

## 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 $P$  = pressure $V$  = volume $S$  = entropy $H$  = enthalpy $G$  = Gibbs free energy $R$  = molar gas constant $n$  = number of moles $M$  = molar $m$  = molal

L, mL = liter(s), milliliter(s)

g = gram(s)

nm = nanometer(s)

atm = atmosphere(s)

mm Hg = millimeters of mercury

J, kJ = joule(s), kilojoule(s)

V = volt(s)

mol = mole(s)

## 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)  $\text{CO}_2$
- (B)  $\text{H}_2\text{O}$
- (C)  $\text{CH}_4$
- (D)  $\text{C}_2\text{H}_4$
- (E)  $\text{PH}_3$

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)  $\text{PbSO}_4$
- (B)  $\text{CuO}$
- (C)  $\text{KMnO}_4$
- (D)  $\text{KCl}$
- (E)  $\text{FeCl}_3$

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

Questions 8-10 refer to the following gases at  $0^\circ\text{C}$  and 1 atm.

- (A) Ne
- (B) Xe
- (C)  $\text{O}_2$
- (D) CO
- (E) NO

- 8. Has an average atomic or molecular speed closest to that of  $\text{N}_2$  molecules at  $0^\circ\text{C}$  and 1 atm
- 9. Has the greatest density
- 10. Has the greatest rate of effusion through a pinhole

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Questions 11-14 refer to the reactions represented below.

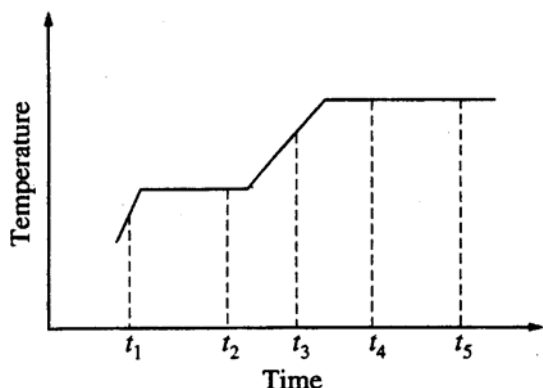
- (A)  $\text{H}_2\text{SeO}_4(\text{aq}) + 2 \text{Cl}^-(\text{aq}) + 2 \text{H}^+(\text{aq}) \rightarrow \text{H}_2\text{SeO}_3(\text{aq}) + \text{Cl}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$
- (B)  $\text{S}_8(\text{s}) + 8 \text{O}_2(\text{g}) \rightarrow 8 \text{SO}_2(\text{g})$
- (C)  $3 \text{Br}_2(\text{aq})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

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

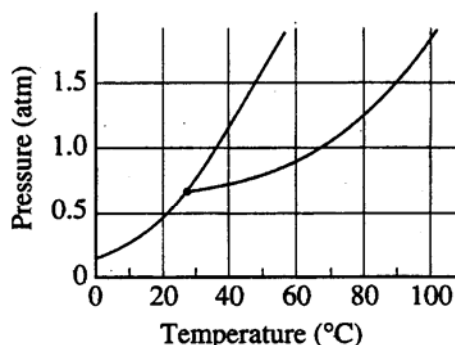
(A)  $t_1$   
(B)  $t_2$   
(C)  $t_3$   
(D)  $t_4$   
(E)  $t_5$

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°C to 100°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°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 sublimates to vapor at an equilibrium temperature of about 20°C.  
(E) It remains a solid until the temperature is greater than 100°C.

## Section I

## Part B

19. In which of the following species does sulfur have the same oxidation number as it does in  $\text{H}_2\text{SO}_4$ ?

(A)  $\text{H}_2\text{SO}_3$   
 (B)  $\text{S}_2\text{O}_3^{2-}$   
 (C)  $\text{S}^{2-}$   
 (D)  $\text{S}_8$   
 (E)  $\text{SO}_2\text{Cl}_2$

20. A flask contains 0.25 mole of  $\text{SO}_2(g)$ , 0.50 mole of  $\text{CH}_4(g)$ , and 0.50 mole of  $\text{O}_2(g)$ . The total pressure of the gases in the flask is 800 mm Hg. What is the partial pressure of the  $\text{SO}_2(g)$  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,  $\text{H}_2(g)$  can be produced by adding which of the following to 1 M  $\text{HCl}(aq)$ ?

