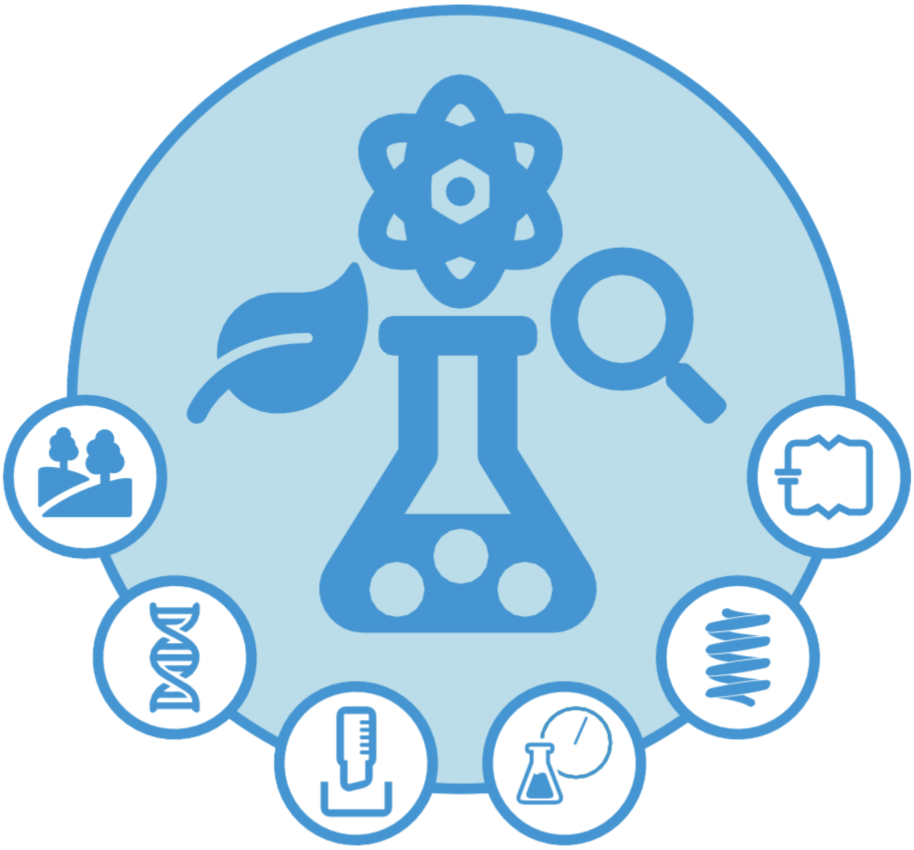
EXEMPLAR LESSON

DETERMINING THE HARDNESS OF RIVER WATER BY EDTA TITRATION



Acknowledgements

Ministry of Education

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CENDLOS
CENTRE FOR NATIONAL DISTANCE LEARNING AND OPEN SCHOOLING
Nexus of virtual learning

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OpenSTEM Africa

For information on OpenSTEM Africa see: www.open.ac.uk/ido

OPITO

OPITO for their generous support, which has made OpenSTEM Africa and the development of the Virtual Laboratory and these materials possible.

The Open University

Contents

Exemplar lessons for the OpenSTEM Africa Virtual Laboratory applications

All the exemplar lessons are examples of lessons which could be used both individually and by whole classes of Senior High School (SHS) students in the elective sciences of Biology, Chemistry and Physics. Each of the lessons is linked specifically to one of the applications in the OpenSTEM Africa Virtual Laboratory. The exemplar lesson is created to give, both to SHS students and to SHS teachers, a clear example of the ways in which the applications can be used in the learning and teaching of practical science. There is a focus throughout the lesson on the student's development of the practical and experimental skills which, along with knowledge and understanding, are integral to the profile of learning, teaching and assessment in SHS sciences.

The 'you' in this lesson is 'you', the Senior High School student. Remember that you can repeat the experiments and activities in this lesson as often as you have time for in class. This freedom to repeat experiments and activities is also important if you are accessing the lesson outside the classroom, for example for homework. Every application in the OpenSTEM Africa Virtual Laboratory contains real data – the experiments are real experiments. This means you might make mistakes the first or second or third time you try an experiment or an activity – and that is exactly what often happens in the real world in the sciences. So, it is helpful for you as a student to share in some of the real-world trial and error of science as you develop your skills as a scientist.

The exemplar lesson also contains a set of teaching notes at the end of this document for 'you' the SHS science teacher, to suggest how you might want to set up this particular lesson with one of your classes. Hopefully it will also generate ideas for other lessons on the same topic, or other lessons which use the same OpenSTEM Africa Virtual Laboratory application.

