Contents

Atoms and Molecules

1. Consider the following reactions (equations are not balanced).

$ZrC(s) + Cl_2(g) \rightarrow ZrCl_4(g) + CCl_4(g)$
$ZrCl_4(g) + Mg(s) \rightarrow Zr(s) + MgCl_2(l)$

How many moles of Zr(s) are produced from 5.00 moles of chlorine gas and 2.00 moles of ZrC(s)?

A) 2.00 mol
B) 4.00 mol
C) 0.800 mol
D) 1.25 mol

2. How many oxygen atoms are present in 2.00 millimoles of H_2SO_4?

A) 4.82×10^{21}
B) 1.20×10^{24}
C) 6.02×10^{23}
D) 1.20×10^{21}

3. Consider the reaction below:

$2Sb(s) + 3Cl_2(g) \rightarrow 2SbCl_3(s)$

What is the limiting reactant and the number of moles of the other reactant remaining when 5.0 moles of antimony and 5.0 moles of chlorine gas react?

A) Cl_2 and 1.7 mol Sb remaining
B) Sb and 2.5 mol of Cl_2 remaining
C) Sb and 1.7 mol of Cl_2 remaining
D) Cl_2 and 3.3 mol of Sb remaining

4. The molarity of a solution of KOH is 8.00 M and has a density of 1.30 g/mL. The solvent of the solution is unknown and the molality of this solution is

A) 8.00 m
B) 9.39 m
C) 6.15 m
D) depends on the solvent used.

5. What is the ground-state electron configuration of a titanium atom?

A) $[Ar]3d^54s^1$
B) $[Ar]3d^4$
C) $[Ar]3d^14s^2$
D) $[Ar]3d^24s^2$

6. What is the total energy of one mole of photons of wavelength 285 nm?

A) 6.98×10^{-19} J
B) 3.50×10^{-18} J
C) 3.15×10^{5} J
D) 4.20×10^{5} J

7. Which of the following sets of quantum numbers is not possible?

	n	l	m_l	m_s
A.	1	0	0	+1/2
B.	4	0	0	+1/2
C.	3	3	–3	–1/2
D.	2	1	1	–1/2

8. Which of the following ions has the largest radius?

A) Se^{2-}
B) Na^{+}
C) Mg^{2+}
D) S^{2-}

9. Which of the following statements is/are correct?

(i) The electronegativity of the elements in Group 1 increases with increasing atomic number.
(ii) Na, Al and Ti all have one (and only one) unpaired electron in their ground states.
(iii) In order of first ionization energies, from largest to smallest

Ne > N > As > K

A) (i) and (iii) only
B) (iii) only
C) none
D) (i) and (ii) only

10. Which of the following statements is/are correct?

(i) The radius of the O^{2-} ion is greater than that of the O atom
(ii) The first ionization energy of Se is greater than that of Br
(iii) The electronegativity of O is less than of C

A) (i) and (iii) only
B) (ii), and (iii) only
C) only one of (i), (ii) or (iii)
D) all of (i), (ii) and (iii)

11. Which atom has the lowest first ionization energy?

A) Li
B) Na
C) K
D) Mg

12. Which one of the following bonds is the most ionic in character?

A) Be–N
B) Li–F
C) Be–F
D) B–N

13. Which of the following is false?

(i) Electrons occupy orbitals in a way that maximizes the energy of the atom.
(ii) No two electrons in an atom may have all 4 quantum numbers alike.
(iii) When orbitals of different energies (degenerate) are available, electrons initially occupy these orbitals singly.

A) (i)
B) (ii)
C) (iii)
D) (i) and iii)

14. Elements in a group (column) of the Periodic Table have chemical properties that show many similarities because:

    A) They have the same number of electrons
    B) Their orbitals are the same size
    C) Their orbitals are the same shape
    D) They have the same number of valence electrons

Gases

15. The density of gas at STP is 1.25g•L^{-1}, what is this gas? (Gas constant, R = 8.3145kPa•L•K^{-1}•mol^{-1}; 0.082058 atm•L•K^{-1}•mol^{-1})

    A) CO_2 (44.0g•mol^{-1})
    B) CO (28.0g•mol^{-1})
    C) CH_4 (16.0g•mol^{-1})
    D) O_2 (32.0 g•mol^{-1})

16. Which graph represents the plot of pressure vs. temperature in degrees Celsius for an ideal gas at constant volume and number of moles?

(a) (b) (c) (d)

17. A weather balloon filled with helium gas has a volume of 2.00×10^3 m^3 at ground level where the atmospheric pressure is 1.000 atm and the temperature is 27°C. After the balloon rises high above the Earth, to a point where the atmospheric pressure is 0.340 atm, its volume increases to 5.00×10^3 m^3. What is the temperature of the atmosphere at this altitude?

