Moles, Empirical and Molecular Formulas

1. How many of phosphate ions are present in $3.01 \times 10^{23}$ formula units of copper (II) phosphate?
   (A) 2
   (B) 3
   (C) $6.02 \times 10^{23}$
   (D) $1.2 \times 10^{24}$
   (E) $3.01 \times 10^{23}$

2. A gas sample contains 16.0 g of CH$_4$, 16.0 g of O$_2$, 16.0 g of SO$_2$, and 33.0 g of CO$_2$. What is the total number of moles of gas in the sample?
   (A) 2.25 moles
   (B) 2.50 moles
   (C) 2.75 moles
   (D) 3.00 moles
   (E) 4.00 moles

3. How many grams of calcium fluoride contain 38 grams of fluoride atoms?
   (A) 39 grams
   (B) 78 grams
   (C) 38 grams
   (D) 57 grams
   (E) 59 grams

4. How many mL of SO$_2$ gas are present at STP in a 100 gram sample that is 6.4% SO$_2$ by mass?
   (A) 2.24 mL
   (B) 22.4 mL
   (C) 2240 mL
   (D) 1120 mL
   (E) 11.2 mL

5. How many moles of chloride ions are present in a 66.7 gram sample of AlCl$_3$?
   (A) 0.5 moles
   (B) 1.0 mole
   (C) 1.5 moles
   (D) 2.0 moles
   (E) 1.33 moles

6. How many oxygen atoms are there in 22.0 g of carbon dioxide?
   (A) $1.42 \times 10^{24}$
   (B) $6.02 \times 10^{23}$
   (C) $1.20 \times 10^{24}$
7. The empirical formula for an oxide of nitrogen that is 30.4% by mass nitrogen is

(A) NO
(B) NO₂
(C) N₂O
(D) NO₄
(E) NO₃

8. Rubbing alcohol was found to contain 60.0% carbon, 13.4% hydrogen, and the remaining mass was due to oxygen. What is the empirical formula of rubbing alcohol?

(A) C₃H₈O
(B) C₂H₆O
(C) CH₃O
(D) C₂H₄O
(E) CHO

9. Potassium metal (3.91 g) is allowed to react with excess oxygen (O₂). The reaction yields 7.11 g of an explosive, yellow solid called a “superoxide.” What is the empirical formula of the compound?

(A) KO
(B) KO₂
(C) K₂O
(D) K₂O₃
(E) K₃O₂

10. Hydrated salts are very common. If you heat 2.374 g of CoCl₂ • x H₂O, and find that 1.294 g of CoCl₂ remains, what is the value of x?

(A) 2
(B) 3
(C) 4
(D) 5
(E) 6

11. When a hydrate of Na₂CO₃ is heated until all the water is removed, it loses 33.8 percent of its mass. The formula of the hydrate is

(A) Na₂CO₃ • 10 H₂O
(B) Na₂CO₃ • 7 H₂O
(C) Na₂CO₃ • 5 H₂O
(D) Na₂CO₃ • 3 H₂O
(E) Na₂CO₃ • H₂O
12. A compound has an empirical formula of $\text{C}_2\text{H}_4\text{O}$. An independent analysis gave a value of 132 g for its molar mass. What is the molecular formula of the compound?

(A) $\text{C}_4\text{H}_4\text{O}_5$
(B) $\text{C}_{10}\text{H}_{12}$
(C) $\text{C}_7\text{O}_3$
(D) $\text{C}_6\text{H}_{12}\text{O}_3$
(E) $\text{C}_4\text{H}_8\text{O}_5$

13. A 54 gram sample of an unknown hydrocarbon was burned in the presence of excess oxygen to produce 44.0 grams of carbon dioxide and 27.0 grams of water. A mass spectrometry analysis produced a molecular ion peak with an mass of 30.08 u. What is the molecular formula of the hydrocarbon?

(A) $\text{CH}_3$
(B) $\text{C}_2\text{H}_3$
(C) $\text{CH}_6$
(D) $\text{C}_2\text{H}_8$
(E) $\text{C}_2\text{H}_6$

14. In a quantitative analysis study, 4.624 grams of a compound containing carbon, hydrogen and oxygen yielded 6.557 g of $\text{CO}_2$ and 5.00 L of $\text{H}_2\text{O}$ vapor (at STP) in a combustion analysis apparatus. Determine the empirical formula of the compound.

(A) $\text{CH}_2\text{O}$
(B) $\text{CH}_3\text{O}$
(C) $\text{CH}_4\text{O}$
(D) $\text{C}_2\text{H}_4\text{O}$
(E) $\text{C}_4\text{H}_2\text{O}$

15. To find the formula of a compound composed of iron and carbon monoxide, $\text{Fe}_x(\text{CO})_y$, you burn the compound in pure oxygen according to the following, unbalanced equation.

$$\text{Fe}_x(\text{CO})_y(s) + \text{O}_2(g) \rightarrow \text{Fe}_2\text{O}_3(s) + \text{CO}_2(g)$$

If you burn 1.959 g of $\text{Fe}_x(\text{CO})_y$ and find 0.860 g of $\text{Fe}_2\text{O}_3$ and 2.133 g of $\text{CO}_2$, what is the empirical formula of $\text{Fe}_x(\text{CO})_y$?

(A) $\text{Fe(CO)}_4$
(B) $\text{Fe}_2(\text{CO})_9$
(C) $\text{Fe(CO)}_5$
(D) $\text{Fe(CO)}_6$
(E) $\text{Fe}_2(\text{CO})_3$

**Chemical Reactions and Stoichiometry**

16. Consider the hypothetical chemical reaction represented by the equation

$$3 \text{ A} + 2 \text{ B} \rightarrow \text{A}_3\text{B}_2$$

Which of the following is a correct interpretation of this equation?
I. 3 grams of A react with 2 grams of B to form 1 gram of $A_3B_2$

II. 3 atoms of A react with 2 atoms of B to form 1 molecule of $A_3B_2$

III. 3 moles of A react with 2 moles of B to form 1 mole of $A_3B_2$

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

17. Aluminum metal is added to an aqueous solution of Copper(II)sulfate to produce aluminum sulfate and copper metal. When balanced, what is the coefficient in front of elemental aluminum?