Determining the hardness of river water by EDTA titration

Lesson objectives

By the end of this lesson, you will be able to:

- Understand the general principles of a titration and the chemistry involved in a complexometric titration.
- Appreciate how to handle liquids in the laboratory.
- Determine the hardness of river water samples by carrying out titrations.

The following practical and experimental skills will be developed:

- Taking measurements of volume
- Recording data
- Carrying out titration calculations
- Interpreting results.

Background

What is hard water?

Hard water is caused by the presence of naturally occurring calcium and magnesium salts in water. Water hardness is usually noticed because of difficulty in lathering soap and the formation of a scum when washing. Calcium and magnesium ions (Ca^{2+} and Mg^{2+}) form insoluble salts with soaps causing precipitation of this soap scum. Also, hard water can react with dissolved carbonates in water to form a precipitate of insoluble calcium carbonate ($CaCO_3$). This “scale” (also called “limescale”) can build up on the inside of water pipes to such a degree that the pipes become almost completely blocked. Hard water is considered a problem to industries, agriculture and households that have to spend more money on extra soap and the replacement of blocked pipes.

Different geographic areas have varying amounts of calcium and magnesium salts in the water, caused by soft rainwater filtering through different rocks dissolving these molecules on the way. Magnesium is found in rocks, such as dolomite and magnesite, whilst calcium is more abundant in limestone and some basalts.

The unit of measurement for hardness is milligrams per litre of calcium carbonate ($mg\ l^{-1}\ CaCO_3$).

Water with less than 50 $mg\ l^{-1}$ of calcium carbonate is regarded as soft, with quantities between 50 and 200 $mg\ l^{-1}$ as intermediate, and with quantities greater than 200 $mg\ l^{-1}$ as hard.

The effect of hard water on health is monitored by the World Health Organisation (WHO). It is found to potentially cause eczema in young children and there may also be a relationship between water hardness and cardiovascular health, so it is recommended to maintain a minimum total hardness of drinking water of 150 $mg\ l^{-1}\ CaCO_3$.

What is a titration?

Titration is a chemical analysis where a **standard solution** of known concentration is used to determine the unknown concentration of a particular chemical solution. The known standard solution is added from a **burette** to the sample containing an unknown quantity of the chemical of interest, which it reacts with in a definite and known proportion. An indicator is often used to indicate the end point of the reaction.

In this experiment the concentration of Ca^{2+} and Mg^{2+} ions is determined using a known concentration of EDTA (ethylenediaminetetraacetic acid). EDTA is a large molecule that captures metal ions by forming several bonds to a single ion. The metal–EDTA complex is stable, and its formation takes place in a controlled 1:1 mole ratio (one mole of metal ions reacts with one mole of EDTA, forming one mole of the metal–EDTA complex).

What is a mole? How do you calculate the mass of a mole of any substance?
Go to Appendix 3 for the answer.

Volumetric glassware used in titration

Glass is used to produce glassware for use in the chemistry laboratory because it is relatively unreactive, highly durable, easily customisable, and inexpensive (see Figure 1).

Choosing the correct **volumetric glassware** for an experiment is important. Some glassware is used to precisely measure the volume of solutions as it has been calibrated to a high level of accuracy, for example volumetric pipettes and burettes. Although much glassware is graduated, in some cases these graduations are just approximate (for example in conical flasks) and they should not be used if an accurate volumetric measurement is required.

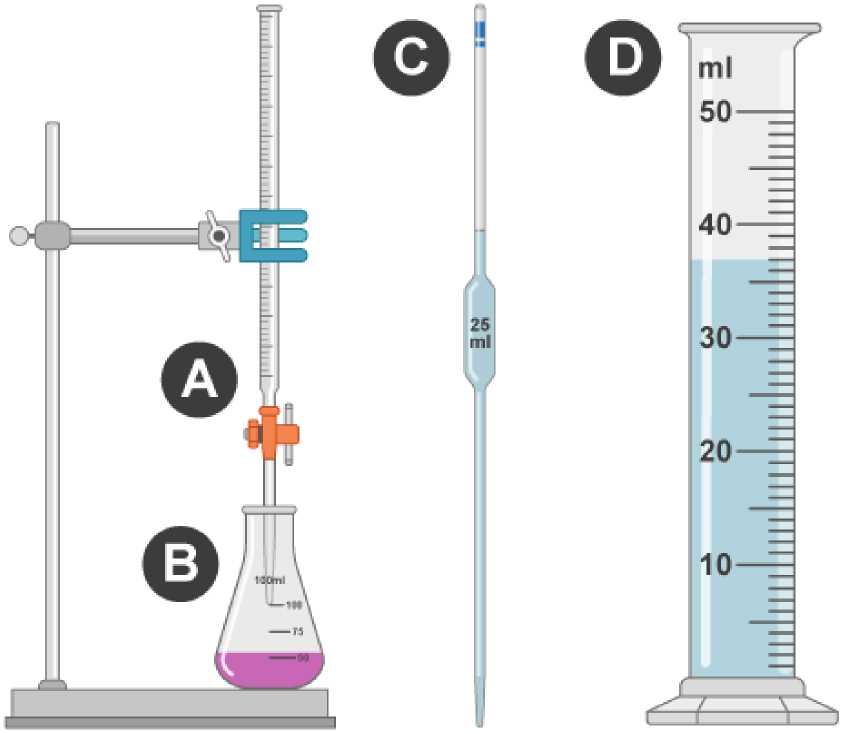


Figure 1. Images of glassware used in a titration experiment.

