4.1: The Chemical Equation

1. From the statement “nitrogen and hydrogen react to produce ammonia,” identify the reactants and the products.

2. From the statement “sodium metal reacts with water to produce sodium hydroxide and hydrogen,” identify the reactants and the products.

3. From the statement “magnesium hydroxide reacts with nitric acid to produce magnesium nitrate and water,” identify the reactants and the products.

4. From the statement “propane reacts with oxygen to produce carbon dioxide and water,” identify the reactants and the products.

5. Write and balance the chemical equation described by Exercise 1.

6. Write and balance the chemical equation described by Exercise 2.

7. Write and balance the chemical equation described by Exercise 3.

8. Write and balance the chemical equation described by Exercise 4. The formula for propane is C3H8.


10. Balance: ___N2 + ___H2 → ___N2H4

11. Balance: ___Al + ___O2 → ___Al2O3

12. Balance: ___C2H4 + ___O2 → ___CO2 + ___H2O

13. How would you write the balanced chemical equation in Exercise 10 if all substances were gases?

14. How would you write the balanced chemical equation in Exercise 12 if all the substances except water were gases and water itself were a liquid?

Answers

1. reactants: nitrogen and hydrogen; product: ammonia

3. reactants: magnesium hydroxide and nitric acid; products: magnesium nitrate and water

6. N2 + 3H2 → 2NH3

8. Mg(OH)2 + 2HNO3 → Mg(NO3)2 + 2H2O

10. 2NaClO3 → 2NaCl + 3O2

12. 4Al + 3O2 → 2Al2O3
4.2: Types of Chemical Reactions - Single and Double Displacement Reactions

1. What are the general characteristics that help you recognize single-replacement reactions?
2. What are the general characteristics that help you recognize double-replacement reactions?
3. Assuming that each single-replacement reaction occurs, predict the products and write each balanced chemical equation.
   a. Zn + Fe(NO$_3$)$_2$ → ?
   b. F$_2$ + FeI$_3$ → ?
4. Assuming that each single-replacement reaction occurs, predict the products and write each balanced chemical equation.
   a. Li + MgSO$_4$ → ?
   b. NaBr + Cl$_2$ → ?
5. Assuming that each single-replacement reaction occurs, predict the products and write each balanced chemical equation.
   a. Sn + H$_2$SO$_4$ → ?
   b. Al + NiBr$_2$ → ?
6. Assuming that each single-replacement reaction occurs, predict the products and write each balanced chemical equation.
   a. Mg + HCl → ?
   b. Hl + Br$_2$ → ?
7. Use the periodic table or the activity series to predict if each single-replacement reaction will occur and, if so, write a balanced chemical equation.
   a. FeCl$_2$ + Br$_2$ → ?
   b. Fe(NO$_3$)$_3$ + Al → ?
8. Use the periodic table or the activity series to predict if each single-replacement reaction will occur and, if so, write a balanced chemical equation.
   a. Zn + Fe$_3$(PO$_4$)$_2$ → ?
   b. Ag + HNO$_3$ → ?
9. Use the periodic table or the activity series to predict if each single-replacement reaction will occur and, if so, write a balanced chemical equation.
   a. NaI + Cl$_2$ → ?
   b. AgCl + Au → ?
10. Use the periodic table or the activity series to predict if each single-replacement reaction will occur and, if so, write a balanced chemical equation.
    a. Pt + H$_3$PO$_4$ → ?
    b. Li + H$_2$O → ? (Hint: treat H$_2$O as if it were composed of H$^+$ and OH$^-$ ions.)
11. Assuming that each double-replacement reaction occurs, predict the products and write each balanced chemical equation.
   a. Zn(NO\textsubscript{3})\textsubscript{2} + NaOH → ?
   b. HCl + Na\textsubscript{2}S → ?

12. Assuming that each double-replacement reaction occurs, predict the products and write each balanced chemical equation.
   a. Ca(C\textsubscript{2}H\textsubscript{3}O\textsubscript{2})\textsubscript{2} + HNO\textsubscript{3} → ?
   b. Na\textsubscript{2}CO\textsubscript{3} + Sr(NO\textsubscript{2})\textsubscript{2} → ?

13. Assuming that each double-replacement reaction occurs, predict the products and write each balanced chemical equation.
   a. Pb(NO\textsubscript{3})\textsubscript{2} + KBr → ?
   b. K\textsubscript{2}O + MgCO\textsubscript{3} → ?

