H + ions in water

Introduction
Teachers who have not used the problems before should read the section Using the problems before starting.

Prior knowledge
Avogadro's number and ability to use the algebraic definition of pH and K_w. A detailed knowledge is unnecessary as students are encouraged to consult textbooks and data books during the exercise.

Resources
Scientific calculators, along with data books and physical chemistry textbooks should be available for reference. Small (10 cm^3) measuring cylinder).

Group size
2–3.

Possible method
(i) For pure water, pH = 7 at 25 °C, $[H^+(aq)] = 10^{-7}$ mol dm^{-3}
Students will have to estimate the volume of a drop of water eg by counting the number of drops needed to make 1 cm^3 of water in a 10 cm^3 measuring cylinder. A typical figure is 0.05 cm^3.

There is 10^{-7} mole of $H^+(aq)$ in 1000 cm^3 of water, and thus in one drop of water there are 10^{-7} x 6 x 1023 x 0.05/1000 = 3 x 1012 H^+ ions per drop of water.

(ii) For 1.0 mol dm^{-3} hydrochloric acid, $[H^+(aq)]$ is 1.0 mol dm^{-3} (10o mol dm^{-3}).
This is 107 greater than the figure just calculated for water, hence 1.0 mol dm^{-3} hydrochloric acid has about 3 x 1019 H^+ ions per drop.

Conversely, for 1.0 mol dm^{-3} sodium hydroxide, [OH–(aq)] is 1 mol dm^{-3}.
Now $[H^+(aq)][OH–(aq)] = 10^{-14}$, at 25 °C ⇒ $[H^+(aq)] = 10^{-14}$ mol dm^{-3}

This is 107 less than the figure for water, hence 1.0 mol dm^{-3} sodium hydroxide has about 3 x 105 H^+ ions per drop. ie 1.0 mol dm^{-3} hydrochloric acid has about 3 x 1019 H^+ ions per drop; water has about 3 x 1012 H^+ ions per drop; and 1.0 mol dm^{-3} sodium hydroxide has about 3 x 105 H^+ ions per drop.

The latter figure is comparable with the populations of:
_ Birmingham = 9.3 x 10^5;
_ Glasgow = 6.5 x 10^5; and
_ Belfast = 2.8 x 10^5.

Compare the other two figures with:
_ the UN estimate for the 1990 world population = 5.25 x 10^9;
_ the number of cells in a 370 kg man = 10^{14}; and
_ the number of cells in the largest living creature, the blue whale = 10^{17}.
This exercise is a useful opportunity to discuss the number of significant figures that is appropriate at each stage and for the answer.

Suggested approach

During trialling the following instructions were given to students and proved to be extremely effective:
You can divide the work amongst you but keep one another informed of progress.

1. Working as a group, discuss the problem, carry out any necessary practical work, and try to work out answers.
Discussion can play a vital part in working out solutions to problems like this.
Several minds working together on a problem can stimulate ideas that one on its own could not manage. About 10 minutes should be spent on this initially with further discussion as required.

2. Write a brief account of what you did.

3. Working as a group, prepare a short (ca 5-minute maximum) presentation to give to the rest of the class. If possible all group members should take part: any method of presentation (such as a blackboard, overhead projector, etc) can be used.

Outline the problem, describe what you did and try to put the figures that you have obtained into some sort of context. After the presentation, be prepared to accept and answer questions and to discuss what you did with the rest of the class.

H + ions in water

Estimate the number of $H^+(aq)$ ions in a single drop of:

(i) water;
(ii) 1.0 mol dm^{-3} HCl; and
(iii) 1.0 mol dm^{-3} NaOH.

This problem gives little information and at first it may appear impossible to solve. However, by discussing the problem and by probing your memories you should be able to get answers.

You should refer to any sources of information that you think might help such as your notebooks, textbooks and data books. Ask for assistance if you get stuck.

Safety

There are no special requirements. Normal safety procedures when handling chemicals should be adhered to and eye protection worn.
You must get your method checked for safety before starting on the practical work.