

**CHEMISTRY**  
**Section I**  
**50 Questions**  
**Time—90 minutes**

**CALCULATORS ARE NOT 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.

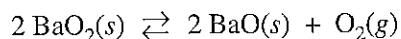
**Directions:** Each of the questions or incomplete statements below is followed by four suggested answers or completions. Select the one that is best in each case and then fill in the corresponding circle on the answer sheet.

Compound	Molar Mass (grams)
Na <sub>2</sub> O	62.0
MgO	40.3
K <sub>2</sub> O	94.2
CaO	56.1

- According to the information in the table above, a 1.00 g sample of which of the following contains the greatest mass of oxygen?  
(A) Na<sub>2</sub>O  
(B) MgO  
(C) K<sub>2</sub>O  
(D) CaO
- Which of the following could be the identity of a white crystalline solid that exhibits the following properties?
  - It melts at 320°C.
  - It does not conduct electricity as a solid.
  - It conducts electricity in an aqueous solution.

(A) C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>(s)  
(B) NaOH(s)  
(C) SiO<sub>2</sub>(s)  
(D) Cu(s)
- Which of the following correctly identifies which has the higher first-ionization energy, Cl or Ar, and supplies the best justification?

(A) Cl, because of its higher electronegativity  
(B) Cl, because of its higher electron affinity  
(C) Ar, because of its completely filled valence shell  
(D) Ar, because of its higher effective nuclear charge



$$\Delta H^\circ = 162 \text{ kJ/mol}_{\text{rxn}}$$

4. A sealed rigid vessel contains  $\text{BaO}_2(s)$  in equilibrium with  $\text{BaO}(s)$  and  $\text{O}_2(g)$  as represented by the equation above. Which of the following changes will increase the amount of  $\text{BaO}_2(s)$  in the vessel?

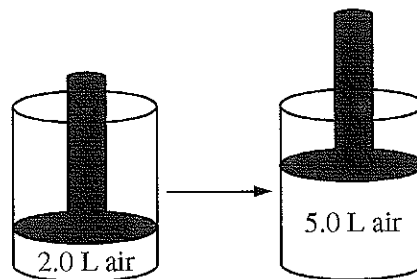
(A) Removing a small amount of  $\text{O}_2(g)$   
 (B) Removing a small amount of  $\text{BaO}(s)$   
 (C) Adding He gas to the vessel  
 (D) Lowering the temperature

5. Which of the following best helps to explain why the value of  $\Delta H^\circ$  for the dissolving of  $\text{CaF}_2$  in water is positive?

(A)  $\text{CaF}_2(s)$  is insoluble in water.  
 (B)  $\text{CaF}_2(s)$  dissolves in water to form  $\text{CaF}_2(aq)$  particles.  
 (C)  $\text{Ca}^{2+}$  ions have very strong ion-ion interactions with  $\text{F}^-$  ions in the crystal lattice.  
 (D)  $\text{Ca}^{2+}$  ions have very strong ion-dipole interactions with water molecules in the solution.

6. Under which of the following conditions of temperature and pressure will  $\text{H}_2$  gas be expected to behave most like an ideal gas?

- (A) 50 K and 0.10 atm
- (B) 50 K and 5.0 atm
- (C) 500 K and 0.10 atm
- (D) 500 K and 50 atm



7. The volume of a sample of air in a cylinder with a movable piston is 2.0 L at a pressure  $P_1$ , as shown in the diagram above. The volume is increased to 5.0 L as the temperature is held constant. The pressure of the air in the cylinder is now  $P_2$ . What effect do the volume and pressure changes have on the average kinetic energy of the molecules in the sample?

- (A) The average kinetic energy increases.
- (B) The average kinetic energy decreases.
- (C) The average kinetic energy stays the same.
- (D) It cannot be determined how the kinetic energy is affected without knowing  $P_1$  and  $P_2$ .

Questions 8-10 refer to the following.

$M^+$  is an unknown metal cation with a +1 charge. A student dissolves the chloride of the unknown metal,  $MCl$ , in enough water to make 100.0 mL of solution. The student then mixes the solution with excess  $AgNO_3$  solution, causing  $AgCl$  to precipitate. The student collects the precipitate by filtration, dries it, and records the data shown below. (The molar mass of  $AgCl$  is 143 g/mol.)

Mass of unknown chloride, $MCl$	0.74 g
Mass of filter paper	0.80 g
Mass of filter paper plus $AgCl$ precipitate	2.23 g


8. What is the identity of the metal chloride?

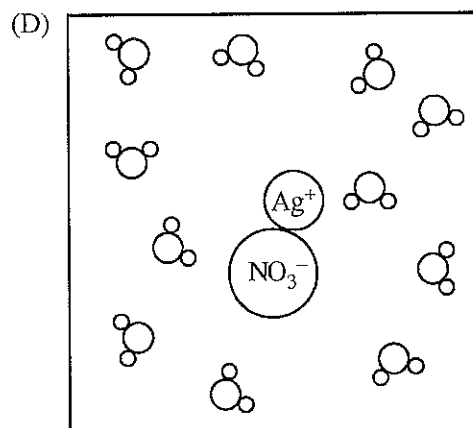
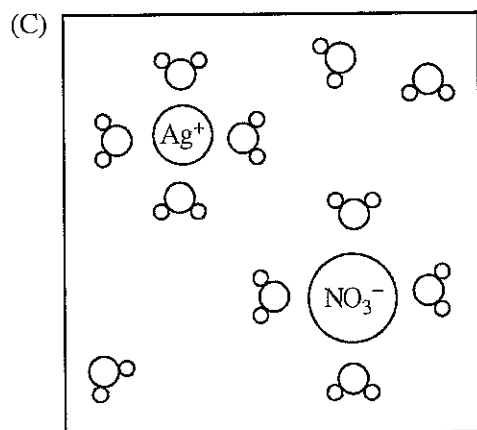
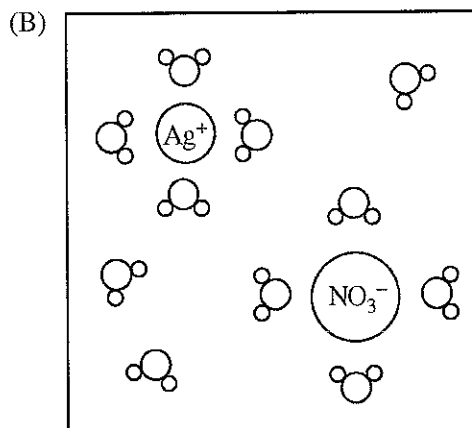
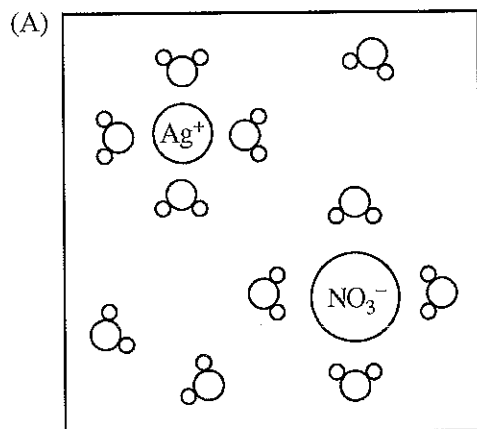
- (A)  $NaCl$
- (B)  $KCl$
- (C)  $CuCl$
- (D)  $LiCl$

