EQUATIONS

			Integrated Rate Laws
$\ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$	$E = E^\circ - \frac{RT}{nF}\ln Q$		zero: $[A] = [A]_0 - kt$
$\mathrm{pH} = \mathrm{p}K_a + \log\left(\frac{[A^-]}{[HA]}\right)$	$\Delta U = q + w$	$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$	first: $\ln[A] = \ln[A]_0 - kt$
$\Delta E_{H\text{-atom}} = R_H\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$	$\Delta G^\circ = -RT\ln K$	$\Delta G^\circ = -nFE^\circ$	second: $\frac{1}{[A]} = \frac{1}{[A]_0} + kt$

$E = E^\circ - (0.0592\text{V}/n)\log Q$, $R = 8.3145$ J/(mol K), $F = 96{,}485$ C/(mol e^-), 1A = 1C/s
first order half life = $t_{1/2} = 0.693/k$

Reduction half reaction	**E°(V)**
$Ag^+(aq) + e^- \rightarrow Ag(s)$	0.80
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	0.34
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	-0.13
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	-0.76
$Mn^{2+}(aq) + 2e^- \rightarrow Mn(s)$	-1.180
$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$	-1.665

1. What is the strongest type of intermolecular force present in NH_2CH_3?
A) dispersion
B) dipole-dipole
C) hydrogen bonding
D) ion-dipole
E) none of the above

2. Place the following compounds in order of **increasing** strength of intermolecular forces.

CH_4 $CH_3CH_2CH_3$ CH_3CH_3

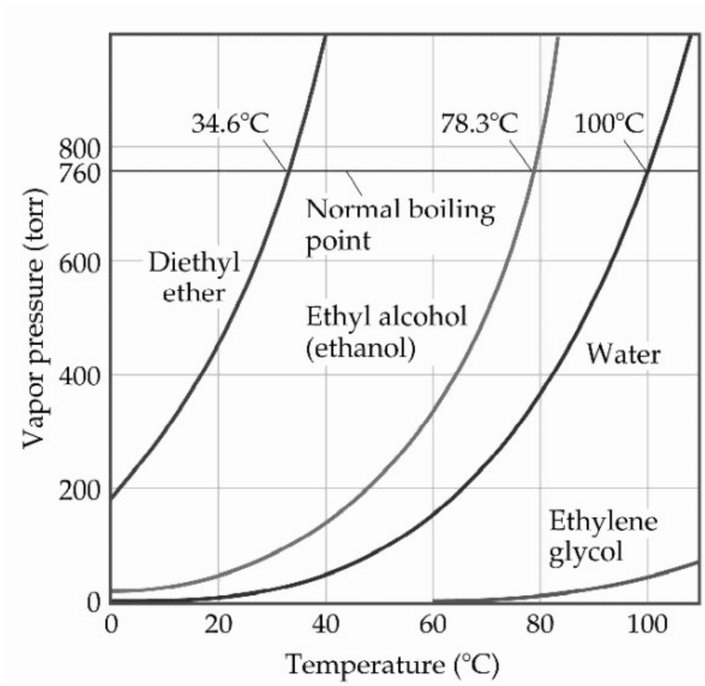
A) $CH_3CH_2CH_3 < CH_4 < CH_3CH_3$
B) $CH_3CH_2CH_3 < CH_3CH_3 < CH_4$
C) $CH_3CH_3 < CH_4 < CH_3CH_2CH_3$
D) $CH_4 < CH_3CH_2CH_3 < CH_3CH_3$
E) $CH_4 < CH_3CH_3 < CH_3CH_2CH_3$

3. The normal boiling point for H_2Se is higher than the normal boiling point for H_2S. This can be explained by
A) larger dipole-dipole forces for H_2Se.
B) larger dispersion forces for H_2Se.
C) larger hydrogen-bond forces for H_2Se.
D) larger dipole-dipole forces, larger dispersion forces, and larger hydrogen-bond forces for H_2Se.

