Glycoelectricity

Introduction

In modern days, the emphasis of using renewable energy has been arisen to substitute the finite and polluting fossil fuels in generating electricity. In 2013, renewable energies made up 22% of the total electricity generation worldwide. Among different sources of renewables, most of them are variable renewable energies, which are based on sources that fluctuate during the course of any given days or seasons. This indicates that the supply of variable renewables will increase pressure to energy liability and security. Thus, an alternative method of green, renewable and sustainable energy production is indispensable. As a result, glucose battery, which is of high accessibility and high environmental friendliness, is suggested to be a new form of energy source.

Objective

In this investigation, we have probed into the properties of a glucose oxidation fuel cell using glucose and potassium hydroxide as reductants, and with oxygen and water as oxidants. Nickel foam coated with gold nanoparticles (Au/Ni foam) were employed as the electrodes. The effects of glucose and potassium hydroxide concentration, as well as the presence of catalysts and different temperatures, on electromotive force of the fuel cell has been examined. We are hoping to provide an insight to improvements of the fuel cell with our findings. The fuel cell will not cause pollution and create heavy metal which current batteries do. We believe that it could be one of the solutions to the current environmental problems.

Principles

Glucose and many other carbohydrates, such as fructose and maltose, are categorized as aldoses due to the presence of an aldehyde group. Compounds with an aldehyde group can be oxidized to carboxylic acids, giving out electrons in the process. Therefore, they have the ability to act as a reducing agent, hence the name 'reducing sugars'.

In the studied fuel cell, glucose is oxidized to gluconic acid, the reaction can be described the following half equation:

$$C_6H_{12}O_7 + 2OH^- \rightarrow C_6H_{12}O_7 + H_2O + 2e^-$$

While the reduction reaction is carried out according to the following half equation:

$$H_2O + \frac{1}{2}O_2 + 2e- \rightarrow 2OH^-$$

Thus, the full equation for the redox reaction will be:

$$C_6H_{12}O_6 + \frac{1}{2}O_2 \rightarrow C_6H_{12}O_7$$

The gold catalysts facilitate the oxidation of glucose. Oxygen molecules dissociate and attach to the surface of the nano-gold particles. During the reaction, the oxygen atoms on the gold surface oxidizes the glucose molecules. As the oxygen atoms are lost from the catalyst, it will be re-oxidized by hydroxide ions, giving out 2 electrons in the process. The reaction can be described by the following equation :

$$Au_nO_{m-1} + 2OH^- \leftrightharpoons Au_nO_m + H_2O + 2e^-$$

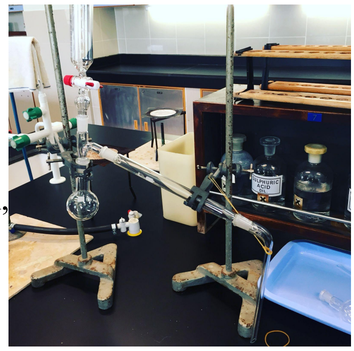
Methodology

General Setup — Fuel Cell

Unlike normal fuel cells, we take the Voltaic cell setup as reference. One of the beakers is filled with a mixture of 6M KOH and 0.5M glucose. In the other beaker, O_2 is bubbled into water. A salt bridge soaked with Potassium Nitrate solution (KNO_3) links the two beakers.. Electrodes of the fuel cell are composed of graphite rods wrapped with Gold/Nickel Foam. The salt bridge was first immersed in KNO_3 solution before adding to the fuel cell.

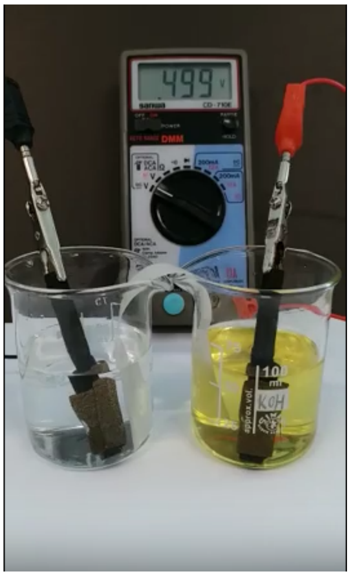
General Setup — Oxygen generator

1) Hydrogen Peroxide is added to Sodium Hypochlorite to generate oxygen, which is then supplied to beaker B via a delivery tube
2) Oxygen was produced during the electrolysis of water in an electrolytic cell



Experiments

- ❖ 6 experiments were conducted, and each corresponds to a change in the independent variable(s) (e.g. Temperature, Concentration etc.)
- ❖ If not specified, Alkaline Medium Concentration = 6M ;
  $C_6H_{12}O_6$ Concentration = 0.5M



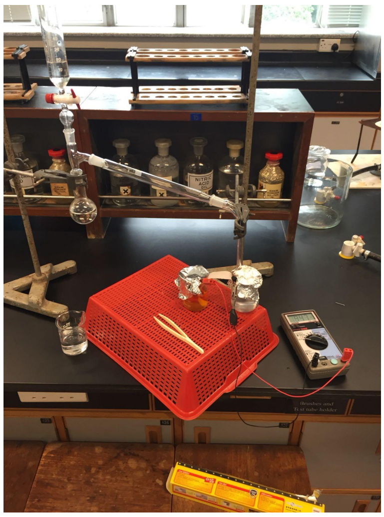
1. Effect of Glucose Concentration on Electromotive Force
   Independent Variables: Glucose Concentration — 0.1 - 1.1
   Dependent Variable: Electromotive Force

