UNIQUE GLOBAL POSSIBILITIES GROUP

Hydrogen Production

Carbon dioxide as a catalyst in the production of hydrogen

Contents

Introduction

Hydrogen is one of the most energy dense molecules known. Hydrogen is also one of the cleanest energy sources known because hydrogen combustion produces only water as an end product. Hydrogen is prominent in the Federal Government's energy technology road map which promotes funding for clean hydrogen production, batteries, green steel production and carbon capture and storage.

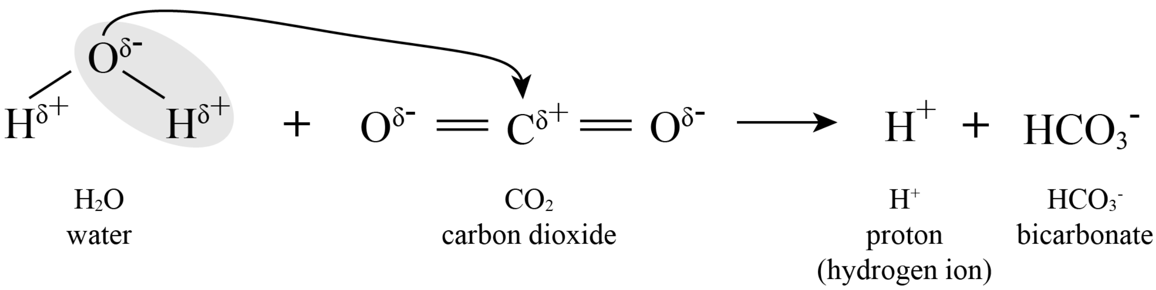
Unique Global Possibilities has developed a process to produce hydrogen from carbon dioxide emissions and water. Carbon dioxide under moderate pressure in water is used as a catalyst to split water into appropriate ions. The hydrogen ions are converted to hydrogen gas with a low voltage electric current.

Chemistry of hydrogen production

The carbon dioxide and water chemical reaction

In chemistry, water is described as a polar molecule with a dipole moment of 1.85 Debyes. Carbon dioxide does not possess a dipole moment but has a polarisability of 2.63 x 10^{-24} cm^3. Carbon dioxide can be seen as a linear resonance. When carbon dioxide is dissolved in water, the slight negative charge on the oxygen atom of the water molecule attracts the slight positive charge on the carbon atom of carbon dioxide. The product of this interaction is a hydrogen ion (proton, H^+) and a bicarbonate ion (HCO_3^-). The equilibrium constant, under standard conditions, for this interaction is given generally as $K_a = 4.3 \times 10^{-7}$ (pH = 6.4) and is described (in both chemistry and medicine) as the equilibrium constant for 'carbonic acid'.

The production of protons and bicarbonate ions by the reaction of carbon dioxide and water can be represented schematically by the following chemical equation:



Carbonic anhydrase enzyme catalyses the reaction of carbon dioxide and water to produce protons

In biological systems, the enzyme carbonic anhydrase is the fastest enzyme known. The enzyme is ubiquitous in nature – from primitive plants to humans. In humans, depending on the isoenzyme and conditions, each molecule of carbonic anhydrase is able to catalyse (hydrate) between 10,000 and 1,000,000 molecules of carbon dioxide per second to produce protons. This enzyme speed becomes important at all levels of cell and organ physiology; from mitochondria in all body cells to specifically the lungs, stomach, kidneys and red blood cells. White blood cells use the reaction to produce concentrations of hydrogen ions (protons) to dissolve bacteria and viruses. The parietal cells of the stomach use the reaction to produce stomach acid.

In biological systems, including humans, carbonic anhydrase enzyme is capable of producing protons to a concentration of pH = 2 to pH = 3 which far exceeds the equilibrium constant for the carbon dioxide and water reaction $K_a = 4.3 \times 10^{-7}$ (pH = 6.4). Therefore, under certain conditions carbon dioxide can be utilised to produce meaningful proton concentrations. Biological systems utilise the carbonic anhydrase enzyme to capture and orientate the carbon dioxide and water reactants so that a chemical reaction occurs to produce protons. Non biological systems can utilise thermodynamic parameters (pressure, concentration, temperature) to achieve the same outcome (that is, correct orientation of reactants so that a chemical reaction occurs to produce protons).

In a human, approximately 0.5 kilograms or 300 litres of carbon dioxide derived from metabolism is processed by carbonic anhydrase enzymes each day. This prevents carbon dioxide from metabolism forming gas bubbles in the blood which lead to heart attacks and strokes.