14. Assuming that each double-replacement reaction occurs, predict the products and write each balanced chemical equation.
   a. Sn(OH)\textsubscript{2} + FeBr\textsubscript{3} → ?
   b. CsNO\textsubscript{3} + KCl → ?

15. Use the solubility rules to predict if each double-replacement reaction will occur and, if so, write a balanced chemical equation.
   a. Pb(NO\textsubscript{3})\textsubscript{2} + KBr → ?
   b. K\textsubscript{2}O + Na\textsubscript{2}CO\textsubscript{3} → ?

16. Use the solubility rules to predict if each double-replacement reaction will occur and, if so, write a balanced chemical equation.
   a. Na\textsubscript{2}CO\textsubscript{3} + Sr(NO\textsubscript{2})\textsubscript{2} → ?
   b. (NH\textsubscript{4})\textsubscript{2}SO\textsubscript{4} + Ba(NO\textsubscript{3})\textsubscript{2} → ?

17. Use the solubility rules to predict if each double-replacement reaction will occur and, if so, write a balanced chemical equation.
   a. K\textsubscript{3}PO\textsubscript{4} + SrCl\textsubscript{2} → ?
   b. NaOH + MgCl\textsubscript{2} → ?

18. Use the solubility rules to predict if each double-replacement reaction will occur and, if so, write a balanced chemical equation.
   a. KC\textsubscript{2}H\textsubscript{3}O\textsubscript{2} + Li\textsubscript{2}CO\textsubscript{3} → ?
   b. KOH + AgNO\textsubscript{3} → ?

**Answers**

1. One element replaces another element in a compound.
2.
3. a. Zn + Fe(NO\textsubscript{3})\textsubscript{2} → Zn(NO\textsubscript{3})\textsubscript{2} + Fe
   b. 3F\textsubscript{2} + 2FeI\textsubscript{3} → 3I\textsubscript{2} + 2FeF\textsubscript{3}
4.
5. a. Sn + H\textsubscript{2}SO\textsubscript{4} → SnSO\textsubscript{4} + H\textsubscript{2}
b. \(2\text{Al} + 3\text{NiBr} \rightarrow 2\text{AlBr}_3 + 3\text{Ni}\)

6. 

7. 
   a. No reaction occurs.
   b. \(\text{Fe(NO}_3\text{)}_3 + \text{Al} \rightarrow \text{Al(NO}_3\text{)}_3 + \text{Fe}\)

8. 

9. 
   a. \(2\text{NaI} + \text{Cl}_2 \rightarrow 2\text{NaCl} + \text{I}_2\)
   b. No reaction occurs.

10. 

11. 
   a. \(\text{Zn(NO}_3\text{)}_2 + 2\text{NaOH} \rightarrow \text{Zn(OH)}_2 + 2\text{NaNO}_3\)
   b. \(2\text{HCl} + \text{Na}_2\text{S} \rightarrow 2\text{NaCl} + \text{H}_2\text{S}\)

12. 

13. 
   a. \(\text{Pb(NO}_3\text{)}_2 + 2\text{KBr} \rightarrow \text{PbBr}_2 + 2\text{KNO}_3\)
   b. \(\text{K}_2\text{O} + \text{MgCO}_3 \rightarrow \text{K}_2\text{CO}_3 + \text{MgO}\)

14. 

15. 
   a. \(\text{Pb(NO}_3\text{)}_2 + 2\text{KBr} \rightarrow \text{PbBr}_2(\text{s}) + 2\text{KNO}_3\)
   b. No reaction occurs.

16. 

17. 
   a. \(2\text{K}_3\text{PO}_4 + 3\text{SrCl}_2 \rightarrow \text{Sr}_3(\text{PO}_4)_2(\text{s}) + 6\text{KCl}\)
   b. \(2\text{NaOH} + \text{MgCl}_2 \rightarrow 2\text{NaCl} + \text{Mg(OH)}_2(\text{s})\)

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### 4.3: Ionic Equations - A Closer Look

1. Write a chemical equation that represents \(\text{NaBr(s)}\) dissociating in water.

2. Write a chemical equation that represents \(\text{SrCl}_2(\text{s})\) dissociating in water.

3. Write a chemical equation that represents \((\text{NH}_4)_3\text{PO}_4(\text{s})\) dissociating in water.

4. Write a chemical equation that represents \(\text{Fe(C}_2\text{H}_3\text{O}_2)_3(\text{s})\) dissociating in water.

5. Write the complete ionic equation for the reaction of \(\text{FeCl}_2(\text{aq})\) and \(\text{AgNO}_3(\text{aq})\). You may have to consult the solubility rules.

