Process for Separating Atomic Species

By

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Abstract

A method and apparatus for separating atomic species uses static electric and magnetic fields and polarized electromagnetic radiation to first align, then disrupt the chemical bonds comprising a dipolar molecule whose constituents have non-zero magnetic moments. A second electric field urges the constituents to move to opposite sides of a physical barrier where they remain separated and can be used or stored for later use. Use of the method and apparatus to dissociate water molecules is described, although other compounds can also be separated. The polarized electromagnetic radiation can be supplied by a standard lamp, such as a gas-discharge lamp. Alternatively, the radiation can be obtained from the sun, especially in space borne applications.

Background—Decomposition of Water

The use of electrolysis and thermolysis for decomposing, splitting, or dissociating water are well-known. In 1833, Michael Faraday demonstrated the electrolytic separation of water containing a dilute solution of mobile ions into hydrogen and oxygen. When a direct current passes through electrodes in contact with water containing an acid, such as sulfuric acid, a salt, such as sodium chloride, or a base, such as sodium hydroxide, hydrogen is produced at the negative electrode and oxygen is produced at the positive electrode. While this method is successful in the separation of water into its constituent atomic species, it is not energy-efficient. Le., more energy is required to produce the hydrogen and oxygen than can be reclaimed when the two gases are recombined. The bond between hydrogen and oxygen in water can also be split by the addition of thermal energy equal to 286 kilojoules per mole or 18 grams of water. Heating of a volume of water vapor to 2,500 degrees Kelvin causes about 4% of the vapor to be split into hydrogen and oxygen. The addition of chemicals permits equivalent splitting of water at lower temperatures. For example, in U.S. patent 3,821,358 (1974), Interrante et al. show a closed-cycle apparatus for the thermochemical production of hydrogen and oxygen using copper and magnesium compounds and chlorine. Operating temperatures of the various reactions in their system range from 80 to 550 degrees Celsius. This system requires the input of energy in the form of heat, resulting in a loss of efficiency.

Summary

A method and apparatus for the decomposition of water uses externally applied electric, magnetic, and electromagnetic fields to advantageously align and then disrupt the hydrogen-oxygen bond. Once separated, the hydrogen and oxygen are urged in separate directions by an electric field, whereupon they can be captured and stored. Although water is discussed, other compounds that are dipolar and have atomic constituents with nonzero magnetic moments can also be decomposed in the way shown. The apparatus shown requires no addition of heat or chemicals to facilitate the decomposition. Permanent magnets and static electric fields are used to align and separate the atomic species. The principal energy-consuming component in the apparatus is a source of electromagnetic radiation. In space-borne applications, this radiation can be obtained directly from sunlight.

Description—Dissociation of Water Molecules—Figs. 1 through 4

Fig. 1 shows a water molecule, H_2O, comprising two hydrogen atoms H and one oxygen atom O. The water molecule is polar, i.e., the two hydrogen atoms that are joined to the oxygen atom share at least one electron and so are disposed to one side of the oxygen atom. The angle between H-O-H bonds is nominally 104.5 degrees. In the absence of electric and magnetic fields and flow, the orientation of the water molecule is random.

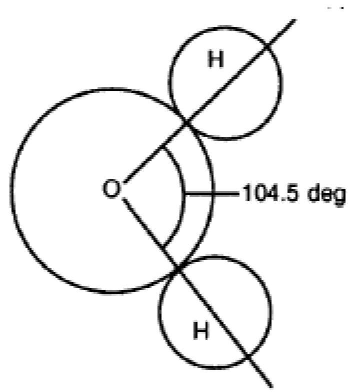

Fig. 1

Fig. 2 shows a water molecule immersed in a static electric field. Since they are polar, individual water molecules have an associated non-zero electric field. When placed in an external electrical field, **E** (bold case indicates a vector quantity), indicated by arrow 200, water molecules will align in such a way as to reduce their potential energy within the field.