Match the names of the glassware with the images labelled A to D in Figure 1. • **Burette** • **Pipette** • **Conical flask** • **Graduated (or measuring) cylinder**
Go to Appendix 3 for the answer.

Volumetric measurements using narrow tubular glassware such as a burette, can be challenging. This is because the surface of the water has a pronounced curvature, the **meniscus**, as shown in Figure 2. Volumetric pipettes and burettes are calibrated to take this into account.

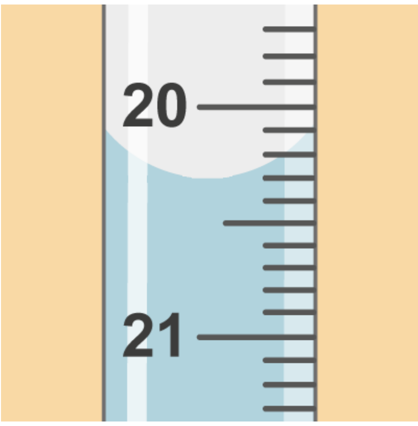


Figure 2. The water meniscus in a burette (note that it is curved).

What is the volume of solution in the burette shown in Figure 2?
Go to Appendix 3 for the answer.

A complexometric titration

Water hardness can be measured using a procedure known as **complexometric titration** by adding a known concentration of the **chelating agent** EDTA through a burette to a sample containing an unknown amount of calcium and magnesium ions. **EDTA** reacts and captures these metal ions creating a larger metal complex. So, whilst there are Ca^{2+} and Mg^{2+} ions in the solution the EDTA will react with them until all metal ions are used up.

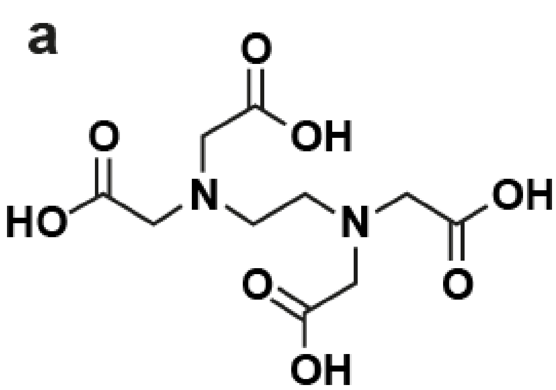


Figure 3. (a) EDTA molecule; (b) EDTA metal complex (the complex has a negative charge which is not shown in this representation).

The end point of this titration is indicated by a change in the colour of the solution, aided by the addition of an indicator. An indicator is a substance that has a marked colour change on completion of a particular chemical reaction, which makes it easier to identify when the end point has been reached.

Mg^{2+} and Ca^{2+} ions are colourless at pH 10 but the solution will turn pink to red in colour when adding the indicator Eriochrome Black T (ErioT). On titration with EDTA, the solution will eventually turn blue when sufficient EDTA has been added and reacted with all the Ca^{2+} and Mg^{2+} ions present in the sample.

