Titration of Vinegar

Problem: To find out if the strength of a product is the same as what a company claims it to be, E.g. ethanoic acid in vinegar, or alcohol in wine.

Select a Problem:

I chose to figure out if the product *Idun* vinegar contains 7% ethanoic acid which is what they claim it to be. There are a number of ways to do so; this includes combining the vinegar with an alkali of known concentration, with an indicator to show when it has been neutralised, from this data you can calculate how many moles of ethanoic acid there are according to how much alkali was required to achieve it, this is called a titration. Another method would be to combine the vinegar with a metal (magnesium) which is known to create a salt and hydrogen when combined. What this means is we can measure the amount of hydrogen, salt, or metal required to finish the reaction, and then find the number of moles of ethanoic acid in *Idun* vinegar. For these calculations to work the concentration (amount of moles) of one of the reactants or products must be known. I decided to use the method called a titration to find out if the commercial vinegar is 7% ethanoic acid, as they claim it to be.

Hypothesis:

Combining an alkali of a known concentration to an acid can be used to determine the amount of moles of ethanoic acid in the commercial vinegar. This is because an alkali can neutralise an acid, what this means is that if we know how much of an alkali there is in a solution and we know how much of it used to completely neutralise the acid we can calculate how many moles of ethanoic acid there are in the commercial vinegar.

Introduction:

What is a titration?

A titration is a method of finding out an unknown concentration of a known reactant. A titration is when you combine an acid and an alkali (often they are strong acids and alkalis). You use it to figure out how many moles you have in an acid or alkali, you need to know how many moles there are in the other for this to be of any use. You add the acid into the alkali using the burette until the pH is 7 this is when the titration normally ends if you are using acids and alkalis of equal strength. The endpoint of the titration is reached when there is an equal concentration of the titrant and the solution of unknown concentration.

How is this titration different?

The difference between a conventional titration and the titration I did is that I dropped the alkali into the acid as opposed to dropping the acid into the alkali. I did this to prevent any unwanted harm to my mouth which would occur had I sucked up the sodium hydroxide with the pipettes instead of the vinegar.

Apparatus:

Burette, pipette, conical flask, beakers, retort stand, wash bottles, volumetric flask

Method:

I started by making diluted vinegar which I did by adding 2 pipettes full (1 pipette is 10ml) of the commercial vinegar into a 250 ml flask. I then filled the rest with water up to the 200 ml mark, this means I used a 1:9 ratio to dilute the vinegar this means the dilute vinegar is 10% of the original concentrated solution which is in perfect proportion to the 0.1 molar solution of sodium hydroxide we used. I diluted the vinegar to conserve the NaOH (sodium hydroxide). To make the 0.1 molar solution of sodium hydroxide I had to find 1 mole of sodium hydroxide (NaOH). To do this I found the atomic mass of NaOH which is 23 for sodium, 16 for oxygen and 1 for hydrogen. 23+16+1=40, the sum of this is 40g which is the mass of a mole of sodium hydroxide. But since I wanted a 0.1 molar solution that means I had to divide 40g by 10, 40/10=4g, this results in 4g in 1 litre of water for a 0.1 molar solution. However I only needed to make 500ml of NaOH meaning it must be divide by 2, 4/2=2, this results in 2g of sodium hydroxide into 500ml of solution. The event following shows us pouring the pre-made 0.1 molar solution of sodium hydroxide. This was created by mixing 2g of NaOH base to 500ml of water. Now that I had all the solutions required I set up the alkali in the burette (to avoid unfortunate accidents, like burning my mouth by sucking up sodium hydroxide instead). I then used the pipette and added 20 ml of the diluted vinegar to a conical flask and 3 drops of phenolphthalein indicator. We recorded how much sodium hydroxide was required for the indicator in the solution to go from colourless to purple. Once everything was setup I started the trials by dropping the alkali slowly into the diluted vinegar. The results can be seen below.

Results:

The result is the required amount of NaOH to turn the colourless solution purple (due to the indicator phenolphthalein). This means that it takes 26.5 ml of NaOH to achieve the required pH. The mean of all the readings is 26.5 ml taking into account that the first reading (27.1 ml) was a rough result.

Trial	1	2	3	4
Result	27.1 ml	26.5 ml	26.5 ml	26.6 ml

Calculation:

