## 3.5) FUEL CELL DYNAMICS

**Objective:** In this laboratory exercise you will construct a simple fuel cell that demonstrates how the process of "reverse electrolysis" serves to produce electricity. You also will use a wattmeter to record the charging efficiency of a regenerative fuel cell. This serves as a basis for discussing the pros and cons of a hydrogen economy.

**Introduction:** Internal combustion engines only use about 20% of the gasoline energy to create movement. The other 80% is lost as heat through the tail pipe. Fuel cells bypass the heat-intensive combustion process by using a platinum catalyst to convert the chemical energy directly into electricity. This is why fuel cell vehicles get about twice the miles per unit fuel as their internal combustion engine counterparts.

In theory, fuel cells can be designed for any combustible gas or liquid but most fuel cells are designed to run on hydrogen. Proponents of the "hydrogen economy" like to point out that the oxidation of hydrogen only produces water vapor. However, this fuel has two major disadvantages: First, hydrogen is not an energy "source," but an energy *carrier* that relies on energy *sources* such as natural gas or electrolysis for its production. Second, hydrogen's low boiling point of 253 °C below zero makes it very challenging to liquefy on an industrial scale (for the sake of comparison, methane has a boiling point of 161 °C below zero). So given current technological limitations, the energy cost of a hydrogen infrastructure cancels out the efficiency benefits of hydrogen fuel cell vehicles. Breakthroughs are needed in the design of fuel cells that run on fuels that are less problematic.

**Part A: Reverse Electrolysis** *This procedure was modified from one that was developed by the Scitoys Company. It is being used here with their permission. Here is the original procedure as described by Scitoys:* https://scitoys.com/fuel_cell.html

1) Organize all the items you need to assemble your fuel cell (Fig. 1). These include a beaker, glass stirring rod, adhesive tape, battery clip, copper wire, 9-volt battery, and platinum electrodes.
2) Organize all the items you need to measure the charge on your fuel cell (Fig. 2). These include a multimeter, alligator test leads, and digital stopwatch.

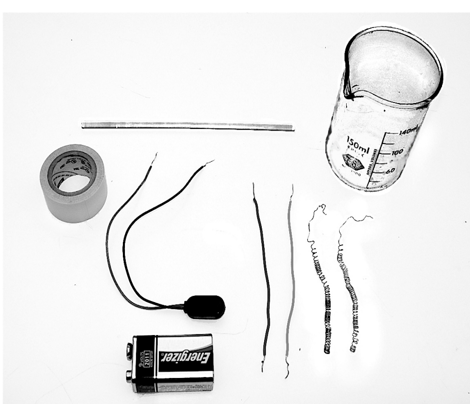

**Fig. 1**

**Fig. 2**

3) Twist together the exposed ends of the battery clip to the exposed ends of two lengths of wire (Fig. 3).

4) Twist the ends of the electrodes to these wires (Fig. 4).

5) Use the glass rod to suspend the wire assembly over the beaker while inserting the electrodes into the beaker. Use tape to hold the assembly in place and fill the beaker near the top with tap water (Fig. 5). Add one teaspoon sodium sulfate to increase the conductivity.

6) Connect the 9-volt battery (Fig. 5). This will result in the appearance of hydrogen bubbles on the negative terminal and oxygen bubbles on the positive terminal. Your fuel cell is being "charged" by way of electrolysis.

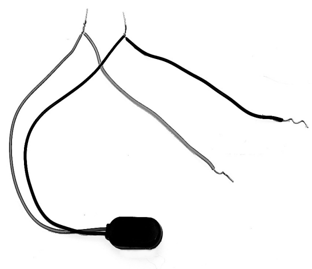

**Fig. 3**

**Fig. 4**

**Fig. 5**

7) After about 10 seconds, connect the multi-meter to the wires to take a voltage reading, then disconnect the battery (Fig. 6). Note that the voltage does not go to zero but stays between 0.5 to 1.5 volts, then slowly decreases.

8) Remove the battery from your digital stopwatch; then connect your alligator leads to the positive and negative terminals of your stopwatch (Fig. 7). *In button-battery instruments the anode is in the middle and the cathode is on the side.*

9) Charge your fuel cell again, then *immediately after* disconnecting your battery, connect your electrodes to the leads from your stopwatch (Fig. 8). *Do not connect the stopwatch while the 9-volt battery is still connected or the high voltage may damage the watch!* Note how long the stopwatch runs before running out of current.

**Fig. 6**

**Fig. 7**

**Fig. 8**

10) Charge the fuel cell again and connect the multimeter as in step 8. Tap the beaker gently after disconnecting the battery in order to release some of the gas bubbles that are sticking to the electrodes. Note the effect this has on the voltage level.

**Optional Procedure:**

1) Add 200 mL of water to a beaker then heat this solution on a hot plate

2) When the water is boiling, add 5 grams of agar and stir until it is completely dissolved, then add one teaspoon of sodium sulfate.

3) Pour this solution into your fuel cell assembly beaker (just as you did before in Step 7) and wait for it to solidify. For best results, leave the assembly overnight in a refrigerator.

4) After gel formation, charge the fuel cell as before. Because the gel is opaque, you may have trouble seeing the gas bubbles. You will know that it is charging when some of the excess bubbles reach the surface of the gel.

5) Evaluate the fuel cell with the multimeter and stopwatch and note how the addition of agar affects the duration and voltage of the current.

**Part B: Fuel Cell Charging Efficiency**

1) Prepare your fuel cell for charging as indicated by the kit instructions. This usually involves filling it with distilled water.
2) Organize all the items you need to charge your fuel cell (Fig. 9). These include the fuel cell kit: AA batteries, battery holder, battery connector, alligator clips, and DC wattmeter connected to an auxiliary cable and 9-volt battery.
3) Assemble these items (Fig. 10) to charge your fuel cell and record the watt-hours that are consumed to fill the tanks with hydrogen and oxygen.