9. During the course of the experiment, which of the following happens to the  $NO_3^-$  ions?

- (A) They are oxidized by  $Cl^-$  ions.
- (B) They are reduced to  $NO_2^-$  ions.
- (C) They are decomposed by reacting with  $M^+$  ions.
- (D) They remain dissolved in the filtrate solution.

10. Which of the following diagrams best represents the  $\text{AgNO}_3$  solution before the reaction occurs?

Note: water molecules are represented by the symbol .



11. When 200. mL of 2.0 M NaOH(aq) is added to 500. mL of 1.0 M HCl(aq), the pH of the resulting mixture is closest to

- (A) 1.0
- (B) 3.0
- (C) 7.0
- (D) 13.0

13. Which of the following equations represents a reaction for which the standard entropy change is positive ( $\Delta S^\circ > 0$ ) ?

- (A)  $3 \text{O}_2(g) \rightarrow 2 \text{O}_3(g)$
- (B)  $2 \text{H}_2(g) + \text{O}_2(g) \rightarrow 2 \text{H}_2\text{O}(l)$
- (C)  $\text{CaCO}_3(s) \rightarrow \text{CaO}(s) + \text{CO}_2(g)$
- (D)  $\text{I}_2(g) + 2 \text{K}(s) \rightarrow 2 \text{KI}(s)$

Element	First Ionization Energy (kJ/mol)	Atomic Radius (pm)
B	801	85
C	1086	77
N	1400	75
O	1314	73
F	1680	72
Ne	2080	70

12. The table above shows the first ionization energy and atomic radius of several elements. Which of the following best helps to explain the deviation of the first ionization energy of oxygen from the overall trend?

- (A) The atomic radius of oxygen is greater than the atomic radius of fluorine.
- (B) The atomic radius of oxygen is less than the atomic radius of nitrogen.
- (C) There is repulsion between paired electrons in oxygen's 2p orbitals.
- (D) There is attraction between paired electrons in oxygen's 2p orbitals.

Questions 14-16 refer to the following.

The table below contains information about samples of four different gases at 273 K. The samples are in four identical rigid containers numbered 1 through 4.

Container	Gas	Pressure (atm)	Mass of Sample (g)
1	He	2.00	?
2	Ne	2.00	?
3	?	2.00	16.0
4	SO <sub>2</sub>	1.96	64.1

14. On the basis of the data provided above, the gas in container 3 could be

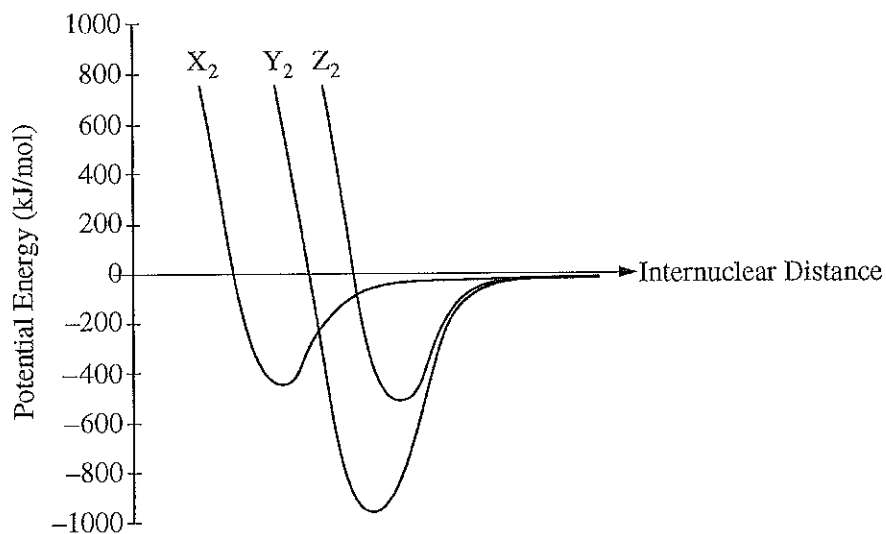
- (A) CH<sub>4</sub>
- (B) O<sub>2</sub>
- (C) Ar
- (D) CO<sub>2</sub>

15. Under the conditions given, consider containers 1, 2, and 4 only. The average speed of the gas particles is

- (A) greatest in container 1
- (B) greatest in container 2
- (C) greatest in container 4
- (D) the same in containers 1, 2, and 4

16. The best explanation for the lower pressure in container 4 is that SO<sub>2</sub> molecules

- (A) have a larger average speed than the other three gases
- (B) occupy a larger portion of the container volume than the other three gases
- (C) have stronger intermolecular attractions than the other three gases
- (D) contain  $\pi$  bonds, while the other gases contain only  $\sigma$  bonds



17. The potential energy as a function of internuclear distance for three diatomic molecules,  $X_2$ ,  $Y_2$ , and  $Z_2$ , is shown in the graph above. Based on the data in the graph, which of the following correctly identifies the diatomic molecules,  $X_2$ ,  $Y_2$ , and  $Z_2$ ?