26.5 ml of sodium hydroxide will have x number of moles. 1000 ml of sodium hydroxide has 0.1 moles. This means that 1 ml must contain, 0.1/1000=0.0001 moles, which means we must simply multiply by 26.5 to get the number of moles in 26.5ml of sodium hydroxide, 0.0001 x 26.5= 0.00265; the result is 0.00265 moles in 26.5 ml of sodium hydroxide. This must mean that there are 0.00265 moles in the 20 ml of diluted vinegar as well. This is because the OH-(OH- is what makes it an alkali) in the sodium hydroxide combines with the H+ in the ethanoic acid (H+ is what makes it an acid) to create H_2O. What this means is that the amount of OH- is equal to the amount of H+. so knowing that there is 0.00265 moles of ethanoic acid in 20ml of diluted vinegar I can conclude that there must be 50 times as much in 1000ml (1 litre), 0.00265x50=0.1325, the product is 0.1325 moles in 1000ml with a 1/10 dilution this means that to get it back to the concentration of the undiluted vinegar you must multiply 0.1325 by 10, 0.1325x10=1.325, the product being 1.325 moles. This means that there are 1.325 moles in 1 litre of commercial vinegar. Now I need to convert this into a percentage. To do this I need the mass of 1 mole which is the atomic mass of ethanoic acid, the chemical expression for ethanoic acid is CH_3COOH. Knowing this I can find the atomic mass of 1 mole of ethanoic acid using the periodic table. C for carbon is 12, H for hydrogen is 1 but since there are 3 that makes 3, C again for carbon is 12, O is for oxygen which is 16, another O gives an additional 16, and finally another H giving 1. The sum of this is, 12+3+12+16+16+1=60, 60, which means the mass of 1 mole of ethanoic acid is 60g. Knowing this I simply need to multiply 60 by the number of moles I have to get the correct mass of ethanoic acid in one litre of vinegar, 60x1.325=79.5g. All that remains is the final step of calculating a percentage, to divide the weight of the number of moles by the total amount of solution (1000ml) and multiplying it by 100, 79.5/1000[1]=0.0795, 0.0795x100=7.95%. At last the result has been reached which ends up telling me that according to my titration the commercial vinegar contains 7.95% of ethanoic acid.

Discussion:

The hypothesis seems accurate when compared to the results of my experiment. If the company producing the vinegar are to be trusted and the vinegar does contain 7% ethanoic acid, the results I got were very good considering I did not have analar grade sodium hydroxide which is the grade required for high quality analyses. The problems that this could cause is that the base of the NaOH could have been affected by long term storage or an inaccurate measurement could easily have been made without professional equipment like the equipment we used for the dilution of the vinegar. Therefore, logically, the natural conclusion to make is that this experiment cannot be said to be 100% chemically accurate due to the sodium hydroxide not being prepared professionally. In addition to this, this is the first time I have done this kind of an experiment and I am therefore inexperienced and could easily have made a mistake during the experiment which ended up affecting the result.

This experiment is not valid in the sense that I can't go to the producer of the vinegar and say that they are lying to the public by putting 7.95% instead of 7% ethanoic acid into the vinegar. I cannot do this because the sodium hydroxide was not prepared by a professional chemist who makes them extraordinarily accurately.

This method was reliable however, due to the method of titration being an accepted method of finding the concentration of something within a solution. Also it was done using proper equipment (burette pipette, conical flask, retort stand, and volumetric stand) which is exactly how professional chemists would have done it, except for the fact that we dropped the alkali into the acid instead of the reverse, this is however chemically acceptable. To make this experiment even more reliable I could have done more readings in order to show more clearly what the mean of my readings were. Finally to fix a variable that is easily prone to error I could have repeated the dilution the vinegar several times and check to see if there was a difference in my readings. This way my experiment would be much more reliable.

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[1] This is assuming the 7% commercial vinegar weighs the same as water, but the commercial vinegar actually has a weight of 1003.43g/l which was measured using a hydrometer in relation to the weight of ethanoic acid being 1049g/l according to http://www.simetric.co.uk/si_liquids.htm, the difference is much too small to make a large difference to the end result.

My hypothesis is valid due to the fact that my investigation produced a satisfactory result when all the factors have been considered (possibility of mistake, unreliable alkali). Because of the fact that the calculation worked to produce a satisfactory result when compared to the commercial claim of ethanoic acid, it can be said that my hypothesis was valid.

To improve the investigation I conducted I could have taken more readings concerning the amount of sodium hydroxide required to achieve the target pH. I could also, as I discussed earlier, use a more accurate solution of sodium hydroxide to achieve reliable and more accurate results. In addition to this when using the pipette some spit could have entered the solution and as a result change the pH. This means that less sodium hydroxide would be required to achieve the target pH (because spit is alkali it would neutralise some acid). To fix this the only thing plausible is experience and practice with the pipette. Also *Idun* does not say if the ethanoic acid is 7% of the volume or 7% of the mass and seeing as those two are two different things the result could end up being affected if it is 7% of the volume, seeing as we found 7% of the mass.

Conclusion:

In my investigation I was testing to see whether my hypothesis was correct or incorrect. To do this I tested the concentration of ethanoic acid in vinegar using the method known as a titration. The titration did work and the only thing preventing perfect results is inexperience and lack of analytical quality of sodium hydroxide. This means that a titration is a valid form of finding the concentration of a substance within a solution. In addition if this is accepted as true that means that the solution to the original problem of whether Idun Vinegar contains 7% ethanoic acid is that it most likely does due to problems which may have caused inaccuracies in the experiment.

Bibliography:

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