Key Questions & Exercises

1. Do all compounds contain molecules?
   No. Only molecular compounds contain molecules of the compound. (Ionic compounds
   may contain molecular ions, but these compounds are not composed of molecules
   corresponding to their empirical formulas.)

2. What is the difference between a molecular and empirical formula?
   A molecular formula represents the composition of molecules in a molecular compound.
   An empirical formula is the lowest whole-number ratio of elements in the compound.

3. What kinds of compounds (molecular, ionic, network) can be represented with a
   molecular formula?
   Only molecular compounds

4. What kinds of compounds (molecular, ionic, network) can be represented with an
   empirical formula?
   All three types. With ionic compounds and network solids, an empirical formula is the
   only appropriate type of chemical formula.

5. Using the periodic table, predict the chemical formula of the ionic compound formed by
   the following pairs of elements:
   Ga and F: GaF₃
   Ca and O: CaO
   Na and N: Na₃N
   Al and O: Al₂O₃

6. Complete the following table by filling in the formula for the ionic compound formed by
   each pair of cations and anions, as shown for the first pair.

<table>
<thead>
<tr>
<th>Ion</th>
<th>K⁺</th>
<th>NH₄⁺</th>
<th>Mg²⁺</th>
<th>Fe³⁺</th>
</tr>
</thead>
<tbody>
<tr>
<td>S²⁻</td>
<td>K₂S</td>
<td>(NH₄)₂S</td>
<td>MgS</td>
<td>Fe₂S₃</td>
</tr>
<tr>
<td>NO₃⁻</td>
<td>KNO₃</td>
<td>NH₄NO₃</td>
<td>Mg(NO₃)₂</td>
<td>Fe(NO₃)₃</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>K₂SO₄</td>
<td>(NH₄)₂SO₄</td>
<td>MgSO₄</td>
<td>Fe₂(SO₄)₃</td>
</tr>
<tr>
<td>PO₄³⁻</td>
<td>K₃PO₄</td>
<td>(NH₄)₃PO₄</td>
<td>Mg₃(PO₄)₂</td>
<td>FePO₄</td>
</tr>
</tbody>
</table>

7. Predict whether each the following compounds is molecular or ionic: PF₅ - molecular,
   NaI - ionic, SCl₂ - molecular, B₂H₆ - molecular, LiNO₃ - ionic, NOCl - molecular, CoCO₃
   - ionic, NF₃ - molecular
8. In the chemical formula and name, which element is given first, a metal or nonmetal? Metals are a named first, then nonmetals.

9. What suffix (ending) is added to the root of the name of the nonmetal in naming an ionic compound? The suffix -ide is added to the root; e.g., sulfur is named sulfide in an ionic compound.

10. When a metal ion can form more than one kind of cation, how is the charge on the cation indicated in the name of a compound? The charge on the cation, which can be deduced from the known charge on the anion and the number of anions in the empirical formula, is indicated by Roman numerals in parentheses; e.g., CrCl₃ is chromium(III) chloride.

11. Name the following molecular compounds: SCl₂, N₂O₄, P₄O₁₀, PF₅
   - SCl₂ - sulfur dichloride
   - N₂O₄ - dinitrogen tetroxide (The “a” of tetra- is dropped before the “o” of oxide.)
   - P₄O₁₀ - tetraphosphorous decoxide (The “a” of deca- is dropped before the “o” of oxide.)
   - PF₅ - phosphorous pentafluoride

12. Some molecular compounds are not named systematically, but rather retain their traditional names. Name the following compounds that retain their traditional names:
   - H₂O, NH₃, H₂O₂, H₂S
   - H₂O - water (not dihydrogen oxide)
   - NH₃ - ammonia (not nitrogen trihydride)
   - H₂O₂ - hydrogen peroxide (not dihydrogen dioxide)
   - H₂S - hydrogen sulfide (not dihydrgen sulfide, because there is no other hydrogen compound of sulfur)