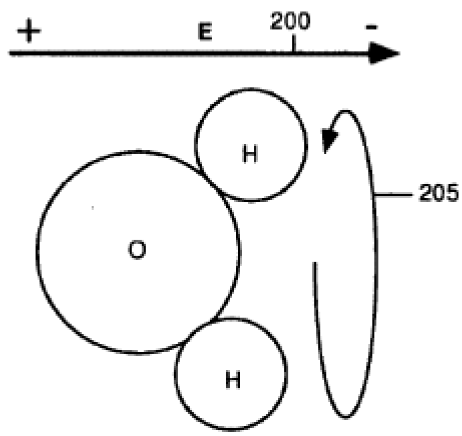

Fig. 2

By convention, the direction of the electric field vector is arranged to point from a higher electrical potential to a lower potential, as indicated by the plus and minus signs. Since the oxygen atom in the water molecule is negatively charged and the hydrogen atoms are positively charged, the water molecule exhibits a net dipole moment. Thus the water molecule preferentially aligns in the electric field with its oxygen atom on the left, or higher potential energy side, and the hydrogen atoms on the right, or lower potential energy side. Because of thermal motion, not all water molecules will be oriented in the same direction. Instead, only a fraction of the molecules will orient as shown. On average, some molecules will be fully aligned, others anti-aligned or facing in the opposite direction to the applied field, and others in-between. With increasing electric field strength, more molecules will align as shown. The strongest electrical field strength possible should be used to ensure maximum alignment. At sea level, air breaks down or arcs at an electric field strength of about 3 million volts per meter. Therefore a practical value for use in this process is somewhat less than this. Although the oxygen and hydrogen atoms generally align left-to-right as shown, the hydrogen atoms on oriented molecules can still move within a plane containing both atoms, as shown by arrow 205, since their potential energy within the electric field is the same, independent of where they are in the plane.

Fig. 3 shows a water molecule immersed in an external magnetic field, **H** (also a vector quantity). Hydrogen and oxygen both have a non-zero magnetic moment, i.e., both atoms have a net magnetic field. When placed in an external magnetic field, **H**, indicated by arrow 300, their magnetic moments will anti-align with the magnetic field. As described above, because of thermal motion, not all water molecules or their constituent atoms will be oriented in the same direction. Only a fraction of the molecules will orient as shown. On average, some molecules will be fully aligned, others anti-aligned, and others in-between. By increasing the strength of the magnetic field, more molecules will align as shown. Commercially available permanent magnets have a maximum magnetic field strength of about 1 Tesla. The hydrogen atoms on oriented molecules can still move within two parallel planes that contain both atoms, as shown by arrows 305, since their potential energy within the magnetic field is the same, independent of where they lie in their own planes. Thus the molecule will rotate about its center of mass, as indicated by the dashed line.

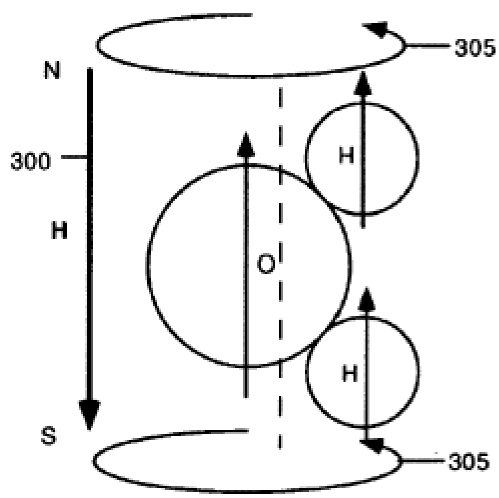

Fig. 3

Bond Energies.

The hydrogen atoms are bound to the oxygen atom with an energy of 10 electron volts (eV) or less. Light with the equivalent energy level has a wavelength of 124 nanometers, i.e., its wavelength is in the ultraviolet region of the electromagnetic spectrum. Properly applied, light having this wavelength, or less, is capable of breaking the bonds that form the water molecule.

Breaking Bonds.

The bond joining an individual hydrogen atom and the oxygen atom is electrical in nature. An electric field, **E**, exists between the two atoms, as shown in Fig. 4. Vectors 400 and 405 represent the electric field vectors between the hydrogen atoms and the oxygen atom. Light comprises orthogonal electric and magnetic fields. The electric and magnetic fields in unpolarized light are randomly oriented. In polarized light, the electric field vector is oriented in a predictable and controllable fashion.

