Problems

Answer the following questions. You have 25 minutes, and you may not use a calculator. You may use the periodic table in the back of the book. For each question, circle the letter of your choice.

1. How many milliliters of 0.100 M H₂SO₄ are required to neutralize 50.0 mL of 0.200 M KOH?
   A. 25.0 mL
   B. 30.0 mL
   C. 20.0 mL
   D. 50.0 mL
   E. 60.0 mL

2. A sample of oxalic acid, H₂C₂O₄, is titrated with standard sodium hydroxide, NaOH, solution. A total of 45.20 mL of 0.1200 M NaOH is required to completely neutralize 20.00 mL of the acid. What is the concentration of the acid?
   A. 0.2712 M
   B. 0.1200 M
   C. 0.1356 M
   D. 0.2400 M
   E. 0.5424 M

3. A solution is prepared by mixing 50.0 mL of 0.20 M arsenic acid, H₃AsO₄, and 50.0 mL of 0.20 M sodium hydroxide, NaOH. Which anion is present in the highest concentration?
   A. HAsO₄²⁻
   B. OH⁻
   C. H₂AsO₄⁻
   D. Na⁺
   E. AsO₃³⁻

4. 14 H⁺ + 6 Fe²⁺ + Cr₂O₇²⁻ → 2 Cr³⁺ + 6 Fe³⁺ + 7 H₂O
   This reaction is used in the titration of an iron solution. What is the concentration of the iron solution if it takes 45.20 mL of 0.1000 M Cr₂O₇²⁻ solution to titrate 50.00 mL of an acidified iron solution?
   A. 0.5424 M
   B. 0.1000 M
   C. 1.085 M
   D. 0.4520 M
   E. 0.2712 M
5. Tungsten metal may be prepared by reducing WO$_3$ with H$_2$ gas. How many grams of tungsten may be prepared from 0.0500 mol of WO$_3$ with excess hydrogen?
   A. 5.58 g  
   B. 0.500 g  
   C. 9.19 g  
   D. 184 g  
   E. 18.4 g

6. Manganese, Mn, forms a number of oxides. A particular oxide is 63.2% Mn. What is the simplest formula for this oxide?
   A. MnO  
   B. Mn$_2$O$_3$  
   C. Mn$_3$O$_4$  
   D. MnO$_2$  
   E. Mn$_2$O$_7$

7. Vanadium forms a number of oxides. In which of the following oxides is the vanadium-to-oxygen mass ratio 2.39:1.00?
   A. VO  
   B. V$_2$O$_3$  
   C. V$_3$O$_4$  
   D. VO$_2$  
   E. V$_2$O$_5$

8. How many grams of nitrogen are in 25.0 g of (NH$_4$)$_2$SO$_4$?
   A. 5.30 g  
   B. 1.30 g  
   C. 0.190 g  
   D. 2.65 g  
   E. 14.0 g

9. Nitrogen forms a number of oxides. Which of the following oxides is 64% nitrogen?
   A. N$_2$O$_5$  
   B. N$_2$O$_4$  
   C. N$_2$O$_3$  
   D. N$_2$O$_2$  
   E. N$_2$O

10. Sodium sulfate forms a number of hydrates. A sample of a hydrate is heated until all the water is removed. What is the formula of the original hydrate if it loses 43% of its mass when heated?
    A. Na$_2$SO$_4$·H$_2$O  
    B. Na$_2$SO$_4$·2H$_2$O  
    C. Na$_2$SO$_4$·6H$_2$O  
    D. Na$_2$SO$_4$·8H$_2$O  
    E. Na$_2$SO$_4$·10H$_2$O
11. \[3\text{Cu} + 8\text{HNO}_3 \rightarrow 3\text{Cu(NO}_3)_2 + 2\text{NO} + 4\text{H}_2\text{O}\]
Copper metal reacts with nitric acid according to the above equation. A 0.30-mol sample of copper metal and 10.0 mL of 12 M nitric acid are mixed in a flask. How many moles of NO gas will form?
A. 0.060 mol  
B. 0.030 mol  
C. 0.010 mol  
D. 0.20 mol  
E. 0.10 mol

12. Gold(III) oxide, \(\text{Au}_2\text{O}_3\), can be decomposed to gold metal, \(\text{Au}\), plus oxygen gas, \(\text{O}_2\). How many moles of oxygen gas will form when 221 g of solid gold(III) oxide is decomposed? The formula mass of oxygen gas is 442.
A. 0.250 mol  
B. 0.500 mol  
C. 1.50 mol  
D. 1.00 mol  
E. 0.750 mol