4. Which substance below has the strongest intermolecular forces?

A) A_2X, ΔH_{vap}= 39.6 kJ/mol
B) BY_2, ΔH_{vap}= 26.7 kJ/mol
C) C_3X_2, ΔH_{vap}= 36.4 kJ/mol
D) DX_2, ΔH_{vap}= 23.3 kJ/mol
E) EY_3, ΔH_{vap}= 21.5 kJ/mol

5. Which of the following substances would you predict to have the highest ΔH_{vap}?
A) Xe
B) CH_4
C) He
D) Br_2
E) N_2

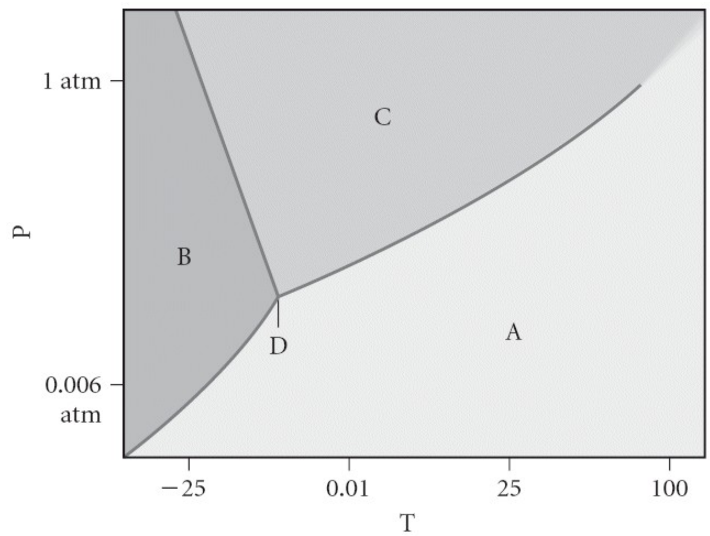


6. Based on the figure above, the boiling point of ethyl alcohol under an external pressure of 0.0724 atm is __________°C.
A) 80
B) 60
C) 70
D) 40
E) 20

7. The heat of vaporization of water at 100°C is 40.66 kJ/mol. Calculate the quantity of heat that is absorbed/released when 9.00 g of steam condenses to liquid water at 100°C.
A) 20.3 kJ of heat are absorbed.
B) 20.3 kJ of heat are released.
C) 81.3 kJ of heat are absorbed.
D) 81.3 kJ of heat are released.

8. Ethyl chloride, C_2H_5Cl, is used as a local anesthetic. It works by cooling tissue as it vaporizes; its heat of vaporization is 26.4 kJ/mol. How much heat could be removed by 20.0 g of ethyl chloride?
A) 8.18 kJ
B) 341 kJ
C) 528 kJ
D) 3410 kJ

9. Assign the appropriate labels to the phase diagram shown below.



A) A = liquid, B = solid, C = gas, D = critical point
B) A = gas, B = solid, C = liquid, D = triple point
C) A = gas, B = liquid, C = solid, D = critical point
D) A = solid, B = gas, C = liquid, D = supercritical fluid
E) A = liquid, B = gas, C = solid, D = triple point

10. Which of the following is considered an ionic solid?
A) $(NH_4)_2CO_3$
B) CCl_4
C) $SeBr_2$
D) XeF_4
E) None of these is an ionic solid.

11. Identify the type of solid for ice.
A) metallic atomic solid
B) ionic solid
C) nonbonding atomic solid
D) molecular solid
E) networking atomic solid

12. Which of the following compounds will be most soluble in pentane (C_5H_{12})?

A) pentanol ($CH_3CH_2CH_2CH_2CH_2OH$)
B) benzene (C_6H_6)
C) acetic acid (CH_3CO_2H)
D) ethyl methyl ketone ($CH_3CH_2COCH_3$)
E) None of these compounds should be soluble in pentane.