6. Write the complete ionic equation for the reaction of \(\text{BaCl}_2(\text{aq})\) and \(\text{Na}_2\text{SO}_4(\text{aq})\). You may have to consult the solubility rules.

7. Write the complete ionic equation for the reaction of \(\text{KCl(aq)}\) and \(\text{NaC}_2\text{H}_3\text{O}_2(\text{aq})\). You may have to consult the solubility rules.

8. Write the complete ionic equation for the reaction of \(\text{Fe}_2(\text{SO}_4)_3(\text{aq})\) and \(\text{Sr(NO}_3)_2(\text{aq})\). You may have to consult the solubility rules.
9. Write the net ionic equation for the reaction of FeCl$_2$(aq) and AgNO$_3$(aq). You may have to consult the solubility rules.

10. Write the net ionic equation for the reaction of BaCl$_2$(aq) and Na$_2$SO$_4$(aq). You may have to consult the solubility rules.

11. Write the net ionic equation for the reaction of KCl(aq) and NaC$_2$H$_3$O$_2$(aq). You may have to consult the solubility rules.

12. Write the net ionic equation for the reaction of Fe$_2$(SO$_4$)$_3$(aq) and Sr(NO$_3$)$_2$(aq). You may have to consult the solubility rules.

13. Identify the spectator ions in Exercises 9 and 10.

14. Identify the spectator ions in Exercises 11 and 12.

**Answers**

1. NaBr(s) $\xrightarrow{H_2O}\text{Na}^+(aq) + \text{Br}^-(aq)$

2. $\text{(NH}_4\text{)}_3\text{PO}_4(s) \xrightarrow{H_2O} 3\text{NH}_4^+(aq) + \text{PO}_4^{3-}(aq)$

3. Fe$^{2+}$(aq) + 2Cl$^-$ (aq) + 2Ag$^+$(aq) + 2NO$_3^-$ (aq) $\rightarrow$ Fe$^{2+}$(aq) + 2NO$_3^-$ (aq) + 2AgCl(s)

4. K$^+$ (aq) + Cl$^-$ (aq) + Na$^+$ (aq) + C$_2$H$_3$O$_2^-$ (aq) $\rightarrow$ Na$^+$ (aq) + Cl$^-$ (aq) + K$^+$ (aq) + C$_2$H$_3$O$_2^-$ (aq)

5. 2Cl$^-$ (aq) + 2Ag$^+$ (aq) $\rightarrow$ 2AgCl(s)

6. There is no overall reaction.

7. In Exercise 9, Fe$^{2+}$(aq) and NO$_3^-$ (aq) are spectator ions; in Exercise 10, Na$^+$ (aq) and Cl$^-$ (aq) are spectator ions.

**4.4: Composition, Decomposition, and Combustion Reactions**

1. Which is a composition reaction and which is not?
   a. NaCl + AgNO$_3$ $\rightarrow$ AgCl + NaNO$_3$
   b. CaO + CO$_2$ $\rightarrow$ CaCO$_3$

2. Which is a composition reaction and which is not?
   a. H$_2$ + Cl$_2$ $\rightarrow$ 2HCl
   b. 2HBr + Cl$_2$ $\rightarrow$ 2HCl + Br$_2$

3. Which is a composition reaction and which is not?
a. $2\text{SO}_2 + \text{O}_2 \rightarrow 2\text{SO}_3$

b. $6\text{C} + 3\text{H}_2 \rightarrow \text{C}_6\text{H}_6$

4. Which is a composition reaction and which is not?
   a. $4\text{Na} + 2\text{C} + 3\text{O}_2 \rightarrow 2\text{Na}_2\text{CO}_3$
   b. $\text{Na}_2\text{CO}_3 \rightarrow \text{Na}_2\text{O} + \text{CO}_2$

5. Which is a decomposition reaction and which is not?
   a. $\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$
   b. $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$

6. Which is a decomposition reaction and which is not?
   a. $3\text{O}_2 \rightarrow 2\text{O}_3$
   b. $2\text{KClO}_3 \rightarrow 2\text{KCl} + 3\text{O}_2$