	$X_2$	$Y_2$	$Z_2$
(A)	$H_2$	$N_2$	$O_2$
(B)	$H_2$	$O_2$	$N_2$
(C)	$N_2$	$O_2$	$H_2$
(D)	$O_2$	$H_2$	$N_2$

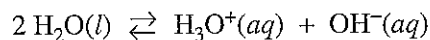


18. A 10. g cube of copper at a temperature  $T_1$  is placed in an insulated cup containing 10. g of water at a temperature  $T_2$ . If  $T_1 > T_2$ , which of the following is true of the system when it has attained thermal equilibrium? (The specific heat of copper is  $0.385 \text{ J/(g}\cdot^\circ\text{C)}$  and the specific heat of water is  $4.18 \text{ J/(g}\cdot^\circ\text{C)}$ .)

- (A) The temperature of the copper changed more than the temperature of the water.
- (B) The temperature of the water changed more than the temperature of the copper.
- (C) The temperature of the water and the copper changed by the same amount.
- (D) The relative temperature changes of the copper and the water cannot be determined without knowing  $T_1$  and  $T_2$ .

19. A solution containing HCl and the weak acid  $\text{HClO}_2$  has a pH of 2.4. Enough  $\text{KOH(aq)}$  is added to the solution to increase the pH to 10.5. The amount of which of the following species increases as the  $\text{KOH(aq)}$  is added?

- (A)  $\text{Cl}^-(\text{aq})$
- (B)  $\text{H}^+(\text{aq})$
- (C)  $\text{ClO}_2^-(\text{aq})$
- (D)  $\text{HClO}_2(\text{aq})$



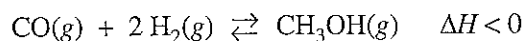
20. The autoionization of water is represented by the equation above. Values of  $\text{p}K_w$  at various temperatures are listed in the table below.

Temperature ( $^\circ\text{C}$ )	$\text{p}K_w$
0	14.9
10	14.5
20	14.2
30	13.8
40	13.5

Based on the information above, which of the following statements is true?

- (A) The dissociation of water is an exothermic process.
- (B) The pH of pure water is 7.00 at any temperature.
- (C) As the temperature increases, the pH of pure water increases.
- (D) As the temperature increases, the pH of pure water decreases.

Questions 21-24 refer to the following information.



The synthesis of  $\text{CH}_3\text{OH}(g)$  from  $\text{CO}(g)$  and  $\text{H}_2(g)$  is represented by the equation above. The value of  $K_c$  for the reaction at 483 K is 14.5.

21. Which of the following explains the effect on the equilibrium constant,  $K_c$ , when the temperature of the reaction system is increased to 650 K?

- (A)  $K_c$  will increase because the activation energy of the forward reaction increases more than that of the reverse reaction.
- (B)  $K_c$  will increase because there are more reactant molecules than product molecules.
- (C)  $K_c$  will decrease because the reaction is exothermic.
- (D)  $K_c$  is constant and will not change.

22. A 1.0 mol sample of  $\text{CO}(g)$  and a 1.0 mol sample of  $\text{H}_2(g)$  are pumped into a rigid, previously evacuated 2.0 L reaction vessel at 483 K. Which of the following is true at equilibrium?

- (A)  $[\text{H}_2] = 2[\text{CO}]$
- (B)  $[\text{H}_2] < [\text{CO}]$
- (C)  $[\text{CO}] = [\text{CH}_3\text{OH}] < [\text{H}_2]$
- (D)  $[\text{CO}] = [\text{CH}_3\text{OH}] = [\text{H}_2]$

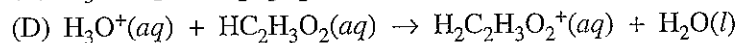
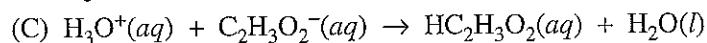
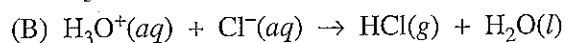
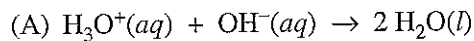
23. A mixture of  $\text{CO}(g)$  and  $\text{H}_2(g)$  is pumped into a previously evacuated 2.0 L reaction vessel. The total pressure of the reaction system is 1.2 atm at equilibrium. What will be the total pressure of the system if the volume of the reaction vessel is reduced to 1.0 L at constant temperature?

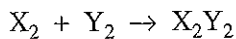
- (A) Less than 1.2 atm
- (B) Greater than 1.2 atm but less than 2.4 atm
- (C) 2.4 atm
- (D) Greater than 2.4 atm

24. Which of the following statements is true about bond energies in this reaction?

- (A) The energy absorbed as the bonds in the reactants are broken is greater than the energy released as the bonds in the product are formed.
- (B) The energy released as the bonds in the reactants are broken is greater than the energy absorbed as the bonds in the product are formed.
- (C) The energy absorbed as the bonds in the reactants are broken is less than the energy released as the bonds in the product are formed.
- (D) The energy released as the bonds in the reactants are broken is less than the energy absorbed as the bonds in the product are formed.

25. A solution is prepared by adding 100 mL of 1.0  $M$   $\text{HC}_2\text{H}_3\text{O}_2(aq)$  to 100 mL of 1.0  $M$   $\text{NaC}_2\text{H}_3\text{O}_2(aq)$ . The solution is stirred and its pH is measured to be 4.73. After 3 drops of 1.0  $M$   $\text{HCl}$  are added to the solution, the pH of the solution is measured and is still 4.73. Which of the following equations represents the chemical reaction that accounts for the fact that acid was added but there was no detectable change in pH?

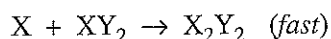
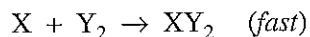
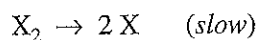




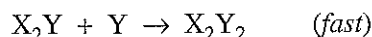
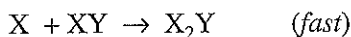
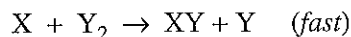
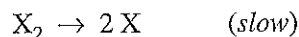
$$\text{rate} = k[X_2]$$

28. A reaction and its experimentally determined rate law are represented above. A chemist proposes two different possible mechanisms for the reaction, which are given below.

