

## General Chemistry Questions

### Electronic Structure and Periodic Table

1. What value or values of  $m_l$  are allowable for an orbital with  $l = 2$ ?
  - a. 0
  - b. 2
  - c. -1
  - d. none of the above
  - e. all of the above
2. According to Bohr Theory, which of the following transitions in the hydrogen atom will give rise to the **least energetic** photon?  
Use the equation:  $E_n = (-2.18 \times 10^{-18} \text{ J})(1/n^2)$ 
  - a.  $n = 5$  to  $n = 3$
  - b.  $n = 6$  to  $n = 1$
  - c.  $n = 4$  to  $n = 3$
  - d.  $n = 5$  to  $n = 4$
  - e.  $n = 6$  to  $n = 5$
3. Consider a  $3d_{xz}$  orbital. Which of the following statements is **incorrect**?
  - a. The  $xz$  plane is a nodal surface.
  - b. The  $xz$  plane divides the electron probability distribution into two identical mirror-image halves.
  - c. The  $xy$  plane divides the electron probability distribution into two identical mirror-image halves.
  - d. The  $yz$  plane divides the electron probability distribution into two identical mirror-image halves.
  - e. The nucleus is located at a node.
4. The electronic configuration of the element whose atomic number is 26 is:
  - a.  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^8$
  - b.  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$
  - c.  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$
  - d.  $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^4 4p^2$
  - e. none of the above
5. Which of the following has the largest radius?
  - a. F
  - b. N
  - c. C
  - d. O
  - e. Ne

6. Which of the following elements has the largest ionization energy?
- Na
  - Ne
  - F
  - K
  - Rb
7. Which of the following has the greatest electron affinity (most negative value)?
- Cl
  - K
  - He
  - Na
  - Rb
8. Which of the following species is not isoelectronic with any of the others?
- $V^{3+}$
  - $Ca^{2+}$
  - Ar
  - $Cl^-$
  - $S^{2-}$
9. In Bohr's model of the hydrogen atom, the radius of an orbit
- is proportional to  $n^2$ .
  - is smallest for the highest energy state.
  - increases when a photon of light is emitted from an excited atom.
  - can have any value that is larger than the ground-state radius.
  - none of the above
10. Which of the following atoms is **not** a one-electron system?
- H
  - $He^+$
  - $Li^{2+}$
  - $Be^{2+}$
  - $O^{7+}$
11. Which of the following statements about periodic properties is incorrect?
- Both electron affinity and ionization energy decrease down a group.
  - Atomic size increases to the right across a period.
  - Ionization energy increases to the right across a period.
  - Atomic size increases down a group.
  - Electron affinity increases to the right across a period.

## Bonding

- Which one of the following is most likely to be an ionic compound?
  - $\text{HNF}_2$
  - $\text{H}_2\text{CO}$
  - $\text{N}_2\text{H}_4$
  - $\text{CaCl}_2$
  - $\text{CH}_3\text{Cl}$
- In which of the following processes does the enthalpy change ( $\Delta H$ ) directly represent the magnitude of the lattice energy of  $\text{KCl}(s)$ ?
  - $\text{Cl}_2(g) + 2\text{K}(s) \rightarrow 2\text{KCl}(s)$
  - $\text{KCl}(s) \rightarrow \text{K}^+(aq) + \text{Cl}^-(aq)$
  - $\text{KCl}(s) \rightarrow \text{K}^+(g) + \text{Cl}^-(g)$
  - $\text{KCl}(s) \rightarrow \text{K}(s) + \text{Cl}(g)$
  - $\text{KCl}(s) \rightarrow \text{K}(s) + \text{Cl}(g)$
- Order the following by increasing bond strength:  $\text{N}\equiv\text{N}$ ,  $\text{N}=\text{N}$ ,  $\text{N}-\text{N}$ 
  - $\text{N}\equiv\text{N}$ ,  $\text{N}=\text{N}$ ,  $\text{N}-\text{N}$
  - $\text{N}\equiv\text{N}$ ,  $\text{N}-\text{N}$ ,  $\text{N}=\text{N}$
  - $\text{N}-\text{N}$ ,  $\text{N}=\text{N}$ ,  $\text{N}\equiv\text{N}$
  - $\text{N}=\text{N}$ ,  $\text{N}-\text{N}$ ,  $\text{N}\equiv\text{N}$
  - $\text{N}=\text{N}$ ,  $\text{N}\equiv\text{N}$ ,  $\text{N}-\text{N}$
- Which of the following compounds has the greatest bond polarity?
  - $\text{PH}_3$
  - $\text{NH}_3$
  - $\text{HF}$
  - $\text{H}_2\text{S}$
  - $\text{CH}_4$
- Which of the following is not planar?
  - $\text{BCl}_3$
  - $\text{ClF}_3$
  - $\text{PCl}_3$
  - $\text{XeF}_4$
  - $\text{C}_2\text{H}_4$

6. Use VSEPR theory to predict the ideal bond angles around the two carbon atoms in acetaldehyde,  $\text{CH}_3\text{CHO}$ . (The first carbon has single bonds to three H atoms and one C atom; the second carbon has single bonds to C and H, and a double bond to O.)

