

Electrolytic Gas

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Preamble

This paper sets out to describe why an experimental apparatus, namely a 12 valve Toyota 1600cc 4cyl engine runs on electrolytic¹ gas. That is not so strange in itself as it is well known that Hydrogen is a fuel*. The benefit of using electrolytic gas is that the Hydrogen has with it, its own oxidiser – Oxygen. Already perfectly proportioned, no gas mixing is required and so complete combustion is accomplished without the need for additional air. Here's the rub; the car engine uses a separate belt driven three phase marine alternator in a “Y” winding with output rated at 150 Amps at 24 Volts which is fed into three electrolysis cells, each cell gets a single phase. Beginning at 12 Volts the cells are heated partly by hot exhaust gas and partly by way of voltage on the plates within acting as heating elements. When the cells get up to temperature (about 75° C) the alternator tickle supply is reduced to a range between 1.24 to 2.00 volts which then serves to increase electrolysis efficiency in accordance with Faraday's Law(s) of electrolysis and thus efficiencies in the order of 97.5% are achieved the cells consuming circa 600 Amps each the process becomes endothermic and provides gas more than sufficient to fuel the engine.

Thus the engine generates its own fuel (and oxidiser) with ample power to spare. Most argue that this is an impossible situation; at best the engine becomes a dynamic brake and at worst it just won't work. The explanation being that you can't get more energy out than what you put in and in citing various texts, at first glance appears quite correct. The fact of the matter – as this paper will prove – is that the texts are either wrong or fail to supply all of the information.

Definitions

Various figures are provided in texts for the energy value of the Hydrogen bond strength² of 104kcal/(1/mole) or 104kcal/mole⁻¹. So far as the mole fraction is concerned some express such as the inverse function and others as a reciprocal (*mole⁻¹*) and (*1/mole*) respectively. In any case the purpose is to detail a part of the mole or indeed one molecule at a time. Following electrolysis the demised atoms may be at their lowest, or induced to increased energy their electrons orbiting above the lowest energy state. In order to reveal the correct figures for all sides of the reaction[s], there is wisdom in beginning with the elemental gases and their oxidation reaction and finish with decomposition in order that the results comply with Thermodynamic law. For the remainder of the paper *kcal* will be converted to *kjoule* (kj) so that 104kcal = 435kj and unless specified otherwise molar quantities are 1/mole (mole⁻¹), denoting singular molecules as opposed to Avogadro's Number which denotes 6.02 x 10²³ molecules. When this approach is taken the energy content latent in the oxidation is realised, not so when the calculations start with water – something appears to get lost.

¹ Also called: Water Gas, Rhodes Gas, Browns Gas.

² Organic Chemistry. Morrison & Boyd. Allyn and Bacon, Inc. LCCCN:66-25695

Electrochemical -V- Physical reactions

There are two bonds on the molecule – one for each Hydrogen atom (of course). Therefore for one molecule of H₂O 870kj will break apart the water molecule and the equivalent energy, it is said, will *initiate* the gas recombination. Gas and oxidiser atoms never being in isolation, there being billions of them in *n* volume they undergo a chain reaction until all available atoms are recombined releasing enormous energy in quick time. The plasma speed is 3.9km/sec. The ash is water. Few texts referenced to date accounts for the energy release during recombination, more information about this apparent dichotomy will be discussed.

The heat flame (plasma) total energy is calculated by multiplying the respective atoms' ionisation energies for the process. The ionisation energies³ of H = 1312.06kj and O = 1313.95kj^{ie}₁, (3388.33kj^{ie}₂, 5300.51kj^{ie}₃) upon combustion the (outer in Oxygen) electron orbits interact, merge and settle down to stable orbits:

$$H^{ie_1} + H^{ie_1} O^{ie_1} = 3,447,962.47kj \quad (1)$$

Where ^{ie} is Ionisation Energy and _n the energy layer (three in Oxygen) and only one in Hydrogen.