7. Which is a decomposition reaction and which is not?
   a. $\text{Na}_2\text{O} + \text{CO}_2 \rightarrow \text{Na}_2\text{CO}_3$
   b. $\text{H}_2\text{SO}_3 \rightarrow \text{H}_2\text{O} + \text{SO}_2$

8. Which is a decomposition reaction and which is not?
   a. $2\text{C}_7\text{H}_5\text{N}_3\text{O}_6 \rightarrow 3\text{N}_2 + 5\text{H}_2\text{O} + 7\text{CO} + 7\text{C}$
   b. $\text{C}_6\text{H}_12\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$

9. Which is a combustion reaction and which is not?
   a. $\text{C}_6\text{H}_12\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$
   b. $2\text{Fe}_2\text{S}_3 + 9\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3 + 6\text{SO}_2$

10. Which is a combustion reaction and which is not?
    a. $\text{CH}_4 + 2\text{F}_2 \rightarrow \text{CF}_4 + 2\text{H}_2$
    b. $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$

11. Which is a combustion reaction and which is not?
    a. $\text{P}_4 + 5\text{O}_2 \rightarrow 2\text{P}_2\text{O}_5$
    b. $2\text{Al}_2\text{S}_3 + 9\text{O}_2 \rightarrow 2\text{Al}_2\text{O}_3 + 6\text{SO}_2$

12. Which is a combustion reaction and which is not?
    a. $\text{C}_2\text{H}_4 + \text{O}_2 \rightarrow \text{C}_2\text{H}_4\text{O}_2$
    b. $\text{C}_2\text{H}_4 + \text{Cl}_2 \rightarrow \text{C}_2\text{H}_4\text{Cl}_2$

13. Is it possible for a composition reaction to also be a combustion reaction? Give an example to support your case.

14. Is it possible for a decomposition reaction to also be a combustion reaction? Give an example to support your case.

15. Complete and balance each combustion equation.
    a. $\text{C}_4\text{H}_9\text{OH} + \text{O}_2 \rightarrow ?$
    b. $\text{CH}_3\text{NO}_2 + \text{O}_2 \rightarrow ?$

16. Complete and balance each combustion equation.
    a. $\text{B}_2\text{H}_6 + \text{O}_2 \rightarrow ?$ (The oxide of boron formed is $\text{B}_2\text{O}_3$.)
b. Al2S3 + O2 → ? (The oxide of sulfur formed is SO2.)
c. Al2S3 + O2 → ? (The oxide of sulfur formed is SO3.)

**Answers**

1. a. not composition  
   b. composition  
2. 
3. a. composition  
   b. composition  
4. 
5. a. not decomposition  
   b. decomposition  
6. 
7. a. not decomposition  
   b. decomposition  
8. 
9. a. combustion  
   b. combustion  
10. 
11. a. combustion  
    b. combustion  
12. 
13. Yes; 2H2 + O2 → 2H2O (answers will vary)  
14. 
15. a. C4H9OH + 6O2 → 4CO2 + 5H2O  
   b. 4CH3NO2 + 3O2 → 4CO2 + 6H2O + 2N2  

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**4.5: Neutralization Reactions**

1. What is the Arrhenius definition of an acid?  
2. What is the Arrhenius definition of a base?  
3. Predict the products of each acid-base combination listed. Assume that a neutralization reaction occurs.  
   a. HCl and KOH  
   b. H2SO4 and KOH  
   c. H3PO4 and Ni(OH)2  
4. Predict the products of each acid-base combination listed. Assume that a neutralization reaction occurs.  
   a. HBr and Fe(OH)3  
   b. HNO2 and Al(OH)3  
   c. HClO3 and Mg(OH)2
5. Write a balanced chemical equation for each neutralization reaction in Exercise 3.

6. Write a balanced chemical equation for each neutralization reaction in Exercise 4.

7. Write a balanced chemical equation for the neutralization reaction between each given acid and base. Include the proper phase labels.
   a. HI(aq) + KOH(aq) → ?
   b. H2SO4(aq) + Ba(OH)2(aq) → ?

8. Write a balanced chemical equation for the neutralization reaction between each given acid and base. Include the proper phase labels.
   a. HNO3(aq) + Fe(OH)3(s) → ?
   b. H3PO4(aq) + CsOH(aq) → ?

