Jules Verne's vision meets Green Hydrogen: exploring didactic insights from the story of Dr. Ox

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ABSTRACT
We present a learning activity based on a literary piece authored by Jules Verne. The provided text serves as a vehicle for the instructor to explore topics related to chemical equations, Gibbs free energy, and hypothesis formation. The text also enables the introduction of the concept of green energy generation. Furthermore, it facilitates a thoughtful reflection concerning the ethical considerations surrounding experimentation involving human subjects and the concomitant requirement of informed consent.

Keywords: Jules Verne, hydrogen, and informed consent.

1 INTRODUCTION
The relationship between scientific knowledge, conjectures, and the literature of adventure or science fiction has been fascinating throughout texts for young people. In many cases, scientific knowledge provides a context for the articulation of a concern present in a society.

Universal literary texts are a tool that a teacher can use to dialogue with students about different items of science education.

Jules Verne's adventure literature incorporates basic science and takes readers on thrilling journeys, from exploring the ocean depths to the moon's surface.
We present an abridged text of a chapter from a Jules Verne story to enable the teacher to discuss and examine a series of chemistry concepts and the context in which an experiment is carried out (Annex 1). We believe that the discussion of this text is suitable for students in the initial steps of chemistry in biology or medicine.

The aims of this study are as follows:

a) To teach students redox reactions that generate oxygen and hydrogen through electrolysis.

b) To analyze and compare the formulation of hypotheses using the information presented in the text.

c) To introduce the dilemma and question of informed consent within the context of experiment development.

d) To explore current perspectives on the "Green Hydrogen" discussion.

Students are required to read the authored text by Verne, after which the teacher will engage them in a discussion on the topics presented. The teacher should emphasize that the complete text is available on Project Gutenberg.

2 THE HISTORY OF QUIQUENDONE.

Quiquendone is a serene town located in some place in Flanders. That place eludes the confines of any map. Its inhabitants embody tranquility, with their heart rates never surpassing 50 beats per minute. A Quiquendonean may take forty minutes to respond to a query and regularly walk at a pace of 5 meters per hour.

In this idyllic setting, the city's ruler, the esteemed Burgomaster, and his trusted advisor agree with the renowned chemist, Dr. Ox, to provide a blend of oxygen and hydrogen to illuminate the town. Little do they know, Dr. Ox and his inspired advisor have clandestinely devised a plan. This plan is driven by secret experimental objectives and aims to saturate the inhabitants with the generated oxygen.

Eventually, a social upheaval erupts. This social storm finished the operation, and Dr. Ox and his assistant vanished into obscurity, interpreting the consequences of their experiment.

3 ACTIVITIES FOR STUDENTS

1) Please read the excerpts presented from Chapter 4.

a) Formulate the chemical equation representing the electrolysis of water, yielding the mentioned gases.

b) What do you think explains the disparity in volume between the gases mentioned in the text?

c) From a thermodynamic perspective, elaborate on the potential dangers when mixing these gases.

d) Which initial conditions were taken into consideration before experimenting?
e) Illustrate Dr. Ox's hypothetical proposition for his experiment.

f) Based on the text, discuss the ethical considerations under which a trial on human beings should be carried out.

g) Examine the relationship between the electrolysis analyzed and ongoing Green Hydrogen initiatives.

4 GUIDELINES FOR TEACHER-STUDENT DISCOURSE

On previous occasions (2), we have acknowledged the impossibility of providing general guidelines for teacher-student dialogues. In our particular case, involving students in a medical biochemistry course, there has been considerable curiosity about the issue of informed consent and its purpose (see Annex 2). Thus, the interests of each group may vary, which underlines the importance of the teacher's ability to accommodate and nurture these individual interests.

a), b), and c) Firstly, it is crucial to address the matter of the electrolysis equation:

Figure 1: Electrolysis reactions and water formation.

a) Electrolysis.

Cathode with reduction reaction.

\[ 2 \text{H}_2\text{O}(l) + 2 e^- \rightarrow \text{H}_2(g) + 2 \text{OH}^-(aq) \]

Anode with oxidation reaction.

\[ 2 \text{OH}^-(aq) \rightarrow \frac{1}{2} \text{O}_2(g) + \text{H}_2\text{O}(l) + 2 e^- \]

Combining the two reactions.

\[ \text{H}_2\text{O}(l) \rightarrow \text{H}_2(g) + \frac{1}{2} \text{O}_2(g) \]

b) Synthesis.

\[ \text{H}_2(g) + \frac{1}{2} \text{O}_2(g) \rightarrow \text{H}_2\text{O}(l) \quad \Delta G^\circ = -68,30 \text{ Kcal/mol} \]

Source: Prepared by the authors themselves.