    A) 255°C
    B) 46°C
    C) -40°C
    D) -18°C

18. Which one of the following statements is **true**?

    A) Under the same conditions of temperature and pressure, H_2 molecules move faster, on average, than O_2 molecules.
    B) Under the same conditions of temperature and pressure, the average kinetic energy of O_2 molecules is less than that of H_2 molecules.
    C) The volume of 1.00 mol of an ideal gas at 25.0°C, 1.00 atm is 22.4 L.
    D) The volume of 1.00 mol of H_2 gas is only one-sixteenth of the volume of 1.00 mol of O_2 gas, at the same temperature and pressure.

19. Oxygen gas can be prepared in the laboratory by heating potassium chlorate ($KClO_3$) in the presence of manganese dioxide:

$$2KClO_3(s) \xrightarrow{MnO_2} 2KCl(s) + 3O_2(g)$$

    The gas is collected over water at 25.0°C and 756 torr. If a 1.23 g sample of $KClO_3$ yields 332 mL of gas, then what is the percentage yield of the experiment? The vapour pressure of water is 23.8 torr at 25.0°C.

    A) 86.8%
    B) 89.7%
    C) 92.5%
    D) 76.5%

20. If a gas effuses 1.7 times faster than carbon dioxide, which gas might it be?

    A) Cl_2
    B) CH_4
    C) N_2
    D) PCl_3

21. If you have 11.2 liters of each of the following gases at STP, which one would contain the least molecules (if the gases behave ideally)?

A) CO_2
B) O_2
C) O_3
D) Each gas would have the same number of molecules at STP.

22. A container of gas is allowed to expand so that its volume triples. What would happen to the temperature of the gas?

A) It stays constant.
B) It increases.
C) It decreases.
D) The direction of the temperature change would depend on the PV work done by the expansion of the gas.

Chemical Kinetics

23. The following data were obtained for the reaction of NO with O_2. Concentrations are in molecules/cm^3 and rates are in molecules/$cm^3 \cdot s$.

$[NO]_0$	$[O_2]_0$	Initial Rate
1×10^{18}	1×10^{18}	2.0×10^{16}
2×10^{18}	1×10^{18}	8.0×10^{16}
3×10^{18}	1×10^{18}	18.0×10^{16}
1×10^{18}	2×10^{18}	4.0×10^{16}
1×10^{18}	3×10^{18}	6.0×10^{16}

Which of the following is the correct rate law?

A) Rate = $k[NO][O_2]$
B) Rate = $k[NO][O_2]^2$
C) Rate = $k[NO]^2[O_2]$
D) Rate = $k[NO]^2$

24. The rate constant k depends on

A) the concentration of the reactants and the temperature.
B) the nature of the reactants and the order of the reaction
C) the nature of the reactants and the temperature
D) the order of the reaction and the concentration of the reactants

25. The rate law for a reaction is rate = $k[A]^2[B]$. Which of the following mechanisms supports this rate law?

i) $A + B \longrightarrow E$ (fast)
$E + B \longrightarrow C + D$ (slow)

ii) $A + B \longrightarrow E$ (fast)
$E + A \longrightarrow C + D$ (slow)

iii) $A + A \longrightarrow E$ (slow)
$E + B \longrightarrow C + D$ (fast)

A) i
B) ii
C) iii
D) two of these

26. If the reaction of $2\,AB \longrightarrow A_2 + B_2$ is second order, which of the following plots will be linear?

A) log[AB] vs. time
B) ln[AB] vs. time
C) ln[AB] vs. 1/time
D) 1/[AB] vs. time

27. Which of the following statements is/are correct?

    1. A catalyst speeds up a reaction by changing ΔH, the enthalpy of the reaction
    2. Addition of a catalyst to a reaction changes the equilibrium constant
    3. A catalyst increases the rates of both the forward and reverse reactions

    A) 2 only
    B) 2 & 3 only
    C) 3 only
    D) 1 & 2 only

28. The conversion of *tert*-butyl bromide to *tert*-butyl alcohol has been found to be first-order with respect to *tert*-butyl bromide. This reaction was carried out twice. The conditions in the two instances were identical, except that in the second case, the concentration of *tert*-butyl bromide was twice as high as it was in the first case. In the second case:

    A) the reaction rate is half that of the first case.
    B) the reaction rate is twice that of the first case.
    C) the rate constant is half of what it is in the first case.
    D) the rate constant is twice as much as in the first case.

29. For catalysts, all of the following statements are true, EXCEPT:

    A) Catalysts increase the rate of the reverse reaction.
    B) Catalysts change the equilibrium constant so as to shift the equilibrium to the right.
    C) Catalysts lower the activation energy.
    D) Catalysts are not consumed in the reaction.

