Chemical circuit breaker

A Professor has invented a 'portable chemical circuit breaker' which when activated breaks an electrical circuit after a time delay of two minutes.

However, she is so absent-minded and forgetful that she can't remember (**i**) where she has put her laboratory notebook; (**ii**) how to make the 'circuit breaker' again and (**iii**) what it would be used for? However, she does remember that it contained a metal and dilute sulphuric acid. Also she can remember thinking to herself that it would enable her to become a millionaire!

- Your task

Help the Professor reconstruct her device (remember it must break the circuit two minutes after being activated) and suggest what it might be used for?

- Your device must be ready for operation at the end of the practical and will be activated when the Professor says so. Once activated the circuit should then be broken without you having to touch your device anymore. Evidence of circuit break is to be clearly visible.

NB A chemical reaction must be involved

- A diagram of your invention, with some explanation, will be needed.

Based on a suggestion by R.F. Kempa.

Time

170 minutes (this time can be split into a 30 minute planning lesson where students have all the apparatus available to look at, and two 70 minute practical sessions).

Group size

2–3

Equipment & materials

Eye protection.

Items from the 'junk' list (see ‘In search of solutions’ additional handout) – to encourage creativity.

General
Filter paper, rubber and glass tubing of various sizes, small pieces of polythene sheeting, plastic syringes, stopclocks. Small electric bulb, electric battery (dry cell) suitable for use with light bulb.

Per group
Copper wire SWG 28 .... 35 cm

zinc foil .... 1.5 g
magnesium ribbon .... 2 g

sulphuric acid (1 mol dm^{-3}) .... 300 cm^3

copper(II)sulphate as "catalyst" (to enable zinc to be used). Depending on the knowledge of students it might be better to treat the zinc with dilute copper sulphate solution first.

Health & Safety notes

This is an open-ended problem solving activity, so the guidance given here is necessarily incomplete. Teachers need to be particularly vigilant, and a higher degree of supervision is needed than in activities which have more closed outcomes. Students must be encouraged to take a responsible attitude towards safety, both their own and that of others. In planning an activity students should always include safety as a factor to be considered. Plans should be checked by the teacher before implementing them.

You must always comply with your employer's procedures and in some cases may decide that a particular activity is inappropriate in your situation. Further information on Health and Safety should be obtained from reputable sources such as CLEAPSS [*http://science.cleapss.org.uk/*] in England, Wales and Northern Ireland and, in Scotland, SSERC [*https://www.sserc.org.uk/*].

Students should be told not to concentrate the acid provided. Teachers need to be vigilant that groups do not generate gas in a sealed container (other than a syringe, plastic bag or similar) because of the risk of a pressure build up/spraying acid around.

Sulfuric acid, 1 mol dm^{-3} H_2SO_4(aq), is an IRRITANT..

Zinc powder, Zn (s) is FLAMMABLE and hazardous to the aquatic environment.
Magnesium ribbon, Mg (s) is FLAMMABLE.
Copper(II) sulphate solution, $CuSO_4$ (aq)causes eye damage, is harmful if ingested and is HAZARDOUS to the aquatic environment.

Hydrogen gas is highly flammable and hydrogen/air mixtures can be explosive. Keep away from sources of ignition.

Eye protection should be worn.

Disposal: Zinc and copper are harmful for the environment. Solutions containing these should be kept for disposal. (It may be easier to precipitate as the carbonate, filter and store the solid).It is the responsibility of the teacher to carry out a suitable risk assessment.

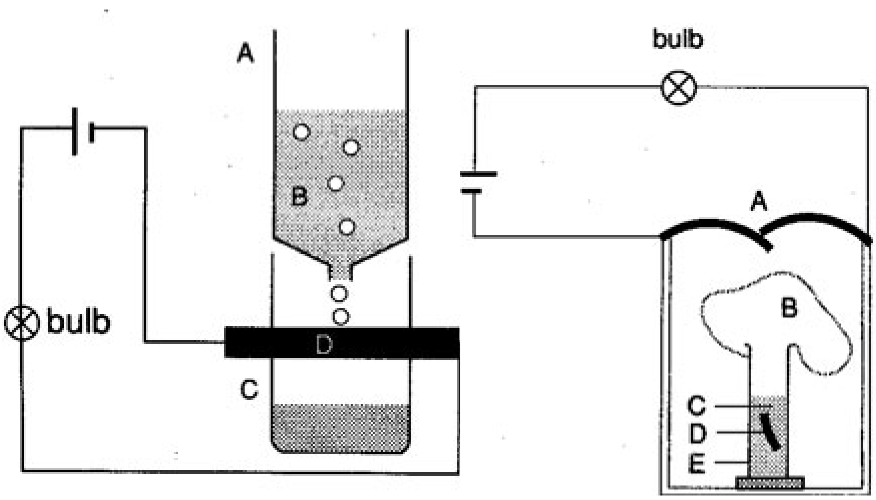
Curriculum links

Reaction of acids with metal to produce hydrogen.

Possible approaches

There is no obvious best method. Approaches already noted:

1 Reservoir of sulphuric acid dripping onto a magnesium fuse calibrated so that the magnesium dissolves after required time. Varying accuracy depending on construction.
2 Magnesium/acid reaction used to generate hydrogen. Hydrogen inflated balloon and movement of balloon breaks circuit contact. Variations on this method were most successful.
3 Magnesium/acid reaction used to generate hydrogen. Hydrogen production moves syringe which operates circuit breaker. Combination of acid concentration and distance moved by plunger used to vary time. Times variable depending on neatness of construction. All those adopting this method were short of time.



Left diagram: A = Top of plastic washing up bottle. B = Acid reservoir. C = Bottom of plastic washing up bottle. D =Magnesium ribbon contacts.

Right diagram: A = Magnesium ribbon contacts. B = Balloon. C = Acid reservoir. D = Magnesium ribbon. E = Glass tube.

Evaluation of solution

These are suggestions only:

1 Target time = 2 minutes. (**NB** Times which are too short approach the natural reaction time of magnesium with acid in a school laboratory, and therefore limit the problem. Times which are too long make the testing of devices a rather tedious procedure, rather than a high spot.)
2 Attainment of target time for circuit to be broken – subtract credit for each second *off* the target time.
3 Portability of fuse **–** credit could be awarded by subjective assessment of device constructed, taking into account fragility of device, ease of construction on site *etc.*
4 Size (smallness) of fuse – credit could be awarded by subjective assessment (as with (**2**) above).
5 The device should allow the "fuse" to be started and the circuit should be broken without any further intervention by the students.

Evidence of circuit break is to be clearly visible.

Extension work

Some students may wish to refine their device in their own time.

Credits

Health & safety checked May 2018

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