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Chapter 12. Chapter 12: Physical Properties of Solutions

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[12.1]. Which of the following liquids would make a **good solvent** for bromine, **Br_2**?

A. CCl_4 B. H_2O C. CH_3OH D. NH_3

[A]

[12.2] . A 20.0 % by mass solution of phosphoric acid (H_3PO_4) in water has a density of 1.114 g/mL at 20°C. What is the **molarity** of this solution?
The molar mass of phosphoric acid (H_3PO_4) is 97.99 g.

A. 0.0114 M B. 0.0568 M C. 0.114 M D. 2.27 M E. 5.51 M

[D]

[12.3]. What is the **molarity** of **0.645 m** glucose ($C_6H_{12}O_6$) aqueous solution (Solvent: H_2O).
The molar mass of glucose is 180.2 g. The density of the solution is 1.18 g/mL.

A. 0.0251 M B. 0.1256 M C. 0.454 M D. 0.682 M E. 0.737 M

[D]

[12.4]. A **mole fraction** of solute (methanol: CH_3OH) in aqueous solution (Solvent: H_2O) is **X= 0.2**. What is the **molality** of this solution ?
The molar mass of methanol is 32.04 g and the molar mass of water is 18.02 g.

A. 0.0147 m B. 5.757 m C. 13.873 m D. 34.589 m E. 55.427 m

[C]

[12.5]. Which response lists all the following pairs that are miscible liquids.

Pair #1: octane (C_8H_{18}) and water
Pair #2: acetic acid (CH_3COOH) and water
Pair #3: octane (C_8H_{18}) and carbon tetrachloride(CCl_4)

A) 1, 3 B) 1, 2 C) 3 D) 2 E) 2, 3

[E]

[12.6]. An exothermic solution process is described by which of the following?

A) $\Delta H > 0$, solution feels cold
B) $\Delta H > 0$, solution feels hot
C) $\Delta H < 0$, solution feels cold
D) $\Delta H < 0$, solution feels hot
E) $\Delta H = 0$

[D]

[12.7]. Calculate the mole fraction of KI in a solution made by dissolving 3.4 g of KI in 5.8 g of water.

A) 0.060 B) 0.064 C) 0.37 D) 0.59 E) 6.4

[A]

[12.8]. A 9.50 % by mass solution of acetone (C_3H_6O) in water has a density of 0.9849 g/mL at 20°C. What is the molarity of this solution?

A) 0.621 M B) 1.61 M C) 1.66 M D) 1.71 M E) 16.9 M

[B]

[12.9]. A solution that is 33.6 % by mass of phenol (C_6H_5OH) in water is prepared. What is the mole fraction of the phenol?

A) 0.0969 B) 0.0643 C) 0.0883 D) 0.0604 E) 0.357

[C]

[12.10]. What is the molality of an aqueous KBr solution with a mole fraction of KBr, X, equal to 0.245?

A) 0.325 *m* B) 0.682 *m* C) 13.6 *m* D) 18.0 *m* E) 29.2 *m*

[D]

[12.11]. Oxygen gas makes up 21 % of the atmosphere by volume. What is the solubility of $O_2(g)$ in water at 25°C if the atmospheric pressure is 741 mmHg? The Henry's law constant for oxygen gas at 25°C is 1.3×10^{-3} mol/L·atm.

A) 2.7×10^{-4} M
B) 1.3×10^{-3} M
C) 6.2×10^{-3} M
D) 9.6×10^{-3} M
E) 0.96 M

[A]

[12.12]. The vapor pressure of water at 20°C is 17.5 mmHg. What is the vapor pressure of water over a solution prepared from 2.00×10^2 g of sucrose ($C_{12}H_{22}O_{11}$) and 3.50×10^2 g water?

A) 0.51 mmHg
B) 16.0 mmHg
C) 17.0 mmHg
D) 18.0 mmHg
E) 19.4 mmHg

[C]

[12.13]. What is the boiling point of a solution of 11.0 g of lactose ($C_{12}H_{22}O_{11}$) in 145.0g of water? (K_b (H_2O) = 0.52 °C/*m*)

A) 0.1°C B) 99.9 °C C) 100.1°C D) 102.2 °C E) 105.7 °C

[C]

[12.14]. How many grams of propanol (C_3H_7OH, 60.10 g/mol) would be needed to make 750 mL of a solution with an osmotic pressure of 25 atm at 25°C? (R = 0.0821 L·atm/K·mol)

[46 g]

[12.15] How many grams of water are needed to dissolve 27.8 g of ammonium nitrate NH_4NO_3 in order to prepare a 0.452 m solution?

A) 769 g B) 36.2 g C) 100. g D) 0.157 g E) 157 g

Ans: A

[12.16] A solution is 40.0% by mass benzene (C_6H_6) in carbon tetrachloride (CCl_4) at 20°C. The vapor pressure of pure benzene and pure carbon tetrachloride at this temperature is 74.61 mmHg and 91.32 mmHg, respectively. Calculate the vapor pressure of the solution at 20°C:

A) 66.4 mmHg
B) 73.8 mmHg
C) 81.8 mmHg
D) 83.0 mmHg
E) 84.6 mmHg

[Ans: C]

[12.17] A solution of chloroform, $CHCl_3$, and acetone, $(CH_3)_2CO$, exhibits a negative deviation from Raoult's law. This result implies that

A) chloroform-chloroform interactions are stronger than chloroform-acetone interactions.
B) chloroform-chloroform interactions are weaker than chloroform-acetone interactions.
C) acetone-acetone interactions are stronger than chloroform-acetone interactions.
D) acetone-acetone interactions are weaker than chloroform-acetone interactions.
E) Both B and D.
F) Both A and C.
G) Both A and D.

[Ans: E]

[12.18] Which of the following aqueous solutions has the highest boiling point (assume 100% dissociation for all soluble ionic compounds)?

A) 0.10*m* $Al(NO_3)_3$
B) 0.11*m* Na_2SO_4
C) 0.15*m* K_2CO_3
D) 0.18*m* NaCl
E) 0.35*m* $C_6H_{12}O_6$

[Ans: C]

[12.19] When 24.0 g of glucose (a nonelectrolyte) are dissolved in 500. g of water, the solution has a freezing point of –0.47°C. What is the molar mass of glucose? K_f of water is 1.86°C/m.

A) 41.9 g B) 47.5 g C) 54.9 g D) 178 g E) 190. g

[Ans: E]

[12.20] Pure benzene, C_6H_6, freezes at 5.5° and boils at 80.1°C. What is the boiling point of a solution consisting of cyclohexane (C_6H_{12}) dissolved in benzene if the freezing point of this solution is 0.0°C? (For benzene, K_f = 5.12 °C/m, K_b = 2.53 °C/m; for cyclohexane, K_f = 20.0 °C/m, K_b = 2.79°C/m)

A) 77.4°C B) 80.9°C C) 82.8°C D) 83.1°C E) 91.2°C

[Ans: C]

[12.21] An aqueous fructose solution having a density of 1.049 g/cm^3 is found to have an osmotic pressure of 17.0 atm at 25°C. Find the temperature at which this solution freezes.
[Given: for water K_f = 1.86 °C/m; molecular mass of fructose = 180.16 g/mol]

A) –1.30°C B) –1.41°C C) –1.52°C D) –1.57°C E) –1.69°C

[Ans: B]

[12.22] The vapor pressure of water at 45.0 °C is 71.93 mmHg. Calculate the vapor pressure of a solution of 1.50*m* K_2CO_3 at this temperature (assume 100% dissociation)

A) 1.89 mmHg
B) 5.39 mmHg
C) 66.5 mmHg
D) 70.0 mmHg
E) 108 mmHg

[Ans: C]

[12.23] Thyroxine, an important hormone that controls the rate of metabolism in the body, can be isolated from the thyroid gland. If 0.455 g of thyroxine is dissolved in 10.0 g of benzene, the freezing point of the solution is 5.144°C. Pure benzene freezes at 5.444°C and has a K_f of 5.12°C/m. What is the molar mass of thyroxine?

[
Ans: 777 g/mol]

[12.24] List the following solutions in order of decreasing melting point: 0.20*m* glycerol, 0.11*m* $Sc(NO_3)_3$, 0.15*m* K_2CO_3

[Ans: glycerol < $Sc(NO_3)_3$ < K_2CO_3]

[12.25]. Which of the following gives the molarity of a 17.0% by mass solution of sodium acetate, CH_3COONa (molar mass = 82.0 g/mol) in water?
The density of the solution is 1.09 g/mL.

A) 2.26×10^{-6} M B) 0.207 M C) 2.07 M D) 2.26 M E) 2.72 M

Ans: D

[12.26]. What is the percent by mass of a Na_2SO_4 solution in water with a mole fraction of Na_2SO_4, X = 0.350 ?

A) 2.76% B) 4.25% C) 19.1% D) 73.4 % E) 80.9%

Ans: E

[12.27] The vapor pressure of water at 45.0 °C is 71.93 mmHg. What is the vapor pressure of water over a solution prepared from 75.0 g of citric acid ($C_6H_8O_7$) in 0.420 kg of water at this temperature?

A) 1.22 mmHg
B) 42.3 mmHg
C) 43.0 mmHg
D) 70.7 mmHg
E) 73.2 mmHg

Ans: D

[12.28] . What is the freezing point of a solution that contains 10.0 g of glucose ($C_6H_{12}O_6$) in 100.g of H_2O? K_f for water is 1.86°C/m.

A) +0.10°C B) +0.186°C C) –0.10°C D) –0.186°C E) –1.03°C

Ans: E

[12.29]. How many grams of sucrose ($C_{12}H_{22}O_{11}$, 342.3 g/mol) would be needed to make 2.5 L of a solution with an osmotic pressure of 14 atm at 25°C? (R = 0.0821 L·atm/K·mol)

A) 0.57 g B) 6.8 g C) 2.0×10^2 g D) 4.9×10^2 g E) 5.8×10^3 g

Ans: D

[12.30]. 0.102 g of an unknown compound dissolved in 100. mL of water has an osmotic pressure of 28.1 mmHg at 20°C. Calculate the molar mass of the compound.

A) 727 g/mol
B) 663 g/mol
C) 1.10×10^2 g/mol
D) 1.15 g/mol
E) 0.872 g/mol

Ans: B

[12.31]. Assuming 100% dissociation, which of the following compounds is listed *incorrectly* with its van't Hoff factor *i*?

A) Na_2SO_4, $i = 3$
B) NH_4NO_3, $i = 2$
C) Sucrose, $i = 1$
D) $Al_2(SO_4)_3$, $i = 4$
E) $Mg(NO_3)_2$, $i = 3$

Ans: D

[12.32]. During osmosis

A) pure solvent diffuses through a membrane but solutes do not.
B) pure solutes diffuse through a membrane but solvent does not.
C) pure solvent and a solution both diffuse at the same time through a membrane.
D) gases diffuse through a membrane into a solution and build up pressure.

Ans: A

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Chapter 13: Chemical Kinetics

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[13.1]. Chlorine dioxide reacts in basic water to form chlorite and chlorate according to the following chemical equation:

$$2ClO_2(aq) + 2OH^-(aq) \rightarrow ClO_2^-(aq) + ClO_3^-(aq) + H_2O(l)$$

Under a certain set of conditions, the initial rate of disappearance of chlorine dioxide was determined to be 2.30×10^{-1} M/s. What is the initial rate of appearance of chlorite ion (ClO_2^-) under those same conditions?