Chemical Equilibrium

30. Given: $P_4(s) + 6Cl_2(g) \leftrightarrow 4PCl_3(l)$ K
    The equilibrium constant for the reaction below is

    $$2PCl_3(l) \leftrightarrow 3Cl_2(g) + \tfrac{1}{2} P_4(s)$$

    A) $1/K$
    B) $K^{1/2}$
    C) $-K^{1/2}$
    D) $1/K^{1/2}$

31. The equilibrium constant for the reaction $2NOCl\ (g) \leftrightarrow 2NO(g) + Cl_2(g)$ is 0.51 at a certain temperature. A mixture of NOCl, NO and Cl_2 with concentrations 1.3, 1.2, and 0.60M, respectively, was introduced into a container at this temperature. Which of the following is true?

    A) The concentration of $Cl_2(g)$ increases until equilibrium is reached.
    B) $[NOCl] = [NO] = [Cl_2]$ at equilibrium
    C) $[Cl_2] = 0.30M$
    D) We are at equilibrium and thus no net change takes place.

32. For the following equilibrium, which is endothermic in the forward direction, choose the single **correct** statement.

    $CH_3CHO\ (g) \rightleftharpoons CH_4\ (g) + CO\ (g)$

    A) A decrease in temperature will increase the pressure in the system.
    B) Addition of methane will increase the heat absorbed by the system.
    C) An increase in the volume of the system will increase the total moles of CO at equilibrium.
    D) At constant total pressure, an increase in temperature will increase the amount of CH_3CHO at equilibrium.

33. What is the proper expression for *K*c for the reaction

CaCO3(s) ⇄ CaO(*s*) + CO2(*g*) ?

A) *K*c = [CO2]
B) *K*c = [CO2] [CaO] / [CaCO3]
C) *K*c = [CaCO3] / ([CO2] [CaO])
D) *K*c = [CO2] [CaO] [CaCO3]

34. The equilibrium constant for the reaction below is $K_c = 2.5 \times 10^{-4}$ at 25°C. If the initial concentrations were $[N_2] = [C_2H_2] = [HCN] = 1.00$ mol L^{-1}, then what is [HCN] at equilibrium?

$N_2(g) + C_2H_2(g) \rightleftarrows 2\,HCN(g)$

A) 0.024 mol L^{-1}
B) 0.063 mol L^{-1}
C) 0.51 mol L^{-1}
D) 1.22 mol L^{-1}

35. For a reaction at equilibrium, all of the following are true, EXCEPT:

A) The concentrations of the reactants and products are not changing.
B) The enthalpy change for the reaction is zero.
C) The rate of the forward reaction is the same as the rate of the reverse reaction.
D) The Gibbs free energy is at a minimum.

36. Which one of the following statements about equilibrium constant, K, and reaction quotient, Q, is true?

A) If Q is greater than K, the reaction shifts away from equilibrium.
B) If Q is less than K, the reaction shifts away from equilibrium.
C) If Q is less than K, the reaction shifts to the left.
D) If Q is less than K, the reaction shifts to the right.

Thermodynamics

37. A 1.00 g sample of the rocket fuel hydrazine, N_2H_4, is burned in a bomb calorimeter surrounded by 1200 g of water (specific heat = 4.18 J g^{-1} $^{\circ}C^{-1}$). The temperature of the water and the bomb calorimeter rise from 24.62°C to 28.16°C. The heat capacity of the bomb calorimeter itself is 837 J $^{\circ}C^{-1}$. From these data, the heat of combustion of hydrazine is, in kJ mol^{-1}

A) –665
B) +20.7
C) –152
D) +47.4

38. Given the following heats of reaction, measured at 25°C:

	ΔH (kJ)
$2ClF(g) + O_2(g) \rightarrow Cl_2O(g) + F_2O(g)$	167.4
$2ClF_3(g) + 2O_2(g) \rightarrow Cl_2O(g) + 3F_2O(g)$	341.4
$2F_2(g) + O_2(g) \rightarrow 2F_2O(g)$	–43.4

at the same temperature, ΔH for the reaction

$$ClF(g) + F_2(g) \rightarrow ClF_3(g)$$

is, in kJ

A) –217.5
B) –130.2
C) +217.5
D) –108.7

39. Given the following specific heats (heat capacitites g^{-1}) of metals

Metal	Specific heat (J/g°C)
Manganese	0.447
Sodium	1.225
Strontium	0.301
Aluminum	0.899
Beryllium	1.823

If the same amount of heat is added to a 100.0g sample of each of the metals which are initially at the same temperature, which metal will have the highest rise in temperature?

A) Mn
B) Na
C) Sr
D) Al

40. When 150g of water at 75°C are added to 180g of ice at 0.0°C, what mass(g) of ice remains once equilibrium is reached?