2. Effect of Au/Ni foam on Electromotive Force
   Independent Variables: Au/Ni foam; Ni foam
   Dependent Variable: Electromotive Force

3. Effect of Temperature on Electromotive Force
   Independent Variables: Temperature in Beaker A (NaOH/KOH)
   Dependent Variable: Electromotive Force

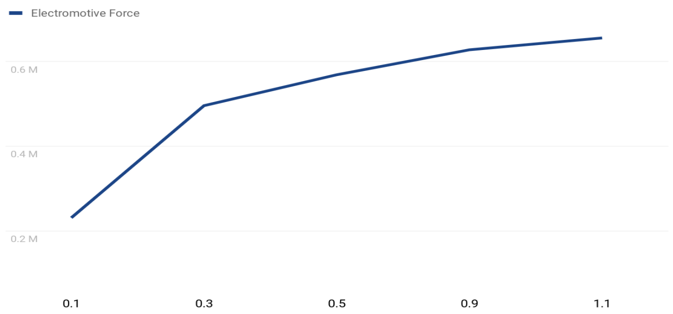
4. Effect of KOH Concentration on Electromotive Force
   Independent Variables: KOH Concentration — 1-6M
   Dependent Variable: Electromotive Force

5. Effect of Maltose Concentration on Electromotive Force
   Independent Variables: Maltose Concentration — 0.1-0.6M
   Dependent Variable: Electromotive Force



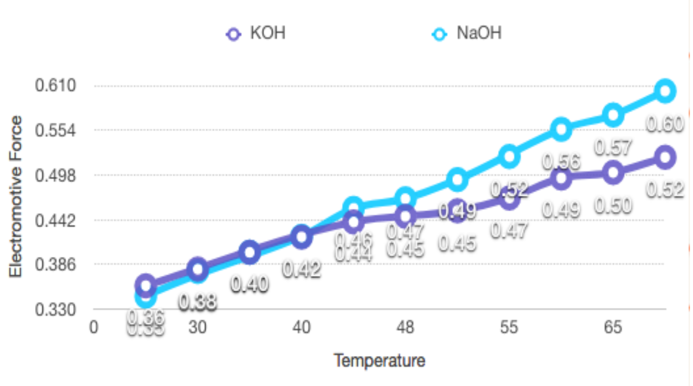
Results

Effect of Glucose Concentration on Electromotive Force



Effect of Au/Ni Foam on Electromotive Force

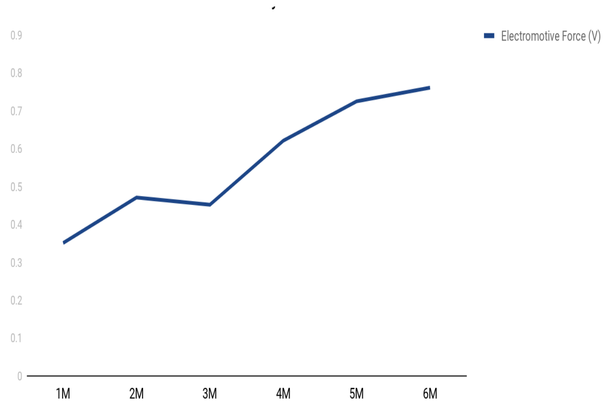
Concentration of KOH (M)	Concentration of glucose (M)	Electrode	Electromotive Force (V)
6	0.5	Au/Ni foam	0.761
		Ni foam	0.121
4	0.333	Au/Ni foam	0.621
		Ni foam	0.05



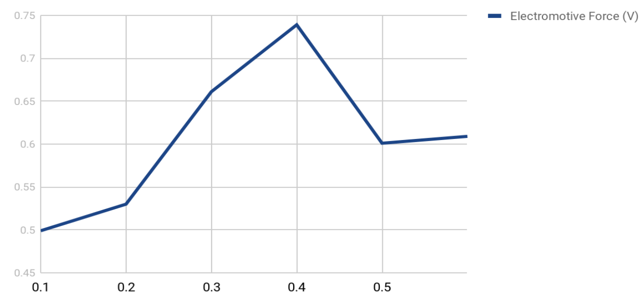
Effect of Temperature on Electromotive Force

Temperature (°C)	Electromotive force of KOH + glucose	Electromotive force of NaOH + glucose
28 (room temp)	0.359	/
30	0.38	/
35	0.401	0.401
40	0.42	0.421
45	0.439	0.456
48	0.446	/
50	0.474	0.492
55	0.469	0.521
60	0.494	0.555
65	0.501	0.573
70	0.500	0.603

Effect of KOH Concentration on Electromotive Force



Effect of Maltose Concentration on Electromotive Force



Summary and Further Development

To sum up, the effectiveness of the fuel cell is highly dependent on the concentration of KOH and reducing sugar, as well as varying temperatures. The nano-gold particles which act as catalysts are also essential to the cell as they can greatly enhance the performance of the fuel cell.

In the future, we propose to use a closed system for the fuel cell. The results show that glucose has high potential in energy generation. With further investigation on the optimal operation conditions, more efficient fuel cells can be made. Even more, we speculate the aldehyde groups in other reducing sugars can also be oxidized. Thus we hope that more variations of fuel can be used.