Chapter 9
Answers to Questions

1. *Word equation*:
Silicon Tetrachloride + Water $\rightarrow$ Silicon Dioxide + Hydrogen Chloride
Formulas:
Next, the chemical formulas are needed. As these are all covalent compounds, the formulas are comparatively easy to construct:
Silicon tetrachloride = $SiCl_4$
Water = H_2O
Silicon dioxide = SiO_2
Hydrogen chloride = HCl
Formula equation:
The unbalanced formula equation is:
$SiCl_4(l) + H_2O(l) \rightarrow SiO_2(s) + HCl(g)$
Thus the balanced formula equation is:
$SiCl_4(l) + 2\ H_2O(l) \rightarrow SiO_2(s) + 4\ HCl(g)$

2. *Word equation*:
Sodium Chloride + Lead(II) Nitrate $\rightarrow$ Lead(II) Chloride + Sodium Nitrate
Formulas:
Next, the chemical formulas are needed. As these are all ionic compounds, the formulas are more difficult to construct:
Sodium chloride contains the Na^+ ion and the Cl^- ion. The formula is NaCl.
Lead(II) nitrate contains the Pb^{2+} ion and the NO_3^- ion. The formula is $Pb(NO_3)_2$.
Lead(II) chloride contains the Pb^{2+} ion and the Cl^- ion. The formula is $PbCl_2$.
Sodium nitrate contains the Na^+ ion and the NO_3^- ion. The formula is $NaNO_3$.
Formula equation:
The unbalanced formula equation is:
$NaCl(aq) + Pb(NO_3)_2(aq) \rightarrow PbCl_2(s) + NaNO_3(aq)$
Thus the balanced formula equation is:
$2\ NaCl(aq) + Pb(NO_3)_2(aq) \rightarrow PbCl_2(s) + 2\ NaNO_3(aq)$

3. *Word equation*:
Butane + Oxygen $\rightarrow$ Carbon Dioxide + Water
Formulas:
Next, the chemical formulas are needed. As these are all covalent compounds, the formulas are comparatively easy to construct:
Butane = C_4H_{10}

Oxygen = O_2
Carbon dioxide = CO_2
Water = H_2O
Formula equation:
The unbalanced formula equation is:
$C_4H_{10}(g) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$
Thus the balanced formula equation is:
$2\ C_4H_{10}(g) + 13\ O_2(g) \rightarrow 8\ CO_2(g) + 10\ H_2O(l)$

4. *Word equation*:
Magnesium Nitride + Water $\rightarrow$ Magnesium Hydroxide + Ammonia
Formulas:
Next, the chemical formulas are needed. The formulas of the ionic compounds are more difficult to construct:
Magnesium nitride contains the Mg^{2+} ion and the N^{3-} ion. The formula is Mg_3N_2.
Magnesium hydroxide contains the Mg^{2+} ion and the OH^- ion. The formula is $Mg(OH)_2$.
Ammonia = NH_3
Formula equation:
The unbalanced formula equation is:
$Mg_3N_2(s) + H_2O(l) \rightarrow Mg(OH)_2(s) + NH_3(g)$
Thus the balanced formula equation is:
$Mg_3N_2(s) + 6\ H_2O(l) \rightarrow 3\ Mg(OH)_2(s) + 2\ NH_3(g)$

5. (a) This is a combination reaction of two elements, one metal and one nonmetal, so an ionic compound will be formed. As lithium forms Li^+ and fluorine forms F^-, the product has to be LiF.
The unbalanced equation is:
$Li(s) + F_2(g) \rightarrow LiF$
The balanced equation is:
$2\ Li(s) + F_2(g) \rightarrow 2\ LiF$

(b) This is a combination reaction of an acid oxide (nonmetal oxide) and water to give an acid. As the product contains 2H, 1S, and 4O, the formula of the acid must be H_2SO_4 (sulfuric acid).
The balanced equation is:
$SO_3(g) + H_2O(l) \rightarrow H_2SO_4$

6. (a) This is a combination of two elements, one metal and one nonmetal, so an ionic compound will be formed. As aluminum forms Al^{3+} and sulfur S^{2-}, the product has to be Al_2S_3.

