Teacher’s notes

34 Acid, alkali titration using a burette

Read
This is a standard pH titration investigation that uses the EasySense software to record the volumes of acid / alkali added and the change in pH.

Titration is an activity that can prove troublesome for many students; their lack of practical skills becomes apparent as the practical progresses. Using the data logger takes some of the confusion away from the student. Experience has often shown that for a task of this complexity, that students will focus on getting one part right (recording burette volumes for example) and forget to take the pH reading.

The activity uses the "Asks for a Volume" function in SnapShot. The function prompts the student for the volume added after each pH reading has been taken. Hopefully the need to "snap" the data and the visual prompt for additional information will keep the student on task.

With the data recorded electronically analysis of the data will become easier and access to further tools of analysis becomes possible.

The activity can be seen as its own ends to means or it can be the foundation for studies using an automated titration system.

The method can easily be modified for any combination of solutions or measure of reaction e.g. temperature, conductivity.

Apparatus
1. An EASYSENSE logger
2. A Smart Q pH sensor
3. 100 ml conical flask
4. Stirrer - glass rod or magnetic
5. Retort stand and clamp
6. 2.5 ml pipettes or syringe
7. 100 ml beaker
8. 20 cm³ Sodium hydroxide (0.1 mol dm⁻³ NaOH)
9. 20 cm³ Hydrochloric acid (0.1 mol dm⁻³ HCl)

Note: Solutions should all be at the same temperature

Set up of the software and logger
Use the setup file 34 Acid alkali titration using burette.
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The volume the student is asked for is the cumulative volume added. When using a burette which was "zeroed" before the start of the titration this reading will be the volume indicated on the burette after each addition.

**Notes**

The student’s notes suggest they take the pH reading 10 seconds after the addition of the acid. There can be a danger that if the students wait for the instrument to stabilise and take a reading they are then waiting for the 'correct result'.

The solutions can be purchased ready made to the concentrations given; the molarities are well controlled by most chemical suppliers and are probably more accurate than dilutions of strong stock to the same nominal value.

Readings to within 0.5 of a pH unit will be more than acceptable at the introductory level of this investigation. The readings even at 0.5 of pH unit will be more accurate than values derived from universal indicator solutions or papers, indicators may be even more accurate, but to the naïve user the colour change can be missed (or misinterpreted)

If the activity is conducted as a whole class experiment the students may well need a reminder of the fragility of the pH sensor. Suggestions that they should not be used for stirring and they should be left in the storage solution when not in use would be appropriate.

It would be sensible to have some storage solution at hand to replace any spillages of the solution. Use the recipe in the pH sensor manual.

The pH sensor can be calibrated to standard buffers solutions if high accuracy is required, the nature of the calibration may create a loss of accuracy at the extreme ends of the scale but will enhance mid range readings.

Consider also the effect of temperature when deciding to calibrate the pH sensor, heat produced in the reaction can introduce a greater error than the suspected calibration. Please refer to the pH sensor manual for more details.

**Results**

Data as collected, 1 cm³ additions. Note how volume is incremental, in this example no attempt was made to refine the volume added as the end point was reached.
Data display altered, axis changed to give pH vs. Volume, line used for the graph not bar. Notice in the table that reading number has gone and time appeared - it took 8 minutes to do this experiment!

**Analysis of data**

With the data recorded electronically there is no real need to make the pH vs. Volume graph. Using Values will tell the observer both the pH and the volume at that pH. It is at first counter intuitive but when you get used to it it easier to use than re-plotting data.

**Using first and second derivative**

If a first derivative function \( \frac{dx}{dt} \) is applied to the pH data you will get a “spike” when the rate of change in pH is greatest. The point of the derived spike is the "end point" of the reaction and gives a very accurate definition of the end point / point of neutralization.

If a second derivative function \( \frac{dx}{dt} \) is applied to the first derivative data you will get a double spike with one peak above the x-axis and another below the x-axis. The line joining the two spikes intersects the x-axis, this indicates where the rate of change in pH is greatest. The intersect is the end point of the reaction and gives a very accurate definition of the end point / point of neutralization.

The \( \frac{dx}{dt} \) function can be accessed by two routes,

1. **As a Preset function**: From the Tools menu select Post-log Function, Preset function, Titration, First derivative of pH.
2. **As a Formula function**: a \( \frac{dx}{dt} \). This does the same work as the preset function but exposes the students to the math in a more obvious manner. From the Tools menu select Post-log Function, Formula, a \( \frac{dx}{dt} \).

   - Follow the wizard, the student will need to indicate the channel that contained the pH data, the name of the new channel (\( \Delta \text{pH} \)) and give the axis limits
   - A multiplier is also asked for as the value “a”, if pH is falling a will equal "-1" (or bigger number) this will be needed to convert the values to a positive, and to make them large enough to be seen. The exact value of the multiplier will subject to trial and error, it depend upon the strength of the reagents and the reaction. A useful starting value is -10 or +10
Application of 1\textsuperscript{st} derivative to a titration of sodium bicarbonate with hydrochloric acid.

Sample data collected using a Drop counter. You can get very good results with a burette / pipette but you do need to increase the resolution of the addition regime i.e. use the accuracy of the burette to add 0.1 cm\(^3\) of titrant. The clarity of the end point is obvious.

Application of second derivative to a titration of sodium bicarbonate with hydrochloric acid, note the intercept of the x-axis and the double peak – one positive and one negative.