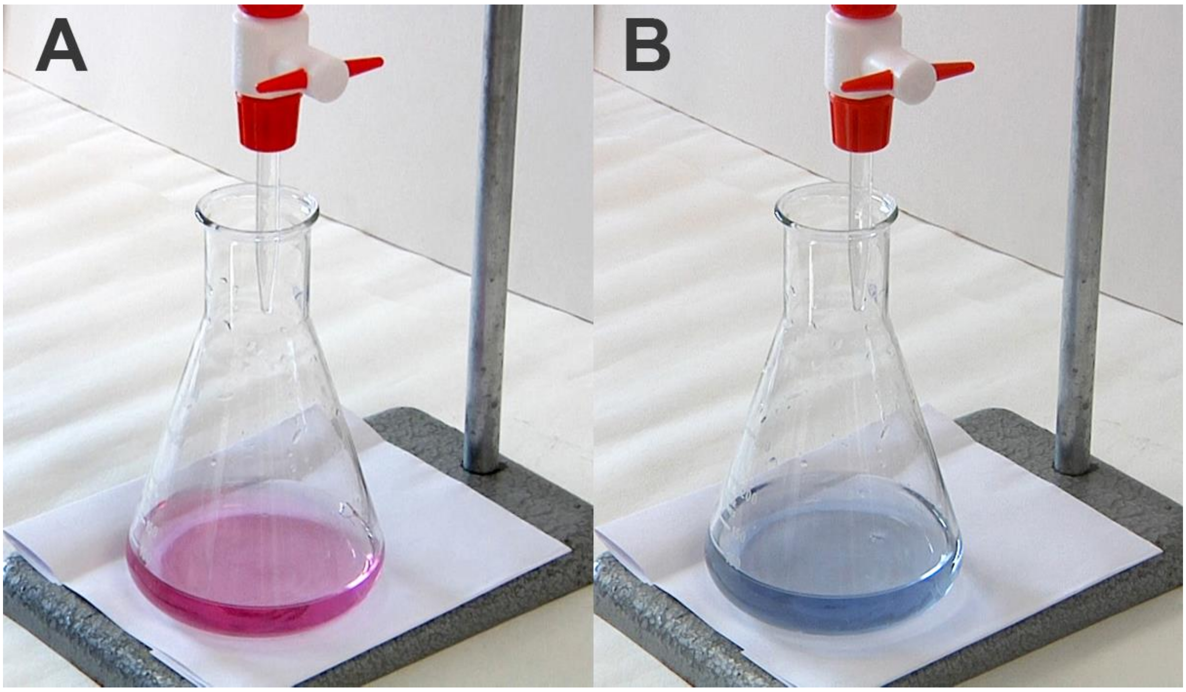


Figure 4. Water sample containing Ca^{2+} and Mg^{2+} ions and the indicator ErioT: (a) before titration (colour pink), (b) at the end point (colour blue).

An ammonia **buffer solution** is used to make sure that the sample stays at pH 10. This is important because at this pH, a marked colour change is observed at the end point and the EDTA will not react with any other metal ions in the solution (such as Fe^{2+}) that may be present in the water sample.

What is a buffer solution?
Go to Appendix 3 for the answer.

Practical activity

Read the following sections before attempting the experiment.

In the online experiment you will measure the total hardness of a water sample by following the chemical reaction of Ca^{2+} and Mg^{2+} ions with EDTA:

Task 1: You will determine the precise concentration of the EDTA solution by reaction with a calcium solution of known concentration; this process is called standardisation.

Task 2: Using the standardised EDTA solution, you will titrate a river water sample, and then calculate the concentration of calcium and magnesium ions in your sample.

Task 1: Standardisation of EDTA

To accurately calculate the concentration of EDTA it is necessary to titrate it against a **standard solution** of calcium carbonate of a known concentration (to a high degree of accuracy). You will be using a solution of calcium carbonate of a concentration of 0.010 mol l^{-1}.

The concentration of the EDTA solution is precisely calculated by titration of a known volume (10.00 ml) of a primary standard calcium solution of a known concentration (0.010 mol l^{-1}). The molar concentration (or molarity M) of the EDTA solution by titrating 10.00 ml of a standard calcium solution of concentration 0.010 mol l^{-1} is determined as follows:

$M \times V_1$= (0.010 mol l^{-1} x 10.00 ml)

where V_1 is the volume (ml) of EDTA used in the standardisation titration.

$$M = \frac{0.010\, mol\, l^{-1}\, x\, 10.00\, ml}{V_1}$$

You will use the Complexometric titration application to determine the precise concentration of the EDTA solution that you will later use to determine the hardness of your river water sample. Detailed instructions are provided within the experiment but the following is a summary of the steps you need to take:

1. Fill your burette with EDTA solution.
2. Measure as accurately as possible 10.00 ml of the standard calcium solution using the appropriate glassware and transfer into a conical flask.
3. Add deionised water by selecting appropriate glassware and dilute to 50 ml.
4. Add 2.00 ml ammonia buffer solution using the appropriate glassware.
5. Add one or two drops of ErioT indicator. The solution will turn pink.
6. Record the initial burette reading.
7. Titrate with the EDTA solution until the colour of the mixture turns from pink, through purple, to blue. While adding EDTA, make sure the solution in the conical flask is thoroughly mixed using a magnetic stirrer. As the end point approaches and the solution turns purple, the EDTA should be added very slowly – drop by drop. At the end point the last of the pinkish tinge disappears and a pure blue colour is left.
8. Record the volume of EDTA added.

Note that it is good practice to do a ‘rough’ titration first to estimate the approximate volume of EDTA required and then do the titration more carefully adding drop-by-drop as you approach the estimated end point. You should repeat this standardisation procedure at least twice. You may need a third replicate measurement if your analytical results lack precision. Although you should include the value of your 'rough' standardisation in your records, you should not use it in any subsequent calculations.