The unbalanced equation is:
$Al(s) + S(s) \rightarrow Al_2S_3$
The balanced equation is:
$2\ Al(s) + 3\ S(s) \rightarrow Al_2S_3$

(b) This is a combination reaction of a basic oxide (metal oxide) and water to give a base (a metal hydroxide). Lithium ion is Li^+ and hydroxide ion is OH^-, so the compound formed will be LiOH.
The unbalanced equation is:
$Li_2O(s) + H_2O(l) \rightarrow LiOH$
The balanced equation is:
$Li_2O(s) + H_2O(l) \rightarrow 2\ LiOH$

7. (a) This is a decomposition reaction of two nonmetals. The element xenon is monatomic, Xe. The element oxygen is diatomic, O_2.
The unbalanced equation is:
$XeO_4(s) \rightarrow Xe + O_2$
The balanced equation is:
$XeO_4(s) \rightarrow Xe + 2\ O_2$

(b) This is the decomposition of a base (an ionic compound containing the hydroxide ion. These decompose to give a basic oxide (metal oxide) and water. If 2H and 1O are removed from $Ba(OH)_2$, the other product is BaO. This makes sense as barium ion is Ba^{2+} and oxide ion is O^{2-}, so BaO would be the expected formula.
The balanced equation is:
$Ba(OH)_2(s) \rightarrow BaO + H_2O$

8. (a) This is a decomposition of a metal and a nonmetal. The element silver is Ag. The element oxygen is diatomic, O_2.
The unbalanced equation is:
$Ag_2O(s) \rightarrow Ag + O_2$
The balanced equation is:
$2\ Ag_2O(s) \rightarrow 4\ Ag + O_2$

(b) This is the decomposition of an acid. These decompose to give an acidic oxide (nonmetal oxide) and water. If 2H and 1O are removed from H_2SO_3, the other product is SO_2.
The balanced equation is:
$H_2SO_3(aq) \rightarrow H_2O + SO_2$

9. (a) iron (b) sodium

10. (a) calcium (b) copper.

11. (a) According to the activity series, zinc replaces the silver ion in silver nitrate. The zinc ion is Zn^{2+} and the nitrate ion is NO_3^-, so zinc nitrate is $Zn(NO_3)_2$.
The unbalanced equation is:
$Zn(s) + AgNO_3(aq) \rightarrow Ag(s) + Zn(NO_3)_2(aq)$
The balanced equation is:
$Zn(s) + 2\ AgNO_3(aq) \rightarrow 2\ Ag(s) + Zn(NO_3)_2(aq)$

(b) According to the activity series, aluminum replaces the hydrogen ion in hydrochloric acid. The aluminum ion is Al^{3+} and the chloride ion is Cl^-, so aluminum chloride is $AlCl_3$. The element hydrogen exists as the diatomic molecule H_2.
The unbalanced equation is:
$Al(s) + HCl(aq) \rightarrow AlCl_3(aq) + H_2(g)$
The balanced equation is:
$2\ Al(s) + 6\ HCl(aq) \rightarrow 2\ AlCl_3(aq) + 3\ H_2(g)$

12. (a) According to the activity series, magnesium replaces the iron(III) ion in iron(III) chloride. The magnesium ion is Mg^{2+} and the bromide ion is Br^-, so magnesium bromide is $MgBr_2$.
The unbalanced equation is:
$Mg(s) + FeBr_3(aq) \rightarrow Fe(s) + MgBr_2(aq)$
The balanced equation is:
$3\ Mg(s) + 2\ FeBr_3(aq) \rightarrow 2\ Fe(s) + 3\ MgBr_2(aq)$

(b) According to the activity series, calcium replaces one of the hydrogen atoms in water. The calcium ion is Ca^{2+} and the hydroxide ion is OH^-, so calcium hydroxide is $Ca(OH)_2$. The element hydrogen exists as H_2.
The unbalanced equation is:
$Ca(s) + H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$
The balanced equation is:
$Ca(s) + 2\ H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$