13. Name the following ionic compounds: AlCl₃, Li₃PO₄, Ba(ClO₄)₂, Cu(NO₃)₂, Fe₂(SO₄)₃, Ca(C₂H₃O₂)₂, Cr₂(CO₃)₃, K₂CrO₄, (NH₄)₂SO₄
   - AlCl₃ - aluminum chloride
   - Li₃PO₄ - lithium phosphate
   - Ba(ClO₄)₂ - barium perchlorate
   - Cu(NO₃)₂ - copper(II) nitrate
   - Fe₂(SO₄)₃ - iron(III) sulfate
   - Ca(C₂H₃O₂)₂ - calcium acetate
   - Cr₂(CO₃)₃ - chromium(III) carbonate
   - K₂CrO₄ - potassium chromate
   - (NH₄)₂SO₄ - ammonium sulfate

14. Give the name or chemical formula, as appropriate, for each of the following acids:
   - HClO₄, HBr, H₃PO₄, hypochlorous acid, iodic acid, sulfurous acid
   - HClO₄ - perchloric acid
   - HBr - hydrobromic acid
   - H₃PO₄ - phosphoric acid
   - hypochlorous acid - HOCl (or HClO)
iodic acid - HIO₃
sulfurous acid - H₂SO₃

15. Name the following simple organic compounds: CH₄ - methane, C₂H₆ - ethane, CH₃OH - methanol, C₂H₅OH - ethanol

16. Balance the following skeletal equations, using lowest whole-number coefficients:

\[
\begin{align*}
\text{N}_2\text{O}_5 + \text{H}_2\text{O} & \rightarrow 2 \text{HNO}_3 \\
3 \text{Ca(OH)}_2 + 2 \text{H}_3\text{PO}_4 & \rightarrow \text{Ca}_3(\text{PO}_4)_2 + 6 \text{H}_2\text{O} \\
2 \text{C}_5\text{H}_{10}\text{O}_2 + 13 \text{O}_2 & \rightarrow 10 \text{CO}_2 + 10 \text{H}_2\text{O}
\end{align*}
\]

17. Why is it incorrect to talk about the molecular weight of NaCl?
There are no molecules of NaCl. We can only define a formula weight, based on the empirical formula.

18. Would the sum of the masses of all atoms in the chemical formula C₂H₅OH be a molecular weight or a formula weight?
This is a molecular compound, because it is composed entirely of nonmetals. Also, it is an organic compound, which we recognize as an alcohol. The given formula, then, is a molecular formula, so the sum of atomic weights multiplied by the numbers of each element would give a molecular weight.

19. Is there a difference between the molecular weight and formula weight of the molecular compound N₂O₅?
No, because the molecular formula in this case happens to involve a lowest whole-number ratio; viz., 2:5. Thus, the empirical and molecular formulas are identical.

20. Calculate the molecular weight and formula weight of glucose, C₆H₁₂O₆.

\[
\begin{align*}
\text{m.w.} &= (6)(12.01 \text{ u}) + (12)(1.008 \text{ u}) + (6)(16.00 \text{ u}) = 180.156 \text{ u} = 180.16 \text{ u} \\
\text{empirical formula} &= \text{CH}_2\text{O} \\
\text{f.w.} &= 12.01 \text{ u} + (2)(1.008 \text{ u}) + 16.00 \text{ u} = 30.0267 \text{ u} = 30.03 \text{ u}
\end{align*}
\]
Note that in this case m.w. = 6 × f.w. As expected, the molecular weight is a whole number multiple of the formula weight.

21. Calculate the percent composition of glucose.

\[
\begin{align*}
\% \text{ C} &= \frac{(6)(12.01)}{180.16} \times 100\% = 40.00\% \\
\% \text{ H} &= \frac{(12)(1.008)}{180.16} \times 100\% = 6.714\% \\
\% \text{ O} &= \frac{(6)(16.00)}{180.16} \times 100\% = 53.29\%
\end{align*}
\]
With possibly slight differences due to rounding, the same numbers will be obtained if the empirical formula is used, instead of the molecular formula.

\[
\% \text{ C} = \frac{12.01}{30.02_{67}} \times 100\% = 40.00\%
\]

\[
\% \text{ H} = \frac{(2)(1.008)}{30.02_{67}} \times 100\% = 6.714\%
\]

\[
\% \text{ O} = \frac{16.00}{30.02_{67}} \times 100\% = 53.29\%
\]