Mechanism 1

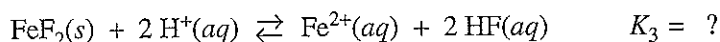
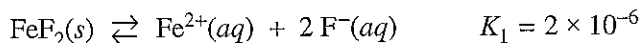


Mechanism 2



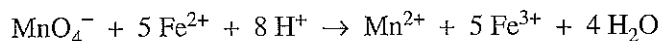
Based on the information above, which of the following is true?

- (A) Only mechanism 1 is consistent with the rate law.
- (B) Only mechanism 2 is consistent with the rate law.
- (C) Both mechanism 1 and mechanism 2 are consistent with the rate law.
- (D) Neither mechanism 1 nor mechanism 2 is consistent with the rate law.

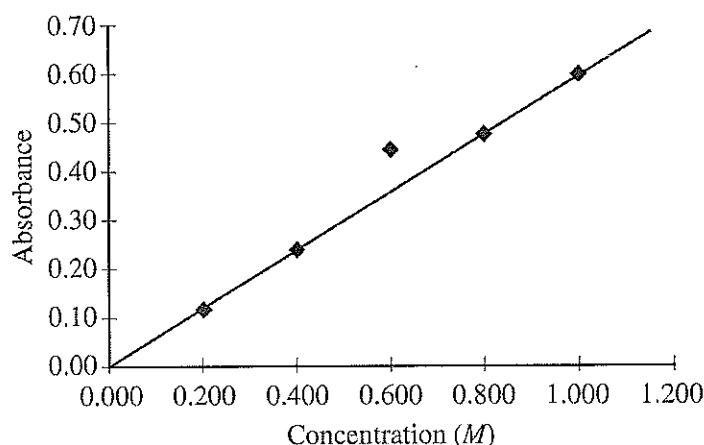


29. On the basis of the information above, the dissolution of  $FeF_2(s)$  in acidic solution is

- (A) thermodynamically favorable, because  $K_2 > 1$
- (B) thermodynamically favorable, because  $K_3 > 1$
- (C) not thermodynamically favorable, because  $K_1 < 1$
- (D) not thermodynamically favorable, because  $K_3 < 1$



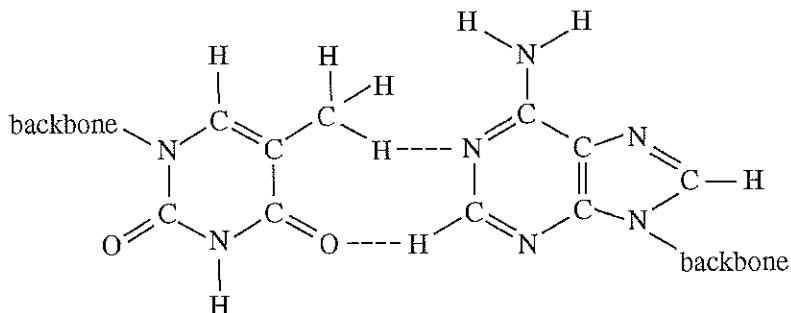
26. In the reaction represented above, the number of  $\text{MnO}_4^-$  ions that react must be equal to which of the following?
- (A) One-fifth the number of  $\text{Fe}^{2+}$  ions that are consumed
  - (B) Eight times the number of  $\text{H}^+$  ions that are consumed
  - (C) Five times the number of  $\text{Fe}^{3+}$  ions that are produced
  - (D) One-half the number of  $\text{H}_2\text{O}$  molecules that are produced



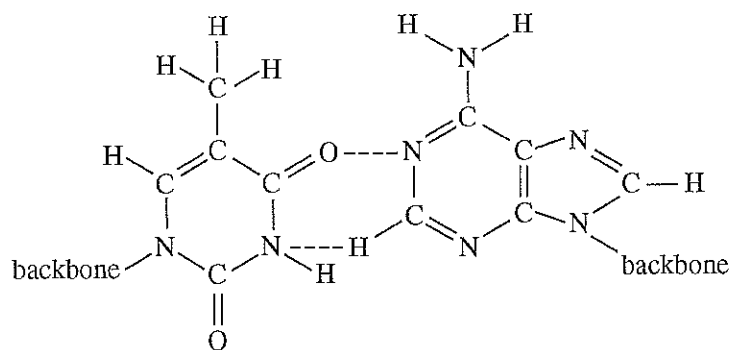
27. A student prepared five solutions of  $\text{CuSO}_4$  with different concentrations, and then filled five cuvettes, each containing one of the solutions. The cuvettes were placed in a spectrophotometer set to the appropriate wavelength for maximum absorbance. The absorbance of each solution was measured and recorded. The student plotted absorbance versus concentration, as shown in the figure above. Which of the following is the most likely explanation for the variance of the data point for the 0.600 M  $\text{CuSO}_4$  solution?
- (A) The cuvette into which the 0.600 M solution was placed had some water droplets inside.
  - (B) The cuvette into which the 0.600 M solution was placed was filled slightly more than the other cuvettes.
  - (C) The wavelength setting was accidentally moved away from that of maximum absorbance.
  - (D) The cuvette used for the 0.600 M solution had not been wiped clean before being put in the spectrophotometer.

30. Thymine and adenine form a base pair in the DNA molecule. These two bases can form a connection between two strands of DNA via two hydrogen bonds. Which of the following diagrams shows the correct representation of the hydrogen bonding (denoted by dashed lines) between thymine and adenine base pairs? (In each diagram, thymine is shown at the left and adenine is shown at the right. The bases are attached to the backbone portion of the DNA strands.)