13. \[\_\text{C}_4\text{H}_11\text{N} + \_\text{O}_2 \rightarrow \_\text{CO}_2 + \_\text{H}_2\text{O} + \_\text{N}_2\]
When the above equation is balanced, the lowest whole number coefficient for \(\text{O}_2\) is:
A. 4  
B. 16  
C. 22  
D. 27  
E. 2

14. \[2\text{KMnO}_4 + 5\text{H}_2\text{C}_2\text{O}_4 + 3\text{H}_2\text{SO}_4 \rightarrow \text{K}_2\text{SO}_4 + 2\text{MnSO}_4 + 10\text{CO}_2 + 8\text{H}_2\text{O}\]
How many moles of \(\text{MnSO}_4\) are produced when 1.0 mol of \(\text{KMnO}_4\), 5.0 mol of \(\text{H}_2\text{C}_2\text{O}_4\), and 3.0 mol of \(\text{H}_2\text{SO}_4\) are mixed?
A. 4.0 mol  
B. 5.0 mol  
C. 2.0 mol  
D. 2.5 mol  
E. 1.0 mol

15. \[\_\text{KClO}_3 \rightarrow \_\text{KCl} + \_\text{O}_2\]
After the above equation is balanced, how many moles of \(\text{O}_2\) can be produced from 4.0 mol of \(\text{KClO}_3\)?
A. 2.0 mol  
B. 4.0 mol  
C. 5.0 mol  
D. 6.0 mol  
E. 3.0 mol
16. When the following equation is balanced, it is found that 1.00 mol of C$_8$H$_{18}$ reacts with how many moles of O$_2$?

\[
\_C_8H_{18} + \_O_2 \rightarrow \_CO_2 + \_H_2O
\]

A. 1.00 mol
B. 10.0 mol
C. 25.0 mol
D. 37.5 mol
E. 12.5 mol

17. Ca + 2 H$_2$O $\rightarrow$ Ca(OH)$_2$ + H$_2$

Calcium reacts with water according to the above reaction. What volume of hydrogen gas, at standard temperature and pressure, is produced from 0.200 mol of calcium?

A. 5.60 L
B. 2.24 L
C. 3.36 L
D. 1.12 L
E. 4.48 L

18. 2CrO$_4^{2-}$ + 3SnO$_2^{2-}$ + H$_2$O $\rightarrow$ 2 CrO$_2^{-}$ + 3 SnO$_3^{2-}$ + 2 OH$^-$

How many moles of OH$^-$ form when 50.0 mL of 0.100 M CrO$_4^{2-}$ is added to a flask containing 50.0 mL of 0.100 M SnO$_2^{2-}$?

A. 0.100 mol
B. $6.66 \times 10^{-3}$ mol
C. $3.33 \times 10^{-3}$ mol
D. $5.00 \times 10^{-3}$ mol
E. $7.50 \times 10^{-3}$ mol

19. A solution containing 0.20 mol of KBr and 0.20 mol of MgBr$_2$ in 2.0 liters of water is provided. How many moles of Pb(NO$_3$)$_2$ must be added to precipitate all the bromide as insoluble PbBr$_2$?

A. 0.10 mol
B. 0.50 mol
C. 0.60 mol
D. 0.30 mol
E. 0.40 mol
Answers and Explanations

There are multiple "correct" ways to do these calculations. Only one calculation is shown for each answer.

1. **D**—The reaction is \( \text{H}_2\text{SO}_4 + 2 \text{KOH} \rightarrow \text{K}_2\text{SO}_4 + 2 \text{H}_2\text{O} \)

\[
\begin{align*}
50.0 \text{ mL base} \times \frac{0.200 \text{ mol base}}{1000 \text{ mL base}} \times \frac{1 \text{ mol acid}}{2 \text{ mol base}} \\
\times \frac{1000 \text{ mL acid}}{0.100 \text{ mol acid}} = 50.0 \text{ mL}
\end{align*}
\]

2. **C**—The reaction is \( \text{H}_2\text{C}_2\text{O}_4 + 2 \text{NaOH} \rightarrow \text{Na}_2 \text{C}_2\text{O}_4 + 2 \text{H}_2\text{O} \)

\[
\begin{align*}
45.20 \text{ mL base} \times \frac{0.1200 \text{ mol base}}{1000 \text{ mL base}} \times \frac{1 \text{ mol acid}}{2 \text{ mol base}} \\
\times \frac{1}{20.00 \text{ mL}} \times \frac{1000 \text{ mL}}{L} = 0.1356 \text{ mL}
\end{align*}
\]

3. **C**—Moles acid = \((50.0 \text{ mL})(0.20 \text{ mol acid/1000 mL}) = 0.0100 \text{ mol}\)

\[
\begin{align*}
\text{Moles base} = (50.0 \text{ mL})(0.20 \text{ mol base/1000 mL}) = 0.0100 \text{ mol}
\end{align*}
\]

There is sufficient base to react completely with only one of the ionizable hydrogens from the acid. This leaves \( \text{H}_2\text{AsO}_4^- \).