A) 5.75×10^{-2} M/s
B) 1.15×10^{-1} M/s
C) 2.30×10^{-1} M/s
D) 4.60×10^{-1} M/s
E) 9.20×10^{-1} M/s

[B]

[13.2]. The reaction A + 2B $\rightarrow$ products has been found to have the rate law, rate = k[A] $[B]^2$. While holding the concentration of A constant, the concentration of B is increased from *x* to 3*x*. Predict by what factor the rate of reaction increases.

A) 3 B) 6 C) 9 D) 27 E) 30

[C]

[13.4]. The reaction A + 2B $\rightarrow$ products was found to follow the rate law: rate = k $[A]^2$ [B]. Predict by what factor the rate of reaction will increase when the concentration of A is doubled, the concentration of B is tripled, and the temperature remains constant.

A) 5 B) 6 C) 12 D) 18 E) None of these.

[C]

[13.5] . It takes 42.0 min for the concentration of a reactant in a first-order reaction to drop from 0.45 M to 0.32 M at 25°C. How long will it take for the reaction to be 90% complete?

A) 13.0 min B) 86.0 min C) 137 min D) 222 min E) 284 min

[E]

[13.6]. Use the following data to determine the rate law for the reaction shown below.

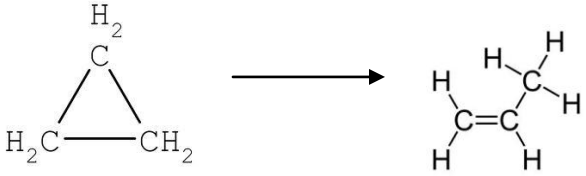
$$2NO + H_2 \rightarrow N_2O + H_2O$$

Expt. #	$[NO]_0$	$[H_2]_0$	Initial rate
1	0.021	0.065	1.46 M/min
2	0.021	0.260	1.46 M/min
3	0.042	0.065	5.84 M/min

A) rate = k $[NO]$
B) rate = k $[NO]^2$
C) rate = k $[NO]$ $[H_2]$
D) rate = k $[NO]^2$ $[H_2]$
E) rate = k $[NO]^4$ $[H_2]^2$

[B]

[13.7]. The isomerization of cyclopropane to form propene is a first-order reaction.



At 760 K, 85% of a sample of cyclopropane changes to propene in 79.0 min. Determine the rate constant for this reaction at 760 K.

A) 3.66×10^{-2} min^{-1}
B) 1.04×10^{-2} min^{-1}
C) 2.42
D) 2.06×10^{-3} min^{-1},
E) 2.40×10^{-2} min^{-1},

[E]

[13.8]. A city's water supply is contaminated with a toxin at a concentration of 0.63 mg/L. Fortunately, this toxin decomposes to a safe mixture of products by first-order kinetics with a rate constant of 0.27 day^{-1}. How long will it take for half of the toxin to decompose?

A) 0.17 days B) 0.27 days C) 0.38 days D) 2.3 days E) 2.6 days

[E]

[13.9]. The isomerization of cyclopropane to form propene is a first-order reaction. At 760 K, 15% of a sample of cyclopropane changes to propene in 6.8 min. What is the half-life (the time required for the half of the initial amount of the reactant to be converted into the product) of cyclopropane at 760 K?

A) 3.4×10^{-2} min B) 2.5 min C) 23 min D) 29 min E) 230 min

[D]

[13.10] . The activation energy for the reaction $CH_3CO \rightarrow CH_3 + CO$ is 71 kJ/mol. How many times greater is the rate constant for this reaction at 170°C than at 150°C?

A) 0.40 B) 1.1 C) 2.5 D) 4.0 E) 5.0

[C]

[13.11]. The isomerization of methyl isocyanide, $CH_3NC \rightarrow CH_3CN$, follows first-order kinetics. The half-lives were found to be 161 min at 199°C and 12.5 min at 230°C. Calculate the activation energy for this reaction.

A) 6.17×10^{-3} kJ/mol
B) 31.4 kJ/mol
C) 78.2
D) 124 kJ/mol
E) 163 kJ/mol

[E]

[13.12] The rate law for the reaction $2NO_2 + O_3 \rightarrow N_2O_5 + O_2$ is rate = $k[NO_2][O_3]$. Which one of the following mechanisms is consistent with this rate law?

A) $NO_2 + NO_2 \rightarrow N_2O_4$ (*fast*)
$N_2O_4 + O_3 \rightarrow N_2O_5 + O_2$ (*slow*)

B) $NO_2 + O_3 \rightarrow NO_5$ (*fast*)
$NO_5 + NO_5 \rightarrow N_2O_5 + {}^5/_2O_2$ (*slow*)

C) $NO_2 + O_3 \rightarrow NO_3 + O_2$ (*slow*)
$NO_3 + NO_2 \rightarrow N_2O_5$ (*fast*)

D) $NO_2 + NO_2 \rightarrow N_2O_2 + O_2$ (*slow*)
$N_2O_2 + O_3 \rightarrow N_2O_5$ (*fast*)

[Ans: C]

[13.13] The activation energy of a certain uncatalyzed reaction is 64 kJ/mol. In the presence of a catalyst, the E_a is 55 kJ/mol. How many times faster is the catalyzed than the uncatalyzed reaction at 400°C? Assume that the frequency factor remains the same.

A) 5.0 times B) 1.16 times C) 15 times D) 2.0 times E) 0.2 times

[Ans: A]

[13.14] What is the rate law that corresponds to the data shown for the reaction $2A + B \rightarrow C$?

Exp.	Initial [A]	Initial [B]	Initial rate
1	0.015	0.022	0.125
2	0.030	0.044	0.500
3	0.060	0.044	0.500
4	0.060	0.066	1.125

Rate = $k[B]^2$.

[13.15] For the reaction whose rate law is rate = k[X], a plot of which of the following is a straight line?

A) [X] versus time
B) ln [X] versus time
C) 1/[X] versus time
D) [X] versus 1/time
E) ln [X] versus 1/time

[B]

[13.16] A reaction is experimentally found to follow the rate law, Rate = $k[A]^2$ where $k = 0.355\ M^{-1}min^{-1}$. Starting with $[A]_o = 1.55$ M, how many seconds will it take for $[A]_t = 0.150$M

A) 6.58 s B) 395 s C) 6.02 s D) 17.0 s E) 1.02×10^3 s

[E]

[13.17] The thermal decomposition of acetaldehyde, $CH_3CHO \rightarrow CH_4 + CO$, is a second-order reaction. The following data were obtained at 518°C.

time, s	Pressure CH_3CHO, mmHg
0	364
42	330
105	290
720	132

Based on the data given, what is the half-life for the disappearance of acetaldehyde?

A) 1.5×10^5 s B) 410 s C) 5.4×10^7 s D) 520 s E) 305 s

[B]

[13.18] Concerning the rate law, Rate = $k[A]_0$, what are appropriate units for the rate constant k?

A) s^{-1} B) $M^{-1}s^{-1}$ C) $M^{-2}\,s^{-1}$ D) M/s E) M^2/s

[D]

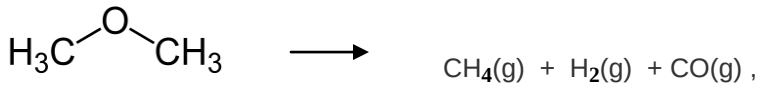
[13.19] At 25°C, the second-order reaction $NOCl(g) \rightarrow NO(g) + {}^1/_2Cl_2(g)$ is 50% complete after 5.82 hours when the initial concentration of NOCl is 4.46 mol/L. How long will it take for the reaction to be 75% complete?

A) 8.22 hr B) 11.6 hr C) 15.5 hr D) 17.5 hr E) 23.0 hr

[D]

[13.20]

The first-order rate constant for the decomposition of dimethyl ether



$CH_4(g) + H_2(g) + CO(g)$,

is $3.2 \times 10^{-4}\ s^{-1}$ at 450 **°C**. The reaction is carried in a constant volume flask. Initially only dimethyl ether is present and the pressure is 0.350 atm. What is the pressure of the system after 8 min. Assume ideal behavior.

[0.45 atm]

[13.21] For the chemical reaction A $\rightarrow$ C, a plot of $1/[A]_t$ versus time was found to give a straight line with a positive slope. What is the order of reaction?

A) zeroth
B) first
C) second
D) Such a plot cannot reveal the order of the reaction.

[C]

[13.22]. The reaction A + 2B $\rightarrow$ products was found to have the rate law, rate = $k[A][B]^2$. Predict by what factor the rate of reaction will increase when the concentration of A is doubled and the concentration of B is also doubled.

A) 2 B) 4 C) 6 D) 8 E) 9

Ans: D

[13.23]. Concerning the rate law, Rate = k[A][B], what are appropriate units for the rate constant k?

A) s^{-1} B) $M^{-1}\,s^{-1}$ C) $M^{-2}\,s^{-1}$ D) M/s E) M^2 / s

Ans: B

[13.24]. Chlorine dioxide reacts in basic water to form chlorite and chlorate according to the following chemical equation:

$$2ClO_2(aq) + 2OH^-(aq) \rightarrow ClO^{2-}(aq) + ClO^{3-}(aq) + H_2O(l)$$

A kinetic study of this reaction under a certain set of conditions yielded the data below.

Exp	$[ClO_2]$ (M)	$[OH^-]$ (M)	$-\Delta[ClO_2]/\Delta t$ (M/s)
1	0.0500	0.100	5.75×10^{-2}
2	0.100	0.100	2.30×10^{-1}
3	0.100	0.0500	1.15×10^{-1}

Which one of the following is the rate law for this reaction?

A) rate = $k[ClO_2]\ [OH^-]$
B) rate = $k[ClO_2]^2\ [OH^-]$
C) rate = $k[ClO_2]\ [OH^-]^2$
D) rate = $k[ClO_2]^2\ [OH^-]^2$
E) rate = $k[ClO_2]^4\ [OH^-]$

Ans: B

[13.25]. At 25°C the rate constant for the first-order decomposition of a pesticide solution is 6.40×10^{-3} min^{-1}. If the starting concentration of pesticide is 0.0314 M, what concentration will remain after 62.0 min at 25°C?

A) 1.14×10^{-1} M
B) 47.4 M
C) –8.72.0 M
D) 2.11×10^{-2} M
E) 2.68×10^{-2} M

Ans: D

[13.25]. The Arrhenius equation is $k = Ae^{-Ea/RT}$. The slope of a plot of ln k vs. 1/T is equal to

A) –k B) k C) E_a D) $-E_a/R$ E) A

Ans: D

[13.26]. The activation energy for the following first-order reaction is 102 kJ/mol.

$N_2O_5(g) \rightarrow 2NO_2(g) + {}^1/_2O_2(g)$

The value of the rate constant (k) is $1.35 \times 10^{-4}\ s^{-1}$ at 35°C.
What is the value of k at 0°C?

