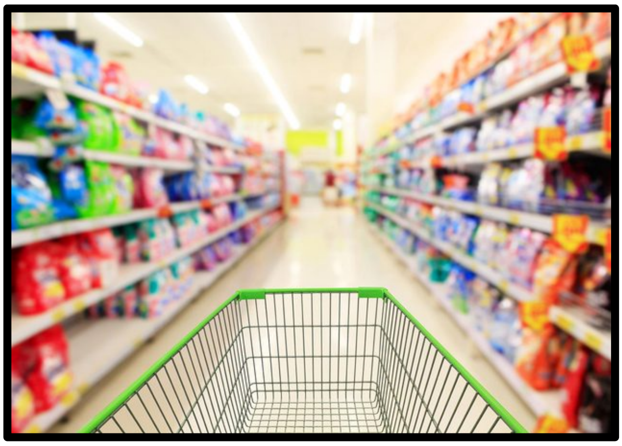
The great chem-mystery

Are we being swindled?

How can we find out exactly what and how much is in the products we buy?



Supermarkets are full of labels and advertising trying desperately to get your attention and pocket money. In this increasingly health-conscious world, how can you know exactly what is in the foods you buy? How can you be sure that sneaky marketers or sly food manufacturers aren't pulling the wool over your eyes? The answer is – chemistry.

Chemistry is the study of matter, its properties, and how and why substances combine and separate. **Chemists** often use a technique called titration. By adding known concentrations of specific chemicals to unknown mixtures, and by using the rules of chemistry, we can work backwards to discover exactly what was in the original unknown mixture.

Did you know?

Two New Zealand schoolgirls rumbled one of the world's biggest food and drug companies after their school science experiment found that their ready-to-drink Ribena contained almost no trace of vitamin C, despite the product claiming plenty of it. The company behind Ribena was forced to pay big fines and change its advertising.

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The Experiment – Acetic Acid Titration!

How much acetic acid is in different vinegar brands?

In this experiment, you will use titration to work out exactly how much acetic acid is in three different brands of vinegar, and thus check if the brands are telling the truth.

Theory	Practice
Letter **symbols** are used to represent atoms. The symbols are either a capital letter only or a capital letter followed by a lower case letter	H is the symbol for hydrogen O is the symbol for oxygen C is the symbol for _____________ Na is the symbol for _____________
All atoms have a mass called the **atomic mass**. The units are called atomic mass units (amu)	The atomic mass for H is 1 amu O is 16 amu C is ______ amu Na is _____ amu
Compounds are a combination of more than one atom	NaOH is sodium hydroxide CH_3COOH is acetic acid (the common name for this chemical is ____________). The subscript number means that there are 3 hydrogen atoms
The mass of a compound is called the **molecular mass**. The molecular mass is the addition of the masses of all atoms in that compound	The molecular mass of: NaOH is 23+16+1= ______ amu CH_3COOH is 12+3+12+16+16+1= _____ amu
Amounts of chemical compounds are measured in quantities called **moles**. One mole of a compound has the same number of particles as one mole of another compound.	1 mole of a compound = 6.02×10^{23} particles (It's a little bit like the word "dozen", 1 dozen eggs = 12 eggs)

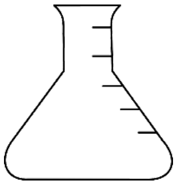
Theory	Practice
One **mole** is simply the atomic mass or molecular mass in grams.	One mole of NaOH is 23+16+1=_______ g CH_3COOH is 12+3+12+16+16+1=_______ g
The strength of a chemical solution is called its **concentration** and is the number of moles in a known volume.	The concentration of NaOH solution that you will use today is: _________________ moles per litre (mol. L^{-1}) (Think of how a cordial drink can be weak or strong depending on how much cordial we add to the glass of water)
Acids combine with bases in a reaction called **neutralisation**.	Chemical equation for the reaction you will use today: $1NaOH + 1CH_3COOH \rightarrow 1CH_3COONa + 1H_2O$
The **equivalence point** of a neutralisation reaction is when the acid and base are present in equal quantities.	How many moles of NaOH will neutralise 1 mole of CH_3COOH ? ______________ This can be written as a mole ratio: NaOH : CH_3COOH 1 : 1
Today you will perform a **titration** that will determine how much acid is present in your sample of vinegar by determining the equivalence point.	This will be when just enough NaOH is added to neutralise the CH_3COOH in your sample. An indicator is added to the vinegar flask that will change colour when this happens. Because we know the concentration of NaOH we can work backwards to find the unknown concentration of CH_3COOH

Procedure

You will be split into small groups and provided with a burette, and conical flask, as well as a brand of vinegar (A or B) and a sodium hydroxide (NaOH) solution. The demonstrators will show you how to use the equipment.

Burette: 

Pipette: 

Conical flask: 

Safety Note: Sodium hydroxide solutions are corrosive to clothing and the skin.
If there are any spillages, inform the demonstrator immediately.