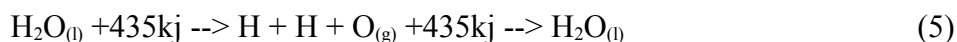
In order of energy strength...The formation of Hydrogen is a nuclear reaction. Oxidisation (burning) of Hydrogen is a physical reaction. And electrolytic decomposition is a[n] [electro]chemical reaction. The notion of water being a fuel rests in Electrolysis, of the low energy order – a chemical reaction and Combustion – a physical reaction of the middle energy order being vastly disproportionate. This can be shown to be the case; let $\beta = 870kj$ be the total energy consumed in splitting H₂O and ϵ be the oxidisation expenditure in equation (1) of [combustion] energy.

$$\epsilon / \beta = 3963.18 \quad (2)$$

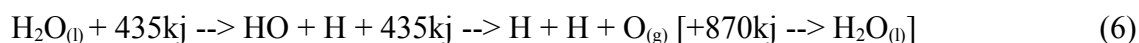
This does not describe some “hidden” energy, nor do special-pleading of over-unity claims have any relevance. The calculation reflects the starting position of the two gases. Even if the bond strength is subtracted from both sides:

$$(\epsilon - \beta) / \beta = 3962.18 \quad (3)$$

...it is apparent that the combustion product is highly energetic. So which is it? The chemical equation given:



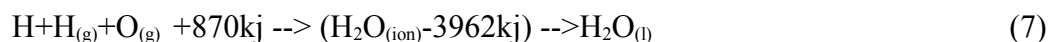
is clearly mistaken because, a) only half the required energy is given and b) there is a continuing addition of energy on both sides and appears not to factor-in any energy *release*. In any case equation (5) plugs in the correct values to the formula provided in the text (footnote #2) and equation (6) enlarges to include the energy release.



On the one hand energy is expended to break the bonds and on the other hand energy must be expended to remake them and clearly this imbalanced situation leaves a lot to be desired. What actually happens is that 870kj/mole⁻¹ is expended to begin the recombination process and

³ www.ktf-split.hr/periodni/en

3962kj/mole⁻¹ is liberated as a net gain. The reason for this is that the ionisation process in electrolysis is [electro]chemical, the initiating energy is [electro]chemical however the resultant ionisation (combustion) process is physical.



...and then multiply this reaction by the gas volume denoted by Avogadro's number.

The author of this paper is not in isolation insofar as these apparently anomalous results are concerned, others have addressed the issue. ⁴" The smallest amount of energy needed to electrolyse one mole of water is 65.3 Wh at 25 degrees Celsius (77 degrees F). When the Hydrogen and Oxygen are recombined into water during combustion 79.3 Wh of energy is released. 14 Wh more energy is released in burning Hydrogen and Oxygen than is required to split water. This excess must be absorbed from the surrounding media(environment) in the form of heat during electrolysis." [...] "At 25 degrees celcius, for voltages of 1.23 to 1.47 V, the electrolysis reaction ABSORBS HEAT. At over 1.47 V at 25 degrees celcius, the reaction gives off heat."

One mole of water weighs 18 grams.

$$1000 \text{ Grams water} = 1 \text{ Liter}$$

$$1000 \text{ grams} / 18\text{grams} = 55.55\text{moles}$$

Therefore 1 Liter H₂O produces 55.55 Moles of Hydrogen and 27.775 Moles of Oxygen. 870Kj / (1/ Mole) H₂O produces as above which is then equal to 48328.50kj per Liter H₂O. Conversion to kWhr divide by 3600 (or x by .0002778) = 3.658 kWhr per Liter H₂O

1 Mole of Gas = 24.450 liters of gas at room temperature, "T" and atmospheric pressure "P". 55.55 x 24.450 = 1,358.3 liters of Hydrogen (and 679.15 liters of Oxygen) from 1 Liter of H₂O.

