THERMALLY REVERSIBLE HYDRINO CATALYST SYSTEMS AS A NEW POWER SOURCE

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ABSTRACT

A catalyst comprising a chemical or physical process with an enthalpy change equal to an integer multiple m of the potential energy of atomic hydrogen, 27.2 eV, resonantly accepts this quantum of energy for atomic hydrogen via radiationless dipole-dipole coupling. Characteristic high-energy continuum radiation was observed from the transition. The product is H(1/p), fractional Rydberg states of atomic hydrogen called "hydrino atoms" wherein n=1/2,1/3,1/4,...,1/p (p≤137 is an integer) replaces the well-known parameter n=integer in the Rydberg equation for hydrogen excited states. The energy balance for representative power and regeneration reactions of hydrino catalyst systems involving exchange reactions were tested wherein K and NaH served as catalysts since they form K^{3+} and Na^{2+} ions by absorbing $3 \cdot 27.2$ eV and $2 \cdot 27.2$ eV respectively. Typical parameters measured by absolute water-flow calorimetry were 2–5 times energy gain relative to regeneration chemistry, 7 Wcm^{-3}, and 300–400 kJ/mole oxidant. The predicted molecular hydrino and hydrino hydride products $H_2(1/4)$ and $H^-(1/4)$ corresponding to 50 MJ/mole H_2 consumed were confirmed by the solution ^{1}H NMR peak at 1.2 ppm and XPS peak at 11 eV, respectively.

Introduction

Classical physics (CP) gives closed-form solutions of the hydrogen atom, the hydride ion, the hydrogen molecular ion, and the hydrogen molecule and predicts corresponding species having fractional principal quantum numbers [1, 2 and references therein]. The nonradiative state of atomic hydrogen, which is historically called the "ground state" forms the basis of the boundary condition of CP to solve the bound electron. CP predicts a reaction involving a resonant, nonradiative energy transfer from otherwise stable atomic hydrogen to a catalyst capable of accepting the energy to form hydrogen in lower-energy states than previously thought possible. Specifically, CP predicts that atomic hydrogen may undergo a catalytic reaction with certain atoms, excimers, ions, and diatomic hydrides which provide a reaction with a net enthalpy of an integer multiple of the potential energy of atomic hydrogen, E_h=27.2 eV where E_h is one Hartree. Specific species (e.g. He^+, Ar^+, Sr^+, K, Li, HCl, and NaH) identifiable on the basis of their known electron energy levels are required to be present with atomic hydrogen to catalyze the process. The reaction involves a nonradiative energy transfer of an integer multiple of 27.2 eV from atomic hydrogen to the catalyst followed by $q \cdot 13.6$ eV continuum emission or $q \cdot 13.6$ eV transfer to another H to form extraordinarily hot, excited-state H and a hydrogen atom that is lower in energy than unreacted atomic hydrogen that corresponds to a fractional principal quantum number. That is, in the formula for the principal energy levels of the hydrogen atom:

$$E_n = -\frac{e^2}{n^2 8\pi\varepsilon_o a_H} = -\frac{13.598 \ eV}{n^2} \tag{1}$$

$$n=1,2,3,\ldots \tag{2}$$

where a_H is the Bohr radius for the hydrogen atom (52.947 pm), e is the magnitude of the charge of the electron, and ε_o is the vacuum permittivity, fractional quantum numbers:

$$n = 1, \frac{1}{2}, \frac{1}{3}, \frac{1}{4}, ..., \frac{1}{p}; \quad p \le 137 \text{ is an integer} \tag{3}$$

replace the well known parameter n=integer in the Rydberg equation for hydrogen excited states. Then, a hydrino atom also comprises an electron, a proton, and a photon. However, the electric field of the latter increases the binding corresponding to desorption of energy rather than decreasing the central field with the absorption of energy as in an excited state, and the resultant photon-electron interaction of the hydrino is stable rather than radiative. The Maxwellian solutions to both excited and hydrino states are given in Ref. [1].

