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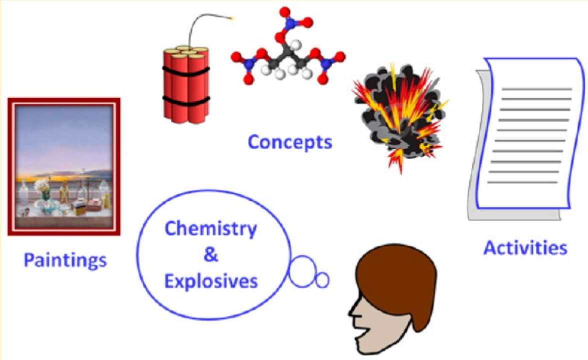
Chemistry and Explosives: An Approach to the Topic through an Artistic and Historical Contribution Made by a Spanish Global Explosives Supplier

Gabriel Pinto*,† and Amalio Garrido-Escudero‡

†Grupo de Innovación Educativa de Didáctica de la Química, E.T.S. de Ingenieros Industriales, Universidad Politécnica de Madrid, Madrid, Spain 28006

‡Environmental Engineering and Toxicology Department, Catholic University of San Antonio, Guadalupe, Murcia, Spain 30107

ABSTRACT: We present ideas about how to incorporate discussion of a paintings collection in chemistry classrooms. Specifically, it is a collection of paintings that have illustrated calendars since 1900, from a traditional Spanish explosives' company (founded by Alfred Nobel and now known as Maxam). The case is discussed in relation to the "chemistry in context" literature. Through suggested activities, students are encouraged to discuss a wide variety of topics of general chemistry (nomenclature, chemical reactions, stoichiometry, etc.) and other topics, such as chemistry of explosives, history and ethics of science and technology, the origin of the Nobel prizes, introduction to the chemical industry, chemistry of fireworks, and environmental chemistry, among others.



KEYWORDS: *General Public, High School/Introductory Chemistry, History/Philosophy, Public Understanding/Outreach, Applications of Chemistry*

INTRODUCTION

Most people, including students of different levels of chemistry education and even a number of teachers, perceive everything related to explosives with a certain negative connotation. Indeed, apart from its unfortunate use for wars and terrorism, we can say that thanks to explosives humanity has made important progress in the last 150 years on issues such as mining and construction of railways, highways, ports, bridges, large buildings, tunnels, canals, water dams and so on. As explained in this *Journal* in 1928, explosives may be "formidable materials of wars" but also "powerful auxiliaries of peace".[1] Furthermore, the use of explosives in mining and public works, compared with mechanical means—for instance, for digging and grinding—reduces hydrocarbon consumption and consequently minimizes greenhouse gases emissions. Explosives are an important family of products obtained by a significant sector of the chemical industry.

A collection of paintings that has illustrated calendars since 1900, distributed as advertisements of a traditional Spanish civil explosives company (founded by Alfred Nobel more than 140 years ago and now known as Maxam), is presented in this paper. These artworks by Spanish painters of the first level helped popularize this company among many sectors of society (e.g., hunting enthusiasts), with a strong footing throughout Spain. Nowadays, Maxam is an industrial group that manufactures civil explosives, cartridges, and gunpowder for sports hunting and chemicals and fertilizers, among other products.

Interesting papers on the chemistry in the manufacture of paints and pigments have been published in this *Journal*.[2−5] This article goes beyond paints to paintings, exploring how particular artistic products of painting, used for over a hundred years by Maxam in advertising calendars, can be used to spark students' thinking about the explosives industry in particular and, in some way, chemistry in general. This represents an opportunity to link chemistry and art in the classroom, and to introduce and to discuss different topics of general chemistry (i.e., nomenclature, stoichiometry, chemical reactions, thermochemistry, and properties of substances), chemical explosives, history of science and technology, and other topics. We will explain details for incorporating this information into classroom activities with potential use for high school chemistry, general chemistry, chemistry and art, and liberal education chemistry courses.

There is a continued need for exploring ways to improve educational connections between chemistry and art, as demonstrated by recent publications in this *Journal*, where the paper by André is a very good example that includes additional bibliography on the matter.[6]

This general claim is often heard that science education, and particularly chemistry, remains unpopular around secondary