⁴ "FUEL FROM WATER" M. A.Peavey. Merit, Inc. LCCCN 88-188956 ISBN 0-945516-04-5 Page 22.

Faraday's Laws⁵

$$V = \frac{R \cdot I \cdot T \cdot t}{F \cdot p \cdot z} \quad (8)$$

where:

V = volume of the gas [L],
 R = ideal gas constant = 0.0820577 L*atm/(mol*K), = current [A],
 T = temperature [°K],
 t = time [s],
 F = Faraday's constant = 96485.31 As/mol,
 p = ambient pressure [atm],
 z = number of excess electrons (2 for H₂, 4 for O₂).

Assume that STP (Standard Temperature and Pressure) conditions and the electrolyzer runs at one Amp for one hour:

T = 0 °C
 C = 273.15° K
 p = 1 atm
 t = 3600 seconds
 I = 1 Amp

Total Oxygen-Hydrogen volume is Hydrogen volume + Oxygen volume:

$$V_{H_2} + V_{O_2} = \frac{0.0820577 \cdot 1 \cdot 273.15 \cdot 3600}{96485 \cdot 13 \cdot 1 \cdot 2} + \frac{0.0820577 \cdot 1 \cdot 273.15 \cdot 3600}{96485 \cdot 13 \cdot 1 \cdot 4} = 0.418151 \text{ L} + 0.209075 \text{ L} = 0.627226 \text{ L}$$

This corresponds to about 0.627 liters per hour per Amp or 1.595Ah/l per cell.

If for example you have 7 cells in series and put 11A through the electrolyzer, according to Faraday's Law you would produce:

$$0.627\text{l/Ah} \cdot 11\text{A} \cdot 7 = \sim 48.3 \text{ Liters per hour} \quad (10)$$

at STP conditions.

Note, however, that this applies only at a certain temperature (0°C) and pressure (1 atm). The produced gas volume will scale with ratio of temperatures in Kelvins (higher temperature = higher volume) and inversely with the ratio of pressures (lower pressure = higher volume).

If at 0°C (273.15°K) the production rate is 0.627 l/Ah, then at 25°C:

$$273.15^\circ\text{K} + 25^\circ\text{K} = 298.15\text{K} \quad (11)$$

the production rate is:

⁵ Courtesy Tero Ranta

$$298.15/273.15 = \sim 109\% \quad (12)$$

larger or about 0.685 l / Ah. With 7 cells and 11A this would be 52.5 Liters per hour.

On the other hand is the output gas has a temperature of 40°C while it is being measured and the ambient pressure of 0.75 atm (about 1.5km elevation above sea level), the electrolyzer that produces 48.3 liters per hour at STP will produce:

$$313.15^\circ\text{K}/273.15^\circ\text{K} * 1\text{atm}/0.75\text{atm} * 48.3\text{l/hr} = 73.8\text{l/hr} \quad (13)$$

So even though the volume of the gas is larger at higher temperature and lower pressure, the energy contained in the gas or the energy required to electrolyze it is the same. If you produce the gas at 40C and 0.75ATM and bring it to 0C and 1ATM, the volume will reduce by about 35%. Thus it is very important to include the pressure and temperature in calculations.

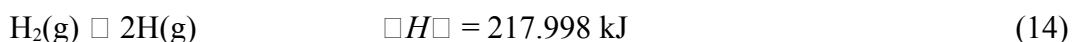
Thermodynamics of Electrolytic Gases⁶

The heat of combustion values for monoatomic and diatomic (conventional) electrolytic oxyhydrogen gas are compared below.

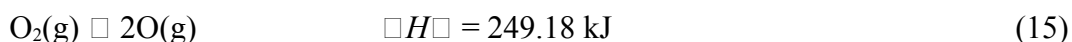
When conventional diatomic (tank gases) oxygen (O₂) and hydrogen (H₂) are combusted, the bonds between the gas atoms in the diatomic gas molecules have to be broken first. This consumes energy. Energy is then released⁸ when the H and O atoms recombine into H₂O. The total amount of energy released is the sum of these two energies, where the other one has + sign and the other one - sign.