A) $8.2 \times 10^{-7}\ s^{-1}$
B) $1.9 \times 10^{-5}\ s^{-1}$
C) $4.2 \times 10^{-5}\ s^{-1}$
D) $2.2 \times 10^{-2}\ s^{-1}$
E) none of these

Ans: A

[13.27]. The following mechanism has been suggested for the reaction:

$$H_2O_2 + 2H^+ + 2I^- \rightarrow I_2 + 2H_2O$$

$H_2O_2 + I^- \rightarrow HOI + OH^-$ *Slow*
$OH^- + H^+ \rightarrow H_2O$ *Fast*
$HOI + H^+ + I^- \rightarrow I_2 + H_2O$ *Fast*

Identify the rate law that is consistent with this mechanism

A) Rate = $k[H_2O_2]\ [I^-]$
B) Rate = $k[HOI]\ [OH^-]$
C) Rate = $k[OH^-]\ [H^+]$
D) Rate = $k[HOI]\ [H^+]\ [I^-]$
E) Rate = $k[H_2O_2]\ [I^-]^2\ [H^+]^2$

Ans: A Category: Medium

[13.28]. The reaction $2A \rightarrow$ *products* is second order with respect to A. If the concentration of A drops from 1.05 M to 0.815 M in a time of 15.0 min, what is the rate constant for this reaction (the same time units may be used)?

Ans: $1.83 \times 10^{-2}\ M^{-1}min^{-1}$

[13.29]. For what order reaction does the half-life get longer as the initial concentration increases?

A) zero order
B) first order
C) second order
D) none of them because half-life is always independent of the initial concentration

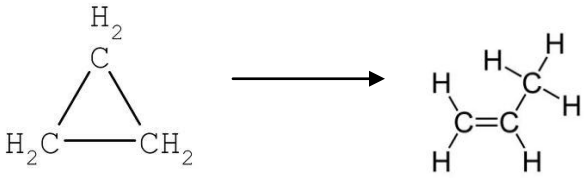
Ans: A

[13.30]. At 30°C, by how much is a reaction's activation energy decreased by the addition of a catalyst if the catalyst triples the reaction rate?

A) 2.77 kJ/mol B) 274 J/mol C) 2.70 J/mol D) 119 J/mol E) 1.20 kJ/mol

Ans: A

[13.31]. At 700 K, the rate constant for the following reaction is 6.2×10^{-4} min^{-1}.



How many minutes are required for 20% of a sample of cyclopropane to isomerize to propene?

A) 1,120 min B) 360 min C) 3710 min D) 1.4×10^{-4} min E) 280 min

Ans: B

[13.32]The isomerization of cyclopropane follows first order kinetics. The rate constant at 700 K is 6.20×10^{-4} min^{-1}, and the half-life at 760 K is 29.0 min.

Calculate the activation energy for this reaction.

A) 5.07 kJ/mol
B) 27.0 kJ/mol
C) 50.7 kJ/mol
D) 60. kJ/mol
E) 270. kJ/mol

Ans: E

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Chapter 14: Chemical Equilibrium

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[14.1] . A reaction with an equilibrium constant $K_c = 1.5 \times 10^{21}$ would consist of which of the following at equilibrium:

A) approximately equal reactants and products
B) some reactants and products with reactants slightly favored
C) some reactants and products with products slightly favored
D) essentially all reactants
E) essentially all products

Ans: E

[14.2]. The solubility of silver chloride can be increased by dissolving it in a solution containing ammonia.

$$AgCl\,(s) \rightleftharpoons Ag^+\,(aq) + Cl^-\,(aq) \qquad K_1 = 1.6 \times 10^{-10}$$

$$Ag^+\,(aq) + 2NH_3\,(aq) \rightleftharpoons Ag(NH_3)_2^+\,(aq) \qquad K_2 = 1.5 \times 10^{7}$$

What is the value of the equilibrium constant for the overall reaction?

$$AgCl\,(s) + 2NH_3\,(aq) \rightleftharpoons Ag(NH_3)_2^+\,(aq) + Cl^-\,(aq) \qquad K_{net} = ?$$

A) 1.5×10^{7} B) 2.4×10^{-3} C) 3.1×10^{-3} D) 2.3×10^{14} E) 2.4×10^{7}

Ans: B

[14.3]. 2.50 mol NOCl was placed in a 2.50 L reaction vessel at 400ºC. After equilibrium was established, it was found that 28% of the NOCl had dissociated according to the equation

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g).$$

Calculate the equilibrium constant, K_c, for the reaction.

A) 0.021 B) 0.039 C) 0.169 D) 26 E) 47

Ans: A

[14.4].

Equilibrium is established for the reaction $2X(s) + Y(g) \rightleftharpoons 2Z(g)$ at 500K, $K_c = 100$. Determine the concentration of Z in equilibrium with 0.2 mol X and 0.50 M Y at 500K.

A) 3.2 M B) 3.5 M C) 4.5 M D) 7.1 M E) None of these.

Ans: D

[14.5]. At 400ºC, $K_c = 64$ for the equilibrium $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$. If 3.00 mol H_2 and 3.00 mol I_2 are introduced into an empty 4.0 L vessel, find the equilibrium concentration of HI at 400ºC.

A) 0.15 M B) 1.2 M C) 2.4 M D) 4.8 M E) 5.8 M

Ans: B

[14.6]. For the following reaction at equilibrium in a reaction vessel, which change will cause the Br_2 concentration to *decrease*?

$$2NOBr(g) \rightleftharpoons 2NO(g) + Br_2(g), \Delta H^o_{rxn} = 30 \text{ kJ/mol}$$

A) Increase the temperature.
B) Remove some NO.
C) Add more NOBr.
D) Compress the gas mixture into a smaller volume.
E) Add a catalyst

Ans: D

[14.7]. Consider the following equilibrium,

$$4NH_3(g) + 3O_2(g) \rightleftharpoons 2N_2(g) + 6H_2O(g) + 1531\ kJ$$

State whether the concentrations of the reactants would *increase*, *decrease*, or *remain constant* when the temperature is increased.

Ans: increase

[14.8]. 4.21 moles of S_2Cl_4 are introduced into a 2.0 L vessel.

$$S_2Cl_4(g) \rightleftharpoons 2SCl_2(g)$$

At equilibrium, 1.25 moles of S_2Cl_4 are found to remain in the container. Calculate K_c for this reaction.

Ans: $K_c = 14.0$

[14.9]. The equilibrium constant expression for the reaction $2BrF_5(g) \rightleftharpoons Br_2(g) + 5F_2(g)$ is

A) $K_c = [Br_2]\,[F_2]\,/\,[BrF_5]$
B) $K_c = [Br_2]\,[F_2]^5\,/\,[BrF_5]^2$
C) $K_c = [Br_2]\,[F_2]^2\,/\,[BrF_5]^5$
D) $K_c = [BrF_5]^2\,/\,[Br_2][F_2]^5$
E) $K_c = 2[BrF_5]^2\,/\,([Br_2] \times 5[F_2]^5)$

Ans: B

[14.10] Carbon tetrachloride reacts at high temperatures with oxygen to produce two toxic gases, phosgene and chlorine.

$$CCl_4(g) + {}^1/_2O_2(g) \rightleftharpoons COCl_2(g) + Cl_2(g), \qquad K_c = 4.4 \times 10^9 \text{ at } 1{,}000\ K$$

Calculate K_c for the reaction $2CCl_4(g) + O_2(g) \rightleftharpoons 2COCl_2(g) + 2Cl_2(g)$.

A) 4.4×10^9 B) 8.8×10^9 C) 1.9×10^{10} D) 1.9×10^{19} E) 2.3×10^{-10}

Ans: D

[14.11] 1.25 moles of NOCl were placed in a 2.50 L reaction chamber at 427ºC. After equilibrium was reached, 1.10 moles of NOCl remained. Calculate the equilibrium constant, K_c, for the reaction

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g).$$

A) 3.0×10^{-4} B) 1.8×10^{3} C) 1.4×10^{-3} D) 5.6×10^{-4} E) 4.1×10^{-3}

Ans: D

[14.12] At 250ºC, the equilibrium constant K_p for the reaction $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ is 1.80. Sufficient PCl_5 is put into a reaction vessel to give an initial pressure of 2.74 atm at 250ºC. Calculate the pressure of PCl_5 after the system has reached equilibrium.

A) 1.50 atm B) 1.24 atm C) 4.24 atm D) 0.94 atm E) 1.12 atm

Ans: B

[14.13] For the reaction at equilibrium $2SO_3 \rightleftharpoons 2SO_2 + O_2$ (ΔH^o_{rxn}= 198 kJ/mol), increasing the reaction temperature would:

A) Shift the equilibrium to the right and increase the value of the equilibrium constant K
B) Shift the equilibrium to the left and increase the value of the equilibrium constant K
C) Shift the equilibrium to the right and decrease the value of the equilibrium constant K
D) Shift the equilibrium to the left and decrease the value of the equilibrium constant K
E) No change

Ans: A

[14.14] 4.21 moles of S_2Cl_4 are introduced into a 2.0 L vessel.

$$S_2Cl_4(g) \rightleftharpoons 2SCl_2(g)$$

At equilibrium, 1.25 moles of S_2Cl_4 are found to remain in the container. Calculate K_c for this reaction.

Ans: K_c = 14.0

[14.15] 75.0 g of $PCl_5(g)$ is introduced into an evacuated 3.00 L vessel and allowed to reach equilibrium at 250ºC.

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

If $K_p = 1.80$ for this reaction, what is the total pressure inside the vessel at equilibrium?

A) 2.88 atm B) 2.27 atm C) 4.54 atm D) 7.42 atm E) 9.69 atm

Ans: D

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Chapter 15: Acids and Bases

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[15.1]. In the reaction: $CH_3COOH(aq) + NH_2^-(aq) \rightleftharpoons CH_3COO^-(aq) + NH_3(aq)$, the conjugate acid-base pairs are:

A) *pair 1*: CH_3COOH and CH_3COO^- ; *pair 2*: NH_2^- and NH_3
B) *pair 1*: CH_3COOH and NH_3; *pair 2*: NH_2^- and CH_3COO^-
C) *pair 1*: CH_3COOH and NH_2^- ; *pair 2*: NH_3 and CH_3OO^-
D) *pair 1*: CH_3COOH and CH_3COO^- ; *pair 2*: NH_4^+ and NH_3
E) *pair 1*: CH_3COOH and CH_3COO^- ; *pair 2*: NH_2^- and NH_3^+

Ans: A

[15.2]. Identify the conjugate acid of SO_4^{2-}

A) H_2SO_4 B) HSO_4^-
C) H_2SO_3 D) H_3O^+ E) SO_3^{2-}

Ans: B

[15.3]. The OH^- concentration in a 2.5×10^{-3} M $Ba(OH)_2$ solution is

A) 4.0×10^{-12} M.
B) 2.5×10^{-3} M.
C) 5.0×10^{-3} M.
D) 1.2×10^{-2} M.
E) 0.025 M.

Ans: C

[15.4] Which of the following solutions is acidic?