Protons produced thermodynamically (pressure, concentration, temperature) by the carbon dioxide and water reaction can be converted to hydrogen using an electric current

Low voltage hydrogen production

The table below demonstrates relative hydrogen production (per minute) from water *per se* versus water with carbon dioxide added under pressure

VOLTAGE (at < 0.01 amps)	Water without CO_2 added	Water with CO_2 added [1,2] (at 1 atmosphere)
	Cathode Hydrogen ppm	Cathode Hydrogen ppm
1 volt	0	400
1.3 volts	10	530
5 volts	50	1,450
10 volts	320	2,550
20 volts	1,080	3,970
30 volts	2,980	4,960

1 Oxygen was produced at the anode above 1 volt. In general, a solution of hydroxide ions can produce oxygen gas at an anode at around 0.5 to 1.0 volts. Therefore, the bicarbonate ion produced by the reaction of carbon dioxide and water may be considered as carbon dioxide hydroxide, $CO_2.OH^-$. That is, not strictly bicarbonate. It appears that carbon dioxide may be considered as an hydroxide ion carrier, hence the potential exists to produce oxygen at low voltage for OxyFuel combustion.

2 There appears to be no deposition of material on electrodes over time, unlike electrolysis where reactions at electrodes occur continuously

Hydrogen production under various carbon dioxide pressures

The table below demonstrates hydrogen production (per minute) under increasing carbon dioxide pressure. Hydrogen produced at 5 volts and less than 0.01 amps

CO_2 atmospheres	Water with CO_2 added Cathode Hydrogen ppm
1	1,400
2	2,100
3	3,300
5	4,300
10	6,800
20	8,200

Cost of hydrogen production

Current commercial hydrogen production

Over three quarters of the global production of hydrogen occurs using steam-methane reformation. The cost of hydrogen using this process is approximately USD $2.00 to $4.00 per kilogram. Hydrogen produced in this process contains contaminants, that either were present in the initial methane or arose during the process, and consequently is not ideal for hydrogen powered (fuel cell) vehicles and many other uses. Steam-methane reformation produces carbon dioxide as a by-product. Several other pollutants are produced also.

Small commercial amounts of ‘clean’ hydrogen without contaminants are produced from the electrolysis of water. In this process, water is decomposed into hydrogen and oxygen using an electric current. The cost of ‘clean’ hydrogen using electrolysis is approximately USD $12.00 to $20.00 per kilogram. The cost of hydrogen production from electrolysis is mainly a linear function of the cost of the electricity that is utilised for splitting water and pressurising the hydrogen gas. Either damage to, or dissolution of, electrodes may occur and the replacement of electrodes results in substantial financial costs.

Unique Global Possibilities hydrogen production

Unique Global Possibilities (Australia) Pty Ltd (‘UGP’) has developed a process to produce clean hydrogen from the carbon dioxide emissions of fossil fuel combustion, cement production, steel production, etc. The process developed by UGP uses carbon dioxide (as a catalyst) under moderate to high pressure mixed in water to produce a concentrated solution of hydrogen ions. The hydrogen ions (protons) are attracted to the cathode of an electrolysis type chamber. The hydrogen ions are then converted to hydrogen gas at relatively low voltage. Because hydrogen ions are produced as a result of the carbon dioxide and water chemical reaction, much less electricity is used than standard electrolysis and it is estimated that the cost of hydrogen production using the UGP process may range from less than USD $2.00 to $4.00 per kilogram. The main cost incurred is the cost of pressurising carbon dioxide.

Electricity costs can be decreased further by utilising renewable energy sources. Indeed, hydrogen production can be utilised as a method of storing excess renewable energy. Unlike batteries, the storage of renewable energy as hydrogen is infinite potentially.

The UGP process of clean hydrogen production can utilise carbon dioxide under pressure that is available already with carbon capture and storage (CCS). CCS places carbon dioxide under pressure at about 20 atmospheres. This is an ideal pressure for the production of hydrogen using the UGP process. The cost of hydrogen in this scenario would be negligible and the sale of clean hydrogen would help to offset the cost of CCS.

For the production of on-site hydrogen at service stations / garages, the carbon dioxide would be supplied and enclosed in a pressure vessel and the carbon dioxide would need replacing only as a result of any leakage. The cost of pressurising carbon dioxide would be spread over multiple hydrogen production outcomes.

No direct comparison with commercial electrolysers has been made as the equipment constructed for the UGP process has been developed within a relatively large laboratory budget rather than a larger commercial budget. However, when standard commercial electrolyte solutions (potassium hydroxide, hydrochloric acid) were utilised in laboratory equipment using platinum electrodes, the hydrogen produced was equivalent in amount to that of carbon dioxide under pressure at 20 atmospheres. The carbon dioxide under pressure utilised lower voltage and less current.

Patents

The UGP process is patented in:

- Australia (No. 2013200983)
- USA (No. 9,090,978 B2)
- Japan (No. 6174703)
- Europe (No. 2898114)
- Europe (No. 3243933)
- India (No. 316518)
- Germany (No.s 602013046869.9 and 602013049784.2)
- France (No.s 3243933 and 2898114)
- Great Britain (No.s 3243933 and 2898114)