(A) 1  
(B) 2  
(C) 3  
(D) 4  
(E) 6

18. When the following equation is balanced, the coefficients are ________.

$$C_8H_{18} + O_2 \rightarrow CO_2 + H_2O$$

(A) 2, 3, 4, 4  
(B) 1, 4, 8, 9  
(C) 2, 12, 8, 9  
(D) 4, 4, 32, 36  
(E) 2, 25, 16, 18

19. When the following equation is balanced, the coefficients are ________.

$$Al(NO_3)_3 + Na_2S \rightarrow Al_2S_3 + NaN_3$$

(A) 2, 3, 1, 6  
(B) 2, 1, 3, 2  
(C) 1, 1, 1, 1  
(D) 4, 6, 3, 2  
(E) 2, 3, 2, 3

20. Write and balance the equation for the combustion of ascorbic acid ($C_6H_8O_6$, vitamin C) in oxygen to CO$_2$ and H$_2$O.

(A) $C_6H_8O_6 + 3O_2 \rightarrow 6CO_2 + 4H_2O$  
(B) $C_6H_8O_6 + 5O_2 \rightarrow 6CO_2 + 4H_2O$  
(C) $2C_6H_8O_6 + 5O_2 \rightarrow 12CO_2 + 8H_2O$  
(D) $C_6H_8O_6 + O_2 \rightarrow CO_2 + H_2O$  
(E) $C_6H_8O_6 + 4O_2 \rightarrow 6CO_2 + 4H_2O$
21. Nitrogen oxide is oxidized in air to give brown nitrogen dioxide.

\[
\text{NO}(g) + \text{O}_2(g) \rightarrow 2 \text{NO}_2(g)
\]

If you have 2.2 moles of NO,

(A) you need 2.2 moles of \( \text{O}_2 \) for complete reaction and produce 2.2 moles of \( \text{NO}_2 \).
(B) you need 1.1 moles of \( \text{O}_2 \) for complete reaction and produce 2.2 moles of \( \text{NO}_2 \).
(C) you need 1.1 moles of \( \text{O}_2 \) for complete reaction and produce 3.3 moles of \( \text{NO}_2 \).
(D) you need 1.0 moles of \( \text{O}_2 \) for complete reaction and produce 2.0 moles of \( \text{NO}_2 \).
(E) you need 2.0 moles of \( \text{O}_2 \) for complete reaction and produce 1.0 moles of \( \text{NO}_2 \).

22. The very stable compound \( \text{SF}_6 \) is made by burning sulfur in an atmosphere of fluorine.

\[
\text{S}_8(s) + 24\text{F}_2(g) \rightarrow 8\text{SF}_6(g)
\]

If you need 2.50 moles of \( \text{SF}_6 \), you will need to use

(A) 0.313 moles of \( \text{S}_8 \) and 7.50 moles of \( \text{F}_2 \).
(B) 1.00 moles of \( \text{S}_8 \) and 24.0 moles of \( \text{F}_2 \).
(C) 0.125 moles of \( \text{S}_8 \) and 3.00 moles of \( \text{F}_2 \).
(D) 8.00 moles of \( \text{S}_8 \) and 24.0 moles of \( \text{F}_2 \).
(E) 2.00 moles of \( \text{S}_8 \) and 12.0 moles of \( \text{F}_2 \).

23. Magnesium and nitrogen react in a combination reaction to produce magnesium nitride:

\[
3 \text{Mg} + \text{N}_2 \rightarrow \text{Mg}_3\text{N}_2
\]

In a particular experiment, a 9.27-g sample of \( \text{N}_2 \) reacts completely. The mass of \( \text{Mg} \) consumed is ________ g.

(A) 8.04
(B) 24.1
(C) 16.1
(D) 0.92
(E) 13.9

24. Given the unbalance equation below, determine how many liters of \( \text{H}_2 \) gas will be produced when 51 grams of \( \text{NH}_3 \) decompose completely @ STP.

\[
\text{NH}_3(g) \rightarrow \text{N}_2(g) + \text{H}_2(g)
\]

(A) 101 L
(B) 11.2 L
(C) 44.8 L
(D) 89.6 L
(E) 67.2 L
25. Propane burns in the presence of oxygen to produce carbon dioxide and water vapor. How many total moles of gas are produced when 50% of a 88.2 gram sample of propane combusts?

(A) 3 mol  
(B) 6 mol  
(C) 7 mol  
(D) 10 mol  
(E) 15 mol

26. An aqueous solution of NaCl gives H₂(g), Cl₂(g), and NaOH when an electrical current is passed through the solution.

\[ \text{2NaCl(aq) + 2H}_2\text{O(l) → H}_2\text{(g) + Cl}_2\text{(g) + 2NaOH(aq)} \]

If you begin with 10. liters of 0.15 M NaCl, how many grams of NaOH can be formed?

(A) 60. g  
(B) 120 g  
(C) 30. g  
(D) 6.0 g  
(E) 40. g

27. How many total liters of gas can be produced @STP if 9.0 grams of aluminum metal react with 200 mL of 10.0 M HCl?

\[ \text{2Al(s) + 6H}^+(aq) → 2\text{Al}^{3+}(aq) + 3\text{H}_2(g) \]

(A) 3.0 L  
(B) 11.2 L  
(C) 22.4 L  
(D) 7.47 L  
(E) 89.6 L

28. Pentacarbonyliron (Fe(CO)₅) reacts with phosphorous trifluoride (PF₃) and hydrogen, releasing carbon monoxide:

\[ \text{Fe(CO)}₅ + \text{PF}_3 + \text{H}_2 → \text{Fe(CO)}₂(\text{PF}_3)(\text{H})₂ + \text{CO} \] (not balanced)

The reaction of 5.0 mol of Fe(CO)₅, 8.0 mol of PF₃ and 6.0 mol of H₂ will release _______ mol of CO.