- a.  $109^\circ, 109^\circ$
- b.  $109^\circ, 120^\circ$
- c.  $120^\circ, 109^\circ$
- d.  $120^\circ, 90^\circ$
- e.  $105^\circ, 105^\circ$

7. In a carbon-carbon triple bond, what is the nature of the bonding between the carbons?

- a. two  $2s$  orbitals overlapping
- b. two  $2p$  orbitals overlapping
- c. two  $sp$  orbitals overlapping, two  $2p_y$  overlapping and two  $2p_z$  overlapping
- d. an  $sp$  and  $sp^2$  overlapping and  $2p$  orbitals overlapping
- e. an  $sp^2$  and  $sp^2$  overlapping and  $2p$  orbitals overlapping

8. Which of the following molecules has  $sp^3$  hybridization and a dipole moment?

- a.  $\text{SiH}_4$
- b.  $\text{BF}_3$
- c.  $\text{NH}_3$
- d.  $\text{BrF}_3$
- e.  $\text{PCl}_5$

9. In the molecular orbital description of bonding in benzene ( $\text{C}_6\text{H}_6$ ), how many electrons occupy delocalized  $\pi$ MOs?

- a. 2
- b. 3
- c. 4
- d. 5
- e. 6

10. In which of the following species is the octet rule violated by the central atom?

- a.  $\text{CH}_4$
- b.  $\text{SF}_4$
- c.  $\text{PCl}_4^+$
- d.  $\text{SO}_2$
- e.  $\text{NH}_3$

11. The number of electron dots in the Lewis symbol for an element equals the

- a. number of outermost  $p$  electrons.
- b. number of electrons needed to fill the outermost  $p$  orbital.
- c. period number that contains the element.
- d. number of outermost  $s$  and  $p$  electrons.
- e. number of outermost  $s$  electrons.

### Phases and Phase Equilibria

1. Calculate the pressure of 0.55 mol of  $\text{NH}_3$  gas in a 2.00 L vessel at 25 °C, using the ideal gas law.

- a. 2.5 atm
- b. 6.7 atm
- c. 0.6 atm
- d. 7.5 atm
- e. 3.4 atm

2. A steel tank contains carbon dioxide at 34 °C and is at a pressure of 13.0 atm. Determine the internal gas pressure when the tank and its contents are heated to 100 °C.

- a. 10.7 atm
- b. 9.4 atm
- c. 38.2 atm
- d. 1.9 atm
- e. 15.8 atm

3. Deviations from the ideal gas law are less at:

- a. high temperatures and high pressures
- b. high temperatures and low pressures
- c. low temperatures and high pressures
- d. low temperatures and low pressures
- e. high volumes and low temperatures

4. A mixture of three gases has a pressure of 1380 mmHg at 298 K. The mixture is analyzed and is found to contain 1.27 mol  $\text{CO}_2$ , 3.04 mol  $\text{CO}$ , and 1.50 mol  $\text{Ar}$ . What is the partial pressure of  $\text{Ar}$ ?

- a. 238 mm Hg
- b. 302 mm Hg
- c. 356 mm Hg
- d. 1753 mm Hg
- e. 8018 mm Hg

5. Which of the following exhibits the most hydrogen bonding?
- LiH
  - CH<sub>4</sub>
  - NH<sub>3</sub>
  - H<sub>2</sub>S
  - CH<sub>2</sub>F<sub>2</sub>
6. Which of the following carbon compounds has the highest melting point?
- CF<sub>4</sub>
  - CCl<sub>4</sub>
  - CBr<sub>4</sub>
  - CI<sub>4</sub>
  - CH<sub>4</sub>
7. Water has such a high specific heat because
- it has such a low molecular weight.
  - it is rather dense.
  - the O-H single bond has a high bond energy.
  - it has many relatively strong hydrogen bonds.
  - it dissolves both ionic and covalent compounds.
8. The triple point is
- an end to the liquid-gas line in a phase diagram.
  - the relationship between the boiling point, melting point and vapor pressure of a substance.
  - the point on a phase diagram where solid, liquid, and gas are in equilibrium.
  - the three pieces of data needed to solve the Clausius-Clapeyron equation.
  - the (P,V,T) coordinate of a point on a phase diagram.
9. The main forces responsible for the structure of DNA are
- ionic bonds and covalent bonds.
  - covalent bonds and ionic bonds.
  - hydrogen bonds and dipole-dipole interactions.
  - covalent bonds and hydrogen bonds.
  - covalent bonds and dipole-dipole interactions.
10. Which of the following is not likely to exhibit hydrogen bonding?
- CH<sub>3</sub>CH<sub>2</sub>OH
  - CH<sub>3</sub>NH<sub>2</sub>
  - H<sub>2</sub>O
  - NH<sub>2</sub>OH
  - (CH<sub>3</sub>)<sub>3</sub>N

## Stoichiometry

1. What is the mass of one mole of acetylsalicylic acid (aspirin),  $C_9H_8O_4$ ?
  - a. 29 g
  - b. 108 g
  - c. 196 g
  - d. 180. g
  - e. none of the above
2. Determine the number of moles of aluminum in  $2.154 \times 10^{-1}$  kg of Al.
  - a. 5816 mol
  - b. 7.984 mol
  - c.  $6.02 \times 10^{23}$  mol
  - d. 4.801 mol
  - e. 8.783 mol
3. How many grams of zinc are there in 22.7 g of  $ZnCl_2$ ?
  - a. 0.35 g
  - b. 0.17 g
  - c. 10.9 g
  - d. 1476 g
  - e. 0.32 g
4. A compound with a composition of 87.5 % N and 12.5 % H was recently discovered. What is the empirical formula for this compound?
  - a.  $NH_2$
  - b.  $N_2H_3$
  - c. NH
  - d.  $N_2H_2$
  - e.  $N_2H$
5. This equation is unbalanced:  $PCl_3 + H_2O \rightarrow H_3PO_3 + HCl$  When it is correctly balanced, the coefficients are, respectively
  - a. 1,3,1,1
  - b. 1,1,1,3
  - c. 1,3,1,3
  - d. 2,3,2,3
  - e. none of the above

