Hgen-E

Sodium Borohydride

fuelled

Hydrogen Generator

Contents

1 Instructions

1.1 Getting started

There is no easier hydrogen generator to use with small fuel cells than this one! The procedure is simple:-

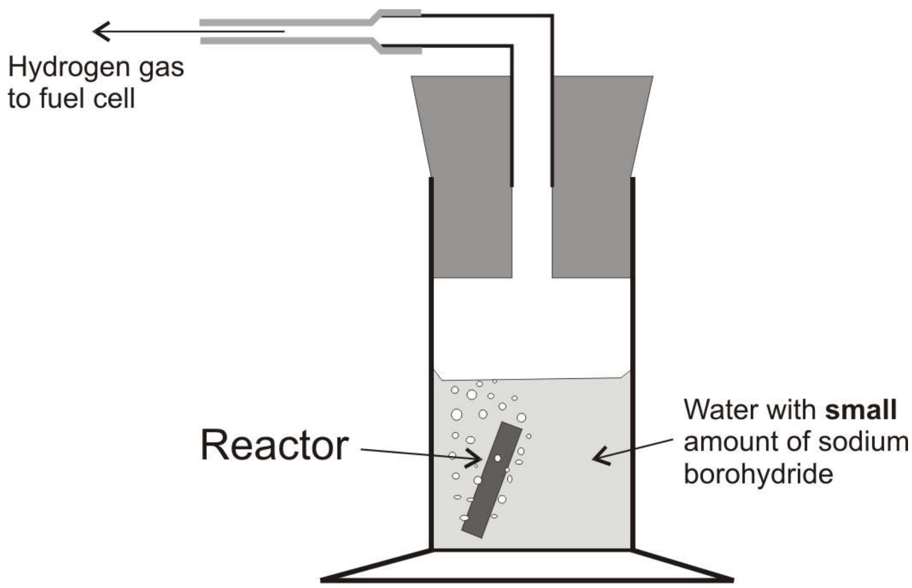
1. Half fill the generator with water – up to the 15 ml mark. Ordinary tap water can by used.

2. Add *about* 0.1g of sodium borohydride to the water. The concentration is not important, but even 0.1 g will last for about an hour. A tenth of a gram is a small pile of about a dozen grains on the end of an electrical screwdriver. A 'pinch' in culinary terms. The sodium borohydride may slowly dissolve, but there will be no significant bubbling.

3. Add the reactor to the water. You will immediately observe a gas bubbling off the reactor. This is due to a catalytic action – the reactor is not actually taking part in the reaction – it is just promoting the reaction between the water and the sodium borohydride.

4. Place the stopper in the top of the generator.

5. Attach the pipe, which is connected to the stopper, to the fuel cell.



6. **WAIT !** It will take a few minutes (typically 3) for the air in the pipes and the fuel cell to be driven out by the hydrogen. You can watch this by connecting a voltmeter to the fuel cell. When the open circuit voltage of the fuel cell has reached about 0.75 – 0.80 volts, it can be used.

1.2 Optional extras

1. The HGen-E unit generates hydrogen at a rate that is suitable for fuel cells of power about 1.5 Watts. If you are using less power than this, much of the hydrogen will be passing straight through the cell. This can be saved by trapping it in a balloon. When the HGen-E unit stops, the balloon will then supply the hydrogen. In this way it can run for a couple of hours.

2. If you need to power a more powerful fuel cell, the rate of hydrogen production can be greatly increased by using hot water in the generator.

3. If you require hydrogen to be produced more slowly, for longer, you can break the reactor in half and place one half only into the generator.

1.3 To Finish

1. Leave the reactor in the solution until bubbling has stopped. This means the solution contains harmless borates, which can safely be disposed of down the drains.

2. The reactor is fragile, handle with great care. Dry it gently with a paper handkerchief, and replace it in the box provided.

3. The reactor represents 90% of the cost of the generator – don't lose it! In reality, it does not matter if it breaks – it works just as well in pieces. *However, it must not be lost down the drain, or accidentally thrown away.*

2 Background and chemistry

2.1 Chemical reactions

The proper systematic name for the compound NaBH4 is sodium tetrahydridoborate. However, it is normally called by the shorter name sodium borohydride. The basic hydrogen producing (hydrolysis) reaction is:-

$$NaBH_4 \ + \ 2H_2O \ \rightarrow \ 4H_2 \ + \ NaBO_2 \qquad \Delta H = -218 \ \text{kJ.mol}^{-1}$$

This reaction does not normally proceed spontaneously, and solutions of $NaBH_4$ in water are quite stable. Some form of catalyst is needed. That is provided by ultra-finely divided catalyst on the surface of the reactor that is placed in the generator.

Note that some of the hydrogen comes from the water – the system produces FOUR hydrogen molecules for each molecule of sodium borohydride. This goes some way to explaining its huge efficiency as a hydrogen carrier.

