A Microscale Hoffman voltameter

Why do this?
The large size Hofmann equipment is very expensive, liable to break. And uses 2M sulfuric acid. The microscale version uses sodium sulfate solution.

This Practical Procedure draws on information from the following guidance.
- Hazcards: HC098B - Sulfamic acid and sulfates(VI)
- GL196 - Make-it guide – microscale Hoffmann voltameter

Suitability
Y11. It is suitable for all age groups if done as a demonstration, as it can be projected onto the screen via a webcam.

Methods for making this equipment can be found in the CLEAPSS Make-it Guides.

Procedure
- Wear eye protection.
- Set up the apparatus as shown above. Make sure the apparatus does not move on the bench. Support the Petri dish on a plastic container or platform and use Blu-Tack® (or similar) to secure the Petri dish in the platform or on the bench.
- Place ~ 0.8 – 1 M sodium sulfate(VI) solution in the Petri dish. (Also add bromothymol blue indicator if you wish.)
- Attach a 10 or 20 cm³ syringe to one of the 3-way taps.
- Adjust the tap and draw up sodium sulfate(VI) solution to fill the syringe and rotate the tap so that the solution remains in the syringe. You may need to add a further small volume of the sodium sulfate(VI) solution to the Petri dish.
• Repeat with the other vertical syringe.
• Place Luer-lock caps on the taps connected to the 5 cm³ syringes.
• Connect the copper wires to the power pack/battery and note which syringe covers (i) the positive electrode (anode) and (ii) the negative electrode (cathode).
• Switch on the power pack/battery and observe the relative volume ratio of the two gases produced.

Extension

• Once electrolysis is completed (i.e. the syringes are each full of gas), attach a 20 cm³ syringe to the ‘anode syringe’ and, by manipulating the 3-way tap correctly, transfer the collected oxygen to the 20 cm³ syringe.
• Repeat the above process at the ‘cathode syringe’, transferring the collected hydrogen into the same 20 cm³ syringe. Place a Luer-lock cap on the syringe.
• Wear eye and ear protection! Light a Bunsen burner about 1 metre away.
  Place a large plastic Petri dish on a tripod, and fill it with bubble mixture.
• Warn the students (all standing at least 3 m away) to place their hands over their ears.
• Light a splint, bubble a small volume of the hydrogen/oxygen gas mixture into the soap solution and then light the bubbles with the splint.

Disposal
All the liquids can be washed down the sink into the foul water drain.

Notes and variations

Hoffman on the make it guides
The final version is shown on the left and instructions to make are in the Technician make it Guides.

The electrolyte

Hoffman voltameters are usually filled with dilute sulfuric(VI) acid but 0.8 to 1M sodium sulfate sodium sulfate(VI) solution used in these demonstrations as it is low hazard.

Chemistry

Water is dissociated into hydrogen and oxygen. The sodium and sulfate(VI) ions are solvated by water and as these units are attracted to the surface of the electrode a redox reaction occurs.

Reaction at the cathode: \(4\text{H}_2\text{O(l)} + 4e^- \rightarrow 2\text{H}_2\text{(g)} + 4\text{OH}^-(\text{aq})\)

Reaction at the anode: \(2\text{H}_2\text{O(l)} \rightarrow \text{O}_2\text{(g)} + 4\text{H}^+(\text{aq}) + 4e^-\)

Sodium ions and sulfate(VI) ions are solvated by water molecules (remain in solution).

Evidence for these reactions is shown by the fact that the gas from the cathode has twice the volume as the gas from the anode. The indicators show the pH values around the electrodes.

But the indicator around the anode is bleached and the gas will quickly oxidise potassium iodide to iodine. The odour also indicates that a tiny volume of ozone is produced.

\[3\text{H}_2\text{O(l)} \rightarrow \text{O}_3\text{(g)} + 6\text{H}^+(\text{aq}) + 6e^-\]