(A) 15  
(B) 5.0  
(C) 24  
(D) 6.0  
(E) 12

29. Consider the following redox reaction. What is the amount of Cr³⁺ formed if 100.0 mL of 0.200M Cr₂O₇⁻ is mixed with 100.0 mL of 0.300M Cl⁻ solution that contains a large excess of H⁺?

\[ 14\text{H}^+ + \text{Cr}_2\text{O}_7^{2-} + 6\text{Cl}^- → 3\text{Cl}_2 + 2\text{Cr}^{3+} + 7\text{H}_2\text{O} \]
30. Consider the following reaction. If 31.6 grams of magnesium hydroxide is combined with 68.0 mL of 0.725 M HBr, how many moles of the excess reagent will be left over when the reaction is complete.

\[ \text{Mg(OH)}_2(s) + 2\text{HBr}(aq) \rightarrow \text{MgBr}_2(aq) + 2\text{H}_2\text{O}(l) \]

(A) 0.0247 mol Mg(OH)
(B) 0.517 mol Mg(OH)
(C) 0.493 mol HBr
(D) 0.0247 mol HBr
(E) 1.08 mol H\(_2\)O

31. Sulfur and oxygen react to produce sulfur trioxide. In a particular experiment, 7.9 grams of SO\(_3\) are produced by the reaction of 5.0 grams of O\(_2\) with 6.0 grams of S. What is the % yield of SO\(_3\) in this experiment?

\[ \text{S} (s) + \text{O}_2(g) \rightarrow \text{SO}_3(g) \] (not balanced)

(A) 32
(B) 63
(C) 75
(D) 95
(E) 99

32. GeF\(_3\)H is formed from GeH\(_4\) and GeF\(_4\) in the combination reaction:

\[ \text{GeH}_4 + 3\text{GeF}_4 \rightarrow 4\text{GeF}_3\text{H} \]

If the reaction yield is 92.6%, how many moles of GeF\(_4\) are needed to produce 8.00 mol of GeF\(_3\)H?

(A) 3.24
(B) 5.56
(C) 6.48
(D) 2.78
(E) 2.16

33. Sulfur and fluorine react in a combination reaction to produce sulfur hexafluoride:

\[ \text{S} (s) + 3\text{F}_2(g) \rightarrow \text{SF}_6(g) \]

In a particular experiment, the percent yield is 79.0%. This means that in this experiment, a 7.90-g sample of fluorine yields _______ g of SF\(_6\).
Precipitation Reactions

34. When aqueous solutions of _______ are mixed, a precipitate forms.

(A) NiBr$_2$ and AgNO$_3$
(B) NaI and KBr
(C) K$_2$SO$_4$ and CrCl$_3$
(D) KOH and Ba(NO$_3$)$_2$
(E) Li$_2$CO$_3$ and CsI

35. Which combination will produce a precipitate?

(A) NaC$_2$H$_3$O$_2$ (aq) and HCl (aq)
(B) NaOH (aq) and HCl (aq)
(C) AgNO$_3$ (aq) and Ca(C$_2$H$_3$O$_2$)$_2$ (aq)
(D) KOH (aq) and Mg(NO$_3$)$_2$ (aq)
(E) NaOH (aq) and HI (aq)

36. The equation for the reaction, BaCl$_2$(aq) + K$_2$CrO$_4$(aq) → BaCrO$_4$(s) + KCl(aq), can be written as an ionic equation. In the ionic equation, the spectator ions are

(A) Ba$^{2+}$ and K$^+$
(B) K$^+$ and CrO$_4^{2-}$
(C) K$^+$ and Cl$^-$
(D) B$^{2+}$ and CrO$_4^{2-}$
(E) Cl$^-$ and CrO$_4^{2-}$

37. Aqueous potassium chloride will react with which one of the following in an exchange (metathesis) reaction?

(A) calcium nitrate
(B) sodium bromide
(C) lead nitrate
(D) barium nitrate
(E) sodium chloride

38. With which of the following will the ammonium ion form an insoluble salt?

(A) chloride
(B) sulfate
(C) carbonate
(D) sulfate and carbonate
(E) none of the above
39. If aqueous solutions of barium iodide are sodium sulfate are mixed and the resulting solution filtered, what ions would be present dissolved in the filtrate?

(A) barium ion and sulfate ions  
(B) barium ion and iodide ion  
(C) sodium ion and iodide ion  
(D) sodium ion and barium ion  
(E) sodium ion and sulfate ion

40. In a qualitative analysis for the presence of Ag\(^{+}\), Mg\(^{2+}\), and Zn\(^{2+}\) ions in an aqueous solution, which of the following will allow the separation of Pb\(^{2+}\) from the other ions at room temperature?

(A) Adding dilute Na\(_2\)S(aq) solution  
(B) Adding dilute HCl(aq) solution  
(C) Adding dilute NaOH(aq) solution  
(D) Adding dilute NH\(_3\) (aq) solution  
(E) Adding dilute HNO\(_3\) (aq) solution

41. The net ionic equation for formation of an aqueous solution of Al(NO\(_3\))\(_3\) via mixing solid Al(OH)\(_3\) and aqueous nitric acid is ________.

(A) Al(OH)\(_3\) (s) + 3HNO\(_3\) (aq) → 3 H\(_2\)O (l) + Al(NO\(_3\))\(_3\) (aq)  
(B) Al(OH)\(_3\) (s) + 3NO\(_3\)^- (aq) → 3OH\(^-\) (aq) + Al(NO\(_3\))\(_3\) (aq)  
(C) Al(OH)\(_3\) (s) + 3NO\(_3\)^- (aq) → 3OH\(^-\) (aq) + Al(NO\(_3\))\(_3\) (s)  
(D) Al(OH)\(_3\) (s) + 3H\(^+\) (aq) → 3 H\(_2\)O (l) + Al\(^{3+}\) (aq)  
(E) Al(OH)\(_3\) (s) + 3HNO\(_3\) (aq) → 3 H\(_2\)O (l) + Al\(^{3+}\) (aq) + NO\(_3\)^- (aq)

42. Two aqueous solutions are mixed forming a yellow precipitate. Which of the following could be the correct identity of the two aqueous solutions?