13. Give the term for the amount of solute in moles per liter of solution.
A) molality
B) molarity
C) mole fraction
D) mole percent
E) mass percent

14. A solution is prepared by dissolving 49.3 g of KBr in enough water to form 473 mL of solution. Calculate the mass % of KBr in the solution if the density is 1.12 g/mL.
A) 10.4%
B) 8.57%
C) 10.1%
D) 11.7%
E) 9.31%

15. A 1.00 L sample of water contains 0.0036 g of Cl^- ions. Determine the concentration of chloride ions in ppm if the density of the solution is 1.00 g/mL.
A) 2.8 ppm
B) 7.2 ppm
C) 3.6 ppm
D) 1.8 ppm
E) 5.4 ppm

16. Choose the solvent below that would show the greatest boiling point elevation when used to make a 0.10 *m* nonelectrolyte solution.
A) CCl_4, K_b = 29.9°C/m
B) C_6H_6, K_b = 5.12°C/m
C) $CH_3CH_2OCH_2CH_3$, K_b = 1.79°C/m
D) CH_3CH_2OH, K_b = 1.99°C/m
E) $CHCl_3$, K_b = 4.70°C/m

17. Place the following solutions in order of **increasing** osmotic pressure.

I. 0.15 M $C_2H_6O_2$ II. 0.15 M $MgCl_2$ III. 0.15 M NaCl

A) III < I < II

B) II < III < I
C) I < II < III
D) II < I < III
E) I < III < II

18. Choose the aqueous solution that has the highest boiling point. These are all solutions of nonvolatile solutes and you should assume ideal van't Hoff factors where applicable.
A) 0.100 *m* $AlCl_3$
B) 0.100 *m* NaCl
C) 0.100 *m* $MgCl_2$
D) 0.100 *m* $C_6H_{12}O_6$
E) They all have the same boiling point.

19. At a given temperature the vapor pressures of benzene and toluene are 183 mm Hg and 59.2 mm Hg, respectively. Calculate the total vapor pressure over a solution of benzene and toluene with $X_{benzene}$ = 0. 580.
A) 106 mm Hg
B) 121 mm Hg
C) 131 mm Hg
D) 242 mm Hg

20. Write a balanced reaction for which the following rate relationships are true.

$$\text{Rate} = -\frac{1}{2}\frac{\Delta[N_2O_5]}{\Delta t} = \frac{1}{4}\frac{\Delta[NO_2]}{\Delta t} = \frac{\Delta[O_2]}{\Delta t}$$

A) $2\ N_2O_5 \rightarrow 4\ NO_2 + O_2$
B) $4\ NO_2 + O_2 \rightarrow 2\ N_2O_5$
C) $2\ N_2O_5 \rightarrow NO_2 + 4\ O_2$
D) $\frac{1}{4} NO_2 + O_2 \rightarrow \frac{1}{2} N_2O_5$
E) $\frac{1}{2} N_2O_5 \rightarrow \frac{1}{4} NO_2 + O_2$

21. What is the overall order of the following reaction, given the rate law?

$$2\ X + 3\ Y \rightarrow 2\ Z \qquad \text{Rate} = k[X]^1[Y]^2$$

A) 3rd order
B) 5th order
C) 2nd order
D) 1st order
E) 0th order

22. What are the units of k in the following rate law?

Rate = k[X][Y]

A) $\frac{M}{s}$

B) Ms

C) $M^{-1}s^{-1}$

D) $\frac{M^2}{s}$

E) $\frac{s}{M^2}$

23. Determine the rate law and the value of k for the following reaction using the data provided.

$CO(g) + Cl_2(g) \rightarrow COCl_2(g)$	$[CO]_i$ (M)	$[Cl_2]_i$ (M)	Initial Rate ($M^{-1}s^{-1}$)
	0.25	0.40	0.696
	0.25	0.80	1.97
	0.50	0.80	3.94

A) Rate = 11 $M^{-3/2}s^{-1}$ $[CO][Cl_2]^{3/2}$

B) Rate = 36 $M^{-1.8}s^{-1}$ $[CO][Cl_2]^{2.8}$

C) Rate = 17 $M^{-2}s^{-1}$ $[CO][Cl_2]^2$

D) Rate = 4.4 $M^{-1/2}s^{-1}$ $[CO][Cl_2]^{1/2}$

E) Rate = 18 $M^{-3/2}s^{-1}$ $[CO]^2[Cl_2]^{1/2}$

24. The rate constant for the first-order decomposition of N_2O is 3.40 s^{-1}. What is the half-life of the decomposition?