While the heat of combustion for conventional diatomic H₂ is shown in thermodynamic tables, the values for the monoatomic 2H + O → H₂O reaction is not usually shown. It is calculated in the following:

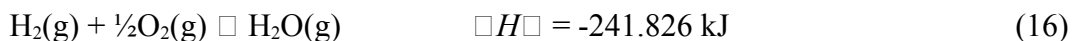
⁷Dissociation of diatomic hydrogen gas into hydrogen atoms (consumes energy):



Dissociation of diatomic oxygen gas into oxygen atoms: (consumes energy):



Combustion of diatomic H₂ and O₂ to form water as steam (releases energy):



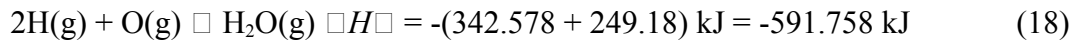
Dissociation of diatomic H₂ and O₂ molecules into monoatomic form (consumes energy):



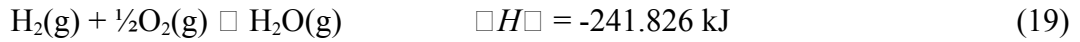
Combustion of monoatomic H and O to form water as steam (releases energy):

⁶ Courtesy Tero Ranta

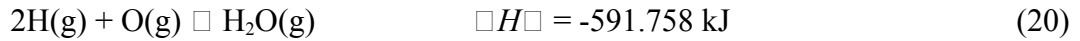
⁷ CRC Handbook of Chemistry and Physics, 84th ed.



Combustion of diatomic oxyhydrogen into water in the form of steam (releases energy):



Combustion of monoatomic oxyhydrogen (releases energy):



Combusting a certain amount (by weight) of oxyhydrogen releases about 2.45 times more energy if the oxyhydrogen is monoatomic instead of diatomic. Monoatomic oxyhydrogen has twice the volume for the same weight than diatomic oxyhydrogen. This means that combusting one liter of monoatomic oxyhydrogen releases only about 1.23 more energy than the same volume of diatomic oxyhydrogen. However the theoretical energy consumption to dissociate one liter of monoatomic oxyhydrogen from water is half of that required to dissociate one liter of conventional diatomic oxygen and hydrogen gases.

§It may also be noted that when the two Hydrogen atoms merge photons in the UV band are released. In order to inhibit this merger it may be possible to subject the Hydrogen to strong UV (class C) radiation

Electrical features in Electrolysis

The theoretical decomposition voltage for electrolysis is 1.23 volts at room temperature (16 – 20 degrees C), however because of over-voltage of H on the cathode and also due to cell resistance itself voltages of 2.00 to 2.25 volts are usually required. Over voltage relates to charge held in the cell, the cell acting as an inefficient battery (resistance, capacitance, inductance). The following table shows the over-voltage as measured in the author's cells at various times and the calculated power input required for electrolysis:

0.02	1.27
0.2	1.45
0.9	2.15
1.12	2.37
1.9	3.15
2	3.25

Table 1

In the left column are voltages read at various times and in the right column are theoretical voltages to apply for electrolysis.

Disc interleave stacked electrodes. Potassium Hydroxide (KOH) 1:100 distilled water, 30°C, 1.27MΩ (with electrolyte) from 120MΩ (without electrolyte). Calculating Ohms Law says that at the higher impedance more current can be supplied:

1. $E = I \times R$. $I = E / R$. $R = E / I$.
2. 12 volts (nominal) / 3 cells = 4 volts per cell
3. To determine current: E / R .
 $E = 4$
 $R = 12 \times 10^6$
 $I = 10 \times 3^6$

When lowering the electrolyte impedance to c.1.2kΩ the current will be 300 Amps, theoretically.