13. (a) According to the activity series, zinc replaces the tin(II) ion in tin(II) iodide. The zinc ion is Zn^{2+} and the iodide ion is I^-, so zinc iodide is ZnI.
The balanced equation is:
$Zn(s) + SnI_2(aq) \rightarrow Sn(s) + ZnI_2(aq)$

(b) According to the activity series, magnesium replaces the hydrogen ions in sulfuric acid. The magnesium ion is Mg^{2+} and the sulfate ion is SO_4^{2-}, so magnesium sulfate is $MgSO_4$. The element hydrogen exists as the diatomic molecule H_2.
The balanced equation is:
$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$

14. (a) According to the halogen replacement series, chlorine replaces the bromide ion in potassium bromide. The potassium ion is K^+ and the chloride ion is Cl^-, so potassium chloride is KCl. The element bromine exists as the diatomic molecule Br_2.
The unbalanced equation is:
$Cl_2(aq) + KBr(aq) \rightarrow Br_2(aq) + KCl(aq)$
The balanced equation is:
$Cl_2(aq) + 2\ KBr(aq) \rightarrow Br_2(aq) + 2\ KCl(aq)$

(b) According to the activity series, tin replaces the hydrogen ion in nitric acid. As mentioned in the text, if a metal can have two possible charges, it is always the lower charge that is formed in a single replacement reaction. The tin ion is Sn^{2+} (not Sn^{4+}) and the nitrate ion is NO_3^-, so tin(II) nitrate is $Sn(NO_3)_2$. The element hydrogen exists as the diatomic molecule H_2.
The unbalanced equation is:
$Sn(s) + HNO_3(aq) \rightarrow Sn(NO_3)_2(aq) + H_2(g)$
The balanced equation is:
$Sn(s) + 2\ HNO_3(aq) \rightarrow Sn(NO_3)_2(aq) + H_2(g)$

15. (c) aluminum hydroxide and (d) barium sulfate

16. (b) calcium chloride and (c) sodium sulfate

17. (a) In this ion exchange:
Lead(II) ion, Pb^{2+}, will combine with chloride ion, Cl^-, to form lead(II) chloride, $PbCl_2$.
Potassium ion, K^+, will combine with nitrate ion, NO_3^-, to form potassium nitrate, KNO_3.
According to the solubility rules, potassium nitrate is soluble, but lead(II) chloride is insoluble. So this is a double replacement reaction to produce a precipitate.
The unbalanced equation is:
$Pb(NO_3)_2(aq) + KCl(aq) \rightarrow PbCl_2(s) + KNO_3(aq)$
The balanced equation is:
$Pb(NO_3)_2(aq) + 2\ KCl(aq) \rightarrow PbCl_2(s) + 2\ KNO_3(aq)$

(b) In this ion exchange:

Magnesium ion, Mg^{2+}, will combine with hydroxide ion, OH^-, to form magnesium hydroxide, $Mg(OH)_2$.

Sodium ion, Na^+, will combine with chloride ion, Cl^-, to form sodium chloride, NaCl.

According to the solubility rules, sodium chloride is soluble, but magnesium hydroxide is insoluble. So this is a double replacement reaction to produce a precipitate.

The unbalanced equation is:

$MgCl_2(aq) + NaOH(aq) \rightarrow Mg(OH)_2(s) + NaCl(aq)$

The balanced equation is:

$MgCl_2(aq) + 2\ NaOH(aq) \rightarrow Mg(OH)_2(s) + 2\ NaCl(aq)$

18. (a) In this ion exchange:

Barium ion, Ba^{2+}, will combine with chloride ion, Cl^-, to form barium chloride, $BaCl_2$.

Hydrogen ion, H^+, will combine with hydroxide ion, OH^-, to form water, H_2O.

According to the solubility rules, barium chloride is soluble. So this is a double replacement reaction to produce water (a neutralization reaction).

The unbalanced equation is:

$Ba(OH)_2(aq) + HCl(aq) \rightarrow BaCl_2(aq) + H_2O(l)$

The balanced equation is:

$Ba(OH)_2(aq) + 2\ HCl(aq) \rightarrow BaCl_2(aq) + 2\ H_2O(l)$

(b) In this ion exchange reaction:

Lead(II) ion, Pb^{2+}, will combine with nitrate ion, NO_3^-, to form lead(II) nitrate, $Pb(NO_3)_2$.