6. Given 6 mol of each reactant, which one would be limiting in the following reaction?  
$$4\text{Au} + 8\text{NaCN} + \text{O}_2 + 2\text{H}_2\text{O} \rightarrow 4\text{NaAu}(\text{CN})_2 + 4\text{NaOH}$$
- Au
  - NaCN
  - $\text{O}_2$
  - $\text{H}_2\text{O}$
  - There is no limiting reactant.
7. In the direct reaction of silicon with  $\text{Cl}_2$  the yield of  $\text{SiCl}_4$  is 50. %. How many grams of silicon must be reacted with excess chlorine in order to obtain 17 g  $\text{SiCl}_4$ ?
- 1.4 g
  - 2.8 g
  - 5.6 g
  - 17 g
  - 28 g
8. In the reaction of  $\text{Fe}_3\text{O}_4$  with carbon to form carbon dioxide and iron, the number of moles of carbon required to convert 23 g of  $\text{Fe}_3\text{O}_4$  to products is
- 0.05
  - 0.1
  - 0.2
  - 0.3
  - 0.4
9. A 20.0 mL sample of an element with a density of 3.0 g/mL contains  $4 \times 10^{23}$  atoms. What is the atomic weight of this element?
- 300
  - 40
  - 60
  - 90
  - none of the above
10. How many moles of oxygen gas will react with 12.4 mol aluminum?  
Equation:  $4\text{Al} + 3\text{O}_2 \rightarrow 2\text{Al}_2\text{O}_3$
- 0.24 mol
  - 0.42 mol
  - 4.8 mol
  - 9.3 mol
  - 16.8 mol



11. Balance the following redox equation occurring in aqueous solution:

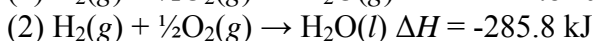
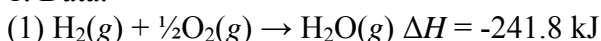


What is the stoichiometric coefficient for chlorine ( $\text{Cl}_2$ ) when the equation is balanced with smallest whole number coefficients?

- a. 1
- b. 3
- c. 5
- d. 8
- e. 10

### Thermodynamics and Thermochemistry

1. Data:



On the basis of the above data, which of the following statements is **false**?

- a. Reaction (1) is exothermic.
- b. Reaction (2) is the formation reaction for  $\text{H}_2\text{O}(\text{l})$ .
- c. The reverse of reaction (2) is endothermic.
- d. The energy content of  $\text{H}_2\text{O}(\text{g})$  is lower than  $\text{H}_2\text{O}(\text{l})$ .
- e.  $\Delta H$  for the reaction:  $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{O}(\text{g})$  is + 44 kJ/mol.

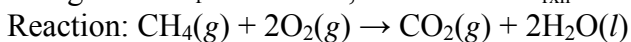
2. What is the amount of heat necessary to raise the temperature of 8.5 kg of water from 12.5 °C to 84 °C?

- a.  $3.0 \times 10^3 \text{ kJ}$
- b. 36 J
- c.  $2.5 \times 10^3 \text{ kJ}$
- d.  $2.5 \times 10^6 \text{ kJ}$
- e. 25 kJ

3. Data:

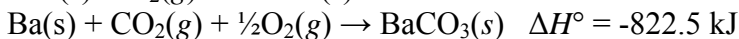
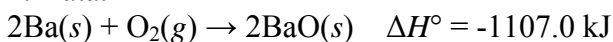
$\Delta H^\circ_f$  values:  $\text{CH}_4(\text{g})$ , -74.8 kJ;  $\text{CO}_2(\text{g})$ , -393.5 kJ;  $\text{H}_2\text{O}(\text{l})$ , -285.8 kJ.

Using the  $\Delta H^\circ_f$  data above, calculate  $\Delta H^\circ_{\text{rxn}}$  for the reaction below.

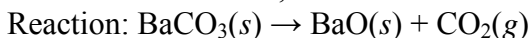


- a. -604.2 kJ
- b. 890.3 kJ
- c. -997.7 kJ
- d. -890.3 kJ
- e. none of the above

4. Data:



Given the data above, calculate  $\Delta H^\circ$  for the reaction below.



- a. -1929.5 kJ
- b. -1376.0 kJ
- c. -284.5 kJ
- d. 269.0 kJ
- e. 537 kJ

5. Which of the following is **not** a state function?

- a.  $\Delta E$
- b.  $\Delta H$
- c.  $q$
- d.  $P$
- e.  $V$

6. Two solutions (the system), each of 25.0 mL volume and at 25.0 °C, are mixed in a beaker. A reaction occurs between them, causing the temperature to drop to 20.0 °C. After the products have equilibrated with the surroundings, the temperature is again 25.0 °C and the total volume is 50.0 mL. No gases are involved in the reaction. Which one of the following relationships concerning the change from initial to final states (both at 25.0 °C) is correct?

- a.  $\Delta E = 0$
- b.  $\Delta H = 0$
- c.  $\Delta E < 0$
- d.  $w = 0$
- e.  $q = 0$

7. Which one of the following processes is exothermic?

- a.  $\text{H}_2(l) \rightarrow \text{H}_2(g)$
- b.  $\text{CO}_2(s) \rightarrow \text{CO}_2(g)$
- c.  $\text{H}_2\text{O}(g) \rightarrow \text{H}_2\text{O}(l)$
- d.  $16\text{CO}_2(g) + 18\text{H}_2\text{O}(l) \rightarrow 2\text{C}_8\text{H}_{18}(l) + 25\text{O}_2(g)$
- e.  $\text{H}_2(g) \rightarrow 2\text{H}(g)$

8. Predict the signs of  $\Delta H^\circ$ ,  $\Delta S^\circ$ , and  $\Delta G^\circ$  for the vaporization of liquid water at 150°C.