The n=1 state of hydrogen and the n=1/integer states of hydrogen are nonradiative, but a transition between two nonradiative states, say n=1 to n=1/2, is possible via a nonradiative energy transfer. Hydrogen is a special case of the stable states given by Eqs. (1) and (3) wherein the corresponding radius of the hydrogen or hydrino atom is given by

$$r = \frac{a_H}{p}, \tag{4}$$

where p=1,2,3... . In order to conserve energy, energy must be transferred from the hydrogen atom to the catalyst in units of

$$m \cdot 27.2 \text{ eV}, \quad m = 1, 2, 3, 4, ... \tag{5}$$

and the radius transitions to $\dfrac{a_H}{m + p}$. The catalyst reactions involve two steps of energy release [1–4]: a nonradiative energy transfer to the catalyst followed by additional energy release as the radius decreases to the corresponding stable final state. Thus, the general reaction is given by

$$m \cdot 27.2 \text{ eV} + Cat^{q+} + H\left[\frac{a_H}{p}\right]$$
$$\rightarrow Cat^{(q+r)+} + re^- + H*\left[\frac{a_H}{(m + p)}\right] + m \cdot 27.2 \text{ eV} \tag{6}$$
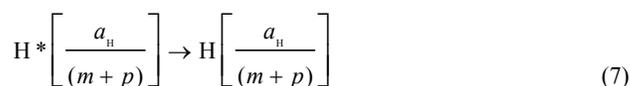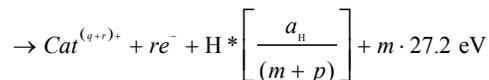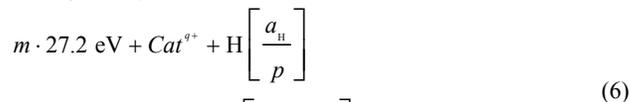
$$H*\left[\frac{a_H}{(m + p)}\right] \rightarrow H\left[\frac{a_H}{(m + p)}\right]$$
$$+[(p + m)^2 - p^2] \cdot 13.6 \text{ eV} - m \cdot 27.2 \text{ eV} \tag{7}$$

$$Cat^{(q+r)+} + re^- \rightarrow Cat^{q+} + m \cdot 27.2 \text{ eV} \tag{8}$$

And, the overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(m + p)}\right] + [(p + m)^2 - p^2] \cdot 13.6 \text{ eV} \tag{9}$$
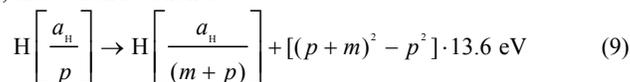
q, r, m, and p are integers. $H*\left[\dfrac{a_H}{(m + p)}\right]$ has the radius of the hydrogen atom (corresponding to the 1 in the denominator) and a central field equivalent to $(m = p)$ times that of a proton, and $H\left[\dfrac{a_H}{(m + p)}\right]$ is the corresponding stable state with the radius of $\dfrac{1}{(m + p)}$ that of H. As the electron undergoes radial acceleration

from the radius of the hydrogen atom to a radius of $\dfrac{1}{(m+p)}$ this distance, energy is released as characteristic light emission or as third-body kinetic energy. The emission may be in the form of an extreme-ultraviolet continuum radiation having an edge at

$$[(p+m)^2 - p^2 - 2m]\cdot 13.6 \text{ eV} \quad \text{or} \quad \frac{91.2}{[(p+m)^2 - p^2 - 2m]} \text{ nm} \quad \text{and}$$

extending to longer wavelengths. In addition to radiation, a resonant kinetic energy transfer to form fast H may occur. Subsequent excitation of these fast H(n=1) atoms by collisions with the background followed by emission of the corresponding H(n=3) fast atoms gives rise to broadened Balmer α emission. Extraordinary (>100 eV) Balmer α line broadening is observed consistent with predictions [3].