Hydrogen ion, H^+, will combine with sulfide ion, S^{2-}, to form hydrogen sulfide, H_2S.

According to the solubility rules, lead(II) nitrate is soluble. Hydrogen sulfide is a gas. So this is a double replacement reaction to produce a gas.

The unbalanced equation is:

$PbS(s) + HNO_3(aq) \rightarrow Pb(NO_3)_2(aq) + H_2S(g)$

The balanced equation is:

$PbS(s) + 2\ HNO_3(aq) \rightarrow Pb(NO_3)_2(aq) + H_2S(g)$

19. (a) $KOH(s) \xrightarrow{dissolve\ in\ water} K^+(aq) + OH^-(aq)$

(b) $FeSO_4(s) \xrightarrow{dissolve\ in\ water} Fe^{2+}(aq) + SO_4^{2-}(aq)$

20. (a) $Al(NO_3)_3(s) \xrightarrow{dissolve\ in\ water} Al^{3+}(aq) + 3\ NO_3^-(aq)$

(b) $(NH_4)_3PO_4(s) \xrightarrow{dissolve\ in\ water} 3\ NH_4^+(aq) + PO_4^{3-}(aq)$

21. (a) In writing the total ionic equation for this single replacement reaction:

$Zn(s)$, being a solid element, stays the same.

$CuSO_4(aq)$ consists of $Cu^{2+}(aq)$ ions and $SO_4^{2-}(aq)$ ions.

$Cu(s)$, being a solid element, stays the same.

$ZnSO_4(aq)$ consists of $Zn^{2+}(aq)$ ions and $SO_4^{2-}(aq)$ ions.

The total ionic equation is:

$Zn(s) + Cu^{2+}(aq) + SO_4^{2-}(aq) \rightarrow Cu(s) + Zn^{2+}(aq) + SO_4^{2-}(aq)$

The sulfate ion, $SO_4^{2-}(aq)$, is a spectator ion, so the net ionic equation is:

$Zn(s) + Cu^{2+}(aq) \rightarrow Cu(s) + Zn^{2+}(aq)$

(b) In writing the total ionic equation for this single replacement reaction:

$Sn(s)$, being a solid element, stays the same.

$HCl(aq)$ consists of $H^+(aq)$ ions and $Cl^-(aq)$ ions.

$SnCl_2(aq)$ consists of $Sn^{2+}(aq)$ ions and $Cl^-(aq)$ ions.

$H_2(g)$, being a covalently-bonded gas, stays the same.

The total ionic equation is:

$Sn(s) + 2\ H^+(aq) + 2\ Cl^-(aq) \rightarrow Sn^{2+}(aq) + 2\ Cl^-(aq) + H_2(g)$

The chloride ion, $Cl^-(aq)$, is a spectator ion, so the net ionic equation is:

$Sn(s) + 2\ H^+(aq) \rightarrow Sn^{2+}(aq) + H_2(g)$

22. (a) In writing the total ionic equation for this single replacement reaction:

$Br_2(aq)$, being a covalently-bonded molecule, stays the same.

$KI(aq)$ consists of $K^+(aq)$ ions and $I^-(aq)$ ions.

$I_2(aq)$, being a covalently-bonded molecule, stays the same.

$KBr(aq)$ consists of $K^+(aq)$ ions and $Br^-(aq)$ ions.

The total ionic equation is:

$Br_2(aq) + 2\ K^+(aq) + 2\ I^-(aq) \rightarrow I_2(aq) + 2\ K^+(aq) + 2\ Br^-(aq)$

The potassium ion, $K^+(aq)$, is a spectator ion, so the net ionic equation is:

$Br_2(aq) + 2\ I^-(aq) \rightarrow I_2(aq) + 2\ Br^-(aq)$

(b) In writing the total ionic equation for this single replacement reaction:

$Ca(s)$, being a solid element, stays the same.

$H_2O(l)$, being a covalently-bonded molecule, stays the same.

$Ca(OH)_2(aq)$ consists of $Ca^{2+}(aq)$ ions and $OH^-(aq)$ ions.

