Captain Nemo's Battery

Chemistry and the Science Fiction of Jules Verne

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1. The Father of "Scientifiction"

My high school English teacher always insisted that the first prerequisite of a good essay was a catchy title, and I flatter myself that my choice for this literary excursion is not half bad. Thus, it is with a great deal of reluctance that I must also immediately confess that it is misleading – misleading because of the existence of two very common and widespread myths about Jules Verne (figure 1).

The first and most fundamental of these is the myth that Verne wrote science fiction – indeed that he not only wrote it but actually invented the genre. This misconception appears to be due to none other than Hugo Gernsback, who in April of 1926 began publication of *Amazing Stories*, America's first science fiction pulp magazine. In his introductory editorial, Gernsback explained exactly what he meant by the kind of literature that he called "scientifiction" – a rather unmelodious term that has happily disappeared from the English lexicon (1):

By scientifiction I mean the Jules Verne, H. G. Wells and Edgar Allan Poe type of story – a charming romance intermingled with scientific fact and prophetic vision.

Figure 1. Jules Verne (1828-1905).

Later, Gernsback would single Verne out from this trio as the "patron saint" of the genre, and the masthead of the magazine would carry a drawing of Verne's tomb at Amiens as a symbol of his everlasting "immortality."

However, as Arthur Evans has shown in his book, *Jules Verne Rediscovered*, Verne never wrote science fiction – or at least not science fiction as the term is now understood (3). There are no alien monsters, no mysterious superforces, no time travel, no magic materials, and no heroines in skimpy futuristic attire in his novels. Rather, his works are a part of a tradition of French didactic writing known as the so-called "scientific novel" and were intended as a way of painlessly popularizing science for the lay public. They use an adventure story, combined with novel but not improbable applications of existing technology, as a framework into which are inserted sizable digressions on the facts of zoology, botany, geography, astronomy, physics, and occasionally even chemistry. In the course of his life, Verne would write over 60 of these novels.

The second common myth is that Verne wrote primarily for children and young adults. This is due to the fact that most English translations of his works have been butchered, with many of the didactic digressions on science – their very *raison d'etre* – having been either deleted or shortened to the point of becoming incomprehensible (3). It was only in the 1970s that Walter James Miller began publishing restored and annotated editions of some of Verne's classics, and it was the reading of Miller's restored edition of *Twenty Thousand Leagues under the Sea* (4) that first awoke my interest in Verne's use of chemistry.

2. Twenty Thousand Leagues under the Sea

First published in 1870, the novel opens with reports of a strange sea monster that has been terrorizing shipping in both the Atlantic and Pacific oceans. The famous French scientist, Professor Aronnax (figure 2), who has been visiting the United States accompanied by his trusty servant, Conseil, agrees to join a U.S. expedition to hunt down the monster. As a result of the expedition's first encounter with the creature, Aronnax, Conseil, and a Canadian harpooner named Ned Land are thrown overboard and become the uninvited guests of Captain Nemo aboard his submarine, the *Nautilus*, which is, of course, the source of the reports of the sea monster.

The first digression on chemistry comes when Aronnax awakens after his first night as a prisoner on the *Nautilus* [4]:

I breathed with difficulty. The heavy air seemed to oppress my lungs. Although the cell was large, we had evidently consumed a great part of the oxygen it contained. Indeed, each man consumes, in one hour, the oxygen contained in more than 176 pints of air and this air, charged with a nearly equal quantity of carbonic acid [carbon dioxide], becomes unbreathable. It became necessary to renew the atmosphere of our prison and no doubt of the whole submarine boat. That gave rise to a question in my mind. How would the commander of this floating dwelling proceed? Would he obtain air by chemical means, in getting by heat the oxygen contained in chlorate of potass [potassium chlorate], and in absorbing carbonic acid by caustic potash [potassium hydroxide]?

Figure 2. Professor Aronnax (modeled by the artist Riou on Jules Verne as a young man).

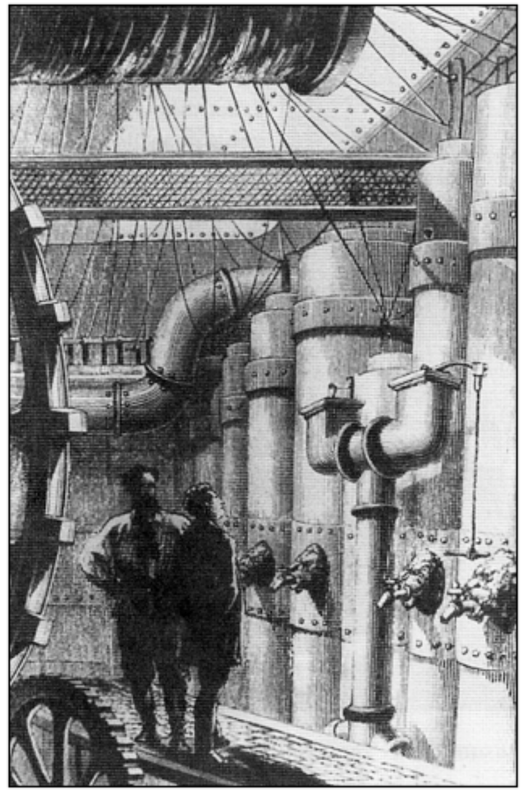

Figure 3. The engine room of the *Nautilus*.

