

Formula Weight Calculations

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THE MEANING OF A CHEMICAL FORMULA

- A chemical formula is a shorthand method of representing the elements in a compound.
- The formula shows:
 - the formulas of the elements in the compound
 - the ratio of the elements to one another.
 - For example, the formula for sodium chloride



tells us that the compound is composed of the elements sodium, Na, and chlorine, Cl, in a one-to-one ratio. That is, one atom of sodium combines with one atom of chlorine.

- When elements combine in different ratios, **subscripts** are added, following the element symbol, to indicate that the number of atoms of that element in the compound if it is greater than one.
- The subscript refers only to the element it immediately follows. For example, the formula for magnesium bromide:



tells us that two bromine atoms combine with one magnesium atom.

- Some elements form stable groups, or **polyatomic ions**, that combine with other elements to form compounds. An example of this is the sulfate polyatomic ion in the compound calcium sulfate:



- In this compound, the SO_4 is called a *sulfate* group or *sulfate polyatomic ion*.
- It consists of one sulfur atom combined with four oxygen atoms.
- The sulfate group cannot exist by itself and must be combined with another element.
- The compound CaSO_4 consists of one calcium atom combined with one sulfate group. Counting atoms, calcium sulfate consists of one calcium atom, one sulfur atom, and four oxygen atoms.

- Another example of an atom combined with a polyatomic ion is barium nitrate:



- This compound consists of a barium atom combined with two nitrate groups.
- Since NO_3 is readily identified as a nitrate group, and barium combines with two nitrates, parentheses are placed around the nitrate and the subscript 2 indicates two nitrate groups.
- Changing the subscripts in the nitrate to N_2O_6 would change the meaning of the formula and is incorrect.
- Counting atoms, barium nitrate consists of one barium atom, two nitrogen atoms, and six oxygen atoms.

- In the compound zinc phosphate:



the polyatomic ion is phosphate, PO₄.

- In this example, three atoms of zinc combine with two phosphate groups.
- Counting atoms, there are three atoms of zinc, two atoms of phosphorus, and eight atoms of oxygen.

**Symbol indicates
the element
sodium**

**Symbol indicates
the element
chlorine**



**No subscripts indicate
only one atom of each
element**

Symbol indicates
the element
magnesium

Symbol indicates
the element
bromine



No subscript
indicates only one
atom of magnesium

Subscript indicates
two atoms of
bromine

Symbol indicates
the element
calcium

Formula indicates
the polyatomic
ion sulfate



Subscript indicates
four atoms of
oxygen in one
sulfate

No subscript
indicates only one
atom of calcium

No subscript
indicates only one
atom of sulfur in
sulfate

Symbol
indicates the
element barium

Formula indicates
the nitrate
polyatomic ion

Subscript indicates
two nitrate
polyatomic ions



No subscript indicates
only one atom of
barium

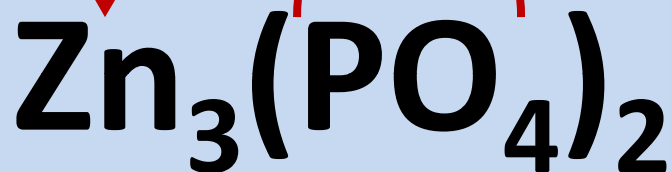
No subscript
indicates only one
atom of nitrogen
in nitrate

Subscript indicates
three atoms of
oxygen in one
nitrate

Symbol
indicates the
element zinc

Formula indicates
the phosphate
polyatomic ion

Subscript indicates
two phosphate
polyatomic ions



Subscript indicates
three atoms of zinc

No subscript
indicates only one
atom of
phosphorous
in phosphate

Subscript indicates
four atoms of
oxygen in one
phosphate

CALCULATING A FORMULA WEIGHT OR MOLECULAR WEIGHT

- The **formula weight** of a substance (element or compound) is the sum of the atomic weights of all the atoms in the chemical formula of the substance.
- A **molecular weight** of a substance is the sum of all the atomic weights of all the atoms in a molecule of a molecular substance.
- The terms formula weight and molecular weight are often used interchangeably, but **formula weight includes simple or empirical formulas of compounds, as well as, molecular formulas.**

To calculate the formula weight or molecular weight of a compound:

- 1. Determine the number of atoms of each element in the compound**
- 2. Look up the atomic weights of each element**
- 3. Multiply the atomic weight by the number of atoms of that element**
- 4. Add the products of the atomic weights of all the atoms**

1. Calculate the formula weight of sodium chloride, NaCl.

Answer:

Set up a table listing the elements in the compound, the number of atoms of each element, and the atomic weight of each element.

Elements in the compound	Number of atoms of each element	Atomic weight
Na	1	23.0
Cl	1	35.5

Elements in the compound	Number of atoms of each element	Atomic weight
Na	1	23.0
Cl	1	35.5

Multiply the number of atoms times the atomic weight to get the total mass of each element:

Elements in the compound	Number of atoms of each element		Atomic weight		Total mass
Na	1	x	23.0	=	23.0
Cl	1	x	35.5	=	35.5

Elements in the compound	Number of atoms of each element		Atomic weight		Total mass
Na	1	x	23.0	=	23.0
Cl	1	x	35.5	=	35.5

Add the total masses:

Elements in the compound	Number of atoms of each element		Atomic weight		Total mass
Na	1	x	23.0	=	23.0
Cl	1	x	35.5	=	35.5

Formula weight = 58.5

Elements in the compound	Number of atoms of each element		Atomic weight		Total mass
Na	1	x	23.0	=	23.0
Cl	1	x	35.5	=	35.5

Formula weight = 58.5

- **Atomic weights and formula weights are expressed:**
 - in **amu** (atomic mass units) for single molecules
 - in **grams** for laboratory quantities.

2. Calculate the formula weight of magnesium bromide, MgBr₂

Answer:

Set up a table similar to the one used in example 1.

Elements in the compound	Number of atoms of each element		Atomic weight		Total mass
Mg	1	x	24.3	=	24.3
Br	2	x	79.9	=	159.8

Formula weight = 184.1

3. Calculate the formula weight of calcium sulfate,
 CaSO_4

Answer:

Elements in the compound	Number of atoms of each element		Atomic weight		Total mass
Ca	1	x	40.1	=	40.1
S	1	x	32.1	=	32.1
O	4	x	16.0	=	64.0

Formula weight = 136.2

4. Calculate the formula weight of barium nitrate,
 $\text{Ba}(\text{NO}_3)_2$

Answer:

Elements in the compound	Number of atoms of each element		Atomic weight		Total mass
Ba	1	x	137.3	=	137.3
N	2	x	14.0	=	28.0
O	6	x	16.0	=	96.0

Formula weight = 261.3

5. Calculate the formula weight of zinc phosphate,
 $\text{Zn}_3(\text{PO}_4)_2$

Answer:

Elements in the compound	Number of atoms of each element		Atomic weight		Total mass
Zn	3	x	65.4	=	196.2
P	2	x	31.0	=	62.0
O	8	x	16.0	=	128.0

Formula weight = 386.2