$H_2(g)$, being a covalently-bonded gas, stays the same.

The total ionic equation is:

$Ca(s) + 2\ H_2O(l) \rightarrow Ca^{2+}(aq) + 2\ OH^-(aq) + H_2(g)$

There are no spectator ions, so the net ionic equation will be exactly the same.

$Ca(s) + 2\ H_2O(l) \rightarrow Ca^{2+}(aq) + 2\ OH^-(aq) + H_2(g)$

23. (a) In writing the total ionic equation for this double replacement reaction:

$KBr(aq)$ consists of $K^+(aq)$ ions and $Br^-(aq)$ ions.

$AgNO_3(aq)$ consists of $Ag^+(aq)$ ions and $NO_3^-(aq)$ ions.

$AgBr(s)$, being a solid compound, stays the same.

$KNO_3(aq)$ consists of $K^+(aq)$ ions and $NO_3^-(aq)$ ions.

The total ionic equation is:

$K^+(aq) + Br^-(aq) + Ag^+(aq) + NO_3^-(aq) \rightarrow AgBr(s) + K^+(aq) + NO_3^-(aq)$

The potassium ion, $K^+(aq)$, and the nitrate ion, $NO_3^-(aq)$ are spectator ions, so the net ionic equation is:

$Br^-(aq) + Ag^+(aq) \rightarrow AgBr(s)$

(b) In writing the total ionic equation for this double replacement reaction:

$CaCl_2(aq)$ consists of $Ca^{2+}(aq)$ ions and $Cl^-(aq)$ ions.

$Na_2CO_3(aq)$ consists of $Na^+(aq)$ ions and $CO_3^{2-}(aq)$ ions.

$CaCO_3(s)$, being a solid compound, stays the same.

$NaCl(aq)$ consists of $Na^+(aq)$ ions and $Cl^-(aq)$ ions.

The total ionic equation is:

$Ca^{2+}(aq) + 2\ Cl^-(aq) + 2\ Na^+(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s) + 2\ Na^+(aq) + 2\ Cl^-(aq)$

The chloride ion, $Cl^-(aq)$ and the potassium ion, $K^+(aq)$ are spectator ions, so the net ionic equation is:

$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$

24. (a) In writing the net ionic equation for this double replacement reaction:

$NH_4Cl(aq)$ consists of $NH_4^+(aq)$ ions and $Cl^-(aq)$ ions.

$KOH(aq)$ consists of $K^+(aq)$ ions and $OH^-(aq)$ ions.

$KCl(aq)$ consists of $K^+(aq)$ ions and $Cl^-(aq)$ ions.

$NH_3(aq)$, being a covalently-bonded molecule, stays the same.

$H_2O(l)$, being a covalently-bonded molecule, stays the same.

The total ionic equation is:

$NH_4^+(aq) + Cl^-(aq) + K^+(aq) + OH^-(aq) \rightarrow K^+(aq) + Cl^-(aq) + NH_3(aq) + H_2O(l)$

The chloride ion, $Cl^-(aq)$ and the potassium ion, $K^+(aq)$ are spectator ions, so the net ionic equation is:

$NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(aq) + H_2O(l)$

(b) In writing the total ionic equation for this double replacement reaction:

$Ba(OH)_2(aq)$ consists of $Ba^{2+}(aq)$ ions and $OH^-(aq)$ ions.
$HCl(aq)$ consists of $H^+(aq)$ ions and $Cl^-(aq)$ ions.
$BaCl_2(aq)$ consists of $Ba^{2+}(aq)$ ions and $Cl^-(aq)$ ions
$H_2O(l)$, being a covalently-bonded molecule, stays the same.

The total ionic equation is:
$Ba^{2+}(aq) + 2\ OH^-(aq) + 2\ H^+(aq) + 2\ Cl^-(aq) \rightarrow Ba^{2+}(aq) + 2\ Cl^-(aq) + 2\ H_2O(l)$
The chloride ion, $Cl^-(aq)$ and the barium ion, $Ba^{2+}(aq)$ are spectator ions, so the net ionic equation is:
$2\ OH^-(aq) + 2\ H^+(aq) \rightarrow 2\ H_2O(l)$