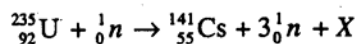
I. 1 M  $\text{NH}_3(aq)$   
 II.  $\text{Zn}(s)$   
 III.  $\text{NaHCO}_3(s)$

(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  $\text{NH}_4^+$  acts as

(A) a catalyst  
 (B) both an acid and a base  
 (C) the conjugate acid of  $\text{NH}_3$   
 (D) the reducing agent  
 (E) the oxidizing agent

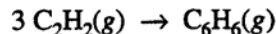


23. Neutron bombardment of uranium can induce the reaction represented above. Nuclide X is which of the following?

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

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)  $\text{KTeO}$   
 (B)  $\text{KTe}_2\text{O}$   
 (C)  $\text{K}_2\text{TeO}_3$   
 (D)  $\text{K}_2\text{TeO}_6$   
 (E)  $\text{K}_4\text{TeO}_6$



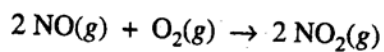
25. What is the standard enthalpy change,  $\Delta H^\circ$ , for the reaction represented above?

( $\Delta H_f^\circ$  of  $\text{C}_2\text{H}_2(g)$  is  $230 \text{ kJ mol}^{-1}$ ;  
 $\Delta H_f^\circ$  of  $\text{C}_6\text{H}_6(g)$  is  $83 \text{ kJ mol}^{-1}$ .)

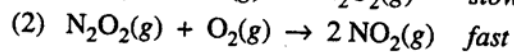
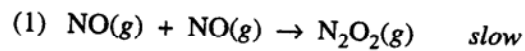
(A)  $-607 \text{ kJ}$   
 (B)  $-147 \text{ kJ}$   
 (C)  $-19 \text{ kJ}$   
 (D)  $+19 \text{ kJ}$   
 (E)  $+773 \text{ kJ}$

26. Approximately what mass of  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  ( $250 \text{ g mol}^{-1}$ ) 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)  $\text{Rate} = k[\text{NO}]^2$

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

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

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

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

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

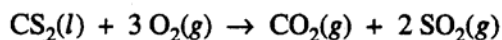
- (A)  $\text{SiCl}_4$
- (B)  $\text{BrCl}$
- (C)  $\text{PCl}_3$
- (D)  $\text{Cl}_2\text{O}$
- (E)  $\text{CaCl}_2$

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  $25^\circ\text{C}$ , 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)  $1 \text{ M}$
- (E)  $8 \text{ M}$



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  $0^\circ\text{C}$  and 1 atm.)

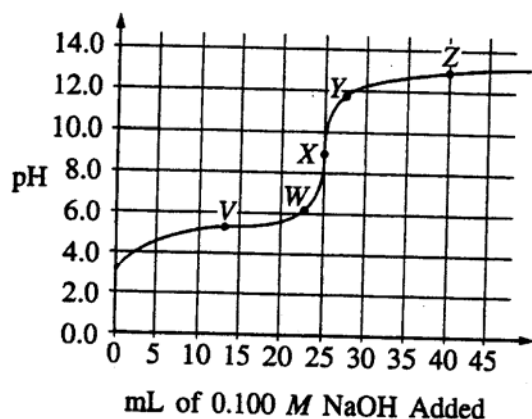
- (A) 12 L
- (B) 22.4 L
- (C)  $\frac{1}{3} \times 22.4 \text{ L}$
- (D)  $2 \times 22.4 \text{ L}$
- (E)  $3 \times 22.4 \text{ L}$

32. Which of the following oxides is a gas at  $25^\circ\text{C}$  and 1 atm?

- (A)  $\text{Rb}_2\text{O}$
- (B)  $\text{N}_2\text{O}$
- (C)  $\text{Na}_2\text{O}_2$
- (D)  $\text{SiO}_2$
- (E)  $\text{La}_2\text{O}_3$

## 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?

| Indicator            | pH Range of Color Change |
|----------------------|--------------------------|
| (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?

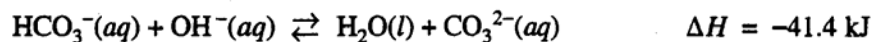
- (A) Point V  
(B) Point X  
(C) Point Z  
(D) Along all of section WY  
(E) Along all of section YZ