It is important to note that the electrolysis process is not spontaneous. It depends on the energy supplied by the electric current system. However, the reverse reaction of water formation has a significant free energy value. The teacher may mention as historical background that this is the reason why hydrogen was no longer used as a gas for hot-air balloons. Later it was replaced by a noble gas such as helium (3).

d) Within the text, it can be inferred that Dr. Ox's assistant mentions the low heartbeat rate among the inhabitants. This serves as an initial value to be evaluated throughout the experiment. The teacher can further suggest that, for control purposes or in parallel, a population with a normal or
higher heartbeat rate could have been considered. Additionally, establishing the normal oxygen/nitrogen ratio and ensuring no oxygen deficiency in the city would provide another reference value.

(e) The text implicitly suggests the idea or hypothesis that increasing the supply of oxygen could raise the oxygen levels in the airways. This, in turn, might lead to an increase in the heart rate of the inhabitants and potentially make them more aggressive. Students will be encouraged to develop their own hypotheses, express them formally, and participate in discussions about the experiments needed to test their hypotheses. This phase allows for the exploration and creation of various hypotheses.

(f) Currently, both human and animal experiments require compliance with "informed consent" procedures. An annex (Annex 2) is available for the instructor to go over with students, demonstrating the information needed for a sarcopenia trial. Although vaccine trials have attracted considerable attention during the Covid-19 pandemic, it's crucial to acknowledge that consent protocols are used in various research areas.

(g) The electrolysis process, used for hydrogen production, has been applied to produce and store a "clean" fuel. A schematic representation of this process is depicted in Figure 2.

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**Figure 2: Clean Energy Production Scheme.**

Source: Prepared by the authors themselves.

It's important to emphasize that the Eastern Republic of Uruguay is actively participating in a hydrogen initiative referred to as "Project Verne" (3).

5 CONCLUSIONS

A text is provided to inspire students to apply the curriculum's training to real-life situations. Various literary or scientific-related concepts can be employed, which can be linked to scenarios relevant to the current technological advancements in society. The instructor can facilitate discussions regarding the regulation of scientific experiments on a social scale, emphasizing the application of knowledge.
Additionally, a conversation can be conducted regarding the generation or dissemination of scientific and technological ideas through adventure literature or science fiction texts.
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ANNEX 1
Extracts from Chapter IV.
IN WHICH DOCTOR OX REVEALS HIMSELF AS A PHYSIOLOGIST OF THE FIRST RANK, AND AS AN AUDACIOUS EXPERIMENTALIST.

Doctor Ox had arrived in Quiquendone five months ago, accompanied by his assistant, who went by the name GédéonYgène; a tall, thin man, proud, but no less lively than his master.

Now, why had Doctor Ox offered to light up the town at his own expense? Why, out of all the Flemish towns, did he choose the peaceful Quiquendonians to introduce an entirely new lighting system? Was it possible that, under this pretext, he aimed to conduct some significant physiological experiment involving living beings? In short, what was this unique character planning to attempt? We do not know, as Doctor Ox confided in no one except his assistant Ygène, who obediently followed his lead.

At least outwardly, Doctor Ox had agreed to illuminate the town, which sorely needed it, "especially at night," as cleverly put by Commissary Passauf. Facilities for producing lighting gas had been set up accordingly; gasometers were ready, and the main pipes, running under the street pavements, would soon emerge as burners in public buildings and the homes of certain forward-thinking individuals.

If the reader recalls, during the lengthy conversation between the councilor and the mayor, it was mentioned that the town's illumination would not rely on the combustion of common coal-derived carbureted hydrogen but on a more modern and twenty times brighter gas called oxyhydrogen gas, produced by mixing hydrogen and oxygen.

