Cambridge Assessment International Education

Teaching Pack

An acid-base volumetric titration

Cambridge International AS & A Level Chemistry 9701

Version 1.0

Cambridge Pathway

Contents

Icons used in this pack:

Briefing lesson

Planning lesson

Lab lesson

Debriefing lesson

Introduction

This pack will help you to develop your learners' experimental skills as defined by assessment objective 3 (AO3 Experimental skills and investigations) in the course syllabus.

Important note
Our *Teaching Packs* have been written by **classroom teachers** to help you deliver topics and skills that can be challenging. Use these materials to supplement your teaching and engage your learners. You can also use them to help you create lesson plans for other experiments.

This content is designed to give you and your learners the chance to explore practical skills. It is not intended as specific practice for Paper 3 (Advanced Practical Skills) or Paper 5 (Planning, Analysis and Evaluation).

This is one of a range of *Teaching Packs* and each pack is based on one experiment. The packs can be used in any order to suit your teaching sequence.

The structure is as follows:

Briefing lesson (1 hour*)
This lesson reinforces the key concepts, relevant skills, knowledge and understanding linked to the experiment.

↓

Planning lesson (1 hour*)
This lesson focuses on planning an experiment.
It ends with a demonstration video of the experiment.

↓

Lab lesson (1 hour*)
This lesson focuses on carrying out the experiment including the collection and recording of observations, measurements and estimates.

↓

Debriefing lesson (1 hour*)
This lesson focuses on the analysis and interpretation of data.
This includes making conclusions, evaluating methods and the quality of data and how improvements could be made.

** the timings are a guide only; you may need to adapt the lessons to suit your circumstances.*

In this pack you will find lesson plans, worksheets and teacher resource sheets.

Experiment: An acid-base volumetric titration

This *Teaching Pack* focuses on how to carry out an acid-base volumetric titration. The concentration of acids and bases can be measured using a volumetric titration.

Learners will use a volumetric titration to work out the concentration of ethanoic acid in a commercial vinegar product.

The syllabus reference for this experiment is:

- 25.1 Ionic equilibria

The experiment covers the following experimental skills, adapted from **AO3: Experimental skills and investigation**:

- plan experiments and investigations
- collect, record and present observations, measurements and estimates
- analyse and interpret data to reach conclusions
- evaluate methods and quality of data and suggest improvements.

Prior knowledge

Knowledge from the following syllabus topics is required for this experiment. It is useful to have covered them before carrying out this experiment. If these have not been covered yet, you will need to explain the concepts during the experiment or virtual experiment lesson.

- 2 Atoms, molecules and stoichiometry
- 7.1 Chemical Equilibria
- 25.1 Ionic equilibria
- 33.1 Carboxylic acids

Briefing lesson: Risk assessment

Resources	• Worksheets A, B and C
Learning objectives	By the end of the lesson: • ***all*** learners should have completed a risk assessment table for the experiment • ***most*** learners should have completed some research on unfamiliar terms and apparatus to be used in the method • ***some*** learners will have completed the questions on acid-base equilibria.

Timings	Activity
5 min	**Introduction** Group learners into pairs and introduce the two pre-experimental exercises that they will undertake. Give learners Worksheet A, Worksheet B and Worksheet C. Tell learners to read and work their way through the three tasks on Worksheet A.
10 min	**Main lesson** *Task 1: Reading the method* Tell learners that they must read the method (Worksheet C) for the acid-base titration and highlight any unfamiliar words or apparatus in their lab books. They can use textbooks and/or the internet to look up these terms and become familiar with them.
30 min	*Task 2: Risk assessment table* Ask each pair to use the method and the links to safety information to produce an individual risk assessment table for the experiment. Abler learners can create their own table. Less able learners can be given the pre-made table (Worksheet B).
10 min	Ask learner pairs to peer assess each other's risk assessments and provide guidance where required. The suggested risk assessment table can be used.
5 min	**Plenary** *Task 3: Background knowledge questions* Set learners the homework task of completing the background knowledge questions ahead of the practical lesson.

Planning lesson: Planning the experiment

Resources	• Worksheets C, D and E • Ideal report • Clean version of experiment video
Learning objectives	By the end of the lesson: • ***all*** learners should have completed the planning sections of their experimental report • ***most*** learners should have detailed information in the planning sections of their experimental report • ***some*** learners will have compared their experimental set-up to the ideal and made adjustments.