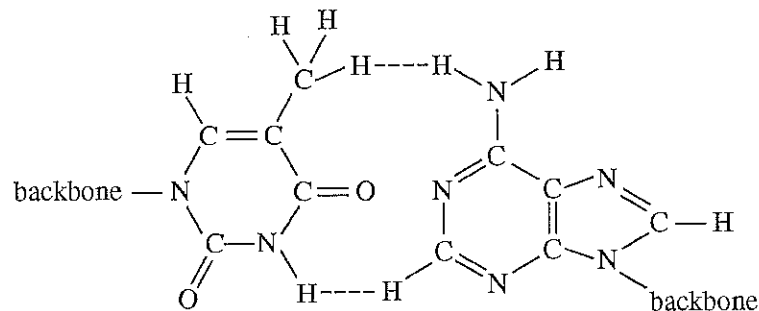
(A)



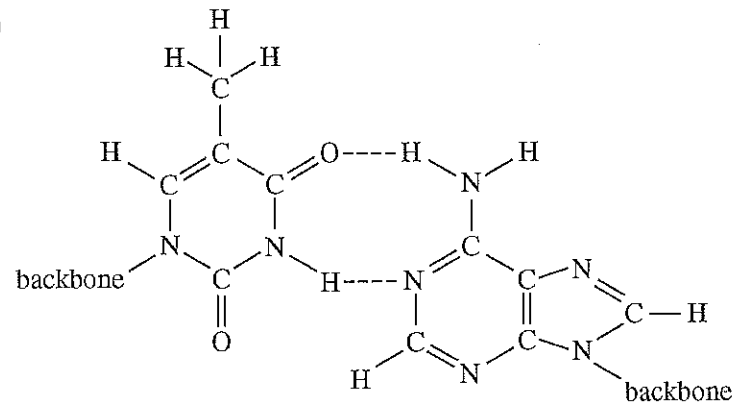
(B)

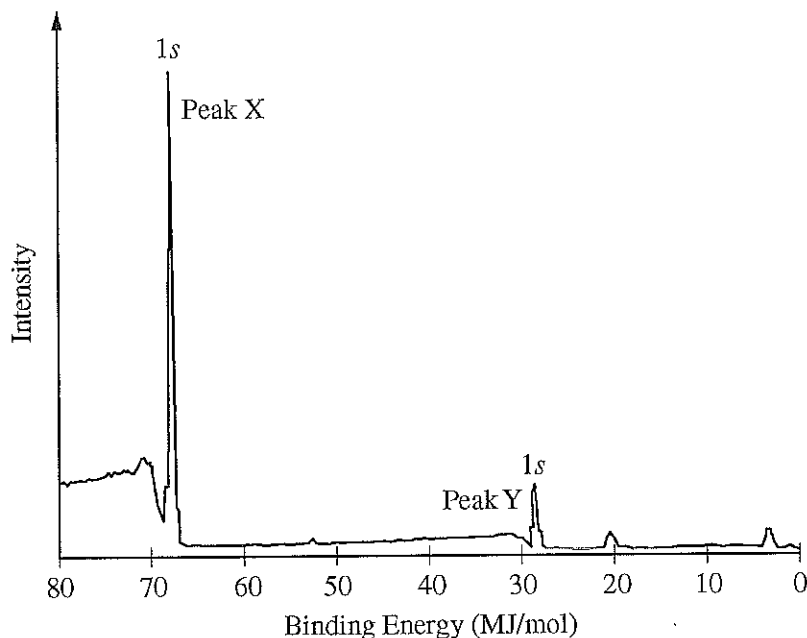


(C)



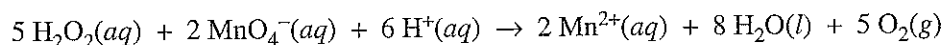
(D)





31. A sample containing atoms of C and F was analyzed using x-ray photoelectron spectroscopy. The portion of the spectrum showing the  $1s$  peaks for atoms of the two elements is shown above. Which of the following correctly identifies the  $1s$  peak for the F atoms and provides an appropriate explanation?
- (A) Peak X, because F has a smaller first ionization energy than C has.
  - (B) Peak X, because F has a greater nuclear charge than C has.
  - (C) Peak Y, because F is more electronegative than C is.
  - (D) Peak Y, because F has a smaller atomic radius than C has.

Questions 32-34 refer to the following.



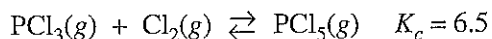
In a titration experiment,  $\text{H}_2\text{O}_2(aq)$  reacts with aqueous  $\text{MnO}_4^-(aq)$  as represented by the equation above. The dark purple  $\text{KMnO}_4$  solution is added from a buret to a colorless, acidified solution of  $\text{H}_2\text{O}_2(aq)$  in an Erlenmeyer flask. (Note: At the end point of the titration, the solution is a pale pink color.)

32. At a certain time during the titration, the rate of appearance of  $\text{O}_2(g)$  was  $1.0 \times 10^{-3} \text{ mol}/(\text{L} \cdot \text{s})$ . What was the rate of disappearance of  $\text{MnO}_4^-$  at the same time?
- (A)  $6.0 \times 10^{-3} \text{ mol}/(\text{L} \cdot \text{s})$   
(B)  $4.0 \times 10^{-3} \text{ mol}/(\text{L} \cdot \text{s})$   
(C)  $6.0 \times 10^{-4} \text{ mol}/(\text{L} \cdot \text{s})$   
(D)  $4.0 \times 10^{-4} \text{ mol}/(\text{L} \cdot \text{s})$
33. Which element is being oxidized during the titration, and what is the element's change in oxidation number?
- (A) Oxygen, which changes from  $-1$  to  $0$   
(B) Oxygen, which changes from  $0$  to  $-2$   
(C) Manganese, which changes from  $-1$  to  $+2$   
(D) Manganese, which changes from  $+7$  to  $+2$
34. Which of the following best describes what happens to the pH of the  $\text{H}_2\text{O}_2$  solution as the titration proceeds?
- (A) The  $+2$  charge on the manganese ions maintains the acidity of the solution.  
(B) The production of water dilutes the solution, making it basic.  
(C) As  $\text{H}^+$  ions are consumed, the solution becomes less acidic and the pH increases.  
(D) As  $\text{H}^+$  ions are consumed, the solution becomes less acidic and the pH decreases.



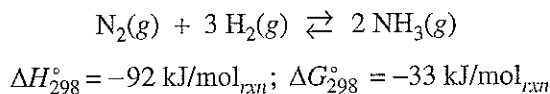
35. The  $\text{BF}_3$  molecule is nonpolar, whereas the  $\text{NF}_3$  molecule is polar. Which of the following statements accounts for the difference in polarity of the two molecules?