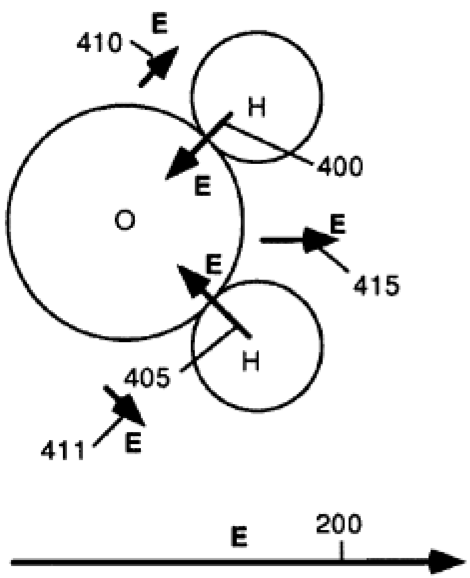

Fig. 4

Orienting polarized light such that its electric field vector 410 points in opposition, or is anti-aligned, to the electric field vector 400, between the upper hydrogen atom and the oxygen atom, will cause this bond to be broken if the light has sufficient energy. When the bond is broken, the hydrogen atom and the oxygen atom are able to move apart. In this case, the energy is 10 eV, the same as the bond strength between the hydrogen and oxygen atoms. Similarly, polarized light **E** vector 411 will break the bond between the lower hydrogen atom and the oxygen atom. Polarized light, with its electric field vector oriented as shown by vector 415, will have sufficient energy to break both bonds, provided its energy is sufficiently large. Its resolved vector component for each hydrogen atom must be equal to or greater than 10 eV. Since the H-O-H bond angle is about 104 degrees, the minimum light energy for optimum splitting of both hydrogen-oxygen bonds must be 10 eV *I* sin 52 degrees = 12.7 eV. The light energy can be obtained from a gas-discharge lamp, from sunlight (in space), or from any other short-wavelength light source of equal or greater energy. Shining unpolarized light on a collection of randomly-oriented water molecules will disrupt only a relatively few molecules on average. Shining polarized light on a collection of oriented water molecules will disrupt more molecules than if the light were not polarized and the molecules were not oriented, resulting in an increase of efficiency.

Application of magnetic and electric fields together can accomplish the desired orientation of the water molecules. The orientation of molecules in liquid water is nearly random, independent of outside influences, because of interaction with other water molecules, thermal motion, and flow. This interaction is minimized when water is in a vapor phase. Therefore, water vapor or steam is used in the present process, as opposed to liquid water, in order to maximize the number of oriented molecules.

Operation—Dissociation of Water Molecules—Figs. 5 through 8

In one aspect, the water molecules are present in a vapor state. This is done to minimize inter-molecular relaxation. In Fig. 5, a water molecule is placed in a region containing strong electric and magnetic fields that are oriented orthogonally. A fraction of the water molecules therefore

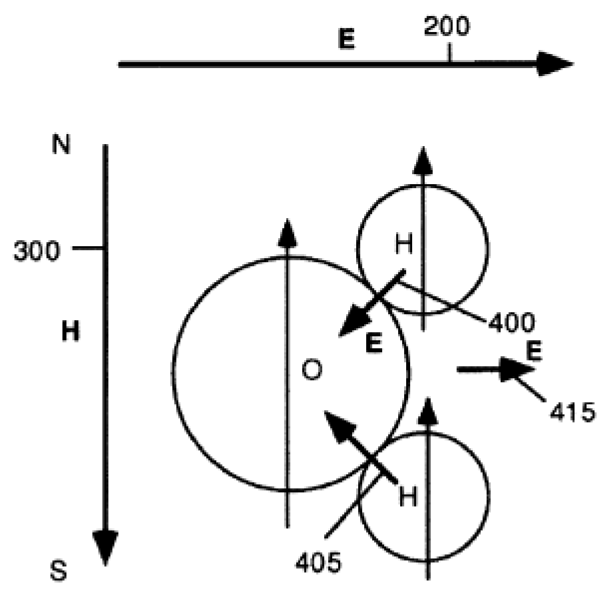

Fig. 5

align as shown. Polarized light, with its electric field vector indicated by vector 415 parallel to electric field vector 200, illuminates the water molecule. In this condition, the water molecule is temporarily restrained so that light of with energy greater than or equal to 12.7 eV can disrupt and break the hydrogen-oxygen bonds. When the bonds are broken, the hydrogen and oxygen atoms are liberated from one-another and free to move independently. Next, the hydrogen and oxygen must be kept separate to facilitate capture and containment of each atomic species.

In Fig. 6, the separated atoms are subjected to another electric field 600. Field 600 is oriented so that oxygen atoms, now double-negatively-charged, move toward the positive electric field terminal.