A) 141
B) 172
C) 7.8
D) 39.2

41. For the reaction

$$As_2(g) + 3F_2(g) \rightarrow 2AsF_3(g)$$

$\Delta H° = -1794kJ$. Therefore $\Delta H_f°$ ($As_2(g)$) is, in kJ/mol…

A) zero
B) +222
C) +1008
D) –2583

42. Which one of the following statements is **true?**

A) Δ*H* is always equal to *q*.
B) Δ*H* is always equal to Δ*U*.
C) Δ*H* equals to Δ*U* for a reaction which is carried out at constant volume.
D) Δ*H* equals *q* for a reaction which is carried out at constant pressure.

43. The enthalpy of vaporization of water at 373 K is 40.0 kJ mol^{-1}. What is the ratio w/q when one mole of water is vaporized at 373 K under a constant external pressure of 101 kPa?

A) 0.057
B) 0.078
C) 0.13
D) 0.25

44. How long would it take for a 0.100 kilowatt heater to warm 0.250 L of water from 20.0°C to 95.0°C in a perfectly insulated calorimeter?

Heat capacity of water = 75.3 J K^{-1} mol^{-1}
Density of water = 1.0 g mL^{-1}
1 kilowatt = 1 kJ s^{-1}

A) 784 s
B) 14 100 s
C) 313 s
D) 56.4 s

45. The reaction $PCl_3(g) + Cl_2(g) \longrightarrow PCl_5(g)$ is exothermic. The reaction is:

A) spontaneous at all temperatures.
B) Nonspontaneous at all temperatures
C) Spontaneous only at low temperatures
D) Spontaneous only at high temperatures.

46. Which of the following processes is endothermic?

A) $H_2O(s) \longrightarrow H_2O(l)$
B) $H_2O(g) \longrightarrow H_2O(l)$
C) $O_2(g) + 2H_2(g) \longrightarrow 2H_2O(g)$
D) $3O_2(g) + C_2H_5OH(g) \longrightarrow 2\,CO_2(g) + 3H_2O(g)$

47. Which of the following statements is <u>false</u> regarding the first law of thermodynamics?

A) Energy, work and heat all have the same units and are all state functions.
B) Positive value of q signifies that heat flows into the system from the surroundings.
C) At constant pressure, the heat given off by a reaction is the enthalpy change, $Q = \Delta H$.
D) The heat absorbed by a system during a process carried out at constant pressure is equal to $\Delta U + P\Delta V$

48. Which statement is *true* of a process in which one mole of a gas is expanded from state A to state B?

A) When the gas expands from state A to state B, the surroundings are doing work on the system.
B) The amount of work done in the process must be the same, regardless of the path.
C) It is not possible to have more than one path for a change of state.
D) The amount of work done by the gas in the process will depend on the path taken.

49. Which of the following statements is correct?

A) The internal energy of a system decreases when work is done on the system and heat is flowing into the system.
B) The surroundings do work on the system when an ideal gas is compressed by a constant external pressure.
C) The internal energy of a system increases when more work is done by the system than the amount of heat flowing into the system.
D) All statements are true.

Properties of Solutions

50. In a saturated solution of lead iodate, $Pb(IO_3)_2$, the concentration of the IO_3^- (*aq*) ion is 7.4×10^{-5} *M*. Therefore, the value of K_{sp} for $Pb(IO_3)_2$ is

A) 8.0×10^{-13}
B) 5.5×10^{-9}
C) 1.0×10^{-13}
D) 2.0×10^{-13}

51. What is the solubility product expression for barium phosphate?

A) $K_{sp} = [Ba^{2+}][PO_4^{3-}]$
B) $K_{sp} = [Ba^{2+}]^2[PO_4^{3-}]^3$
C) $K_{sp} = [Ba^{2+}]^3[PO_4^{3-}]^2$
D) $K_{sp} = [Ba^{2+}]^3[PO_4^{3-}]^3$

52. What is the concentration of bromide ion in a solution prepared by adding 40.0mL of water to 125mL of 0.96M aqueous iron(III) bromide?

A) 3.0M
B) 9.0M
C) 0.73M
D) 2.2M

53. Liquid Q is a polar solvent and liquid R is a nonpolar solvent. On the basis of this information, you would expect:

A) both liquids to be miscible with a third liquid T
B) liquid Q to be miscible with liquid R
C) NaCl to be soluble to both Q and R
D) Liquid Q and H_2O to be miscible

54. Benzene (C_6H_6) and toluene (C_7H_8) form essentially ideal solutions. A solution is prepared by mixing 1.00 mol of benzene and 2.00 mol of toluene at 30°C. At this temperature, the vapour pressure of pure benzene is 119.3 mmHg and that of toluene is 36.66mmHg. The total vapour pressure (in mmHg) of the solution is:

A) 96.31
B) 155.9
C) 51.99
D) 64.21

55. Which of the following statements is/are true?

(i) In order to separate a solution of two liquids by distillation, the vapour pressures of the pure liquids must be different in value.
(ii) Supersaturated solutions can be transformed into unsaturated solutions by the addition of a few crystals of solute.
(iii) The solubility of ionic solids in water depends only on the lattice energy of the solid and the temperature of the solution.

