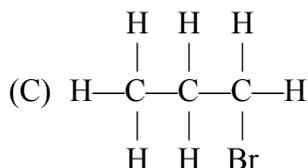
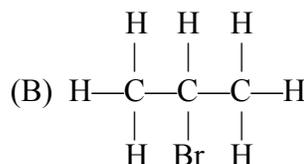
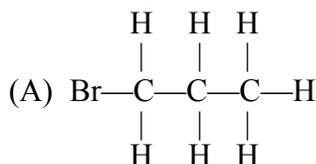
53. According to the VSEPR model, the progressive decrease in the bond angles in the series of molecules CH₄, NH₃, and H₂O is best accounted for by the
(A) increasing strength of the bonds
(B) decreasing size of the central atom
(C) increasing electronegativity of the central atom
(D) increasing number of unshared pairs of electrons
(E) decreasing repulsion between hydrogen atoms

54. Which of the following must be true for a reaction for which the activation energy is the same for both the forward and the reverse reactions?
(A) A catalyst is present.
(B) The reaction order can be obtained directly from the balanced equation.
(C) The reaction order is zero.
(D) ΔH for the reaction is zero.
(E) ΔS for the reaction is zero.

61. How can 100. mL of sodium hydroxide solution with a pH of 13.00 be converted to a sodium hydroxide solution with a pH of 12.00?
- (A) By diluting the solution with distilled water to a total volume of 108 mL
 (B) By diluting the solution with distilled water to a total volume of 200 mL
 (C) By diluting the solution with distilled water to a total volume of 1.00 L
 (D) By adding 100. mL of 0.10 M HCl
 (E) By adding 100. mL of 0.10 M NaOH



62. Which of the following structural formulas represents an isomer of the compound that has the structural formula represented above?



63. Mixtures that would be considered buffers include which of the following?

- I. 0.10 M HCl + 0.10 M NaCl
 II. 0.10 M HF + 0.10 M NaF
 III. 0.10 M HBr + 0.10 M NaBr

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

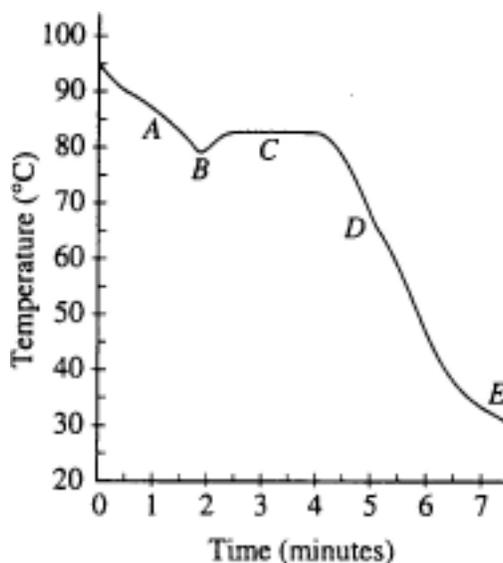
64. Ascorbic acid, $\text{H}_2\text{C}_6\text{H}_6\text{O}_6(s)$, is a diprotic acid with $K_1 = 7.9 \times 10^{-5}$ and $K_2 = 1.6 \times 10^{-12}$. In a 0.005 M aqueous solution of ascorbic acid, which of the following species is present in the lowest concentration?

- (A) $\text{H}_2\text{O}(l)$ (B) $\text{H}_3\text{O}^+(aq)$ (C) $\text{H}_2\text{C}_6\text{H}_6\text{O}_6(aq)$
 (D) $\text{HC}_6\text{H}_6\text{O}_6^-(aq)$ (E) $\text{C}_6\text{H}_6\text{O}_6^{2-}(aq)$

65. Which of the following substances is LEAST soluble in water?

- (A) $(\text{NH}_4)_2\text{SO}_4$ (B) KMnO_4 (C) BaCO_3 (D) $\text{Zn}(\text{NO}_3)_2$ (E) Na_3PO_4

66. A 2 L container will hold about 4 g of which of the following gases at 0°C and 1 atm?
 (A) SO₂ (B) N₂ (C) CO₂ (D) C₄H₈ (E) NH₃
67. Which of the following describes the changes in forces of attraction that occur as H₂O changes phase from a liquid to a vapor?
 (A) H—O bonds break as H—H and O—O bonds form.
 (B) Hydrogen bonds between H₂O molecules are broken.
 (C) Covalent bonds between H₂O molecules are broken.
 (D) Ionic bonds between H⁺ ions and OH⁻ ions are broken.
 (E) Covalent bonds between H⁺ ions and H₂O molecules become more effective.



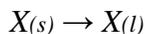
68. Liquid naphthalene at 95°C was cooled to 30°C as represented in the cooling curve above. From which section of the curve can the melting point of naphthalene be determined?
 (A) A (B) B (C) C (D) D (E) E
69. If 200. mL of 0.60 M MgCl_{2(aq)} is added to 400. mL of distilled water, what is the concentration of Mg^{2+(aq)} in the resulting solution? (Assume volumes are additive.)
 (A) 0.20 M (B) 0.30 M (C) 0.40 M (D) 0.60 M (E) 1.2 M
70. Of the following pure substances, which has the highest melting point?
 (A) S₈ (B) I₂ (C) SiO₂ (D) SO₂ (E) C₆H₆
71. In the electroplating of nickel, 0.200 faraday of electrical charge is passed through a solution of NiSO₄. What mass of nickel is deposited?
 (A) 2.94 g (B) 5.87 g (C) 11.7 g (D) 58.7 g (E) 294 g

72. A colorless solution is divided into three samples. The following tests were performed on samples of the solution.

<u>Sample</u>	<u>Test</u>	<u>Observation</u>
1	Add $\text{H}^+(\text{aq})$	No change
2	Add $\text{NH}_3(\text{aq})$	No change
3	Add $\text{SO}_4^{2-}(\text{aq})$	No change

Which of the following ions could be present in the solution at a concentration of 0.10 M?

- (A) $\text{Ni}^{2+}(\text{aq})$ (B) $\text{Al}^{3+}(\text{aq})$ (C) $\text{Ba}^{2+}(\text{aq})$ (D) $\text{Na}^+(\text{aq})$ (E) $\text{CO}_3^{2-}(\text{aq})$



73. Which of the following is true for any substance undergoing the process represented above at its normal melting point?

- (A) $\Delta S < 0$ (B) $\Delta H = 0$ (C) $\Delta H = T\Delta G$ (D) $T\Delta S = 0$ (E) $\Delta H = T\Delta S$

74. A pure, white crystalline solid dissolves in water to yield a basic solution that liberates a gas when excess acid is added to it. On the basis of this information, the solid could be

- (A) KNO_3 (B) K_2CO_3 (C) KOH (D) KHSO_4 (E) KCl

75. In a saturated solution of $\text{Zn}(\text{OH})_2$ at 25°C the value of $[\text{OH}^-]$ is $2.0 \times 10^{-6} \text{ M}$. What is the value of the solubility-product constant, K_{sp} , for $\text{Zn}(\text{OH})_2$ at 25°C ?

- (A) 4.0×10^{-18} (B) 8.0×10^{-18} (C) 1.6×10^{-17} (D) 4.0×10^{-12} (E) 2.0×10^{-6}