16–18 years

Calculating and comparing solution concentrations

ROYAL SOCIETY OF CHEMISTRY

Education
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Learning objectives

1. Recall how to convert between volumes in cm^3 and dm^3.
2. Define the word ‘concentration’ from a given numerical value.
3. Calculate the concentration of a solution in both g dm^{-3} and mol dm^{-3}.
4. Convert the concentration of a solution from g dm^{-3} to mol dm^{-3} and vice versa.

Introduction

In chemistry, concentration describes how much of a substance (the solute) is present in a given volume of solution.

Concentration is most commonly expressed in two ways: grams per cubic decimetre (g dm^{-3}) and moles per cubic decimetre (mol dm^{-3}).

Both units relate the amount of solute to the volume of solution, and being confident in using each is essential for quantitative chemistry, including titrations and stoichiometric calculations.

Introduction

In this lesson, you will recap key information including converting between units, calculating concentration in both g dm^{-3} and mol dm^{-3}, as well as converting between them.

You will use the following equations throughout this worksheet:

$$\text{concentration (g dm}^{-3}) = \frac{\text{mass (g)}}{\text{volume (dm}^3)}$$

$$\text{concentration (mol dm}^{-3}) = \frac{\text{moles (mol)}}{\text{volume (dm}^3)}$$

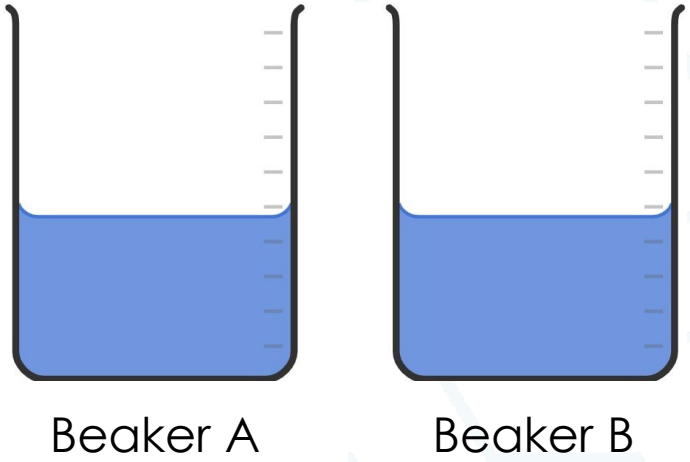
$$\text{moles (mol)} = \frac{\text{mass (g)}}{\text{molar mass (g mol}^{-1})}$$

The molar mass of the solute is used to convert between mol dm^{-3} and g dm^{-3}:

- to convert from mol dm^{-3} to g dm^{-3}, multiply by the molar mass
- to convert from g dm^{-3} to mol dm^{-3}, divide by the molar mass

Comparing solutions – demonstration

- Place 100 cm^3 of copper(II) sulfate solution in each of two beakers A and B.
- Pour half of the solution from beaker A into a third beaker, C.



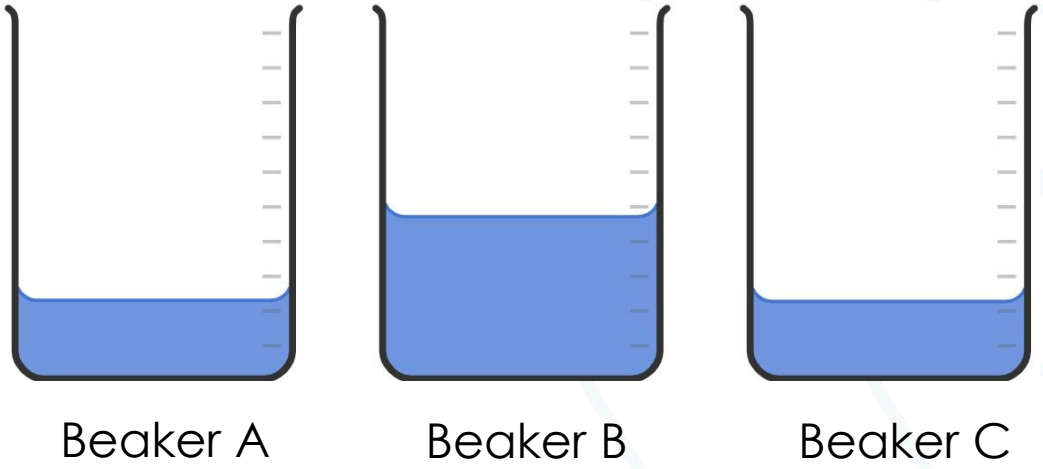
Compare beaker B and beaker C in terms of:

(a) the number of moles of copper(II) sulfate in beakers B and C

Different

Unsure

The same



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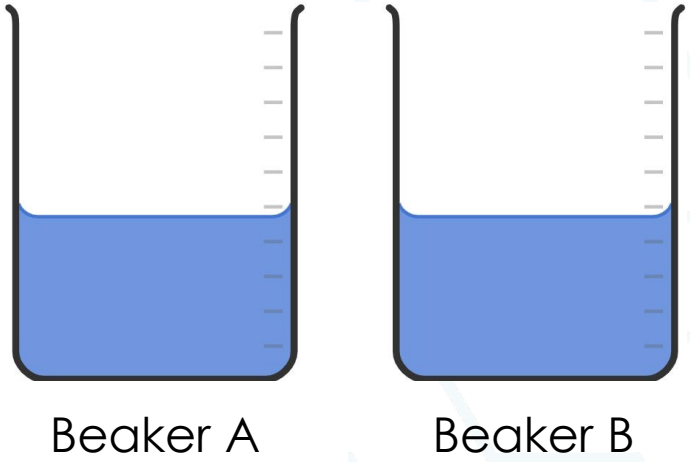


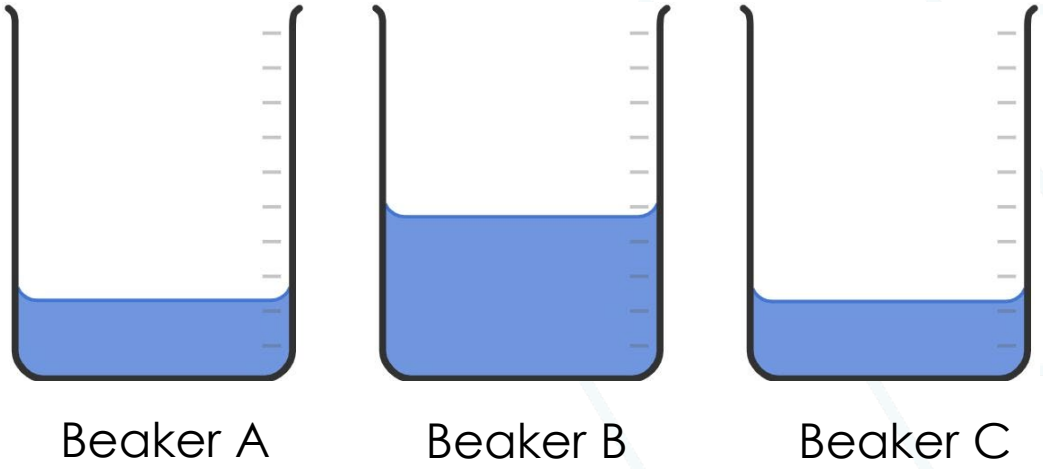
Compare beaker B and beaker C in terms of:

(b) the concentration of copper(II) sulfate in beakers B and C

Different

Unsure

The same



Comparing solutions – demonstration

- Add water to beaker C to make the total volume 100 cm^3 again.

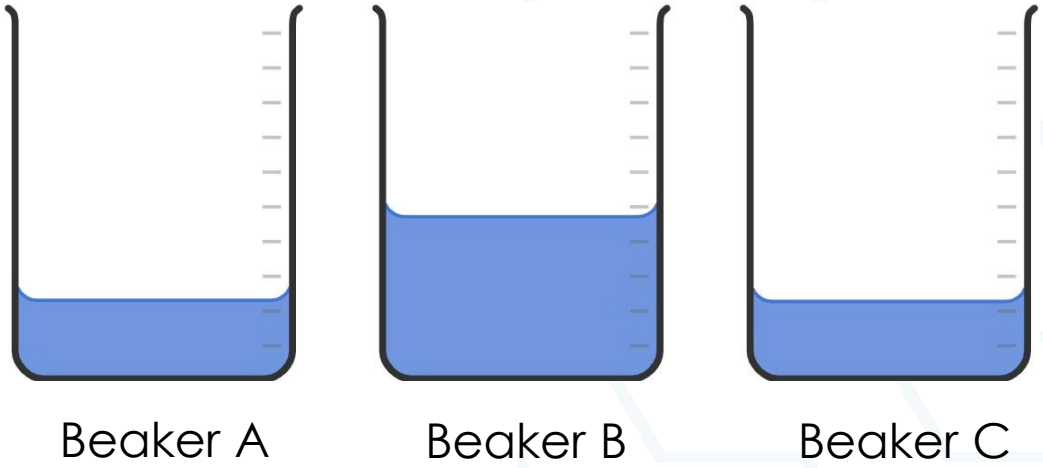
Compare beaker B and beaker C in terms of:

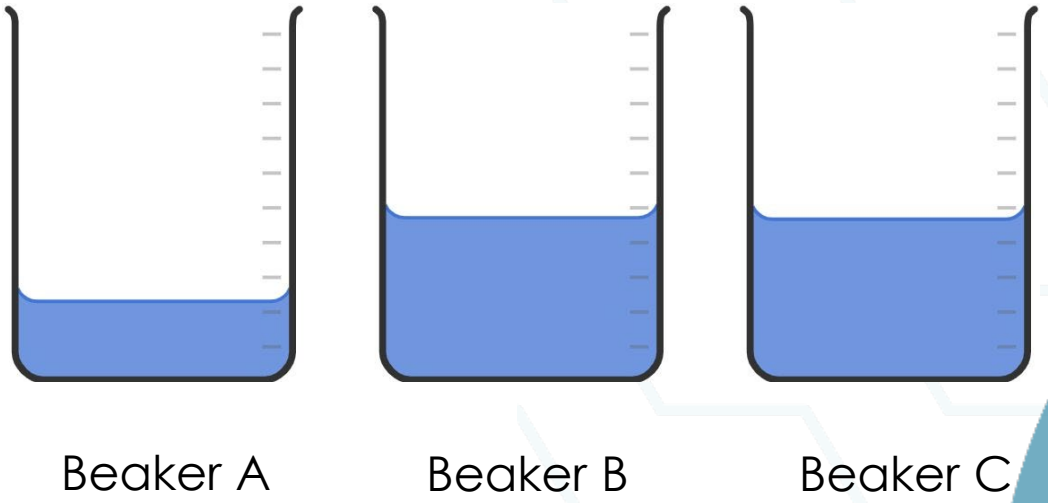
(c) the number of moles of copper(II) sulfate in beakers B and C

Different

Unsure

The same





Comparing solutions – demonstration

- Add water to beaker C to make the total volume 100 cm^3 again.

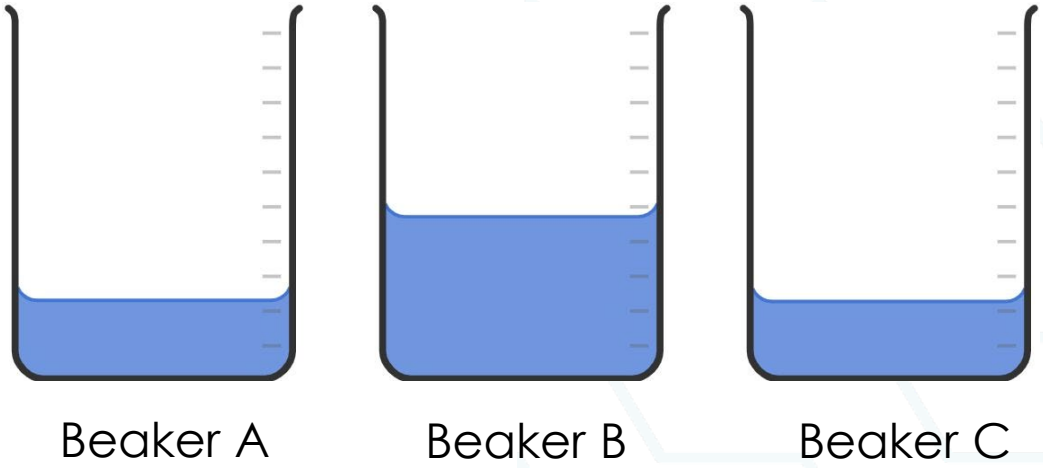
Compare beaker B and beaker C in terms of:

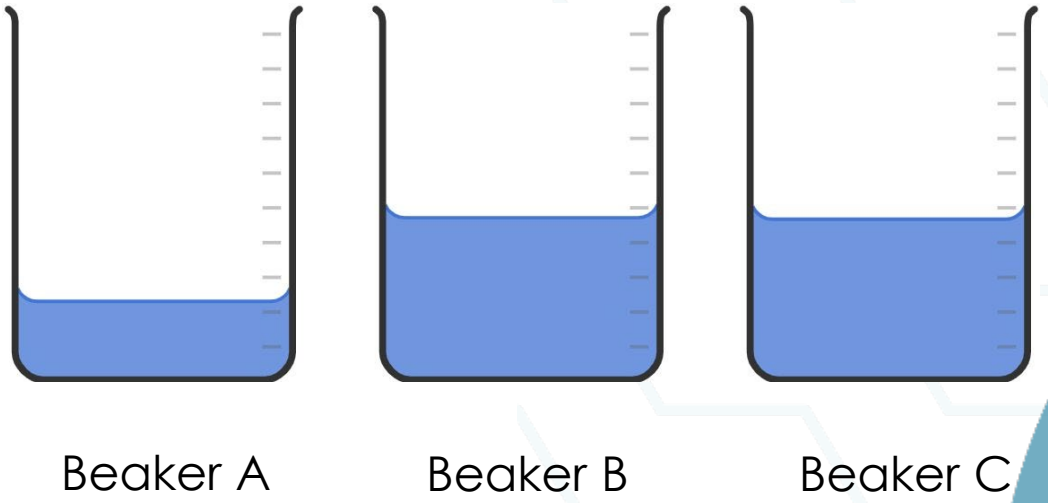
(d) the concentration of copper(II) sulfate in beakers B and C