A) only (i) is true.
B) only (ii) is true.
C) only (i) and (iii) are true.
D) only (ii) and (iii) are true.

56. You were given three flasks with clear, colourless liquids , labeled A, B and C. You were told that one of these flasks contains water, another is an aqueous salt solution, and the third is a non-polar liquid. You made the following observations:
– When the temperature was lowered by a certain amount, the liquid in flask A froze, but not the ones in flasks B and C.
– A small amount of the liquid from flask A was dropped into flasks B and C. Little globules of liquid were seen in flask B but not in flask C.

Which of the following statements is TRUE?

A) Flask A contains water, flask B contains a salt solution, and flask C contains a non-polar liquid.
B) If the temperature of the three flasks is increased, the liquid in flask B will boil before the liquids in flask A and C.
C) If a small pinch of sodium chloride is added to flasks A and C, it will not dissolve.
D) If all the three flasks were heated to boil off the liquids, a white residue will be left in flask A.

57. Which of the following concentration measures changes as the temperature of a solution changes?

A) mass percent.
B) mole fraction.
C) molality
D) molarity

58. Consider the following statements about a solution of two liquids:

i) An application of Raoult's Law is the estimation of the total pressure in the vapour phase above two liquids forming an ideal solution.
ii) If the solution is ideal, then the partial pressure of the more volatile component in the vapour phase is independent of the temperature.
iii) If the solution is ideal then the mole fraction of the more volatile component in the vapour phase is higher or equal to the mole fraction of the more volatile component in the liquid phase.

The correct statement(s) is (are):

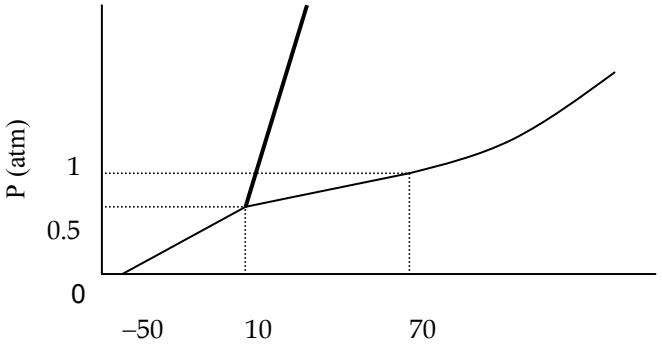
A) (i) only
B) (ii) only
C) (i) and (ii)
D) (i) and (iii)

59. A solution that is 167mM (millimolar) NaCl(aq) is isosmotic with plasma. This means that cells neither swell nor shrink in this solution. How many grams of NaCl are required to make up 100.0mL of isosmotic NaCl(aq)? The molar mass of NaCl is 58.44g/mol.

A) 0.976g
B) 5.84g
C) 9.76g
D) 28.6g

Heat Capacity, Phase Changes, and Colligative Properties

60. The phase diagram for a certain substance is shown below. At which of the following values of T and P is the substance a pure liquid?



A) T = 8°C, P = 1 atm
B) T = 10°C, P = 0.5 atm
C) T = 70°C, P = 1.2 atm
D) T = 80°C, P = 1atm

61. The following statements refer to a one-component phase diagram. The single **correct** or single **incorrect** statement is:

A) A one-component phase diagram has a single triple point where solid, liquid and vapour phases co-exist.
B) A one-component phase diagram has a single critical point above which the liquid phase does not exist.
C) A liquid will boil (i.e. the vapour pressure above the liquid equals the total pressure) at a single temperature.
D) At a given pressure, the solid phase melts at a single temperature.

62. When a nonvolatile solute is added to a volatile solvent, the solution vapour pressure _____, the boiling point _____, the freezing point _____, and the osmotic pressure across a semipermeable membrane _____.

