

Relative formula mass

4.3.1.2 · Quantitative chemistry · revision notes

Relative formula mass (M_r) is the sum of the relative atomic masses of all the atoms in a formula. You need it for almost every calculation in quantitative chemistry. Questions also ask you to work out the percentage by mass of an element in a compound, or to show that the M_r values balance in an equation.

Key facts

- A_r = relative atomic mass (from the periodic table)
- A_r and M_r have no units
- Balanced equation: total M_r of reactants = total M_r of products
- M_r = sum of the A_r values of all the atoms in the formula
- % by mass of element = $(A_r \times \text{number of atoms}) \div M_r \times 100$
- Useful values: $H_2O = 18$, $O_2 = 32$, $CO_2 = 44$, $NaCl = 58.5$, $CaCO_3 = 100$

Notes

A_r and M_r

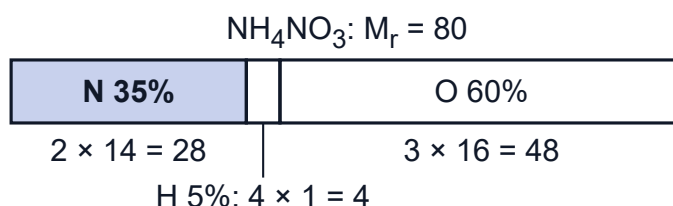
- The **relative atomic mass** (A_r) of an element is an average mass of its atoms that takes account of the abundance of its isotopes. Read it from the periodic table you are given in the exam: it is the larger number in each element's box.
- The **relative formula mass** (M_r) of a compound is the sum of the relative atomic masses of the atoms in the numbers shown in the formula.
- A_r and M_r have **no units**, because they are relative values.
- Elements made of molecules have an M_r too: $O_2 = 2 \times 16 = 32$.

Working out M_r

- Count the atoms of each element, multiply by its A_r , then add everything up.
- Example: $H_2SO_4 = (2 \times 1) + 32 + (4 \times 16) = 98$.
- With brackets, work out the group first: $Al_2(SO_4)_3 = (2 \times 27) + 3 \times (32 + 4 \times 16) = 54 + 288 = 342$.

Percentage by mass of an element

- % by mass of an element = $(A_r \times \text{number of atoms of that element}) \div M_r \times 100$
- Example: nitrogen in ammonium nitrate, NH_4NO_3 . $M_r = 14 + (4 \times 1) + 14 + (3 \times 16) = 80$. There are 2 nitrogen atoms, so % N = $28 \div 80 \times 100 = 35\%$.



Each element's share of $M_r = 80$ gives its percentage by mass; the shares add up to 100%.

- The percentages of all the elements in a compound add up to 100%.

M_r in balanced equations

- In a balanced equation, the total M_r of the reactants (in the quantities shown) equals the total M_r of the products. This is conservation of mass again.
- Example: $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$. Reactants: $(2 \times 24) + 32 = 80$. Products: $2 \times (24 + 16) = 80$.
- Work out the M_r of one formula first, then multiply by the balancing number.

How to answer each type of question

Calculate the relative formula mass

1 to 2 marks

Grade 4

1. Count the atoms of each element, taking care with brackets.
2. Multiply each count by the A_r given.
3. Add them up and show the working. Do not give a unit.

Example. Calculate the relative formula mass (M_r) of magnesium nitrate, $\text{Mg}(\text{NO}_3)_2$.

Relative atomic masses (A_r): N = 14; O = 16; Mg = 24 [2 marks]

Model answer. $24 + 2 \times (14 + 3 \times 16)$ (1)
 $= 24 + 124 = 148$ (1)

Don't lose marks

- ✗ Multiplying only the first atom after a bracket: in $\text{Ca}(\text{OH})_2$ both the O and the H are doubled.
- ✗ Using the atomic number instead of the relative atomic mass from the periodic table.
- ✗ Counting only one atom of the element for % by mass, e.g. using 14 instead of 28 for nitrogen in NH_4NO_3 .

- ✗ Including the balancing number when asked for the M_r of a substance: the M_r of water is 18, even if the equation shows $2H_2O$.
- ✗ Rounding A_r values: use 35.5 for chlorine and 63.5 for copper, as printed.
- ✗ Giving a unit such as g with an M_r .

More tips

Memory tricks

- Learn the M_r values you use most (water 18, carbon dioxide 44, calcium carbonate 100) to save time and check answers.
- Brackets first: work out the group (e.g. $NO_3 = 62$), then multiply by the number outside.
- Sense check for % by mass: it must be less than 100%, and all the elements together add up to 100%.
- Type the whole calculation into your calculator in one go, using brackets, to avoid rounding errors.

Exam technique

- Use the A_r values given in the question, or on the periodic table, exactly as printed.
- Show each step: a mark is often given for the working even if the final answer is wrong.
- Look for 'Give your answer to 3 significant figures' in percentage by mass questions.
- In 'show that' questions, write out both totals in full and say that they are equal.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3

Read relative atomic masses from the periodic table

A_r is the larger of the two numbers in each box, e.g. O = 16, Na = 23.

Grade 4

Calculate M_r of a simple formula

Add the A_r of every atom, e.g. $CO_2 = 12 + (2 \times 16) = 44$.

Grade 5

Calculate M_r for formulae with brackets

Multiply everything inside the bracket, e.g. $Ca(OH)_2 = 40 + 2 \times (16 + 1) = 74$.

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