4. **A**—\( \text{Ox} = \text{oxidizing agent} = \text{Cr}_2\text{O}_7^{2-}; \text{Red} = \text{reducing agent} = \text{Fe}^{2+} \)

\[
\begin{align*}
45.20 \text{ mL Ox} \times \frac{0.1000 \text{ mol Ox}}{1000 \text{ mL Ox}} \times \frac{6 \text{ mol Red}}{1 \text{ mol Ox}} \times \frac{1}{50.00 \text{ mL}} \\
\times \frac{1000 \text{ mL}}{L} = 0.5424 \text{ M}
\end{align*}
\]

5. **C**—The reaction is \( \text{WO}_3 + 3 \text{H}_2 \rightarrow \text{W} + 3 \text{H}_2\text{O} \)

\[
(0.0500 \text{ mol WO}_3)(1 \text{ mol W/1 mol WO}_3) (183.8 \text{ g W/1 mol W}) = 9.19 \text{ g W}
\]

6. **D**—63.2% Mn leaves 36.8% O

\[
63.2/54.94 = 1.15 \text{ Mn } 36.8/16.0 = 2.30 \text{ O}
\]

Thus, there is 1 Mn/2 O.

7. **C**—V: \( 2.39/50.94 = 0.0469 \text{ O:1.00/16.0} = 0.0625 \)
0.0469/0.0469 = 1  0.0625/0.0469 = 1.33

Multiplying both by three gives: 3 V and 4 O.

8. A—(25.0 g(NH₄)₂SO₄)(1 mol(NH₄)₂SO₄/132 g) × (2 mol N/1 mol(NH₄)₂SO₄)(14.0 g N/1 mol N) = 5.30 g

\[ \frac{2 \text{ N} \times 14.0 \text{ g/mol}}{44.0 \text{ g N}_2O} \times 100\% = 64\% \]

9. B—[(6 mol H₂O)(18 g/mol H₂O)]/(250 g Na₂SO₄ · 6 H₂O) × 100% = 43%

10. C—[(6 mol H₂O)(18 g/mol H₂O)]/(250 g Na₂SO₄ · 6 H₂O) × 100% = 43%

11. B—Calculate the moles of acid to compare to the moles of Cu: (10.0 mL)(12 mol/1000 mL) = 0.12 mol

The acid is the limiting reactant, and will be used to calculate the moles of NO formed.

\[(0.12 \text{ mol acid})(2 \text{ mol NO/8 mol acid}) = 0.030 \text{ mol} \]

12. E—the balanced chemical equation is:

\[ 2 \text{ Au}_2\text{O}_3 \rightarrow 4 \text{ Au} + 3 \text{ O}_2 \]

13. D—the balanced equation is:

\[ 4 \text{ C}_4\text{H}_11\text{N(l)} + 27 \text{ O}_2(\text{g}) \rightarrow 16 \text{ CO}_2(\text{g}) + 22 \text{ H}_2\text{O}(\text{1}) + 2 \text{ N}_2(\text{g}) \]

14. E—the KMnO₄ is the limiting reagent. Each mole of KMnO₄ will produce a mole of MnSO₄.

15. D—the balanced equation is:

\[ 2 \text{ KClO}_3 \rightarrow 2 \text{ KCl} + 3 \text{ O}_2 \]

16. E—the balanced equation is:

\[ 2 \text{ C}_8\text{H}_18 + 25 \text{ O}_2 \rightarrow 16 \text{ CO}_2 + 18 \text{ H}_2\text{O} \]

17. E—(0.200 mol Ca)(1 mol H₂/l mol Ca)(22.4 L at STP/l mol H₂) = 4.48 L

18. C—There are 5.00 × 10⁻³ mol of CrO₄²⁻ and an equal number of mol of SnO₂²⁻. Thus SnO₂²⁻ is the limiting reactant (larger coefficient in the balanced reaction).

\[(5.00 \times 10^{-3} \text{ mol SnO}_2^{2-})(2 \text{ mol OH}^-/3 \text{ mol SnO}_2^{2-}) = 3.33 \times 10^{-3} \text{ mol OH}^- \]

19. D—the volume of water is irrelevant.

0.20 mol of KBr will require 0.10 mol of Pb(NO₃)₂
0.20 mol of MgBr₂ will require 0.20 mol of Pb(NO₃)₂

Total the two yields.