The great chem-mystery

There will be a 10-minute laboratory induction by chemistry personnel.

1. Prepare laboratory materials and equipment. Enough for 6 groups?
2. Cover theory by going through the table while looking at the periodic table:
   a) **Symbols** – ask students to find the name of the atoms C and Na
   b) **Atomic mass** – ask students to find the atomic mass of C and Na
   c) **Compounds** – ask students if they know the common name for acetic acid
   d) **Molecular mass** – ask students to calculate the masses of NaOH and acetic acid
   e) **Moles** – use the word dozen as an analogy for mole
   f) **Grams** – the mass of one mole can be expressed in grams
   g) **Concentration** – use the analogy of cordial for concentration; also ask students to copy down the NaOH concentration after showing the label.
   h) **Neutralisation** – explain reactants and products
   i) **Equivalent point** – ask students how many moles of base will neutralise the acid according to the chemical equation. This is the mole ratio.
   j) **Titration** – explain the titration is a procedure for determining an unknown concentration.
3. Show students the equipment they will be using and how to use each one.
4. Split students into groups of 3.
5. Explain that a titration involves a neutralisation between and acid and a base. They may not know what these substances are. Mention that a swimming pool is often tested for pH (this measures how much acid is present. If there is too much then it needs to be neutralised and this is done by adding a base. There are many kinds of acids and bases. Acids include lemon juice, vinegar, sulphuric acid. Bases include caustic soda, dishwashing powder, laundry powder.
6. Modelling activity: Give 5 students yellow post-it notes and 10 students pink post-it notes to wear on their clothes. The 5 yellow students represent the amount of moles of acetic acid in the flask. Add one pink student to the flask, representing 1 mole of NaOH. Pair up a yellow and pink student to show that they have been neutralised and are no longer able to act as an acid. Repeat until all yellow students are paired. This represents the equivalence point where the same quantities of acid and base exactly neutralise each other according to the equation in a 1:1 ratio. If we add more NaOH there is no more acid to neutralise and it is left floating around the flask, and this will change the pH of the solution which the indicator will show. As we add more NaOH we have excess of the base present.

7. Explain that there are special chemicals called indicators that change colour if an acid or a base is present in a solution. We will use an indicator to tell us when the base we are using neutralises the acid we are testing.
8. Explain that acids and bases come in different strengths or concentrations. Just like we can make cordial strong or weak, we can have acids and bases that are strong or weak. We measure the strength using a special unit called moles. Moles is a unit that tells us how many molecules of a substance is present in a solution. So, something that is 10 moles in 1 litre is very concentrated. Something that is 0.01 moles in 1 litre is very weak.
9. Explain that chemists do a titration to work out how much of a substance is present when it is unknown. We will be doing the same with different brands of vinegar just to check if the manufacturers are telling the truth.
10. Show the different vinegar brands. Tell them that they will be testing these to find out how much acid is present. The acid in vinegar is called acetic acid.
11. Show the sodium hydroxide solution. We know the concentration of this solution so we will use it to work out the concentration of the acid. These two chemicals will react with each other in a neutralisation reaction. In other words, the acid and the base will cancel each other out – but only if they are present in the right amounts. If there is not enough base added then the acid will not be completely neutralised and the solution will still be acidic. And if we add too much base then there will be an excess of base in the solution, and it won't be neutral, it will be basic.
12. Demonstrate a titration then hand out prepared flasks of diluted vinegar solution to which students will add 3 drops of phenolphthalein.
13. Students first record the brand of vinegar and the NaOH concentration in Table 1.
14. When the burette is filled, students record the level and record in Table 1 'initial' column.
15. Students add NaOH as demonstrated. When end point is reached (solution stays pink after swirling) read the level of NaOH in the burette and record in Table 1. This will be an approximate value. A more accurate value will be obtained when the students do a dropwise addition near the end point for the following titrations.
16. Repeat this procedure (steps 13-15) two more times.
17. Once the titrations are finished, students clear away equipment and work on calculations.
18. First calculate the titre volume by subtracting the final burette reading from the initial burette reading, record in Table for each trial.
19. Convert the volumes in mL to Litres (divide by 1000).
20. Average the titre volume.
21. Answer Q1 – write in the titre volume of NaOH.
22. Answer Q2 – write in the concentration of NaOH from the label.

23. The ratio of 1:1 means that the amount of NaOH that we added in the burette must be the same as the amount of acid present in the flask. This means we can work backwards to find out how strong the vinegar is.

24. Answer Q3 - Use the concentration formula to calculate how many moles of NaOH were needed to neutralise the acid – use the titre volume:

$$\boldsymbol{Number\ of\ moles = Concentration\ (mol.L^{-1}) \times Volume\ (L)}$$

$$\boldsymbol{i.e.\ Moles = Concentration\ (mol.L^{-1}) \times \frac{Volume\ (mL)}{1000\ (mL.L^{-1})}}$$

25. Explain that the number of moles of NaOH must equal the number of moles of CH_3COOH that was already in the flask because the mole ration from the equation is 1:1

26. Answer Q4 - Use the Moles formula again to find how many moles of CH_3COOH were in the flask at the start.

27. Convert the number of moles of CH_3COOH into concentration using knowing that the volume of vinegar in the flask was 50 mL (0.05 L).

$$\boldsymbol{Concentration\ (mol.L^{-1}) = Number\ of\ moles \div Volume\ (L)}$$

28. The vinegar solution was diluted 1/10 so need to multiply by 10 to obtain the actual molar concentration of the brand vinegar.

29. Provide students with a chart the correlates the molarity with the percentage so that students can compare with the advertised strength of the brand vinegar.

30. Now reveal the actual concentrations of the vinegar brands and compare.

31. Discuss the honesty of the manufacturers, the accuracy of the results, how it could be improved, use of digital pH probes rather than eye.

Challenge Question Answers

$$\boxed{1H_2SO_4 + 2NaOH \rightarrow 1Na_2SO_4 + 2H_2O}$$

1. At the equivalence point, what is the ratio between moles of H_2SO_4 and moles of NaOH? 1:2

If the H_2SO_4 has a known concentration of 2.5 mol. L^{-1}, and the titre volume was found to be 0.01 L:

2. How many moles of H_2SO_4 were used in the titration? 0.025 mol

3. How many moles of NaOH were used in the titration? (Hint: Use the ratio from Q. 1) 0.05 mol

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

4. What is the concentration of the NaOH? 2 mol. L^{-1}