- a.  $\Delta H^\circ > 0$ ,  $\Delta S^\circ > 0$ ,  $\Delta G^\circ > 0$
- b.  $\Delta H^\circ < 0$ ,  $\Delta S^\circ < 0$ ,  $\Delta G^\circ < 0$
- c.  $\Delta H^\circ > 0$ ,  $\Delta S^\circ < 0$ ,  $\Delta G^\circ > 0$
- d.  $\Delta H^\circ > 0$ ,  $\Delta S^\circ > 0$ ,  $\Delta G^\circ < 0$
- e. none of the above

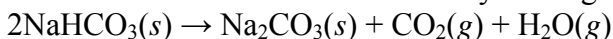
9. Which of the following substances has the lowest standard molar entropy ( $S^\circ$ ) at  $25^\circ\text{C}$ ?

- a.  $\text{CH}_3\text{OH}(l)$
- b.  $\text{CO}(g)$
- c.  $\text{MgO}(s)$
- d.  $\text{H}_2\text{O}(l)$
- e.  $\text{CaCO}_3(s)$

10. When crystalline solid barium hydroxide octahydrate and crystalline solid ammonium nitrate are mixed in a beaker at room temperature, a spontaneous reaction occurs. The temperature of the beaker contents rapidly falls to below  $0^\circ\text{C}$ . Use this information to decide whether the reaction is exothermic or endothermic and what the signs of  $\Delta H$  and  $\Delta S$  are.

- a. endothermic;  $\Delta H > 0$ ;  $\Delta S > 0$
- b. exothermic;  $\Delta H < 0$ ;  $\Delta S > 0$
- c. endothermic;  $\Delta H < 0$ ;  $\Delta S < 0$
- d. endothermic;  $\Delta H < 0$ ;  $\Delta S > 0$
- e. exothermic;  $\Delta H > 0$ ;  $\Delta S < 0$

11. Sodium carbonate can be made by heating sodium hydrogen carbonate:



For this reaction,  $\Delta H^\circ = 128.9\text{ kJ}$  and  $\Delta S^\circ = 321\text{ J/K}$ . At approximately what temperature will  $K = 1$ ?

- a. 401.6 K
- b.  $401.6^\circ\text{C}$
- c. 33.1 K
- d.  $33.1^\circ\text{C}$
- e. none of the above

### Rate Processes in Chemical Reactions—Kinetics and Equilibrium

1. For the overall hypothetical reaction  $\text{A} + 5\text{B} \rightarrow 4\text{C}$ , the rate of appearance of C given by  $\Delta[\text{C}]/\Delta t$  is the same as

- a.  $\Delta[\text{A}]/\Delta t$
- b.  $-(5/4)(\Delta[\text{B}]/\Delta t)$
- c.  $-(4/5)(\Delta[\text{B}]/\Delta t)$
- d.  $-(1/4)(\Delta[\text{A}]/\Delta t)$
- e. none of the above.

2. The initial rate of the reaction



is increased a factor of four when the concentration of  $\text{PCl}_5$  is doubled. Therefore, the rate

- depends on the concentrations of  $\text{PCl}_3$  and  $\text{Cl}_2$ .
- is first order with respect to  $\text{PCl}_5$ .
- is second order with respect to  $\text{PCl}_5$ .
- is fourth order with respect to  $\text{PCl}_5$ .
- is first order with respect to  $\text{PCl}_3$ .

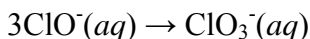
3. Consider the reaction  $\text{A} \rightarrow \text{products}$ . Which of the following plots is consistent with a zero-order reaction?

- $[\text{A}]$  plotted against time gives a horizontal, straight line.
- $\ln [\text{A}]$  plotted against time gives a straight line of negative slope.
- $1/[\text{A}]$  plotted against time gives a straight line of positive slope.
- $[\text{A}]$  plotted against time gives a straight line of negative slope.
- $[\text{A}]$  plotted against time gives a curved line of negative slope, decreasing in magnitude as time increases

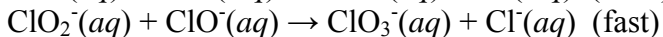
4. The rate constant of a first-order reaction is  $3.68 \times 10^{-2} \text{ s}^{-1}$  at  $150^\circ\text{C}$ , and the activation energy is  $71 \text{ kJ/mol}$ . What is the value of the rate constant at  $170^\circ\text{C}$ ?

- $9.2 \times 10^{-2} \text{ s}^{-1}$
- $3.7 \times 10^{-2} \text{ s}^{-1}$
- $2.49 \text{ s}^{-1}$
- $4.0 \times 10^{-2} \text{ s}^{-1}$
- none of the above

5. The reaction



+  $2\text{Cl}^-(aq)$  has been proposed to occur by the following mechanism.



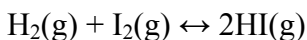
Which rate law is consistent with this mechanism?

- rate =  $k[\text{ClO}^-]$
- rate =  $k[\text{ClO}^-]^3$
- rate =  $k[\text{ClO}_2^-][\text{ClO}^-]$
- rate =  $k[\text{ClO}^-]^2$
- rate =  $k[\text{Cl}^-][\text{ClO}^-]^2$

6. A catalyst speeds up a reaction by

- increasing the number of high-energy molecules.
- increasing the temperature of the molecules in the reaction.
- increasing the number of collisions between molecules.
- increasing the activation energy for the reaction.
- providing a new reaction pathway for molecules.

7. Consider the following gas-phase equilibrium:



At a certain temperature, the equilibrium constant  $K_c$  is 4.0. Starting with equimolar quantities of  $\text{H}_2$  and  $\text{I}_2$  and no  $\text{HI}$ , when equilibrium was established, 0.20 moles of  $\text{HI}$  was present. How much  $\text{H}_2$  was used to start the reaction?

