Concentration and Titrations Notes

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Titrations are a really useful practical in chemistry and are used in the chemical and pharmaceutical industries as well as the food industry. But, before we get into titrations let's look at concentrations.

Concentration: the amount of a solute present in a given quantity of a solution or mixture.

Concentration is usually measured in moles per decimetre cubed, it is written as mol/dm^3. In addition to this, grams per decimetre cubed written as g/dm^3 can also be used.

A quick reminder that a solute is the substance that is dissolved in a solvent. A solvent is the substance that solutes get dissolved in and a solution is what we get when we put a solute and solvent together.

Working with Concentrations

As mentioned above, concentrations can be given in mol/dm^3 or g/dm^3 and we need to be able to calculate these values from data that we are given and be able to convert between them if we are asked.

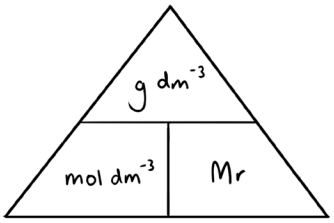
But what is a decimetre? The volume 1 dm^3 is equal to 1000 cm^3. Please do learn this. It is very important to know.

Also, just a quick little note. We could see the concentration written as **mol/dm^3** and **mol/dm^{-3}**. These mean the same thing and there is no real difference between them at all so don't worry if you see one that is different to what you have been using normally to calculate concentrations.

We often need to convert the concentration of a substance between mol/dm^3 and g/dm^3. This is really straightforward 😊. Let's look how to do this and some examples.

Converting mol/dm^3 into g/dm^3

For this calculation we use a slightly modified version of the equation to calculate moles.



If you remove the dm^{-3} from the equation then it's just the mole equation 😊

So, we use the equation: $\boldsymbol{g/dm^3 = mol/dm^3 \times Mr}$

Let's look at a few examples.

Example 1. Convert 0.2 mol/dm^3 into g/dm^3 for a solution of sodium hydroxide.

Step 1: Find the Mr of NaOH

$$23 + 16 + 1 = 40$$

Step 2: substitute the values into the equation and solve for the concentration in g/dm^3.

$$\text{g/dm}^3 = 0.2 \times 40 = 8 \text{ g/dm}^3.$$

This means that if we had 1000 cm^3 of the solution then there would be 8 g of NaOH within it. 😊

Example 2: Convert 0.5 mol/dm^3 into g/dm^3 for a solution of potassium hydroxide (KOH).

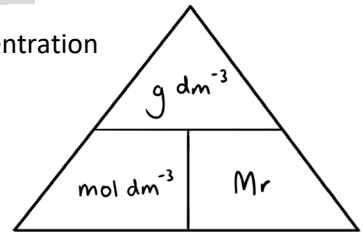
Step 1: Find the Mr of KOH.

$$39 + 16 + 1 = 56$$

Step 2: substitute the values into the equation and solve for the concentration in g/dm^3.

$$\text{g/dm}^3 = 0.5 \times 56 = 28 \text{ g/dm}^3$$

Convert g/dm³ into mol/dm³



Example 3: A solution contains 20.0 g/dm³ of hydrochloric acid (HCl). What is the concentration of the solution in mol/dm³?

We use the equation: $\boldsymbol{mol/dm^3 = g/dm^3 \div Mr}$

Step 1: Find the Mr of HCl.

$$1 + 35.5 = 36.5$$

Step 2: substitute the values into the equation and solve for the concentration in mol/dm³.

$$mol/dm^3 = g/dm^3 \div Mr$$

$$mol/dm^3 = 20 \div 36.5$$

$$mol/dm^3 = 0.547\ mol/dm^3$$

Example 4: A solution contains 15.0 g/dm³ of sulfuric acid (H_2SO_4). What is the concentration of the solution in mol/dm³?

Step 1: Find the Mr of H_2SO_4.

$$2 + 32 + (4 \times 16) = 98$$

Step 2: substitute the values into the equation and solve for the concentration in mol/dm³.

$$mol/dm^3 = g/dm^3 \div Mr$$

$$mol/dm^3 = 15 \div 98$$

$$mol/dm^3 = 0.153\ mol/dm^3$$

What if we see a question where we need to calculate the g/dm³ before we find the mol/dm³. This is nice problem to get and a few of these have come up in the GCSE exams since 2018. Check out the example below.

Example 5: 15 g of sodium hydroxide is dissolved in water and made up to exactly 250 cm³.
What is the concentration in mol/dm³?

