# Concentration and moles

This resource is from the **Johnstone's triangle** series, which can be viewed at: rsc.li/43jMfSn. In this series you will also find our Johnstone's triangle worksheets which introduce the triangle in the contexts of concentrations of common acids (rsc.li/3NhHCE7), and determining an unknown concentration (rsc.li/4brRDbJ).

## Learning objectives

| LO | Objective | Where assessed |
|---|---|---|
| 1 | Determine the concentration of a solution in mol/dm$^3$ from a given number of moles of solute and a volume of 1 or 2 dm$^3$ of water. | Q1 |
| 2 | Determine the number of each ion in a solute that are present in a solution with concentration 1 mol/dm$^3$. | Q2 |
| 3 | Interpret particle diagrams of solutions in terms of water molecules and solute ions. | Q3 |
| 4 | Calculate the number of moles of solute from the volume (in cm$^3$) and concentration of solution. | Q4 |
| 5 | Calculate the concentration of sodium hydroxide solution from the volume of hydrochloric acid that reacts exactly with a given volume. | Q5 |

## How to use this resource

| | | | | |
|---|---|---|---|---|
| **When to use?** | Introduce | **Develop** | **Revise** | Assess |
| | Use after initial teaching or discussion of this topic to develop ideas further. You can also use as a revision activity. | | | |
| **Group size?** | **Independent** | **Small group** | **Whole class** | **Homework** |
| | Suitable for independent work either in class or at home. Or use the questions for group or class discussions. | | | |
| **How long?** | | | 15–30 mins | |

This resource aims to develop learners' understanding of concentration in mol/$dm^3$. The questions encourage learners to think about what concentration means at the sub-microscopic level as well has how it can be calculated. As a result, learners should develop more secure mental models to support their thinking about this topic.

## Johnstone's triangle

Johnstone's triangle is a model of the three different conceptual levels in chemistry: macroscopic, sub-microscopic and symbolic. You can use Johnstone's triangle to build a secure understanding of chemical ideas for your learners.

Find further reading about Johnstone's triangle and how to use it in your teaching at rsc.li/4aLcZAH.

### Johnstone's triangle and this resource

The icons in the margin indicate which level of understanding each question is developing to help prompt learners in their thinking.

**Macroscopic:** what we can see. Think about the properties that we can observe, measure and record.

**Sub-microscopic:** smaller than we can see. Think about the particle or atomic level.

**Symbolic:** representations. Think about how we represent chemical ideas including symbols and diagrams.

The levels are interrelated, for example, learners need visual representation of the sub-microscopic in order to develop mental models of the particle or atomic level. Our approach has been to apply icons to questions based on what the learners should be thinking about.

Questions may be marked with two or all three icons, indicating that learners will be thinking at more than one level. However, individual parts of the question may require learners to think about only one or two specific levels at a time.

## Support

This worksheet is ramped so that the earlier questions are more accessible. The activity becomes more challenging in the later questions. You can give extra explanations for the more challenging questions. If completing as an in-class activity it is best to pause and check understanding at intervals, as often one question builds on the previous one.

It is useful for learners to observe macroscopic properties first-hand. You could circulate examples of substances in the classroom, run a class practical of a chemical reaction or show a teacher demonstration of properties.

Give learners physical models to use and manipulate, such as a Molymod kits or counters.

Additional support may be needed for any learners still lacking in confidence in the required symbolic representation, for example by sharing and explaining a diagram or a simulation that can show movement of the particles.

## Answers

1. *Guidance note:* This question develops learners' understanding of the expression of concentration with the units moles per $dm^3$ ($mol/dm^3$). Although a mole represents a number of sub-microscopic particles, in this question the focus is on a mole as a quantity of the solute (macroscopic understanding).