2.2 Advantages

There are a number of different ways hydrogen can by supplied to fuel cells. The advantages of this particular system are:-

- The reaction is highly controllable – remove the catalyst and it stops.
- The reaction needed to release the hydrogen requires no energy, and can operate at ambient temperature and pressure.
- For small quantities of gas, it is by far the **simplest** way of generating hydrogen.
- For small quantities of hydrogen, it is by far the **cheapest** method, other than those using calcium/water or zinc/acid. However, these also produce acidic or caustic vapors that will certainly damage a PEM fuel cell.
- It is easy to ensure that no high pressures are produced, which could damage a fuel cell. (Note: this is obviously a problem with pressurized hydrogen, but is also very difficult when using metal hydride stores.)
- Hydrogen is the only gas produced, it is not diluted with carbon dioxide
- If the system is warm, water vapor will be mixed with the hydrogen, which is highly desirable for PEM fuel cell systems.
- The rate of reaction is very steady – H_2 is produced slowly and steadily over a period. This is exactly what is required for small demonstration systems

- No acidic or caustic vapors are produced which can damage a PEM fuel cell – this is not the case with calcium/water and zinc/sulphuric acid chemical generators.

In short, this method is ideal for very small systems such as demonstration fuel cells. However, it can also be used with larger systems, and Fractal Carbon is developing its use for larger systems. Here the advantages are not so clear cut, as the cost of the sodium borohydride becomes a factor, as do the problems of disposing of large amounts of sodium borate solution. For a full and clear discussion of the different ways of producing hydrogen, see Chapter 8 of Fuel Cell Systems Explained (2nd edition) by Larminie and Dicks, published by Wiley, ISBN 0 470 84857X.

2.3 Background

Although rather overlooked in recent years, $NaBH_4$ has been known as a viable hydrogen generator since 1943. The compound was discovered by the Nobel laureate Herbert C. Brown, and the story is full of interest and charm, but is well told by Prof. Brown himself, and can be found at http:// www.chem.purdue.edu/hcbrown/Lecture.htm. Suffice to say that shortly before the end of the 1939-1945 war plans were well advanced to bulk manufacture the compound for use in hydrogen generators by the US Army Signals Corps, presumably for hydrogen balloons. The end of the war caused these plans to be shelved. However, in the following years many other uses of sodium borohydride, notably in the paper processing industries, were discovered, and it is produced at the rate of about 5,000 tonnes per year, mostly using Brown's method, by Morton International (merged with Rohm and Haas in 1999).

The essentials of our generator are those of the original generators built by Brown in the 1940s. The main problem is the cost of sodium borohydride. If this is solved, then this method will certainly become very widely used for supplying hydrogen to fuel cells.

3 Safety

3.1 General

The HGen-E hydrogen generator produces hydrogen gas very slowly, typically at about 10 cm^3 per minute. The possibilities of a dangerous quantity of the gas being made are therefore extremely remote. For an explosive mixture, about 18% of the gas present must be hydrogen – it is utterly inconceivable that such a situation could arise even in the smallest of rooms. In any case, hydrogen escapes very easily, and will react spontaneously, over time, with oxygen in the air, producing water. There are thus no safety or environmental concerns with leaving the unit running, even if the hydrogen is not used in a fuel cell.

The issue of **pressure** build up in the Hgen-E unit is important. The hydrogen producing reaction continues, even if the pressure is very high. So, if the exit of the HGen-E unit is blocked, the pressure will build up slowly and steadily. From a safety point of view this will not be a problem, as the rubber bung will 'pop' out of the top of the unit before any explosion can occur. However, it is possible that the pressure could have built up sufficiently high to damage the membrane electrode assembly in a PEM fuel cell. It is therefore not advisable to run PEM fuel cells 'dead ended', i.e. with the exit pipe firmly blocked off. Rather, you should either vent the excess hydrogen air (and waste it) or, better, affix a bag or balloon to the exit pipe, as in bullet (1) of section 1.2 above.

3.2 Sodium borohydride

The use of sodium borohydride, $NaBH_4$, is essential to this equipment. The main safety problems associated with this compound are summarized below.

The systematic chemical name for the compound is **sodium tetrahydridoborate**, the 'tetra' indicating the four hydrogen atoms per molecule. It is often called **sodium borohydride**, a simpler form. The chemical formula is $NaBH_4$. The EINECS number is 2410044. CAS number 16940-66-2. Merck number 12,8735.

Toxic if swallowed. Can be absorbed by skin contact, so wash hands after using the material. Keep away from food and beverages. It causes caustic reaction if swallowed, so give plenty of water. **NOTE. The powder looks similar to sugar and salt, so KEEP OUT OF THE REACH OF CHILDREN**.

Highly flammable. It reacts with water to give off hydrogen, so in case of fire use sand to extinguish. However, we supply the compound in small quantities, usually about 10g, and this amount poses no particular hazards.

3.3 Sodium borate

The waste product from the reaction is sodium borate, $NaBO_2$. This is a naturally occurring compound, close to the mineral borax, which is used to make soap. In the minute quantities generated from this apparatus it can perfectly easily be disposed of down the normal drains – far larger quantities are generated by the use of soap.

.