Different

Unsure

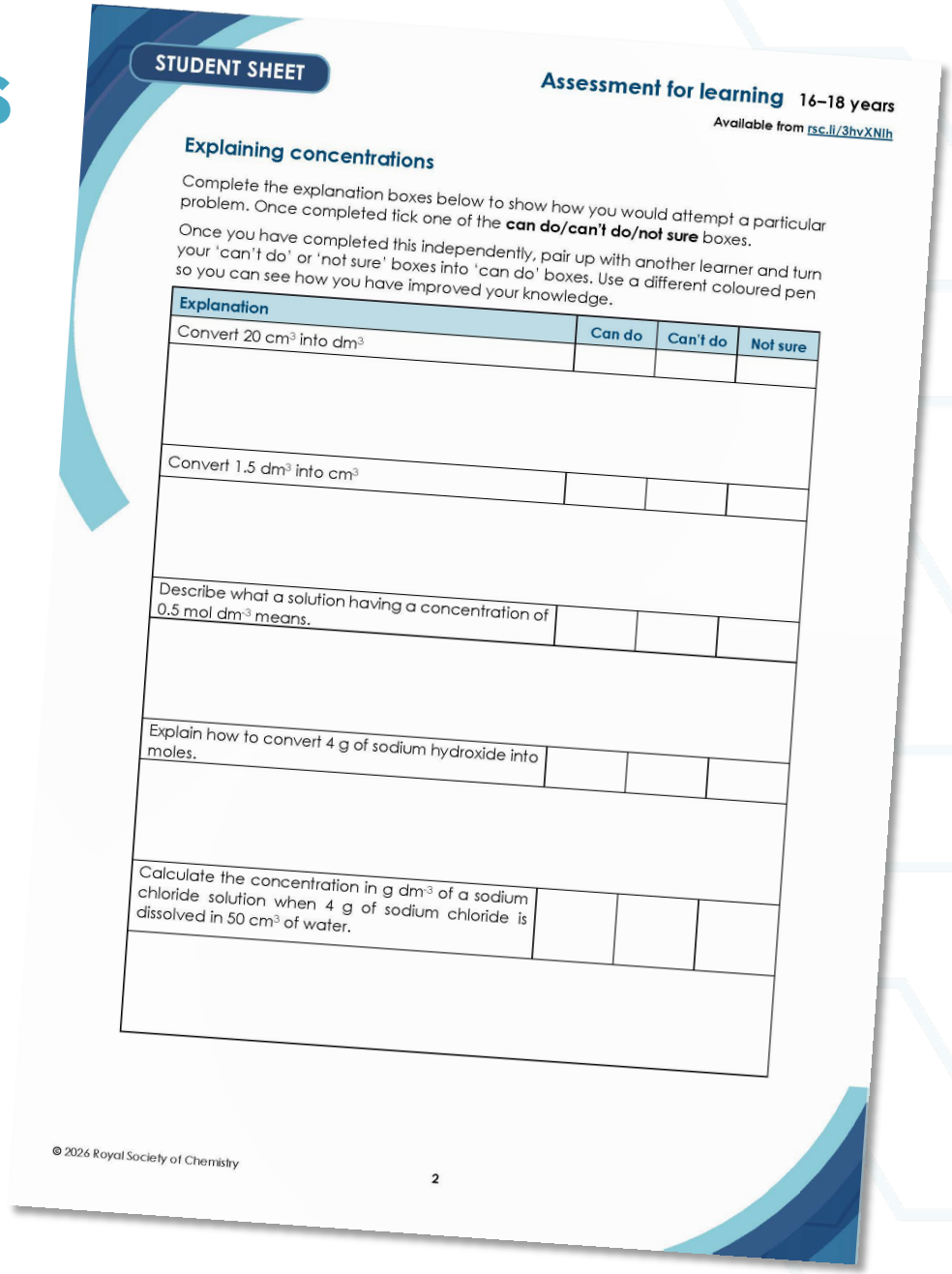
The same





Explaining concentrations

- Complete the following explanation boxes to show how you would attempt a particular problem. Once completed tick one of the **can do/can't do/not sure** boxes.
- Once you have completed this independently, pair up with another person and turn your 'can't do' or 'not sure' boxes into 'can do' boxes. Use a different coloured pen so you can see how you have improved your knowledge.



STUDENT SHEET

Assessment for learning 16–18 years

Available from rsc.li/3hvXNIh

Explaining concentrations

Complete the explanation boxes below to show how you would attempt a particular problem. Once completed tick one of the **can do/can't do/not sure** boxes.

Once you have completed this independently, pair up with another learner and turn your 'can't do' or 'not sure' boxes into 'can do' boxes. Use a different coloured pen so you can see how you have improved your knowledge.

Explanation	Can do	Can't do	Not sure
Convert 20 cm^3 into dm^3			
Convert 1.5 dm^3 into cm^3			
Describe what a solution having a concentration of 0.5 mol dm^{-3} means.			
Explain how to convert 4 g of sodium hydroxide into moles.			
Calculate the concentration in g dm^{-3} of a sodium chloride solution when 4 g of sodium chloride is dissolved in 50 cm^3 of water.			

Explaining concentrations – answers

Explanation

Convert 20 cm^3 into dm^3

To convert from cm^3 to dm^3 you must divide by 1000.

Therefore $\frac{20}{1000} = 0.02\ \mathrm{dm}^3$

Explaining concentrations – answers

Explanation

Convert 1.5 dm^3 into cm^3

To convert from dm^3 to cm^3 you must multiply by 1000.

Therefore $1.5 \times 1000 = 1500\ cm^3$

Explaining concentrations – answers

Explanation

Describe what a solution having a concentration of 0.5 mol dm^{-3} means.

A solution of 0.5 mol dm^{-3} means that there is 0.5 mol of a solute dissolved in every 1 dm^3 (one litre) of the total solution.

Explaining concentrations – answers

Explanation

Explain how to convert 4 g of sodium hydroxide into moles.

First, you must calculate the molar mass of NaOH.

$$23 + 16 + 1 = 40$$

Then substitute this into the equation below:

$$\text{moles (mol)} = \frac{\text{mass (g)}}{\text{molar mass (g mol}^{-1}\text{)}}$$

$$\text{moles (mol)} = \frac{4}{40} = 0.1 \text{ mol}$$

Explaining concentrations – answers

Explanation

Calculate the concentration in g dm^{-3} of a sodium chloride solution when 4 g of sodium chloride is dissolved in 50 cm^3 of water.

The first step is to convert from cm^3 to dm^3 by dividing by 1000.

$$\frac{50}{1000} = 0.05 \text{ dm}^3$$

Then you can substitute the numbers into the below equation:

$$\text{concentration (g dm}^{-3}) = \frac{\text{mass (g)}}{\text{volume (dm}^3)}$$

$$\text{concentration (g dm}^{-3}) = \frac{4}{0.05} = 80 \text{ g dm}^{-3}$$

Card matching: task 1

- Your teacher will provide you with a series of concentration cards (reproduced on the right).
- Work in pairs to match each concentration with the correct mass and volume.
- Use the equations from the introduction to support you.
- Write your answers in the table.