(A) Pb(NO\(_3\))\(_2\)(aq) and AgNO\(_3\)(aq)  
(B) NaI(aq) and AgNO\(_3\)(aq)  
(C) CuNO\(_3\)(aq) and MgSO\(_4\)(aq)  
(D) AgC\(_2\)H\(_3\)O\(_2\)(aq) and K\(_2\)S(aq)  
(E) Sr(NO\(_3\))\(_2\)(aq) and KOH(aq)

43. Two aqueous solutions are mixed forming a blue precipitate. Which of the following could be the correct identity of the two aqueous solutions?

(A) Fe(NO\(_3\))\(_2\)(aq) and AgNO\(_3\)(aq)  
(B) NaI(aq) and AgNO\(_3\)(aq)  
(C) CuNO\(_3\)(aq) and NaOH(aq)  
(D) AgC\(_2\)H\(_3\)O\(_2\)(aq) and K\(_2\)S(aq)  
(E) Sr(NO\(_3\))\(_2\)(aq) and KOH(aq)

44. A yellow precipitate forms when 0.10 M NaI(aq) is added to a 0.10 M solution of which of the following ions?

(A) Pb\(^{2+}\)(aq)  
(B) Zn\(^{2+}\)(aq)
45. A 20.0-milliliter sample of 0.200-molar Na₂CO₃ solution is added to 30.0 milliliters of 0.400-molar Sr(NO₃)₂ solution. Strontium carbonate precipitates. The concentration of strontium ion, Sr²⁺, in solution after reaction is

(A) 0.150 M  
(B) 0.160 M  
(C) 0.200 M  
(D) 0.240 M  
(E) 0.267 M

46. A 1.0 M sample of an aqueous solution contains 0.10 mol of NaI and 0.10 mol of CaI₂. What is the minimum number of moles of PbNO₃ that must be added to the solution in order to precipitate all of the I⁻ as PbI(s) ?

(A) 0.10 mol  
(B) 0.20 mol  
(C) 0.30 mol  
(D) 0.40 mol  
(E) 0.60 mol

47. What would be the correct order of ions from highest to lowest concentration in the solution after 100 mL of 0.2 M Na₃PO₄ is mixed with 100 mL of 0.2 M AgNO₃ (aq)?

(A) [PO₄³⁻] < [NO₃⁻] < [Na⁺]  
(B) [PO₄³⁻] < [Na⁺] < [NO₃⁻]  
(C) [NO₃⁻] < [PO₄³⁻] < [Na⁺]  
(D) [Na⁺] < [NO₃⁻] < [PO₄³⁻]  
(E) [Na⁺] < [PO₄³⁻] < [NO₃⁻]

**Acids and Bases**

48. Which statement below is correct?

(A) All four aqueous hydrogen halides are strong acids.  
(B) Of the four aqueous hydrogen halides, only HF is a weak acid.  
(C) All strong oxoacids have four oxygens.  
(D) All four chlorine oxoacids are strong acids.  
(E) None of the above

49. Which statement below states a fact? (Hint: Remember the difference between dissociation and ionization).

(A) All acids are strong electrolytes and dissociate completely when dissolved in water.  
(B) Some acids are strong electrolytes and ionize completely when dissolved in water.  
(C) Some acids are strong electrolytes and dissociate completely when dissolved in water.  
(D) Some acids are weak electrolytes and ionize completely when dissolved in water.  
(E) Some acids are weak electrolytes and dissociate partially when dissolved in water.
50. An acid-base neutralization is the reaction of

(A) $\text{H}_2(g)$ with $\text{O}_2(g)$ to form $\text{H}_2\text{O}(l)$
(B) $\text{H}_2(aq)$ with $\text{OH}(aq)$ to form $\text{H}_2\text{O}(l)$
(C) $\text{H}^+(aq)$ with $\text{O}_2(g)$ to form $\text{H}_2\text{O}(l)$
(D) $\text{H}^+(aq)$ with $\text{OH}(aq)$ to form $\text{H}_2\text{O}(l)$
(E) $\text{Na}^+(aq)$ with $\text{OH}(aq)$ to form $\text{NaOH}(aq)$

51. Which one of the equations below represents what happens when $\text{NH}_3$ is dissolved in water?

(A) $\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+(aq) + \text{NH}_3(aq)$
(B) $\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^+(aq) + \text{NH}_2^-(aq)$
(C) $\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+(aq) + \text{OH}(aq)$
(D) $\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{H}_3\text{O}^-(aq) + \text{NH}_2^+(aq)$
(E) $\text{NH}_3 + \text{H}_2\text{O} \rightarrow 2 \text{H}^+(aq) + \text{OH}(aq) + \text{NH}_2^-(aq)$

52. Predict the products of the following acid-base reaction:

$\text{HCl(aq)} + \text{NaCH}_3\text{COO(aq)} \rightarrow ?$

(A) $\text{H}_2\text{O}(l) + \text{NaCl}(aq)$
(B) $\text{H}_2\text{O}(l) + \text{OH}^-(aq)$
(C) $\text{NaCl}(aq) + \text{CH}_3\text{COOH(aq)}$
(D) no reaction takes place

53. The following reactants are mixed in equal molar portions. Predict if the resulting solution will be acidic, basic, neutral, or if there is not enough information given to tell for sure.

$\text{HCl(aq)} + \text{NaHCO}_3(aq) \rightarrow ?$

(A) acidic
(B) basic
(C) neutral
(D) cannot be determined from information given

54. In the reaction, $\text{HClO}_3 + \text{N}_2\text{H}_4 \rightleftharpoons \text{ClO}_3^- + \text{N}_2\text{H}_5^+$, which species are a conjugate acid-base pair?