- a. 0.10 mol
- b. 0.23 mol
- c. 0.20 mol
- d. 4.0 mol
- e. Need to know the volume of the reaction vessel.

8. At a certain temperature the equilibrium constant  $K_p = 0.132$  for the reaction:



At equilibrium, the partial pressures of both  $\text{PCl}_5$  and  $\text{PCl}_3$  are 100. mmHg. What is the total pressure of the equilibrium system, in mmHg?

- a. 100. mmHg
- b. 200. mmHg
- c. 300. mmHg
- d. 400. mmHg
- e. 332 mmHg

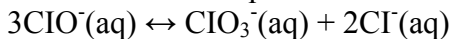
9. Ammonium iodide dissociates reversibly to ammonia and hydrogen iodide:



At  $400^\circ\text{C}$ ,  $K_p = 0.215$ . If 150 g of ammonium iodide is placed into a 3.00-L vessel and heated to  $400^\circ\text{C}$ , calculate the partial pressure of ammonia when equilibrium is reached.

- a. 0.22 atm
- b. 0.46 atm
- c. 0.11 atm
- d. 0.88 atm
- e. 1.2 atm

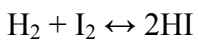
10. Consider the equilibrium reaction:



The equilibrium constant  $K_c = 3.2 \times 10^3$ . The following concentrations are present:  $[\text{Cl}^-] = 0.50 \text{ mol/L}$ ;  $[\text{ClO}_3^-] = 0.32 \text{ mol/L}$ ;  $[\text{ClO}^-] = 0.24 \text{ mol/L}$ . Is the mixture at equilibrium and, if not, in which direction will reaction proceed?

- a. The system is at equilibrium.
- b. The system is not at equilibrium; reaction will proceed left to right.
- c. The system is not at equilibrium; reaction will proceed right to left.
- d. The system cannot reach equilibrium since the  $\text{ClO}_3^-$  and  $\text{Cl}^-$  concentrations are not in the stoichiometric ratio.
- e. There is not enough information to tell.

11. Consider the following reaction in the gas phase:



If the pressure increased by reducing the the volume of the flask,

- more HI will be produced.
- more  $\text{H}_2$  and  $\text{I}_2$  will be produced.
- the results will depend on what the amounts of each are.
- the amount of HI will remain the same.
- the equilibrium constant will change.

### Solution Chemistry

1. Which of the following ions has an **incorrect** charge?

- $\text{N}^{3-}$
- $\text{Al}^{3+}$
- $\text{S}^{2-}$
- $\text{Cl}^-$
- $\text{Mg}^{2-}$

2. Which of the following pairs of elements would be most likely to form an ionic compound?

- P and Br
- Zn and K
- C and O
- Al and Rb
- F and Ca

3. What is the name of NaI?

- sodium iodide
- sodium(I) iodide
- sodium monoiodide
- sodious iodide
- sodium iodine

4. Which of the following combinations of names and formulas is incorrect?

- $\text{H}_3\text{PO}_4$  phosphoric acid
- $\text{HNO}_3$  nitric acid
- $\text{NaHCO}_3$  sodium carbonate
- $\text{H}_2\text{CO}_3$  carbonic acid
- $\text{KOH}$  potassium hydroxide

5. Calculate the concentration of calcium ions in a saturated calcium phosphate solution. ( $K_{sp}$  for  $\text{Ca}_3(\text{PO}_4)_2 = 1.3 \times 10^{-26}$ )

- a.  $1.2 \times 10^{-5}$  mol/L
- b.  $2.0 \times 10^{-5}$  mol/L
- c.  $6.6 \times 10^{-6}$  mol/L
- d.  $7.8 \times 10^{-6}$  mol/L
- e.  $8.3 \times 10^{-6}$  mol/L

6. Calculate the molar solubility of silver carbonate in 1.0 M sodium carbonate solution. ( $K_{sp}$  for  $\text{Ag}_2\text{CO}_3 = 8.1 \times 10^{-12}$ )

- a.  $8.1 \times 10^{-12}$  M
- b.  $2.8 \times 10^{-6}$  M
- c.  $1.4 \times 10^{-6}$  M
- d.  $1.4 \times 10^{-8}$  M
- e.  $2.0 \times 10^{-4}$  M

7. Calculate the pH of a solution necessary to just begin the precipitation of  $\text{Mg}(\text{OH})_2$  when  $[\text{Mg}^{2+}] = 0.001$  M. ( $K_{sp}$  for  $\text{Mg}(\text{OH})_2 = 1.2 \times 10^{-11}$ )

- a. 11
- b. 10
- c. 9
- d. 8
- e. 4

8. In qualitative analysis, the metals of Ion Group 1 can be separated from other ions by precipitating them as chloride salts. A solution initially contains  $\text{Ag}^+$  and  $\text{Pb}^{2+}$  at a concentration of 0.10 M. Aqueous HCl is added to this solution until the  $\text{Cl}^-$  concentration is 0.10 M. What will the concentrations of  $\text{Ag}^+$  and  $\text{Pb}^{2+}$  be at equilibrium? ( $K_{sp}$  for  $\text{AgCl} = 1.8 \times 10^{-10}$ ;  $K_{sp}$  for  $\text{PbCl}_2 = 1.7 \times 10^{-5}$ )

- a.  $[\text{Ag}^+] = 1.8 \times 10^{-11}$  M;  $[\text{Pb}^{2+}] = 1.7 \times 10^{-6}$  M
- b.  $[\text{Ag}^+] = 1.8 \times 10^{-7}$  M;  $[\text{Pb}^{2+}] = 1.7 \times 10^{-4}$  M
- c.  $[\text{Ag}^+] = 1.8 \times 10^{-11}$  M;  $[\text{Pb}^{2+}] = 8.5 \times 10^{-5}$  M
- d.  $[\text{Ag}^+] = 1.8 \times 10^{-9}$  M;  $[\text{Pb}^{2+}] = 1.7 \times 10^{-3}$  M
- e.  $[\text{Ag}^+] = 1.8 \times 10^{-9}$  M;  $[\text{Pb}^{2+}] = 8.5 \times 10^{-6}$  M