In other words, Aronnax is proposing the use of the following standard reactions as a means of maintaining the air quality aboard the Nautilus (5):

$$2KClO_3(s) + heat \rightarrow 2KCl(s) + 3O_2(g) \quad [1]$$

$$2KOH(aq) + CO_2(g) \rightarrow K_2CO_3(aq) + H_2O(l) \quad [2]$$

In the end, however, he decides that this chemical scheme is impractical and that surfacing every 24 hours, like a whale, to replenish the air supply would be best, which is in fact exactly what Nemo does.

The most interesting digression on chemistry, however, occurs when Nemo shows Aronnax the engine room of the *Nautilus* and they discuss how the submarine is powered (figure 3). This is also the part of the novel that has been most flagrantly misrepresented, since in Walt Disney's 1954 movie adaptation – starring James Mason as Nemo, Paul Lukas as Aronnax, Kirk Douglas as Ned Land, and Peter Lorre grotesquely miscast as Conseil – it is implied that the *Nautilus* is powered by atomic energy and that Verne foresaw the nuclear age (6). However, Nemo is very explicit about the power source of his submarine (4):

There is a powerful agent, obedient, rapid, easy, which conforms to every use, and reigns supreme on board my vessel. Everything is done by means of it. It lights it, warms it, and is the soul of my mechanical apparatus. This agent is electricity.

We need to remember that in 1870 electricity was the power source of the future just as atomic energy was in 1954. And what is the source of Nemo's electricity? The answer is none other than chemical voltaic cells or batteries.

At the time Verne was writing, there were three important types of chemical voltaic cells (figure 4): the Grove cell, invented by the British chemist, William Grove, in 1839; the Bunsen cell, invented by the German chemist, Robert Bunsen, in 1841; and the dichromate or bichromate cell, apparently proposed by several different scientists in the period 1841-1842, including Bunsen, the German physicist Johann C. Poggendorff, and the Englishman Robert Warington (7, 8).

The Grove and Bunsen cells were both based on the same chemical reactions, namely, the oxidation of zinc at the anode:

$$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^- \qquad E° = +0.76\ V \quad [3]$$

and the reduction of nitric acid at the cathode for a net cell potential of 1.72 V:

$$NO_3^-(aq) + 4H^+(aq) + 3e^- \rightarrow NO(g) + 2H_2O(l) \quad E° = +0.96\ V \quad [4]$$

the colorless nitrogen oxide by-product quickly reverting to reddish-brown nitrogen dioxide on contact with air (9). The sole difference between the two was that Bunsen had replaced the expensive platinum cathode of Grove's original cell with an inexpensive one made of porous coke.

Grove or Bunsen cells would have been impractical on a submarine because of the necessity of venting the NO_2 fumes, so the best choice would have been the dichromate cell, which substituted the reduction of the dichromate anion for the reduction of nitric acid at the cathode:

$$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l) \quad E° = +1.33\ V \quad [5]$$

and in the process also increased the net standard potential of the cell from 1.72 V to 2.09 V (10).

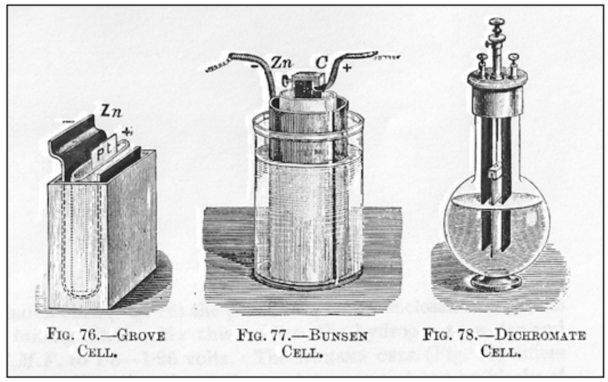

Figure 4. *From left to right:* Typical 19th-century Grove, Bunsen, and dichromate cells.

Nemo, however, has a fetish about obtaining all of his material needs from the ocean and, when Aronnax asks him where he gets the zinc for his batteries, he replies that he doesn't use zinc, but rather sodium metal extracted from seawater (4):

So it is this sodium that I extract from sea water, and of which I compose my ingredients ... Mixed with mercury, sodium forms an amalgam which can take the place of zinc in Bunsen batteries. The mercury is never consumed, only the sodium is used up, and that is supplied from sea water. Moreover, sodium batteries are the most powerful, since their motive force is twice that of zinc batteries.

Though Verne does not cite quantitative $E°$ values, it is interesting to note that use of modern data shows that Verne's estimate of the "idealized" relative strength of Captain Nemo's sodium/dichromate cell, versus that of the conventional zinc/dichromate cell, is accurate (i.e., 4.04 V versus 2.09 V) provided one uses the standard reduction potential for pure sodium metal [11]:

$$Na(Hg) \rightarrow Na^+(aq) + e^- \qquad E° = +2.71\ V \quad [6]$$

This strongly suggests that Nemo's cell was based on an actual experimental account published in the scientific literature of the period. Though I have not been able to trace the original reference, the most likely candidates for all of Verne's information on electrochemistry, as we will see in greater detail later, are the writings of the French electrochemist Antoine-Cesar Becquerel (1788-1878). In passing, it is also of interest to note that Antoine-Cesar was the grandfather of Antoine-Henri Becquerel, best known for his discovery of radioactivity in 1896 (12).

Aronnax then raises the question of how Nemo extracts his sodium (4):

I can see how sodium serves your needs. And there is plenty of it in sea water. But you have to manufacture it, to extract it. How? You could use your batteries to extract it, but it seems to me you would need more sodium for such equipment than it would be extracting. I mean, would you not consume more than you produce?