A) $[OH^-] = 1.0 \times 10^{-7}$ M
B) $[OH^-] > 1.0 \times 10^{-7}$ M
C) $[OH^-] = 1.0 \times 10^{-10}$ M
D) $[H_3O^+] = 1.0 \times 10^{-10}$ M
E) $[H_3O^+] < 1.0 \times 10^{-7}$ M

Ans: C

[15.5]. Calculate the pH of a 0.14 M HNO_2 solution that is 5.7% ionized.

A) 0.85 B) 1.70 C) 2.10 D) 11.90 E) 13.10

Ans: C

[15.6]. Calculate the hydrogen ion concentration in a solution having a pH of 4.60.

A) 4.0×10^{-3} M
B) 4.0×10^{-9} M
C) 4.0×10^{-10} M
D) 2.5×10^{-5} M
E) 2.5×10^{-4} M

Ans: D

[15.7]. A 5.2 L sample of a 1.1 M KOH solution is mixed with 2.3 L of a 0.20 M $Sc(OH)_3$ solution. What is the pH of the mixture?

A) 13.67 B) 13.89 C) 14.11 D) 14.23 E) 13.98

Ans: E

[15.8]. Arrange the acids HBr, H_2Se, and H_3As in order of increasing acid strength.

A) HBr < H_2Se < H_3As
B) HBr < H_3As < H_2Se
C) H_2Se < H_3As < HBr
D) H_3As < H_2Se < HBr
E) H_3As < HBr < H_2Se

Ans: D

[15.9]. Which one of these net ionic equations represents the reaction of a *strong acid* with a *weak base*?

A) $H^+(aq) + OH^-(aq) \rightarrow H_2O(aq)$
B) $H^+(aq) + CH_3NH_2(aq) \rightarrow CH_3NH_3^+(aq)$
C) $OH^-(aq) + HCN(aq) \rightarrow H_2O(aq) + CN^-(aq)$
D) $HCN(aq) + CH_3NH_2(aq) \rightarrow CH_3NH_3^+(aq) + CN^-(aq)$

Ans: B

[15.10]. The pH of a 0.14 M solution of an unknown monoprotic acid is 5.85. Calculate the K_a of the acid.

A) 1.4×10^{-6} B) 1.4×10^{-11} C) 1.0×10^{-5} D) 7.1×10^{-9} E) 2.0×10^{-7}

Ans: B

[15.11]. The hydrolysis of NH_4F will result in which of the following types of solutions given:

($K_a(NH_4^+) = 5.6 \times 10^{-10}$, $K_b(F^-) = 1.4 \times 10^{-11}$)

A) acidic, pH < 7 B) basic, pH > 7 C) neutral, pH = 7

Ans: A

[15.12] . The equilibrium constant for the reaction

$$C_6H_5COOH(aq) + CH_3COO^-(aq) \rightleftharpoons C_6H_5COO^-(aq) + CH_3COOH(aq)$$

is 3.6 at 25°C. If K_a for CH_3COOH is 1.8×10^{-5}, what is the acid dissociation constant for C_6H_5COOH?

A) 5.0×10^{-6} B) 6.5×10^{-5} C) 2.3×10^{-4} D) 8.3×10^{-5} E) 5.6×10^{-6}

Ans: B

[15.13]. What mass of sodium formate (HCOONa) must be added to 350. mL of water in order to obtain a solution having a pH of 8.50? [$K_a(HCOOH) = 1.77 \times 10^{-4}$]

A) 0.23 g B) 4.3 g C) 35 g D) 12 g E) 130 g

Ans: B

[15.14]. Write the formula for the conjugate acid of HPO_4^{2-}

Ans: $H_2PO_4^-$

[15.15] The oxides CO_2 and SO_3 will form the following acids in water, respectively.

A) $H_2CO_3(aq)$ and $H_2SO_3(aq)$
B) $H_2CO_3(aq)$ and $H_2SO_4(aq)$
C) $H_2CO_2(aq)$ and $H_2SO_3(aq)$
D) $H_2CO_2(aq)$ and $H_2SO_4(aq)$
E) $HCOO^-(aq)$ and $H_2SO_3(aq)$

Ans: B

[15.16] Which of the following is both a Lewis Acid and Brønsted Acid?

A) BF_3 B) NH_3 C) CO_2 D) HNO_2 E) PCl_3

Ans: D

[15.17]. Consider the two gaseous equilibria:

$$SO_2(g) + {}^1/_2O_2(g) \rightleftharpoons SO_3(g) \qquad K_1$$

$$2SO_3(g) \rightleftharpoons SO_2(g) + O_2(g) \qquad K_2$$

The values of the equilibrium constants K_1 and K_2 are related by

A) $K_2 = K_1^2$ B) $K_2^2 = K_1$ C) $K_2 = 1/K_1^2$ D) $K_2 = 1/K_1$ E) none of these.

Ans: C

[15.18]. When the following reaction is at equilibrium, which of these relationships is *always* true?

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

A) $[NO]\,[Cl_2] = [NOCl]$
B) $[NO]_2\,[Cl_2] = [NOCl]^2$
C) $[NOCl] = [NO]$
D) $2[NO] = [Cl_2]$
E) $[NO]^2\,[Cl_2] = K_c\,[NOCl]^2$

Ans: E

[15.19].

The brown gas NO_2 and the colorless gas N_2O_4 exist in equilibrium, $2NO_2 \rightleftharpoons N_2O_4$.

In an experiment, 0.625 mole of N_2O_4 was introduced into a 5.00 L vessel and was allowed to decompose until equilibrium was reached. The concentration of N_2O_4 at equilibrium was 0.0750 M. Calculate K_c for the reaction.

A) 7.5 B) 0.125 C) 0.0750 D) 0.10 E) 0.050

Ans: A

[15.20].

Consider the reaction $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$, for which $K_c = 0.10$ at 2,000ºC. Starting with initial concentrations of 0.040 M of N_2 and 0.040 M of O_2, determine the equilibrium concentration of NO.

A) 5.4×10^{-3} M B) 0.0096 M C) 0.013 M D) 0.080 M E) 0.10 M

Ans: C

[15.21] Concerning the following reaction at equilibrium:

$3Fe(s) + 4H_2O(g) \rightleftharpoons Fe_3O_4(s) + 4H_2(g)$, increasing the concentration of the Fe(s) would:

A) Shift the equilibrium to the right
B) Shift the equilibrium to the left
C) Increase the value of the equilibrium constant, K
D) Decrease the value of the equilibrium constant, K
E) No change

Ans: E

[15.22]. The data below refer to the following reaction:

$2NO(g) + Br_2(g) \rightleftharpoons 2NOBr(g)$

Concentration (M)	[NO]	[Br_2]	[NOBr]
Initial	2.5	5.0	1.0
Equilibrium	2.0	____	____

Find the concentration of NOBr when the system reaches equilibrium.

Ans: 1.5 M

[15.23] If the reaction $2H_2S(g) \rightleftharpoons 2H_2(g) + S_2(g)$ is carried out at 1065°C, $K_p = 0.0120$. Starting from pure H_2S introduced into an evacuated vessel at 1065°C, what will the total pressure in the vessel be at equilibrium if the equilibrated mixture contains 0.300 atm of $H_2(g)$?

A) 1.06 atm B) 1.36 atm C) 2.39 atm D) 4.20 atm E) 1.51 atm

Ans: E

[15.24].

In the reaction: $2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$ the conjugate acid-base pairs are

A) *pair 1*: H_2O and H_2O; *pair 2*: H_3O^+ and OH^-
B) *pair 1*: H_3O^+ and OH^-; *pair 2*: H_3O^+ and H_2O
C) *pair 1*: H_3O^+ and OH^-; *pair 2*: OH^- and H_2O
D) *pair 1*: H_2O and OH^-; *pair 2*: H_2O and H_3O^+
E) *pair 1*: H_3O^+ and HO^-: *pair 2*: OH^- and H_3O^+

Ans: D

[15.25]. What is the H^+ ion concentration in a 4.8×10^{-2} M KOH solution?

A) 4.8×10^{-2} M D) 4.8×10^{-12} M
B) 1.0×10^{-7} M E) 2.1×10^{-13} M
C) 4.8×10^{-11}M

Ans: E

[15.26]. A 0.10 M HF solution is 8.4% ionized. Calculate the H^+ ion concentration.

A) 0.84 M B) 0.12 M C) 0.10 M D) 0.084 M E) 8.4×10^{-3} M

Ans: E

[15.27]. A 5.5 L sample of a 0.25 M HNO_3 solution is mixed with 1.2 L of a 0.34 M HCl solution. What is the pH of the mixture?

A) 0.23 B) 0.57 C) 1.07 D) 0.50 E) 0.84

Ans: B

[15.28]. Arrange the acids H_2Se, H_2Te, and H_2S in order of increasing acid strength.

A) $H_2S < H_2Se < H_2Te$
B) $H_2S < H_2Te < H_2Se$
C) $H_2Te < H_2S < H_2Se$
D) $H_2Se < H_2S < H_2Te$
E) $H_2Se < H_2Te < H_2S$

Ans: A

[15.29]. When comparing acid strength of binary acids HX, as X varies within a particular group of the periodic table, which *one* of these factors dominates in affecting the acid strength?

A) bond strength
B) electron withdrawing effects
C) percent ionic character of the H–X bond
D) solubility
E) Le Châtelier's principle

Ans: A

[15.30]. Predict the direction in which the equilibrium will lie for the reaction

$$H_2CO_3 + F^- \rightleftharpoons HCO_3^- + HF.$$

$$K_{a1}(H_2CO_3) = 4.2 \times 10^{-7} \; ; \; K_a(HF) = 7.1 \times 10^{-4}$$

A) to the right B) to the left C) in the middle

Ans: B

[15.31]. Calculate the pH of a 0.055 M solution of CH_3COONa ($K_a(CH_3COOH) = 1.8 \times 10^{-5}$)

A) 12.74 B) 4.74 C) 8.74 D) 9.26 E) 5.26

Ans: C

[15.32] The equilibrium constant for the reaction

$$C_7H_{15}COOH(aq) + HCOO^-(aq) \rightleftharpoons C_7H_{15}COO^-(aq) + HCOOH(aq)$$

is 7.23×10^{-2} at 25°C. If K_a for formic acid (HCOOH) is 1.77×10^{-4}, what is the acid dissociation constant for $C_7H_{15}COOH$?

A) 2.45×10^{-3}
B) 4.08×10^{-2}
C) 7.81×10^{-4}
D) 1.00×10^{-4}
E) 1.28×10^{-5}

Ans: E

[15.33] Which of these species will act as a Lewis acid?

A) NH_3 B) NH_4^+ C) H_2O D) BF_3 E) F^-

Ans: D

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Chapter 16: Acid-Base Equilibria and Solubility Equilibria

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A table of ionization constants and K_a's is required to work some of the problems in this chapter

[16.1]. Which of the following yields a buffer solution when equal volumes of the two solutions are mixed?

A) 0.050 M H_3PO_4 and 0.050M HCl
B) 0.050M H_3PO_4 and 0.025 M HCl
C) 0.050M NaH_2PO_4 and 0.025M NaOH
D) 0.050M Na_3PO_4 and 0.050M M NaOH
E) 0.050M Na_3PO_4 and 0.025M NaOH

Ans: C

[16.2] Which of the following is the most acidic solution?