Timings	Activity
	**Introduction** Give a brief explanation of the learning outcomes for the planning lesson. • To read the method and complete the introduction and experimental set-up parts of a report. • To watch a video of a similar experiment and adjust their report accordingly.
	**Main lesson** Group learners into pairs and give them the following information: *'Volumetric titrations can be used to measure the concentration of substances in solutions. You are going to plan an experiment to find out the concentration of ethanoic acid in a commercial vinegar sample.'* Give learners Worksheet C, Worksheet D and Worksheet E to help scaffold the learning. Each group should discuss the variables involved in the experiment and start to write a report in their lab books.
	Then learners should have a discussion about the equipment they would choose and how they would set it up. They should use Worksheet D to help with this. Remind them they will not need to use all of the equipment, reagents and the tests that might be needed. They must remember to accurately draw their equipment set-up which should be annotated so that their decisions are explained.
	**Plenary** Show the learners the video of the experiment. Ask learners to compare their experimental illustrations with the video. Show them the section of the ideal report which details the experimental set-up. Get the learners to adjust their experimental set-up in their lab books.

Lab lesson: Run the experiment

Resources	• Teacher notes • *Teacher Walkthrough* video • Worksheets C, D, E and F • Equipment as outlined in the notes
Learning objectives	By the end of the lesson: • ***all*** learners should have carried out a rough and at least two accurate titrations • ***most*** learners should be able to calculate the concentration of ethanoic acid in the vinegar • ***some*** learners will be able to start the interpretation and evaluation of their experimental data.

Timings	Activity
5 min	**Introduction** Learners should be put into pairs. Hand out Worksheet F to each group (they should already have Worksheet C, Worksheet D and Worksheet E from the briefing and planning lessons). Inform the class of the approximate timings for each part of the experiment: (1) set-up (5 min), (2) carrying out titrations and recording results (30 min) and (4) clean-up (5 min).
5 min	Brief learners on basic lab safety. Start by ensuring that all learners are wearing fastened lab coats and that they wear goggles throughout the experiment. Learners with long hair should tie it up safely. Remind learners about spillages and safe movement around the lab.
5 min	**Main lesson** **(1) Set-up** Learners should use Worksheet C and Worksheet D to allow them to collect the correct materials and equipment.
30 min	**(2) Carrying out titrations and recording results.** Learners should follow the appropriate method on Worksheet C. Make sure that the observations are recorded in their lab books. Learners can use Worksheet F to help with any calculations. **Safety** Circulate the classroom at all times during the experiment and make sure that learners are safe and that the data they are collecting is accurate.
5 min	**(3) Clean-up** Make sure that the learners tidy up after themselves and clean up any bench spills. Finally, they should wash their hands.
10 min	**Plenary** Learners complete the conclusion and evaluation sections in their lab books. Ask learners to discuss and write down in their reports, three ways how they could improve the neutralisation experiment. Tell them they need to think about: • the effectiveness of the method • limitations of equipment • possible sources of errors/uncertainties.

Teacher notes

Watch the *Teacher Walkthrough* video for the acid-base volumetric titration experiment and read these notes.

Each group will require:

- 250 cm^3 medium beaker labelled 'waste beaker'
- 100 cm^3 conical flask
- 25 cm^3 bulb pipette
- 20 cm^3 bulb pipette
- 50 cm^3 burette
- 250 cm^3 standard flask with lid
- burette holder (or clamp stand)
- pipette filler
- commercially bought vinegar [5% v/v]
- sticky labels
- thymolphthalein indicator solution
- wash bottle containing deionised water
- filter funnel
- white tile
- 250 cm^3 of standardised sodium hydroxide solution [0.1 mol dm^{-3}]
- plastic dropper.

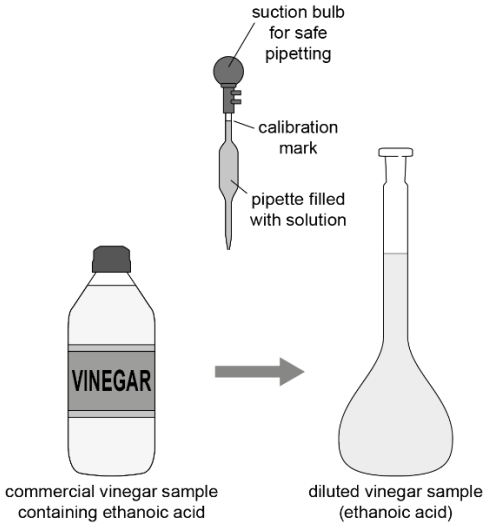
Safety

The information in the table below is a summary of the key points you should consider before undertaking this experiment with your learners.
It is your responsibility to carry out an appropriate risk assessment for this experiment.