A) 0.491 s

B) 0.204 s

C) 0.236 s

D) 0.424 s

E) 0.294 s

25. For a reaction, what generally happens if the temperature is increased?

A) a decrease in k occurs, which results in a faster rate

B) a decrease in k occurs, which results in a slower rate

C) an increase in k occurs, which results in a faster rate

D) an increase in k occurs, which results in a slower rate

E) there is no change with k or the rate

26. Given the following proposed mechanism, predict the rate law for the overall reaction.

$2NO_2 + Cl_2 \rightarrow 2NO_2Cl$ (overall reaction)

Mechanism
$NO_2 + Cl_2 \rightarrow NO_2Cl + Cl$ slow
$NO_2 + Cl \rightarrow NO_2Cl$ fast

A) Rate = $k[NO_2][Cl_2]$
B) Rate = $k[NO_2]^2[Cl_2]$
C) Rate = $k[NO_2][Cl]$
D) Rate = $k[NO_2Cl][Cl]$
E) Rate = $k[NO_2Cl]^2$

27. The decomposition of dinitrogen pentoxide is described by the chemical equation
$2\,N_2O_5(g) \rightarrow 4\,NO_2(g) + O_2(g)$
If the rate of disappearance of N_2O_5 is equal to 1.60 mol/min at a particular moment, what is the rate of appearance of NO_2 at that moment?
A) 0.800 mol/min
B) 1.60 mol/min
C) 3.20 mol/min
D) 6.40 mol/min

28. A particular first-order reaction has a rate constant of $1.35 \times 10^2\ s^{-1}$ at 25.0°C. What is the magnitude of k at 75.0°C if E_a = 85.6 kJ/mol?
A) $3.47 \times 10^4\ s^{-1}$
B) $1.92 \times 10^4\ s^{-1}$
C) $670\ s^{-1}$
D) $3.85 \times 10^6\ s^{-1}$
E) $1.36 \times 10^2\ s^{-1}$

29. The equilibrium constant is given for one of the reactions below. Determine the value of the missing equilibrium constant.

$2\,SO_2(g) + O_2(g) \rightleftharpoons 2\,SO_3(g)$ $K_c = 1.7 \times 10^6$
$SO_3(g) \rightleftharpoons 1/2\,O_2(g) + SO_2(g)$ $K_c = ?$

A) 3.4×10^2
B) 8.5
C) 1.3×10^3

D) 1.2×10^{-6}
E) 7.7×10^{-4}

30. Determine the value of K_c for the following reaction if the equilibrium concentrations are as follows: $[N_2]_{eq} = 3.6$ M, $[O_2]_{eq} = 4.1$ M, $[N_2O]_{eq} = 3.3 \times 10^{-18}$ M.

$$2\ N_2(g) + O_2(g) \rightleftharpoons 2\ N_2O(g)$$

A) 2.2×10^{-19}
B) 4.5×10^{18}
C) 2.0×10^{-37}
D) 5.0×10^{36}
E) 4.9×10^{-17}

31. In a reaction mixture containing only products, what is the value of Q?
A) -1
B) 1
C) ∞
D) 0
E) It cannot be determined without concentrations.

32. Consider the following reaction and its equilibrium constant:

$$4\ CuO(s) + CH_4(g) \rightleftharpoons CO_2(g) + 4\ Cu(s) + 2\ H_2O(g) \qquad K_c = 1.10$$

A reaction mixture contains 0.22 M CH_4, 0.67 M CO_2 and 1.3 M H_2O. Which of the following statements is TRUE concerning this system?
A) The reaction will shift in the direction of products.
B) The equilibrium constant will increase.
C) The reaction quotient will increase.
D) The reaction will shift in the direction of reactants.
E) The system is at equilibrium.