In short, Aronnax is suggesting that Nemo use his batteries to electrolyze seawater:

$$\text{electricity} + 2NaCl(aq) \rightarrow 2Na(Hg) + Cl_2(g) \quad [7]$$

though he immediately realizes that such a process would violate the conservation of energy. Nemo replies:

No, I do not use batteries, at least not for the extraction process. I use heat generated by coal.

This answer is ambiguous but probably refers to the production of sodium via the carbon reduction of sodium carbonate, which was the standard method of manufacture in the 1870s (13):

$$Na_2CO_3(s) + 2C(s) \rightarrow 2Na(g) + 3CO(g) \quad [8]$$

In keeping with his theme of "all from the sea," Nemo implies that he mines the necessary coal at the bottom of the ocean. However, the need to convert NaCl into Na_2CO_3, which requires use of either the Leblanc or the Solvay process, as well as the necessity of manufacturing the sulfuric acid and potassium dichromate required for the cathode reaction, strongly suggest that Nemo must have a land base somewhere to carry on these processes, and, as we will see later, this is indeed the case.

Note that not only is Nemo's claim of "all from the sea" chemically weak in this case, it is also geologically weak, as the coal that he mines on the bottom of the ocean is certainly not a product of the ocean itself but the result of the submergence of conventional land-based coal deposits formed from the decomposition of prehistoric land-based plant life. Indeed, in a later chapter entitled "The Submarine Coal Mines," Verne as much as admits that this is the case, though Nemo's submerged coal deposits are rather improbably located in the crater of an extinct volcano which is connected to the ocean via an underwater system of caves. Prior to large-scale industrialization and mining of coal in the eighteenth century, chunks of coal were often found along ocean beaches, where they were collected by women and children. Though this material was actually broken off from submerged shore-line coal outcroppings and washed ashore by wave action, it appeared to the common man to be a product of the ocean and was consequently known as "sea coal." This incorrect association was still prevalent among the uneducated classes in the nineteenth century and is exploited by Nemo in the course of his discussion with Aronnax.

One final point of interest. When Nemo takes Aronnax for a walk on the ocean floor in one of his special diving suits, Aronnax asks Nemo what he uses to light his way in the blackness of the ocean abyss (figure 5). Nemo replies that he uses one of his special sodium batteries and a "Ruhmkorff apparatus" (i.e., an induction coil) connected to a special lantern (4):

In this lantern is a spiral glass which contains a small quantity of carbonic gas [carbon dioxide]. When the apparatus is at work this gas becomes luminous, giving out a white and continuous light.

What Nemo is describing is, of course, a Geissler tube – a sort of crude precursor of the fluorescent light (figure 6) – and this same contrivance is used to light the interior of the Nautilus. H. W. Meyer in his book, *A History of Electricity and Magnetism*, describes a similar device (14):

About the year 1895, D. McFarlan Moore of the United States began experimenting with long glass tubes filled

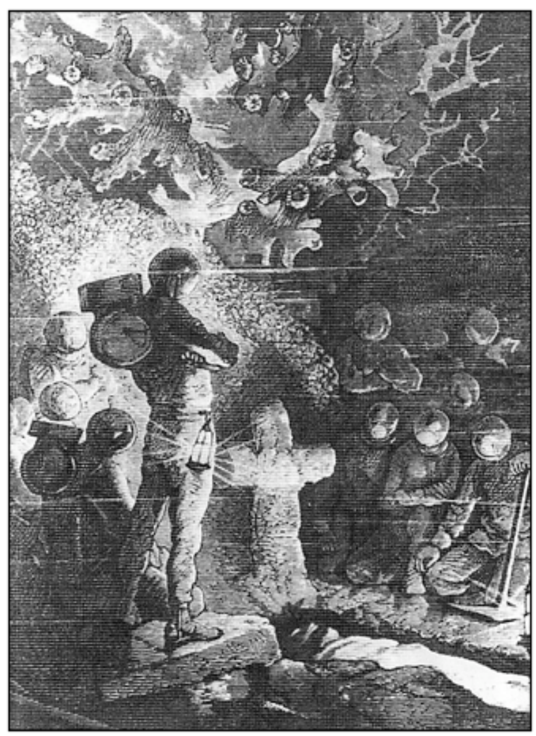

Figure 5. Captain Nemo's electric carbon dioxide lamps at work.

with carbon dioxide gas, which gave off a good quality white light when a current of electricity was sent through them at relatively high voltage. Beginning about the year 1904, many installations of such tube lighting were made, especially in stores.

So it would appear that Verne was prophetic about new applications of existing technology after all!

3. The Mysterious Island

This brings us to the sequel to *Twenty Thousand Leagues under the Sea*, the three-part novel *The Mysterious Island*, which was published in 1874, four years after *Twenty Thousand Leagues* (15). Set during the American Civil War, the story involves a group of Union prisoners held in Richmond, Virginia, who escape the city in March of 1865 in a Confederate observation balloon in the midst of a violent storm. The storm blows them west across the United States and out into the Pacific Ocean, where they crash on an uncharted island. Events eventually reveal that this island is one of Captain Nemo's land bases, hinted at in *Twenty Thousand Leagues*, but it is the first two parts of the novel that are of most interest to us.