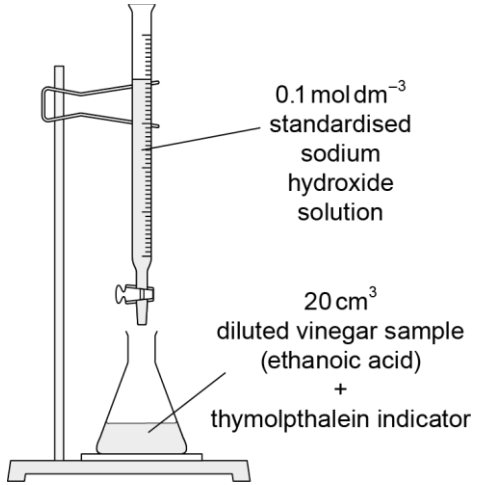
Substance	Hazard	First aid measures
Sodium hydroxide solution [0.1 mol dm^{-3}]	 GHS07 (*moderate hazard* **MH**)	**In the eye:** rinse thoroughly with plenty of water for at least 15 min and consult a doctor. **Swallowed:** wash out the mouth with water. Do not induce vomiting. Never give anything by mouth to an unconscious person. Consult a doctor. **If inhaled:** move person into fresh air. If not breathing, give artificial respiration. Consult a doctor. **Spilt on skin or clothing:** remove contaminated clothing and shoes immediately and rinse. Wash off the skin with plenty of water. Consult a doctor.
Thymolphthalein indicator solution	Low hazard	**In the eye:** rinse thoroughly with plenty of water for at least 15 min and consult a doctor. **Swallowed:** wash out the mouth with water. Do not induce vomiting. Never give anything by mouth to an unconscious person. Consult a doctor. **If inhaled:** move person into fresh air. If not breathing, give artificial respiration. Consult a doctor. **Spilt on skin or clothing:** remove contaminated clothing and shoes immediately and rinse. Wash off skin with plenty of water. Consult a doctor.
Dilute ethanoic acid (If less than 1.7 mol dm^{-3}) 5% v/v is equivalent to 0.833 mol dm^{-3}	 GHS07 (*moderate hazard* **MH**)	**In the eye:** flood the eye with gently running tap water for 10 min. See a doctor. **Swallowed:** Do no more than wash out the mouth with water. Do not induce vomiting. Sips of water may help cool the throat and help keep the airway open. See doctor. **If inhaled:** remove to fresh air. Call a doctor if breathing is difficult. **Spilt on the skin or clothing:** remove contaminated clothing then drench the skin with plenty of water. If a large area is affected or blistering occurs, see a doctor. **Spilt on the floor, bench, etc.:** wipe up small amounts with a damp cloth and rinse it well. For large spills, and especially for (moderately) concentrated acid, cover with mineral absorbent (e.g. cat litter) and scoop into bucket. Neutralise with sodium carbonate. Rinse with plenty of water.

Experiment set-up

Dilution of vinegar sample



Titration reaction with sodium hydroxide solution



Teacher method

This is your version of the method for this experiment that accompanies the teacher video.

Do not share this method with learners. Give them Worksheet C.

Before you begin

Plan how you will group your learners during the experiment.

Think about:

- the number of pairs you will need
- the amount of equipment/chemicals required.

Experiment

Circulate during the experiment in case learners encounter any difficulties.

Steps	Notes
1. Learners should collect all the equipment they need from the front of the class.	*Remind learners they need to be wearing gloves throughout this experiment.*
2. Learners should rinse a 25 cm^3 pipette with deionised water.	
3. Learners should then pipette 25 cm^3 of the vinegar to be tested into a clean 250 cm^3 standard flask and fill it up to the graduation mark with deionised water.	*Remind learners that they should add water using a wash bottle until they are about 1 cm^3 from the mark and then slowly add to the mark using a dropper.*
4. Learners should then stopper the flask and invert three times to mix. Learners should label this as the 'diluted stock solution'.	*Remind learners they need to hold the base and top of the flask when inverting.*
5. Learners should then attach a 50 cm^3 burette to a burette holder, rinse it with the sodium hydroxide solution and fill it to the zero mark with the same solution.	*Remind learners to make sure the funnel is not left in the burette, as it may cause an air bubble to form.* *Also, remind them that the sodium hydroxide solution meniscus should be sitting on the zero mark.*
6. Learners should then rinse out a 20 cm^3 pipette with a little of the diluted vinegar and pipette 20 cm^3 of it into a conical flask.	
7. Learners should add eight drops of thymolphthalein indicator to the diluted vinegar sample in the flask and place it on a white tile, under the burette.	

8. Learners should record the initial volume of the sodium hydroxide solution in the burette and add 1 cm^3 at a time until the end-point is reached.

Remind learners to gently mix the flask each time they add sodium hydroxide from the burette until the end-point is reached–appearance of a blue colour.

9. Learners should then record the final volume in the burette and work out the volume of sodium hydroxide that has been added.

Remind learners that this is the 'rough' titre and should be used as a guide only. It is not to be used in any titration calculations.

10. Learners should then take another 20 cm^3 sample of diluted vinegar from the standard flask, transfer it to a clean conical flask and add indicator.

11. Learners should record the volume of sodium hydroxide in the burette. Then add ¾ of the 'rough' titre sodium hydroxide volume to the flask and mix.