Step 1: We notice that we are given the mass in 250 cm³ but we need to know what it is in 1000 cm³ (a dm³). What would we have to do to 250 cm³ to get it up to 1000 cm³? Multiply it by four 😊. We also do this to the 15 g.

$$15\ g = 250\ cm^3$$
$$\times 4 \qquad \times 4$$

$$60\ g = 1000\ cm^3$$

Doesn't this mean that if we had 1000 cm³ we would have 60 g of sodium hydroxide in it? Yes!
This means our concentration is **60 g/dm³**.

Step 2: Find the Mr of sodium hydroxide, NaOH.

$$23 + 16 + 1 = 40$$

Step 3: substitute the values into the equation and solve for the concentration in mol/dm³.

$$mol/dm^3 = g/dm^3 \div Mr$$

$$mol/dm^3 = 60 \div 40$$

$$mol/dm^3 = 1.5\ mol/dm^3$$

Titrations

What is a titration? It's a method of quantitative analysis used to measure accurately the amount of one substance present in a solution using another solution of known concentration.

What does this mean? Imagine a new student has joined your group from a different school and we want to know how quickly they can run. We have no idea. So we race them against you because we know how fast you are. So we will find out if they are faster, the same speed or slower than you. We're using someone we know to find out something we don't know about someone else. 😊 . Let's look at some of the key terms and equipment.

Burette: a long, cylindrical piece of laboratory glassware used to accurately measure volumes of liquid during experiments.

Pipette: a laboratory tool used to measure and carry a specific volume of liquid accurately. It is really useful for making precise measurement of volumes in experiments.

Indicator: a substance that is added to the experiment that changes colour to show when a reaction is complete.

End point: the point during a titration when the indicator changes colour. This shows that the reaction is complete.

Initial volume: the volume of liquid that is measured at the start of an experiment.

Final volume: the volume of a liquid that is measured at the end of an experiment.

How to do a Titration

This can come up on its own as a 5 or 6 mark question. We can also be asked how we would do a titration using specific solutions. It doesn't matter really. Titrations are always done in the same way.

Below we have the 6 points of how to do a titration. Please do learn these 😊 .

1. **Set up our apparatus** – we place a burette on a stand and clamp it securely. We need to make sure that all of the glassware is clean and dry before the titration.

2. **Measure the volume of our alkali** – a volume we know, which is usually 25 cm^3, of an alkali is measured using a pipette and then it is put into to a conical flask.

3. **Add an indicator** – a few drops of a suitable indicator are added to the conical flask. Place the conical flask on a white tile so that the colour change at the end point is easier to see clearly.

4. **Fill the burette** – fill the burette with the acid solution. We need to record the initial volume of the burette.

5. **Run the titration** – we will gently open the tap of our burette so our acid is slowly added from the burette into the conical flask. We should swirl the conical flask as we add the acid from the burette.
   As we get close to when we think the titration is nearly finished then we need to add the acid drop by drop to make sure the figure of the final volume needed is as accurate as possible.

6. **Repeat** – we should then repeat the titration until we get at least two concordant results no more than 0.1 cm^3 apart. The concordant results are averaged. This is to ensure the result is reliable.

Note: the method above is for an acid titrating an alkali. If you are asked for an alkali titrating an acid we could do the same method but just swap the acid into the conical flask and the alkali into the burette. That's all 😊

Indicators

There are two common indicators that are used in titration practicals, these are Phenolphthalein and Methyl orange.

Phenolphthalein – is pink in alkali solutions and colourless in neutral solutions. The end point is the change from pink to colourless.

Methyl orange – shows a red colour in acidic solutions and yellow colour in alkali solutions. It is usually used in titration for acids. The end point is the change from red to yellow. This colour change can be hard to see.

Titration Calculations

Titration calculations are carried out in a step by step method that is similar to how we calculate moles.

Step 1: convert any volumes given in centimetres cubed (cm^3) to decimetres cubed (dm^3).

Step 2: Write a balanced chemical equation for the reaction.

Step 3: Find the number of moles of the compound with the concentration we know.

Step 4: Use the equation to find the number of moles of the compound whose concentration **or** volume we don't know.

Step 5: Finally, we convert this number of moles into a concentration or a volume.

There are two types of titration calculation. Calculations in which we have to find a concentration, these are known as type 1 calculations these are the most common type asked and calculations in which we must find an unknown volume, these are known as type 2 calculations.