Unlike the castaways in Johann Wyss's famous novel *The Swiss Family Robinson*, who have access to the cargo of their wrecked ship and are amply supplied with tools, provisions, guns, and domestic animals, the castaways in Verne's novel have only the clothes on their backs, the knowledge in their heads, and a single match – the wrecked balloon having been blown back out to sea (16). What follows might be appropriately called "The Chemical Swiss Family Robinson." It is a paean to the now defunct advertising phrase "better things for better living through chemistry" and a celebration of the engineer as hero.

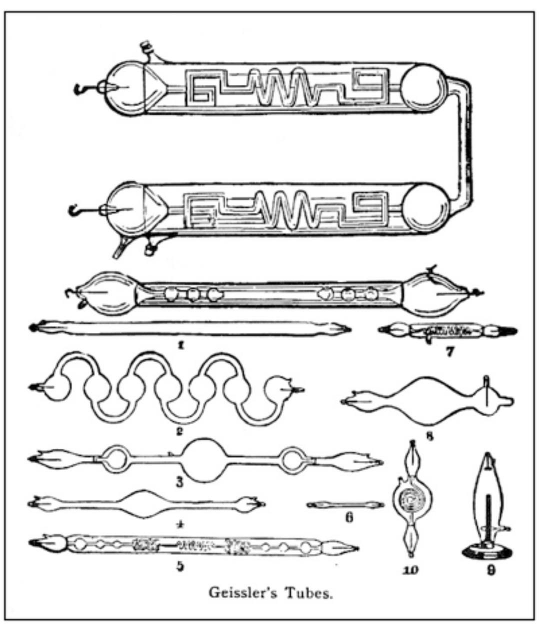

Figure 6. Typical 19th-century Geissler tubes.

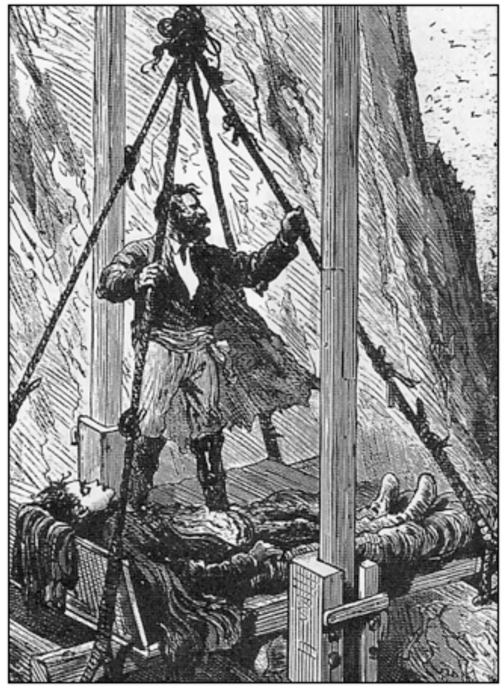

Figure 7. Cyrus Harding, the engineer-hero of *Mysterious Island*.

The engineer in question is one Cyrus Harding (figure 7), and the worship of his fellow castaways is apparent from the beginning of the novel (15):

The engineer was to them a microcosm, a compound of every science, a possessor of all human knowledge. It was better to be with Cyrus Harding on a desert island than without him in the midst of the most flourishing town in the United States. With him they could want nothing; with him they would never despair.

The island itself, which the castaways name "Lincoln Island" in a display of patriotism, is of volcanic origin and is particularly rich in minerals. What follows is a partial chronology of the rise of "chemical man" on Lincoln Island, and it goes without saying that in each instance Verne inserts a short digression painlessly describing for the reader the chemistry involved.

Within eight days of their arrival (i.e., by the 31st of March) Cyrus Harding has discovered pyrites, clay, limestone, and coal deposits on the island. These materials are quickly put to use. Between the 2nd and 15th of April, the castaways manufacture bricks from fired clay and make mortar from stone and lime, the latter being produced by thermally decomposing limestone and slaking the resulting quicklime with water (13, 15):

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g) \qquad [9]$$

$$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s) \qquad [10]$$

The bricks and mortar are then used to construct a pottery kiln (figure 8), which the castaways use to fire crude pots, dishes, etc.

By the 17th of April, Harding has added niter (KNO_3) and iron ore to his mineralogical discoveries and begins the construction of a large bellows using the skin of a dead seal and clay pipe manufactured in the pottery kiln. Between the 21st of April and the 5th of May, the resulting forced-air furnace is used, along with the iron ore and the coal discovered earlier, to produce iron and steel (figure 9):

$$Fe_3O_4(s) + 2C(s) \rightarrow 3Fe(s) + 2CO_2(g) \qquad [11]$$

which is then employed to make crude saws, hammers, nails, axes, hatchets, chisels, spades, and pickaxes.

Between the 7th and 18th of May, Harding extracts green vitriol ($FeSO_4 \bullet 7H_2O$) and alum from schistose pyrites and soda (Na_2CO_3) from the ashes of marine plants. He then uses the soda to produce soap and glycerin by saponifying the fat of a dugong that has been mysteriously killed after attacking the castaway's pet dog, Top:

Figure 8. The castaways make pottery.