12. Learners should then slow down the whole process by adding sodium hydroxide three drops at a time until the colour change is observed.

Remind learners that this is an 'accurate' titration.

13. Learners should record the volume in the burette and work out the volume that has been added.

Remind learners that the burette may have to be re-filled between titrations.

14. Learners should repeat the procedure for the 'accurate' titration until they obtain two concordant titre volumes.

Remind learners that this means they must have the titre volumes within 0.1 cm^3 of each other and that the 'rough' titre volume cannot be used.

15. Learners should use their recorded values to work out the average volume of sodium hydroxide added and the concentration of ethanoic acid in the vinegar.

Clean-up

After the experiment learners should:

- clean all glassware, tidy up their work space and ensure any spillages are mopped up
- empty their chemical waste into the main chemical waste bottle in a central location
- return all equipment and any unused chemicals to you
- wash their hands with soap and water.

Alternative methods

Indicators
Alternative indicators to use would be phenolphthalein which would change from colourless (vinegar) to a pink-red, or thymol blue which would change from yellow (vinegar) to blue. Both of these indicators are used with weak acid-strong base titrations.

Extension ideas

Different indicators
A good extension activity would be to carry out the same titration using the indicator methyl orange. This will give a completely different end-point as it has a $pK_{in} = 3.7$, pH range of 3.1–4.4, and is normally used for reactions between a weak base and a strong acid. Its colour change is red (vinegar) to yellow. The concentration values obtained using both the thymolphthalein ($pK_{in} = 9.9$, pH range of 9.4–10.6) and methyl orange could be compared and used to illustrate that a weak acid and strong base produces a salt solution that is alkaline in nature. Therefore, an indicator that has an equilibrium position within the alkaline range is required to give accurate results – methyl orange would not be suitable.

Different vinegars
Another extension activity could be a quantitative comparison of three different commercial vinegar products using the same indicator used in the practical pack experiment (or one of the alternatives).

Debriefing lesson: Evaluating the experiment

Resources	• Worksheet G • Ideal report
Learning objectives	By the end of the lesson: • ***all*** learners should be able to write a conclusion based on their findings • ***most*** learners should be able to evaluate the experiment • ***some*** learners will be able to review their finished report in line with success criteria and offer improvements.

Timings	Activity
10 min	**Introduction** Ask learners to complete and review their findings from the experiment. Encourage them to share their findings with other learners.
20 min	**Main lesson** Ask learners to discuss the characteristics of a good scientific report. Get them to write out suggestions and ask them to stick these on the board. Use this as the focal point of a classroom discussion. They are likely to suggest things like: explains processes, uses clear language, writing is concise, uses technical language or presents data clearly.
20 min	Share with learners the ideal report. Leaners should then swap their report with a member of another group they haven't worked with. Using the success criteria in Worksheet G, they should assess the report they have been given. You can guide their progress using the ideal report if required.
10 min	**Plenary** Learners should return the work they have assessed. Each learner should read the feedback given by their partners and act on it by rewriting a section of their work, incorporating the improvements that have been suggested.

Worksheets and answers

	Worksheets	Answers
For use in *Briefing lesson*:		
A: Pre-experiment exercises	**17**	**25**
B: Example risk assessment table	**18**	**26**
C: Method	**19**	**—**
For use in *Planning lesson*:		
C: Method	**19**	**—**
D: Choosing the correct equipment	**20**	**—**
E: Experiment report guidelines	**21**	**—**
For use in *Lab lesson*:		
C: Method	**19**	**—**
D: Choosing the correct equipment	**20**	**—**
E: Experiment report guidelines	**21**	**—**
F: Calculation guidance	**22**	**—**
For use in *Debriefing lesson*:		
G: Assessing a scientific report	**24**	**—**
Ideal report	**—**	**27**

Worksheet A: Pre-experiment exercises

In chemistry there are two types of chemical analysis that can be carried out, qualitative (measures quality) and quantitative (measures quantity).

Volumetric titration is one of the major techniques used in quantitative analysis and utilises volumes and stoichiometric (balanced) equations to measure the level of a chemical in an unknown solution. The simplest type of volumetric titration is between and acid and a base.

Complete the following exercises before you carry out the experiment, writing all your responses in your lab book.

Exercise 1

Read the method that will be used for the experiment and carefully highlight unfamiliar words or equipment. Use your course notes, textbooks or the internet to look up these terms.

Exercise 2

Prepare a risk assessment table for the experiment. It should list the hazards associated with all the chemicals in the experiment (solvents, starting chemicals and any products), as well as safety precautions and first aid measures. You can use textbooks and/or the internet to help with this exercise.

Exercise 3

Homework task

Answer the following background knowledge questions before the lab lesson.