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



37. When the reaction represented by the equation above is at equilibrium at 1 atm and 25°C, the ratio

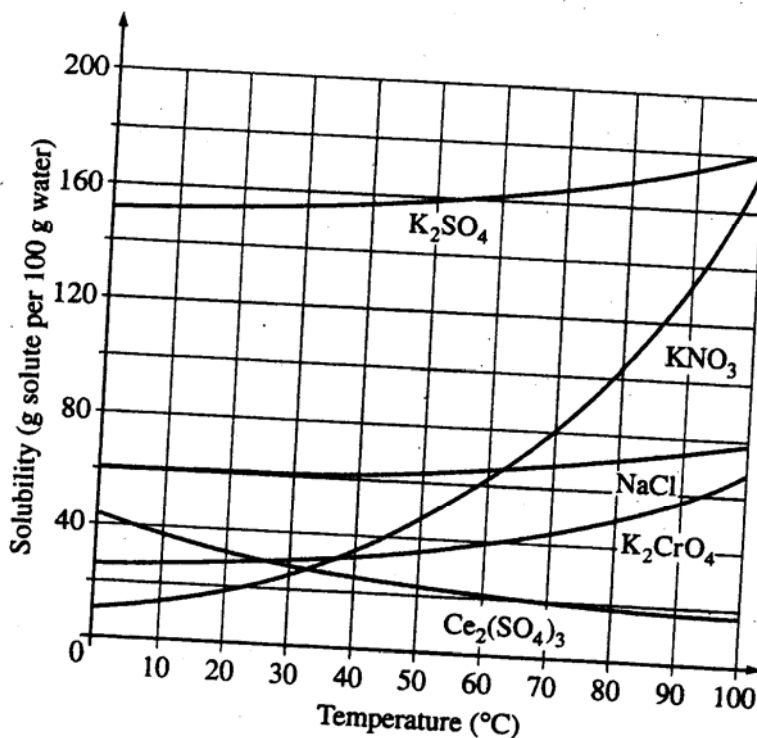
$\frac{[\text{CO}_3^{2-}]}{[\text{HCO}_3^-]}$  can be increased by doing which of the following?

- (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,  $\text{Na}_2\text{SO}_4$ , is a better conductor of electricity than a 0.10 *M* aqueous solution of sodium chloride,  $\text{NaCl}$ . Which of the following best explains this observation?

- (A)  $\text{Na}_2\text{SO}_4$  is more soluble in water than  $\text{NaCl}$  is.
- (B)  $\text{Na}_2\text{SO}_4$  has a higher molar mass than  $\text{NaCl}$  has.
- (C) To prepare a given volume of 0.10 *M* solution, the mass of  $\text{Na}_2\text{SO}_4$  needed is more than twice the mass of  $\text{NaCl}$  needed.
- (D) More moles of ions are present in a given volume of 0.10 *M*  $\text{Na}_2\text{SO}_4$  than in the same volume of 0.10 *M*  $\text{NaCl}$ .
- (E) The degree of dissociation of  $\text{Na}_2\text{SO}_4$  in solution is significantly greater than that of  $\text{NaCl}$ .





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<sub>3</sub>
- (C) K<sub>2</sub>CrO<sub>4</sub>
- (D) K<sub>2</sub>SO<sub>4</sub>
- (E) Ce<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>

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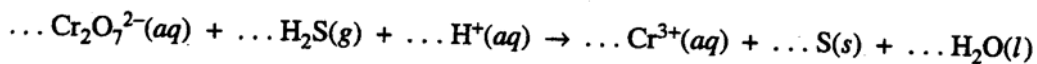
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40. An excess of  $\text{Mg}(s)$  is added to 100. mL of 0.400 M  $\text{HCl}$ . At  $0^\circ\text{C}$  and 1 atm pressure, what volume of  $\text{H}_2$  gas can be obtained?
- (A) 22.4 mL  
(B) 44.8 mL  
(C) 224 mL  
(D) 448 mL  
(E) 896 mL
41. When solid  $\text{NH}_4\text{SCN}$  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  $\Delta G$ ,  $\Delta H$ , and  $\Delta S$  for the process?
- |     | $\Delta G$ | $\Delta H$ | $\Delta S$ |
|-----|------------|------------|------------|
| (A) | -          | -          | -          |
| (B) | -          | +          | -          |
| (C) | -          | +          | +          |
| (D) | +          | -          | +          |
| (E) | +          | -          | -          |
42. At a certain temperature, the value of the equilibrium constant,  $K$ , for the reaction represented above is  $2.0 \times 10^5$ . What is the value of  $K$  for the reverse reaction at the same temperature?
- (A)  $-2.0 \times 10^{-5}$   
(B)  $5.0 \times 10^{-6}$   
(C)  $2.0 \times 10^{-5}$   
(D)  $5.0 \times 10^{-5}$   
(E)  $5.0 \times 10^{-4}$
- $\text{H}_2(g) + \text{Br}_2(g) \rightleftharpoons 2 \text{HBr}(g)$
43. The atomic mass of copper is 63.55. Given that there are only two naturally occurring isotopes of copper,  $^{63}\text{Cu}$  and  $^{65}\text{Cu}$ , the natural abundance of the  $^{65}\text{Cu}$  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  $\text{H}_2\text{O}$  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?