- (A) In  $\text{NF}_3$ , each F is joined to N with multiple bonds, whereas in  $\text{BF}_3$ , each F is joined to B with single bonds.
- (B) N – F bonds are polar, whereas B – F bonds are nonpolar.
- (C)  $\text{NF}_3$  is an ionic compound, whereas  $\text{BF}_3$  is a molecular compound.
- (D) Unlike  $\text{BF}_3$ ,  $\text{NF}_3$  has a nonplanar geometry due to an unshared pair of electrons on the N atom.



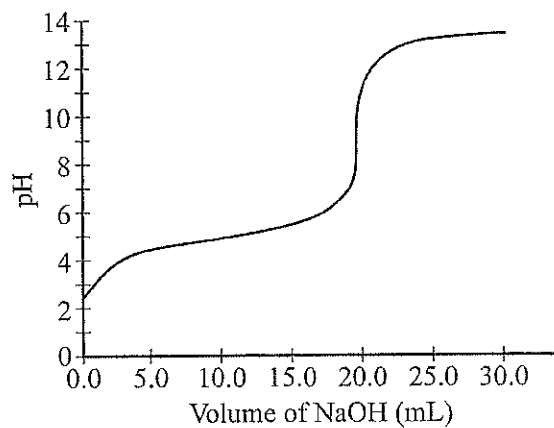
36. At a certain point in time, a 1.00 L rigid reaction vessel contains 1.5 mol of  $\text{PCl}_3(g)$ , 1.0 mol of  $\text{Cl}_2(g)$ , and 2.5 mol of  $\text{PCl}_5(g)$ . Which of the following describes how the measured pressure in the reaction vessel will change and why it will change that way as the reaction system approaches equilibrium at constant temperature?

- (A) The pressure will increase because  $Q < K_c$ .
- (B) The pressure will increase because  $Q > K_c$ .
- (C) The pressure will decrease because  $Q < K_c$ .
- (D) The pressure will decrease because  $Q > K_c$ .



37. Consider the reaction represented above at 298 K. When equal volumes of  $\text{N}_2(g)$  and  $\text{H}_2(g)$ , each at 1 atm, are mixed in a closed container at 298 K, no formation of  $\text{NH}_3(g)$  is observed. Which of the following best explains the observation?

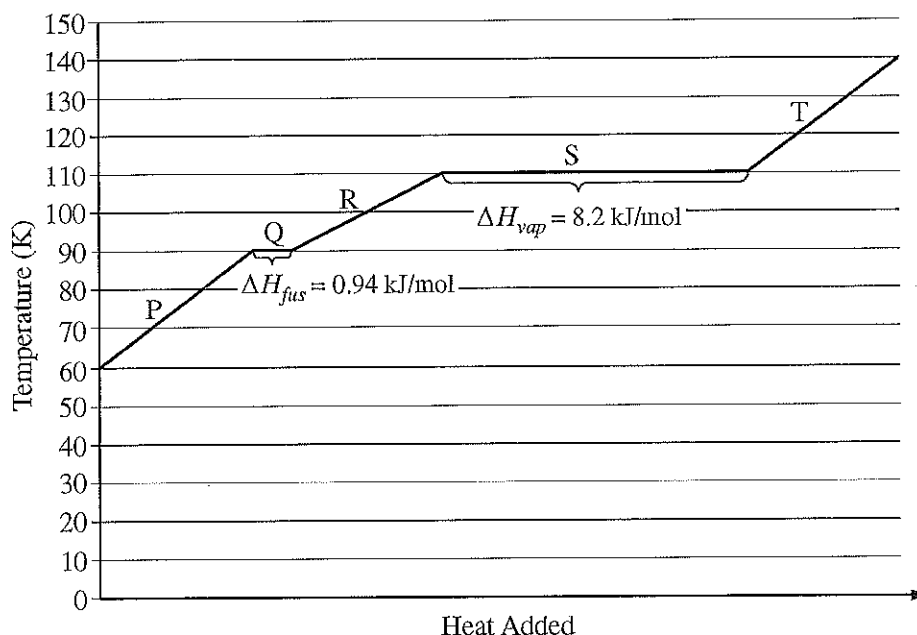
- (A) The  $\text{N}_2(g)$  and the  $\text{H}_2(g)$  must be mixed in a 1:3 ratio for a reaction to occur.
- (B) A high activation energy makes the forward reaction extremely slow at 298 K.
- (C) The reaction has an extremely small equilibrium constant, thus almost no product will form.
- (D) The reverse reaction has a lower activation energy than the forward reaction, so the forward reaction does not occur.



38. Data collected during the titration of a 20.0 mL sample of a 0.10 *M* solution of a monoprotic acid with a solution of NaOH of unknown concentration are plotted in the graph above. Based on the data, which of the following are the approximate  $pK_a$  of the acid and the molar concentration of the NaOH?

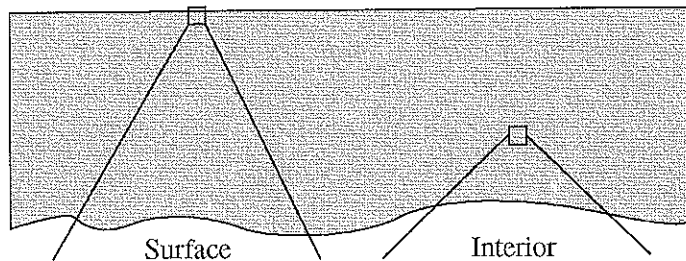
	$pK_a$	[NaOH]
(A)	4.7	0.050 <i>M</i>
(B)	4.7	0.10 <i>M</i>
(C)	9.3	0.050 <i>M</i>
(D)	9.3	0.10 <i>M</i>

Questions 39-41 refer to the following graph, which shows the heating curve for methane,  $\text{CH}_4$ .