A) 0.10 M CH_3COOH and 0.10 M CH_3COONa
B) 0.10 M CH_3COOH
C) 0.10 M HNO_2
D) 0.10 M HNO_2 and 0.10 M $NaNO_2$
E) 0.10 M CH_3COONa

Ans: C

[16.3] You have 500.0 mL of a buffer solution containing 0.30 M acetic acid (CH_3COOH) and 0.20 M sodium acetate (CH_3COONa). What will the pH of this solution be after the addition of 20.0 mL of 1.00 M NaOH solution? [$K_a = 1.8 \times 10^{-5}$]

A) 4.65 B) 4.71 C) 4.56 D) 4.84 E) 5.07

Ans: B

[16.4] 50.00 mL of 0.10 M HNO_2 (nitrous acid, $K_a = 4.5 \times 10^{-4}$) is titrated with a 0.10 M KOH solution. After 25.00 mL of the KOH solution is added, the pH in the titration flask will be

A) 2.17 B) 3.35 C) 2.41 D) 1.48 E) 7.00

Ans: B

[16.5] The molar solubility of manganese(II) carbonate is 4.2×10^{-6} M. What is K_{sp} for this compound?

A) 4.2×10^{-6} B) 8.4×10^{-6} C) 3.0×10^{-16} D) 1.8×10^{-11} E) 2.0×10^{-3}

Ans: D

[16.6] A saturated sodium carbonate solution at 100°C contains 45.5 g of dissolved sodium carbonate per 100. mL of solution. The solubility product constant for sodium carbonate at this temperature is

A) 79.0 B) 0.316 C) 0.0790 D) 36.8 E) 316

Ans: E

[16.7] Solid sodium iodide is slowly added to a solution that is 0.0050 M Pb^{2+} and 0.0050 M Ag^+. [K_{sp} (PbI_2) = 1.4×10^{-8}; K_{sp} (AgI) = 8.3×10^{-17}] Calculate the Ag^+ concentration when PbI_2 just begins to precipitate.

Ans: 5.0×10^{-14} M

[16.8] NaCl is added slowly to a solution that is 0.010 M each in Cu^+, Ag^+, and Au^+. The K_{sp}'s for CuCl, AgCl, and AuCl are 1.9×10^{-7}, 1.8×10^{-10}, and 2.0×10^{-13}, respectively.

Which compound will precipitate first?

Ans: AuCl

[16.9] The percent ionization of a weak acid HA is greater in a solution containing the salt NaA than it is in a solution of the weak acid only.

Ans: False

[16.10] What mass of ammonium nitrate must be added to 350. mL of a 0.150 M solution of ammonia to give a buffer having a pH of 9.00? ($K_b(NH_3) = 1.8 \times 10^{-5}$)

A) 7.6 g B) 2.4 g C) 5.4 g D) 11 g E) 3.3 g

Ans: A

[16.11] . In which one of the following solutions will acetic acid have the greatest percent ionization?

A) 0.1 M CH_3COOH
B) 0.1 M CH_3COOH dissolved in 1.0 M HCl
C) 0.1 M CH_3COOH plus 0.1 M CH_3COONa
D) 0.1 M CH_3COOH plus 0.2 M CH_3COONa

Ans: A

[16.12]. Which of the following yields a buffer solution when equal volumes of the two solutions are mixed?

A) 0.10M HCl and 0.10 M NaCl
B) 0.15 M HNO_3 and 0.15 M $NaNO_3$
C) 0.10M HF and 0.10M NaF
D) 0.10M $HClO_4$ and 0.10 $NaClO_4$
E) 0.15M HBr and 0.15M NaBr

Ans: C

[16.13]. Calculate the pH of a buffer solution that contains 0.25 M benzoic acid ($C_6H_5CO_2H$) and 0.15M sodium benzoate (C_6H_5COONa). [$K_a = 6.5 \times 10^{-5}$ for benzoic acid]

A) 3.97 B) 4.83 C) 4.19 D) 3.40 E) 4.41

Ans: A

[16.14]. You are asked to go into the lab and prepare an acetic acid - sodium acetate buffer solution with a pH of 4.00 ± 0.02. What molar ratio of CH_3COOH to CH_3COONa should be used?

A) 0.18 B) 0.84 C) 1.19 D) 5.50 E) 0.10

Ans: D

[16.15]. Calculate the pH of a solution that is 0.410 M in HOCl and 0.050 M in NaOCl.

[$K_a(HOCl) = 3.2 \times 10^{-8}$]

A) 0.39 B) 3.94 C) 6.58 D) 7.49 E) 8.40

Ans: C

[16.16]. For which type of titration will the pH be basic at the equivalence point?

A) Strong acid vs. strong base.
B) Strong acid vs. weak base.
C) Weak acid vs. strong base.
D) All of the above.
E) None of the above.

Ans: C

[16.17]. 24.00 mL of a 0.25 M NaOH solution is titrated with 0.10M HCl. What is the pH of the solution after 24.00 mL of the HCl has been added?

A) 13.40 B) 13.17 C) 11.56 D) 12.88 E) 7.00

Ans: D

[16.18]. The solubility product for calcium phosphate is $K_{sp} = 1.3 \times 10^{-26}$. What is the molar solubility of calcium phosphate?

$$Ca_3(PO_4)_2 \rightleftharpoons 3Ca^{2+}(aq) + 2PO_4^{3-}(aq)$$

A) 1.3×10^{-26} M
B) 1.5×10^{-7} M
C) 2.6×10^{-6} M
D) 4.6×10^{-6} M
E) 6.6×10^{-6} M

Ans: C

[16.19]. A saturated sodium carbonate **(Na_2CO_3)** solution at 0°C contains 7.1 g of dissolved sodium carbonate per 100. mL of solution. The solubility product constant for sodium carbonate at this temperature is

A) 1.2 B) 0.30 C) 3.0×10^{-4} D) 0.90 E) 1.2×10^{-3}

Ans: A

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Chapter 17: Entropy, Free Energy, and Equilibrium

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[17.1] Which of these species would you expect to have the lowest standard entropy (S°)?

A) $Br_2(l)$ B) $Cl_2(g)$ C) $F_2(g)$ D) $H_2(g)$ E) $I_2(s)$

Ans: E

[17.2] Arrange the following substances in the order of increasing entropy at 25°C.
HF(g), NaF(s), $SiF_4(g)$, $SiH_4(g)$, Al(s)

lowest → highest

A) $SiF_4(g) < SiH_4(g) < NaF(s) < HF(g) < Al(s)$
B) $HF(g) < Al(s) < NaF(s) < SiF_4(g) < SiH_4(g)$
C) $Al(s) < NaF(s) < HF(g) < SiH_4(g) < SiF_4(g)$
D) $Al(s) < HF(g) < NaF(s) < SiF_4(g) < SiH_4(g)$
E) $NaF(s) < Al(s) < HF(g) < SiF_4(g) < SiH_4(g)$

Ans: C

[17.3] Which one of the following reactions would you expect to have highest $\Delta S°$?

A) $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$
B) $C_2H_2(g) + {}^5/_2O_2(g) \rightarrow 2CO_2(g) + H_2O(g)$
C) $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$
D) $C_2H_6(g) + {}^7/_2O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$

Ans: D

[17.4] Sulfur can be separated from lead in the mineral galena, PbS(*s*), by "roasting" the ore in the presence of oxygen as shown in the following reaction:

$$2PbS(s) + 3O_2(g) \rightarrow 2PbO(s) + 2SO_2(g)$$

Calculate $\Delta S°$ for this reaction using the thermodynamic data provided below.

Compound	S°(J/K·mol)
PbS(*s*)	91.2
$O_2(g)$	205.0
PbO(*s*)	69.45
$SO_2(g)$	248.5

A) –410 J/K·mol
B) –161.5 J/K·mol
C) –47.7 J/K·mol
D) 21.8 J/K·mol
E) 43.5 J/K·mol

Ans: B

[17.5] With respect to the system only, a reaction with $\Delta H > 0$ and $\Delta S < 0$ is predicted to be:

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

Ans: D

[17.6] At 1500°C the equilibrium constant for the reaction $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$ has the value $K_p = 1.4 \times 10^{-7}$. Calculate $\Delta G°$ for this reaction at 1500°C.

A) 105 kJ/mol
B) 1.07 kJ/mol
C) –233 kJ/mol
D) –105 kJ/mol
E) 233 kJ/mol

Ans: E

[17.7] Calculate K_p at 298 K for the reaction $SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g)$.

	$\Delta G°_f$
$SO_2(g)$	–300.4 kJ/mol
$SO_3(g)$	–370.4 kJ/mol
$NO(g)$	86.7 kJ/mol
$NO_2(g)$	51.8 kJ/mol

A) 6.99×10^{-7} B) 5.71×10^{-8} C) 14.2 D) 475 E) 1.42×10^{6}

Ans: E

[17.8] For the reaction $SbCl_5(g) \rightleftharpoons SbCl_3(g) + Cl_2(g)$,

$\Delta G°_f(SbCl_5) = –334.34$ kJ/mol
$\Delta G°_f(SbCl_3) = –301.25$ kJ/mol
$\Delta H°_f(SbCl_5) = –394.34$ kJ/mol
$\Delta H°_f(SbCl_3) = –313.80$ kJ/mol

Will this reaction proceed spontaneously at 298 K and 1 atm pressure?

Ans: No

[17.9] Consider the reaction $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(l)$ at 25°C.

$\Delta G°_f(CO) = –137.3$ kJ/mol
$\Delta G°_f(CH_3OH) = –166.3$ kJ/mol
$\Delta H°_f(CO) = –110.5$ kJ/mol
$\Delta H°_f(CH_3OH) = –238.7$ kJ/mol
$S°(CO) = 197.9$ J/K·mol
$S°(CH_3OH) = 126.8$ J/K·mol

Calculate value of the equilibrium constant (K_p) for this reaction at 25°C.

Ans: 1.21×10^{5}

[17.10] Given the following data, calculate the boiling point of HCOOH (formic acid).

	$\Delta H°_f$ (kJ/mol)	S° (J/K·mol)
HCOOH(l)	–410	130
HCOOH(g)	–363	251

Ans: 115°C

[17.11] Using the thermodynamic data provided below, calculate K_a for HCN(*aq*) at 25°.

	$\Delta H°_f$ (kJ/mol)	S° (J/K·mol)
H^+ (*aq*)	0	0
CN^- (*aq*)	151.0	117.99
HCN(*aq*)	105.4	128.9

Ans: 2.8×10^{-9} (compared to the experimental value of 4.9×10^{-10})

[17.12]. Which of these species has the highest entropy (S°) at 25°C?

A) CO(g) B) CH_4(g) C) NaCl(s) D) H_2O(l) E) Fe(s)

Ans: B

[17.13]. Aluminum forms a layer of aluminum oxide when exposed to air which protects the bulk metal from further corrosion.

$$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$$

Using the thermodynamic data provided below, calculate $\Delta S°$ for this reaction.

	S°(J/K·mol)
Al(*s*)	28.3
$O_2(g)$	205.0
$Al_2O_3(s)$	50.99

A) 182.3 J/K·mol
B) 131.5 J/K·mol
C) –182.3 J/K·mol
D) –626.2 J/K·mol
E) –802.9 J/K·mol

Ans: D

[17.14]. Nitrosyl chloride (NOCl) decomposes at elevated temperatures according to the equation

$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$. Calculate K_p for this reaction at 227°C.

