

Chapter 5: Molecules and Compounds

**Compound:** a pure substance that contains...

**Chemical formula:** ratio of elements

**Law of constant composition:** ratio in a compound is consistent if the compound is pure

**Formula unit:** atoms represented by a chemical formula

One formula unit of  $\text{Ca}_3(\text{PO}_4)_2$  contains...

Molecular compounds

**Molecular compounds:** made of molecules (groups of bonded atoms)

Contains which type of elements?

$\text{H}_2\text{O}$ :

$\text{CO}_2$ :

$\text{C}_{12}\text{H}_{22}\text{O}_{11}$ :

$\text{H}_2$ :

$\text{H}_2$  is a **diatomic element** (exists as pairs of atoms)

There are 7 diatomic elements:

## Ionic compounds

**Ionic compounds:** contain positive and negative ions

- Usually 1 metal and 1 or more nonmetals
- Forms a 3-dimensional lattice of opposite ions



Formation of an ionic compound from Na and Cl:

Ionic compounds must be...

What is the formula of the compound formed from calcium and chlorine?

## Naming ionic compounds

Write the name and formula of the compound formed from calcium and chlorine

Ion pair:

Name: cation (+) name then anion (-) name

Anion names:

|                 |                  |                 |
|-----------------|------------------|-----------------|
| <u>VA</u>       | <u>VIA</u>       | <u>VIIA</u>     |
| N <sup>3-</sup> | O <sup>2-</sup>  | F <sup>-</sup>  |
| P <sup>3-</sup> | S <sup>2-</sup>  | Cl <sup>-</sup> |
|                 | Se <sup>2-</sup> | Br <sup>-</sup> |
|                 |                  | I <sup>-</sup>  |

Formula:

Write the name and formula of the cpd with Mg and Br:

Write the name and formula of the cpd with Ca and N:

Naming ionic compounds

Write the formula for magnesium oxide

|                   | <u>Ion pair</u> | <u>Formula</u> |
|-------------------|-----------------|----------------|
| aluminum selenide |                 |                |
| lithium phosphide |                 |                |
| barium sulfide    |                 |                |
| barium chloride   |                 |                |

Types of binary compounds (two elements only):

|           | <u>Type I</u> | <u>Type II</u> | <u>Type III (molecular)</u> |
|-----------|---------------|----------------|-----------------------------|
| Ions?     |               |                |                             |
| Elements? |               |                |                             |
| Example:  |               |                |                             |

Type II ionic compounds

**Transition metals:**

- do not form a single stable ion like nonmetals do
- can form multiple different stable ions

For instance, the iron cation can be  $\text{Fe}^{2+}$  or  $\text{Fe}^{3+}$

iron chloride is an incomplete name

$\text{FeCl}_3$ :

### Type II ionic compounds

Name                      Ion pair    Ratio    Formula

titanium (IV) chloride

titanium (IV) oxide

Formula    Ratio    Ion pair    Name

WF<sub>6</sub>

MnP<sub>2</sub>

Cu<sub>2</sub>O<sub>3</sub>

Formula    Type    Ratio    Ion pair    Name

K<sub>2</sub>O

CrO<sub>2</sub>

MgI<sub>2</sub>

Ni<sub>2</sub>O

### Type III (Molecular) Compounds

**Molecular compounds** contain nonmetals only and have no ions!

Binary (2 element) molecular compounds are named from the formula using Greek prefixes to show quantity

NO<sub>3</sub>:

N<sub>2</sub>O<sub>4</sub>:

CO<sub>2</sub>:

NO<sub>2</sub>:

CO:

P<sub>2</sub>Cl<sub>5</sub>:

Greek prefixes  
(for quantity)

1: mono

2: di

3:

4:

5:

6:

Binary nomenclature practice

Do you know the difference between the 3 types?

Formula Type Ion pair Name

AlBr<sub>3</sub>

FeBr<sub>3</sub>

BBr<sub>3</sub>

Type Ion pair Name/Formula

Mn<sub>3</sub>N<sub>7</sub>

platinum (IV) oxide

IF<sub>6</sub>

AuS<sub>2</sub>

Type I or Type II?

Type I:

Type II:

A few important exceptions...