Table 1 shows a template you could use to record your experimental data.

Table 1 Volumetric data for the standardisation of EDTA solution

	Rough	**Trial 1**	**Trial 2**	**Trial 3** (if needed)
Initial burette reading /ml				
Final burette reading /ml				
Volume of EDTA solution used /ml				
Average volume of EDTA solution used (V_1) /ml				

You are now ready to attempt Task 1 – the standardisation of EDTA solution.

Complexometric titration

Go to the OpenSTEM Africa Virtual Laboratory.

Click on the icon to access the [Complexometric titration application]() homepage.

Watch the introductory video before entering the experiment to carry out Task 1.

Once you have completed Task 1, you can calculate the concentration of the EDTA solution supplied in this experiment.

Work through the example calculation below to familiarise yourself with the calculation required to complete Task 1.

An average of 10.50 ml of EDTA solution was required to titrate 10.00 ml of a standard calcium solution of 0.010 mol l^{-1}. Determine the concentration of the EDTA solution.

Go to Appendix 3 for the answer.

You should now calculate the concentration of the EDTA solution supplied in this investigation using the average volume of EDTA used.

Task 2: Determining the hardness of a river water sample

The total hardness (concentration of calcium and magnesium ions) is expressed in mg l^{-1} $CaCO_3$ and it is calculated as:

$$Total\ hardness = \frac{molar\ mass\ of\ CaCO_3\ x\ 1000\ x\ M\ X\ V_2}{volume\ of\ water\ sample\ used\ (ml)}$$

where M (mol l^{-1}) is the molarity of EDTA solution, V_2 (ml) is the volume of EDTA used in the titration of a river water and the molar mass of $CaCO_3$ = 100.09 g mol^{-1}.

You will now return to the Complexometric titration application and select a water sample from a selection of different rivers across the world and will titrate it against your standardised EDTA solution to determine its hardness. Detailed instructions are provided within the experiment but the following is a summary of the steps you need to take:

1. Choose a river water sample from the list of possible locations.
2. Measure as accurately as possible 50.00 ml of the water sample using the appropriate glassware and transfer into a conical flask.
3. Add 2.00 ml ammonia buffer solution selecting the appropriate glassware.
4. Add one or two drops of ErioT indicator. The solution will turn pink.
5. Record the initial burette reading.
6. Titrate with the EDTA solution until the colour of the mixture turns from pink, through purple, to blue. While adding EDTA, make sure the solution in the conical flask is thoroughly mixed using a magnetic stirrer. As the end point approaches and the solution turns purple, the EDTA should be added very slowly – drop by drop. At the end point the last of the pinkish tinge disappears and a pure blue colour is left.
7. Record the volume of EDTA added.

Judging the exact end point can be difficult and the volume of EDTA required cannot be predicted. You may like to do a 'rough' titration first to estimate the approximate volume and then repeat, adding drop by drop as you approach the estimated end point. You should not include the value of your 'rough' titration in your calculation. Repeat the titration using the water sample at least twice.

Table 2 shows a template you could use to record your experimental data.

Table 2 volumetric data of EDTA used to reach equivalence

	Rough	**Trial 1**	**Trial 2**	**Trial 3** (if needed)
Initial burette reading /ml				
Final burette reading /ml				
Volume of EDTA solution used /ml				
Average volume of EDTA solution used (V_2) /ml				

Use your data to calculate the total hardness of your chosen river water sample. When you have completed your calculation consider whether you would describe your water sample as soft, intermediate or hard.

Work through the example calculation below to familiarise yourself with the calculation required to complete Task 2.

Titration of a 50.00 ml sample of mineral water at pH 10 required an average of 16.80 ml of EDTA solution from the previous example (0.0095 mol l^{-1}). Calculate the total hardness of $CaCO_3$ in the mineral water.
Go to Appendix 3 for the answer.

Summary

Titration is a volumetric technique widely used in chemistry to determine the concentration of an unknown quantity in a solution. In this experiment you have used the chelating agent, EDTA, to determine the concentration of calcium and magnesium metal ions in water. However, to do this, you have actually performed two titration tasks: the first was to determine or standardise the concentration of EDTA; and the second to use this information to determine the hardness of a river water sample.

A key step in both tasks is that you used a dye (the indicator ErioT) to determine the endpoint of the reaction, and importantly, you also used a buffer to maintain the pH at 10 so that the reaction was targeted at calcium and magnesium metal ions.

Quiz

Answer the questions, then search for the correct answers in Appendix 4.

