2.8 Formulas, Names and Masses of Compounds

- **Chemical formula** – shows the elemental composition of a compound
- **Molecular formula (MF)** – gives the number of atoms of each type in a molecule
  - butane → C_4H_{10} → 4C &10H atoms in 1 molecule
- **Empirical formula (EF)** – shows the relative number of atoms of each type in terms of the smallest whole numbers
  - butane, MF → C_4H_{10} , EF → C_2H_5

- **Structural formula** – gives the type and number of atoms in a molecule and how they are bonded (water → H–O–H)
- **Nomenclature** – system of naming compounds (common and systematic names)

Names of Ions

- Monatomic cations
  - ***name of element* + *ion*** (Ca^{2+} → calcium ion)
  - *Roman numeral* for the charge of the ion, if more than one charges are possible (Fe^{2+} → iron(II) ion, Fe^{3+} → iron(III) ion)
  - No roman numerals for group 1&2 cations, Al^{3+}, Zn^{2+}, Cd^{2+} and Ag^{+}

- Monatomic anions
  - ***root of element name* + *-ide* + *ion*** (Cl^- → chlor*ide* ion, O^{2-} → ox*ide* ion)
- Polyatomic ions - Table 2.5 (memorize)
  - oxoanions
    - ***root of element name* + *-ate* + *ion*** (SO_4^{2-} → sulf*ate* ion)
    - oxoanions with different number of O atoms - ***hypo-* (*per-*) + *root of element name* + *-ite* (*-ate*) + *ion*** (ClO^- → *hypo*clor*ite*, ClO_2^- → chlor*ite*, ClO_3^- → chlor*ate*, ClO_4^- → *per*chlor*ate* ion)
  - H-containing anions – add ***"hydrogen"*** to the name ($H_2PO_4^-$ dihydrogen phosphate ion)

Names & Formulas of Ionic Compounds

- ***Name of cation + name of anion***

- Names from formulas
  - $MgSO_4$ → Mg^{2+}, SO_4^{2-} → magnesium sulfate
- Charge balance
  - Co_2S_3 → $Co_2^{X+}S_3^{2-}$ → 2(+X) + 3(-2) = 0 → X=+3 → cobalt(III) sulfide
- Formulas from names (**cross rule**)
  - Aluminum sulfate → Al^{3+}, SO_4^{2-} → $Al_2(SO_4)_3$
- Formulas of ionic compounds are empirical

- **Hydrates** – ionic compounds containing a definite proportion of water ($CoCl_2 \cdot 6H_2O$ → cobalt(II) chloride hexahydrate)
  - Greek prefixes - ***mono-, di-,...*** (memorize)

Table 2.6 Numerical Prefixes for Hydrates and Binary Covalent Compounds

Number	Prefix
1	mono-
2	di-
3	tri-
4	tetra-
5	penta-
6	hexa-
7	hepta-
8	octa-
9	nona-
10	deca-

Examples:

- Give the systematic names of Na_2HPO_4 and $CuSO_4 \cdot 5H_2O$.

  Na^+ , HPO_4^{2-} → sodium hydrogen phosphate

  Cu^{2+} , SO_4^{2-} → copper(II) sulfate pentahydrate
- Give the formulas of manganese(II) fluoride and barium oxide.

  Manganese(II) fluoride (Mn^{2+} F^-) → MnF_2

  Barium oxide (Ba^{2+} O^{2-}) → Ba_2O_2 → BaO

Names & Formulas of Covalent Compounds

- **Binary molecular compounds**
  - ***name of 1st element + root for 2nd element + ide***
  - Greek prefixes for the # of atoms of each type; *mono-* can be omitted except for O
  - The element with lower group # is written 1st (exception → O is always last)

Examples:

N_2O → *di*nitrogen *mono*x*ide*

SF_4 → sulfur *tetra*fluor*ide*

H_2S → *di*hydrogen sulf*ide*

- **Acids** – release H^+ in water
  - Aqueous solutions of **binary** compounds containing H ($HCl_{(aq)}$, $H_2S_{(aq)}$, $HCN_{(aq)}$, ...)
    - ***hydro- + root of element + -ic + acid*** (*hydro*chlor*ic* acid, *hydro*sulfur*ic* acid, *hydro*cyan*ic* acid)
    - parent acids of anions ending on *-ide*
  - **Oxoacids** – parent acids of oxoanions; the # of acidic H atoms equals the charge of the anion (HNO_3, H_2SO_3, H_3PO_4, …)
    - ***root of element + -ic + acid*** - for anions ending on *-ate* (HNO_3 → nitric acid)
    - ***root of element + -ous + acid*** - for anions ending on *-ite* (H_2SO_3 → sulfurous acid)

Examples:

- Name the acids: $HBr_{(aq)}$, HClO, H_2CO_3, $HBrO_4$

  *hydro*brom*ic* acid ← (Br^- , brom*ide*)

  hypochlor*ous* acid ← (ClO^- , hypochlor*ite*)

  carbon*ic* acid ← (CO_3^{2-} , carbon*ate*)

  perbrom*ic* acid ← (BrO_4^- , perbrom*ate*)

- How to distinguish between ionic and molecular compounds
  - Molecular – typically consist of nonmetals (H_2O, NH_3, CO_2, C_2H_6O, ...)
  - Ionic – combination of metals and nonmetals (NaCl, $MgSO_4$, $AlPO_4$, KOH, ... exception NH_4^+ containing)

Example:

- Classify the compounds CH_5N, NH_4NO_3 and HCl as ionic or covalent and identify the ions if present.

Problem:

- Name the compounds: PF_5, CrF_3, N_2O_3, Fe_2O_3
  - molecular → phosphorus pentafluoride
  - ionic, F^- , Cr^{3+} → chromium(III) fluoride
  - molecular → dinitrogen trioxide
  - ionic, O^{2-}, Fe^{3+} → iron(III) oxide

Problem:

- Write the formulas of: zinc phosphate, vanadium(V) oxide, xenon tetrafluoride, cobalt(II) chloride hexahydrate
  - Zn^{2+} , PO_4^{3-} (cross rule) → $Zn_3(PO_4)_2$
  - V^{5+} , O^{2-} (cross rule) → V_2O_5
  - molecular → XeF_4
  - Co^{2+} , Cl^- (cross rule) → $CoCl_2 \cdot 6H2O$

Molecular and Formula Mass

- **Molecular mass –** sum of the atomic masses of the atoms in a molecule
  - $CO_2 \rightarrow 1\times12.01 + 2\times16.00 = 44.01$ amu
- **Formula mass –** sum of the atomic masses of the atoms in one formula unit of an ionic compound
  - $Ca(ClO_4)_2 \rightarrow 1\times40.08 + 2\times35.45 + 8\times16.00 =$
    $= 238.98$ amu