33. The following reaction is exothermic. Which change will shift the equilibrium to the left?

$$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$$

A) raising the temperature
B) adding SO_3
C) removing O_2
D) all of the above
E) none of the above

34. Consider the following reaction at equilibrium. What effect will increasing the volume of the reaction mixture have on the system?

$$2\ H_2S(g) + 3\ O_2(g) \rightleftharpoons 2\ H_2O(g) + 2\ SO_2(g)$$

A) The reaction will shift to the right in the direction of products.
B) No effect will be observed.
C) The reaction will shift to the left in the direction of reactants.
D) The equilibrium constant will decrease.
E) The equilibrium constant will increase.

35. At a certain temperature the equilibrium constant, K_c, equals 0.11 for the reaction:

$$2\ ICl(g) \rightleftharpoons I_2(g) + Cl_2(g).$$

What is the equilibrium concentration of ICl if 0. 45 mol of I_2 and 0. 45 mol of Cl_2 are initially mixed in a 2.0-L flask?
A) 0. 14 M
B) 0. 17 M
C) 0. 27 M
D) 0. 34 M

36. Which of the following is a Brønsted-Lowry base?
A) CH_4
B) HCN
C) NH_3
D) Cl_2
E) None of the above are Brønsted-Lowry bases.

37. What is the conjugate base of $H_2PO_4^-$?
A) HPO_4^{2-}
B) PO_4^{3-}
C) H_3PO_4
D) H_3O^+
E) OH^-

38. Give the characteristics of a strong acid.
A) ionizes completely in aqueous solutions
B) has a very electronegative atom attached to the oxygen
C) has a polar bond
D) has a weaker bond to hydrogen
E) all of the above

39. Which of the following is a WEAK acid?

A) $HClO_4$
B) H_2SO_4
C) HCl
D) HCO_2H
E) HNO_3

40. Which of the following is TRUE?
A) A neutral solution contains $[H_2O] = [H_3O^+]$
B) An neutral solution does not contain any H_3O^+ or OH^-
C) An acidic solution has $[H_3O^+] > [OH^-]$
D) A basic solution does not contain H_3O^+
E) None of the above are true.

41. Calculate the concentration of OH^- in a solution that contains 3.9×10^{-4} M H_3O^+ at 25°C. Identify the solution as acidic, basic or neutral.
A) 2.6×10^{-11} M, acidic
B) 2.6×10^{-11} M, basic
C) 3.9×10^{-4} M, neutral
D) 2.7×10^{-2} M, basic
E) 2.7×10^{-2} M, acidic

42. Calculate the hydroxide ion concentration in an aqueous solution with a pH of 9.85 at 25°C.
A) 7.1×10^{-5} M
B) 4.2×10^{-10} M
C) 8.7×10^{-10} M
D) 6.5×10^{-5} M
E) 1.4×10^{-10} M

43. Which of the following acids is the WEAKEST? The acid is followed by its K_a value.
A) $HC_2H_3O_2$, 1.8×10^{-5}
B) HIO, 2.3×10^{-11}
C) HBrO, 2.3×10^{-9}
D) HClO, 2.9×10^{-8}
E) $C_6H_5CO_2H$, 6.3×10^{-5}

44. Determine the pH of a 0.116 M $Ba(OH)_2$ solution at 25°C.
A) 8.62
B) 13.06
C) 13.37

D) 0.63
E) 12.56

45. Determine the K_b for CN^- at 25°C. The K_a for HCN is 4.9×10^{-10}.
A) 4.9×10^{-14}
B) 2.3×10^{-9}
C) 1.4×10^{-5}
D) 2.0×10^{-5}
E) 3.7×10^{-7}

46. Determine the pH of a 0.18 M H_2CO_3 solution. Carbonic acid is a diprotic acid whose $K_{a1} = 4.3 \times 10^{-7}$ and $K_{a2} = 5.6 \times 10^{-11}$.
A) 11.00
B) 10.44
C) 5.50
D) 4.31
E) 3.56

47. A solution with a hydrogen ion concentration of 3.25×10^{-6} M is __________ and has a hydroxide ion concentration of __________.
A) acidic, 3.08×10^{-8} M
B) acidic, 3.08×10^{-9} M
C) basic, 3.08×10^{-8} M
D) basic, 3.08×10^{-9} M

48. Which one of the following salts, when dissolved in water, produces the solution with a pH *closest* to 7.00?
A) NH_4Br
B) Ca O
C) K HSO_4
D) Cs I

49. Which one of the following statements is TRUE?
A) A buffer is an aqueous solution composed of two weak acids.
B) A buffer can absorb an unlimited amount of acid or base.
C) A buffer resists pH change by neutralizing added acids and bases.
D) A buffer does not change pH when strong acid or base is added.
E) None of the above are true.