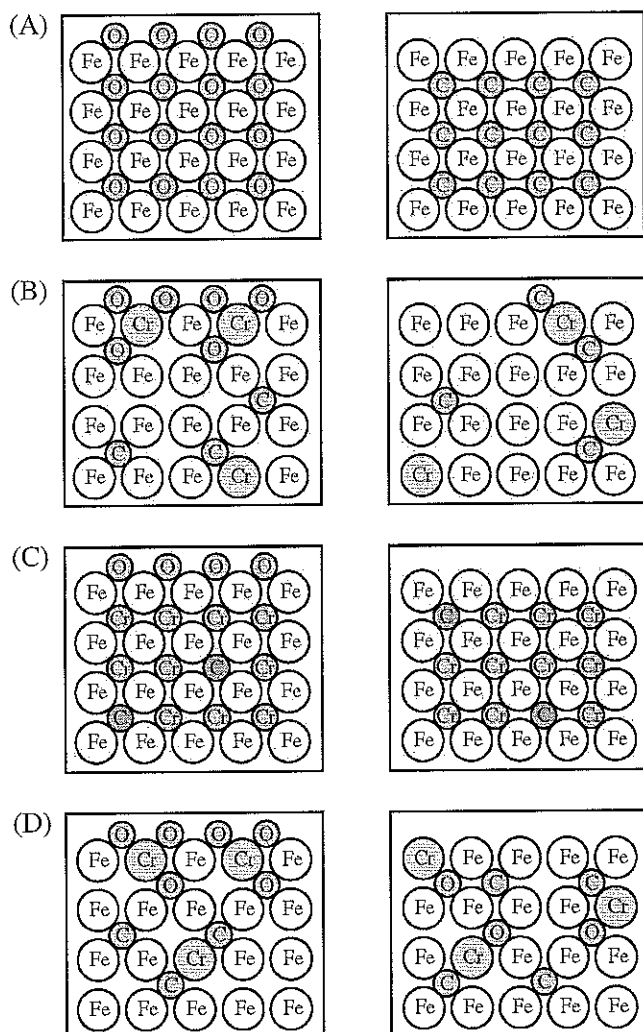


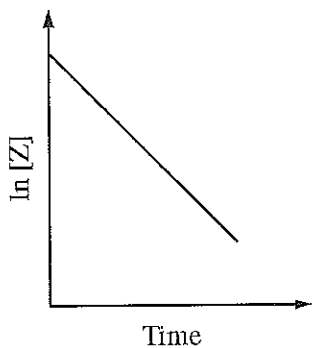
39. How much energy is required to melt 64 g of methane at 90 K? (The molar mass of methane is 16 g/mol.)
- (A) 0.24 kJ  
(B) 3.8 kJ  
(C) 33 kJ  
(D) 60. kJ
40. Which of the following best explains why more energy is required for the process occurring at 110 K than for the process occurring at 90 K?
- (A) Intermolecular attractions are completely overcome during vaporization.  
(B) Intermolecular attractions in the solid phase are weaker than in the liquid phase.  
(C) Electron clouds of methane molecules are less polarizable at lower temperatures.  
(D) Vaporization involves a large increase in temperature.
41. The enthalpy of vaporization of water is 40.7 kJ/mol. Which of the following best explains why the enthalpy of vaporization of methane is less than that of water?
- (A) Methane does not exhibit hydrogen bonding, but water does.  
(B) Methane has weaker dispersion forces.  
(C) Methane has a smaller molar mass.  
(D) Methane has a much lower density.

42. Steel is an alloy consisting of Fe with a small amount of C. Elemental Cr can be added to steel to make the steel less likely to rust; Cr atoms react with oxygen in the air to form a nonreactive layer of chromium oxide on the surface of the steel, preventing the oxidation of underlying Fe atoms. A sample of steel-chromium alloy contains 15 percent Cr by mass. Which of the following diagrams best shows a particle-level view of a surface section and an interior section of the alloy represented below at the left? (The atomic radii of the atoms involved are given in the table below at the right.)



Element	Molar Mass (g/mol)	Atomic Radius (pm)
Fe	55.85	125
Cr	52.00	127
C	12.01	77
O	16.00	73

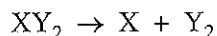




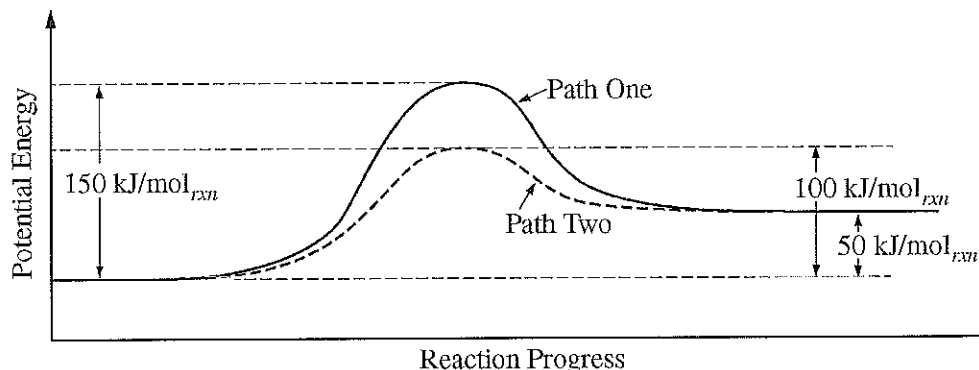
43. Consider the reaction represented by the equation  $2 X + 2 Z \rightarrow X_2Z_2$ . During a reaction in which a large excess of reactant X was present, the concentration of reactant Z was monitored over time. A plot of the natural logarithm of the concentration of Z versus time is shown in the figure above. The order of the reaction with respect to reactant Z is

(A) zero order  
(B) first order  
(C) second order  
(D) third order

Questions 44-46 relate to the following information.

