ELECTROLYTIC PRODUCTION OF HYDROGEN

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of application Ser. No. 09/929,940, filed Aug. 15, 2001, the disclosure of which is herein incorporated by reference.

FIELD OF THE INVENTION

[0002] This invention pertains to electrolytic reactions of organic substances to form hydrogen gas. More specifically, this invention pertains to the generation of hydrogen gas through the electrolysis of organic substances in the presence of water, acids and/or bases. Most specifically, this invention pertains to the production of hydrogen gas at or near room temperature through the electrolysis of alcohols in the presence of a base.

BACKGROUND OF THE INVENTION

[0003] Modern societies are critically dependent on energy to maintain their standards of living and economic viabilities. All aspects of modem life, ranging from the generation of electricity to the powering of automobiles, require the consumption of energy. Conventional fossil fuels are primarily used to meet the energy needs of today's societies. As more societies modernize and existing modem societies expand, the consumption of energy continues to increase at ever growing rates. The increased worldwide use of fossil fuels is creating a number of problems. First, fossil fuels are a finite resource and concern is growing that fossil fuels will become fully depleted in the foreseeable future. Scarcity raises the possibility that escalating costs could destabilize economies as well as the likelihood that nations will go to war over the remaining reserves. Second, fossil fuels are highly polluting. The greater combustion of fossil fuels has prompted recognition of global warming and the dangers it poses to the stability of the earth's ecosystem. In addition to greenhouse gases, the combustion of fossil fuels produces soot and other pollutants that are injurious to humans and animals. In order to prevent the increasingly deleterious effects of fossil fuels, new energy sources are needed.

[0004] The desired attributes of a new fuel or energy source include low cost, plentiful supply, renewability, safety, and environmental compatibility. Hydrogen is currently the best prospect for these desired attributes and offers the potential to greatly reduce our dependence on conventional fossil fuels. Hydrogen is the most ubiquitous element in the universe and, if realized, offers an inexhaustible fuel source to meet the increasing energy demands of the world. Hydrogen is available from a variety of sources including coal, natural gas, hydrocarbons in general, organic materials, inorganic hydrides and water. These sources are geographically well distributed around the world and accessible to most of the world's population without the need to import. In addition to being plentiful and widely available, hydrogen is also a clean fuel source. Combustion of hydrogen produces water as a by-product. Utilization of hydrogen as a fuel source thus avoids the unwanted generation of the carbon and nitrogen based greenhouse gases that are responsible for global warming as well as the unwanted production of soot and other carbon based pollutants in industrial manufacturing. Hydrogen truly is a green energy source.

[0005] The realization of hydrogen as a ubiquitous source of energy ultimately depends on its economic feasibility. Economically viable methods for producing hydrogen as well as efficient means for storing, transferring, and consuming hydrogen, are needed. Chemical and electrochemical methods have been proposed for the production of hydrogen. The most readily available chemical feedstocks for hydrogen are organic compounds, primarily hydrocarbons and oxygenated hydrocarbons. Common methods for obtaining hydrogen from hydrocarbons and oxygenated hydrocarbons are dehydrogenation reactions and oxidation reactions. Dehydrogenation reactions produce hydrogen by transforming saturated hydrocarbons to unsaturated hydrocarbons. Reformation reactions are a common type of oxidation reaction and involve the breaking of bonds between hydrogen and other atoms such as carbon, oxygen or nitrogen. Hydrogen atoms released upon bond breakage combine to form the desired diatomic hydrogen molecules. The broken bonds remaining on the feedstock molecules recombine or reform to produce new molecules. The reformation process is formally an oxidation reaction of the feedstock molecules.

[0006] Production of hydrogen from hydrocarbon and oxygenated hydrocarbon feedstocks is frequently accomplished with a steam reformation process. In steam reformation processes, a hydrocarbon or oxygenated hydrocarbon (e.g. methanol) feedstock is contacted with water in a high temperature reactor to produce hydrogen gas (H_2) along with carbon monoxide (CO) and/or carbon dioxide (CO_2). Representative hydrogen producing steam reformation reactions for a general hydrocarbon (C_nH_m) and a general alcohol (C_pH_qOH), are given below:

$$C_nH_m + xH_2O \leftrightarrows (m/2+x)H_2 + yCO_2 + (n-y)CO$$

$$C_pH_qOH + rH_2O \leftrightarrows (\tfrac{1}{2}(q+1)+r)H_2 + vCO_2 + (p-v)CO$$

[0007] The hydrocarbon C_nH_m can be an alkane, alkene or alkyne and the group C_pH_q on the general alcohol can be an alkyl, alkenyl, or alkynyl group. Similar reactions can be used to describe the production of hydrogen from other oxygenated hydrocarbons such as aldehydes, ketones, and ethers. The relative amounts of CO_2 and CO produced depend on the specific reactant molecule, the amount of water used, and the reaction conditions (e.g. temperature and pressure).

[0008] Although the prior art steam reformation processes effectively generate hydrogen, they suffer from several drawbacks. First, the reactions are endothermic at room temperature and therefore require heating. Temperatures of a few to several hundred degrees are needed to realize acceptable reaction rates. These temperatures are costly to provide, impose special requirements on the materials used to construct the reactors, and limit the range of applications. Second, the required high temperatures imply that steam reformation reactions occur in the gas phase. This means that hydrogen must be recovered from a mixture of gases through some means of separation. The separation means adds cost and complexity to the reformation process and make it difficult to obtain perfectly pure hydrogen. Finally, the production of CO_2 and/or CO is environmentally undesirable since both gases contribute to the greenhouse effect believed to be responsible for global warming.