9. Silver chloride is relatively insoluble in water ( $K_{sp}$  for  $\text{AgCl} = 1.8 \times 10^{-10}$ ) but it is soluble in aqueous ammonia, due to the formation of the complex ion  $\text{Ag}(\text{NH}_3)_2^+$ . How many moles of  $\text{AgCl}$  will dissolve in 1.00 L of solution containing 6.0 moles of free  $\text{NH}_3$ ? ( $K_f$  for  $\text{Ag}(\text{NH}_3)_2^+ = 1.7 \times 10^7$ )

- a.  $9.1 \times 10^{-6}$  mol
- b.  $2.9 \times 10^{-4}$  mol
- c. 0.0091 mol
- d. 0.084 mol
- e. 0.33 mol

10. What is the mass of  $C_{12}H_{22}O_{11}$  in 60.0 mL of 0.0880 M solution?

- a. 0.181 g
- b. 1.81 g
- c. 5.02 g
- d. 5.28 g
- e. none of the above

11. The freezing point of pure camphor is 178.4 °C, and its molal freezing-point constant,  $K_f$  is 40.0 °C/m. Find the freezing point of a solution containing 3.00 g of a compound of molar mass 125 g/mol in 45.0 g of camphor.

- a. 174.1 °C
- b. 157.1 °C
- c. 135.2 °C
- d. 140.4 °C
- e. 11.6 °C

### Acids and Bases

1. Calculate the **hydroxide** ion concentration of a solution if its pH is 6.389.

- a.  $1.00 \times 10^{-14}$  mol/L
- b.  $4.08 \times 10^{-7}$  mol/L
- c.  $9.92 \times 10^{-7}$  mol/L
- d.  $2.45 \times 10^{-8}$  mol/L
- e. none of the above

2. Which of the following is a correct description of the natural direction of a Brønsted-Lowry acid-base reaction?

- a. weaker acid + weaker base  $\rightarrow$  stronger acid + stronger base
- b. weaker acid + stronger base  $\rightarrow$  stronger acid + weaker base
- c. stronger acid + weaker base  $\rightarrow$  weaker acid + stronger base
- d. stronger acid + stronger base  $\rightarrow$  weaker acid + weaker base
- e. None of the above statements is always correct.

3. In a 0.100 M HF solution, the percent dissociation is determined to be 9.5%. Calculate the  $K_a$  for HF based on this data.

- a.  $9.5 \times 10^{-2}$
- b.  $1.0 \times 10^{-3}$
- c.  $3.1 \times 10^{-3}$
- d.  $7.6 \times 10^{-4}$
- e.  $9.5 \times 10^{-4}$



4. What is the pH of a solution prepared from 0.250 mol of  $\text{NH}_3$  dissolved in sufficient water to make 1.00 L of solution? ( $K_b = 1.8 \times 10^{-5}$ )

- a. 2.12
- b. 2.67
- c. 8.92
- d. 11.33
- e. 13.40

5. Which of the following reactions illustrate  $\text{Al}(\text{OH})_3$  acting as a Lewis acid?

- a.  $\text{Al}(\text{OH})_3 \rightarrow \text{Al}^{3+} + 3\text{OH}^-$
- b.  $\text{Al}(\text{OH})_3 + \text{OH}^- \rightarrow \text{Al}(\text{OH})_2\text{O}^- + \text{H}_2\text{O}$
- c.  $\text{Al}(\text{OH})_3 + \text{OH}^- \rightarrow \text{Al}(\text{OH})_4^-$
- d.  $\text{Al}(\text{OH})_3 + 3\text{H}^+ \rightarrow \text{Al}^{3+} + 3\text{H}_2\text{O}$
- e.  $\text{Al}^{3+} + 3\text{OH}^- \rightarrow \text{Al}(\text{OH})_3$

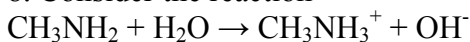
6. Which of the following pairs of species is **not** a conjugate acid-base pair?

- a.  $\text{HCl}$  and  $\text{H}^+$
- b.  $\text{HSO}_4^-$  and  $\text{SO}_4^{2-}$
- c.  $\text{H}_2\text{SO}_4$  and  $\text{HSO}_4^-$
- d.  $\text{H}_2\text{O}$  and  $\text{OH}^-$
- e.  $\text{NH}_3$  and  $\text{NH}_2^-$

7. Consider each of the following pairs of acids. Which statement is correct?

- a.  $\text{HClO}_2$  is a stronger acid than  $\text{HClO}_4$ .
- b.  $\text{H}_2\text{SO}_4$  is a stronger acid than  $\text{H}_2\text{SeO}_4$ .
- c.  $\text{H}_2\text{O}$  is a stronger acid than  $\text{HF}$ .
- d.  $\text{H}_2\text{S}$  is a stronger acid than  $\text{H}_2\text{Se}$ .
- e.  $\text{HS}^-$  is a stronger acid than  $\text{H}_2\text{S}$ .

8. Consider the reaction



where  $\text{CH}_3\text{NH}_2$  is methylamine and  $\text{CH}_3\text{NH}_3^+$  is the methylammonium ion. Select the correct description of this reaction in terms of Lewis acid-base theory.