Type 1 Calculations – finding an unknown concentration

Example 6: Find the concentration of a solution of sulfuric acid for which exactly 25.0 cm^3 requires 22.5 cm^3 of 0.20 mol/dm^3 lithium hydroxide solution.

Step 1: convert any volumes given in centimetres cubed (cm^3) to decimetres cubed (dm^3).

We can convert cm^3 to dm^3 by dividing the volume in cm^3 by 1000.

This means that the volume of sulfuric acid in dm^3 would be $25 \div 1000 = \frac{1}{40}$ or 0.025 dm^3

The volume of lithium hydroxide would be $22.5 \div 1000 = \frac{9}{400}$ or 0.0225 dm^3

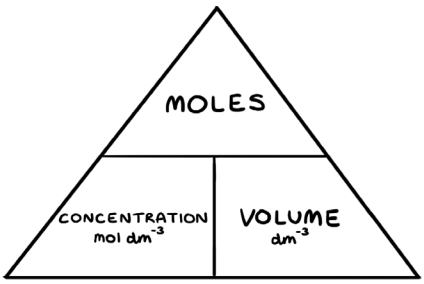
Step 2: Write a balanced chemical equation for the reaction.

$$H_2SO_4\ (aq) + 2LiOH\ (aq) \rightarrow Li_2SO_4\ (aq) + 2H_2O\ (l)$$

Vol = 0.025 dm^3 **Vol** = 0.0225 dm^3

Conc = ? **Conc** = 0.20 mol/dm^3

Note: under the equation I like to put in **conc**, short for concentration and **vol** short for volume under each species. This helps me to avoid any mix ups. Feel free to use it 😊 If you don't like it, please ignore it.



Step 3: moles of LiOH = conc × vol (dm^3) = $0.20 \times 0.0225 = \frac{9}{2000}$ mol

Step 4: moles H_2SO_4 = 0.5 × LiOH = $0.5 \times {}^{9}/_{2000} = {}^{9}/_{4000}$

Step 5: concentration of $H_2SO_4 = \frac{moles}{volume\ (dm^3)}$

$$= \frac{{}^{9}/_{4000}}{0.025} = 0.09\ mol/dm^3$$

Tips:

1. Try to work in fractions if you can. They are more accurate than using decimals and they're shorter.
2. Always make sure that you have included your unit in your answer.

Type 2 Calculations – finding an unknown volume

Example 7: What volume of a 0.200 mol/dm^3 calcium hydroxide solution neutralises 25.0 cm^3 of a 0.100 mol/dm^3 nitric acid solution? Give your answer to 3 significant figures.

Step 1: convert any volumes given in centimetres cubed (cm^3) to decimetres cubed (dm^3).

<u>We can convert cm^3 to dm^3 by dividing the volume in cm^3 by 1000</u>.

This means that the volume of nitric acid in dm^3 would be $25 \div 1000 = \frac{1}{40}$ or 0.025 dm^3

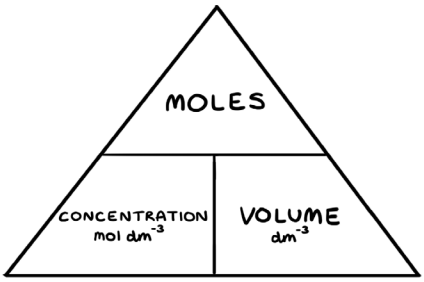
Step 2: Write a balanced chemical equation for the reaction.

$$Ca(OH)_2\,(aq) + 2HNO_3\,(aq) \rightarrow Ca(NO_3)_2\,(aq) + 2H_2O\,(l)$$

Vol = ? **Vol** = 0.025 dm^3

Conc = 0.200 **Conc** = 0.100

Note: a question might (and probably will) ask us to give the volume in centimetres cubed, cm^3. All we have to do then is multiply our dm^3 volume by 1000 😊



Step 3: moles of HNO_3 = conc × vol (dm^3) = $0.100 \times 0.025 = \frac{1}{400}$

Step 4: moles $Ca(OH)_2$ = $0.5 \times$ mols of $HNO_3 = 0.5 \times \frac{1}{400} = \frac{1}{800}$

Step 5: volume of $Ca(OH)_2$ = $\frac{moles}{concentration} = \frac{\frac{1}{800}}{0.200} = 0.00625$ dm^3

So, in this example it would be $0.00625 \times 1000 =$ **6.25 cm^3**

Note: I know these seem a bit big and scary but just like everything else practise will make them feel easier. If someone doesn't practise cycling, they will find that very hard. The exact same principle applies here.

So, practise, practise, practise 😊