SECTION I

Time—90 minutes

Directions: Select the best answer choice and fill in the corresponding oval on the answer sheet. **You may NOT use a calculator for this section. You may use the Periodic Table provided on page 469 of this book.**

1. Which of the following statements about nuclear stability is correct?
   A. Heavier, more stable nuclei have somewhat larger numbers of protons than neutrons.
   B. A stable nucleus cannot undergo a nuclear reaction, even with the addition of external energy.
   C. Unstable nuclei do not spontaneously change to stable nuclei.
   D. Lighter nuclei tend to have equal numbers of protons and neutrons.
   E. Heavier nuclei have significantly more neutrons than protons.

2. Rank the following in order of increasing acidity: propionic acid ($K_a = 1.3 \times 10^{-5}$), benzoic acid ($K_a = 6.3 \times 10^{-5}$), hypobromous acid ($K_a = 2.6 \times 10^{-9}$).
   A. Benzoic acid < propionic acid < hypobromous acid
   B. Hypobromous acid < propionic acid < benzoic acid
   C. Propionic acid < benzoic acid < hypobromous acid
   D. Hypobromous acid < benzoic acid < propionic acid
   E. Benzoic acid < hypobromous acid < propionic acid

3. Which of the following compounds contain(s) no covalent bonds?

   KCl PH_3 O_2 B_2H_6 H_2SO_4

   A. KCl, PH_3, and B_2H_6 only
   B. KCl and H_2SO_4 only
   C. PH_3, O_2, and B_2H_6 only
   D. KCl only
   E. KCl and B_2H_6 only

4. Which of the following nuclear reactions is *incorrect*?
   A. ${}^{14}_{7}N + {}^{4}_{2}He \rightarrow {}^{17}_{8}O + {}^{1}_{1}H$
   B. ${}^{9}_{4}Be + {}^{4}_{2}He \rightarrow {}^{12}_{6}C + {}^{1}_{0}n$
   C. ${}^{30}_{15}P + {}^{-30}_{-14}Si \rightarrow {}^{0}_{-1}\beta$
   D. ${}^{3}_{1}H + {}^{3}_{2}He \rightarrow {}^{1}_{-1}\beta$
   E. None of the above

5. What is the hydrogen ion concentration in a solution of 0.00200 M potassium hydroxide?
   A. $[H^+] = \dfrac{K_w}{0.00200}$
   B. $[H^+] = K_w(0.00200)$
   C. $[H^+] = \dfrac{0.00200}{K_w}$
   D. $[H^+] = -\log\dfrac{K_w}{0.00200}$
   E. $[H^+] = -\log\dfrac{0.00200}{K_w}$

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6. What is the correct coefficient on the Fe^{3+} ion when the following reaction is balanced?

$Fe^{2+} + ClO_3^- + H^+ \rightarrow Fe^{3+} + Cl^- + H_2O$

A. 2
B. 3
C. 5
D. 6
E. 7

7. The van der Waals equation includes 2 terms, "a" and "b," that are not present in the ideal gas law. Which of the following statements is true about these terms?

A. "a" corrects for attractive forces between gas particles and "b" corrects for the volume of the container.

B. "a" corrects for the external pressure of the gas and "b" corrects for the internal pressure of the gas.

C. "a" corrects for interactions between gas particles and "b" corrects for the volume of the gas particles.

D. "a" corrects for the volume of the gas particles and "b" corrects for the repulsive forces between gas particles.

E. None of the above

8. Which of the following molecular structures is not possible?

A. OF_2

B. SF_2

C. OF_4

D. SF_4

E. O_2F_2

9. Which of the following is *not* a postulate of the kinetic molecular theory?

A. Gas molecules travel in random, straight paths.

B. The energy of a gas molecule is determined by quantum mechanics.

C. The collisions between gas molecules are elastic.

D. The absolute temperature of a substance is equal to the average kinetic energy of its particles.

E. The particles of a sample of gas have no volume.

10. Which parameter of a chemical reaction will change with a catalyst?

A. Free energy change
B. Entropy change
C. Equilibrium constant
D. Rate constant
E. Enthalpy change

11. A plot of $1/[NO_2]$ versus time for the decomposition of NO_2 was found to be linear. This means that the reaction:

A. is zero order with respect to NO_2.

B. is first order with respect to NO_2.

C. is second order reaction with respect to NO_2.

D. is third order reaction with respect to NO_2.

E. Order cannot be determined from the information given.

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12. Which of the following is not a characteristic of ionic substances?
    A. High melting point
    B. Fragility
    C. Crystalline (in the solid form)
    D. Deforms when struck
    E. Well-defined three-dimensional structure