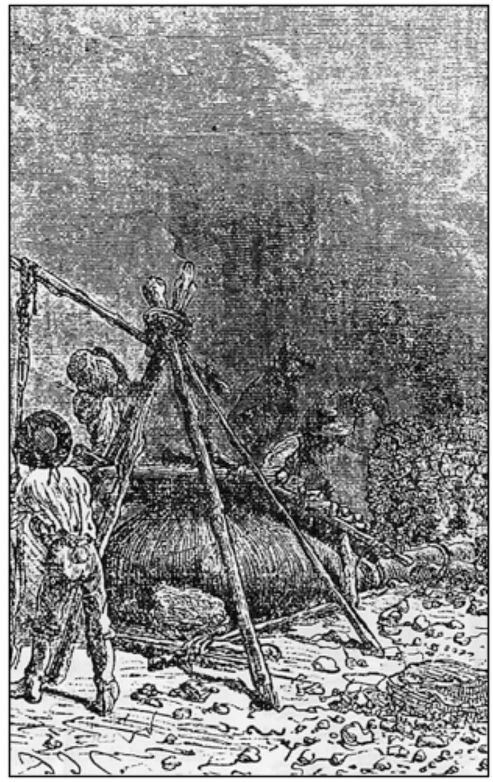

Figure 9. The castaways make iron and steel.

$$Na_2CO_3(s) + H_2O(l) \rightarrow 2Na^+(aq) + OH^-(aq) + HCO_3^-(aq) \qquad [12]$$

$$C_3H_5(OOCR)_3(s) + 3OH^-(aq) \rightarrow C_3H_5(OH)_3(l) + 3RCOO^-(aq) \qquad [13]$$

$$RCOO^-(aq) + Na^+(aq) \rightarrow Na(OOCR)(s) \qquad [14]$$

Given that Harding has already manufactured slaked lime (equations 9-10), it is surprising that he doesn't use it to convert his soda into caustic soda (NaOH):

$$Ca(OH)_2(aq) + Na_2CO_3(aq) \rightarrow 2NaOH(aq) + CaCO_3(s) \qquad [15]$$

since this would have made a much more effective saponifying agent:

$$C_3H_5(OOCR)_3(s) + 3NaOH(aq) \rightarrow C_3H_5(OH)_3(l) + 3Na(OOCR)(s) \qquad [16]$$

On the 20th of May, Harding, using chemical apparatus made in the pottery kiln, manufactures sulfuric acid via the destructive distillation of the green vitriol:

$$2FeSO_4{\bullet}7H_2O(s) \rightarrow H_2SO_4(l) + Fe_2O_3(s) + 13H_2O(l) + SO_2(g) \quad [17]$$

He then uses this, along with the niter discovered earlier, to produce concentrated "azotic acid" (nitric acid):

$$H_2SO_4(l) + 2KNO_3(s) \rightarrow K_2SO_4(s) + 2HNO_3(l) \quad [18]$$

and this, in turn, is used, in combination with the sulfuric acid and glycerin, to make nitroglycerin (figure 10), which is subsequently used for various large-scale engineering projects on the island:

$$C_3H_5(OH)_3(l) + 3HNO_3(l) \rightarrow C_3H_5(NO_3)_3(l) + 3H_2O(l) \quad [19]$$

On the 5th of June, Harding manufactures candles from seal fat, lime, and sulfuric acid and, finally, to round out their first year on the island, he extracts sugar from a local variety of the maple tree on the 25th of August.

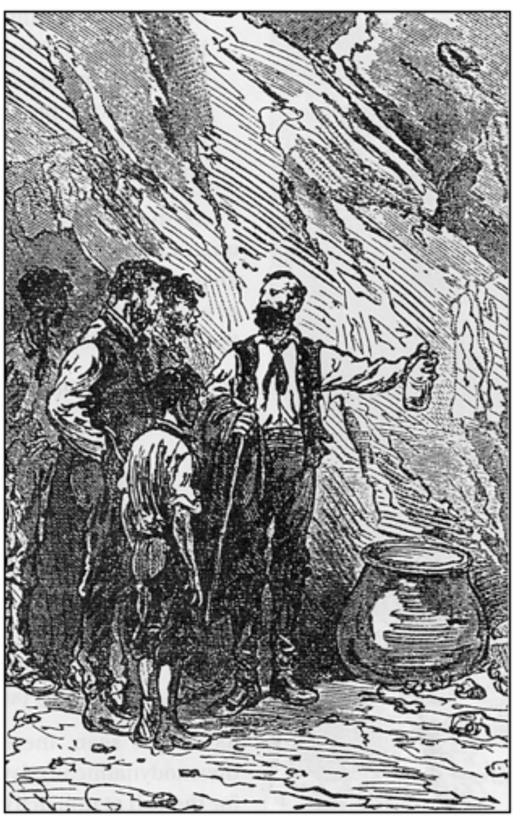

Figure 10. "It's nitroglycerin!"

In early January of their second year on the island, Harding uses his supply of sulfuric and nitric acids, in combination with native plant cellulose, to manufacture pyroxylin or guncotton. On the 28th of March, he makes glass using sand, chalk produced from limestone, and soda extracted from seaweed, and in January of their third, and last, year on the island, he decides to build an electric telegraph in order to facilitate communication between the various outposts that the castaways have established. This brings Verne back to the subject of electricity and chemical batteries. In this case, his choice is an unusual acid/alkaline battery invented in 1820 by the French physicist and electrochemist Antoine Cesar Becquerel, whom we met earlier in connection with Captain Nemo's sodium cell. Verne describes Becquerel's cell in great detail and in terms which strongly suggest that he has read Becquerel's original account (17, 18):

Cyrus Harding, after mature consideration, decided to manufacture a very simple battery ... in which zinc only is employed [obtained from the lining of a sea chest in which Captain Nemo has anonymously left supplies for the castaways]. The other substances, azotic [nitric] acid and potash [potassium carbonate], were all at his disposal. The way in which the battery was composed was as follows, and the results were to be attained by the reaction of acid and potash on each other. A number of glass bottles were made and filled with azotic acid. The engineer corked them by means of a stopper through which passed a glass tube, bored at its lower extremity, and intended to be plunged into the acid, by means of a clay stopper secured by a rag. Into this tube, through its upper extremity, he poured a solution of potash, previously obtained by burning and reducing to ashes various plants, and in this way the acid and potash could act on each other through the clay [see figure 11].