As given in Chp. 5 of Ref [1], and Refs. [3–7], hydrogen atoms $H(1/p)$ $p = 1, 2, 3, ...137$ can undergo further transitions to lower-energy states given by Eqs. (1) and (3) wherein the transition of one atom is catalyzed by a second that resonantly and nonradiatively accepts $m \cdot 27.2$ eV with a concomitant opposite change in its potential energy. The overall general equation for the transition of $H(1/p)$ to $H(1/(p+m))$ induced by a resonance transfer of $m \cdot 27.2$ eV to $H(1/p')$ is represented by

$$H(1/p') + H(1/p) \rightarrow H + H(1/(p+m))$$
$$+ \left[2pm + m^2 - p'^2 + 1\right]\cdot 13.6 \text{ eV} \tag{10}$$
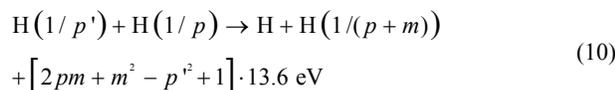
Hydrogen atoms may serve as a catalyst wherein m=1, m=2, and m=3 for one, two, and three atoms, respectively, acting as a catalyst for another. The rate for the two-atom-catalyst, 2H, may be high when extraordinarily fast H as reported previously [3] collides with a molecule to form the 2H wherein two atoms resonantly and nonradiatively accept 54.4 eV from a third hydrogen atom of the collision partners. By the same mechanism, the collision of two hot H_2 provide 3H to serve as a catalyst of $3 \cdot 27.2$ eV for the fourth. The EUV continua at 22.8 nm and 10.1 nm (Figure 1), extraordinary (>50 eV) Balmer α line broadening, highly excited H states, and the product gas $H_2(1/4)$ were observed as predicted [3,5–7].

Thus, a catalyst provides a net positive enthalpy of reaction of $m \cdot 27.2$ eV (i.e. it resonantly accepts the nonradiative energy transfer from hydrogen atoms and releases the energy to the surroundings to affect electronic transitions to fractional quantum energy levels). K can serve as a catalyst since the ionization of K to K^{3+} is about 81.6 eV ($3 \cdot 27.2$ eV). As a consequence of the nonradiative energy transfer, the hydrogen atom becomes unstable and emits further energy until it achieves a lower-energy nonradiative state having a principal energy level given by Eqs. (1) and (3). Thus, the catalysis releases energy from the hydrogen atom with a commensurate decrease in size of the hydrogen atom, $r_n = n a_H$ where n is given by Eq. (3). For example, the catalysis of H(n=1) to H(n=1/4) releases 204 eV, and the hydrogen radius decreases from a_H to $1/4 a_H$. The corresponding molecular hydrino $H_2(1/4)$ and hydrino hydride ion $H^-(1/4)$ are preferred final products [3–7] consistent with observation.
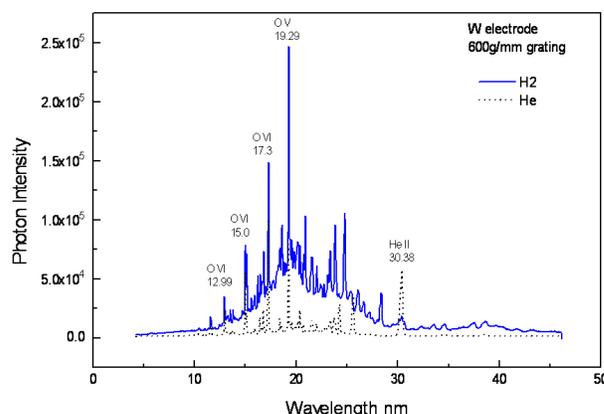

Figure 1. Emission spectra (3-46 nm) of electron-beam-initiated, high-voltage pulsed discharges in hydrogen (solid) and helium (dashed) with W electrodes recorded by the EUV grazing incidence spectrometer showing two continuum bands. The predicted continua from the transitions $H*[a_H/3] \rightarrow H[a_H/3] + 54.4$ eV and $H*[a_H/4] \rightarrow H[a_H/4] + 122.4$ eV were observed with short wavelength cutoffs at 22.8 nm and 10.1 nm, respectively, for hydrogen only.