A) decreases, increases, decreases, decreases
B) increases, increases, decreases, increases
C) increases, decreases, increases, decreases
D) decreases, increases, decreases, increases

63. Exactly 150 g of metal, initially at 80°C is placed into 150 g of water, initially at 20°C in an insulated container. The final temperature of the metal and the water is 23.3°C. What is the specific heat of the metal? (for water, the specific heat is 4.18 $J \cdot g^{-1} \cdot °C^{-1}$)

A) 0.24 $J \cdot g^{-1} \cdot °C^{-1}$
B) 0.96 $J \cdot g^{-1} \cdot °C^{-1}$
C) 0.48 $J \cdot g^{-1} \cdot °C^{-1}$
D) 0.72 $J \cdot g^{-1} \cdot °C^{-1}$

64. Which ONE of the following statements about liquids is FALSE?

A) At equilibrium in a closed container the rate of evaporation is less than the rate of condensation.
B) Surface tension is a measure of the elastic force in the surface of a liquid
C) At the liquid-vapour interface, molecules are continually leaving the liquid.
D) The vapour pressure of a pure liquid increases with temperature.

65. The increasing vapor pressure caused by heating a liquid is due to:

A) increased intermolecular interactions
B) increasing potential energy of molecules
C) increasing kinetic energy of molecules.
D) decreasing surface tension.

66. All of the following are gases at room temperature and 1.00 atm pressure. Which one is most likely to liquefy first if the temperature is lowered but the pressure remains the same?

A) Ar
B) H_2
C) SiH_4
D) NH_3

67. Which ONE of the following decreases as the strength of the attractive intermolecular forces increases?

A) the heat of vaporization
B) the normal boiling point
C) the extent of deviations from the ideal gas law
D) the vapor pressure of a liquid

68. The vapour pressure of a liquid compound at 25 °C is 100 torr. At the same temperature and under a pressure of 80 torr the compound will be

A) a solid
B) a liquid
C) a gas and liquid in equilibrium
D) a liquid and solid in equilibrium

69. The main component of automobile antifreeze is ethylene glycol, $C_2H_6O_2$. When 200 g of ethylene glycol is dissolved in 900 g of water, the freezing point of the solution is closest to: (The freezing point depression constant for water is 1.86 °C-kg/mol)

A) 6.7 °C
B) 3.0 °C
C) -3.2 °C
D) -6.7 °C

70. To calculate the freezing point of an ideal solution of a single, nondissociating solute in a solvent, the *minimum* information required is:

A) Molality of the solute
B) The molality of the solute and the freezing point depression constant (K_f) of the solvent.
C) The quantities in (b) and the freezing point of the pure solvent
D) The quantities in (c) and the molecular weight of the pure solute

71. Which of the following 0.10 M aqueous solutions would have the lowest freezing point?

A) KBr
B) Na_2SO_4
C) $NaNO_3$
D) All the above will have the same freezing point.

72. Lysozyme is an enzyme found in tears, whose function is to break down bacterial cell walls, thus killing bacteria to protect the eye from infection. A solution containing 0.100 g of lysozyme in 150g of water (density = 1.00 g/mL) at 25°C is found to have an osmotic pressure of 8.90 torr. What is the molar mass of lysozyme?

A) 1.39×10^3 g/mol
B) 7.18×10^{-5} g/mol
C) 209 g/mol
D) 1.83 g/mol

73. A cucumber is placed in a concentrated salt solution. Which of the following is most likely to happen?

A) Water will flow from the cucumber to the solution.
B) Water will flow from the solution to the cucumber.
C) No change will occur.
D) Salt will precipitate from the solution.

Acids and Bases

74. Which of the following produces the strongest conjugate base?

A) HF (pKa = 3.45)
B) HCOOH (pKa = 3.75)
C) HClO (pKa = 7.53)
D) HIO (pKa = 10.64)

75. Calculate the OH^- concentration of an aqueous solution with a pH of 9.45.

A) 0.35M
B) 1.0×10^{-14}M
C) 2.8×10^{-5}M
D) 3.5×10^{-10}M

76. The pKb for methylamine, CH_3NH_2, is 3.44. This expression refers to which of the following reactions?

A) $CH_3NH_3^+(aq) + OH^-(aq) \rightleftharpoons CH_3NH_2(aq) + H_2O(aq)$
B) $CH_3NH_2(aq) + H_3O^+(aq) \rightleftharpoons CH_3NH_3^+(aq) + H_2O(l)$
C) $H_3O^+(aq) + OH^-(aq) \rightleftharpoons 2H_2O(l)$
D) $CH_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$

77. For the solution labelled "0.10 M H_2SO_4 (aq),"

A) the pH equals 1.0
B) the pH is greater than 1.0
C) the pH is less than 1.0
D) $[HSO_4^-]$ is greater than 0.10M

78. Which of the following 0.10M aqueous solutions has the highest pH?

A) $KHCO_3$
B) HNO_2
C) NaI
D) NH_4I

79. A 0.010M solution of N_2H_4(aq) is 1.3% protonated. Calculated the Kb for N_2H_4.

A) 1.7×10^{-8}
B) 1.7×10^{-6}
C) 1.3×10^{-4}
D) 1.0×10^{-4}

80. In a titration, a 0.483 g sample of an acid, HX, requires a 37.7 mL of 0.0915M NaOH(aq) for complete reaction. Calculate the molar mass of the acid.