   (a)
   i. 2 $mol/dm^3$
   ii. 0.1 $mol/dm^3$

   (b) 1 $mol/dm^3$

   (c) 0.8 moles

   (d) 0.8 $mol/dm^3$

   (e) Solution A

2. *Guidance note:* This question develops learners' understanding of how the concentration of a solution in $mol/dm^3$ connects to the number of moles of each ion (sub-microscopic understanding) in the formula (symbolic understanding) of the solute. This question also supports learners to connect mass (macroscopic understanding) to number of moles. This question uses the term 'formula unit' to describe the basic number of ions shown in a chemical formula. For example, the formula unit of $\mathrm{MgO}$ would be one magnesium ion and one oxide ion and the formula unit of $\mathrm{MgCl_2}$ contains one magnesium ion and two chloride ions. The focus is on interpretation of the formula rather than on the term formula unit.

   (a) $\mathrm{Cu^{2+}}$: 1, $\mathrm{Cl^-}$: 2

   (b) 23 + 35.5 = 58.5 g

   (c) 63.5 + 35.5 x 2 = 134.5 g

   (d) There are two $\mathrm{Cl^-}$ ions in the formula unit of copper chloride so one mole of the formula unit contains 2 x one mole of $\mathrm{Cl^-}$ ions.

3. *Guidance note:* This question develops learners' understanding of how to calculate concentration in mol/dm³ (macroscopic understanding). It then supports learners to understand particle diagrams of a solution (symbolic understanding) in terms of water molecules and solute ions.
This question supports learners to convert from cm³ to dm³ but assumes prior familiarity with dm³ as a unit of volume.

(a)

| Solution | Number of moles of copper sulfate | volume in cm³ | volume in dm³ | concentration in mol/dm³ |
|---|---|---|---|---|
| X | 2 | 1000 | **1** | **2** |
| Y | 2 | 2000 | **2** | **1** |
| Z | 2 | 500 | **0.5** | **4** |

(b)
i. Light grey circles: water molecule
ii. Blue circles: copper ions and sulfate ions

(c) Solution X and Z contain the same number of copper **ions** and sulfate **ions**. Solution Z contains fewer water **molecules** than solution Z. This means that solution Z has more copper and sulfate **ions** compared to the number of water **molecules.** Therefore solution Z is more concentrated.

4. *Guidance note:* This question develops learners' understanding of how to calculate the number of moles (sub-microscopic understanding) of solute from the volume (in cm³) and concentration of a solution.

(a)
i. 0.1 moles
ii. 0.2 moles
iii. 0.05 moles

(b)

| concentration mol/dm³ | volume in cm³ | volume in dm³ | Number of moles of solute |
|---|---|---|---|
| 0.5 | 10 | **0.01** | **0.005** |
| 0.1 | 5 | **0.005** | **0.0005** |
| 0.2 | 25 | **0.025** | **0.005** |

5. *Guidance note:* This question develops learners' understanding of how the balanced chemical equations (symbolic understanding) provide the relationship between the number of moles in a given volume of an unknown concentration of alkali (sub-microscopic understanding) and the number of moles of acid that react exactly with it. Learners are then supported to use this information and the volume of acid that has reacted with the alkali (macroscopic understanding) to calculate the concentration of the alkali. This question assumes familiarity with the quantitative meaning of a balanced chemical equation in terms of the ratio of moles of reactant that react. Familiarity of the experimental process of titration is not expected.

(a) Each mole of hydrochloric acid reacts with **one** mole of sodium hydroxide to form **one** mole of sodium chloride.

(b) number of moles = concentration x volume

(c) number of moles = 0.1 x 10/1000 = 0.001
(The volume must be in $dm^3$)

(d) 0.001 moles

(e) concentration = number of moles/volume

(f) concentration = 0.01 / (5/1000)
= 0.2 mol/$dm^3$
(The volume must be in $dm^3$)

(g) Hydrochloric acid reacts with sodium hydroxide with a 1:1 ratio. 10 $cm^3$ of the sodium hydroxide solution does not contain the same number of moles as 10 $cm^3$ of hydrochloric acid solution. It is more concentrated, so a smaller volume reacts with the 10 $cm^3$ of hydrochloric acid.

(Some learners may notice that as the concentration of the $NaOH$ is double that of the $HCl$ only half the volume is needed.)