13. Which of the following behaves most like an ideal gas?
    A. H_2
    B. He
    C. O_2
    D. CO_2
    E. Ne

14. The change in enthalpy of a system is equal to *Q*, the heat flow between the system and the surroundings, under which conditions?
    A. Constant volume
    B. Constant pressure
    C. Constant temperature
    D. Absence of pressure-volume work
    E. None of the above

15. Which statement about metals is *incorrect*?
    A. Metals exhibit higher electronegativities than non-metals.
    B. Metals are reducing agents.
    C. Metals form basic hydroxides.
    D. Metals exhibit low ionization potentials.
    E. Metals generally have one to five electrons in their outermost shell.

16. 40 L of an ideal gas at 25°C and 750 mmHg is allowed to expand to 50 L and the pressure is increased to 765 mmHg. What is the final temperature of the gas?
    A. $\frac{(298)(750)(50)}{(40)(765)}$
    B. $\frac{(298)(765)(50)}{(40)(750)}$
    C. $\frac{(298)(750)(40)}{(50)(765)}$
    D. $\frac{(750)(40)}{(50)(298)(765)}$
    E. $\frac{(298)(765)(40)}{(50)(750)}$

17. Rutherford's scattering experiments demonstrated:
    A. the existence of X-rays.
    B. the existence of α-particles.
    C. the nature of blackbody radiation.
    D. the mass-to-charge ration of the electron.
    E. the nuclear model of the atom.

18. Elements not found in nature, synthesized in nuclear reactions and involving the completion of the *5f* atomic orbitals are known as:
    A. lanthanides.
    B. halogens.
    C. actinides.
    D. transition metals.
    E. rare gases.

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19. Which of the following statements is (are) true about the half-reactions shown below?

I. As written, the standard potential for the overall reaction is –1.56 V.

II. As written, the overall reaction is spontaneous.

III. The sign of the potential of the overall reaction indicates whether or not the reaction is spontaneous.

$Ag \rightarrow Ag^+ + e^- \quad E° = -0.80\ V$

$Zn^{2+} + 2\ e^- \rightarrow Zn \quad E° = -0.76\ V$

A. I only
B. II only
C. III only
D. I and III only
E. II and III only

20. K_p for the reaction below is 1.36 at 499 K. Which of the following equations can be used to calculate K_c for this reaction?

$$PCl_3\ (g) + Cl_2\ (g) \rightarrow PCl_5\ (g)$$

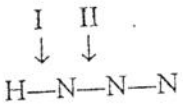
A. $K_c = \dfrac{[(0.0821)(499)]^{-1}}{1.36}$

B. $K_c = \dfrac{1.36(0.0821)}{499}$

C. $K_c = \dfrac{1.36}{[(0.0821)(499)]^{-1}}$

D. $K_c = 1.36 \cdot [(0.0821)(499)]^{-1}$

E. $K_c = \dfrac{1.36(499)}{0.0821}$



21. The Third Law of Thermodynamics states that at absolute zero temperature, all perfect crystals have:

A. the same crystal lattice.
B. the same lattice energy.
C. the same enthalpy.
D. the same free energy.
E. the same entropy.

22. Which of the following has the smallest ionic radius?

A. Li^+
B. Na^+
C. K^+
D. Rb^+
E. Cs^+

23. The van der Waals equation for non-ideal gases differs from the ideal gas law in that it accounts for:

I. the mass of each particle of gas.
II. the volume of each particle of gas.
III. the attractive forces between particles of gas.

A. I only
B. II only
C. III only
D. I and III only
E. II and III only

24. What is the molarity of a sulfuric acid solution if 50.0 mL completely neutralizes 1.00 L of a 0.10 M potassium hydroxide solution?

A. 1.0 M
B. 0.10 M
C. 2.0 M
D. 0.20 M
E. 10.0 M

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25. Which of the following is an intensive property of a system?
    A. Pressure
    B. Mass
    C. Enthalpy
    D. Volume
    E. None of the above

26. Which of the following salts produces the most basic aqueous solution?
    A. $Al(CN)_3$
    B. $KC_2H_3O_2$
    C. $FeCl_3$
    D. KCl
    E. $Pb(C_2H_3O_2)_2$

27. How many molecules are present in 0.20 g of hydrogen gas?
    A. $\frac{0.20}{1.008} \cdot 6.02 \times 10^{23}$
    B. $0.20 \cdot 1.008$
    C. $0.20 \cdot 2.016$
    D. $\frac{0.20}{2.016} \cdot 6.02 \times 10^{23}$
    E. $\frac{0.20}{6.02 \times 10^{23}} \cdot 2.016$

28. The least accurate of the volumetric measuring devices is a:
    A. pipet.
    B. buret.
    C. volumetric flask.
    D. graduated cylinder.
    E. beaker.