A) 35.0g/mol
B) 2.80×10^2g/mol
C) 70.0 g/mol
D) 1.40×10^2 g/mol

81. The pH of a 0.012M aqueous solution of calcium hydroxide is

A) 1.92
B) 12.38
C) 12.08
D) 1.62

82. Consider a solution of 2.0 M HCN and 1.0 M NaCN. K_a for HCN is 6.2×10^{-10}. Which statement is TRUE?

A) The solution is not a buffer because [HCN] is not equal to $[CN^-]$.
B) The pH is below 7.00 because the concentration of the acid is greater than that of the base.
C) $[OH^-] > [H^+]$.
D) The buffer is more resistant to pH changes from addition of strong acid than of strong base.

83. Which one of the following indicators changes colour closest to the pH expected at the equivalence point when a 0.10 *M* solution of cyanoacetic acid ($K_a = 3.65 \times 10^{-3}$) is titrated with 0.10 *M* NaOH solution ?

A) Thymol blue, $pK_a = 1.7$
B) Methyl orange, $pK_a = 3.7$
C) Bromocresol green, $pK_a = 4.7$
D) Bromothymol blue, $pK_a = 7.1$

84. A titration curve has two end-points. Which ONE of the following is TRUE?

A) It is likely that superacid is being titrated.
B) It is likely that a polyprotic acid is being titrated.
C) It is not possible to observe two end-points.
D) It is likely that a buffer solution is being titrated.

85. Recall the equation $pH = pK_{HIn} + \log\left(\frac{[In^-]}{[HIn]}\right)$. For the acid-base indicator HIn, $K_a = 1\times10^{-6}$. At pH = 8.0, what is the ratio of acid form of the indicator to its conjugate base form?

A) 200/1
B) 1/200
C) 50/1
D) 1/100

86. Which ONE of the following is a conjugate acid-base pair?

A) HCl and OCl^-
B) NH_4^+ and NH_3
C) H_2SO_4 and SO_4^{2-}
D) H_3O^+ and OH^-

87. At 0 °C the ion product constant of water is $K_w = 1.2\times10^{-15}$. What is the pH of pure water at 0 °C ?

A) 6.88
B) 7.00
C) 7.46
D) 7.56

Electrochemistry

88. In a redox reaction, the reducing agent

A) gains electrons and is reduced
B) gains electrons and is oxidized
C) loses electrons and is oxidized
D) loses electrons and is reduced

89. A strip of copper is placed in a 1 M solution of copper nitrate and a strip of silver is placed in a 1M solution of silver nitrate. The two metal strips are connected to a voltmeter by wires and a salt bridge connects the solutions. The following standard reduction potentials apply:

$Ag^+(aq) + e^- \longrightarrow Ag(s)\ E^\circ = +0.80$ V

$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)\ E^\circ = +0.34$ V

When the voltmeter is removed and the two electrodes are connected by a wire, which of the following *does not* take place?

A) Electrons flow in the external circuit from the copper electrode to the silver electrode.
B) The silver electrode increases in mass as the cell operates.
C) There is a net general movement of silver ions through the salt bridge to the copper half-cell.
D) Negative ions pass through the salt bridge from the silver half-cell to the copper half-cell.

90. Which of the following is the strongest oxidizing agent?

$MnO_4^- + 4\,H^+ + 3\,e^- \longrightarrow MnO_2 + 2\,H_2O \quad E^\circ = 1.68$ V
$I_2 + 2\,e^- \longrightarrow 2\,I^- \quad E^\circ = 0.54$ V
$Zn^{2+} + 2\,e^- \longrightarrow Zn \quad E^\circ = -0.76$ V

A) MnO_4^-
B) I_2
C) Zn^{2+}
D) MnO_2

91. For the galvanic cell,

Cu (*s*) | Cu^{2+} (*aq*, 1.0 M) | | Ag^{+} (*aq*, 1.0 M) | Ag (*s*)

Which of the following does NOT take place?

A) The silver electrode increases in mass as the cell operates.
B) The cell, as described above, would be operating at standard state conditions.
C) The cell potential, E would be less than E° if the concentration of Cu^{2+} was greater than 1.0 M.
D) The concentration of Cu^{2+} decreases as the cell operates.

92. Under standard conditions, the following redox reactions are observed to occur in aqueous solution.

$A^{+} + B \rightarrow A + B^{+}$
$A^{+} + C \rightarrow$ no reaction
$2\ B^{+} + D \rightarrow 2B + D^{2+}$

Determine the order of reactivity (most easily oxidized to least easily oxidized).