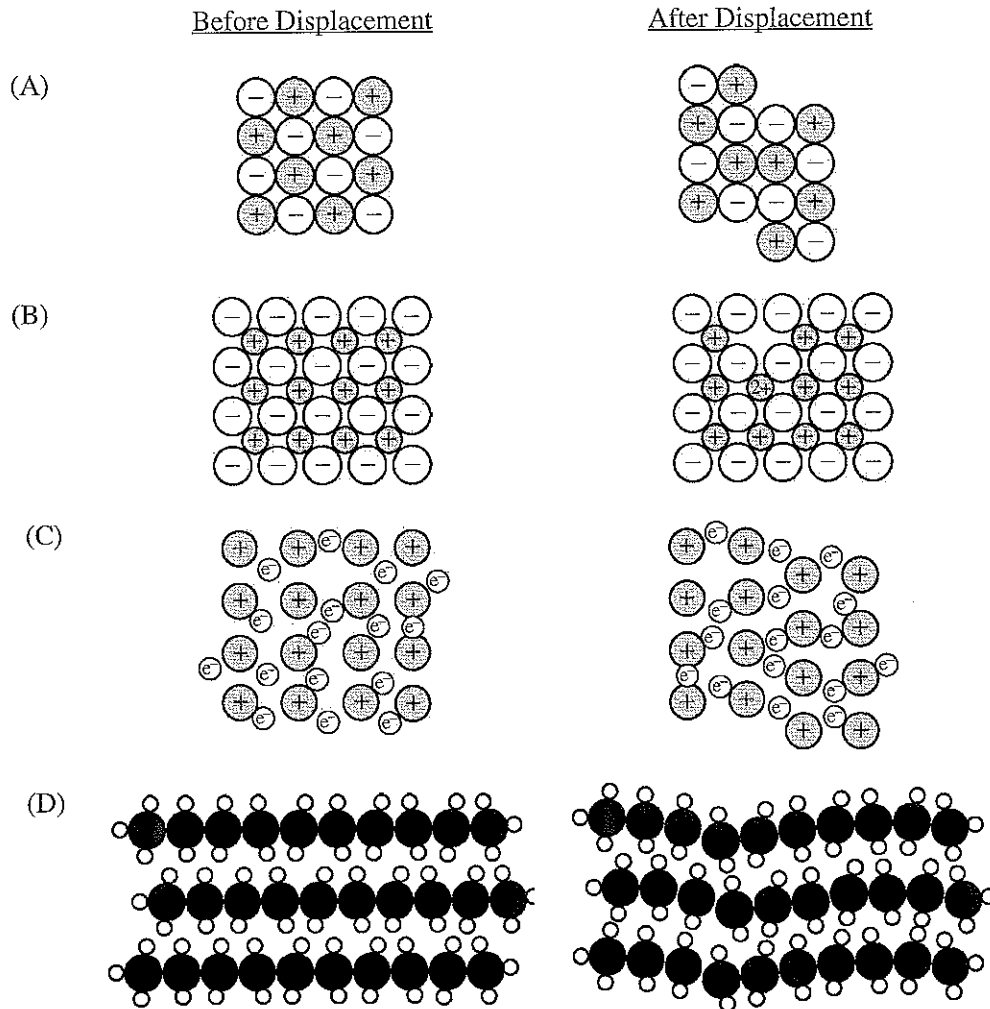


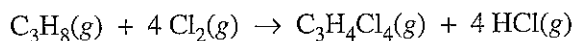
The equation above represents the decomposition of a compound  $\text{XY}_2$ . The diagram below shows two reaction profiles (path one and path two) for the decomposition of  $\text{XY}_2$ .



44. Which of the following most likely accounts for the difference between reaction path one and reaction path two?
- (A) A higher temperature in path one
  - (B) A higher temperature in path two
  - (C) The presence of a catalyst in path one
  - (D) The presence of a catalyst in path two
45. Which of the following best describes the flow of heat when 1.0 mol of  $\text{XY}_2$  decomposes?
- (A) 50 kJ of heat is transferred to the surroundings.
  - (B) 50 kJ of heat is transferred from the surroundings.
  - (C) 100 kJ of heat is transferred to the surroundings.
  - (D) 100 kJ of heat is transferred from the surroundings.
46. The reaction is thermodynamically favorable under standard conditions at 298 K. Therefore, the value of  $\Delta S^\circ$  for the reaction must be
- (A) equal to zero
  - (B) equal to  $\Delta H^\circ/298 \text{ K}$
  - (C) greater than  $\Delta H^\circ/298 \text{ K}$
  - (D) less than  $\Delta H^\circ/298 \text{ K}$

47. Which of the following diagrams best illustrates how a displacement in an ionic crystal results in cleavage and brittleness?





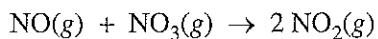
48. A 6.0 mol sample of  $\text{C}_3\text{H}_8(g)$  and a 20. mol sample of  $\text{Cl}_2(g)$  are placed in a previously evacuated vessel, where they react according to the equation above. After one of the reactants has been totally consumed, how many moles of  $\text{HCl}(g)$  have been produced?

- (A) 4.0 mol  
(B) 8.0 mol  
(C) 20. mol  
(D) 24 mol

Name	Structural Formula	Molar Mass (g/mol)
Acetone	$\begin{array}{ccccc} & \text{H} & & \text{O} & & \text{H} \\ &   & &    & &   \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - \text{H} \\ &   & & & &   \\ & \text{H} & & & & \text{H} \end{array}$	58.1
1-propanol	$\begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{H} & \\ &   & &   & &   & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - \text{O} - \text{H} \\ &   & &   & &   & \\ & \text{H} & & \text{H} & & \text{H} & \end{array}$	60.1
Butane	$\begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{H} & & \text{H} \\ &   & &   & &   & &   \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - \text{H} \\ &   & &   & &   & &   \\ & \text{H} & & \text{H} & & \text{H} & & \text{H} \end{array}$	58.1

49. The table above shows the structural formulas and molar masses for three different compounds. Which of the following is a list of the compounds in order of increasing boiling points?
- (A) Butane < 1-propanol < acetone  
(B) Butane < acetone < 1-propanol  
(C) 1-propanol < acetone < butane  
(D) Acetone = butane < 1-propanol





$$\text{rate} = k[\text{NO}][\text{NO}_3]$$

50. The reaction represented above occurs in a single step that involves the collision between a particle of NO and a particle of NO<sub>3</sub>. A scientist correctly calculates the rate of collisions between NO and NO<sub>3</sub> that have sufficient energy to overcome the activation energy. The observed reaction rate is only a small fraction of the calculated collision rate. Which of the following best explains the discrepancy?
- (A) The energy of collisions between two reactant particles is frequently absorbed by collision with a third particle.
  - (B) The two reactant particles must collide with a particular orientation in order to react.
  - (C) The activation energy for a reaction is dependent on the concentrations of the reactant particles.
  - (D) The activation energy for a reaction is dependent on the temperature.