29. Which of the following describes the equilibrium constant for a spontaneous reaction?
    A. $K = 0$
    B. $K < 0$
    C. $K = 1$
    D. $K < 1$
    E. $K > 1$

30. Which of the following oxides is amphoteric?
    A. Na_2O
    B. ZnO
    C. MgO
    D. Cl_2O_7
    E. P_2O_5

31. It takes 250.0 J to raise the temperature of a 50.0 g sample of a metal by 10.0°C. What is the specific heat capacity of this metal?
    A. 5.00×10^{-4} J/g·K
    B. 1.25×10^{5} J/g·K
    C. 0.500 J/g·K
    D. 1.25×10^{2} kJ/g·K
    E. 50.0 J/g·K

32. What is the molecular geometry of IF_5?
    A. Tetrahedral
    B. Trigonal bipyramidal
    C. Square pyramidal
    D. Octahedral
    E. Seesaw

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33. How much barium nitrate is required to prepare 250.0 mL of a 0.100 M solution? (The molar mass of barium nitrate is 199.344.)

A. $\frac{(250.0)(199.344)}{(1000)(0.100)}$

B. $\frac{(250.0)(0.100)}{(1000)(199.344)}$

C. $\frac{(250.0)(0.100)(199.344)}{(1000)}$

D. $\frac{(250.0)}{(1000)(199.344)(0.100)}$

E. None of the above

34. What is the oxidation number of chlorine in ClO_4^-?

A. +1
B. +3
C. +5
D. +7
E. +8

35. A neutral atom has the ground-state electron configuration $1s^2 2s^2 2p^6 3s^1$. It will gain or lose electrons to form an ion of charge:

A. –2.
B. –1.
C. +1.
D. +2.
E. +3.

36. The emission of an alpha particle from $^{226}_{88}Ra$ will yield:

A. $^{223}_{86}Rn$.

B. $^{222}_{86}Rn$.

C. $^{223}_{87}Fr$.

D. $^{222}_{87}Fr$.

E. $^{222}_{88}Ra$.

37. The Rydberg equation was a very useful result of Bohr's model of the hydrogen atom. The Rydberg equation gives:

A. the velocity of electrons as they move through spectral lines.

B. the rate of absorption of hydrogen atoms in the ultraviolet region.

C. the rate of emission of hydrogen atoms in the Lyman series.

D. the rate of emission of heated hydrogen atoms.

E. the frequencies of the series of lines in the hydrogen spectrum.

38. Which of the characteristics below is *not* necessary for a reaction to be used in a titration?

A. The reaction can have no side reactions.

B. The equilibrium constant of the reaction must be very large.

C. The reaction should proceed according to a definite chemical equation.

D. The reaction should proceed very slowly so that the endpoint is readily observable.

E. A method should be available to indicate when to stop the titration.

39. Which of the following molecules or ions is linear?

A. H_2O

B. ClO_2^-

C. NO_2^-

D. NO_2

E. NO_2^+

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40. Which of the following statements about equilibrium is correct?

I. Equilibrium is reached when $\Delta G = 0$.

II. $\Delta G° = -RT\ln K_{eq}$

III. At equilibrium, $\Delta G°$ is dependent on pressure.

A. I only
B. II only
C. III only
D. I and II only
E. I, II, and III

41. The triple point pressure of water is 4.58 mmHg and the triple point temperature is 273.16 K. From this we can conclude that:

A. steam cannot exist at temperatures below 273.16 K.

B. the vapor pressure of ice is 4.58 mmHg for temperatures below 273.16 K.

C. the vapor pressure of water is less than 4.58 mmHg in most cases.

D. liquid water cannot exist at pressures below 4.58 mmHg.

E. ice cannot exist at pressures below 4.58 mmHg.

42. The molecular geometry of the ammonium ion, NH_4^+, is:

A. trigonal planar.
B. trigonal pyramidal.
C. square planar.
D. tetrahedral.
E. octahedral.

43. Which of the following statements is (are) true about an oxygen atom in the ground state?

I. Electrons in the 1*s* atomic orbital may be described using the quantum numbers (1, 0, 0, +1/2) and (1, 0, 0, −1/2).

II. Electrons in the 2*s* atomic orbital may be described using the quantum numbers (2, 1, 1, +1/2) and (2, 1, 1, −1/2).

III. The fourth quantum number, m_s, describes the ways that an electron may be aligned with a magnetic field.

A. I only
B. I and II only
C. I and III only
D. II and III only
E. I, II, and III

44. LeChâtelier's principle states that:

A. equilibrium is only reached under certain conditions of temperature and pressure.

B. when stress is applied to a system at equilibrium, the reaction shifts in the direction that minimizes the stress.

C. increasing the temperature while decreasing the pressure increases the equilibrium constant.

D. neither temperature nor pressure has a major effect on equilibrium.

E. equilibrium is eventually obtained, regardless of reaction conditions.

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45. Which of the following statements about carbon-containing compounds is (are) true?

I. Carbon monoxide is produced when carbon is burned with insufficient oxygen.

II. Carbon dioxide may undergo sublimation.

III. Carbonic acid is a diprotic acid.

A. I only
B. II only
C. III only
D. I and III only
E. I, II, and III

46. An ionic bond is formed between two ions. Which of the following has no effect on the strength of the bond?

I. Doubling the charge on both ions
II. Doubling the temperature
III. Doubling the radii of both ions

A. I only
B. II only
C. III only
D. Both I and II
E. Both II and III

47. Which of the alkali metals is most electronegative?

A. Li
B. Na
C. K
D. Rb
E. Cs

48. How many carbon atoms are there in 27.3 g of trichloroacetic acid? (The molar mass of trichloroacetic acid is 163.5.)

A. $\frac{(27.3)(2)(6.02 \times 10^{23})}{163.5}$

B. $\frac{(27.3)(2)}{163.5}$

C. $\frac{(27.3)(163.5)}{(2)(6.02 \times 10^{23})}$

D. $\frac{(27.3)(6.02 \times 10^{23})(163.5)}{(2)(12.01)}$

E. $\frac{(27.3)(6.02 \times 10^{23})}{163.5}$

49. The primary weakness of the Bohr model of the atom is that:

A. it only works for the hydrogen atom.

B. it treats the electron as a wave rather than a particle.

C. it doesn't consider the role of the neutron.

D. it neglects the radiation emitted by accelerating charged particles.

E. it only allows for certain energy levels.

50. Which of the following statements is not true for the reaction shown below?

$$Fe^{3+} + 1\ e^- \rightarrow Fe^{2+}$$

A. Fe^{3+} is being reduced.

B. The oxidation state of Fe has changed.

C. Fe^{3+} is the oxidizing agent in this reaction.

D. The reaction is similar to the reaction between magnesium metal and hydrogen gas.

E. Both Fe^{3+} and Fe^{2+} are anions.

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51. How much heat is released when the temperature of 100 g of water decreases from 25°C to 5°C? (The specific heat of water is 4.18 J/g · K.)

A. $(100)(4.18)(25 - 5)$

B. $(100)(4.18)(5 - 25)$

C. $\frac{2000}{4.18}$

D. $\frac{-2000}{4.18}$

E. $\frac{-20(4.18)}{100}$

52. Increasing the temperature of a reaction increases:

A. the reaction order.

B. the activation energy.

C. the number of collisions in the correct orientation.

D. the kinetic energy of the molecules.

E. None of the above.

53. Glass is an example of an amorphous solid which can be characterized as:

A. a malleable solid.
B. crystal-like in structure.
C. a good conductor.
D. a molecular solid.
E. a very viscous fluid.

54. The K_a of the ammonium ion is 5.6×10^{-10} at 25°C. What is the approximate pH of a 1.0 M ammonium chloride solution?

A. 9
B. 7
C. 5
D. 3
E. 1

55. Which of the following pairs of elements does not have approximately the same electronegativity?

A. C and S
B. Co and Ni
C. B and Al
D. U and Pu
E. Fe and Ni

56. Which of the following salts will produce a basic solution when dissolved in water?

A. NH_4Cl

B. NaCl

C. $NaNO_3$

D. Na_2SO_4

E. Na_2CO_3

57. A pH 7 buffer solution contains H_2CO_3 and $NaHCO_3$. What must the ratio of $[NaHCO_3]/[H_2CO_3]$ be in order to maintain the solution at pH 7? The K_a of H_2CO_3 is 4.3×10^{-7}.