1. Write the brand of vinegar your group is using into Table 1.
2. You will find a burette filled with a sodium hydroxide (NaOH) solution. Record the concentration (strength) of NaOH in Table 1.
3. Read the level of NaOH in the burette and record it in Table 1 in the column marked ‘Initial Burette reading (ml)’.
4. You will also find four conical flasks each containing 5 mL of the prepared vinegar solution and 50 mL of water. The prepared vinegar solution was diluted to 1/10 of the original vinegar from the supplier.
5. Add approximately 3 drops of the phenolphthalein indicator to the vinegar solution.
6. In the first titration, add the sodium hydroxide (NaOH) solution to the vinegar solution in 0.5ml steps. Continue carefully until the first moment a pale pink colour of the indicator doesn’t disappear after swirling. This signals the approximate **end point** of the titration.
7. In the next 3 titrations, add the sodium hydroxide (NaOH) solution to the vinegar solution in 0.5ml steps. Continue carefully until you reach 1 mL from the previous titration (if you measured 10 mL in the first titration then stop after adding 9 mL).
8. Add the sodium hydroxide (NaOH) solution one drop at a time of into the vinegar solution, swirling after each addition. Continue carefully until the first moment a pale pink colour of the indicator doesn’t disappear after swirling. This signals the **end point** of the titration.
9. Read the new level of NaOH in the burette. Record in Table 1 in the column marked ‘Final Burette reading (ml)’.
10. Repeat the previous steps 8-10 two more times, and record your burette values in Table 1.
11. Find the average of your three values, and record in Table 1. Remember to convert to litres (L).

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Table 1: Titration Data

Vinegar Brand:				
NaOH concentration:				
Titration number:	**INITIAL Burette reading (ml)**	**FINAL Burette reading (ml)**	**Titre volume (ml)**	
Approximate:				
1				
2				Average Titre volume (L)*
3				
	Average Titre Volume (mL):			

*Volume (L) = Volume (mL) ÷ 1000

Calculations

The equivalence point is when the NaOH added has neutralised all of the CH_3COOH in the flask (the end point of the titration, where the colour turned slightly pink). The equation shows that this occurs when the acid and the base are present in quantities that have a **1:1 ratio.** For every 1 mole of Sodium Hydroxide (NaOH), there is 1 mole of Acetic Acid (CH_3COOH). So if we know how much NaOH we have added (the burette readings tell us) then we can calculate how much acetic acid was in the flask.

The equation for the reaction involved in this titration is:

$$\mathbf{1NaOH + 1CH_3COOH \rightarrow 1CH_3COONa + 1H_2O}$$

1. At the equivalence point, what volume (L) of NaOH was added to the flask?

2. What is the concentration of the NaOH solution?

The number of moles of NaOH can be calculated because you have the volume and the concentration:

$$\boldsymbol{Number\ of\ moles = Concentration\ (mol/L) \times Volume\ (L)}$$

$$\boldsymbol{i.e.\ Moles = Concentration\ (mol/L) \times \frac{Volume\ (mL)}{1000\ (mL/L)}}$$

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3. What is the number of moles of NaOH added to the flask?

Calculation:	In words:

Number of moles of acetic acid is the same as the number of moles of NaOH calculated above.

4. Therefore, what is the number of moles of acetic acid (CH_3COOH) in the flask?

5. What volume (L) of acetic acid was in the flask at the start of the titration?

The concentration of acetic acid (final value and units) is calculated from the equation

$$\boldsymbol{Concentration\ (mol/L) = Number\ of\ moles\ \div\ Volume\ (L)}$$

6. What is the concentration of the vinegar (acetic acid (CH_3COOH)) solution?

Calculation:	In words:

The concentration of your vinegar solution was diluted to 1/10 of the original vinegar purchased from the company.

7. What is the concentration of the original vinegar (acetic acid (CH_3COOH)) in the bottle?

Calculation:	In words:

8. Was your brand of vinegar telling the truth about its acetic acid concentration?

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Want to make your life a little easier?

Check out these chemistry life hacks: https://www.youtube.com/watch?v=mAqJmEjCy4E

Challenge

A second titration is performed. This time Sulphuric Acid (H_2SO_4), which is battery acid, is titrated with Sodium Hydroxide (NaOH). The reaction equation is:

$$1H_2SO_4 + 2NaOH \rightarrow 1Na_2SO_4 + 2H_2O$$

1. At the equivalence point, what is the ratio between moles of H_2SO_4 and moles of NaOH?

If the H_2SO_4 has a known concentration of 2.5 mol/L, and the titre volume was found to be 0.01 L, then calculate:

2. How many moles of H_2SO_4 were used in the titration?

3. How many moles of NaOH were used in the titration? (Hint: use the ratio from Q1)

The original volume of NaOH used in the titration is known to be 0.025 L:

4. What is the concentration of the NaOH?

Puzzle

Using only the numbers 1, 7, 7, 7 and 7, and the addition, subtraction, multiplication and division operations, how close to the number 100 can you get? (Hint: you may need to use brackets)

To gain **EXP** and level-up your mathematician, email your answers to the **Challenge** and **Puzzle** questions to Dr Greg at Gregory.Boyle@my.jcu.edu.au.

Q: Why are chemists great for solving problems?

A: Because they have all the solutions!

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