Section 2.4: Chemical Formulas and Nomenclature

Tutorial 1 Practice, page 75
1. Chemical formula for binary ionic compound:
   (a) Magnesium oxide:
   
   \[
   \begin{align*}
   &2 + 2 - \rightarrow (+2) + (-2) = 0 \\
   &\text{Mg O} \rightarrow \text{MgO}
   \end{align*}
   \]
   The chemical formula for magnesium oxide is MgO.

   (b) Aluminum fluoride:
   
   \[
   \begin{align*}
   &3 + 1 - \rightarrow (+3) + 3(-1) = 0 \\
   &\text{Al F} \rightarrow \text{AlF}_3
   \end{align*}
   \]
   The chemical formula for aluminum fluoride is AlF₃.

   (c) Potassium oxide:
   
   \[
   \begin{align*}
   &1 + 2 - \rightarrow 2(+1) + (-2) = 0 \\
   &\text{K O} \rightarrow \text{K}_2\text{O}_1
   \end{align*}
   \]
   The chemical formula for potassium oxide is K₂O.

2. Chemical formula for polyatomic ionic compound:
   (a) Magnesium hydroxide:
   
   \[
   \begin{align*}
   &2 + 1 - \rightarrow (+2) + 2(-1) = 0 \\
   &\text{Mg OH} \rightarrow \text{Mg(OH)}_2
   \end{align*}
   \]
   The chemical formula for magnesium hydroxide is Mg(OH)₂.

   (b) Sodium bicarbonate:
   
   \[
   \begin{align*}
   &1 + 1 - \rightarrow (+1) + (-1) = 0 \\
   &\text{Na HCO}_3 \rightarrow \text{NaHCO}_3
   \end{align*}
   \]
   The chemical formula for sodium bicarbonate is NaHCO₃.

   (c) Aluminum phosphate:
   
   \[
   \begin{align*}
   &3 + 3 - \rightarrow (+3) + (-3) = 0 \\
   &\text{Al PO}_4 \rightarrow \text{AlPO}_4
   \end{align*}
   \]
   The chemical formula for aluminum phosphate is AlPO₄.
Tutorial 2 Practice, pages 77 and 78

1. Chemical name for ionic compound:
   (a) CuSO₄ contains copper, which is a multivalent metal.
   SO₄ is the sulfate ion, with a charge of –2.
   The total negative charge is –2, so the total positive charge is +2.
   So, the charge on the Cu ion is +2.
   The IUPAC name of CuSO₄ is copper(II) sulfate.
   (b) CuCl contains copper, which is a multivalent metal.
   The second element is Cl, so the second part of the compound’s name is chloride.
   The Cl ion has a charge of –1. The total negative charge is –1.
   The charge on the Cu ion may be +1 or +2.
   The total positive charge is +1, so the charge on the Cu ion is +1.
   The IUPAC name of CuCl is copper(I) chloride.
   (c) SnCl₄ contains tin, which is a multivalent metal.
   The second element is Cl, so the second part of the compound’s name is chloride.
   The Cl ion has a charge of –1. There are 4 Cl ions, each with a –1 charge. The total negative charge is –4.
   The charge on the Sn ion may be +2 or +4.
   The total positive charge is +4, so the charge on the Sn ion is +4.
   The IUPAC name of SnCl₄ is tin(IV) chloride.
   (d) SnO contains tin, which is a multivalent metal.
   The second element is O, so the second part of the compound’s name is oxide.
   The O ion has a charge of –2. The total negative charge is –2.
   The charge on the Sn ion may be +2 or +4.
   The total positive charge is +2, so the charge on the Sn ion is +2.
   The IUPAC name of SnO is tin(II) oxide.