(A) $\text{HClO}_3, \text{N}_2\text{H}_4$
(B) $\text{N}_2\text{H}_4, \text{ClO}_3^-$
(C) $\text{HClO}_3, \text{N}_2\text{H}_5^+$
(D) $\text{N}_2\text{H}_4, \text{N}_2\text{H}_5^+$
(E) $\text{ClO}_3^-, \text{N}_2\text{H}_5^+$

55. The conjugate base of $\text{H}_2\text{PO}_4^-$ is ________.
56. The conjugate acid of HSO$_4^-$ is __________.

   (A) SO$_4^{2-}$
   (B) H$_2$SO$_4$
   (C) HSO$_4^+$
   (D) H$^+$
   (E) H$_2$O$_3^+$

57. Which of the following substances is not amphoteric?

   (A) H$_2$O(l)
   (B) HCO$_3^-$ ion
   (C) NH$_4^+$ ion
   (D) H$_2$PO$_4^-$ ion
   (E) NH$_3$(aq)

58. Which species is amphoteric?

   (A) HNO$_3$(aq)
   (B) Cl(g)
   (C) CO$_3^{2-}$(aq)
   (D) HSO$_3^-$(aq)
   (E) PO$_4^{3-}$(aq)

59. Aqueous solutions of a compound did not form precipitates with Cl$^-$, Br$^-$, I$^-$, SO$_4^{2-}$, CO$_3^{2-}$, PO$_4^{3-}$, OH$^-$, or S$^{2-}$. This highly water-soluble compound produced the foul-smelling gas H$_2$S when the solution was acidified. This compound is __________.

   (A) Pb(NO$_3$)$_2$
   (B) (NH$_4$)$_2$S
   (C) KBr
   (D) Li$_2$CO$_3$
   (E) AgNO$_3$

60. The reaction between strontium hydroxide and chloric acid produces __________.

   (A) a molecular compound and a weak electrolyte
   (B) two weak electrolytes
   (C) two strong electrolytes
   (D) a molecular compound and a strong electrolyte
   (E) two molecular compounds

61. The balanced molecular equation for complete neutralization of H$_2$SO$_4$ by KOH in aqueous solution is __________.
62. The balanced reaction between aqueous nitric acid and aqueous strontium hydroxide is ________.

(A) \( \text{HNO}_3 \text{(aq)} + \text{Sr(OH)}_2 \text{(aq)} \rightarrow \text{Sr(NO}_3\text{)}_2 \text{(aq)} + \text{H}_2 \text{(g)} \)
(B) \( \text{HNO}_3 \text{(aq)} + \text{Sr(OH)}_2 \text{(aq)} \rightarrow \text{Sr(NO}_3\text{)}_2 \text{(aq)} + \text{H}_2 \text{O (l)} \)
(C) \( \text{HNO}_3 \text{(aq)} + \text{SrOH} \text{(aq)} \rightarrow \text{SrNO}_3 \text{(aq)} + \text{H}_2 \text{O (l)} \)
(D) \( 2\text{HNO}_3 \text{(aq)} + \text{Sr(OH)}_2 \text{(aq)} \rightarrow 2 \text{H}_2 \text{O (l)} + \text{Sr(NO}_3\text{)}_2 \text{(aq)} \)
(E) \( 2\text{HNO}_3 \text{(aq)} + \text{Sr(OH)}_2 \text{(aq)} \rightarrow 2 \text{H}_2 \text{O (l)} + \text{SrSO}_4 \text{(s)} \)

63. The net ionic equation for the reaction between aqueous nitric acid and aqueous sodium hydroxide is ________.

(A) \( \text{H}^+ \text{(aq)} + \text{HNO}_3 \text{(aq)} + 2\text{OH}^- \text{(aq)} \rightarrow 2 \text{H}_2 \text{O (l)} + \text{NO}_3^- \text{(aq)} \)
(B) \( \text{HNO}_3 \text{(aq)} + \text{NaOH} \text{(aq)} \rightarrow \text{NaNO}_3 \text{(aq)} + \text{H}_2 \text{O (l)} \)
(C) \( \text{H}^+ \text{(aq)} + \text{OH}^- \text{(aq)} \rightarrow \text{H}_2 \text{O (l)} \)
(D) \( \text{HNO}_3 \text{(aq)} + \text{OH}^- \text{(aq)} \rightarrow \text{NO}_3^- \text{(aq)} + \text{H}_2 \text{O (l)} \)
(E) \( \text{H}^+ \text{(aq)} + \text{Na}^+ \text{(aq)} + \text{OH}^- \text{(aq)} \rightarrow \text{H}_2 \text{O (l)} + \text{Na}^+ \text{(aq)} \)

64. The net ionic equation for the reaction between aqueous solutions of HF and KOH is ________.

(A) \( \text{HF} + \text{KOH} \rightarrow \text{H}_2 \text{O} + \text{K}^+ + \text{F}^- \)
(B) \( \text{HF} + \text{OH}^- \rightarrow \text{H}_2 \text{O} + \text{F}^- \)
(C) \( \text{HF} + \text{K}^+ + \text{OH}^- \rightarrow \text{H}_2 \text{O} + \text{KF} \)
(D) \( \text{H}^+ + \text{OH}^- \rightarrow \text{H}_2 \text{O} \)
(E) \( \text{H}^+ + \text{F}^- + \text{K}^+ + \text{OH}^- \rightarrow \text{H}_2 \text{O} + \text{K}^+ + \text{F}^- \)

65. Which of the following are strong acids?

I. HI
II. HNO3
III. HF
IV. HBr

(A) III, IV
(B) I, II, III, IV
(C) I, III, IV
(D) II, III, IV
(E) I, II, IV

66. Which set below contains only weak acids?

(A) HC\(_2\)H\(_3\)O\(_2\), HCN, HNO\(_2\)
(B) HC\(_2\)H\(_3\)O\(_2\), HCN, HNO\(_3\)
(C) HC\(_2\)H\(_3\)O\(_2\), HCl, HNO\(_2\)
(D) HClO, HCN, HBrO\(_3\)
(E) HNO\(_2\), HC\(_2\)H\(_3\)O\(_2\), HI
67. Classify the following compounds as weak acids (W) or strong acids (S):

<table>
<thead>
<tr>
<th>Compound</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>benzoic acid</td>
<td>Weak, Weak, Weak</td>
</tr>
<tr>
<td>nitric acid</td>
<td>Strong, Strong, Strong</td>
</tr>
<tr>
<td>acetic acid</td>
<td>Strong, Weak, Weak</td>
</tr>
</tbody>
</table>

68. Which hydroxides are weak bases?

(A) KOH, Ba(OH)$_2$
(B) Sr(OH)$_2$, KOH, NaOH, Ba(OH)$_2$
(C) KOH, NaOH
(D) KOH, NaOH, Ba(OH)$_2$
(E) None of these is a weak base.