50. You wish to prepare an $HC_2H_3O_2$ buffer with a pH of 5.44. If the pK_a of is 4.74, what ratio

of $C_2H_3O_2^-/HC_2H_3O_2$ must you use?
A) 0.70
B) 0.20
C) 1.4
D) 5.0
E) 1.1

51. Calculate the pH of a solution formed by mixing 200.0 mL of 0.30 M HClO with 100.0 mL of 0.20 M KClO. The K_a for HClO is 2.9×10^{-8}.
A) 5.99
B) 8.01
C) 7.54
D) 7.06
E) 6.46

52. Which of the following acids (listed with pK_a values) and their conjugate base would form a buffer with a pH of 8.10?
A) $HC_7H_5O_2$, $pK_a = 4.19$
B) HF, $pK_a = 3.46$
C) HClO, $pK_a = 7.54$
D) HCN, $pK_a = 9.31$
E) $HClO_2$, $pK_a = 1.96$

53. A 100.0 mL sample of 0.18 M $HClO_4$ is titrated with 0.27 M LiOH. Determine the pH of the solution before the addition of any LiOH.
A) 1.74
B) 1.05
C) 0.74
D) 0.57
E) 1.57

54. A 100.0 mL sample of 0.10 M $Ca(OH)_2$ is titrated with 0.10 M HBr. Determine the pH of the solution after the addition of 300.0 mL HBr.
A) 1.60
B) 1.30
C) 1.00
D) 12.40
E) 1.12

55. Determine the molar solubility of CuCl in a solution containing 0.050 M KCl.

K_{sp} (CuCl) = 1.0×10^{-6}.
A) 1.0×10^{-12} M
B) 5.0×10^{-7} M
C) 2.0×10^{-5} M
D) 1.0×10^{-3} M
E) 0.050 M

56. Determine the molar solubility of BaF_2 in pure water. K_{sp} for BaF_2 = 2.45×10^{-5}.
A) 1.83×10^{-2} M
B) 1.23×10^{-5} M
C) 2.90×10^{-2} M
D) 4.95×10^{-3} M
E) 6.13×10^{-6} M

57. Which of the following solutions is a good buffer system?
A) A solution that is 0.10 M $HC_2H_3O_2$ and 0.10 M $LiC_2H_3O_2$
B) A solution that is 0.10 M HF and 0.10 M $NaC_2H_3O_2$
C) A solution that is 0.10 M HCl and 0.10 M NH_4^+
D) A solution that is 0.10 M NaOH and 0.10 M KOH
E) None of the above are buffer systems.

58. Which of the following compounds solubility will not be affected by a low pH in solution?
A) AgCl
B) $Mg(OH)_2$
C) CaF_2
D) CuS
E) $BaCO_3$

59. Which of the following processes have a $\Delta S > 0$?
A) $CH_3OH(l) \rightarrow CH_3OH(s)$
B) $N_2(g) + 3 H_2(g) \rightarrow 2 NH_3(g)$
C) $CH_4(g) + H_2O (g) \rightarrow CO(g) + 3 H_2(g)$
D) $Na_2CO_3(s) + H_2O(g) + CO_2(g) \rightarrow 2 NaHCO_3(s)$
E) All of the above processes have a DS > 0.

60. Consider a reaction that has a positive ΔH and a positive ΔS. Which of the following statements is TRUE?
A) This reaction will be spontaneous only at high temperatures.
B) This reaction will be spontaneous at all temperatures.

C) This reaction will be nonspontaneous at all temperatures.
D) This reaction will be nonspontaneous only at high temperatures.
E) It is not possible to determine without more information.

