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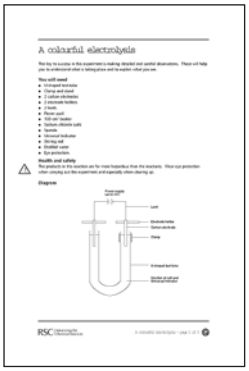
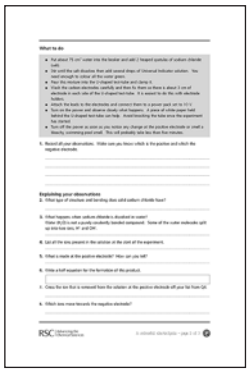
A colourful electrolysis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3 sheets

This experiment is an interesting introduction to the electrolysis of brine. It is probably not best used as the first example of electrolysis that students encounter – without any prior experience they are likely to struggle to explain for themselves what is going on.

The experiment could be followed by work on the electrolysis of salt solution in industry – perhaps using the video and question sheets provided on the RSC's *Alchemy*? CDROM.

Prior knowledge required

- The process of electrolysis and relevant terminology, *eg* electrode
- Structure and bonding in ionic compounds
- Writing balanced half equations
- Acids, alkalis and the colours of Universal Indicator
- How to test for chlorine gas
- For Q15 only: understanding of the term 'atom economy'.

Equipment required

Per pair or group of students:

- U-shaped test-tube
- Clamp and stand
- 2 graphite electrodes
- 2 electrode holders or other suitable means of securing the electrodes (not bungs)
- 2 leads
- Power pack
- 100 cm^3 beaker
- Sodium chloride (salt) – two spatulas per group
- Spatula
- Universal Indicator – approx 0.5 cm^3 per group

- Stirring rod
- Distilled water – if this is a problem then tap water could be used, but it may affect the colours produced, especially in areas with hard water
- Eye protection.

Health and safety

The products of this experiment (hydrogen, chlorine and sodium hydroxide solution) are all more hazardous than the reactants. Ensure the current is turned off as soon as a trace of chlorine is detected. Chlorine can be a problem for very asthmatic pupils. If the directions in the students' notes are followed then very little chlorine is produced.

Sodium hydroxide is corrosive.

Ensure students wear eye protection, especially when they are clearing up after the experiment.

Answers to questions

1. When the power supply is switched on gas bubbles are formed at both electrodes. At the negative electrode the indicator turns purple. At the positive electrode the indicator initially turns red and is then bleached colourless. A cautious sniff of the product at the positive electrode reveals that it has a bleachy smell. The indicator in the U-tube between the electrodes remains green.

2. Sodium chloride has a giant ionic structure.

3. When sodium chloride dissolves, the ions separate and spread or diffuse through the water.

4. H^+, OH^-, Na^+, Cl^-

5. Chlorine is made – it turns the indicator red and then bleaches it. It also smells of bleach.

6. $2\ Cl^-(aq) \rightarrow Cl_2(g) + 2\ e^-$

7. H^+, OH^-, ✗, Na^+

8. H^+, Na^+

9. Hydrogen gas.

10. $2\ H^+(aq) + 2\ e^- \rightarrow H_2\ (g)$

11. ✗, OH^-, Na^+, ✗

12. Na^+, OH^-. These ions form sodium hydroxide.

13. The indicator goes purple because sodium hydroxide is produced and it is an alkali.

14. The products are hydrogen, chlorine and sodium hydroxide.

15. 100% – all the reactants are converted into products and there are no byproducts.

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16. Uses of the products:

Sodium hydroxide – cleaning products, making other chemicals, making fibres such as nylon, making paper.

Chlorine – making bleach, making other chemicals (such as PVC), making solvents, water purification.

Hydrogen – making margarine, making other chemicals.

A colourful electrolysis

The key to success in this experiment is making detailed and careful observations. These will help you to understand what is taking place and to explain what you see.