Cyrus Harding then took two slips of zinc, one of which was plunged into the azotic acid, the other into the solution of potash. A current was immediately produced, which was transmitted from the slip of zinc in the bottle to that in the tube, and the two slips having been connected by a metallic wire, the slip in the tube became the positive pole and that in the bottle the negative pole of the apparatus. Each bottle, therefore, produced as many currents as, united, would be sufficient to produce all the phenomena of the electric telegraph.

As in the case of Verne's paraphrase, Becquerel's own account of his cell tells us little about its chemistry other than the fact that dioxygen gas is generated at the anode, probably via the reaction (18):

$4CO_3^{2-}(aq) + 2H_2O(l) \rightarrow$
$4HCO_3^-(aq) + O_2(g) + 4e^-$ $E° = -0.62$ V [20]

while Benjamin, who refers to it as the "Becquerel Oxygenated Gas Cell" in his 1893 treatise on the voltaic cell, claims that the cathode reaction corresponds to the reduction of the concentrated nitric acid to ammonium nitrate (19):

$10H^+(aq) + NO_3^-(aq) + 8e^- \rightarrow$
$NH_4^+(aq) + 3H_2O(l)$ $E° = +0.88$ V [21]

As can be seen, these half-reactions give us a thermodynamically favorable net potential of only +0.26 V for the cell at unit activities.

I must confess, however, to having certain reservations about representing the cathode reaction in terms of equation 21, since Latimer reports that the reduction of nitric acid to nitric oxide, as observed in the case of the Grove cell, is slightly more favorable (20):

$4H^+(aq) + NO_3^-(aq) + 3e^- \rightarrow$
$NO(g) + 2H_2O(l)$ $E° = +0.96$ V [22]

This would give us a favorable net potential of around +0.34 V at unit activity.

In his original account, Becquerel used platinum, rather than zinc, for his electrodes, and a quick replication of the cell in my laboratory, using a saturated potassium carbonate solution and 16 M nitric acid, gave a potential of around +0.87 V, provided that one used either platinum or nichrome wire electrodes, though I could observe no gas evolution at either electrode. This is not bad agreement given the enormous deviations from unit activities. Unfortunately, Verne's substitution of zinc in place of platinum for his electrode material appears to be the source of a serious defect in his scheme, since I found that all attempts to use zinc for the electrode in the nitric acid half-cell led to its rapid destruction, regardless of how dilute the acid (21).

Though Verne does not explicitly spell out his reasons for choosing this rather unusual cell, it appears to be related to the fact that the castaways have access to a continuous supply of only one metal – iron. As a consequence, they are unable to construct batteries based on the chemical difference between two metal electrodes, since that would lead to the net consumption of their strictly limited supply of zinc from the lining of the sea chest. Verne emphasizes this circumstance when he discusses their substitution of iron for lead in making shot for their guns and iron for copper when making the wires for their telegraph. If this is, in fact, the true reason for Verne's choice of a cell having two identical metal electrodes, then it is elegant testimony

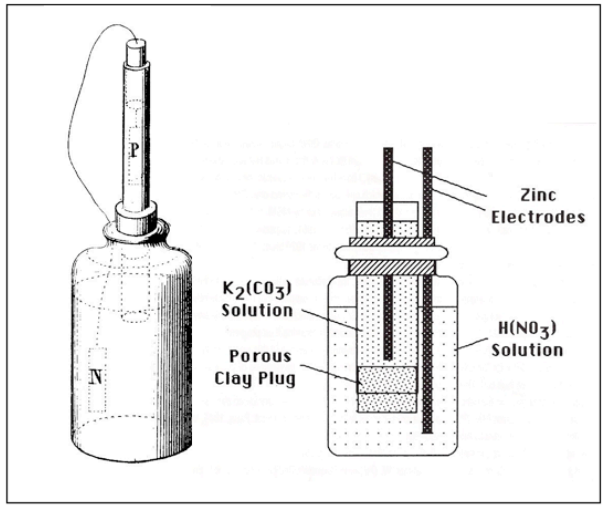

Figure 11. *Left:* Becquerel's original acid-alkali cell. *Right*: a reconstruction of the modified acid-alkali cell as described by Cyrus Harding in *The Mysterious Island*.

to the care with which he planned the scientific details of his novels, even though, as already indicated, he negated this advantage via his ill-advised substitution of zinc in place of platinum.

Based on his comments in both *Twenty Thousand Leagues under the Sea* and *The Mysterious Island*, there is little doubt that electricity was Verne's favorite choice as the power source of the future. Nevertheless, he was not unaware of society's ultimate dependence on fossil fuels, and at one point in *The Mysterious Island* he has the castaways discuss the possibility of a future energy crisis. A castaway by the name of Gideon Spilett begins this discussion by asking Harding how he is able to square the consequences of such a crisis with his habitually optimistic view of mankind's technological future (15):

But now, my dear Cyrus, all this industrial and commercial movement to which you predict a continual advance, does it not run the danger of being sooner or later completely stopped ... by the want of coal, which may justly be called the most precious of minerals.