69. Which of the following would you predict to be basic when dissolved in water?

I. Sodium nitrate NaNO$_3$
II. Ammonium iodide NH$_4$I
III. Sodium bicarbonate NaHCO$_3$
IV. Sodium hypochlorite NaOCl
V. Potassium acetate KCH$_3$CO$_2$

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

70. What is the molarity of a NaOH solution if 28.2 mL of a 0.355 M H$_2$SO$_4$ solution is required to neutralize a 25.0-mL sample of the NaOH solution?

(A) 0.801
(B) 0.315
(C) 0.629
(D) 1.125
(E) 0.400

71. Oxalic acid is a diprotic acid. If a solid material contains 53.66 percent of oxalic acid (H$_2$C$_2$O$_4$), by mass, then a 0.6543-g sample of that solid will require ______ mL of 0.3483 M NaOH for neutralization.

(A) 11.19
(B) 97.78
(C) 28.59
(D) 1.119
(E) 22.39
72. A 25.5 mL aliquot of HCl (aq) of unknown concentration was titrated with 0.113 M NaOH (aq). It took 51.2 mL of the base to reach the endpoint of the titration. The concentration (M) of the acid was _________.

(A) 1.02  
(B) 0.114  
(C) 0.454  
(D) 0.113  
(E) 0.227

73. A 13.8 mL aliquot of 0.176 M H₃PO₄ (aq) is to be titrated with 0.110 M NaOH (aq). What volume (mL) of base will it take to reach the equivalence point?

(A) 7.29  
(B) 22.1  
(C) 199  
(D) 66.2  
(E) 20.9

74. What is the molar mass of a diprotic acid if after 0.965 gram sample of it is dissolved in water, and 45.91 mL of 0.404 M KOH is needed to titrate it completely?

(A) 104.06 g/mol  
(B) 52.028 g/mol  
(C) 26.014 46 g/mol  
(D) 260.14 46 g/mol  
(E) 36.46 g/mol

75. What is the identity of a monoprotic acid if after 1.26 gram sample of it is dissolved in water, 50 mL of 0.4 M NaOH is needed to titrate it completely?

(A) HClO₃  
(B) HCl  
(C) HBr  
(D) HC₃H₆O₃  
(E) HNO₃

76. Potassium hydrogen phthalate is used as a primary standard in finding the concentration of a solution of sodium hydroxide by the reaction

\[ \text{KHC}_8\text{H}_4\text{O}_4 + \text{NaOH} \rightarrow \text{NaK}_2\text{C}_8\text{H}_4\text{O}_4 + \text{H}_2\text{O} \]

What is the molarity of the base if 32.75 mL is required to titrate 1.732 g of the primary standard?

(A) 0.5189 M  
(B) 0.2590 M  
(C) 1.732 M  
(D) 3.861 M  
(E) 3.275 M
Redox Reactions

77. What is the oxidation number of potassium in KMnO4?

(A) 0
(B) +1
(C) +2
(D) -1
(E) +3

78. What is the oxidation number of bromine in the BrO3- ion?

(A) -1
(B) +1
(C) +3
(D) +5
(E) +7

79. What is the oxidation number of nitrogen in the HNO3?

(A) -1
(B) +1
(C) +3
(D) +5
(E) +7

80. What is the oxidation number of chromium in Cr2O72- ion?

(A) +3
(B) +6
(C) +7
(D) +12
(E) +14

81. Which statement is true concerning an oxidation-reduction reaction?

(A) The reactant which is reduced is the reducing reagent.
(B) The reactant which is oxidized is the reducing reagent.
(C) The reactant which gains electrons is the reducing reagent.
(D) The reactant which loses electrons is the oxidizing reagent.
(E) None of the statements, a—d, is true.

82. The activity series of metals is

Au < Ag < Cu < Sn < Cd < Zn < Al < Mg < Na < Cs

Which reaction below does not occur spontaneously upon mixing the reagents shown?
83. Which of the following involves oxidation?

(A) Ca^{2+}(aq) + CO_3^{2-}(aq) → CaCO_3(s)
(B) 2 H^+(aq) + SO_3^{2-}(aq) → H_2O(l) + SO_2(g)
(C) VO_4^{3-}(aq) → VO_2^{2+}(aq)
(D) CrO_2^{2-}(aq) → CrO_4^{2-}(aq)
(E) 2 S_2O_7^{2-}(aq) + H_2O(l) → 2 SO_4^{2-}(aq) + 2 H^+(aq)

84. ________ is reduced in the following reaction:

Cr_2O_7^{2-} + 6S_2O_3^{2-} + 14H^+ → 2Cr^{3+} + 3S_4O_6^{2-} + 7H_2O

(A) Cr^6+
(B) S^2+
(C) H^+
(D) O^2-
(E) S_4O_6^{2-}

85. ________ is the oxidizing agent in the reaction below.