- a. Methylamine serves as a Lewis acid in the forward reaction and methylammonium ion serves as a Lewis base in the reverse reaction.
- b. Water serves as a Lewis base in the forward reaction and the hydroxide ion serves as a Lewis base in the reverse reaction.
- c. Methylamine serves as a Lewis base in the forward reaction and hydroxide ion serves as a Lewis acid in the reverse reaction.
- d. Water serves as a Lewis acid in the forward reaction and methylammonium ion serves as a Lewis base in the reverse reaction.
- e. Methylamine serves as a Lewis base in the forward reaction and hydroxide ion serves as a Lewis base in the reverse reaction.

9. What is the pH of a buffer prepared by adding 180 mL of 0.100 M NaOH to 200 mL of 0.100 M acetic acid?

( $K_a$  for  $\text{CH}_3\text{COOH} = 1.8 \times 10^{-5}$ )

- a. 3.79
- b. 4.34
- c. 4.74
- d. 5.04
- e. 5.70

10. Consider the titration of 50.00 mL of 0.1000 M HBr with 0.1000 M KOH. Calculate the pH after 49.00 mL of the base has been added to the 50.00 mL of HBr.

- a. 2.0
- b. 3.0
- c. 4.0
- d. 6.0
- e. 7.0

11. An aqueous solution of a weak acid, HA, is titrated with NaOH solution. The pH at the midpoint of the buffer region is 4.5. What is the  $K_a$  of the acid?

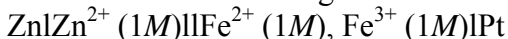
- a.  $3.2 \times 10^{-5}$
- b.  $3.2 \times 10^{-10}$
- c.  $1.8 \times 10^{-3}$
- d.  $7.0 \times 10^{-7}$
- e. 4.5

## Electrochemistry

1. Which of the following statements is incorrect?

- a. In an electrolytic cell, reduction occurs at the anode.
- b. Aluminum metal would form at the cathode during the electrolysis of molten  $\text{AlBr}_3$ .
- c. The cathode is labeled "+" in a voltaic cell.
- d. Oxidation occurs at the anode in a voltaic cell.
- e. Electrons flow from the anode to the cathode in all electrochemical cells.

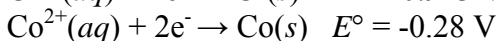
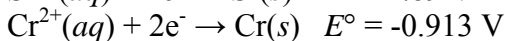
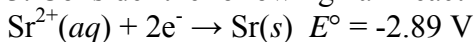
2. Consider the following notation for an electrochemical cell



What is the balanced equation for the cell reaction?

- a.  $\text{Zn}(s) + 2\text{Fe}^{3+}(aq) \rightarrow 2\text{Fe}^{2+}(aq) + \text{Zn}^{2+}(aq)$
- b.  $\text{Zn}^{2+}(aq) + 2\text{Fe}^{2+}(aq) \rightarrow \text{Zn}(s) + 2\text{Fe}^{3+}(aq)$
- c.  $\text{Zn}(s) + 2\text{Fe}^{2+}(aq) \rightarrow 2\text{Fe}^{3+}(aq) + \text{Zn}^{2+}(aq)$
- d.  $\text{Zn}(s) + \text{Fe}^{3+}(aq) \rightarrow \text{Fe}^{2+}(aq) + \text{Zn}^{2+}(aq)$
- e.  $\text{Zn}(s) + \text{Fe}^{2+}(aq) \rightarrow \text{Fe}(s) + \text{Zn}^{2+}(aq)$

3. Consider the following half-reactions and select the strongest oxidizing agent present:

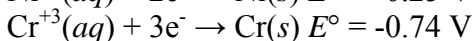
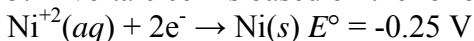


- $\text{Cr}^{2+}(\text{aq})$
- $\text{Sr}^{2+}(\text{aq})$
- $\text{Co}^{2+}(\text{aq})$
- $\text{Sr}(\text{s})$
- $\text{Co}(\text{s})$

4. In an electrolytic cell, how many grams of Cu could be plated out of a  $\text{CuSO}_4$  solution at a current of 5.00 A for 2.00 min? ( $F = 96500 \text{ C/mol}$ )

- 318 g
- 0.395 g
- $0.329 \times 10^{-3} \text{ g}$
- 0.198 g
- 5.31 g

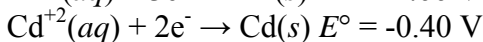
5. A voltaic cell is based on the following two half-reactions:



Sketch the cell and then select the correct statement about it.

- Cr serves as the cathode.
- The direction of electron flow through the external wire is from the Ni to the Cr electrode.
- Anions in solution will migrate **toward** the  $\text{Ni}^{+2}/\text{Ni}$  electrode.
- The net cell reaction is  $3\text{Ni}^{+2}(\text{aq}) + 2\text{Cr}(\text{s}) \rightarrow 3\text{Ni}(\text{s}) + 2\text{Cr}^{+3}(\text{aq})$
- $E^{\circ}_{\text{cell}} = 0.99 \text{ V}$

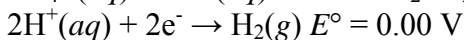
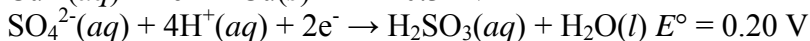
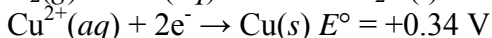
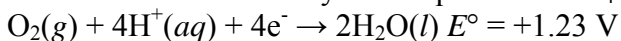
6. Consider the following two electrode reactions and their standard electrode potentials:



Write the cell reaction for a voltaic cell based on these two electrodes, and calculate the standard cell potential,  $E^{\circ}_{\text{cell}}$ .