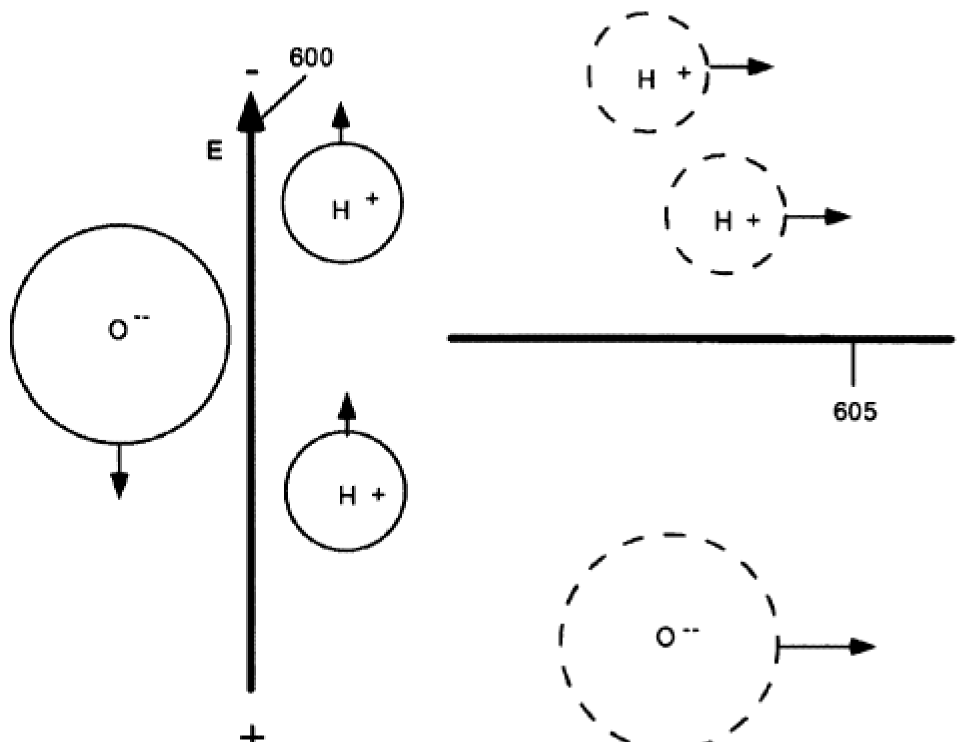

Fig. 6

Hydrogen atoms, now positively charged, moved toward the negative electric field terminal. The separated atoms are urged from left to right by the flow of water vapor as it passes through a reaction volume (Fig. 7). A physical barrier 605 keeps the two atomic species separate once they leave the region of field 600. At this point, the separated hydrogen and oxygen can be captured and contained for future use. The hydrogen and oxygen atoms will combine to form lower energy pairs H_2 and O_2, respectively.

Fig. 7 shows a side view of an apparatus according to one aspect of the present embodiment. Water vapor enters at the left side of the figure as indicated by the Vapor Flow legend and arrow. The vapor may come from a steam generator, a source of waste steam, or water-saturated air, for example, and passes through an approximately cubic reaction volume region 702 between North and South poles 715 and 720, respectively, of a magnet. Poles 715 and 720 are spaced by approximately one cm. Region 702 thus has a magnetic field 300. An electric field 200 is also directed into region 702 by a parallel pair of metal plates 700. Plates 700 are oriented parallel to the plane of the paper and therefore are shown by dotted lines. Only a first plate is shown. The second plate (not shown) lies parallel to plate 700 and is preferably about one cm away from plate 700. This field extends in a direction into the paper as indicated by symbol 200, a circle containing an X. Plates 700 are energized by an external direct-current voltage source (not