Cr_2O_7^{2-} + 6S_2O_3^{2-} + 14H^+ → 2Cr^{3+} + 3S_4O_6^{2-} + 7H_2O

(A) Cr_2O_7^{2-}
(B) S_2O_3^{2-}
(C) H^+
(D) Cr^{3+}
(E) S_4O_6^{2-}

86. Which substance is serving as the reducing agent in the following reaction?

14H^+ + Cr_2O_7^{2-} + 3Ni → 3Ni^{2+} + 2Cr^{3+} + 7H_2O

(A) H^+
(B) Cr_2O_7^{2-}
(C) Ni
(D) H_2O
(E) Ni^{2+}

87. Which substance is the reducing agent in the reaction below?

Pb + PbO_2 + 2H_2SO_4 → 2PbSO_4 + 2H_2O

(A) Pb
(B) H_2SO_4
(C) PbO_2
88. Which element is reduced in the reaction below?

\[ \text{Fe}^{2+} + \text{H}^+ + \text{Cr}_2\text{O}_7^{2-} \rightarrow \text{Fe}^{3+} + \text{Cr}^{3+} + \text{H}_2\text{O} \]

(A) Fe  
(B) Cr  
(C) O  
(D) H

89. Which element is oxidized in the reaction below?

\[ \text{I}^{-} + \text{MnO}_4^{-} + \text{H}^+ \rightarrow \text{I}_2 + \text{MnO}_2 + \text{H}_2\text{O} \]

(A) I  
(B) Mn  
(C) O  
(D) H

90. Which element is reduced in the reaction below?

\[ \text{I}^{-} + \text{MnO}_4^{-} + \text{H}^+ \rightarrow \text{I}_2 + \text{MnO}_2 + \text{H}_2\text{O} \]

(A) I  
(B) Mn  
(C) O  
(D) H

91. Which one of the following reactions is a redox reaction?

(A) \( \text{NaOH} + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O} \)
(B) \( \text{Pb}^{2+} + \text{Cl}^- \rightarrow \text{PbCl}_2 \)
(C) \( \text{AgNO}_3 + \text{HCl} \rightarrow \text{HNO}_3 + \text{AgCl} \)
(D) None of the above is a redox reaction.

92. Which element is oxidized in the reaction below?

\[ \text{Fe(CO)}_5(l) + 2\text{Hl}(g) \rightarrow \text{Fe(CO)}_4\text{l}_2(s) + \text{CO}(g) + \text{H}_2(g) \]

(A) Fe  
(B) C  
(C) O  
(D) H  
(E) I

93. Which element is reduced in the reaction below?

\[ \text{Fe(CO)}_5(l) + 2\text{Hl}(g) \rightarrow \text{Fe(CO)}_4\text{l}_2(s) + \text{CO}(g) + \text{H}_2(g) \]
94. Which substance is the reducing agent in the following reaction?

$$\text{Fe}_2\text{S}_3 + 12\text{HNO}_3 \rightarrow 2\text{Fe(NO}_3)_3 + 3\text{S} + 6\text{NO}_2 + 6\text{H}_2\text{O}$$

(A) HNO$_3$
(B) S
(C) NO$_2$
(D) Fe$_2$S$_3$
(E) H$_2$O

95. Zinc metal reacts with perchloric acid solution to produce zinc perchlorate (in solution) and hydrogen gas, which escapes. The species being oxidized in this reaction is

(A) HClO$_4$\text{(aq)}
(B) H$_2$\text{(g)}
(C) Zn$^{2+}$\text{(aq)}
(D) Zn\text{(s)}
(E) Zn(ClO$_4$)$_2$\text{(aq)}

96. Which of the following statements is true about oxidizing and reducing agents?

(A) Good reducing agent must lose electrons easily. Neutral metals or substances with low ionization energies
(B) Good reducing agent must gain electrons easily. Neutral metals or substances with low ionization energies
(C) Good oxidizing agents must lose electrons easily. Neutral or positive nonmetals or highly positive metals
(D) Good oxidizing agents must gain electrons easily. Neutral or negative nonmetals or highly negative metals

97. Which of the following are considered good oxidizing agents?

I. Na
II. MnO$_4^-$
III. F$_2$
IV. I$^-$
V. Fe$^{3+}$

(A) I and II
(B) II and III
(C) II and III
(D) III and IV
(E) I and IV

98. Which of the following are considered good reducing agents?
I. HNO$_3$ (concentrated)
II. K
III. Cr$_2$O$_7^{2-}$
IV. Fe$^{2+}$
V. F$^-$

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

99. What is the coefficient of the permanganate ion when the following equation is balanced?

\[ \text{MnO}_4^- + \text{Br}^- \rightarrow \text{Mn}^{2+} + \text{Br}_2 \quad \text{(acidic solution)} \]

(A) 1  
(B) 2  
(C) 3  
(D) 5  
(E) 4

100. What is the coefficient of the dichromate ion when the following equation is balanced?

\[ \text{Fe}^{2+} + \text{Cr}_2\text{O}_7^{2-} \rightarrow \text{Fe}^{3+} + \text{Cr}^{3+} \quad \text{(acidic solution)} \]

(A) 1  
(B) 2  
(C) 3  
(D) 5  
(E) 6

101. What is the coefficient of Fe$^{3+}$ when the following equation is balanced?

\[ \text{CN}^- + \text{Fe}^{3+} \rightarrow \text{CNO}^- + \text{Fe}^{2+} \quad \text{(basic solution)} \]

(A) 1  
(B) 2  
(C) 3  
(D) 4  
(E) 5

102. Balance the half-reaction, H$_2$S $\rightarrow$ S$_8$, taking place in acidic media. How many electrons are needed to balance the half reaction?

(A) 12 electrons, left side
(B) 16 electrons, right side
(C) 14 electrons, left side
(D) 6 electrons, right side
(E) 8 electrons, right side
103. Balance the half-reaction, \( C_8H_{10} \to C_8H_4O_4^{2-} \), taking place in basic media. How many electrons are needed to balance the half reaction?

(A) 4 electrons, left side  
(B) 8 electrons, right side  
(C) 8 electrons, left side  
(D) 12 electrons, left side  
(E) 12 electrons, right side

104. Complete the balancing of the following half-reaction, taking place in basic media,

\[
\text{Cr(OH)}_4^-(aq) \to \text{CrO}_4^{2-}(aq)
\]

How many hydroxide ions are needed to balance it?