9. Write the net ionic equation for each neutralization reaction in Exercise 7.

10. Write the net ionic equation for each neutralization reaction in Exercise 8.

11. Write the complete and net ionic equations for the neutralization reaction between HClO3(aq) and Zn(OH)2(s).
    Assume the salt is soluble.

12. Write the complete and net ionic equations for the neutralization reaction between H2C2O4(s) and Sr(OH)2(aq).
    Assume the salt is insoluble.

13. Explain why the net ionic equation for the neutralization reaction between HCl(aq) and KOH(aq) is the same as the net ionic equation for the neutralization reaction between HNO3(aq) and RbOH.

14. Explain why the net ionic equation for the neutralization reaction between HCl(aq) and KOH(aq) is different from the net ionic equation for the neutralization reaction between HCl(aq) and AgOH.

15. Write the complete and net ionic equations for the neutralization reaction between HCl(aq) and KOH(aq) using the hydronium ion in place of H⁺. What difference does it make when using the hydronium ion?

16. Write the complete and net ionic equations for the neutralization reaction between HClO3(aq) and Zn(OH)2(s) using the hydronium ion in place of H⁺. Assume the salt is soluble. What difference does it make when using the hydronium ion?

Answers

1. An Arrhenius acid increases the amount of H⁺ ions in an aqueous solution.

2.

3. a. KCl and H₂O
   b. K₂SO₄ and H₂O
   c. Ni₃(PO₄)₂ and H₂O

4.

5. a. HCl + KOH → KCl + H₂O
   b. H₂SO₄ + 2KOH → K₂SO₄ + 2H₂O
   c. 2H₃PO₄ + 3Ni(OH)₂ → Ni₃(PO₄)₂ + 6H₂O

6.

7. a. HI(aq) + KOH(aq) → KCl(aq) + H₂O(ℓ)
   b. H₂SO₄(aq) + Ba(OH)₂(aq) → BaSO₄(s) + 2H₂O(ℓ)

8.
9. a. \( \text{H}^+ (\text{aq}) + \text{OH}^- (\text{aq}) \rightarrow \text{H}_2\text{O}(\ell) \)

b. \( 2\text{H}^+ (\text{aq}) + \text{SO}_4^{2-} (\text{aq}) + \text{Ba}^{2+} (\text{aq}) + 2\text{OH}^- (\text{aq}) \rightarrow \text{BaSO}_4(\text{s}) + 2\text{H}_2\text{O}(\ell) \)

10. 

11. Complete ionic equation: \( 2\text{H}^+ (\text{aq}) + 2\text{ClO}_3^- (\text{aq}) + \text{Zn}^{2+} (\text{aq}) + 2\text{OH}^- (\text{aq}) \rightarrow \text{Zn}^{2+} (\text{aq}) + 2\text{ClO}_3^- (\text{aq}) + 2\text{H}_2\text{O}(\ell) \)

Net ionic equation: \( 2\text{H}^+ (\text{aq}) + 2\text{OH}^- (\text{aq}) \rightarrow 2\text{H}_2\text{O}(\ell) \)

12. 

13. Because the salts are soluble in both cases, the net ionic reaction is just \( \text{H}^+ (\text{aq}) + \text{OH}^- (\text{aq}) \rightarrow \text{H}_2\text{O}(\ell) \).

14. 

15. Complete ionic equation: \( \text{H}_3\text{O}^+ (\text{aq}) + \text{Cl}^- (\text{aq}) + \text{K}^+ (\text{aq}) + \text{OH}^- (\text{aq}) \rightarrow 2\text{H}_2\text{O}(\ell) + \text{K}^+ (\text{aq}) + \text{Cl}^- (\text{aq}) \)

Net ionic equation: \( \text{H}_3\text{O}^+ (\text{aq}) + \text{OH}^- (\text{aq}) \rightarrow 2\text{H}_2\text{O}(\ell) \)

The difference is simply the presence of an extra water molecule as a product.

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### 4.6: Oxidation-Reduction Reactions

1. Is the reaction

\[ 2\text{K}(s) + \text{Br}_2(\ell) \rightarrow 2\text{KBr}(s) \]

an oxidation-reduction reaction? Explain your answer.

2. Is the reaction

\[ \text{NaCl}(\text{aq}) + \text{AgNO}_3(\text{aq}) \rightarrow \text{NaNO}_3(\text{aq}) + \text{AgCl}(\text{s}) \]

an oxidation-reduction reaction? Explain your answer.