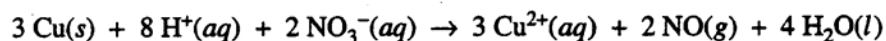
- (A)  $\text{H}_2\text{O}$
- (B)  $\text{CCl}_4$
- (C)  $\text{HF}$
- (D)  $\text{CH}_3\text{OH}$
- (E)  $\text{CH}_3\text{COOH}$



49. When the equation above is correctly balanced and all coefficients are reduced to lowest whole-number terms, the coefficient for  $\text{H}^+(\text{aq})$  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.  $\text{Cu}(s)$  acts as an oxidizing agent.
- II. The oxidation state of nitrogen changes from +5 to +2.
- III. Hydrogen ions are oxidized to form  $\text{H}_2\text{O}(l)$ .

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

52. Propane gas,  $\text{C}_3\text{H}_8$ , 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  $\text{O}_2$  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  $\text{CH}_4$ ,  $\text{NH}_3$ , and  $\text{H}_2\text{O}$  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)  $\Delta H$  for the reaction is zero.
- (E)  $\Delta S$  for the reaction is zero.

| Time (days)          | 0   | 1  | 2  | 3  | 4  | 5  | 6  | 7  | ... | 10 | ... | 20 |
|----------------------|-----|----|----|----|----|----|----|----|-----|----|-----|----|
| % Reactant remaining | 100 | 79 | 63 | 50 | 40 | 31 | 25 | 20 |     | 10 |     | 1  |

55. A reaction was observed for 20 days and the percentage of the reactant remaining after each day was recorded in the table above. Which of the following best describes the order and the half-life of the reaction?

| Reaction Order | Half-life (days) |
|----------------|------------------|
| (A) First      | 3                |
| (B) First      | 10               |
| (C) Second     | 3                |
| (D) Second     | 6                |
| (E) Second     | 10               |

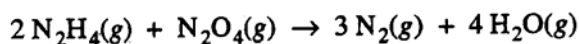
56. The boiling points of the elements helium, neon, argon, krypton, and xenon increase in that order. Which of the following statements accounts for this increase?

(A) The London (dispersion) forces increase.  
(B) The hydrogen bonding increases.  
(C) The dipole-dipole forces increase.  
(D) The chemical reactivity increases.  
(E) The number of nearest neighbors increases.

$$\text{Rate} = k[\text{M}][\text{N}]^2$$

57. The rate of a certain chemical reaction between substances M and N obeys the rate law above. The reaction is first studied with [M] and [N] each  $1 \times 10^{-3}$  molar. If a new experiment is conducted with [M] and [N] each  $2 \times 10^{-3}$  molar, the reaction rate will increase by a factor of

(A) 2  
(B) 4  
(C) 6  
(D) 8  
(E) 16

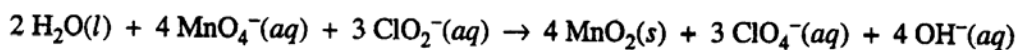


58. When 8.0 g of  $\text{N}_2\text{H}_4$  ( $32 \text{ g mol}^{-1}$ ) and 92 g of  $\text{N}_2\text{O}_4$  ( $92 \text{ g mol}^{-1}$ ) are mixed together and react according to the equation above, what is the maximum mass of  $\text{H}_2\text{O}$  that can be produced?

(A) 9.0 g  
(B) 18 g  
(C) 36 g  
(D) 72 g  
(E) 144 g

59. All of the halogens in their elemental form at  $25^\circ\text{C}$  and 1 atm are

(A) conductors of electricity  
(B) diatomic molecules  
(C) odorless  
(D) colorless  
(E) gases



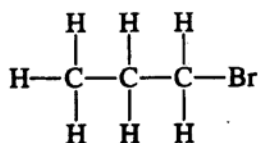
60. According to the balanced equation above, how many moles of  $\text{ClO}_2^-(aq)$  are needed to react completely with 20. mL of 0.20 M  $\text{KMnO}_4$  solution?