<i>Volts</i>	<i>Electrolyte R Ohm</i>	<i>Amps</i>
4	1200	300
4	1000	250
4	100	25
4	10	2.5
4	1	0.25
4	0.1	0.025
4	0.01	0.0025

Table 2

...takes no consideration any voltage drop at the electrodes. On Mk1.1 the reactor experienced an 8 to 10 Volt drop when powered at 12 – 14 Volts. If three cells are connected in series the voltage at each is 4 volts, the voltage drop therefore renders the reactor inoperative and in series only the centre cell produces significant quantities of gas. As

electrolyte is added and the cell impedance drops the power consumption increases as does the gas output. This defies Ohms Law.

Ohms Law dictates the current and voltage levels in the cell are relative to resistance, however clear signs emerge during testing that there is a kink in this Law. Whereas the cell resistance at $10k\Omega$, 1.23 Volts - load should equate to 0.13 milli-Amps in fact the reciprocal of this value is obtained. In all electronic/electrical circuits heat is generated. When powering the cell with increased voltages ranging from 6 to 40 volts heat is generated and the cell warms up as would be expected in an exothermic system. When voltage is reduced to that dictated by Faraday's Laws of Electrolysis the cell cools and begins to absorb energy from the surrounding atmosphere, that is; the circuit becomes endothermic. In order to keep the cell temperature at that required for electrolysis IR radiation must be introduced to keep the electrolyte warm.

This breakage in Ohms Law is repugnant to most and many have stated that it is impossible. The clamp meter does not lie, how can Ohms Law be rent asunder in this manner? The answer lies within thermodynamic systems reported by Willhelm Wein in studies of Black Body radiation and is defined in the Wein Displacement Law:

$$b=l_{max} T=C^2/4.96511423 \quad (21)$$

And that electrolysis does not follow the usual VI curve usually associated with electronic circuits.

⁸"The v-i transfer function always applies. Impedance is the instantaneous slope of that function". Mathematically this can be stated resistance: $R = dV / dI$. Ohm's law, as stated, is just a specific case of the above where dV / dI remains constant for a (in practice limited) range of voltage and current. Materials where R is constant over a useful range of voltages are sometimes referred to as 'ohmic'. The "big R" in $R = dV / dI$ is NOT intended to denote a constant, since the differential term dV / dI (or slope) is only a constant in the linear case. R is a variable representing a variable resistance. R is a constant r is a variable. The issue is that the resistance of a cell is nonlinear which means that it exhibits different resistances at different operating points of voltage and current. At any given point of current and voltage, ohms law very much does apply. When you measure the resistance with a simple ohmmeter, you are measuring it at one point, a point with a very low sense voltage. The resistance is high at this voltage, the cell is barely in conduction. At a different, higher voltage, say several volts, the cells conduction increases, the resistance drops and the current comes on as you have observed. If you had an ohmmeter that measured at that higher voltage, it would show the appropriate low resistance. There are many electrical devices that exhibit non-linear behavior besides electrolytic cells. The common diode comes to mind. There the resistance is a function of polarity in addition to being nonlinear in the forward direction. At a few millivolts of forward voltage, most diodes have a resistance of megohms. This decreases down to an ohm or below as the voltage exceeds .7 volts. Note that these non-linearities have nothing to do with reactance as applied to AC circuits with inductors and capacitors.

⁸ [nntp://sci.energy.hydrogen](http://sci.energy.hydrogen)

*Hydrogen is NOT just an energy carrier

Don Lancaster, co-inventor of the microprocessor, in his paper ⁹EnergFun claims that Hydrogen is not in fact a fuel but merely an energy carrier.

There are only three elements in combustion, known as the combustion triangle, namely; Fuel, Oxidiser and Heat. If this is the case then Hydrogen is clearly a fuel. Every fuel known to mankind features Hydrogen in the mix: Hydrocarbons, fuel gas(es), coal and even wood all contain various amounts of Hydrogen and in the Hydrocarbons, the lengths of the Hydrogen Carbon chains determine it's combustive potency; Ipso Facto Hydrogen is a Fuel.

