

Simple Step-by-Step
Guides to Solving
Chemistry Problems

Relative Molecular Mass



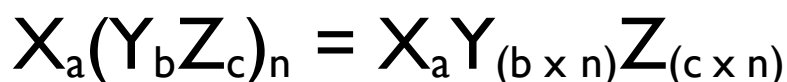
Nigel Freestone
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RELATIVE MOLECULAR MASS (M_r)

Elements rarely occur alone in nature. Instead they form compounds by combining together. Chemical compounds are substances formed by two or more elements, in a fixed and constant proportion, held together by chemical bonds. For example, water (H_2O) comprises hydrogen and oxygen atoms in the ratio 2:1. If this ratio is changed to 1:1 then a new compound formed, the disinfectant and bleach, hydrogen peroxide (H_2O_2). Compounds have a definite formula with its constituents combined in fixed proportions. There are over 8 million known chemical compounds. The smallest unit of a compound is the **molecule**. Compounds contain two or more elements chemically combined. Thus, all compounds (e.g. CH_4 , NaCl , CuSO_4) are molecules, but not all molecules are compounds (e.g. H_2 , O_2 , P_4 , S_8)

Chemical formula spells out the composition of chemical compounds and even the way in which the atoms are arranged using a single line of chemical element symbols, numbers, and other symbols, such as dashes, commas, brackets, and plus (+) and minus (-) signs.

Chemical Formula



X, Y and Z are chemical symbols and the subscripts (a, b, c) – gives the number of atoms of each element in a molecule. If no subscript, then assume “1”.

	Number of types of atoms	Number of each atom type	Total number of atoms
$\text{X}_a\text{Y}_b\text{Z}_c$	3 types: X, Y and Z	a atoms of X b atoms of Y c atoms of Z	$a + b + c$
NO_2	2 types: N and O	1 atom of N 2 atoms of O	$1 + 2 = 3$
MgCO_3	3 types: Mg, C and O	1 atom of Mg 1 atom of C 3 atoms of O	$1 + 1 + 3 = 5$
$\text{X}_a(\text{Y}_b\text{Z}_c)_n$	3 types: X, Y and Z	a atoms of X $b \times n$ atoms of Y $c \times n$ atoms of Z	$a + nb + nc$
$\text{Al}_2(\text{SO}_4)_3$	3 types: Al, S and O	2 atoms of Al 3 atoms of S 12 atoms of O	$2 + 3 + 12 = 17$

$K_4Pt(CN)_6$	4 types: K, Pt, C and N	4 atoms of K 1 atom of Pt 6 atoms of C 6 atoms of N	$4 + 1 + 6 + 6 = 17$
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To find the relative molecular mass* (M_r) of a compound, you just add together the relative atomic mass (A_r) values for all the atoms in its formula:

Step 1: Identify the number of atoms of each element present;

Step 2: Find the relative atomic mass (A_r) for each element present;

Step 3: Calculate the total mass of each element present in the chemical formula of the compound, i.e.

Mass of element in compound = relative atomic mass \times number of atoms present;

Step 4: Add together all of the masses to obtain the Relative Molecular Mass (M_r).

* Relative Formula Mass is used if the species is ionic.

These steps are summarised in the following relative molecular mass calculating frame for the compound, $X_aY_bZ_c$.

Relative Molecular Mass (M_r) Calculating Frame, $X_aY_bZ_c$

Element	No. of atoms	A_r	Mass
X	a	$A_r(X)$	$a \times A_r(X)$
Y	b	$A_r(Y)$	$b \times A_r(Y)$
Z	c	$A_r(Z)$	$c \times A_r(Z)$
Total			M_r

Step 1

Step 2

Step 3

Step 4

$$M_r = a \times A_r(X) + b \times A_r(Y) + c \times A_r(Z)$$

Example 1: Determine the relative formula mass of sodium chloride (NaCl)?

Step 1: Determine the number of atoms of each element present

Element	No. of atoms	A_r	Mass
Na	1		

Cl	1		
Total			

Step 2: Find the A_r for each element present

Element	No. of atoms	A_r	Mass
Na	1	23	
Cl	1	35.5	
Total			

Step 3: Calculate the total mass of each element present in the chemical formula of the compound

Element	No. of atoms	A_r	Mass
Na	1	23	$1 \times 23 = 23$
Cl	1	35.5	$1 \times 35.5 = 35.5$
Total			

Step 4: Add together all of the masses to obtain the Relative Formula Mass (M_r)

Element	No. of atoms	A_r	Mass
Na	1	23	$1 \times 23 = 23$
Cl	1	35.5	$1 \times 35.5 = 35.5$
Total			58.5

$$M_r [\text{NaCl}] = 58.5$$

Example 2: What is the relative molecular mass of water (H_2O)?