Question 1

What's the name of a solution containing a precisely known concentration of a chemical?

a) Buffer solution

b) Indicator solution

c) Standard solution

Question 2

How many moles of Ca^{2+} ions are in 10.00 ml of a solution of calcium carbonate of concentration 0.010 mol l^{-1}?

a) 0.10 moles

b) 0.010 moles

c) 0.0010 moles

d) 0.0001 moles

Question 3

Which of the following statements is correct?

1. Graduated glassware (for example volumetric pipettes and conical flasks) have been calibrated to a high level of accuracy and they are used in the laboratory to precisely measure the volume of solutions.

2. Choosing the correct volumetric glassware for an experiment is important. Some glassware is used to precisely measure the volume of solutions as it has been calibrated to a high level of accuracy, for example volumetric pipettes and burettes.

Question 4

How does EDTA react with Ca^{2+} and Mg^{2+} ions? Complete the paragraph below by selecting <u>one</u> option to fill in the gap.

EDTA is a large molecule that captures metal ions by forming several bonds to a single ion. The formation of the metal–EDTA complex takes place in a controlled 1:1 mole ratio (one mole of metal ions reacts with one mole of EDTA forming __________ of the metal–EDTA complex).

[two moles, one mol, one molecule]

Glossary

Buffer solution – Aqueous solutions resistant to changes in pH when small volumes of an acid or a base are added to it.

Burette – A graduated glass tube with a stopcock at the bottom, used to precisely measure the volume of a liquid.

Chelating agent – Chemical compound that react with metal ions to form a stable complex.

Chelate complex – Complex compound consisting of a central metal atom attached to a large molecule.

Complexometric titration – Titration wherein the coloured complex is used to determine its endpoint.

EDTA – Ethylenediaminetetraacetic acid.

Indicator – Chemical that undergoes a colour change when conditions in its solution change.

Meniscus – The curved upper surface of a liquid in a tube.

Mole – An amount of a substance.

Precipitate – Insoluble solid emerging from a liquid solution.

Standard solution – Solution containing a precisely known concentration of a chemical

Standardisation – Finding the exact concentration of a solution

Titration – Analytical technique to measure the concentration of a certain chemical in a given solution

Volumetric glassware – Calibrated glassware used in the laboratory to accurately determine and measure specific volumes.

Appendix 1: Teacher notes – organisation of the lesson

Teaching notes for the Complexometric titration application and the exemplar lesson on determining the hardness of river water by EDTA titration.

Combined with using the Complexometric titration application, this lesson links to the following units in the Teaching Syllabus for Chemistry:

- SHS 1 Section 1 Introduction to Chemistry, Unit 2: Measurement of physical quantities
- SHS 1 Section 4 Conservation of Matter and Stoichiometry, Unit 1: Carbon-12 scale
- SHS 1 Section 4 Conservation of Matter and Stoichiometry, Unit 2: Solutions
- SHS 2 Section 4 Acids and Bases, Unit 2: Properties of Acids, Bases and Acid-base indicators

Ideas for organising this exemplar lesson link directly to activities and teaching examples in the OpenSTEM Africa CPD units *Linking Science to everyday life* and *Using ICT to support learning*.

A full list of the OpenSTEM Africa CPD units can be found at: https://www.open.edu/openlearncreate/CPD_units

Overview

If it can be arranged through your Head of Science and the Head of ICT, this lesson should take place in the ICT Lab in your school. If the lesson takes place in the ICT Lab, it may be possible for each student to work individually at a computer; otherwise divide the class so that students are in small groups at a computer.

If it isnot possible to use the ICT Lab for this lesson, then try to set up this lesson in your classroom. You may be lucky enough in your school to have a set of 'empty' tablets or mobile phones which students can use. Or you may be able to bring a laptop connected to the internet or to your school intranet – and perhaps connected to a projector to make it possible for the whole class to view at once. If access to ICT is a real challenge in your school but you want your students to view an experiment, you might be able demonstrate it to small groups of your students at a time using your own mobile phone.

Whatever way(s) you set up the class, it would still be helpful to the students to be able to work in pairs or small groups for at least some of the lesson. Do remember as well that students need desk space to be able to write in their notebooks and to draw diagrams.

Steps in organising the lesson

Step 1: This takes place in the lesson before the one where you and your class access the OpenSTEM Africa Virtual Laboratory Complexometric titration application. Have students work in pairs to pre-read the Background section of the exemplar lesson. They should ask each other the questions in the Background section and check with each other that each understands the answers. While they are doing so, you may want to walk round the class, checking their general understanding of titration as well as the specifics of EDTA titration. Do think about making connections with their everyday lives and the ways water hardness can affect e.g., plumbing, the use of detergents etc. This is important for this exemplar lesson.

Step 2: At the beginning of this exemplar lesson, check understanding by asking (again!) the students the questions in the Background section. Organise the class, if possible, to work in the same pairs as in the previous lesson. Have each person in the pair create the tables for their experimental data in their own laboratory notebook in preparation for their data collection from the practical activity.