1. What is the Brønsted-Lowry definition of an acid and a base?

2. What is the difference between a strong and weak acid?

3. Methanoic acid is a weak acid and the equation showing its dissociation can be seen below.

$$HCOOH(aq) + H_2O(l) = HCOO^-(aq) + H_3O^+(aq)$$

The extent of dissociation can be measured using the dissociation constant K_a.

a. What is the conjugate base of methanoic acid in the above dissociation?
b. Write an expression for the dissociation constant for methanoic acid.

4. Indicators are used to study the reactions between acids and bases. They only undergo colour changes over a specific pH range and this is dependent on the type of acid and base being reacted.

a. With which combination of acid and base would the use of an indicator not be applicable?
b. Explain your answer.

Worksheet B: Example risk assessment table

Substance	Hazard	First aid measures

Worksheet C: Method

An acid-base volumetric titration

1. Collect all the equipment from the front of the class.

Preparation of dilute vinegar sample

2. Rinse a 25 cm^3 pipette with deionised water.
3. Take a sample of commercial vinegar and pipette 25 cm^3 of it into a clean 250 cm^3 standard flask. Fill to the graduation mark with deionised water.

   Note: Add water until about 1 cm^3 from the graduation mark and then carefully add water drop by drop until the meniscus is on the mark.
4. Stopper the standard flask and invert it several times to ensure the contents are thoroughly mixed.

Preparation for titration

5. Attach a 50 cm^3 burette to a burette holder and rinse it (including the tip) with the sodium hydroxide solution and then fill it with the same solution using a filter funnel

   Note: make sure the funnel is not left in the burette as it may cause an air bubble to form.
6. Rinse a fresh 20 cm^3 pipette with a little of the diluted vinegar and pipette 20 cm^3 of it into a clean conical flask. Add eight drops of thymolphthalein indicator to the diluted vinegar sample in the flask and place the flask on a white tile, under the burette.

Titration of diluted vinegar sample with standardised sodium hydroxide solution

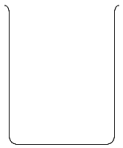
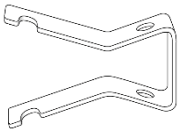
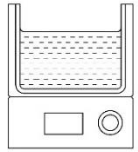
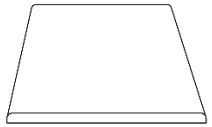
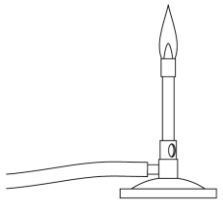
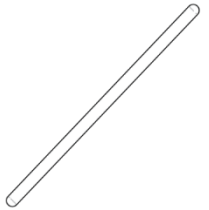
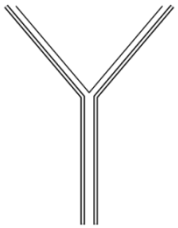
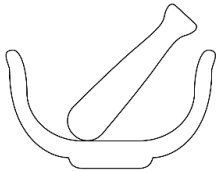
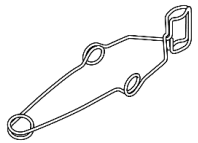
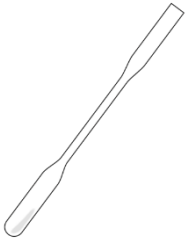
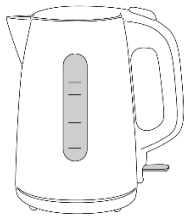
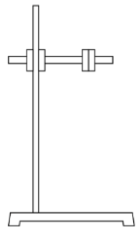
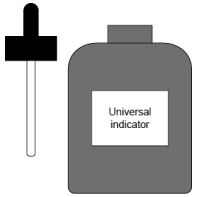
7. Record the initial volume of the sodium hydroxide solution in the burette and add 1 cm^3 of it to the flask contents at a time, with mixing, until the end-point is reached. This is indicated by the appearance of a blue colour.
8. Record the final volume in the burette and work out the volume of sodium hydroxide that has been added. This is the 'rough' titre and should be used as a guide only. It is not to be used in any titration calculations.
9. Take another 20 cm^3 sample of the diluted vinegar sample from the standard flask, transfer to a clean conical flask and add indicator.
10. Note and record the volume of sodium hydroxide in the burette. Add ¾ of the 'rough' titre sodium hydroxide volume to the flask and mix. Then add sodium hydroxide three drops at a time until the colour change is observed. Note the volume in the burette and work out the volume that has been added. This is an 'accurate' titration.
11. Repeat the 'accurate' titration procedure until two results are within 0.1 cm^3 of each other.