2. Chemical name for ionic compound:
   (a) Pb(SO₃)₂ contains lead, which is a multivalent metal.
   SO₃ has one less O than the sulfate ion, SO₄²⁻, so it is the sulfite ion, with a charge of –2.
   The charge on the Pb ion may be +2 or +4.
   There are 2 SO₃ ions, each with a –2 charge. The total negative charge is –4.
   The total positive charge is +4, so the charge on the Pb ion is +4.
   The IUPAC name of Pb(SO₃)₂ is lead(IV) sulfite.
   (b) Pb(NO₃)₂ contains lead, which is a multivalent metal.
   NO₃ is the nitrate ion, with a charge of –1.
   The charge on the Pb ion may be +2 or +4.
   There are 2 NO₃ ions, each with a –1 charge. The total negative charge is –2.
   The total positive charge is +2, so the charge on the Pb ion is +2.
   The IUPAC name of Pb(NO₃)₂ is lead(II) nitrate.
   (c) Cu₃PO₄ contains copper, which is a multivalent metal.
   PO₄ is the phosphate ion, with a charge of –3. The total negative charge is –3.
   The charge on the Cu ion may be +1 or +2.
   The total positive charge is +3, and there are 3 Cu ions, so the charge on the Cu ion is +1.
   The IUPAC name of Cu₃PO₄ is copper(I) phosphate.
(d) Fe(OH)₃ contains iron, which is a multivalent metal. OH is the hydroxide ion, with a charge of −1. The charge on the Fe ion may be +2 or +3. There are 3 OH ions, each with a −1 charge. The total negative charge is −3. The total positive charge is +3, so the charge on the Fe ion is +3. The IUPAC name of Fe(OH)₃ is iron(III) hydroxide.

(e) NaClO contains the sodium ion, Na, with a charge of +1. ClO is an oxyanion with 2 fewer oxygen atoms than chlorate, so it is the hypochlorite ion, with a charge of −1. The IUPAC name of NaClO is sodium hypochlorite.

(f) (NH₄)₂CO₃ contains the ammonium ion, NH₄, with a charge of +1, and the oxyanion CO₃, carbonate, with a charge of −2. There are 2 ammonium ions, so the total positive charge is 2(+1) = +2. The IUPAC name of (NH₄)₂CO₃ is ammonium carbonate.

**Tutorial 3 Practice, page 79**

1. (a) For a compound of calcium and chlorine, 1 Ca atom is needed for every Cl atom. The molecular compound is CaCl, or calcium chloride. There are 2 water molecules for each CaCl molecule, so this is a hydrate, and the prefix for “hydrate” is di-. The name of the hydrate is calcium chloride dihydrate, and the chemical formula is CaCl·2H₂O.

   (b) The sodium ion, Na, has a charge of 1+ and the sulfate ion, SO₄, has a charge of 2−. Two Na ions are needed for each SO₄ ion to bring the total charge to zero. The chemical formula for sodium sulfate is Na₂SO₄. There are 10 water molecules per formula unit of sodium sulfate, so this is a hydrate, and the prefix for “hydrate” is deca-. The name of the hydrate is sodium sulfate decahydrate, and the chemical formula is Na₂SO₄·10H₂O.

**Tutorial 4 Practice, page 80**

1. Name of molecular compound:
   (a) CCl₄ is carbon tetrachloride.
   (b) NO₂ is nitrogen dioxide.
   (c) P₂O₅ is diphosphorous pentoxide.
   (d) CF₄ is carbon tetrafluoride.

2. Chemical formula for molecular compound:
   (a) Carbon monoxide is CO.
   (b) Sulfur dioxide is SO₂.
   (c) Phosphorus pentfluoride is PF₅.
Research This: What’s in a Name?, page 80
Answers may vary. Sample answers:
A. Ingredients for dry cat food included brown rice, potassium chloride, ferrous sulfate, copper sulfate, manganous oxide, calcium iodate, and sodium selenite. These are all ionic compounds, except for brown rice.
B. The brown rice is a molecular compound.
C. Ionic compounds are composed of a metallic element combined with one or more non-metallic elements. Potassium, iron, copper, manganese, calcium, and sodium are all metals. Carbohydrates, such as rice, are made up of carbon, hydrogen, and oxygen, which are all non-metals, so carbohydrates are molecular compounds.
D. The chemical formulas of the compounds are: potassium chloride, KCl; ferrous sulfate, FeSO$_4$; copper sulfate, CuSO$_4$; manganous oxide, MnO; calcium iodate, Ca(IO$_3$)$_2$; and sodium selenite, Na$_2$SeO$_3$. Rice is a polysaccharide with the chemical formula C$_x$(H$_2$O)$_y$.
E. Not all of the compounds were named according to the IUPAC system. Ferrous sulfate is iron(II) sulfate or iron(III) sulfate, copper sulfate is copper(II) sulfate, manganous oxide is manganese(II) oxide, and calcium iodate is calcium diiodate.