3. In the reaction

\[ 2\text{Ca}(s) + \text{O}_2(\ell) \rightarrow 2\text{CaO} \]

indicate what has lost electrons and what has gained electrons.

4. In the reaction

\[ 16\text{Fe}(s) + 3\text{S}_8(\text{s}) \rightarrow 8\text{Fe}_2\text{S}_3(\text{s}) \]

indicate what has lost electrons and what has gained electrons.

5. In the reaction

\[ 2\text{Li}(s) + \text{O}_2(\ell) \rightarrow \text{Li}_2\text{O}_2(\text{s}) \]

indicate what has been oxidized and what has been reduced.

6. In the reaction
2Ni(s) + 3I₂(s) → 2NiI₃(s)

indicate what has been oxidized and what has been reduced.

7. What are two different definitions of oxidation?

8. What are two different definitions of reduction?

9. Assign oxidation numbers to each atom in each substance.
   a. P₄
   b. SO₂
   c. SO₂²⁻
   d. Ca(NO₃)₂

10. Assign oxidation numbers to each atom in each substance.
    a. PF₅
    b. (NH₄)₂S
    c. Hg
    d. Li₂O₂ (lithium peroxide)

11. Assign oxidation numbers to each atom in each substance.
    a. CO
    b. CO₂
    c. NiCl₂
    d. NiCl₃

12. Assign oxidation numbers to each atom in each substance.
    a. NaH (sodium hydride)
    b. NO₂
    c. NO₂⁻
    d. AgNO₃

13. Assign oxidation numbers to each atom in each substance.
    a. CH₂O
    b. NH₃
    c. Rb₂SO₄
    d. Zn(C₂H₃O₂)₂

14. Assign oxidation numbers to each atom in each substance.
    a. C₆H₆
    b. B(OH)₃
    c. Li₂S
    d. Au

15. Identify what is being oxidized and reduced in this redox equation by assigning oxidation numbers to the atoms.
2NO + Cl₂ → 2NOCl

16. Identify what is being oxidized and reduced in this redox equation by assigning oxidation numbers to the atoms.

Fe + SO₃ → FeSO₃

17. Identify what is being oxidized and reduced in this redox equation by assigning oxidation numbers to the atoms.

2KrF₂ + 2H₂O → 2Kr + 4HF + O₂

18. Identify what is being oxidized and reduced in this redox equation by assigning oxidation numbers to the atoms.

SO₃ + SCl₂ → SOCl₂ + SO₂

19. Identify what is being oxidized and reduced in this redox equation by assigning oxidation numbers to the atoms.

2K + MgCl₂ → 2KCl + Mg

20. Identify what is being oxidized and reduced in this redox equation by assigning oxidation numbers to the atoms.

C₇H₁₆ + 11O₂ → 7CO₂ + 8H₂O

Answers
1. Yes; both K and Br are changing oxidation numbers.

3. Ca has lost electrons, and O has gained electrons.

5. Li has been oxidized, and O has been reduced.

7. loss of electrons; increase in oxidation number

9. a. P: 0  
b. S: +4; O: −2  
c. S: +2; O: −2  
d. Ca: 2+; N: +5; O: −2

11. a. C: +2; O: −2  
b. C: +4; O: −2  
c. Ni: +2; Cl: −1  
d. Ni: +3; Cl: −1

13. a. C: 0; H: +1; O: −2  
b. N: −3; H: +1  
c. Rb: +1; S: +6; O: −2  
d. Zn: +2; C: 0; H: +1; O: −2

15. N is being oxidized, and Cl is being reduced.

17. O is being oxidized, and Kr is being reduced.

19. K is being oxidized, and Mg is being reduced.

Additional Exercises

1. Chemical equations can also be used to represent physical processes. Write a chemical reaction for the boiling of water, including the proper phase labels.

2. Chemical equations can also be used to represent physical processes. Write a chemical reaction for the freezing of water, including the proper phase labels.

3. Explain why
   \[ 4\text{Na(s)} + 2\text{Cl}_2(\text{g}) \rightarrow 4\text{NaCl(s)} \]
   should not be considered a proper chemical equation.

4. Explain why
   \[ \text{H}_2(\text{g}) + 1/2\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O(\ell)} \]
should not be considered a proper chemical equation.

5. Does the chemical reaction represented by
   \[3\text{Zn}(s) + 2\text{Al(NO}_3\text{)}_3(aq) \rightarrow 3\text{Zn(NO}_3\text{)}_2(aq) + 2\text{Al}(s)\]
   proceed as written? Why or why not?