- $2\text{Al}^{+3}(\text{aq}) + 3\text{Cd}^{+2}(\text{aq}) \rightarrow 2\text{Al}(\text{s}) + 3\text{Cd}(\text{s}) \quad E^{\circ}_{\text{cell}} = 2.10 \text{ V}$
- $2\text{Al}(\text{s}) + 3\text{Cd}^{+2}(\text{aq}) \rightarrow 2\text{Al}^{+3}(\text{aq}) + 3\text{Cd}(\text{s}) \quad E^{\circ}_{\text{cell}} = 1.26 \text{ V}$
- $2\text{Al}(\text{s}) + 3\text{Cd}^{+2}(\text{aq}) \rightarrow 2\text{Al}^{+3}(\text{aq}) + 3\text{Cd}(\text{s}) \quad E^{\circ}_{\text{cell}} = 3.78 \text{ V}$
- $2\text{Al}^{+3}(\text{aq}) + 3\text{Cd}(\text{s}) \rightarrow 2\text{Al}(\text{s}) + 3\text{Cd}^{+2}(\text{aq}) \quad E^{\circ}_{\text{cell}} = 1.26 \text{ V}$
- $2\text{Al}^{+3}(\text{aq}) + 3\text{Cd}(\text{s}) \rightarrow 2\text{Al}(\text{s}) + 3\text{Cd}^{+2}(\text{aq}) \quad E^{\circ}_{\text{cell}} = 2.10 \text{ V}$

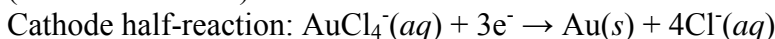
7. Use the following standard electrode potentials to predict the species formed at the electrodes in the electrolysis of aqueous  $\text{CuSO}_4$ .



- $\text{H}_2, \text{O}_2, \text{H}^+$
- $\text{Cu}, \text{O}_2, \text{H}^+$
- $\text{Cu}, \text{H}_2$
- $\text{H}_2, \text{H}_2\text{SO}_3, \text{H}_2\text{O}$
- $\text{H}_2\text{SO}_3, \text{H}_2\text{O}, \text{O}_2, \text{H}^+$

8. A constant current was passed through a solution of  $\text{KAuCl}_4$  between gold electrodes. Over a period of 20.00 min, the cathode increased in mass by 2.664 g. What was the current in amperes?

( $F = 96500 \text{ C/mol}$ )



- 1.08 A
- 3.26 A
- 2.17 A
- 6.52 A
- 3.48 A

9. A voltaic cell is constructed from the following half-cells, linked by a  $\text{KCl}$  salt bridge:

(a) an Fe electrode in 1.0 M  $\text{FeCl}_2$  solution

(b) a Ni electrode in 1.0 M  $\text{Ni}(\text{NO}_3)_2$  solution

Use the table of standard electrode potentials in your textbook to decide which one of the following statements is correct.

- The Ni electrode is the anode.
- Electrons flow from the iron electrode to the nickel electrode.
- The iron electrode is positively charged.
- The iron electrode will gain mass when current flows.
- The salt bridge conducts electrons through solution.

10. Which one of the following reactions must be carried out in an electrolytic cell, rather than a voltaic cell?

- $\text{Zn} + \text{Cd}^{2+} \rightarrow \text{Cd} + \text{Zn}^{2+}$
- $\text{Al} + 3/2\text{Br}_2 \rightarrow \text{Al}^{3+} + 3\text{Br}^-$
- $2\text{Al}^{3+} + 3\text{Fe} \rightarrow 2\text{Al} + 3\text{Fe}^{2+}$
- $\text{H}_2 + \text{I}_2 \rightarrow 2\text{H}^+ + 2\text{I}^-$
- $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$

11. How many minutes does it take to plate 0.800 g of silver metal onto a serving tray from an aqueous solution of  $\text{AgNO}_3$  at a current of 2.50 A? ( $F = 96500 \text{ C/mol}$ )

- a. < 2 minutes
- b. 2.38 minutes
- c. 4.77 minutes
- d. 9.54 minutes
- e. 23.8 minutes

# General Chemistry Answers

## Electronic Structure and Periodic Table

1. (e)
2. (e)
3. (a)
4. (c)
5. (c)
6. (b)
7. (a)
8. (a)
9. (a)
10. (d)
11. (b)

## Bonding

1. (d)
2. (c)
3. (c)
4. (c)
5. (c)
6. (b)
7. (c)
8. (c)
9. (e)

10. (b)

11. (d)

### **Phases and Phase Equilibria**

1. (b)

2. (e)

3. (b)

4. (c)

5. (c)

6. (d)

7. (d)

8. (c)

9. (d)

10. (e)

### **Stoichiometry**

1. (e)

2. (b)

3. (c)

4. (a)

5. (c)

6. (b)

7. (c)

8. (c)

9. (d)

10. (d)

11. (c)

### **Thermodynamics and Thermochemistry**

1. (d)

2. (c)

3. (d)

4. (d)

5. (c)

6. (d)

7. (c)

8. (d)

9. (c)

10. (a)

11. (a)

### **Rate Processes in Chemical Reactions—Kinetics and Equilibrium**

1. (c)

2. (c)

3. (d)

4. (a)

5. (d)

6. (e)

7. (c)

8. (c)

9. (b)



10. (b)

11. (d)

### **Solution Chemistry**

1. (e)

2. (e)

3. (a)

4. (c)

5. (d)

6. (c)

7. (b)

8. (d)

9. (e)

10. (b)

11. (b)

### **Acids and Bases**

1. (d)

2. (d)

3. (b)

4. (d)

5. (c)

6. (a)

7. (b)

8. (e)

9. (e)

10. (b)

11. (a)

### **Electrochemistry**

1. (a)

2. (a)

3. (c)

4. (d)

5. (d)

6. (b)

7. (b)

8. (b)

9. (b)

10. (c)

11. (c)