Anales de Química de la Real Sociedad Española de Química Magazine
original publication

RADICALES (MUY) LIBRES

Los múltiples colores de un gas incoloro

Original title: “Los Múltiples Colores de un Gas Incoloro”
Translation from Spanish to English by Hethos Operating
www.hethos.earth

An Array of Colors for a Color-less Gas

(Accepted 12/06/2022)

“Verde que te quiero verde
verde viento verdes ramas
el barco sobre la mar
el caballo en la montaña”

These first verses from García de la Lorca´s song book (1928), also featured in the movie How Green Was My Valley from John Ford (1941) are a sample that the color green has always been fashionable. Even more so today, because we relate it to purity and sustainability, to the color of a meadow and the color of the planet´s salvation; even though I´ve declared a few times that our planet neither needs, nor asks, to be saved. If we continue acting foolishly, some changes might be accelerated, though it is likely we will not play a part in the resulting equilibrium. However, all things “green” are not always associated with something positive. It is enough to recall how we refer to someone lacking maturity as someone green, and analogously we do the same with fruits like bananas and tomatoes, though not all fruits change colors when they ripen. Beyond those minor contradictions and ramblings, the cult of green remains unstoppable, with big corporations at the head, obviously including oil & gas as well as the whole energy industry; the more guilt they seem to carry, the more the momentum. If they could, besides lush green meadows and idyllic scenery, they would make the smell of fresh-cut grass emanating from our tv´s a part of their publicity campaign.

The same thing occurs with energy “sources”; they are given the term green when their generation or consumption does not produce greenhouse gases or adds to the carbon footprint, something that does happen with fossil fuels. I have placed quotation marks around the word sources to distinguish it from simple carriers, that transport an energy generated from a distinct origin. This is the case with electricity as well as with hydrogen, the object of this chronicle, given that all the hydrogen needs to be fabricated because, as has always been said, hydrogen does not exist as a free gas in our planet, because it so reactive that nobody ever believed it could survive below the Earth´s crust, even at a certain depth. Or, could it? Further ahead, we will see that natural hydrogen exists amongst us in significant quantities, and its extraction is relatively simple…besides being renewable! Before we speak of it, and of the other colors we use to label this color-less gas, let´s refresh our memory on some of its chemistry.

Hydrogen is the most abundant element in the universe, and in its molecular form it is considered the ideal fuel, since it only produces energy and water after reacting with oxygen. Because it is also the lightest element in the periodic table, it contains more energy per unit mass than any other fuel. The enthalpy, or heat of reaction, of its reaction with oxygen is of -285,87 kJ/mol. The inverse reaction, meaning the decomposition of water to form oxygen and hydrogen, which is what is used to generate it, logically requires the same amount of energy supply with the inverse sign, +285,87 kJ/mol. However, if we take into account that to break water there is an added requirement for activation energy which is considerable (kinetic aspects that are not minor to the issue at hand), that require electrolysis, catalyzers, etc., the energetic cost results much greater than the benefit. On the other hand, hydrogen is a very light and volatile gas, difficult to store and transport, because like methane it is explosive, but unlike methane it is very reactive and cannot be transported through the same gas pipes due to the corrosion it would cause. Despite recent advances in battery technology, or in adsorption of gases encapsulated in porous chemical structures that are complex to design and to repair, the issues with storage, manipulation and transport of hydrogen are also essential, and remain far from being resolved.

Moving on the colors, assigned to hydrogen depending on how it is obtained. Black, or brown, hydrogen, proceeds from coal gasification, which employs non-renewable fossil fuels and emits carbon dioxide (CO_2). Gray hydrogen is what results from catalytic steam reforming, and constitutes the most widely used method today, even though, like black, it requires non-renewable fossil fuels and also emits significant amounts of CO_2 (around 10 kg for each kg of H_2 produced). Blue is hydrogen produced from methane, generating somewhat less carbon dioxide than the previous methods. Not only does the elimination of this undesirable byproduct and other impurities compared to the other colors mentioned in our spectrum elevate the cost, but it generates an important carbon footprint. There are other existent colors that do not emit CO_2, including for example pink hydrogen, that employs nuclear fuel to bring about water electrolysis, or turquoise, generated by methane pyrolysis, but produces solid carbon as a byproduct.