- (A) 0.0030 mol
- (B) 0.0053 mol
- (C) 0.0075 mol
- (D) 0.013 mol
- (E) 0.030 mol

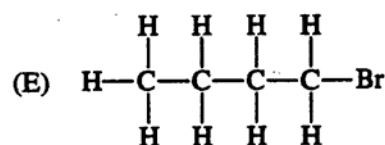
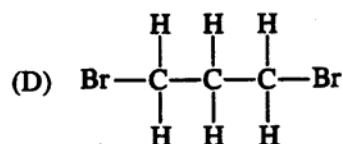
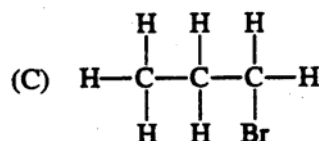
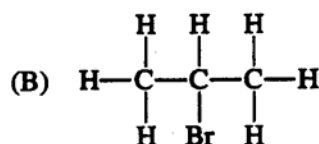
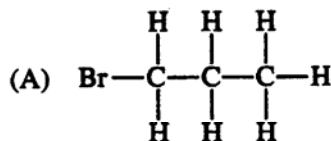
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61. How can 100. mL of sodium hydroxide solution with a pH of 13.00 be converted to a sodium hydroxide solution with a pH of 12.00 ?

- (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?

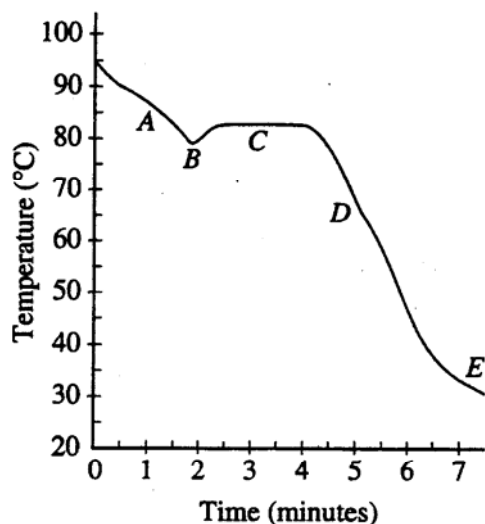
- (A)  $(\text{NH}_4)_2\text{SO}_4$   
 (B)  $\text{KMnO}_4$   
 (C)  $\text{BaCO}_3$   
 (D)  $\text{Zn}(\text{NO}_3)_2$   
 (E)  $\text{Na}_3\text{PO}_4$

66. A 2 L container will hold about 4 g of which of the following gases at  $0^\circ\text{C}$  and 1 atm?

- (A)  $\text{SO}_2$   
 (B)  $\text{N}_2$   
 (C)  $\text{CO}_2$   
 (D)  $\text{C}_4\text{H}_8$   
 (E)  $\text{NH}_3$



67. Which of the following describes the changes in forces of attraction that occur as  $\text{H}_2\text{O}$  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  $\text{H}_2\text{O}$  molecules are broken.
- (C) Covalent bonds between  $\text{H}_2\text{O}$  molecules are broken.
- (D) Ionic bonds between  $\text{H}^+$  ions and  $\text{OH}^-$  ions are broken.
- (E) Covalent bonds between  $\text{H}^+$  ions and  $\text{H}_2\text{O}$  molecules become more effective.



68. Liquid naphthalene at  $95^\circ\text{C}$  was cooled to  $30^\circ\text{C}$ , as represented in the cooling curve above. From which section of the curve can the melting point of naphthalene be determined?

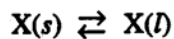
(A) A  
(B) B  
(C) C  
(D) D  
(E) E

69. If 200. mL of  $0.60\text{ M MgCl}_2(\text{aq})$  is added to 400. mL of distilled water, what is the concentration of  $\text{Mg}^{2+}(\text{aq})$  in the resulting solution? (Assume volumes are additive.)
- (A)  $0.20\text{ M}$   
(B)  $0.30\text{ M}$   
(C)  $0.40\text{ M}$   
(D)  $0.60\text{ M}$   
(E)  $1.2\text{ M}$
70. Of the following pure substances, which has the highest melting point?
- (A)  $\text{S}_8$   
(B)  $\text{I}_2$   
(C)  $\text{SiO}_2$   
(D)  $\text{SO}_2$   
(E)  $\text{C}_6\text{H}_6$
71. In the electroplating of nickel, 0.200 faraday of electrical charge is passed through a solution of  $\text{NiSO}_4$ . 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.

| Sample | Test                              | Observation |
|--------|-----------------------------------|-------------|
| 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  $0.10\text{ M}$ ?

(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)  $\text{KNO}_3$
- (B)  $\text{K}_2\text{CO}_3$
- (C)  $\text{KOH}$
- (D)  $\text{KHSO}_4$
- (E)  $\text{KCl}$

75. In a saturated solution of  $\text{Zn(OH)}_2$  at  $25^\circ\text{C}$ , 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  $\text{Zn(OH)}_2$  at  $25^\circ\text{C}$ ?

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

END OF SECTION I