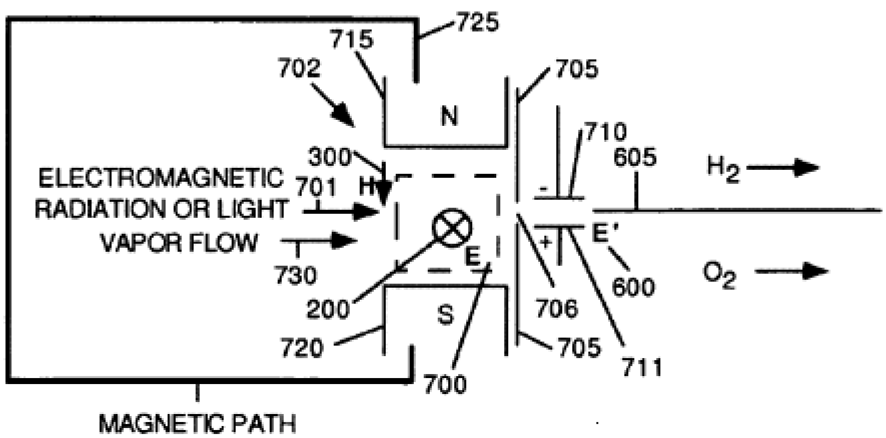

Fig. 7

shown). The generator can be any standard voltage source such as a solar panel, batteries, power supply, and the like. The voltage between plates 700 is preferably just below that which causes electrical breakdown between the plates. Polarized light or other electromagnetic radiation 701 with its electric field axis oriented parallel to field 200 is also provided in region 702 along the vapor flow direction. Thus region 702 has a static electric field, a static magnetic field, and an electromagnetic field (in this case ultraviolet light) polarized with its electric field oriented parallel to the static electric field. A second conductive metal plate forming a shield 705 has an aperture 706 in the center for the vapor and separated atomic species to pass through. Shield 705 is preferably connected to electrical ground potential, along with magnet pole pieces 715 and 720. A pair of parallel, conductive plates 710 is connected to a voltage source that provides field 600 that further separates the positively charged atoms, i.e., hydrogen or other positively charged atom in the case of a molecule other than water, from the negatively charged atoms, i.e., oxygen in this case. Field **E'** 600 is generated by applying a direct-current voltage to plates 710 and 711. Plates 710 and 711 lie on either side of aperture 706 and are spaced by approximately one cm, although other spacings can be used. Plates 710 and 711 can be energized by the same source as that used to energize plates 700, or can have an alternate source. Shield 705 shields electric field 600 from electric field 200, thereby preventing interaction between the two electric fields. Optionally, shield 705 can also comprise a magnetic shielding material in order to prevent interaction between electric field 600 and magnetic field 300. In operation, positively charged hydrogen atoms are urged upward toward plate 710 by field 600. Similarly, negatively charged oxygen atoms are urged downward toward plate 720 by field 600 as they pass from left to right in Fig. 7. Finally, a physical barrier 605 separates the atomic species as they leave field 600 for collection and containment. Residual water vapor can be removed by various means, including freezing, preferential absorption, and the like.

Fig. 8 shows a tuyère having a slit outlet for pre-aligning molecules entering reaction volume 702. The tuyère comprises a rectangular tube or pipe 800 having an open slit end 805. Slit 805 is positioned adjacent reaction volume 702 so that water vapor passes out through the slit and into volume 702 in the direction indicated by arrow 730 (Fig. 7). The lip of the slit is aligned parallel to the magnetic field, **H**. A very narrow slit can act to partially pre-align the water molecules, or other species if another dipolar molecule is to be separated, as they are fed into the magnetic field region. This further increases the number of molecules properly aligned for separation.

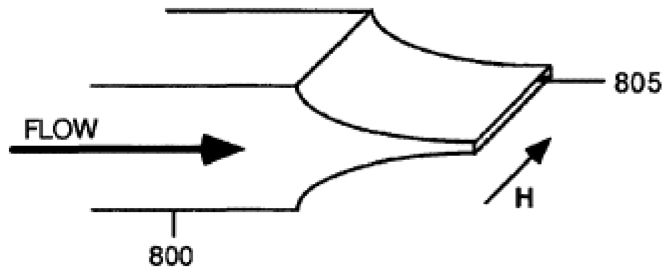

Fig. 8

In one embodiment, the apparatus can be realized by making magnet poles 715 and 720 of rare-earth material such as neodymium and having a size gap between them of one cm, although other sizes and gaps can be used. Poles 715 and 720 are part of an "E-shaped" magnet and are joined by a magnetic path 725. Path 725 can be the same material as poles 715 and 720, or a different magnetic material. The magnetic field strength in volume 702 is approximately one Tesla. Plates 700, 705, 710, and 711 can be any metal that does not corrode in the presence of the vapor entering volume 702. The vapor entering volume 702 can be at or near ambient pressure. It only has to flow through volume 702. Other pressures can be used, if desired.

Conclusion

The embodiments shown of my method and apparatus for dissociating water and other suitable molecules using electric and magnetic fields and light in conjunction with a physical barrier provide several useful and advantageous features. Static electric and magnetic fields used to align and separate joined atomic species consume very little energy, thereby providing a high-efficiency process. In space-borne applications, short-wavelength light can be obtained directly from the sun.

Many variations and ramifications are possible. Other dipolar molecules whose constituents have non-zero magnetic moments can also be separated. An alternative nozzle is included to increase the number of molecules separated by providing prealignment of the vapor stream of the joined molecules prior to entering the reaction chamber of the device. In addition to water, other dipolar molecules comprising atoms having non-zero magnetic moments can be disassociated. The magnet used can be a permanent magnet or an electromagnet. The applied light can have other wavelengths (IR, UV, etc.)