61. Above what temperature does the following reaction become nonspontaneous?

$$2\ H_2S(g) + 3\ O_2(g) \rightarrow 2\ SO_2(g) + 2\ H_2O(g) \qquad \Delta H = -1036\ kJ;\ \ \Delta S = -153.2\ J/K$$

A) 6.762×10^3 K
B) 158.7 K
C) 298 K
D) This reaction is nonspontaneous at all temperatures.
E) This reaction is spontaneous at all temperatures.

62. Given the following equation,

$$N_2O(g) + NO_2(g) \rightarrow 3\ NO(g) \qquad \Delta G°_{rxn} = -23.0\ kJ$$

Calculate $\Delta G°_{rxn}$ for the following reaction.

$$3N_2O(g) + 3NO_2(g) \rightarrow 9\ NO(g)$$

A) -23.0 kJ
B) 69.0 kJ
C) -69.0 kJ
D) -7.67 kJ
E) 23.0 kJ

63. Which of the following is NOT true for ΔG_{rxn}?
A) If $\Delta G°_{rxn} > 0$, the reaction is spontaneous in the forward direction.
B) If Q = 1, then $DG_{rxn} = \Delta G°_{rxn}$.
C) If $\Delta G°_{rxn} = 0$, the reaction is spontaneous in the reverse direction.
D) If $\Delta G°_{rxn} > 0$, the reaction is spontaneous in the reverse direction.
E) Under equilibrium conditions, $\Delta G_{rxn} = 0$.

64. Identify the statement that is FALSE.
A) The entropy of a gas is greater than the entropy of a liquid.
B) Entropy generally increases with increasing molecular complexity.
C) Free atoms have greater entropy than molecules.
D) Entropy increases with dissolution.
E) For noble gasses, entropy increases with size.

65. Balance the following redox reaction if it occurs in basic solution. What are the coefficients in front of Br_2 and OH^- in the balanced reaction?

$$Br_2(l) \rightarrow BrO_3^-(aq) + Br^-(aq)$$

A) $Br_2 = 1$, $OH^- = 2$
B) $Br_2 = 2$, $OH^- = 5$
C) $Br_2 = 3$, $OH^- = 3$
D) $Br_2 = 3$, $OH^- = 6$
E) $Br_2 = 1$, $OH^- = 6$

66. Identify the location of reduction in an electrochemical cell.
A) the anode
B) the cathode
C) the electrode
D) the salt bridge
E) the socket

67. What is the reducing agent in the redox reaction represented by the following cell notation?

$$Ni(s) \mid Ni^{2+}(aq) \,||\, Ag^+(aq) \mid Ag(s)$$

A) $Ni(s)$
B) $Ni^{2+}(aq)$
C) $Ag^+(aq)$
D) $Ag(s)$
E) Pt

68. Use the standard half-cell potentials listed below to calculate the standard cell potential for the following reaction occurring in an electrochemical cell at 25°C. (The equation is balanced.)

$$Pb(s) + Br_2(l) \rightarrow Pb^{2+}(aq) + 2\,Br^-(aq)$$

$Pb^{2+}(aq) + 2\,e^- \rightarrow Pb(s)$ $E° = -0.13$ V
$Br_2(l) + 2\,e^- \rightarrow 2\,Br^-(aq)$ $E° = +1.07$ V

A) +1.20 V
B) +0.94 V
C) -0.94 V
D) -1.20 V
E) -0.60 V

69. Use the tabulated half-cell potentials to calculate ΔG° for the following balanced redox reaction.

$$Pb^{2+}(aq) + Cu(s) \rightarrow Pb(s) + Cu^{2+}(aq)$$

A) -41 kJ
B) -0.47 kJ
C) +46 kJ
D) +91 kJ
E) -21 kJ

70. What is the reduction half-reaction for the following overall galvanic cell reaction?
$Co^{2+}(aq) + 2\ Ag(s) \rightarrow Co(s) + 2\ Ag^{+}(aq)$
A) $Ag(s) + e^{-} \rightarrow Ag^{+}(aq)$
B) $Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$
C) $Co^{2+}(aq) + 2\ e^{-} \rightarrow Co(s)$
D) $Co^{2+}(aq) + e^{-} \rightarrow Co(s)$