The catalyst product, H(1/p), may also react with an electron to form a hydrino hydride ion $H^-(1/p)$, or two H(1/p) may react to form the corresponding molecular hydrino $H_2(1/p)$. Specifically, the catalyst product, H(1/p), may also react with an electron to form a novel hydride ion $H^-(1/p)$ with a binding energy E_B [1–7]:

$$E_B = \frac{\hbar^2 \sqrt{s(s+1)}}{8\mu_e a_0^2 \left[\dfrac{1+\sqrt{s(s+1)}}{p}\right]^2}$$
$$- \frac{\pi\mu_0 e^2 \hbar^2}{m_e^2}\left(\frac{1}{a_H^3} + \frac{2^2}{a_0^3 \left[\dfrac{1+\sqrt{s(s+1)}}{p}\right]^3}\right) \tag{11}$$

where p=integer >1, s=1/2, $\hbar$ is Planck's constant bar, μ_0 is the permeability of vacuum, m_e is the mass of the electron, μ_e is the reduced electron mass given by $\mu_e = \dfrac{m_e m_p}{\left(m_e / \sqrt{\dfrac{3}{4}}\right) + m_p}$ where m_p is the mass of the proton, a_0 is the Bohr radius, and the ionic radius is $r_1 = \dfrac{a_0}{p}\left(1 + \sqrt{s(s+1)}\right)$. From Eq. (11), the calculated ionization energy of the hydride ion is 0.75418 eV, and the experimental value is 6082.99 ± 0.15 cm^{-1} (0.75418 eV).

Upfield-shifted NMR peaks are direct evidence of the existence of lower-energy state hydrogen with a reduced radius relative to ordinary hydride ion and having an increase in diamagnetic shielding of the proton. The shift is given by the sum of that of an ordinary hydride ion H^- and a component due to the lower-energy state [1]:

$$\frac{\Delta B_{\scriptscriptstyle T}}{B} = -\mu_0 \frac{e^2}{12 m_e a_0 \left(1 + \sqrt{s(s+1)}\right)} (1 + \alpha 2\pi\rho) \tag{12}$$

$$= -(29.9 + 1.37 p)\, \text{ppm}$$

where for H$^-$ $p=0$ and p=integer >1 for H$^-$(1/p) and α is the fine structure constant.

H(1/p) may react with a proton and two H(1/p) may react to form H$_2$(1/p)$^+$ and H$_2$(1/p), respectively. The hydrogen molecular ion and molecular charge and current density functions, bond distances, and energies were solved previously [1] from the Laplacian in ellipsoidal coordinates with the constraint of nonradiation.

$$(\eta - \zeta) R_\xi \frac{\partial}{\partial \xi}(R_\xi \frac{\partial \phi}{\partial \xi}) + (\zeta - \xi) R_\eta \frac{\partial}{\partial \eta}(R_\eta \frac{\partial \phi}{\partial \eta})$$
$$+ (\xi - \eta) R_\zeta \frac{\partial}{\partial \zeta}(R_\zeta \frac{\partial \phi}{\partial \zeta}) = 0 \tag{13}$$

The total energy E_T of the hydrogen molecular ion having a central field of $+pe$ at each focus of the prolate spheroid molecular orbital is

$$E_{\scriptscriptstyle T} = -p^2 \left\{ \begin{array}{c} \frac{e^2}{8\pi\varepsilon_o a_{\scriptscriptstyle H}}(4\ln 3 - 1 - 2\ln 3) \\ X \left[1 + p\frac{2\hbar\sqrt{\frac{2e^2}{4\pi\varepsilon_o (2a_{\scriptscriptstyle H})^3}}}{m_e c^2}} \right] \\ -\frac{1}{2}\hbar\sqrt{\frac{\frac{pe^2}{4\pi\varepsilon_o \left(\frac{2a_{\scriptscriptstyle H}}{p}\right)^3} - \frac{pe^2}{8\pi\varepsilon_o \left(\frac{3a_{\scriptscriptstyle H}}{p}\right)^3}}{\mu}} \end{array} \right\} \tag{14}$$