($\Delta H° = 81.2$kJ/mol, $\Delta S° = 128$ J/K·mol)

A) 1.59×10^{-2} B) 2.10×10^{-7} C) 62.8 D) 4.90×10^{6} E) 3.20×10^{9}

Ans: A

[17.15] In the gas phase, methyl isocyanate (CH_3NC) isomerizes to acetonitrile (CH_3CN),

$H_3C–N{\equiv}C\ (g) \rightleftharpoons H_3C–C{\equiv}N\ (g)$

with $\Delta H° = –89.5$ kJ/mol and $\Delta G° = –73.8$ kJ/mol at 25°C. Find the equilibrium constant for this reaction at 100°C.

A) 1.68×10^{-10}
B) 5.96×10^{9}
C) 2.16×10^{10}
D) 4.63×10^{-11}
E) 8.64×10^{12}

Ans: B

[17.16] Assuming $\Delta S°$ and $\Delta H°$ do not vary with temperature, at what temperature will the reaction shown below become spontaneous?

$$C(s) + H_2O(g) \rightarrow H_2(g) + CO(s) \quad (\Delta S° = 133.6 \text{ J/K·mol}; \Delta H° = 131.3 \text{ kJ/mol})$$

Ans: 710°C

[17.17].
At 700 K, the equilibrium constant for the reaction $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$ is 5.10. What is $\Delta G°$ for this reaction at this temperature?

Ans: –9.48 kJ/mol

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Chapter 18: Electrochemistry

NOTE: A table of standard reduction potentials is required to work many of these problems.
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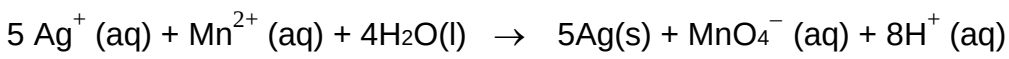
[18.1] What is the total number of moles (*n*) of electrons exchanged between the oxidizing agent and the reducing agent in the overall redox equation:



$$5\,Ag^{+}(aq) + Mn^{2+}(aq) + 4H_2O(l) \rightarrow 5Ag(s) + MnO_4^{-}(aq) + 8H^{+}(aq)$$

A) 1 B) 2 C) 3 D) 5 E) 7

Ans: D

[18.2] Complete and balance the following redox equation. What is the coefficient of H_2O when the equation is balanced with the set of smallest whole-number coefficients?

$$H_2O + MnO_4^{-} + I^{-} \rightarrow MnO_2 + IO_3^{-} \text{ (basic solution)}$$

A) 1 B) 2 C) 4 D) 10 E) None of these.

Ans: A

[18.3] Given the following cell diagram,

$$Al(s) \mid Al^{3+}(aq) \parallel Cd^{2+}(aq) \mid Cd(s)$$

what is the balanced overall (net) cell reaction?

A) $Al(s) + Cd^{2+}(aq) \rightarrow Al^{3+}(aq) + Cd(s)$
B) $Al^{3+}(aq) + Cd(s) \rightarrow Al(s) + Cd^{2+}(aq)$
C) $2Al(s) + 3Cd^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Cd(s)$
D) $2Al^{3+}(aq) + 3Cd(s) \rightarrow 2Al(s) + 3Cd^{2+}(aq)$
E) $3Al^{3+}(aq) + 2Cd(s) \rightarrow 3Al(s) + 2Cd^{2+}(aq)$

Ans: C

[18.4] A galvanic cell has the overall reaction:

$$2Fe(NO_3)_2(aq) + Pb(NO_3)_2(aq) \rightarrow 2Fe(NO_3)_3(aq) + Pb(s)$$

Which is the half reaction occurring at the cathode?

A) $NO^{3-}(aq) + 4H^{+}(aq) + 3e^{-} \rightarrow NO(g) + 2H_2O(l)$
B) $NO^{3-}(aq) + 2H^{+}(aq) + e^{-} \rightarrow NO_2(g) + H_2O(l)$
C) $Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^{-}$
D) $Pb^{2+}(aq) + 2e^{-} \rightarrow Pb(s)$
E) $Fe^{2+}(aq) + e^{-} \rightarrow Fe^{3+}(aq)$

Ans: D

[18.5] Calculate $E°_{cell}$ for a silver-aluminum cell in which the cell reaction is

$$Al(s) + 3Ag^{+}(aq) \rightarrow Al^{3+}(aq) + 3Ag(s)$$

A) –2.46 V B) 0.86 V C) –0.86 V D) 2.46 V E) none of these

Ans: D

[18.6] Consider the following electrochemical cell:

$$U \mid U^{3+}(aq) \parallel Cl^{-}(aq), Cl_2(g) \mid Pt$$

If the standard cell emf is 3.16 V, what is the standard reduction potential for uranium?

A) –3.16 V B) +3.16 V C) –1.80 V D) +1.80 V E) +1.36 V

Ans: C

[18.7] Consider the following standard reduction potentials in acid solution:

	E°(V)
$Al^{3+} + 3e^- \rightarrow Al(s)$	–1.66
$AgBr(s) + e^- \rightarrow Ag(s) + Br^-$	+0.07
$Sn^{4+} + 2e^- \rightarrow Sn^{2+}$	+0.14
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	+0.77

The strongest oxidizing agent among those shown above is

A) Fe^{3+}. B) Fe^{2+}. C) Br^-. D) Al^{3+}. E) Al.

Ans: A

[18.8] For the electrochemical cell Pt(s) | H_2(1 atm) | H^+ (1 M) || Cu^{2+} (1 M) | Cu(s), which one of the following changes will cause an *increase* in the cell voltage?

A) Lower the H_2(g) pressure.
B) Increase the size/mass of the copper electrode.
C) Lower the H^+ (aq) concentration.
D) Decrease the concentration of Cu^{2+} ion.
E) None of the above.

Ans: C

[18.9] Consider an electrochemical cell involving the overall reaction

$$2AgBr(s) + Pb(s) \rightarrow Pb^{2+} + 2Ag(s) + 2Br^-$$

Each half-reaction is carried out in a separate compartment. The anion included in the lead half-cell is NO_3^-. The cation in the silver half-cell is K^+. The two half-cells are connected by a KNO_3 salt bridge. If [Pb^{2+}] = 1.0 M, what concentration of Br^- ion will produce a cell emf of 0.25 V at 298 K?

Given: $AgBr(s) + e^- \rightarrow Ag + Br^-$, E° = +0.07 V.

A) 0.02 M B) 0.14 M C) 0.38 M D) 1.0 M E) 7.0 M

Ans: B

[18.10] How many coulombs (C) of electrical charge must pass through an electrolytic cell to reduce 0.44 mol Ca^{2+} ion to calcium metal?

A) 190,000 C B) 85,000 C C) 21,000 C D) 42,500 C E) 0.88 C

Ans: B

[18.11] How long will it take to produce 78 g of Al metal by the reduction of Al^{3+} in an electrolytic cell with a current of 2.0 A?

A) 0.01 s B) 420 s C) 13 h D) 116 h E) 1.0×10^{12} s

Ans: D

[18.12] Which element is associated with the term "galvanized"?

A) Ga B) Zn C) Cd D) Hg E) Pb

Ans: B

[18.13] What is the total number of moles (*n*) of electrons exchanged between the oxidizing agent and the reducing agent in the overall redox equation:

$$3C_2O_4^{2-}(aq) + Cr_2O_7^{2-}(aq) + 14H^+(aq) \rightarrow 6CO_2(g) + 2Cr^{3+}(aq) + 7H_2O(l)$$

Ans: 6

[18.14] How many grams of copper are deposited on the cathode of an electrolytic cell if an electric current of 2.00 A is passed through a solution of $CuSO_4$ for a period of 19.0 min?

Ans: 0.751 g

[18.15] Many different ways have been proposed to make batteries. One cell is set up with copper and lead electrodes in contact with $CuSO_4(aq)$ and $Pb(NO_3)_2(aq)$, respectively. If the Pb^{2+} and Cu^{2+} concentrations are each 1.0 M, what is the overall cell potential?

$Pb^{2+} + 2e^- \rightarrow Pb$ $\quad E° = -0.22$ V

$Cu^{2+} + 2e^- \rightarrow Cu$ $\quad E° = +0.34$ V

Ans: 0.56 V

[18.16] The electrochemical cell that utilizes the reaction $Zn + Cu^{2+}$ (1 M) $\rightarrow Zn^{2+}$ (1 M) + Cu will have a lower cell emf when the concentrations of Zn^{2+} and Cu^{2+} ions are decreased to 0.1 M.

Ans: False

[18.17] A metal object is to be gold-plated by an electrolytic procedure using aqueous $AuCl_3$ electrolyte. Calculate the number of moles of gold deposited in 3.0 min by a constant current of 10. A.

A) 6.2×10^{-3} mol
B) 9.3×10^{-3} mol
C) 1.8×10^{-2} mol
D) 3.5×10^{-5} mol
E) 160 mol

Ans: A

[18.18]. What is the total number of moles (*n*) of electrons exchanged between the oxidizing agent and the reducing agent in the overall redox equation:

$$Cr_2O_7^{2-}(aq) + 6Fe^{2+}(aq) + 14H^+(aq) \rightarrow 2Cr^{3+}(aq) + 6Fe^{3+}(aq) + 7H_2O(l)$$

A) 1 B) 2 C) 3 D) 6 E) 12

Ans: D

[18.19]. Consider the following standard reduction potentials in acid solution:

	E°(V)
$Al^{3+} + 3e^- \rightarrow Al(s)$	–1.66
$AgBr(s) + e^- \rightarrow Ag(s) + Br^-$	+0.07
$Sn^{4+} + 2e^- \rightarrow Sn^{2+}$	+0.14
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	+0.77

The strongest reducing agent among those shown above is

A) Fe^{3+}. B) Fe^{2+}. C) Br^-. D) Al^{3+}. E) Al.

Ans: E

[18.20]. Consider a Galvanic cell constructed from the following half cells, linked by an external circuit and by a KCl salt bridge.

- an Al(s) electrode in 1.0 M $Al(NO_3)_3$ solution
- a Pb(s) electrode in 1.0 M $Pb(NO_3)_2$ solution

The balanced overall (net) cell reaction is

A) $Pb(s) + Al^{3+}(aq) \rightarrow Pb^{2+}(aq) + Al(s.)$
B) $3Pb(s) + 2Al^{3+}(aq) \rightarrow 3Pb^{2+}(aq) + 2Al(s).$
C) $3Pb^{2+}(aq) + 2Al(s) \rightarrow 3Pb(s) + 2Al^{3+}(aq).$
D) $Pb^{2+}(aq) + Al(s) \rightarrow Pb(s) + Al^{3+}(aq).$

Ans: C

[18.21]

. For the reaction $Ni^{2+}(aq) + 2Fe^{2+}(aq) \rightarrow Ni(s) + 2Fe^{3+}(aq)$, the standard cell potential $E°_{cell}$ is

A) +2.81 V. B) +1.02 V. C) +0.52 V. D) –1.02 V. E) –2.81 V.