Thus, we arrive at green hydrogen, famous for emitting no CO_2 into the atmosphere, due to the employment of electricity for the water electrolysis process, hopefully from sustainable sources such as wind power, hydroelectric, or photovoltaic solar. Even though all governments predict its use as dominant in less than 30 years, and approve massive projects and gas pipelines, backed by international funds, nowadays green hydrogen represents only a timid 2% of total hydrogen production, mainly because of the enormous amount of energy required for electrolysis, very costly if the expectation is to source this energy purely from renewable sources in order to keep the carbon footprint at low numbers. At the moment, it not the most cost-competitive method, with a cost between 3 and 5 $ per kg produced, in fact closer to $5 than $3, even under the happy assumption that renewably-sourced electricity could be obtained a price under $79 per Mwh. These numbers a lot worse than the $1.80 from large-scale grey hydrogen produced from methane reforming. It comes down to the decrease in renewable electricity prices continuing into the future, as the trend has shown. Unfortunately, the transition will not happen as fast, or as cheaply, as most would like to believe. We remain dependent on oil, gas and coal, for 84% of the world´s energy consumption, with wind and solar only adding up to 3.3%. Some might wonder why then hydrogen, such a gaseous and complicated carrier, is being pursued as an option for mobility and long-haul transport, when electricity can be used directly, practically instantaneously, through simple copper filaments and all already available grid; except for the connection points at which we would charge these vehicles. I am not an expert in the matter, nor can I give precise numbers, but I believe the issue lies in the scarce capacity and speed of current batteries, something that is being worked on with much intensity. Of course it´s important to note that hydrogen, just like oil, has other uses other than those that require it to be burnt; it is used in manufacturing other chemicals, like ammonia through a reaction with atmospheric nitrogen (the Haber-Bosc process), gasoline or equivalent fuels with classical carbonated products or from a sustainable source, or many other chemical products that require hydrogen reactions in their preparation. In these cases, hydrogen is not usually stored or transported, rather production and manufacturing factories are strategically built side by side.

Let us talk, at last, about natural hydrogen, called white or golden (everybody has a color assignment here), that does not require preparation, but was believed to exist only in insignificant quantities in our planet. Most often, it appears accompanied by other minor gases; some of them, like helium, quite valuable. However, in the last 15 years it has proven that natural hydrogen is abundant, and curiously had not been detected in routine sampling of oil wells, because hydrogen itself was employed as a carrier gas in the chromatography analysis equipment used. The last decade has seen the situation reverted, as there are already hundreds of publications on this topic in geology and chemistry magazines, some of which I´ve gone through the trouble of reading and have attempted to decipher. I´ve even spoken to geologist and mining experts, making the most of the time offered by my (privileged) condition as a retired professor.

Where then is this natural hydrogen, ready for its use? How is it formed? How much of it is there? Why do so many experts claim it is sustainable? The beginning of so many questions… Without a doubt, I will have to write more columns about this, this is only an aperitif to wake my reader´s appetite, and it has become somewhat long, which is why I will abbreviate, and that in can be found in subsurface rocks (ophiolites, volcanic kimberlites, metamorphic streamers, amongst others), emanating freely from filtrations, vents or craters, and can also be extracted at feasible depths (less than 3,000 meters). It is formed by chemical-physical processes still not fully elucidated (as much as 30 types of interactions between rocks and water, at moderate pressure and temperature, catalyzed by iron ions, magnesium and others, that generate hydrogen). There is still no consensus on the amount of hydrogen available (the same thing happens with oil, after almost two centuries of exploitation), even though the most recent data estimates for hydrogen´s availability are considerable. It has been found in many places, and the scope of maps for its location widens daily. In Europe, and some other places, it seems that drilling holes in the ground is ill-seen, and that prevents authorities from making a concession for prospecting licenses, limiting the evaluation of its abundance; but in the United States, Canada, Brazil, central Africa, Australia or Russia it is an approaching reality, growing steadily. The most important thing is that the process for its generation seems to be continuous, and some emanations emit flows of constant intensity over countless years, since they were discovered. There is a famous chimmney near Antalya (Turkey), that has been burning for over 2,500 years with no sign of loss of pressure, and contains 7,5–11,3% of H_2. It is believed to be the source of the first Olympic flame. If there is regeneration, the obvious question would be, at what rhythm? Because if in the end we consume this natural hydrogen at a faster pace than it is generated naturally (this is unfortunately precisely what we´ve been doing with oil), it would not make sense to pay further attention to the subject. It does seem that its regeneration is faster that of oil, that requires millions of years, taking the previously cited Olympic flame as a sample, as well as many other cases. I end with a prediction, credit due to no less than Jules Verne, considered the father of science fiction, that wrote these prophetic words back in 1865 in his book The Mysterious Island: "Yes, my friends, I believe that water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable". The discussion shall be continued…

Javier de Mendoza
Retired Professor of Organic Chemistry
(Universidad Autónoma de Madrid)
Professor Emeritus, Instituto Catalán de Investigación Química (ICIQ, Tarragona)

jmendoza@iciq.es