Moles

4.3.2.1 · Quantitative chemistry · revision notes

Chemists measure amounts of substances in moles. One mole of any substance contains 6.02×10^{23} particles, and its mass in grams equals its relative formula mass. This subtopic is Higher tier only, and moles = mass ÷ M_r is used in almost every harder calculation.

Key facts

- 1 mole = 6.02×10^{23} particles (the Avogadro constant)
- moles = mass (g) ÷ M_r
- M_r = mass ÷ moles
- Unit of amount of substance: mol
- Mass of 1 mol in grams = A_r or M_r
- mass (g) = moles × M_r
- number of particles = moles × 6.02×10^{23}

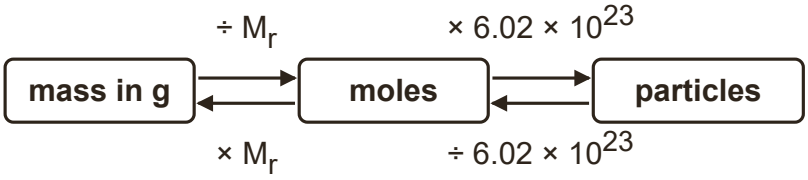
Notes

What a mole is

- Chemical amounts are measured in **moles**. The symbol for the unit is **mol**.
- One mole of any substance contains the same number of particles (atoms, molecules, ions, electrons or formula units): 6.02×10^{23}. This number is the **Avogadro constant**.
- So 1 mol of carbon atoms (C) contains the same number of particles as 1 mol of carbon dioxide molecules (CO_2).
- The mass of one mole of a substance in grams is numerically equal to its A_r or M_r: 1 mol of Na = 23 g, and 1 mol of NaCl = 58.5 g.

Moles, mass and M_r

- moles = mass (g) ÷ M_r
- Rearranged: mass = moles × M_r, and M_r = mass ÷ moles.



Go through moles: mass ÷ M_r gives moles, and moles × the Avogadro constant gives particles.

- Example: 11 g of CO_2 (M_r 44) is 11 ÷ 44 = 0.25 mol.
- Example: 0.40 mol of NaOH (M_r 40) has a mass of 0.40 × 40 = 16 g.
- The mass must be in grams: multiply kilograms by 1000 first.

Numbers of particles

- number of particles = moles × 6.02×10^{23}
- Example: 0.50 mol of water contains $0.50 \times 6.02 \times 10^{23} = 3.01 \times 10^{23}$ molecules.
- Each water molecule has 3 atoms, so the same sample contains $3 \times 3.01 \times 10^{23} = 9.03 \times 10^{23}$ atoms.
- Enter the Avogadro constant with your calculator's $\times 10^x$ (or EXP) key.

How to answer each type of question

Calculate the number of moles in a mass 2 marks **Grade 6**

1. Work out or read the M_r.
2. Divide the mass in grams by the M_r.
3. Give the unit, mol.

Example. Calculate the amount, in moles, of calcium carbonate in 7.50 g.
Relative formula mass (M_r): $CaCO_3$ = 100 [2 marks]

Model answer.

7.50 ÷ 100 (1)
= 0.0750 mol (1)

Calculate the mass of an amount in moles

2 to 3 marks | Grade 7

1. Work out the M_r from the A_r values.
2. Multiply the number of moles by the M_r.
3. Give the unit, g.

Example. Calculate the mass of 0.150 mol of magnesium sulfate, $MgSO_4$.
A_r: O = 16; Mg = 24; S = 32 [3 marks]

Model answer.

$M_r = 24 + 32 + (4 \times 16) = 120$ (1)

mass = 0.150×120 (1)

= 18.0 g (1)

Explain why samples contain the same number of particles

2 marks | Grade 7

1. Work out the number of moles in each sample.
2. Say that equal numbers of moles contain equal numbers of particles (6.02×10^{23} per mole).

Example. A student has 24 g of magnesium and 40 g of calcium.
Explain why both samples contain the same number of atoms.
A_r: Mg = 24; Ca = 40 [2 marks]

Model answer. Each sample is 1 mol ($24 \div 24 = 1$ and $40 \div 40 = 1$) (1). One mole of any element contains the same number of atoms, 6.02×10^{23} (1).

Calculate the number of particles

3 marks | Grade 8

1. Convert the mass to moles: mass ÷ M_r.
2. Multiply the moles by 6.02×10^{23}.
3. If the question asks for atoms, multiply by the number of atoms in one formula.
4. Give the answer in standard form.

Example. Calculate the number of molecules in 8.8 g of carbon dioxide.
M_r: CO_2 = 44
The Avogadro constant is 6.02×10^{23} per mole. [3 marks]

Model answer.

moles = $8.8 \div 44 = 0.20$ mol (1)

molecules = $0.20 \times 6.02 \times 10^{23}$ (1)

= 1.20×10^{23} (1)

Identify a substance from its mass and amount 3 marks **Grade 9**

1. Find the M_r: mass ÷ moles.
2. Subtract the parts of the formula you know.
3. Divide by the number of unknown atoms and match the A_r to an element.

Example. 0.250 mol of a Group 1 metal carbonate, M_2CO_3, has a mass of 34.5 g.
Identify metal M.
A_r: C = 12; O = 16 [3 marks]

Model answer.

$M_r = 34.5 \div 0.250 = 138$ (1)

$2 \times A_r$ of M = 138 − (12 + 3 × 16) = 78, so A_r of M = 39 (1)

M is potassium (1)

Don't lose marks

- Dividing the M_r by the mass instead of the mass by the M_r.
- Using a mass in kg or mg instead of grams.
- Mixing up molecules and atoms: 1 mol of O_2 has 6.02×10^{23} molecules but twice as many atoms.
- Writing 6.02^{23} instead of 6.02×10^{23}, or typing it into the calculator wrongly.
- Rounding the number of moles too early, which makes the final answer wrong.

More tips

Memory tricks

- Formula triangle: mass on top, moles × M_r underneath. Cover the one you want.
- Sense check: a few grams of a substance with an M_r near 100 is well under 1 mol.
- Moles to particles: multiply by 6.02×10^{23}. Particles to moles: divide. A number of particles is always enormous.
- Keep unrounded values in your calculator (use ANS) and round only at the end.

Exam technique

- Write the equation you are using (e.g. moles = mass ÷ M_r) before putting numbers in.
- Give very large or very small answers in standard form, to the significant figures asked for.
- Include units: mol for amount and g for mass. M_r has no unit.
- If the question gives you an M_r, use it rather than working it out again.

What each grade needs

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

Grade 5 **State what one mole contains**

One mole of any substance contains 6.02×10^{23} particles (the Avogadro constant).

Grade 5 **Recall the mass of one mole**

The mass of one mole in grams equals the A_r or M_r, e.g. 1 mol of H_2O has a mass of 18 g.

Grade 6 **Calculate moles from mass**

moles = mass (g) ÷ M_r.

Grade 7 **Calculate mass from moles**

mass (g) = moles × M_r.

Grade 8 **Calculate numbers of particles**

number of particles = moles × 6.02×10^{23}.

Grade 9 **Find M_r from mass and moles**

M_r = mass ÷ moles, then use it to identify a substance or element.

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