Section 2.4 Questions, page 81
1. (a) Lithium chloride:

$$\begin{align*}
1^+ & \quad 1^- & \quad \rightarrow & \quad (+1) + (-1) = 0 & \quad \rightarrow & \quad LiCl \\
Li & \quad Cl & \quad \rightarrow & \quad Li & \quad Cl
\end{align*}$$

The chemical formula for lithium chloride is LiCl.

(b) Potassium sulfide:

$$\begin{align*}
1^+ & \quad 2^- & \quad \rightarrow & \quad 2(+1) + (-2) = 0 & \quad \rightarrow & \quad K_2S
\end{align*}$$

The chemical formula for potassium sulfide is K$_2$S.

(c) Iron(II) chloride:

$$\begin{align*}
2^+ & \quad 1^- & \quad \rightarrow & \quad (+2) + (-1) = 0 & \quad \rightarrow & \quad FeCl_2
\end{align*}$$

The chemical formula for iron(II) chloride is FeCl$_2$.

(d) Aluminum oxide:

$$\begin{align*}
3^+ & \quad 2^- & \quad \rightarrow & \quad 2(+3) + 3(-2) = 0 & \quad \rightarrow & \quad Al_2O_3
\end{align*}$$

The chemical formula for aluminum oxide is Al$_2$O$_3$.

(e) Sodium sulfate:

$$\begin{align*}
1^+ & \quad 2^- & \quad \rightarrow & \quad 2(+1) + (-2) = 0 & \quad \rightarrow & \quad Na_2(SO_4)
\end{align*}$$

The chemical formula for sodium sulfate is Na$_2$SO$_4$. 
(f) Tin(IV) oxide:

\[ \text{Sn}^{4+} + 2\text{O}^{2-} \rightarrow \text{SnO}_2 \]

The chemical formula for tin(IV) oxide is SnO₂.

2. For an ionic compound with a multivalent metal, IUPAC naming rules involve indicating which specific ion it is by using a Roman numeral after the name of the ion; for example, FeO is iron(II) oxide.

3. (a) The IUPAC name for MgCl₂ is magnesium chloride.
(b) The IUPAC name for Cs₂O is cesium oxide.
(c) The IUPAC name for FeS is iron(II) sulfide.
(d) Na is sodium and PO₄ is the phosphate ion. The IUPAC name for Na₃PO₄ is sodium phosphate.
(e) NH₄ is the ammonium ion and NO₃ is the nitrate ion. The IUPAC name for NH₄NO₃ is ammonium nitrate.
(f) Al is aluminum and SO₄ is the sulfate ion. The IUPAC name for Al₂(SO₄)₃ is aluminum sulfate.
(g) Mg is magnesium and ClO₃ is the chlorate ion. The IUPAC name for Mg(ClO₃)₂ is magnesium chlorate.
(h) The IUPAC name for Pb(BrO₃)₂ is lead(II) bromate.
(i) The IUPAC name for ZnHPO₄ is zinc hydrogen phosphate.
(j) The IUPAC name for NaCN is sodium cyanide.

4. (a) The IUPAC name for PCl₅ is phosphorous pentachloride.
(b) The IUPAC name for N₂O₅ is dinitrogen pentoxide.
(c) The IUPAC name for CF₄ is carbon tetrafluoride.
(d) The IUPAC name for SO₂ is sulfur dioxide.

5. Chemical formula for anhydrous cobalt(II) chloride:

\[ 2\text{Co}^{2+} + 1\text{Cl}^- \rightarrow \text{CoCl}_2 \]

The chemical formula for anhydrous cobalt(II) chloride is CoCl₂.

The hydrated form, cobalt(II) chloride hexahydrate, has 6 water molecules for each formula unit of CoCl₂, so the chemical formula for the hydrated form is CoCl₂•6H₂O.

6. (a) The chemical formula for phosphorus trichloride is PCl₃.
(b) The chemical formula for carbon tetrachloride is CCl₄.
(c) The chemical formula for nitrogen monoxide is NO.
(d) The chemical formula for disulfur dichloride is S₂Cl₂.

7. (a) The chemical name for KOH is potassium hydroxide.
(b) The chemical name for NaNO₂ is sodium nitrite.
(c) The chemical name for CuCl is copper(I) chloride.
(d) The chemical name for NaOH is sodium hydroxide.
(e) The chemical name for CaCO₃ is calcium carbonate.

8. It is important to have a standardized IUPAC nomenclature system so that scientists and professionals can communicate the name and chemical formula for any chemical in the same way. This system avoids confusion that could lead to mistakes in use of chemicals.