Calculating the concentration of the ethanoic acid in the undiluted vinegar

12. Calculate the concentration of the ethanoic acid in the diluted vinegar and hence in the undiluted vinegar.

Worksheet D: Choosing the correct equipment

Here is a range of some common lab equipment. Select what you would use in this experiment.

					
bulb pipette	**beaker**	**burette holder**	**burette**	**water bath**	**pH meter**
					
conical flask	**white tile**	**measuring cylinder**	**standard flask**	**Bunsen burner**	**glass rod**
					
filter funnel	**thymolphthalein**	**distilled water**	**pipette**	**pestle and mortar**	**test-tube holder**
					
thermometer	**spatula**	**kettle**	**clamp and stand**	**universal indicator**	**timer**

Worksheet E: Experiment report guidelines

Use the following guidelines to help you prepare your experiment report in your lab book.

Introduction

- Provide a suitable title for your report.
- To give your report some context, write a brief background information section.
- Detail the aims of the experiment.
- Describe the variables for your experiment (independent, dependent and fixed).

Experimental set-up and materials

- Draw a labelled diagram for your experiment.
- List the materials and equipment used.

Method

- Include your method in the report. The method should be written in the past tense using impersonal/formal language, i.e. no 'I' or 'you', etc.
- Make note of any changes to the method given to you by the teacher.

Results and analysis

- Draw a suitable table for your titration results
- Calculate the concentration in the original vinegar sample based on the results of your titrations (use the calculation help worksheet (Worksheet F) if needed).

Conclusions

- Provide conclusions for your results, remembering to link them back to the aims of the experiment.

Evaluation

- Assess whether the experiment you carried out was fair and whether the conclusions you have made are reliable based upon the data collection.
- Think about:
    - the overall fairness of the experiment
    - the accuracy of and reliability of the results
    - sources of uncertainty
    - any improvements you would like to make.

Ensure you include the answers to these questions in your report.

1. Why was the vinegar sample diluted before carrying out the titration?
2. Explain the correct method that should be used to prepare the diluted sample in the 250 cm^3 standard flask.
3. Explain how the burette and bulb pipette were prepared before use in the titration.
4. What are the main uncertainties associated with carrying out a titration?
5. Why has the indicator thymolphthalein been used in this titration?
6. How do you know the end-point of the reaction has been reached?

Worksheet F: Calculation guidance

A 25 cm^3 sample of vinegar was transferred to a 250 cm^3 volumetric flask and made to the mark using deionised water. This was designated the "diluted vinegar sample".

A 20 cm^3 sample of this diluted vinegar sample was titrated against a standardised solution of 0.1 mol dm^{-3} NaOH to find out the concentration of CH_3COOH present in the vinegar.

Calculate the concentration of CH_3COOH in the original vinegar sample.

The titration results from the experiment are shown below.

Titre	Start volume of NaOH (cm^3)	End volume of NaOH (cm^3)	Volume of NaOH added to reach end-point (cm^3)
Rough	0.00	18.00	18.00
Accurate 1	18.00	35.10	17.10
Accurate 2	0.00	17.20	17.20

There are **two** methods that can be used to work out the concentration of ethanoic acid in commercial vinegars.

Method 1: Using $\frac{c_1v_1}{n_1} = \frac{c_2v_2}{n_2}$

c_1 = concentration of NaOH
v_1 = average volume of NaOH
n_1 = number of moles of NaOH

c_2 = concentration of CH_3COOH
v_2 = volume of CH_3COOH sample
n_2 = Number of moles of CH_3COOH

Step 1: Work out the average titre volume based on two titration volumes that are within 0.1 cm^3.

Step 2: Work out the concentration of CH_3COOH in a 20 cm^3 of the diluted vinegar sample.

The chemical reaction is:

$CH_3COOH + NaOH \rightarrow H_2O + CH_3COONa$

1 mole of ethanoic acid reacts with 1 mole of sodium hydroxide.

The concentration c_2 is found using the equation $\frac{c_1v_1n_2}{n_1v_2} = c_2$

Step 3: Work out the concentration of ethanoic acid in the original, undiluted vinegar sample which was added to the 250 cm^3 volumetric flask (original sample was diluted by a factor of 10).

Worksheet F: Calculation guidance, continued

Method 2: Using *n* = *cv*

Step 1:	Calculate the number of moles of NaOH required to neutralise the 20 cm^3 diluted vinegar sample.
Step 2:	Use the balanced equation to work out the number of moles of CH_3COOH in the 20 cm^3 diluted vinegar sample. $CH_3COOH + NaOH \rightarrow H_2O + CH_3COONa$ 1 mole of ethanoic acid reacts with 1 mole of sodium hydroxide.
Step 3:	Work out the concentration of CH_3COOH in the 20 cm^3 diluted vinegar sample used in the titration.
Step 4:	Work out the concentration of ethanoic acid in the original, undiluted sample which was added to the 250 cm^3 volumetric flask (original sample diluted by a factor of 10).