Periodic Table of the Elements

|   | 1              | 2            | 3              | 4            | 5            | 6            | 7            | 8            | 9            | 10           | 11           | 12           | 13           | 14           | 15           | 16           | 17          | 18           |
|---|----------------|--------------|----------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|-------------|--------------|
|   | IA             | IIA          | IIIB           | IVB          | VB           | VIB          | VIB          | VIB          | VIB          | VIB          | IB           | IIA          | IIIA         | IVA          | VA           | VIA          | VIA         | VIA          |
| 1 | H<br>1.008     |              |                |              |              |              |              |              |              |              |              |              |              |              |              |              |             | He<br>4.003  |
| 2 | Li<br>6.939    | Be<br>9.012  |                |              |              |              |              |              |              |              |              |              | B<br>10.81   | C<br>12.01   | N<br>14.01   | O<br>16.00   | F<br>19.00  | Ne<br>20.18  |
| 3 | Na<br>22.99    | Mg<br>24.31  |                |              |              |              |              |              |              |              |              |              | Al<br>26.98  | Si<br>28.09  | P<br>30.97   | S<br>32.06   | Cl<br>35.45 | Ar<br>39.95  |
| 4 | K<br>39.10     | Ca<br>40.08  | Sc<br>44.96    | Ti<br>47.90  | V<br>50.94   | Cr<br>52.00  | Mn<br>54.94  | Fe<br>55.85  | Co<br>58.93  | Ni<br>58.71  | Cu<br>63.54  | Zn<br>65.37  | Ga<br>69.72  | Ge<br>72.59  | As<br>74.92  | Se<br>78.96  | Br<br>79.91 | Kr<br>83.80  |
| 5 | Rb<br>85.47    | Sr<br>87.62  | Y<br>88.91     | Zr<br>91.22  | Nb<br>92.91  | Mo<br>95.94  | Tc<br>(99)   | Ru<br>101.07 | Rh<br>101.07 | Pd<br>106.4  | Ag<br>107.87 | Cd<br>112.40 | In<br>114.82 | Sn<br>118.69 | Sb<br>121.75 | Te<br>127.60 | I<br>126.90 | Xe<br>131.30 |
| 6 | Cs<br>132.90   | Ba<br>137.34 | * Lu<br>174.97 | Hf<br>178.49 | Ta<br>180.95 | W<br>183.85  | Re<br>186.21 | Os<br>190.2  | Ir<br>192.2  | Pt<br>195.09 | Au<br>196.97 | Hg<br>200.59 | Tl<br>204.37 | Pb<br>207.19 | Bi<br>208.98 | Po<br>(210)  | At<br>(210) | Rn<br>(222)  |
| 7 | Fr<br>(223)    | Ra<br>(226)  | ** Lr<br>(257) | Rf<br>(261)  | Db<br>(262)  | Sg<br>(266)  | Bh<br>(264)  | Hs<br>(269)  | Mt<br>(268)  | Ds<br>(271)  | Uuu<br>(272) | Uub<br>(285) | Uut<br>(284) | Uuq<br>(289) | Uup<br>(288) | Uuh<br>(292) |             |              |
|   | * La<br>138.91 | Ce<br>140.12 | Pr<br>140.91   | Nd<br>144.24 | Pm<br>(147)  | Sm<br>150.35 | Eu<br>151.96 | Gd<br>157.25 | Tb<br>158.92 | Dy<br>162.50 | Ho<br>164.93 | Er<br>167.26 | Tm<br>168.93 | Yb<br>173.04 |              |              |             |              |
|   | ** Ac<br>(227) | Th<br>232.04 | Pa<br>(231)    | U<br>238.03  | Np<br>(237)  | Pu<br>(242)  | Am<br>(243)  | Cm<br>(247)  | Bk<br>(248)  | Cf<br>(251)  | Es<br>(252)  | Fm<br>(257)  | Md<br>(258)  | No<br>(259)  |              |              |             |              |

Reference for elements 106-116: <http://www.webelements.com>

## Polyatomic ions

Polyatomic ions are multi-atom ions (charged molecules)

You must have these memorized for quiz 2 (after exam 1)  
(Memorize their names, formulas, and charges!)

|                                     |                                      |
|-------------------------------------|--------------------------------------|
| ammonium                            | $\text{NH}_4^+$                      |
| acetate                             | $\text{C}_2\text{H}_3\text{O}_2^-$   |
| carbonate                           | $\text{CO}_3^{2-}$                   |
| hydrogen carbonate (or bicarbonate) | $\text{HCO}_3^-$                     |
| nitrite                             | $\text{NO}_2^-$                      |
| nitrate                             | $\text{NO}_3^-$                      |
| phosphate                           | $\text{PO}_4^{3-}$                   |
| hydrogen phosphate                  | $\text{HPO}_4^{2-}$                  |
| hypochlorite                        | $\text{ClO}^-$ (chlorine and oxygen) |
| chlorite                            | $\text{ClO}_2^-$                     |
| chlorate                            | $\text{ClO}_3^-$                     |
| perchlorate                         | $\text{ClO}_4^-$                     |
| permanganate                        | $\text{MnO}_4^-$                     |
| sulfite                             | $\text{SO}_3^{2-}$                   |
| sulfate                             | $\text{SO}_4^{2-}$                   |
| hydrogen sulfate (or bisulfate)     | $\text{HSO}_4^-$                     |
| hydrogen sulfite (or bisulfite)     | $\text{HSO}_3^-$                     |
| chromate                            | $\text{CrO}_4^{2-}$                  |
| dichromate                          | $\text{Cr}_2\text{O}_7^{2-}$         |
| cyanide                             | $\text{CN}^-$                        |
| hydroxide                           | $\text{OH}^-$                        |
| peroxide                            | $\text{O}_2^{2-}$                    |

### Fixed-charge transition metals:

|          |                  |
|----------|------------------|
| zinc     | $\text{Zn}^{2+}$ |
| scandium | $\text{Sc}^{3+}$ |
| silver   | $\text{Ag}^+$    |

## Compounds with polyatomic ions



copper (II) nitrate

ammonium phosphate



## Naming acids

For now, we'll call an **acid** an ionic compound with  $H^+$  as its cation.

$H_2SO_4$ :

$HNO_3$ :

$HClO_3$ :

$HClO_4$ :

$H_2SO_3$ :

$HNO_2$ :

$HCl$ :

$HBr$ :

$HI$ :

| <b><u>anion</u></b> |   | <b><u>acid</u></b>     |
|---------------------|---|------------------------|
| <b>-ate</b>         | → | <b>-ic acid</b>        |
| <b>-ite</b>         | → | <b>-ous acid</b>       |
| <b>-ide</b>         | → | <b>hydro- -ic acid</b> |