$$= -p^2\, 16.13392\ \text{eV} - p^3\, 0.118755\ \text{eV}$$

where p is an integer, c is the speed of light in vacuum, and μ is the reduced nuclear mass [1, 7]. The total energy of the hydrogen molecule having a central field of $+pe$ at each focus of the prolate spheroid molecular orbital is

$$E_{\scriptscriptstyle T} = -p^2 \left\{ \begin{array}{c} \frac{e^2}{8\pi\varepsilon_o a_0}\left[\left(2\sqrt{2} - \sqrt{2} + \frac{\sqrt{2}}{2}\right)\ln\frac{\sqrt{2}+1}{\sqrt{2}-1} - \sqrt{2}\right] \\ \times \left[1 + p\frac{2\hbar\sqrt{\frac{e^2}{4\pi\varepsilon_o a_0^3}}}{m_e c^2}} \right] \\ -\frac{1}{2}\hbar\sqrt{\frac{\frac{pe^2}{8\pi\varepsilon_o \left(\frac{a_0}{p}\right)^3} - \frac{pe^2}{8\pi\varepsilon_o \left(\frac{\left(1+\frac{1}{\sqrt{2}}\right)a_0}{p}\right)^3}}{\mu}} \end{array} \right\} \tag{15}$$

$$= -p^2\, 31.351\ eV - p^3\, 0.326469\ eV$$

The bond dissociation energy, E_D, of the hydrogen molecule H$_2$(1/p) is the difference between the total energy of the corresponding hydrogen atoms and E_T

$$E_{\scriptscriptstyle D} = E(2H(1/p)) - E_{\scriptscriptstyle T} \tag{16}$$

where

$$E(2H(1/p)) = -p^2\, 27.20\ \text{eV} \tag{17}$$

E_D is given by Eqs. (16-17) and (15):

$$E_{\scriptscriptstyle D} = -p^2\, 27.20\ \text{eV} - E_{\scriptscriptstyle T}$$
$$= -p^2\, 27.20\ \text{eV} - \left(-p^2\, 31.351\ \text{eV} - p^3\, 0.326469\ \text{eV}\right) \tag{18}$$
$$= p^2\, 4.151\ \text{eV} + p^3\, 0.326469\ \text{eV}$$

The calculated and experimental parameters of H$_2$, D$_2$, H$_2^+$, and D_2^+ match [1].

The NMR of catalysis-product gas provides a definitive test of the theoretically predicted chemical shift of H$_2$(1/4). In general, the ^{1}H NMR resonance of H$_2$(1/p) is predicted to be upfield from that of H$_2$ due to the fractional radius in elliptic coordinates [1] wherein the electrons are significantly closer to the nuclei. The predicted shift, $\Delta B_T/B$, for H$_2$(1/p) derived previously [1] is given by the sum of that of H$_2$ and a term that depends on p=integer >1 for H$_2$(1/p):

$$\frac{\Delta B_{\scriptscriptstyle T}}{B} = -\mu_0 \left(4 - \sqrt{2}\ln\frac{\sqrt{2}+1}{\sqrt{2}-1}\right)\frac{e^2}{36 a_0 m_e}(1 + \pi\alpha\rho) \tag{19}$$

$$\frac{\Delta B_{\scriptscriptstyle T}}{B} = -(28.01 + 0.64 p)\, \text{ppm} \tag{20}$$

where for H$_2$ $p=0$. The experimental absolute H$_2$ gas-phase resonance shift of -28.0 ppm [1, 3–7] is in excellent agreement with the predicted absolute gas-phase shift of -28.01 ppm (Eq. (20)).

The vibrational energies, E_{vib}, for the $\upsilon=0$ to $\upsilon=1$ transition of hydrogen-type molecules H$_2$(1/p) are [1]

$$E_{vib} = p^2\, 0.515902\ \text{eV} \tag{21}$$

where p is an integer.

The rotational energies, E_{rot}, for the J to $J+1$ transition of hydrogen-type molecules H$_2$(1/p) are [1]

$$E_{rot} = E_{J+1} - E_J = \frac{\hbar^2}{I}[J+1] = p^2(J+1)\,0.01509 \text{ eV} \quad (22)$$

where p is an integer, I is the moment of inertia.