Step 1: Determine the number of atoms of each element present

Element	No. of atoms	A_r	Mass
H	2		
O	1		
Total			

Step 2: Find the A_r for each element present

Element	No. of atoms	A_r	Mass
H	2	1	
O	1	16	
Total			

Step 3: Calculate the total mass of each element present in the chemical formula of the compound

Element	No. of atoms	A_r	Mass
H	2	1	$2 \times 1 = 2$
O	1	16	$1 \times 16 = 16$
Total			

Step 4: Add together all of the masses to obtain the Relative Molecular Mass (M_r)

Element	No. of atoms	A_r	Mass
H	2	1	$2 \times 1 = 2$
O	1	16	$1 \times 16 = 16$
Total			18

$$M_r [\text{H}_2\text{O}] = 18$$

Example 3: Calculate the relative formula mass (M_r) of Al_2O_3

Step 1: Determine the number of atoms of each element present

Element	No. of atoms	A_r	Mass
Al	2		
O	3		
Total			

Step 2: Find the A_r for each element present

Element	No. of atoms	A_r	Mass
Al	2	27	
O	3	16	
Total			

Step 3: Calculate the total mass of each element present in the chemical formula of the compound

Element	No. of atoms	A_r	Mass
Al	2	27	$2 \times 27 = 54$
O	3	16	$3 \times 16 = 48$
Total			

Step 4: Add together all of the masses to obtain the Relative Formula Mass (M_r)

Element	No. of atoms	A_r	Mass
Al	2	27	$2 \times 27 = 54$
O	3	16	$3 \times 16 = 48$
Total			102

$$M_r [\text{Al}_2\text{O}_3] = 102$$

Example 5: Determine the relative formula mass (M_r) of $\text{Mg}(\text{OH})_2$

Element	No. of atoms	A_r	Mass
Mg	1	24	$1 \times 24 = 24$
O	2	16	$2 \times 16 = 32$
H	2	1	$2 \times 1 = 2$
Total			58

Note: $\text{Mg}(\text{OH})_2$ could be rewritten as MgO_2H_2

$$M_r [\text{Mg}(\text{OH})_2] = 58$$

Example 6: Determine the relative formula mass (M_r) of $\text{Ca}(\text{NO}_3)_2$

Element	No. of atoms	A_r	Mass
Ca	1	40	$1 \times 40 = 40$
N	2	14	$2 \times 14 = 28$
O	6	16	$6 \times 16 = 96$
Total			164

Note: $\text{Ca}(\text{NO}_3)_2$ can be rewritten as CaN_2O_6

$$M_r [\text{Ca}(\text{NO}_3)_2] = 164$$

Example 7: Determine the relative formula mass (M_r) of ammonium sulphate, $(\text{NH}_4)_2\text{SO}_4$?

Element	No. of atoms	A_r	Mass
N	2	14	$2 \times 14 = 28$
H	8	1	$8 \times 1 = 8$
S	1	32	$1 \times 32 = 32$
O	4	16	$4 \times 16 = 64$

Total			132
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$$M_r [(\text{NH}_4)_2\text{SO}_4] = 132$$

Practice Problems

What is the relative molecular (formula) mass (M_r) of the following chemicals?

- a. Carbon dioxide, CO_2
- b. Iron (II) sulphide, FeS
- c. Copper sulphate, CuSO_4
- d. Benzene, C_6H_6
- e. Calcium hydroxide, $\text{Ca}(\text{OH})_2$
- f. Oxygen, O_2
- g. Sodium oxide, Na_2O
- h. Lead (II) nitrate, $\text{Pb}(\text{NO}_3)_2$
- i. Nitrogen dioxide, NO_2
- j. Ethanoic acid, CH_3COOH
- k. Aluminium sulphate, $\text{Al}_2(\text{SO}_4)_3$
- l. Iron (III) nitrate, $\text{Fe}(\text{NO}_3)_3$
- m. Calcium phosphate, $\text{Ca}_2(\text{PO}_4)_3$
- n. Silver nitrite, AgNO_2
- o. Potassium permanganate, KMnO_4
- p. Potassium dichromate, $\text{K}_2\text{Cr}_2\text{O}_7$
- q. Nickel sulphite, NiSO_3
- r. Copper tartrate, $\text{Cu}_2\text{C}_4\text{H}_4\text{O}_6$
- s. Cobalt (II) chlorate, $\text{Co}(\text{ClO}_3)_2$
- t. Diethyl zinc, $(\text{C}_2\text{H}_5)_2\text{Zn}$

Answers are on the next page.