Ans: D

[18.22]. What current is needed to deposit 0.500 g of chromium metal from a solution of Cr^{3+} in a period of 1.00 hr?

Ans: 0.773 A

[18.23]. Consider an electrochemical cell based on the following cell diagram:

$$Pt \mid Pu^{3+}(aq), Pu^{4+}(aq) \parallel Cl_2(g), Cl^-(aq) \mid Pt$$

Given that the standard cell emf is 0.35 V and that the standard reduction potential of chlorine is 1.36 V, what is the standard reduction potential $E°(Pu^{4+}/Pu^{3+})$?

A) 2.37 V B) 1.01 V C) –1.71 V D) –1.01 V E) 1.71 V

Ans: B

[18.24] If the cell emf of a Zn–Cu cell is 0.80 V when the concentration of Zn^{2+} is 2.0 M, what is the concentration of Cu^{2+}?

Ans: 1.5×10^{-10} M

[18.25] How many coulombs of charge are required to cause reduction of 0.25 mole of Cu^{2+} to Cu?

A) 0.25 C B) 0.50 C C) 1.2×10^4 C D) 2.4×10^4 C E) 4.8×10^4 C

Ans: E

[18.26] Complete and balance the following redox equation. What is the coefficient of H_2S when the equation is balanced using the set of smallest whole-number coefficients?

$H_2S + MnO_4^- \rightarrow Mn^{2+} + SO_4^{2-}$ (acidic solution)

A) 1 B) 2 C) 4 D) 5 E) None of these.

Ans: D

[18.27] Complete and balance the following redox equation. What is the coefficient of OH^- when the equation is balanced using the set of smallest whole-number coefficients?

$MnO_4^- + I^- \rightarrow MnO_2 + IO_3^-$ (basic solution)

A) 1 B) 2 C) 4 D) 10 E) None of these.

Ans: B

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Chapter 19: Nuclear Chemistry

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[19.1] 1. Alpha particles are identical to

A) protons.
B) helium atoms.
C) hydrogen atoms.
D) helium nuclei.
E) electrons.

Ans: D

[19.2] When atoms of beryllium-9 are bombarded with alpha particles, neutrons are produced. What new isotope is also formed?

$$^{4}_{2}\text{He} + {}^{9}_{4}\text{Be} \rightarrow {}^{1}_{0}\text{n} + \text{\_\_\_\_\_}$$

A) $^{12}_{6}\text{C}$ B) $^{5}_{3}\text{Li}$ C) $^{8}_{3}\text{Li}$ D) $^{10}_{5}\text{B}$ E) $^{12}_{5}\text{B}$

Ans: A

[19.3] Consider the following decay series:

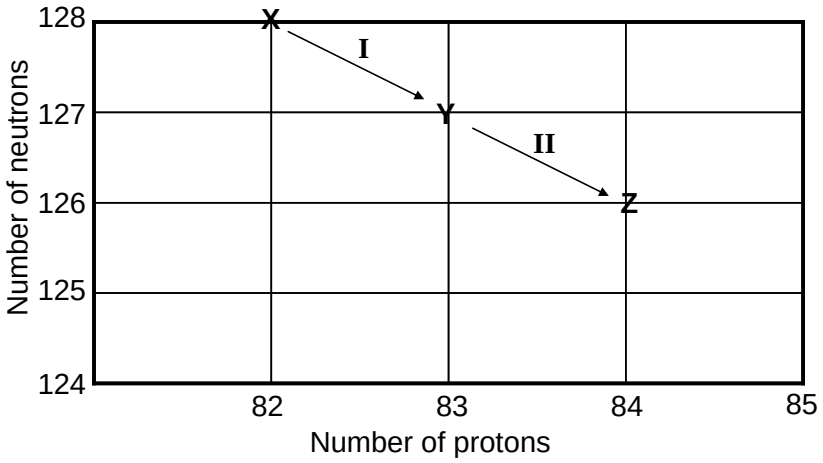
$$^{218}_{84}\text{Po} \xrightarrow{a} {}^{214}_{82}\text{Pb} \xrightarrow{b} {}^{214}_{83}\text{Bi} \xrightarrow{c} {}^{214}_{84}\text{Po} \xrightarrow{d} {}^{210}_{82}\text{Pb}$$

Which type of nuclear process occurs in steps c and d, respectively?

A) α emission, α emission
B) α emission, β emission
C) β emission, positron emission
D) β emission, α emission
E) positron emission, β emission

Ans: D

[19.4] Consider the following decay series:

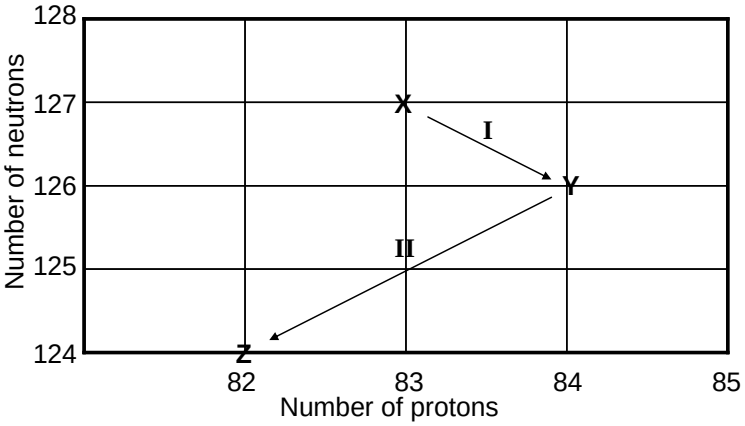


What is the symbol for the product labeled as Z?

A) $^{127}_{83}Bi$ B) $^{128}_{82}Pb$ C) $^{210}_{83}Bi$ D) $^{210}_{82}Pb$ E) $^{210}_{84}Po$

Ans: E

[19.5] Consider the following decay series:



What type of nuclear process occurs at the transformation labeled I?

A) α emission
B) β emission
C) positron emission
D) electron capture
E) gamma radiation

Ans: B

[19.6] A balanced nuclear equation representing the beta emission of iodine-131 is which of the following?

A) $^{131}_{53}I \longrightarrow {}^{131}_{54}Xe + {}^{0}_{-1}\beta$

B) $^{131}_{53}I \longrightarrow {}^{127}_{51}Sb + {}^{4}_{2}He$

C) $^{131}_{53}I + {}^{0}_{-1}\beta \longrightarrow {}^{131}_{52}Te$

D) $^{131}_{53}I \longrightarrow {}^{131}_{52}Te + {}^{0}_{+1}\beta$

E) $^{131}_{53}I + {}^{0}_{-1}e \longrightarrow {}^{131}_{52}Te$

Ans: A

[19.7] Which of the following nuclear processes results in an increase of atomic number in the product element formed?

I. Alpha emission
II. Beta emission
III. Positron emission
IV. Electron capture

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

Ans: D

[19.8] The energy equivalent of a mass defect of – 0.1710 amu is which of the following?

A) -5.130×10^{7} J
B) -1.539×10^{16} J
C) -2.556×10^{-8} J
D) -2.556×10^{-11} J
E) -8.519×10^{-20} J

Ans: D

[19.9] Find the nuclear binding energy of potassium-40 (atomic mass = 39.9632591 amu) in units of joules per nucleon. [Data: neutron mass = 1.674928×10^{-24} g; proton mass = 1.672623×10^{-24}g; electron mass = 9.109387×10^{-28} g; $N_A = 6.0221367 \times 10^{23}$ /mol; c = 2.99792458×10^{8} m/s]

A) 1.37×10^{-12} J/nucleon
B) 5.48×10^{-11} J/nucleon
C) 5.64×10^{-11} J/nucleon
D) 1.41×10^{-12} J/nucleon
E) 2.97×10^{-12} J/nucleon

Ans: A

[19.10] Calculate the energy released in joules when one mole of polonium-214 decays according to the equation

$$^{214}_{84}\text{Po} \rightarrow {}^{210}_{82}\text{Pb} + {}^{4}_{2}\text{He}.$$

[Atomic masses: Pb-210 = 209.98284 amu, Po-214 = 213.99519 amu, He-4 = 4.00260 amu.]

A) 8.78×10^{14} J/mol
B) 7.2×10^{14} J/mol
C) 8.78×10^{11} J/mol
D) -9.75×10^{-3} J/mol
E) 1.46×10^{-9} J/mol

Ans: C

[19.11] Polonium-208 is an alpha emitter with a half-life of 2.90 years. How many milligrams of polonium from an original sample of 2.00 mg will remain after 8.00 years?

A) 0.147 mg B) 0.296 mg C) 0.725 mg D) 6.77 mg E) 1.90 mg

Ans: B

[19.12] A rock contains 0.37 mg of Pb-206 and 0.95 mg of U-238. The half-life of the decay series U-238 → Pb-206 is 4.5×10^9 yr. Assuming no Pb-206 was present in the rock initially, how old is the rock?

A) 1.7×10^9 yr
B) 5.2×10^9 yr
C) 2.7×10^6 yr
D) 4.5×10^9 yr
E) 2.4×10^9 yr

Ans: E

[19.13] The Rb-87/Sr-87 method of dating rocks is often used by geologists:

$^{87}_{37}\text{Rb} \rightarrow {}^{87}_{38}\text{Sr} + {}^{0}_{-1}\beta \qquad t_{1/2} = 6.0 \times 10^{10}$ yr

Estimate the age of a rock sample in which the present-day mole ratio of Rb-87 to Sr-87 is 36:1.

A) 2.4×10^9 yr
B) 1.7×10^9 yr
C) 3.1×10^{11} yr
D) 4.1×10^{-11} yr
E) 3.6×10^{11} yr

Ans: A

[19.14] Decay of ruthenium-93 by positron emission yields

A) technetium-93.
B) molybdenum-89.
C) palladium-97.
D) rhenium-93.
E) ruthenium-92.

Ans: A

[19.15] Strontium-90 has a half-life of 28.8 years. How much strontium-90 was present initially, if after 144 years 10.0 g remain?

Ans: 320 g

[19.16] Balance the equation $^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow ? + {}^{97}_{40}\mathrm{Zr} + 2\,{}^{1}_{0}\mathrm{n}$.

Ans: $^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{137}_{52}\mathrm{Te} + {}^{97}_{40}\mathrm{Zr} + 2\,{}^{1}_{0}\mathrm{n}$

[19.17] The isotope of iodine with mass number 128 undergoes beta decay with a half-life of 25.00 minutes. How long will it take for 93.75% of a sample of pure $^{128}\mathrm{I}$ to decay?

Ans: 100. min

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Chapter 24. Organic Chemistry

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[24.1] *Alkanes* have the general formula

A) C_nH_{2n-4} B) C_nH_{2n-2} C) C_nH_{2n} D) C_nH_{2n+2} E) C_nH_{2n+4}

Ans: D

[24.2] *Cycloalkanes* have the general formula

A) C_nH_{2n-4} B) C_nH_{2n-2} C) C_nH_{2n} D) C_nH_{2n+2} E) C_nH_{2n+4}

Ans: C

[24.3] Select the one molecule that is a *saturated hydrocarbon*.