The doctor, proficient in both chemistry and physiology, knew how to obtain this gas in quantity and quality, not through the use of manganate of soda as per M. Tessié du Motay's method, but through the direct decomposition of slightly acidulated water, using a battery of newly invented elements of his own design. Thus, expensive materials, platinum, retorts, fuel, or delicate machinery were not needed to produce the two gases separately. An electric current was passed through large basins filled with water, and the liquid split into its two components, oxygen and hydrogen. Oxygen exited at one end; hydrogen, twice the volume of its former partner, at the other. As a necessary precaution, they were collected in separate containers, as their mixture could cause a disastrous explosion if ignited. From there, pipes would transport them separately to various burners, positioned to prevent any chance of explosion.
As a result, an exceptionally bright flame would be achieved, its light rivaling that of electric light, which, as everyone knows, according to Cassellmann's experiments, is equal to the light of one thousand one hundred seventy-one wax candles, not one more, not one less.

"Ah," said the doctor, "what does it matter if they think well or ill of us, as long as our experiment succeeds?"

"Moreover," replied the assistant, wearing a mischievous smile, "shouldn't we be concerned that by creating such excitement in their respiratory organs, we might harm the lungs of these good people of Quiquendone?"

"Too bad for them! It's in the interest of science. What would you say if dogs or frogs refused to participate in vivisection experiments?"

It's likely that if frogs and dogs were consulted, they would raise some objections, but Doctor Ox believed he had presented an irrefutable argument, as he sighed contentedly.

"After all, master, you are right," responded Ygène, as if completely convinced. "We couldn't have found better subjects than the people of Quiquendone for our experiment."

"We could not," the doctor said, articulating each word slowly.

"Have you checked the pulse of any of them?"

"Several hundreds."

"What is the average pulse rate you found?"

"Not more than fifty per minute. You see, Ygène, this is a town where there hasn't been a hint of an argument for a century, where carters don't swear, coachmen don't insult each other, horses don't run amok, dogs don't bite, cats don't scratch—a town where the police court has nothing to do all year round—a town where people don't get enthusiastic about anything, be it art or business—a town where gendarmes are a sort of myth, and where a legal indictment hasn't been drawn up for a hundred years—in short, a town where nobody has thrown a punch or exchanged a slap in the face for three centuries. You see, Ygène, this can't go on, and we must change it all."

"Absolutely! Absolutely!" exclaimed the enthusiastic assistant. "Have you analyzed the town's air, doctor?"

"I certainly have. Seventy-nine parts of nitrogen and twenty-one parts of oxygen, along with varying amounts of carbon dioxide and water vapor. These are the usual proportions."

"Good, doctor, good!" replied Ygène. "The experiment will be conducted on a large scale and will be conclusive."

"And if it is conclusive," added Doctor Ox triumphantly, "we will reform the world!"
ANNEX 2
INFORMED CONSENT FORM

You are formally invited to participate in a research study focused on evaluating the effectiveness of ultrasound in diagnosing sarcopenia among intensive care patients. By agreeing to participate, your regular treatment and care routines will remain unchanged.

You will undergo an ultrasound examination of your thigh and abdominal wall to assess muscle mass, and this data will be compared with previous studies (Computed Tomography, CT) performed as part of your ongoing medical evaluation. This procedure will not require any extra transfers, exposure to radiation, or cause any discomfort. If you provide consent for the use of your data, we will take the following precautions during data collection.

Your identity will be safeguarded, and any information or records that could identify you will be kept confidential. They will never be made public. In the event that the study's findings are presented at academic conferences or published in academic journals, your identity will be protected in accordance with the regulations outlined in the Ministry of Health.

If you request it, you will receive the results of the research conducted on you or your family member.

You have the right to withdraw from the study at any time without facing any negative consequences.

Your participation in this study is not expected to result in any direct personal benefits. However, the insights gained by the researchers through your involvement may contribute to a deeper understanding of the effectiveness of specific procedures and ultimately lead to enhanced care in the future.

If you have any questions about your rights in this study, you can reach out to the Institutional Review Board. They have thoroughly reviewed and approved this study to ensure your safety and rights are protected.

The study data will be available to the study investigators, the Institutional Review Board, and regulatory agencies overseeing research.

If you have any questions about the study, you can also contact the Principal Investigator.
Signing this consent form doesn't put aside any of your rights under Argentine law regarding civil liability for damages.

Please note that the Institutional Review Board may randomly select you for an interview to check your understanding and agreement with the study.

I hereby affirm that I have thoroughly read and comprehended this document. I have also had the opportunity to pose any necessary inquiries regarding the study. I am fully aware that my participation in this study is entirely voluntary. I hereby grant explicit authorization to main researcher and their associates to employ the data derived from the studies performed, and medical history records exclusively for research purposes.

DNI/CI/LE/LC/LC:
Patient's Signature:
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