6. Does the chemical reaction represented by
   \[2\text{Au}(s) + 2\text{HNO}_3(aq) \rightarrow 2\text{AuNO}_3(aq) + \text{H}_2(g)\]
   proceed as written? Gold is a relatively useful metal for certain applications, such as jewelry and electronics. Does your answer suggest why this is so?

7. Explain what is wrong with this double-replacement reaction.
   \[\text{NaCl}(aq) + \text{KBr}(aq) \rightarrow \text{NaK}(aq) + \text{ClBr}(aq)\]

8. Predict the products of and balance this double-replacement reaction.
   \[\text{Ag}_2\text{SO}_4(aq) + \text{SrCl}_2(aq) \rightarrow ?\]

9. Write the complete and net ionic equations for this double-replacement reaction.
   \[\text{BaCl}_2(aq) + \text{Ag}_2\text{SO}_4(aq) \rightarrow ?\]

10. Write the complete and net ionic equations for this double-replacement reaction.
    \[\text{Ag}_2\text{SO}_4(aq) + \text{SrCl}_2(aq) \rightarrow ?\]

11. Identify the spectator ions in this reaction. What is the net ionic equation?
    \[\text{NaCl}(aq) + \text{KBr}(aq) \rightarrow \text{NaBr}(aq) + \text{KCl}(aq)\]

12. Complete this reaction and identify the spectator ions. What is the net ionic equation?
    \[3\text{H}_2\text{SO}_4(aq) + 2\text{Al(OH)}_3(s) \rightarrow ?\]

13. Can a reaction be a composition reaction and a redox reaction at the same time? Give an example to support your answer.

14. Can a reaction be a combustion reaction and a redox reaction at the same time? Give an example to support your answer.

15. Can a reaction be a decomposition reaction and a redox reaction at the same time? Give an example to support your answer.

16. Can a reaction be a combustion reaction and a double-replacement reaction at the same time? Give an example to support your answer.

17. Why is \(\text{CH}_4\) not normally considered an acid?

18. Methyl alcohol has the formula \(\text{CH}_3\text{OH}\). Why would methyl alcohol not normally be considered a base?

19. What are the oxidation numbers of the nitrogen atoms in these substances?
    a. \(\text{N}_2\)
b. NH₃
c. NO
d. N₂O
e. NO₂
f. N₂O₄
g. N₂O₅
h. NaNO₃

20. What are the oxidation numbers of the sulfur atoms in these substances?
   1. SF₆
   2. Na₂SO₄
   3. K₂SO₃
   4. SO₃
   5. SO₂
   6. S₈
   7. Na₂S

21. Disproportion is a type of redox reaction in which the same substance is both oxidized and reduced. Identify the element that is disproportionating and indicate the initial and final oxidation numbers of that element.

   2CuCl(aq) → CuCl₂(aq) + Cu(s)

22. Disproportion is a type of redox reaction in which the same substance is both oxidized and reduced. Identify the element that is disproportionating and indicate the initial and final oxidation numbers of that element.

   3Cl₂(g) + 6OH⁻(aq) → 5Cl⁻(aq) + ClO₃⁻(aq) + 3H₂O(l)

Answers

1. H₂O(l) → H₂O(g)

3. The coefficients are not in their lowest whole-number ratio.

5. No; zinc is lower in the activity series than aluminum.

7. In the products, the cation is pairing with the cation, and the anion is pairing with the anion.

9. Complete ionic equation: Ba^{2+}(aq) + 2Cl⁻(aq) + 2Ag⁺(aq) + SO₄^{2-}(aq) → BaSO₄(s) + 2AgCl(s)

10. Net ionic equation: The net ionic equation is the same as the complete ionic equation.

12. Each ion is a spectator ion; there is no overall net ionic equation.

14. Yes; H₂ + Cl₂ → 2HCl (answers will vary)

16. Yes; 2HCl → H₂ + Cl₂ (answers will vary)
17. It does not increase the $\text{H}^+$ ion concentration; it is not a compound of $\text{H}^+$.

19. a. 0  
b. −3  
c. +2  
d. +1  
e. +4  
f. +4  
g. +5  
h. +5

20. Copper is disproportionating. Initially, its oxidation number is +1; in the products, its oxidation numbers are +2 and 0, respectively.