2 g NaOH	4 g NaOH	10 g NaOH
40 g NaOH	100 cm^3 water	0.5 dm^3 water
250 cm^3 water	2 dm^3 water	4 g dm^{-3} NaOH
0.4 mol dm^{-3} NaOH	0.5 mol dm^{-3} NaOH	2.5 mol dm^{-3} Na^+ ions

Concentration	Mass of NaOH	Volume of water
4 g dm^{-3} NaOH		
0.4 mol dm^{-3} NaOH		
0.5 mol dm^{-3} NaOH		
2.5 mol dm^{-3} Na^+ ions		

Card matching: task 1 – answers

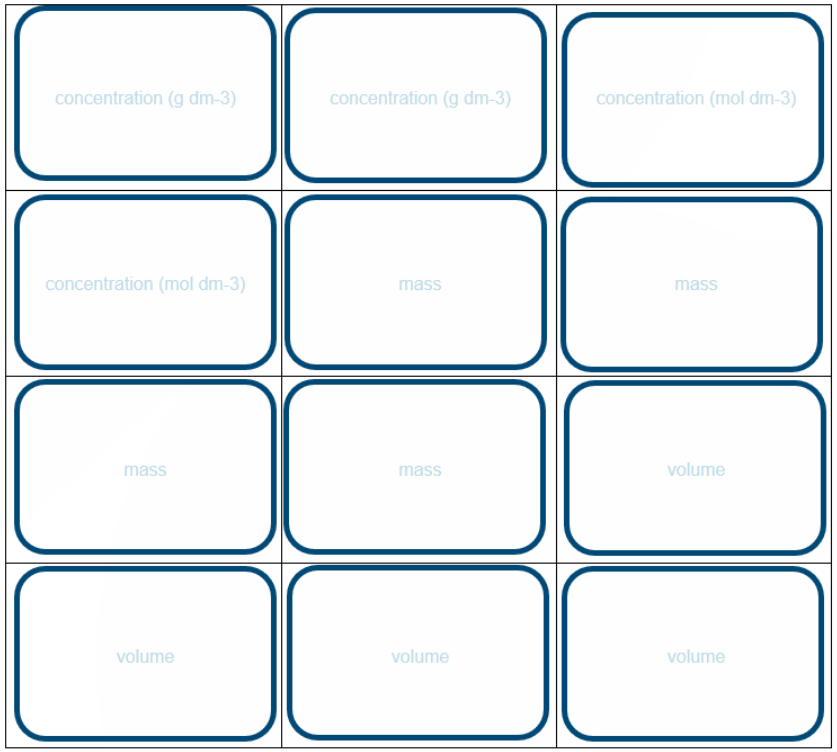
Concentration	Mass of NaOH	Volume of water
4 g dm^{-3} NaOH	2 g	0.5 dm^3
0.4 mol dm^{-3} NaOH	4 g	250 cm^3
0.5 mol dm^{-3} NaOH	40 g	2.0 dm^3
2.5 mol dm^{-3} Na^+ ions	10 g	100 cm^3

Card matching: task 2

You have a set of blank concentration cards. You must pick one solute from the list below and create a series of calculations based on this.

- sodium carbonate
- sulfuric acid
- potassium hydroxide
- calcium bromide
- copper(II) sulfate

As before, you need to have four different concentrations (a mixture of g dm^{-3} and mol dm^{-3}) with the corresponding mass and volume. Record these in the table so that your classmates can assess their answers.



Concentration	Mass of _____	Volume of water

Card matching: task 3

- Swap your concentration cards with another group. Determine the mass and volume needed to make solutions of a certain concentration.
- Write your answers in the table and show any working out.

Concentration	Mass of _____	Volume of water

Extension activity

Calculate the final concentrations in mol dm^{-3} of H^+, Na^+, Cl^- and SO_4^{2-}, when the following three solutions are mixed to give a total volume of 2 dm^3:

- 1000 cm^3 of 0.1 mol dm^{-3} HCl
- 500 cm^3 of 0.2 mol dm^{-3} $NaCl$
- 500 cm^3 of 0.2 mol dm^{-3} Na_2SO_4

Make sure that you show your working.