Facts of the matter so often overlooked, in particular in the Internet newsgroup; <http://groups.google.com/sci.energy.hydrogen> by group participants is that Hydrogen is highly explosive in air. So explosive, in fact that it is considered a ¹⁰concussive, as opposed to an incendiary explosion. And even more explosive still when the Hydrogen gas is proportionately mixed with Oxygen – there being insufficient Oxygen available in air to provide complete combustion. What is missed is that the explosive energy far exceeds the disassociation energy.

Flame speed:

- | | | |
|----------------------|-----------------|------------|
| • Hydrogen in Oxygen | 3900 meters/sec | concussive |
| • Petroleum in air | 30cm/sec | incendiary |

The Infrastructure Hobgoblin

In our consumer society much ado is made of our dependence on multinational corporations to provide materials for our sustenance and advancement. Notwithstanding anecdotal stories of cloak-and-dagger conspiracies, I contend that ill fate suffered by inventors in the energy field has been perpetrated by other jealous inventors and not by way of corporate shenanigans. Even if, in times past such corporations have embarked on criminal activities the world has changed dramatically. The political assemblies becoming more representative of a wider range of populace are somewhat more enlightened than was the case in the relatively recent oil crisis in 1974, dodgy dealings are less likely to be perpetrated now. In 2005 the world faces new energy crises. On one hand the globe is nine ¹¹ times over-subscribed in electricity generation the detraction being found in transmission inefficiencies and on the other hand global conflict and excessive demand has had a negative effect on oil supply thrusting the price of oil to record highs. There is no evidence that the world is running out of oil and there is also no evidence that it is not. Petrochemicals will always have a place in society providing us with useful products including industrial chemicals, lubricants, fuels and plastics. What is a moot point is whether recent discussions about the “Hydrogen Economy” bear any relevance insofar as Hydrogen Infrastructure is concerned. Hydrogen may be produced in almost any location on Earth, the Author envisages appliance sized gas plants placed in homes, plugged into the wall and generating Hydrogen and Oxygen by electrolysis for automotive use. The proponent drives the vehicle into the garage and connects to the Hydrogen source which replenishes the tank(s) thus emptying the stored Hydrogen. After driving off again the appliance continues operating 24/7 refilling tanks for later use.

The foregoing becomes academic in the face of on-board, on-demand fuel systems contained within

⁹ Reproduced, see Appendix 1

¹⁰ Properties of Hydrogen Combustion. NACA report 1383.

¹¹ <http://www.wired.com>

the engine bay which produces all of the engines' needs in which refueling is accomplished either by way of introduced distilled water or by the rain water falling on the vehicle during use that is then collected and distilled in a heat exchanger also within the engine bay. The question then is; what point infrastructure?

Summary

Before there was water there was only gas. In space water is formed by electrical discharges through reasonably dense atomic/molecular clouds. Terrestrial water was formed by three routes:

1. Water captured from space.
2. Electrical discharges, and latterly;
3. Cellular metabolism.

A small electrical discharge sets in motion chain reactions between Hydrogen and Oxygen in a physical event that releases orders of magnitude more energy than is required to then, in an electrochemical reaction, break apart the resulting oxide - there being no detractions from physical law when these facts are processed in their correct order.

So far as Electrolytic Gas' use as an internal combustion fuel is concerned it must be noted that the first ever internal combustion engine¹² invented in 1807 used electrolytic gas as its fuel.

¹² DeRivas

Further Discussion

The most popular forum in which the vicissitudes of all things “electrolytic gas” are discussed may be found at <http://groups.yahoo.com/egaspower>.

Further reading

Not necessarily quoted in this paper:

North American Combustion Handbook.
Chemical Process Industries.

Quality Control

Crown Research Limited. C/- Dr. Tony Clemens.
Dr. Robert Neil Boyd

About the Author

<http://www.geocities.com/peterlowrie>