A thermometric titration

Sodium hydroxide solution is titrated with hydrochloric acid. The temperature change is measured each time a portion of acid is added. The highest temperature indicates the end-point of the titration, and this is used to calculate the concentration of the hydrochloric acid.

Lesson organisation

This is best carried out individually or in pairs. The experiment takes about one hour.

Apparatus and chemicals

Each group will need:
- Eye protection: goggles
- Thermometer (0 – 100 °C) (see note 1)
- Two insulated (polystyrene) cups
- Beaker (250 cm³)
- Burette (50 cm³)
- Burette stand
- Clamp and stand (optional)
- Cork, one-holed (optional - to fit thermometer)
- Pipette (20 or 25 cm³)
- Pipette safety filler

Hydrochloric acid, 2.00 mol dm⁻³ (Irritant at this concentration), about 75 cm³ (see note 2)
Sodium hydroxide solution, 1.50 mol dm⁻³ (Corrosive at this concentration), about 30 cm³ (see note 3)

Technical notes

Hydrochloric acid (Irritant at concentration used) Refer to CLEAPSS® Hazcard 47A and Recipe Card 31
Sodium hydroxide solution (Corrosive at concentration used). Refer to CLEAPSS® Hazcard 91 and Recipe Card 65

1 Instead of using the thermometer to stir the titration mixture, it could be clamped in position in a cork, as shown in the diagram, and the mixture swirled after each addition of acid.

Alternatively, a temperature sensor attached to a computer can be used in place of a thermometer. Data logging software could then be used to provide a detailed plot of the readings.

2 The concentration of the hydrochloric acid should not be indicated on bottle.

3 The concentration of the sodium hydroxide should be indicated on bottle.

4 The solutions need to be as concentrated as they are in order to achieve reasonable changes in temperature.
Procedure

HEALTH & SAFETY: Wear goggles

a Stand an insulated cup in a beaker for support.

b Using a pipette and safety filler, transfer 20 cm³ (or 25 cm³) of the sodium hydroxide solution into the cup, and measure the steady temperature.

c Using the burette, add a small portion (3 – 5 cm³) of dilute hydrochloric acid to the solution in the cup, noting down the actual volume reading. Stir by swirling the cup and measure the highest temperature reached.

d Immediately add a second small portion of the dilute hydrochloric acid, stir, and again measure the highest temperature and note down the volume reading.

e Continue in this way until there are enough readings to decide the maximum temperature reached during this experiment. You will need to add at least 30 cm³ of the acid.

f Plot a graph of temperature against the volume of acid added, and use extrapolation of the two sections of the graph to deduce the maximum temperature reached without heat loss.

g Use your results to calculate the concentration of the hydrochloric acid.

Teaching notes

The main concern in this experiment is the heat loss. If possible a lid should be used. More reliable results can be achieved using two polystyrene cups (one inside the other).

With abler or older students, it is possible to discuss the extrapolation of the cooling curve to estimate the maximum temperature reached without heat loss. The link below gives an example of how extrapolation is used to determine the maximum temperature reached.

To reinforce the theory involved here, an indicator could also be used to show that the endpoint really did occur at the highest temperature.

Reference

This experiment has been reproduced from Practical Chemistry: http://www.practicalchemistry.org/experiments/intermediate/acids-alkalis-and-salts/athermometric-titration,279,EX.html

Useful resource

This link gives an example of a typical plot of temperature vs volume of acid for this experiment, and the use of extrapolation to determine the maximum temperature change. http://www.creative-chemistry.org.uk/alevel/module2/documents/N-ch2-08.pdf

(Website accessed December 2009)