(A) 1 hydroxide ion, on the left side  
(B) 3 hydroxide ions, on the right side  
(C) 3 hydroxide ions, on the left side  
(D) 4 hydroxide ions, on the left side  
(E) 4 hydroxide ions, on the right side

105. After balancing of the equation for the reaction,

\[
H^+ + \text{HSO}_3^-(aq) + \text{MnO}_4^-(aq) \to \text{MnO}_2(s) + \text{HSO}_4^-(aq) + H_2O
\]

what is the sum of ALL the coefficients in the equation?

(A) 7  
(B) 9  
(C) 13  
(D) 15  
(E) 19

106. What is the balanced net ionic equation for the following reaction in an acidic solution?

\[
\text{Cd} + \text{NO}_3^- \to \text{Cd}^{2+} + \text{N}_2\text{O}
\]

(A) \( \text{Cd} + 2\text{NO}_3^- + \text{H}^+ \to 4\text{Cd}^{2+} + \text{N}_2\text{O} + \text{H}_2\text{O} \)  
(B) \( 4\text{Cd} + 2\text{NO}_3^- + 10\text{H}^+ \to 4\text{Cd}^{2+} + \text{N}_2\text{O} + 5\text{H}_2\text{O} \)  
(C) \( \text{Cd} + \text{NO}_3^- + \text{H}^+ \to \text{Cd}^{2+} + \text{N}_2\text{O} + \text{H}_2\text{O} \)  
(D) \( \text{Cd} + 2\text{NO}_3^- \to 4\text{Cd}^{2+} + \text{N}_2\text{O} \)

107. Consider the following half-reaction balanced for an acidic solution:

\[
2\text{H}_2\text{O} + \text{SeO}_2 \to \text{SeO}_4^{2-} + 4\text{H}^+ + 2\text{e}^-
\]

What is the balanced half-reaction for a basic solution?
108. Balance the following equation for a basic solution.

\[ \text{MnO}_4^- + \text{C}_2\text{O}_4^{2-} \rightarrow \text{MnO}_2 + \text{CO}_3^{2-} \]

(A) \[2\text{MnO}_4^- + 3\text{C}_2\text{O}_4^{2-} \rightarrow 2\text{MnO}_2 + 6\text{CO}_3^{2-} + \text{H}_2\text{O} \]

(B) \[2\text{MnO}_4^- + 3\text{C}_2\text{O}_4^{2-} \rightarrow 2\text{MnO}_2 + 6\text{CO}_3^{2-} \]

(C) \[2\text{MnO}_4^- + 3\text{C}_2\text{O}_4^{2-} + 4\text{OH}^- \rightarrow 2\text{MnO}_2 + 6\text{CO}_3^{2-} + \text{H}_2\text{O} \]

(D) \[2\text{MnO}_4^- + 3\text{C}_2\text{O}_4^{2-} + 4\text{OH}^- \rightarrow 2\text{MnO}_2 + 6\text{CO}_3^{2-} + \text{H}_2\text{O} \]

109. The reaction of Cl\(_2\) with itself can be carried out in basic solutions.

\[ \text{Cl}_2 \rightarrow \text{ClO}_3^- + \text{Cl}^- \]

Balance the equation in a basic solution.

(A) \[\text{Cl}_2 + 6\text{H}_2\text{O} \rightarrow 2\text{ClO}_3^- + 12\text{H}^+ + 10\text{e}^- \]

(B) \[6\text{Cl}_2 + 10\text{OH}^- \rightarrow 2\text{ClO}_3^- + 10\text{Cl}^- + 6\text{H}_2\text{O} \]

(C) \[6\text{Cl}_2 \rightarrow 10\text{Cl}^- + 2\text{ClO}_3^- \]

(D) \[6\text{Cl}_2 + 12\text{OH}^- \rightarrow 2\text{ClO}_3^- + 10\text{Cl}^- + 6\text{H}_2\text{O} \]

110. The following is the balanced net ionic equation for an oxidation-reduction reaction.

\[ \text{MnO}_2(\text{s}) + 2 \text{I}^-(\text{aq}) + 4 \text{H}^+(\text{aq}) \rightarrow \text{I}_2(\text{aq}) + \text{Mn}^{2+}(\text{aq}) + 2 \text{H}_2\text{O(1)} \]

If you use 1.234 g of \text{MnO}_2 (\text{molar mass} = 86.937\text{g/mol}), how many milliliters of 0.730M HCl solution are required for complete reaction?

(A) 2.5 mL

(B) 77.8 mL

(C) 4.86 mL

(D) 25.7 mL

(E) 38.9 mL

111. Hydrogen peroxide, H\(_2\)O\(_2\), can be determined by titration with permanganate solution. If it required 80.0 mL of 0.0220 molar \text{MnO}_4^-(aq) solution to titrate 5.0 mL of a H\(_2\)O\(_2\)(aq) solution, what is the molarity of the H\(_2\)O\(_2\)(aq) solution?

\[ 2 \text{MnO}_4^-(aq) + 5 \text{H}_2\text{O}_2(aq) + 6 \text{H}^+ \rightarrow 5\text{O}_2(g) + 2 \text{Mn}^{2+}(aq) + 8 \text{H}_2\text{O} \]

(A) 0.14 M

(B) 0.18 M

(C) 0.35 M

(D) 0.62 M

(E) 0.88 M
Use the following choices to answer question 29-34.

(A) Orange to green
(B) Blue to colorless
(C) purple to colorless
(D) Orange to yellow
(E) green to yellow/brown

What color changes would you expect for the following redox processes

112. ____ Cr₂O₇²⁻(aq) → CrO₄²⁻(aq)
113. ____ MnO₄⁻(aq) → Mn²⁺(aq)
114. ____ Fe²⁺(aq) → Fe³⁺(aq)
115. ____ Cr₂O₇²⁻(aq) → Cr³⁺(aq)
116. ____ Cu²⁺(aq) → Cu⁺(aq)

117. What would be the expected color change in the analyte given the following titration?

MnO₄⁻(aq) + 8H⁺(aq) + 5e⁻ → Mn²⁺(s) + 4H₂O

(A) red to orange
(B) purple to green
(C) Purple to clear
(D) orange to clear
(E) the color will remain the same
## Multiple Choice Review

### Answers

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