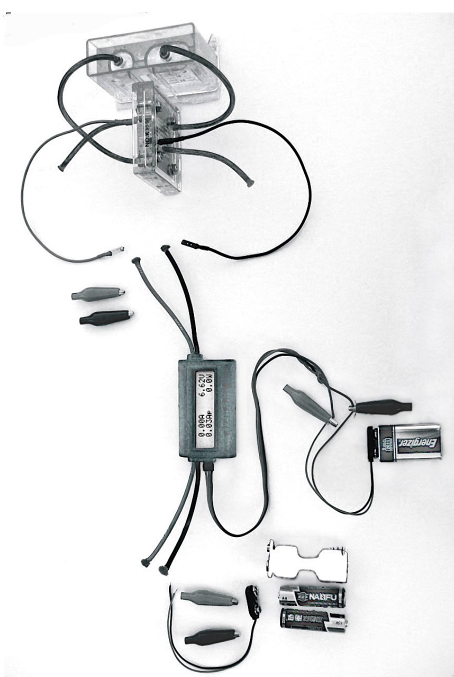

**Fig. 9**

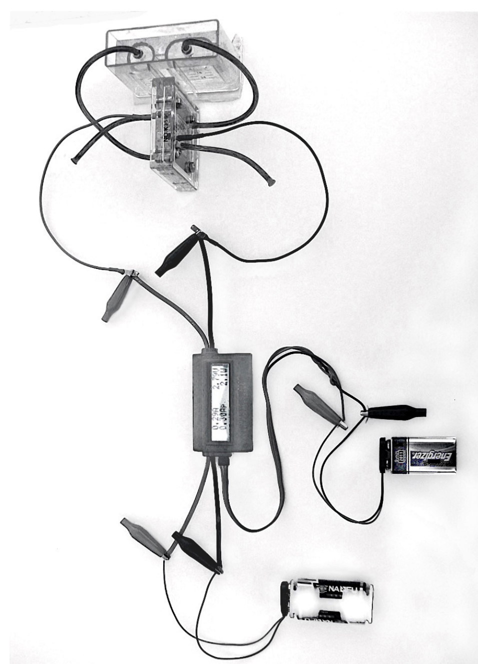

**Fig. 10**

4) After the tanks are full, organize the additional items you need to discharge your fuel cell (Fig. 11). These include your flashlight bulb and holder.
5) Assemble these items (Fig. 12) to discharge your fuel cell and record the watt-hours that were generated by the fuel cell after all the hydrogen and oxygen in the fuel tanks has been consumed.

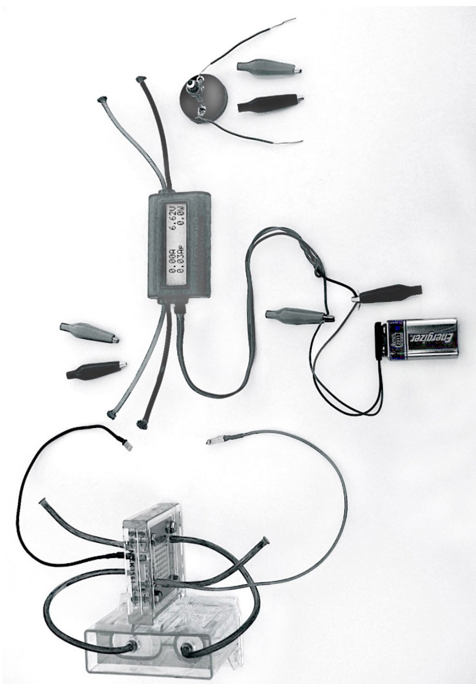

**Fig. 11**

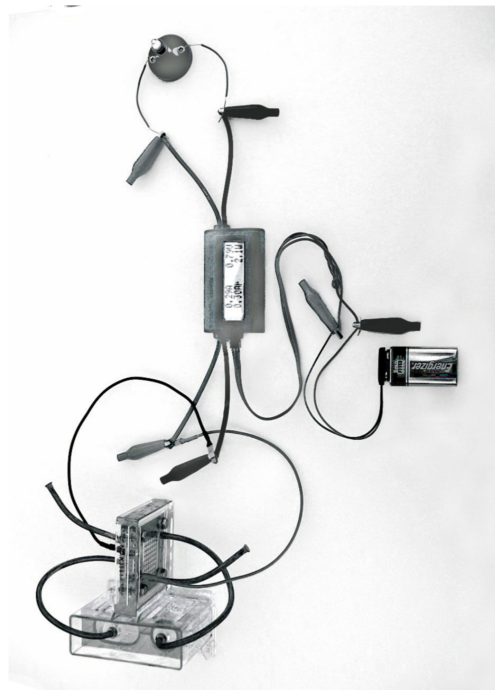

**Fig. 12**

6) Use the following equation to determine charging efficiency:

discharging watt hours ÷ charging watt-hours × 100%

**Questions:**

1. Why is it necessary to use platinum wire in Part A? What role does it serve?

2. How long does your stopwatch to run on the electrode fuel cell?

3. What is the effect of shaking the gas bubbles on the electrode? Why does this happen?

4. The optional procedure involves the use of agar to convert the water into a gel. Why does this increase the duration of the current that runs the stopwatch?

5. What is the efficiency of charging the fuel cell in Part B? How does this compare with the 60-75% average charging efficiency of lead-acid batteries?

6. The fuel cell used in Part B can also be used to power a toy car. What major changes need to be made to the design of the gas tanks (other than size) so that this can be used in a full-size car?