A) C>A>B>D
B) D>B>A>C
C) A>B>C>D
D) $C>A^{+}>B^{+}>D^{2+}$

93. Which of the following represents an oxidation-reduction reaction?

A) $NH_3(g) + H_2O(l) \rightarrow NH_4OH(aq)$
B) $HCl(aq) + NaH_2PO_4(aq) \rightarrow H_3PO_4(aq) + NaCl(aq)$
C) $BaCl_2(aq) + (NH_4)_2SO_4(aq) \rightarrow BaSO_4(s) + 2\ NH_4Cl(aq)$
D) $CO(g) + H_2O(g) \rightarrow CO_2(g) + H_2(g)$

94. Which of the following half-reactions is a reasonable anode reaction for a cell using the reaction below?

$2Hg^{+}_{(aq)} + 2Br^{-}_{(aq)} \rightarrow 2Hg_2Br_{2(s)}$

A) $2Hg^{+}_{(aq)} + 2e^{-} \rightarrow 2Hg_{(l)}$
B) $2Hg_{(l)} + 2Br^{-}_{(aq)} \rightarrow Hg_2Br2_{(s)} + 2e^{-}$
C) $2Hg_2Br_{2(s)} + 2e^{-} \rightarrow 2Hg_{(l)} + 2Br^{-}_{(aq)}$
D) $2Hg^{+}_{(aq)} + 2Br^{-}_{(aq)} \rightarrow Hg_2Br_{2(s)} + 2e^{-}$

95. Consider the reaction below:

$4Fe^{2+}(aq) + 4H^{+}(aq) + O_2(g) \rightarrow 4Fe^{3+}(aq) + 2H_2O(l)$

Identify the reducing agent.

A) H^{+}
B) H_2O
C) Fe^{2+}
D) O_2

96. Consider an electrochemical cell with a cobalt electrode immersed in 1.0 M Co^{2+} and a lead electrode immersed in 1.0 M Pb^{2+}.

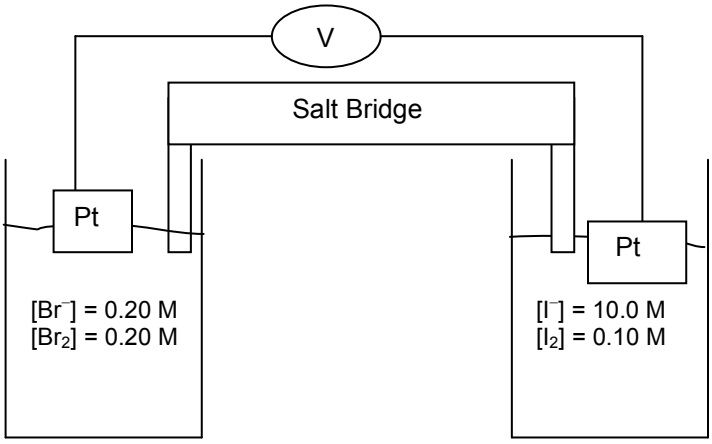
$Co^{2+} + 2e^{-} \longrightarrow Co \qquad E^{\circ} = -0.28$ V

$Pb^{2+} + 2e^{-} \longrightarrow Pb \qquad E^{\circ} = -0.13$ V

Calculate E° for this cell

A) –0.15 V
B) 0.15 V
C) –0.41 V
D) 0.41 V

For the following 2 questions, refer to the half-cell reactions, and the galvanic cell shown below which uses inert platinum electrodes and operates at a temperature of 25°C.



$Br_2(aq) + 2\,e^- \longrightarrow 2\,Br^-(aq)$ $\quad E° = 1.09$ V
$I_2(aq) + 2\,e^- \longrightarrow 2\,I^-(aq)$ $\quad E° = 0.54$ V

97. If current is allowed to flow through the above cell at standard state conditions, which species will be oxidized and which species will be reduced?

A) Br^- is oxidized and I^- is reduced.
B) I^- is oxidized and Br_2 is reduced.
C) Br_2 is oxidized and I_2 is reduced.
D) I_2 is oxidized and H^+ is reduced.

98. In which direction will electrons flow in the external circuit?

A) Left to right
B) Right to left
C) No current flows since the cell is at equilibrium.
D) No current flows since the concentration of Br_2 is exactly the same as that of Br^-.

99. The mass (g) of gold, Au, deposited from a solution that contains Au^{3+} (*aq*) ions when a current of 5.0 amperes flows for 30.0 minutes is

A) 6.1
B) 12
C) 2.0
D) 18

100. A solution containing a 3+ metal ion is electrolyzed by a current of 5.00 A for 10.0 min. What is the identity of the metal if 1.19 g of metal is plated out?

A) Al
B) Cl
C) In
D) Y