Worksheet G: Assessing a scientific report

Report section	Success criteria
Title	Does the report contain a simple and informative title?
Background	Is there a brief explanation of a theory or concept linked to the experiment?
Aim(s)	Does this section say what will be investigated?
Variables	Does the report state what variables were changed, what variables were measured and what were fixed?
Materials and Method(s)	• Is there a list of equipment and chemicals used? • Does this section have a sequence of steps or commands that show how a task should be carried out? • Is it written using impersonal language? • Is there a clear, labelled diagram of the experiment? • Is the language clear so that someone could repeat the experiment without mistakes?
Results	This section should be made up of what can be measured or observed, not guessed. For example, if bubbles were observed, then this is all that can be stated in this section (unless the gas produced was tested). • Is this section well-presented and clear? • Have observations been made as accurately as possible? • Is the data in the form of a table and/or graph? • Have correct headings and units been used? • Has an average (mean) been worked out from repeat readings?
Conclusion(s)	• Have the results been described? • Are any conclusions related to the aims? • Are there any comments on whether the results agree with the hypothesis?
Evaluation	The evaluation is an opportunity to discuss both the strengths and weaknesses of an experiment. It should be specific and explain why the experiment did or did not work well and how it could be improved. • Has the fairness of the experimental design been evaluated? • Is there any mention of the accuracy and reliability of the results? • Does the report mention possible sources of error/uncertainty? • Does the report contain **three** possible improvements?
Overall quality of the report	Look at the whole of the report and decide on its quality. • Does the report follow clearly from start to finish? • Is the vocabulary used in the report precise? • Has technical language been used throughout? • Has impersonal language (no 'I' or 'we') been used?

Worksheet A: Suggested answers

Answers to the homework task on Worksheet A.

1. *acid = proton donor base = proton acceptor*

2. *Strong acids fully dissociate/ionise in water. Weak acids only partially dissociate/ionise.*

3.

   a. $HCOO^-$ (methanoate ion)
   b. $Ka = \frac{[HCOO^-][H_3O^+]}{[HCOOH]}$

4. *Weak acid and weak base. This combination does not generate a large enough change in the pH during the reaction.*

Worksheet B: Suggested answers

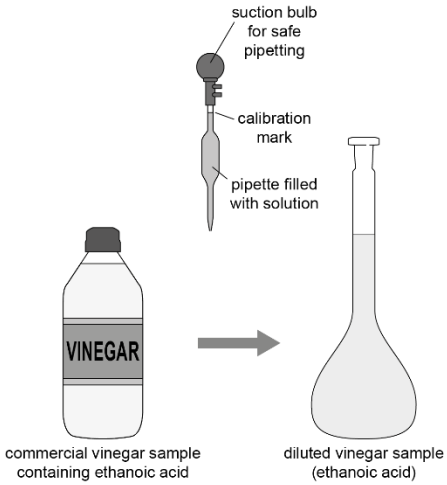
Substance	Hazard	First aid measures
Sodium hydroxide solution [0.1 mol dm^{-3}]	 GHS07 (*moderate hazard* **MH**)	**In the eye:** rinse thoroughly with plenty of water for at least 15 min and consult a doctor. **Swallowed:** wash out the mouth with water. Do not induce vomiting. Never give anything by mouth to an unconscious person. Consult a doctor. **If inhaled:** move person into fresh air. If not breathing, give artificial respiration. Consult a doctor. **Spilt on skin or clothing:** remove contaminated clothing and shoes immediately and rinse. Wash off the skin with plenty of water. Consult a doctor.
Thymolphthalein indicator solution	Low hazard	**In the eye:** rinse thoroughly with plenty of water for at least 15 min and consult a doctor. **Swallowed:** wash out the mouth with water. Do not induce vomiting. Never give anything by mouth to an unconscious person. Consult a doctor. **If inhaled:** move person into fresh air. If not breathing, give artificial respiration. Consult a doctor. **Spilt on skin or clothing:** remove contaminated clothing and shoes immediately and rinse. Wash off skin with plenty of water. Consult a doctor.
Dilute ethanoic acid (If less than 1.7 mol dm^{-3}) 5% v/v is equivalent to 0.833 mol dm^{-3}	 GHS07 (*moderate hazard* **MH**)	**In the eye:** flood the eye with gently-running tap water for 10 min. See a doctor. **Swallowed:** Do no more than wash out the mouth with water. Do not induce vomiting. Sips of water may help cool the throat and help keep the airway open. See doctor. **If inhaled:** remove to fresh air. Call a doctor if breathing is difficult. **Spilt on the skin or clothing:** remove contaminated clothing then drench the skin with plenty of water. If a large area is affected or blistering occurs, see a doctor. **Spilt on the floor, bench, etc.:** wipe up small amounts with a damp cloth and rinse it well. For large spills, and especially for (moderately) concentrated acid, cover with mineral absorbent (e.g. cat litter) and scoop into bucket. Neutralise with sodium carbonate. Rinse with plenty of water.