? Practice Problem Answers:

What is the relative molecular (formula) mass (M_r) of the following chemicals?

a) CO_2

Element	No. of atoms	A_r	Mass
C	1	12	12
O	2	16	32
Total			44

$$M_r [\text{CO}_2] = 44$$

b) FeS

Element	No. of atoms	A_r	Mass
Fe	1	56	56
S	1	32	32
Total			88

$$M_r [\text{FeS}] = 88$$

c) CuSO_4

Element	No. of atoms	A_r	Mass
C	1	63.5	63.5
S	1	32	32
O	4	16	64
Total			159.5

$$M_r [\text{CuSO}_4] = 159.5$$

d) C_6H_6

Element	No. of atoms	A_r	Mass
C	6	12	72
H	6	1	6
Total			78

$$M_r [\text{C}_6\text{H}_6] = 78$$

e) Ca(OH)_2

Element	No. of atoms	A_r	Mass
Ca	1	40	40
O	2	16	32
H	2	1	2
Total			74

$$M_r [\text{Ca(OH)}_2] = 74$$

f) O_2

Element	No. of atoms	A _r	Mass
O	2	16	32
Total			32

$$M_r [\text{O}_2] = 32$$

g) Na_2O

Element	No. of atoms	A _r	Mass
Na	2	23	46
O	1	16	16
Total			62

$$M_r [\text{Na}_2\text{O}] = 62$$

h) $\text{Pb}(\text{NO}_3)_2$

Element	No. of atoms	A _r	Mass
Pb	1	12	12
N	2	14	28
O	6	16	96
Total			331

$$M_r [\text{Pb}(\text{NO}_3)_2] = 331$$

i) NO_2

Element	No. of atoms	A _r	Mass
N	1	14	14
O	2	32	32
Total			46

$$M_r [\text{NO}_2] = 46$$

j) CH_3COOH

Element	No. of atoms	A _r	Mass
C	2	12	24
H	4	1	4
O	2	16	32
Total			60

$$M_r [\text{CH}_3\text{COOH}] = 60$$

k) $\text{Al}_2(\text{SO}_4)_3$

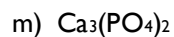
Element	No. of atoms	A _r	Mass
Al	2	27	54
S	3	32	96
O	12	16	192
Total			342

$$M_r [\text{Al}_2(\text{SO}_4)_3] = 342$$

l) $\text{Fe}(\text{NO}_3)_3$

Element	No. of atoms	A _r	Mass
Fe	1	56	56
N	3	14	42
O	9	16	144
Total			242

$$M_r [\text{Fe}(\text{NO}_3)_3] = \mathbf{242}$$



Element	No. of atoms	A _r	Mass
Ca	3	40	120
P	2	31	62
O	8	16	128
Total			310

$$M_r [\text{Ca}_3(\text{PO}_4)_2] = \mathbf{310}$$



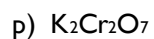
Element	No. of atoms	A _r	Mass
Ag	1	108	108
N	1	14	14
O	2	16	32
Total			331

$$M_r [\text{AgNO}_2] = \mathbf{154}$$



Element	No. of atoms	A _r	Mass
K	1	39	39
Mn	1	55	55
O	4	16	64
Total			158

$$M_r [\text{KMnO}_4] = \mathbf{158}$$



Element	No. of atoms	A _r	Mass
K	2	39	78
Cr	2	52	104
O	7	16	112
Total			294

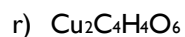
$$M_r [\text{K}_2\text{Cr}_2\text{O}_7] = \mathbf{294}$$



Element	No. of atoms	A _r	Mass
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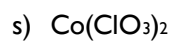
Ni	1	59	59
S	1	32	32
O	3	16	48
Total			139

$$M_r [\text{NiSO}_3] = 139$$



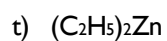
Element	No. of atoms	A_r	Mass
Cu	2	63.5	127
C	4	12	48
H	4	1	4
O	6	16	96
Total			275

$$M_r [\text{Cu}_2\text{C}_4\text{H}_4\text{O}_6] = 275$$



Element	No. of atoms	A_r	Mass
Co	1	59	59
Cl	2	35.5	71
O	6	16	96
Total			226

$$M_r [\text{Co}(\text{ClO}_3)_2] = 226$$



Element	No. of atoms	A_r	Mass
Zn	1	65	65
C	4	12	48
H	10	1	10
Total			123

$$M_r [(\text{C}_2\text{H}_5)_2\text{Zn}] = 123$$