SECTION TWO

Questions 8-11 refer to neutral atoms for which the atomic orbitals are represented below

(A) $\boxed{\uparrow\downarrow}$ 1s

(B) $\boxed{\uparrow\downarrow}$ 1s $\boxed{\uparrow\downarrow}$ 2s $\boxed{\uparrow\ \ \ }$ 2p

(C) $\boxed{\uparrow\downarrow}$ 1s $\boxed{\uparrow\downarrow}$ 2s $\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$ 2p

(D) $\boxed{\uparrow\downarrow}$ 1s $\boxed{\uparrow\downarrow}$ 2s $\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}$ 2p

(E) [Ar] $\boxed{\uparrow\downarrow}$ 4s $\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow}\boxed{\uparrow}$ 3d

8. Is in an excited state

9. Has exactly five valence electrons

10. Has the highest first ionization energy

11. Forms an aqueous cation that is colored

$$CaCl_2(s) \rightarrow Ca^{2+}(aq) + 2\,Cl^-(aq)$$

23. For the process of solid calcium chloride dissolving in water, represented above, the entropy change might be expected to be positive. However, ΔS for the process is actually negative. Which of the following best helps to account for the net loss of entropy?

(A) Cl^- ions are much larger in size than Ca^{2+} ions
(B) The particles in solid calcium chloride are more ordered than are particles in amorphous solids.
(C) Water molecules in the hydration shells of Ca^{2+} and Cl^- ions are more ordered than they are in the pure water.
(D) The $Ca^{2+}(aq)$ and $Cl^-(aq)$ ions are more free to move around in solution than they are in $CaCl_2(s)$.
(E) In the solution, the average distance between $Ca^{2+}(aq)$ and $Cl^-(aq)$ is greater than the average distance between Ca^{2+} and Cl^- in $CaCl_2(s)$.

$$CH_3OCH_3(g) + \quad O_2(g) \rightarrow \quad CO_2(g) + \quad H_2O(g)$$

24. When the equation above is balanced using the lowest whole-number coefficients, the coefficient for $O_2(g)$ is

(A) 6
(B) 4
(C) 3
(D) 2
(E) 1

68. In which of the following are the chemical species correctly ordered from smallest radius to largest radius?

(A) B < C < N
(B) Ar < Xe < Kr
(C) Cl < S < S^{2-}
(D) Na < Na^+ < K
(E) K^+ < Ca^{2+} < K

$$8\,H_2(g) + S_8(s) \rightarrow 8\,H_2S(g)$$

63. When 25.6 g of $S_8(s)$ (molar mass 256 g mol^{-1}) reacts completely with an excess of $H_2(g)$ according to the equation above, the volume of $H_2S(g)$, measured at 0°C and 1.00 atm, produced is closest to

(A) 30 L
(B) 20 L
(C) 10 L
(D) 5 L
(E) 2 L

$$2\,HClO + 3\,O_2 \rightarrow 2\,HClO_4$$

64. As the reaction represented above proceeds to the right, the oxidation number of chlorine changes from

(A) −1 to +3
(B) −1 to +5
(C) +1 to +5
(D) +1 to +7
(E) +3 to +7

72. Of the following gases, which has the greatest average molecular speed at 298 K?

(A) $Cl_2(g)$
(B) $NO(g)$
(C) $H_2S(g)$
(D) $HCN(g)$
(E) $PH_3(g)$

73. Types of hybridization exhibited by carbon atoms in a molecule of propyne, CH_3CCH, include which of the following?

I. sp
II. sp^2
III. sp^3

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

66. At 25°C a saturated solution of a metal hydroxide, $M(OH)_2$, has a pH of 9.0. What is the value of the solubility-product constant, K_{sp}, of $M(OH)_2(s)$ at 25°C?