A) C_2H_4 B) C_4H_8 C) C_4H_6 D) C_4H_{10} E) C_4H_2

Ans: D

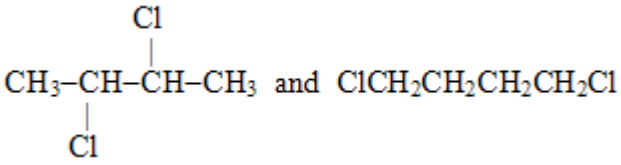
[24.4] Which one of these hydrocarbons does *not* have isomers?

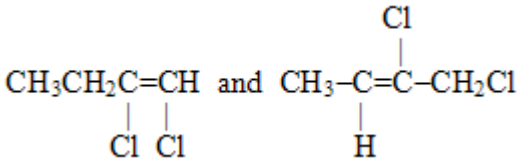
A) C_7H_{16} B) C_6H_{14} C) C_5H_{10} D) C_4H_8 E) C_3H_8

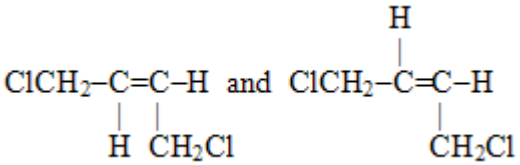
Ans: E

[24.5] Which of these pairs are *geometric isomers*?

A) $CH_3CH_2–O–CH_2CH_3$ and $CH_3CH_2CH_2CH_2OH$

B) 

C) 

D) 

Ans: D

[24.6] The molecule $CHBr_2CHCl_2$ has how many chiral centers?

A) 0 B) 1 C) 2 D) 3 E) 4

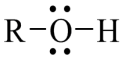
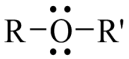
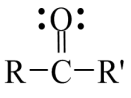
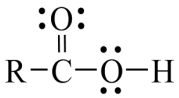
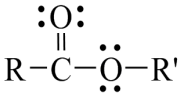
Ans: A

[24.7] Which option represents dimethyl ether?

A) CH_3CH_2OH
B) CH_3OH
C) CH_3COCH_3
D) CH_3OCH_3
E) $CH_3CH_2OCH_3$

Ans: D

[24.8] Which one of the following functional groups is found in *alcohols*.

A.  B.  C.  D.  E. 

A) A B) B C) C D) D E) E

Ans: A

[24.9] The name for the compound with the formula $CH_3CH_2CH_2CH_2OH$ is

A) propanol. B) propane. C) butanol. D) pentane. E) pentanol.

Ans: C

[24.10] The expected product from the addition of HCl to $CH_3–CH_2–CH=CH_2$ is

A) $CH_3–CH_2–CH=CHCl$
B) $CH_3–CH_2–CCl=CH_2$
C) $CH_3–CHCl–CH=CH_2$
D) $CH_3–CH_2–CH_2–CH_2Cl$
E) $CH_3–CH_2–CHCl–CH_3$

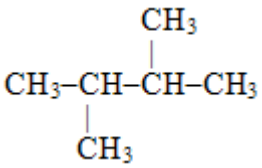
Ans: E

[24.11] Bromination of benzene (C_6H_6), an aromatic compound,

A) occurs by substitution rather than addition.
B) occurs by addition rather than substitution.
C) occurs more rapidly than bromination of a nonaromatic compound.
D) results in formation of 1,2,3,4,5,6-hexabromocyclohexane.
E) occurs in the absence of a catalyst.

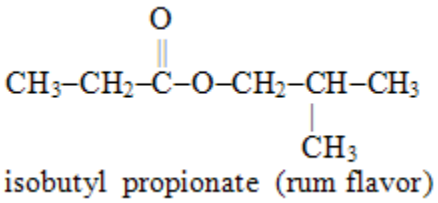
Ans: A

[24.12] Name the following compound:



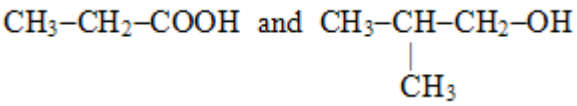
Ans: 2,3-dimethylbutane

[24.13] Write the formula for the alcohol and the carboxylic acid from which the following ester may be synthesized.



isobutyl propionate (rum flavor)

Ans:



[24.14] Which type of organic compound does *not* contain a carbonyl group?

A) ethers B) carboxylic acids C) ketones D) aldehydes E) esters

Ans: A

[24.15] Water and ethylene are combined at high temperature and pressures in the presence of sulfuric acid to produce ethanol according to the following reaction:

$$\mathbf{C}H_2{=}CH_2(g) + H_2O(g) \rightarrow \mathbf{C}H_3CH_2OH(g)$$

What is the hybridization of the bolded carbon atoms in the reactants and products, respectively?
A) sp^3, sp^2 B) sp^2, sp^3 C) sp, sp^2 D) sp^3, sp E) sp^2, sp^2

Ans: B

CHEM 1412 Formulas and Constants

mass of proton = 1.00728 amu	**mass of neutron = 1.00866 amu**
$c = 3.00 \times 10^8$ m/s	**F = 96500 C/(mol of e^-) = 96500 J/(V mol of e^-)**
$K = {}^oC + 273.15$	**R = 0.08206 (L atm)/(mol K) = 8.314 J/(mol K)**
$1\ g = 6.022 \times 10^{23}$ amu	**1 atm = 760 mm Hg**

$S_g = kP_g$ $\quad P_A = X_A P_A^o$ $\quad \Delta T_f = K_f m$ $\quad \Delta T_b = K_b m$

$\pi = MRT$ $\quad PV = nRT$

$[A]_t = -kt + [A]_o$ $\quad t_{1/2} = [A]_o / 2k$

$\ln([A]_t / [A]_o) = -kt$ $\quad \ln[A]_t = -kt + \ln[A]_o$ $\quad t_{1/2} = 0.693 / k$

$1/[A]_t = kt + 1/[A]_o$ $\quad t_{1/2} = 1 / (k[A]_o)$

$k = Ae^{-Ea/RT}$ $\quad \ln(k_1/k_2) = E_a/R\,(1/T_2 - 1/T_1)$

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For the chemical reaction (at Equilibrium):

$$aA + bB \rightleftharpoons cC + dD$$

$$K_c = \frac{[C]^c\,[D]^d}{[A]^a\,[B]^b}$$ **(Law of mass action. General expression of equilibrium constant)**

$$K_p = \frac{P_C{}^c\ P_D{}^d}{P_A{}^a\ P_B{}^b}$$ **(Kp: when equilibrium concentrations are expressed in terms of partial pressures)**

$K_p = K_c (0.0821 * T)^{\Delta n}$, **Relationship between Kp and Kc.**
Δn = moles of gaseous products – moles of gaseous reactants.

$K_c = K_c' \times K_c''$, **The equilibrium constant for the overall reaction is given by the product of the equilibrium constants for the individual reactions.**

Reaction Quotient (Qc) when instead of Equilibrium concentrations, the initial concentrations are used in the equilibrium constant expression. Qc determines the direction in which the net reaction will proceed:
(Qc < Kc: system proceeds from left to right, consuming reactants, forming products)
(Qc = Kc: system is at equilibrium)
(Qc > Kc: system proceeds from right to left, consuming products, forming reactants).

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$K_w = [H^+][OH^-]$ — Ion-product constant of water.

$pH = -\log [H^+]$, — Definition of pH of a solution.

$[H^+] = 10^{-pH}$ — Calculating H+ ion concentration from pH.

$pOH = -\log [OH^-]$, — Definition of pOH of a solution.

$[OH^-] = 10^{-pOH}$ — Calculating OH^- ion concentration from pOH.

$pH + pOH = 14$

$[H^+][OH^-] = 1.0 \times 10^{-14}$

$K_a K_b = K_w = 1.0 \times 10^{-14}$ — Relationship between the acid and base ionization constants of a conjugate acid-base pair.

Calculating pH of a solution containing a weak acid and a soluble salt of a weak acid (e.g. NaA):

$$HA(aq) + H2O(l) \rightleftharpoons H3O^+(aq) + A^-(aq)$$

or

$$HA(aq) + H2O(l) \rightleftharpoons H^+(aq) + A^-(aq)$$

The ionization constant Ka :

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

$$pK_a = -\log K_a \ ,$$

Henderson-Hasselbach equation:

$$pH = pK_a + \log \frac{[\text{conjugate base}]}{[\text{conjugate acid}]}$$

$$\text{Percent ionization} = \frac{\text{ionized acid concentration at equilibrium}}{\text{initial concentration of acid}} \times 100\%$$

Ka = acid ionization (dissociation) constant (measure of a strength of an acid)

$$Ka = \frac{[H3O^+][A^-]}{[HA]} \ .$$

Kb = base ionization (dissociation) constant (measure of a strength of a base).

$$Kb = \frac{[BH^+]\,[OH^-]}{[B]}$$.

The net direction of an acid-base reaction proceeds to the greater extent in the direction in which a stronger acid and stronger base form a weaker acid and weaker base.

Quadratic equation: $a x^2 + b x + c = 0$

$$x = \frac{-b \pm \mathrm{SQRT}(b^2 - 4 a c)}{2a}$$

$pH = pK_a + \log([\text{base}]/[\text{acid}])$

$\Delta G^o = \Delta H^o - T \Delta S^o$ $\Delta G^o = -RT \ln K_{eq}$

$\Delta G = \Delta G^o + RT \ln Q$ $\Delta G^o = -n F E^o$ $E = E^o - (0.0592/n) \log Q$

$\Delta E = \Delta m c^2$ **Coulombs = Amps X seconds**

Soluble Compounds	**Important Exceptions**
Compounds containing NO_3^-	none
Compounds containing $C_2H_3O_2^-$	none
Compounds containing Cl^-	Salts of Ag^+, Hg_2^{2+}, Pb^{2+}
Compounds containing Br^-	Salts of Ag^+, Hg_2^{2+}, Pb^{2+}
Compounds containing I^-	Salts of Ag^+, Hg_2^{2+}, Pb^{2+}
Compounds containing SO_4^{2-}	Salts of Ca^{2+}, Sr^{2+}, Ba^{2+}, Hg_2^{2+}, Pb^{2+}
Insoluble compounds	**Important Exceptions**
Compounds containing S^{2-}	Salts of ammonium, alkali metal cations and Ca^{2+}, Sr^{2+}, Ba^{2+}
Compounds containing CO_3^{2-}	Salts of ammonium, alkali metal cations
Compounds containing PO_4^{3-}	Salts of ammonium, alkali metal cations
Compounds containing OH^-	Salts of ammonium, alkali metal cations and Ca^{2+}, Sr^{2+}, Ba^{2+}

Percent by mass $= \frac{\text{mass of solute}}{[\text{mass of solute} + \text{mass of solvent}]} \times 100\%$

Two-component solution:

Mole fraction of solute A: $\mathbf{X_A} = \dfrac{\text{moles of solute A}}{\text{moles of solute A + moles of solvent B}}$

Molarity = number of moles of solute in **1 L** of solution:

$$\textbf{Molarity} = \frac{\text{moles of solute}}{\text{Liters of solution}}$$

Molality = number of moles of solute dissolved in 1 kg (1000 g) of solvent:

$$\textbf{Molality} = \frac{\text{moles of solute}}{\text{Mass of solvent (1 kg)}}$$

Density = Mass / Volume.