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 × number of atoms) ÷ M_r × 100
- Useful values: H_2O = 18, O_2 = 32, CO_2 = 44, NaCl = 58.5, $CaCO_3$ = 100

Notes

A_r and M_r

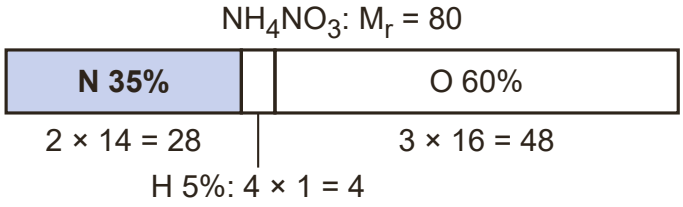
- The **relative atomic mass** (A_r) of an element is an average mass of its atoms that takes account of the abundance of its isotopes. Read it from the periodic table you are given in the exam: it is the larger number in each element's box.
- The **relative formula mass** (M_r) of a compound is the 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 × 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 × 1) + 32 + (4 × 16) = 98.
- With brackets, work out the group first: $Al_2(SO_4)_3$ = (2 × 27) + 3 × (32 + 4 × 16) = 54 + 288 = 342.

Percentage by mass of an element

- % by mass of an element = (A_r × number of atoms of that element) ÷ M_r × 100
- Example: nitrogen in ammonium nitrate, NH_4NO_3. M_r = 14 + (4 × 1) + 14 + (3 × 16) = 80. There are 2 nitrogen atoms, so % N = 28 ÷ 80 × 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: $2Mg + O_2 \rightarrow 2MgO$. Reactants: (2 × 24) + 32 = 80. Products: 2 × (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, $Mg(NO_3)_2$.
Relative atomic masses (A_r): N = 14; O = 16; Mg = 24 [2 marks]

Model answer.

24 + 2 × (14 + 3 × 16) (1)
= 24 + 124 = 148 (1)

Calculate the percentage by mass of an element

2 to 3 marks | **Grade 5**

1. Work out the M_r of the compound.
2. Multiply the A_r of the element by the number of its atoms in the formula.
3. Divide by the M_r, multiply by 100 and round as asked.

Example. Copper(II) sulfate has the formula $CuSO_4$.

Calculate the percentage by mass of copper in copper(II) sulfate.
Give your answer to 3 significant figures.
A_r: O = 16; S = 32; Cu = 63.5 [3 marks]

Model answer.

$M_r = 63.5 + 32 + (4 \times 16) = 159.5$ (1)

$63.5 \div 159.5 \times 100$ (1)

$= 39.8\%$ (1)

Show that the M_r values balance in an equation

2 marks | **Grade 5**

1. Work out the M_r of each substance.
2. Multiply each by its balancing number and add up each side.
3. Write both totals and state that they are equal.

Example. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Show that the total M_r of the reactants is equal to the total M_r of the products.
A_r: H = 1; C = 12; O = 16 [2 marks]

Model answer.

Reactants: $16 + (2 \times 32) = 80$ (1)

Products: $44 + (2 \times 18) = 80$, so the totals are equal (1)

Identify an element from an M_r

2 marks | **Grade 5**

1. Subtract the A_r values you know from the M_r.
2. Divide by the number of atoms of the unknown element.
3. Match the A_r to an element on the periodic table.

Example. Metal X forms an oxide with the formula X_2O. The M_r of X_2O is 62.

Identify metal X. A_r: O = 16 [2 marks]

Model answer.

$2 \times A_r$ of X $= 62 - 16 = 46$, so A_r of X $= 23$ (1)

X is sodium (1)

Don’t lose marks

- Multiplying only the first atom after a bracket: in $Ca(OH)_2$ 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 × 16) = 44.

Grade 5 — **Calculate M_r for formulae with brackets**
Multiply everything inside the bracket, e.g. $Ca(OH)_2$ = 40 + 2 × (16 + 1) = 74.

Grade 5 — **Calculate percentage by mass of an element**
Divide the total A_r of that element in the formula by the M_r, then multiply by 100.

Grade 5 — **Show that M_r values balance in equations**
The total M_r of the reactants (using balancing numbers) equals the total M_r of the products.

Grade 5

Use M_r to identify an unknown element

Work backwards, e.g. if XCl_2 has M_r 111, X = 111 − 71 = 40, so X is calcium.

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