Harding agrees but is not upset, as he foresees a future in which coal will be replaced by an alternative fuel (15):

Water ... but water decomposed into its primitive elements ... and decomposed, doubtless, by electricity which will then become a powerful and manageable force, for all great discoveries, by some inexplicable law, appear to agree and become complete at the same time. 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. Some day the coal-rooms of steamers and the tenders of locomotives will, instead of coal, be stored with these two condensed gases, which will burn in the furnaces with enormous caloric power. There is, therefore, nothing to fear. As long as the earth is inhabited it will supply the wants of its inhabitants, and there will be no want of either light or heat as long as the productions of the vegetable, mineral, or animal kingdoms do not fail us. I believe that when the deposits of coal are exhausted we shall heat and warm ourselves with water. Water will be the coal of the future.*

In this selection Verne exploits the known difference in the heats of combustion per unit mass of dihydrogen gas versus carbon:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l) \qquad \Delta H = -142.93 \text{ kJ/g } H_2 \quad [23]$$

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H = -32.79 \text{ kJ/g C} \quad [24]$$

but unhappily fails to tell us how we are going to generate the electricity necessary to electrolyze all of this water in the first place.

4. Other Examples

Several of Verne's other novels also contain brief digressions on chemistry (22). Thus, in his famous account of space travel, *From the Earth to the Moon* (1865), he discusses the manufacture of aluminum using the Deville process, the manufacture of guncotton, and various chemical schemes for generating dioxygen gas and for absorbing carbon dioxide aboard his proposed spacecraft. In his equally famous novel, *Journey to the Center of the Earth* (1864), he discusses various chemical theories of volcanism and makes use of the same carbon dioxide Geissler lamps later used by Captain Nemo in *Twenty Thousand Leagues*. Likewise, Captain Nemo's sodium cell makes a second appearance in the 1886 novel, *The Clipper of the Clouds* – this time as the power source for a lighter-than-air craft called the "Albatross," which is commanded by a Nemo-like clone by the name of Robur. In the short story *Dr. Ox's Experiment* (1874), Verne once more returns to the subject of various alternative methods of generating dioxygen gas and the effects of increased dioxygen concentrations on the physiological and psychological behavior of living organisms, while in the novel, *The Southern Star Mystery* or *The Star of the South* (1884), he deals with the synthesis of artificial diamonds. But none of these chemical digressions come close to rivaling the chemical versatility of the castaways in *The Mysterious Island*.

In February of 1873, while still in the process of planning the details of *The Mysterious Island*, Verne wrote a letter to his friend and publisher, Pierre-Jules Hetzel, in which he referred to his new project as a "roman chimique" – a chemical romance – and confessed that he had been spending his time doing background research "among Professors of Chemistry and in chemical plants" (23). Surely, it is time that chemists and teachers of chemistry return the compliment and spend some time with Verne enjoying what must surely be the only known example of that most elite of literary genres – the *roman chimique*.

5. References and Notes

1. Quoted in J. Gunn, *Alternate Worlds: The Illustrated History of Science Fiction*, A&W Visual Library: Englewood Cliffs, NJ, 1975, p. 120. See also S. Moskowitz, *Explorers of the Infinite: Shapers of Science Fiction*, Hyperion Press: Westport, CT, 1974, Chapter 19.

2. A. B. Evans, *Jules Verne Rediscovered: Didacticism and the Scientific Novel*; Greenwood Press: Westport, CT, 1988. Though intended for adults and far better researched, Verne's novels actually have more in common with such juvenilia as the Tom Swift series than with modern science fiction.

3. A good example of a butchered version of *Twenty Thousand Leagues* can be found in A. K. Russell, Ed., *Jules Verne, Classic Science Fiction: Three Complete Novels*, Castle Books: Secaucus, NJ, 1981. Though care was taken in this collection and in its earlier companion volume (A. K. Russell, Ed., *The Best of Jules Verne: Three Complete Novels*, Castle Books: Secaucus, NJ, 1978) to reproduce all of the 19th-century French illustrations to the novels, most of which had been deleted from the original English editions, similar care was not taken with the text. As a consequence, the version of *Twenty Thousand Leagues* which it reprints is missing virtually all of the technical passages found in the version given in reference 4 and which I quote in this article.

4. W. J. Miller, Ed., *The Annotated Jules Verne: Twenty Thousand Leagues under the Sea*, Crowell: New York, 1976, pp. 54-55, 75-77, 100.

5. Verne refers to these reactions again in a later chapter entitled "Want of Air" in which the *Nautilus* becomes trapped under the polar ice and the crew is caught in a frantic struggle to free her before they die of suffocation.

6. In addition to the 1954 Disney film, there are two earlier silent-film versions of *Twenty Thousand Leagues Under the Sea*, one made by Universal Studios in 1916 and the other by the French director George Melies in 1907.

7. For historical background on these batteries, see (a) L. Dunsch, *Geschichte der Elektrochemie*, Deutscher Verlag für Grundstoffindustrie: Leipzig, 1985; pp. 56-57; (b) A. Ritter von Urbanitzky, *Electricity in the Service of Man: A Popular and Practical Treatise on the Applications of Electricity in Modern Life*, Cassell: London, 1886, pp. 106-115; (c) T. Lowry, *Inorganic Chemistry*, Macmillan: London, 1931, pp. 208-209; (d) P. Benjamin, *The Voltaic Cell: Its Construction and Capacity*, Wiley: New York, 1893; and (e) J. T. Stock, "Bunsen's Batteries and the Electric Arc," *J. Chem. Educ.*, **1995**, *12*, 99-102.