Step 3: Within each pair, have them check each other's work and that each has set the tables out correctly with the correct headings.

Step 4: Make sure that each pair has access to a scientific calculator so that they can make the calculations. It may be that calculators will need to be shared across the class, with each pair using the calculator in turn for one set of calculations and passing it on.

Step 5: Make sure that each pair has access to/can see the computer screen to begin the actual investigation and observation and carry out the measurements. Ensure that each pair knows how to carry out the measurements **–** or if you are using a laptop/projector, that you draw on the expertise of the class as you go through each step of the investigation, preparing solutions and measurements of volume **–** i.e., ask them what the next step is.

Step 6: Have the class follow the instructions. Make sure, if working in a pair on a PC, that each student in the pair gets to follow all the steps; if working in a group on a PC, have the group leader ensure that everyone in the group is involved.

Step 7: Five minutes before the end of the lesson, tell the students to complete the quiz.

Step 8: If this is possible in your location and with your students, can you think about a follow-up activity/lesson outside the classroom. Are you able to consider a practical activity on measuring water hardness? Is it an issue in the area around the school in which you work?

Appendix 2: Teacher notes – outputs from the lesson

Task 1

Students will standardise the EDTA solution before moving on to determine the hardness of water samples. The given concentration of EDTA solution is around 0.01 mol l^{-1}. Students will be titrating 10.00 ml of standard calcium solution at a concentration of 0.010 mol l^{-1}.

The molar concentration of EDTA solution is determined by:

$$M = \frac{0.010\, mol\, l^{-1}\, x\, 10.00\, ml}{V_1}$$

where V_1 is the volume (ml) of EDTA used in the standardisation titration.

The volume of EDTA used in this standardisation titration will be around 10 ml.

Students will be getting values of 0.010 mol l^{-1} $\pm$ 0.0005

Task 2

Students will determine the hardness of a river sample. Based on titration of 50 ml of sample and using and EDTA solution of 0.010 M, the calculations of water hardness are as follows:

$$Total\ hardness = \frac{100.09\, g\, mol^{-1}\, x\, 1000\, mg\, x\, 0.010\, mol\, l^{-1}\, x\, V_2}{50\, ml}$$

where V_2 (ml) is the volume of EDTA used in the titration of a river water.

Expected range of volumes of EDTA requires and hardness values:

Water sample	**Volumes of EDTA used / ml**	**Hardness / mg $CaCO_3$/l**
Avon river, UK	5.04	119
Tejo river, Spain	10.09	202
Seine river, France	4.94	99
Rhine river, Germany	4.15	83
St Lawrence river, Montreal	2.20	44
Yellow river, China	3.65	73
Kathajodi river, India	3.85	77
Orange river, South Africa	1.40	28
Arkansas river, USA	1.90	38
Rio Grande, Mexico	9.49	190

Students should supply data from replicates and present their average of these.

Appendix 3: In-text question answers

What is a mole? How do you calculate the mass of a mole of any substance?

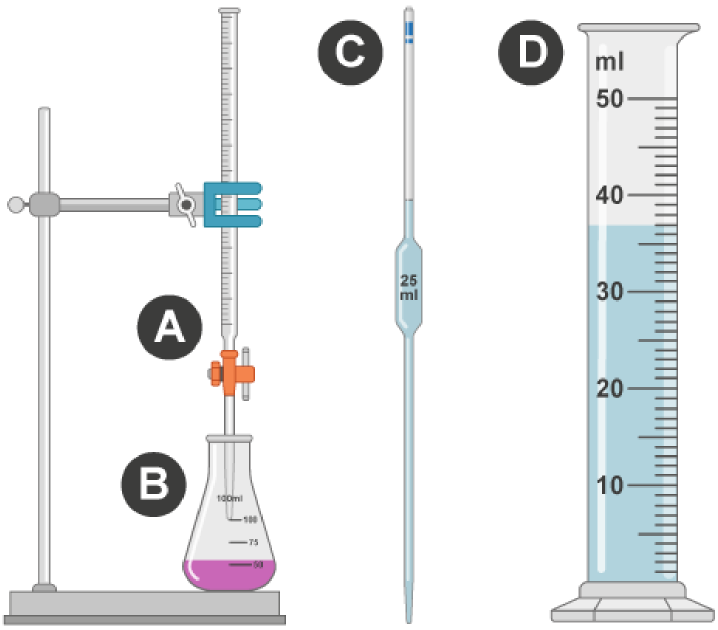
Answer: A mole (mol) is an amount of a substance. Its mass is obtained by adding up the relative atomic masses of the atoms in the formula unit and multiplying the resulting number by 1 gram (g).