(A) 5.0×10^{-28}
(B) 1.0×10^{-27}
(C) 5.0×10^{-19}
(D) 5.0×10^{-16}
(E) 1.0×10^{-15}

$$N_2(g) + O_2(g) + Cl_2(g) \rightleftarrows 2\,NOCl(g) \qquad \Delta H^\circ = +104\ kJ\ mol^{-1}$$

58. The equilibrium system represented above is contained in a sealed, rigid vessel. Which of the following will increase if the temperature of the mixture is raised?

(A) $[N_2(g)]$
(B) The rate of the forward reaction only
(C) The rate of the reverse reaction only
(D) The rates of both the forward and reverse reactions
(E) The total number of moles of gas in the vessel

21. Which of the systems in equilibrium represented below will exhibit a shift to the left (toward reactants) when the pressure on the system is increased by reducing the volume of the system? (Assume that temperature is constant.)

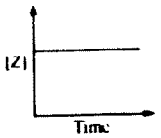
(A) $2\,Mg(s) + O_2(g) \rightleftarrows 2\,MgO(s)$
(B) $SF_4(g) + F_2(g) \rightleftarrows SF_6(g)$
(C) $H_2(g) + Br_2(g) \rightleftarrows 2\,HBr(g)$
(D) $N_2(g) + 3\,H_2(g) \rightleftarrows 2\,NH_3(g)$
(E) $SO_2Cl_2(g) \rightleftarrows SO_2(g) + Cl_2(g)$

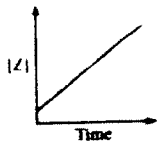
19. What mass of KBr (molar mass 119 g mol^{-1}) is required to make 250. mL of a 0.400 *M* KBr solution?

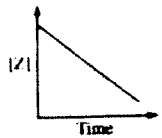
(A) 0.595 g
(B) 1.19 g
(C) 2.50 g
(D) 11.9 g
(E) 47.6 g

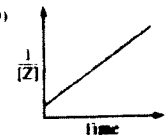
$$Z \rightarrow X + Y$$

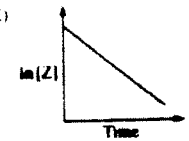
47 A pure substance Z decomposes into two products, X and Y, as shown by the equation above. Which of the following graphs of the concentration of Z versus time is consistent with the rate of the reaction being first order with respect to Z?

(A)


(B)


(C)


(D)


(E)


Questions 37-38 refer to a galvanic cell constructed using two half-cells and based on the two half-reactions represented below.

$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$ $\quad E^\circ = -0.76$ V

$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$ $\quad E^\circ = 0.77$ V

37 As the cell operates, ionic species that are found in the half-cell containing the cathode include which of the following?

I $Zn^{2+}(aq)$
II $Fe^{2+}(aq)$
III $Fe^{3+}(aq)$

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

38 What is the standard cell potential for the galvanic cell?

(A) 0.01 V
(B) 0.01 V
(C) 0.78 V
(D) 1.53 V
(E) 2.31 V

$$CS_2(l) + 3\,O_2(g) \rightarrow CO_2(g) + 2\,SO_2(g)$$

48 When 0.60 mol of $CS_2(l)$ reacts as completely as possible with 1.5 mol of $O_2(g)$ according to the equation above, the total number of moles of reaction products is

(A) 2.4 mol
(B) 2.1 mol
(C) 1.8 mol
(D) 1.5 mol
(E) 0.75 mol

52 Of the following metals, which reacts violently with water at 298 K?

(A) Au
(B) Ag
(C) Cu
(D) Mg
(E) Rb

53 Heat energy is added slowly to a pure solid covalent compound at its melting point. About half of the solid melts to become a liquid. Which of the following must be true about this process?

(A) Covalent bonds are broken as the solid melts.
(B) The temperature of the solid/liquid mixture remains the same while heat is being added.
(C) The intermolecular forces present among molecules become zero as the solid melts.
(D) The volume of the compound increases as the solid melts to become a liquid.
(E) The average kinetic energy of the molecules becomes greater as the molecules leave the solid state and enter the liquid state.