8. There seems to be considerable confusion in the literature as to who actually invented the dichromate cell. Kevin Desmond, in his reference work, *A Timetable of Inventions and Discoveries* (Evans: New York, 1986), claims that it was invented by Heinrich Ruhmkorff in 1855; Dunsch (reference 7a) attributes it to Robert Bunsen in 1842; Benjamin (reference 7d) claims that it was developed by Johann C. Poggendorff the same year; and Stock (reference 7e) claims that it was mentioned in passing by Bunsen in 1841 and discussed in detail by Robert Warington in 1842. Of these four authors, only Stock provides original literature citations to support his claims.

9. The potentials quoted correspond to unit activities. In practice, the nitric acid in the cells was much more concentrated, and Benjamin (reference 7d) reports actual operating values of 1.60-1.90 V for the Grove cell and 1.93-1.96 V for the Bunsen cell, whereas Lowry (reference. 7c) reports values of 180-1.96 V for the Grove cell.

10. The potentials quoted correspond to unit activities. In practice, the solutions were much more concentrated. Benjamin (reference 7d) reports actual operating values of 1.92-2.2 V for the dichromate cell, whereas Lowry (reference 7c) reports a value of 2.0 V.

11. The "idealized" potentials quoted are based on unit activities. The actual voltage of Nemo's sodium cell would depend on the activity of the sodium in the amalgam. The value of 1.957 V for the sodium amalgam half-cell reported by Dietrick et al. (H. Dietrick, E. Yeager, F. Hovorka, *The Electrochemical Properties of Dilute Sodium Amalgams*; U.S. Office of Naval Research, Technical Report 3; Western Reserve University: Cleveland, OH, 1953) would give an overall value of 3.29 V for the cell, which is only about one and half times that of the dichromate cell. This suggests that Nemo was using very concentrated amalgams in his cells.

12. The only nineteenth-century estimates reported by Benjamin (reference 7d) for the half-cell potentials of sodium amalgams are those originally reported by Antoine-Cesar Becquerel and his son, Alexandre-Edmond Becquerel, in their 1855 volume *Traité expérimental de l'électricité et du magnetismé*. These range from 2.303 to 2.334 V, which again gives an net potential that is only about one and half times that of the standard dichromate cell.

13. A nineteenth-century account of the chemistry underlying all of the manufacturing processes described by Verne in both *Twenty Thousand Leagues under the Sea* and *The Mysterious Island* can be found in *The Encyclopaedia of Chemistry, Theoretical, Practical, and Analytical as Applied to the Arts and Manufactures* (2 volumes; Lippincott: Philadelphia, 1879) under the entries for sodium, pottery, cement, iron, steel, soap, alum, sulfuric acid, nitric acid, nitroglycerin, candles, sugar, guncotton, and glass.

14. H. W. Meyer, *A History of Electricity and Magnetism*, MIT Press: Cambridge, MA, 1971, pp. 174-175.

15. J. Verne, *The Mysterious Island*, Burt: New York, no date; pp. 57, 90, 94-95, 96, 107-113, 124-126, 126-127, 145-146, 162-163, 225-226, 234-235, 250-252, 311-312. This is one of many inexpensive rip-off editions of Verne. Other English translations of this novel use the name Cyrus Smith, rather than Cyrus Harding, for the engineer hero. Unfortunately, I have been unable to examine a French edition and so cannot tell which rendition is the correct one. *The Mysterious Island* has been filmed three times: once by MGM in 1929, and twice by Columbia Pictures, in 1951 and 1961, respectively. Captain Nemo was played by Lionel Barrymore in the 1929 production and by Herbert Lom in the 1961 production.

16. Later in the novel, the resources of the castaways are further augmented by accidental finds of supplies that have apparently washed ashore from wrecked ships but which are, in fact, provided by Captain Nemo, who has been secretly observing their progress.

17. There are some obvious confusions in this quote, which again reflect the low quality of most English translations of Verne's novels emphasized by Miller in reference 4.

18. A. C. Becquerel, *Traité de physique considérée dans ses rapports avec la chimie et les sciences naturelles*, Didot: Paris, 1844; Vol. 2, pp. 300-301.

19. Benjamin (reference 7d), p. 267.

20. W. Latimer, *Oxidation Potentials*, 2nd ed., Prentice-Hall: Englewood Cliffs, NJ, 1952, p. 93. For consistency, this reference has been used to calculate all other thermodynamic values cited in the article.

21. Verne may have been misled by Becquerel's remark in reference 18 that the potential of his cell could be increased by substituting zinc for platinum at the anode. He may not have realized that a similar substitution would not work for the cathode, nor that the increase in the potential is due, in the case of the anode substitution, to oxidation of the zinc.

22. I have discussed several of these in greater detail in the essays "Sir Humphry Davy and the Hollow Earth: The Geochemistry of Journey to the Center of the Earth" and "Tom Swift Among the Diamond Makers: Synthetic Diamonds in Fact and Fiction" to be published in future issues of *The Chemical lntelligencer*.

23. Quoted in C. N. Martin, *La vie et l'oeuvre de Jules Verne*; Michel de l'Ormeraie: Paris, 1978; p. 200.