

# **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  $\text{SO}_4$  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  $\text{CaSO}_4$  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  $\text{NO}_3$  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  $\text{N}_2\text{O}_6$  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, PO<sub>4</sub>.

- 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

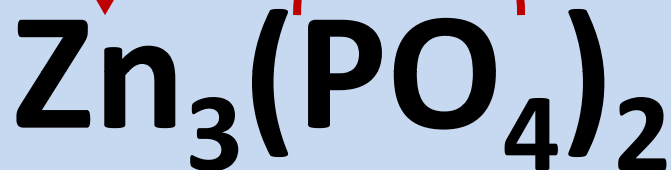
No subscript  
indicates only one  
atom of nitrogen  
in nitrate

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.

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

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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, MgBr<sub>2</sub>

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,  $\text{CaSO}_4$

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**