54 A steady electric current is passed through molten $MgCl_2$ for exactly 1.00 hour, producing 243 g of Mg metal. If the same current is passed through molten $AlCl_3$ for 1.00 hour, the mass of Al metal produced is closest to

(A) 27.0 g
(B) 54.0 g
(C) 120 g
(D) 180 g
(E) 270 g

$$Au^{3+}(aq) + \_\,F^-(aq) \rightarrow Au(s) + \_\,I_2(s)$$

55 When the equation above is balanced using the lowest whole-number coefficients, the coefficient for $I_2(s)$ is

(A) 8
(B) 6
(C) 4
(D) 3
(E) 2

56 What is the empirical formula of a hydrocarbon that is 10.0 percent hydrogen by mass?

(A) CH_3
(B) C_2H_5
(C) C_3H_8
(D) C_4H_9
(E) C_9H_{10}

$$Pb(s) \rightleftarrows Pb(l)$$

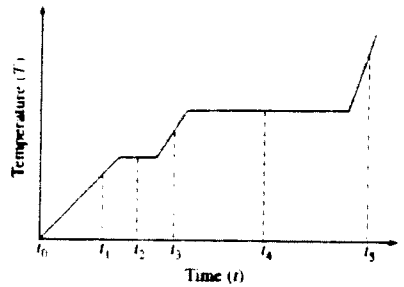
57 Which of the following is true for the process represented above at 327°C and 1 atm? (The normal melting point of Pb(s) is 327°C.)

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

What mass of Cu(s) would be produced if 0.40 mol of $Cu_2O(s)$ was reduced completely with excess $H_2(g)$?

(A) 13 g
(B) 25 g
(C) 38 g
(D) 51 g
(E) 100 g

Questions 16-17 refer to various points in time during an experiment conducted at 1.0 atm. Heat is added at a constant rate to a sample of a pure substance that is solid at time t_0. The graph below shows the temperature of the sample as a function of time.



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

16 Time when the average distance between the particles is greatest

17 Time when the temperature of the substance is between its melting point and its boiling point

Gas	Amount
Ar	0.35 mol
CH_4	0.90 mol
N_2	0.25 mol

29 Three gases in the amounts shown in the table above are added to a previously evacuated rigid tank. If the total pressure in the tank is 3.0 atm at 25°C, the partial pressure of $N_2(g)$ in the tank is closest to

(A) 0.75 atm
(B) 0.50 atm
(C) 0.33 atm
(D) 0.25 atm
(E) 0.17 atm

Ionization Energies for Element X

	1st	2nd	3rd	4th	5th	6th	7th
Ionization Energy ($kJ\ mol^{-1}$)	787	1,580	3,200	4,400	16,000	20,000	24,000

39. The first seven ionization energies of element X are shown in the table above. On the basis of these data, element X is most likely a member of which of the following groups (families) of elements?

(A) Alkaline earth metals
(B) Boron group
(C) Carbon group
(D) Nitrogen group
(E) Halogen group

---

40. Which of the following particles is emitted by an atom of ^{39}Ca when it decays to produce an atom of ^{39}K?

(A) $^{4}_{2}He$
(B) $^{1}_{0}n$
(C) $^{1}_{1}H$
(D) β^-
(E) β^+

41. At approximately what temperature will 40. g of argon gas at 2.0 atm occupy a volume of 22.4 L?

(A) 1,200 K
(B) 600 K
(C) 550 K
(D) 270 K
(E) 140 K

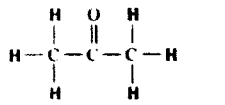
42. Which of the following aqueous solutions has the highest boiling point at 1.0 atm?