Ideal report

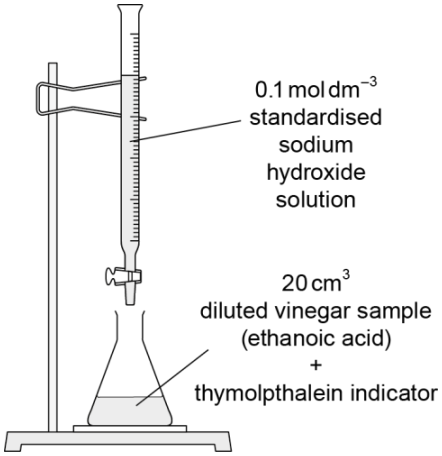
Title	Acid–base volumetric titration
Background information	Most commercial vinegars are dilute solutions of ethanoic acid, a weak acid. Weak acids don't dissociate as well as strong acids. The reaction between weak acids and bases can be studied using volumetric titrations and indicators.
Aim(s)	To calculate the concentration of ethanoic acid (CH_3COOH) in a commercial vinegar using an acid–base titration with sodium hydroxide ($NaOH$).
Experimental variables	**Changed (independent) variable** Commercial vinegar sample. **Measured (dependent) variable** Average volume of sodium hydroxide ($NaOH$) required to produce a permanent colour change (colourless to blue) when titrated against a diluted vinegar sample. **Fixed variables** Volume of diluted vinegar sample added to the conical flask ($20\ cm^3$). Concentration of standardised sodium hydroxide solution ($0.1\ mol\ dm^{-3}$). Apparatus.

Ideal report, continued

Dilution of vinegar sample



Titration reaction with NaOH solution



Materials (list of chemicals and equipment)

- 250 cm^3 medium beaker labelled 'waste beaker'
- 100 cm^3 conical flask
- 25 cm^3 bulb pipette
- 20 cm^3 bulb pipette
- 50 cm^3 burette
- 250 cm^3 standard flask with lid
- burette holder (or clamp stand)
- pipette filler
- commercially bought vinegar [5% v/v]
- sticky labels
- thymolphthalein indicator solution
- wash bottle containing deionised water
- filter funnel
- white tile
- 250 cm^3 of standardised sodium hydroxide solution [0.1 mol dm^{-3}]
- plastic dropper

Ideal report, continued

Results

Titre	Start volume of NaOH / cm^3	End volume of NaOH / cm^3	Volume of NaOH added to reach end-point / cm^3
Rough	0.00	18.00	18.00
Accurate 1	18.00	35.70	17.70
Accurate 2	0.00	17.60	17.60
Accurate 3	n/a	n/a	n/a

Calculation

Average titre volume from similar accurate titres = 17.70 + 17.60/2 =17.65cm^3

Chemical reaction is: $CH_3COOH + NaOH \rightarrow H_2O + CH_3COONa$

$$\frac{c_1v_1}{n_1} = \frac{c_2v_2}{n_2}$$

c_1 = concentration of NaOH

v_1 = average volume of NaOH from titration

n_1 = number of moles of NaOH from balanced equation

c_2 = concentration of CH_3COOH

v_2 = volume of CH_3COOH sample

n_2 = number of moles of CH_3COOH from balanced equation

NaOH	CH_3COOH
$c_1 = 0.1$	$c_2 = ?$
$v_1 = 17.65$ (average)	$v_2 = 20.00$
$n_1 = 1$	$n_2 = 1$

Equation is rearranged to find the concentration of ethanoic acid (c_2) in the diluted vinegar sample.

$$\frac{c_1v_1n_2}{n_1v_2} = c_2$$

$$\frac{0.1 \times 17.65 \times 1}{1 \times 20} = c_2$$

$$\frac{1.765}{20} = c_2$$

$$= 0.0883 \text{ mol dm}^{-3}$$

Ideal report, continued

The concentration of ethanoic acid in the original undiluted vinegar sample is then calculated by multiplying the concentration value by 10 (as the original sample was diluted by a factor of 10.

$$= 0.0883 \times 10 = \underline{\mathbf{0.883\ mol\ dm^{-3}}}$$

Conclusion(s)

The concentration of ethanoic acid in the vinegar was found to be 0.883 mol dm^{-3}.

Evaluation

Overall fairness of experiment	• Only one variable changed, so experimental results are valid.
Accuracy and reliability of results	• **Accuracy**: Results were obtained through correct and careful measurement of volumes. • **Reliability**: Results were reliable as several other groups in the class got similar values.
Sources of error/uncertainties	• Exact end-point for the titration. • Accurate recording of the titre volume. • Inbuilt uncertainties associated with the glassware used in the experiment.
Improvements	• A control titration experiment using a 5% v/v ethanoic acid solution should also be conducted to assess the integrity of the sodium hydroxide used.

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