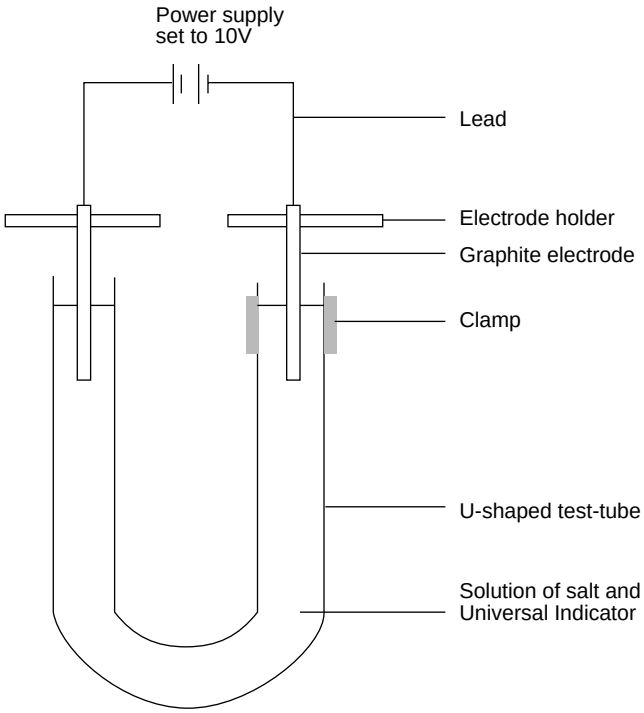
You will need

- U-shaped test-tube
- Clamp and stand
- 2 graphite electrodes
- 2 electrode holders
- 2 leads
- Power pack
- 100 cm^3 beaker
- Sodium chloride (salt)
- Spatula
- Universal Indicator
- Stirring rod
- Distilled water
- Eye protection.

Health and safety

The products in this reaction are far more hazardous than the reactants. Wear eye protection when carrying out the experiment and especially when clearing up.

Diagram



What to do

- Put about 75 cm^3 water into the beaker and add 2 heaped spatulas of sodium chloride (salt).
- Stir until the salt dissolves then add several drops of Universal Indicator solution. You need enough to colour all the water green.
- Pour this mixture into the U-shaped test-tube and clamp it.
- Wash the graphite electrodes carefully and then fix them so there is about 3 cm of electrode in each side of the U-shaped test-tube. It is easiest to do this with electrode holders.
- Attach the leads to the electrodes and connect them to a power pack set to 10 V.
- Turn on the power and observe closely what happens. A piece of white paper held behind the U-shaped test-tube can help. Avoid knocking the tube once the experiment has started.
- Turn off the power as soon as you notice any change at the positive electrode or smell a bleachy, swimming pool smell. This will probably take less than five minutes.

1. Record all your observations. Make sure you know which is the positive and which the negative electrode.

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Explaining your observations

2. What type of structure and bonding does solid sodium chloride have?

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3. What happens when sodium chloride is dissolved in water?

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Water (H_2O) is not a purely covalently bonded compound. Some of the water molecules split up into two ions, H^+ and OH^-.

4. List all the ions present in the solution at the start of the experiment.

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5. What is made at the positive electrode? How can you tell?

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6. Write a half equation for the formation of this product.

7. Cross the ion that is removed from the solution at the positive electrode off your list from Q4. Write out the remainder.

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8. Which ions move towards the negative electrode?

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9. What is made at the negative electrode?

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10. Write a half equation for the formation of this product.

11. Cross the ion that is removed from the solution at the negative electrode off your list from Q4. Write out the remainder.

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12. Which ions are left on your list? What is the name of the substance these ions form?

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13. Why does the indicator go purple near the negative electrode?

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Using the products

14. The electrolysis of sodium chloride solution produces three products. What are they?

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15. What is the atom economy of this reaction? (Assume that you start with NaCl and H_2O).

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16. Find out what each of the products is used for.

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