A. 43
B. 4.3
C. 0.43
D. 86
E. 1.29

58. For which of the following compounds is hydrogen bonding an important component of the intermolecular forces?

A. CH_3Cl

B. CH_3OCH_3

C. CH_3NH_2

D. CH_3CH_3Cl

E. None of the above

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59. The rate data for the reaction $A + B \rightarrow C$ is shown below.

[A]	[B]	rate
1.0	1.0	0.01
1.0	2.0	0.02
3.0	1.0	0.09

The reaction is:

A. first order in both A and B.
B. second order in both A and B.
C. first order in A and second order in B.
D. second order in A and first order in B.
E. second order in A and zero order in B.

60. During a redox reaction, the oxidizing agent:

A. gains electrons.
B. is oxidized.
C. has an increase in oxidation state.
D. is hydrolyzed.
E. loses electrons.

61. Which of the following statements about semiconductors is (are) true?

I. A p-type semiconductor is formed when silicon or germanium is doped with a Group III element.

II. Doping decreases the conductivity of a silicon or germanium crystal.

III. An n-type semiconductor is formed when silicon or germanium is doped with an element that produces non-bonded electrons.

A. I only
B. II only
C. III only
D. I and II only
E. I and III only

62. What is the frequency of light of wavelength 3×10^{-3} cm?

A. 1×10^{13}
B. 2.2×10^{-31}
C. 1×10^{7}
D. 9×10^{7}
E. 2.64×10^{-36}

63. Which of the following substances is a Lewis acid?

A. CCl_4
B. BF_3
C. I_2
D. NaH
E. $(CH_3)_3N$

64. Which of the following compounds has the shortest carbon-halogen bond?

A. CH_3F
B. CH_3Cl
C. CH_3Br
D. CH_3I
E. They are all equal.

65. All of the following statements about entropy change are true EXCEPT:

A. It is a measure of the energy dispersal.
B. The natural tendency is for it to increase.
C. It is not a state function under all conditions.
D. It can be defined both thermodynamically and statistically.
E. Its calculation is only possible for processes involving no temperature change.

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66. Which of the following is not a method for separating mixtures?

A. Filtration
B. Distillation
C. Selective precipitation
D. Absorption chromatography
E. Solvation

67. An atom containing two electrons which possess the following sets of quantum numbers $(3, 1, 1, -\frac{1}{2})$ and $(3, 1, 1, -\frac{1}{2})$ may not exist based on:

A. Pauli exclusion principle.
B. Lewis's law.
C. Hund's rule.
D. Heisenberg uncertainty principle.
E. Bohr model.

68. The natural logarithm of the rate constant of a reaction is:

A. directly proportional to temperature.
B. inversely proportional to temperature.
C. not affected by changes in temperature.
D. only affected by the activation energy.
E. independent of the activation energy and the temperature.

69. Which of the following compounds does not contain a covalent bond?

A. PH_3

B. $GeCl_4$

C. H_2S

D. CsF

E. CH_3Cl

70. In the most stable resonance form of the molecule whose skeleton structure is shown above, the bond orders of bonds I and II are:

A. I = 2 and II = 1
B. I = 2 and II = 20
C. I > 2 and II < 2
D. I > 2 and II > 2
E. I < 2 and II < 2

Match the descriptions in questions 71–73 with the choices given below. A choice may be used once, more than once, or not at all.

(A) BF_3

(B) C_2H_2

(C) $CHCl_3$

(D) XeF_4

(E) NO_2

71. A molecule that has an unpaired electron within its structure.

72. A molecule whose shape is square planar.

73. A molecule that contains 2 pi (π) bonds.

74. A weak acid has a K_a of 1.0×10^{-10}. What is the $[H_3O^+]$ ion concentration in a 0.01 M solution of this acid?

A. 1.0×10^{-12} M

B. 1.0×10^{-10} M

C. 1.0×10^{-8} M

D. 1.0×10^{-6} M

E. 1.0×10^{-5} M

75. All of the following statements are correct EXCEPT:

A. In all spontaneous processes, $\Delta S_{universe} > 0$.

B. The entropy of a perfect crystal is taken to be 0 at 298 K.

C. During freezing, the entropy of the system decreases.

D. A spontaneous process is accompanied by a negative free energy change.

E. The free energy change of a system at equilibrium is 0.

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