The p^2 dependence of the rotational energies results from an inverse p dependence of the internuclear distance and the corresponding impact on the moment of inertia I. The predicted internuclear distance $2c'$ for $H_2(1/p)$ is

$$2c' = \frac{a_o\sqrt{2}}{p} \quad (23)$$

The data from a broad spectrum of investigational techniques strongly and consistently indicates that hydrogen can exist in lower-energy states than previously thought possible and support the existence of these states called hydrino, for "small hydrogen", and the corresponding hydride ions and molecular hydrino. Some of these prior related studies supporting the possibility of a novel reaction of atomic hydrogen, which produces hydrogen in fractional quantum states that are at lower energies than the traditional "ground" (n=1) state, include extreme ultraviolet (EUV) spectroscopy, characteristic emission from catalysts and the hydride ion products, lower-energy hydrogen emission, chemically-formed plasmas, Balmer α line broadening, population inversion of H lines, elevated electron temperature, anomalous plasma afterglow duration, power generation, and analysis of novel chemical compounds [3–7 and references therein].

Results and Discussion

The energy balance for representative power and regeneration reactions of four classes of hydrino catalyst systems were tested [5]. Significant excess power and high thermal regeneration kinetics and high yield were obtained on multiple chemical systems. Each system comprised a thermally-reversible reaction mixture of a catalyst or source of catalyst and a source of hydrogen (KH or NaH), a high-surface-area conductive support (TiC, TiCN, Ti_3SiC_2, WC, YC_2, Pd/C, carbon black (CB), and LiCl reduced to Li), and a reductant (Mg, Ca, or Li). Additionally, two systems comprised an alkaline earth or alkali halide oxidant, or the carbon support comprised the oxidant. The reactions to propagate hydrino formation were (i) (a) an oxidation-reduction reaction involving hydride-halide exchange between NaH or KH and an alkaline earth halide or alkali halide, or (b) carbon served as the oxidant during the reaction with KH to form the intercalation compound KHC_x, (ii) a hydride exchange reaction between NaH or KH and Mg or Li, and (iii) a dispersion reaction of NaH on a support. Typical parameters measured by absolute water-flow calorimetry were 2-5 times energy gain relative to regeneration chemistry, 7 Wcm^{-3}, and 300-400 kJ/mole oxidant. The predicted molecular hydrino and hydrino hydride products $H_2(1/4)$ and $H^-(1/4)$ corresponding to 50 MJ/mole H_2 consumed were confirmed by the solution ^1H NMR peak at 1.2 ppm (Eq. (20)) and XPS peak at 11 eV (Eq. (11)), respectively. Product regeneration in the temperature range of 550-750°C showed that the cell operation temperature was sufficient to maintain the regeneration temperature of cells in the corresponding phase of the power-regeneration cycle wherein the forward and reverse reaction times were comparable.

In general, these reactions demonstrate that hydrinos may be formed using a thermally reversible reaction of a catalyst or source of catalyst, a source of hydrogen, and at least one other reactant to form predictable products based on the corresponding maximum heat release E_{mt} calculable from the known enthalpies of the reactants and products. Additionally, significant energy excess E_{ex} is due to the formation of hydrinos with 50 MJ/mole of H_2 converted. For the power and regeneration cycle, the energy balance is zero except for thermal losses, the energy to replace the H converted to hydrino, and the excess due to the hydrino contribution. The former two are small <5% of E_{mt} and ~2% of E_{ex} considering electrolysis of water ($\Delta H_{H_2O(\ell)} = 285$ kJ/mole) using electricity generated thermally with a 30% energy conversion factor; whereas, E_{ex} was observed to be more than 100% of E_{mt}. The results indicate that continuous generation of power liberated by forming hydrinos is commercially feasible using simplistic and efficient systems [8, 9] that concurrently maintain regeneration as part of the thermal energy balance. The system is closed except that only hydrogen consumed in forming hydrinos need be replaced. Hydrogen to form hydrinos can be obtained ultimately from the electrolysis of water with 200 times the energy release relative to combustion.

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