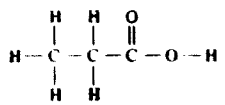
(A) 0.20 *M* $CaCl_2$
(B) 0.25 *M* Na_2SO_4
(C) 0.30 *M* NaCl
(D) 0.30 *M* KBr
(E) 0.40 *M* $C_6H_{12}O_6$

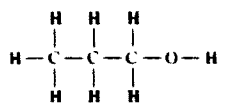
43. A certain reaction is spontaneous at temperatures below 400. K but is not spontaneous at temperatures above 400. K. If $\Delta H°$ for the reaction is −20. kJ mol^{-1} and it is assumed that $\Delta H°$ and $\Delta S°$ do not change appreciably with temperature, then the value of $\Delta S°$ for the reaction is

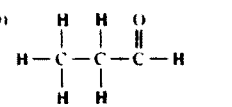
(A) −50. J $mol^{-1}\ K^{-1}$
(B) −20. J $mol^{-1}\ K^{-1}$
(C) −0.050 J $mol^{-1}\ K^{-1}$
(D) 20. J $mol^{-1}\ K^{-1}$
(E) 8,000 J $mol^{-1}\ K^{-1}$

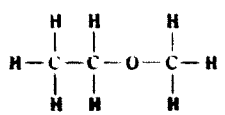
28. Which of the following is a formula for an ether?

(A)


(B)


(C)


(D)


(E)


30. Which of the following best explains why the normal boiling point of $CCl_4(l)$ (350 K) is higher than the normal boiling point of $CF_4(l)$ (145 K)?

(A) The C–Cl bonds in CCl_4 are less polar than the C–F bonds in CF_4.
(B) The C–Cl bonds in CCl_4 are weaker than the C–F bonds in CF_4.
(C) The mass of the CCl_4 molecule is greater than that of the CF_4 molecule.
(D) The electron cloud of the CCl_4 molecule is more polarizable than that of the CF_4 molecule.
(E) The bonds in the CCl_4 molecule are covalent, whereas the bonds in the CF_4 molecule are ionic.

31. At which of the following temperatures and pressures would a real gas be most likely to deviate from ideal behavior?

	Temperature (K)	Pressure (atm)
(A)	100	50
(B)	200	5
(C)	300	0.01
(D)	500	0.01
(E)	500	1

32. After 195 days, a 10.0 g sample of pure ^{95}Zr has decayed to the extent that only 1.25 g of the original ^{95}Zr remains. The half-life of ^{95}Zr is closest to

(A) 195 days
(B) 97.5 days
(C) 65.0 days
(D) 48.8 days
(E) 24.4 days

33. Which of the following would produce the LEAST mass of CO_2 if completely burned in excess oxygen gas?

(A) 10.0 g CH_4
(B) 10.0 g CH_3OH
(C) 10.0 g C_2H_4
(D) 10.0 g C_2H_6
(E) 10.0 g C_4H_9OH

34. Which of the following substances exhibits significant hydrogen bonding in the liquid state?

(A) CH_2F_2
(B) N_2H_4
(C) CH_3OCH_3
(D) C_3H_4
(E) C_2H_2

35. In an aqueous solution with a pH of 11.50 at 25°C, the molar concentration of $OH^-(aq)$ is approximately

(A) $3.2 \times 10^{-12}\ M$
(B) $3.2 \times 10^{-3}\ M$
(C) $2.5 \times 10^{-1}\ M$
(D) 2.5 *M*
(E) $3.2 \times 10^{11}\ M$

36. Which of the following changes to a reaction system in equilibrium would affect the value of the equilibrium constant, K_c, for the reaction? (Assume in each case that all other conditions are held constant.)

(A) Adding more of the reactants to the system
(B) Adding a catalyst for the reaction to the system
(C) Increasing the temperature of the system
(D) Increasing the pressure on the system
(E) Removing some of the reaction products from the system

38. For which of the following processes does entropy decrease ($\Delta S < 0$)?

(A) $H_2O(s) \rightarrow H_2O(l)$
(B) $Br_2(l) \rightarrow Br_2(g)$
(C) Crystallization of $I_2(s)$ from an ethanol solution
(D) Thermal expansion of a balloon filled with $CO_2(g)$
(E) Mixing of equal volumes of $H_2O(l)$ and $CH_3OH(l)$