For example:
1 mol $CaCO_3$ = [atomic mass of Ca + atomic mass of C + (3 x atomic mass of O)] g
= [40.08 + 12.01 + (3 x 16.00)] g
= (40.08 + 12.01 + 48.00) g
= 100.09 g
This is known as the **molar mass**.

Match the names of the glassware with the images labelled A to D in Figure 1.

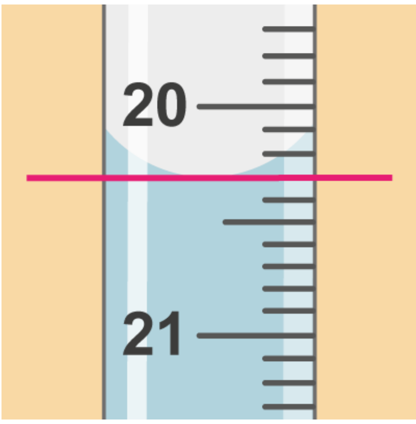
- **Burette**
- **Pipette**
- **Conical flask**
- **Graduated (or measuring) cylinder**

Answer:
A burette, **B** conical flask, **C** graduated cylinder, **D** pipette



What is the volume of solution in the burette shown in Figure 2?

Answer: The volume of solution in the figure is 20.30 ml. When determining the volume of a liquid, ensure that you take the reading at the bottom of the meniscus.



What is a buffer solution?

Answer: Buffer solutions are aqueous solutions containing a mixture of a weak acid and its conjugate base or a weak base and its conjugate acid. They are resistant to changes in pH when small volumes of an acid or a base are added to them.

An average of 10.50 ml of EDTA solution was required to titrate 10.00 ml of a standard calcium solution of 0.010 mol l^{-1}. Determine the concentration of the EDTA solution.

Answer:
The molar concentration or molarity M of the EDTA solution by titrating 10.00 ml of a standard calcium solution of concentration 0.010 mol l^{-1} is determined as follows:

$$M = (0.010 \text{ mol l}^{-1} \times 10.00 \text{ ml}) / V_1$$
$$M = (0.010 \text{ mol l}^{-1} \times 10.00 \text{ ml}) / 10.50 \text{ ml} = 0.0095 \text{ mol l}^{-1}$$

Note that units appearing in both the numerator and denominator of a fraction are cancelling, leaving you with just 'mol l^{-1}' here

Titration of a 50.00 ml sample of mineral water at pH 10 required an average of 16.80 ml of EDTA solution from the previous example (0.0095 mol l^{-1}). Calculate the total hardness of $CaCO_3$ in the mineral water.

Answer:
Total hardness = (100.09 g mol^{-1} x 1000 x 0.0095 mol l^{-1} x 16.80 ml) / 50.00 ml
= 319.5 mg l^{-1} $CaCO_3$
Note that multiplying by 1000 (in the numerator) converts the molar mass units to mg mol^{-1}

Appendix 4: Quiz answers

Correct answers are highlighted in green.

Question 1

What's the name of a solution containing a precisely known concentration of a chemical?

a) Buffer solution

b) Indicator solution

c) Standard solution

Feedback

A standard solution, such as the calcium carbonate solution used in Task 1, contains a known concentration.

Question 2

How many moles of Ca^{2+} ions are in 10.00 ml of a solution of calcium carbonate of concentration 0.010 mol l^{-1}?

a) 0.10 moles

b) 0.010 moles

c) 0.0010 moles

d) 0.0001 moles

Feedback

To calculate the number of moles in 10 ml of solution, first divide the molar concentration by 1000 to calculate how many moles in 1 ml and then multiply by 10 to get the value for 10 ml of solution.

Question 3

Which of the following statements is correct?

1. Graduated glassware (for example volumetric pipettes and conical flasks) have been calibrated to a high level of accuracy and they are used in the laboratory to precisely measure the volume of solutions.
2. **Choosing the correct volumetric glassware for an experiment is important. Some glassware is used to precisely measure the volume of solutions as it has**

been calibrated to a high level of accuracy, for example volumetric pipettes and burettes.

Feedback

When calculating precise concentrations, it is important to have precise measurements of the volumes of solution used in the experiment – this can only be achieved by using volumetric glassware.

Question 4

How does EDTA react with Ca^{2+} and Mg^{2+} ions? Complete the paragraph below by selecting one option to fill in the gap.

EDTA is a large molecule that captures metal ions by forming several bonds to a single ion. The formation of the metal–EDTA complex takes place in a controlled 1:1 mole ratio (one mole of metal ions reacts with one mole of EDTA forming _________ of the metal–EDTA complex).

[two moles, **one mol**, one molecule]

Feedback

Figure 3 shows how one metal ion molecule interacts with one molecule of EDTA to form one molecule of the EDTA-metal complex.

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