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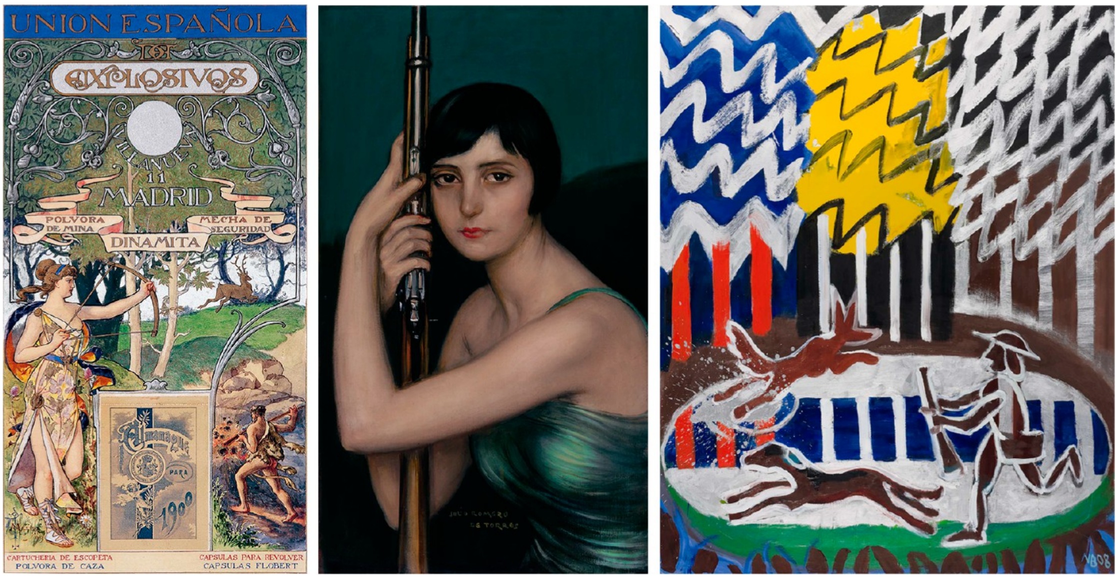

Figure 1. Paintings related to hunting. From left to right: *Diana the Huntress* (Arturo Mélida, 1900), *Hunting Shotgun* (Julio Romero de Torres, 1929), and *Hunting Scene* (Juan Navarro Baldeweg, 2010). Reproduced with permission of Maxam.

school students. They are insufficiently interested by science subjects, among other reasons, because they perceive science education as "irrelevant" both for themselves and for the society in which they live.[7] It is well recognized that making science learning relevant both to the learner personally and to the society should be one of the key goals of science education. But, as mentioned recently by Stuckey et al.,[8] for over decades the term "relevant" has been used with widely variant meanings. They point out three clear dimensions of the term "relevance":

- For preparing students for potential careers in science and technology
- For understanding science phenomena
- For students to become effective future citizens in the society in which they live

Furthermore, these authors outlined that the term "relevance" is broader in science education than the meaning of other terms like "interest" or "meaningfulness".[8] They also found three different dimensions for "relevance" (individual, societal, and vocational) as well as present−future and intrinsic−extrinsic components.

Conversely, in relation to the chemistry education framework by Sjöström and Talanquer,[9] the case of explosives and art discussed in this paper implies an humanistic approach in chemistry teaching, from simple contextualization to socio-scientific orientation. Among other models that seek to integrate humanistic and social components in the conceptualization of chemistry teaching, Sjöström proposed a tetrahedron,[10] which is based on Johnstone's triangle (the "triplet relationship"),[11] capturing the multidimensionality of pure chemistry. The bottom triangle at the base of the tetrahedron includes aspects of chemistry teaching: macro (macroscopic properties of substances), submicro (the submicroscopic models used to describe, explain, and predict chemical properties), and symbolic (the symbolic representations developed to represent chemical concepts). The top of the tetrahedron represents the human element, including both relevant contexts and productive practices. Sjöström proposed that tetrahedron can be subdivided into three levels: applied chemistry (level 1), socio-cultural context (level 2), and a critical−philosophical approach (level 3).[10]

THE INVENTION OF DYNAMITE BY ALFRED NOBEL AND A BRIEF HISTORY OF MAXAM

Nitroglycerin (initially called *pyroglycerine*) was invented by the Italian chemist Ascanio Sobrero in 1847, by reacting glycerin with a mixture of nitric and sulfuric acids.[1,12,13] Alfred Bernhard Nobel (Stockholm, 1833−San Remo, 1896) would become acquainted with Sobrero and his discovery, during his training in the Parisian laboratory of Théophile-Jules Pelouze, between 1850 and 1852. Nobel, who also visited other countries such as United States during these two years, was already familiar with the application of chemistry to create explosive products (his father invented underwater mines and had a factory of explosives in St. Petersburg).[14] To make nitroglycerin a product safe for fabrication, handling, and transportation, Nobel developed inventions such as new detonators. A few accidents at their plants, like the one held in Stockholm in 1864 (where five people were killed, including Alfred's youngest brother), led him to conclude that the solution for reducing risks of manipulation might be to dilute the nitroglycerin (liquid at room temperature) in some type of porous material. In 1866 he patented dynamite.[14] He explained that it was nitroglycerin absorbed in a diatomaceous earth (a very porous silicate), but he proposed a different name (from the Greek word *dynamis*, meaning "power"). Thus, as pointed out by Wisniak, to Sobrero goes the credit of having discovered nitroglycerin and to Alfred Nobel, of transforming it into an industrial commodity.[12]

The demand for the dynamite quickly grew, because this was a historic moment for major infrastructure projects that required blasting operations, and Nobel created different companies for its production and commercialization in different countries.[15] By 1886 there were 93 Nobel factories in the world with an annual production capacity of 66 500 t.[12]

In this context, in 1872, the *Sociedad Anónima Española de la Pólvora Dinamítica Privilegios Alfred Nobel* (Spanish Society of Powder Dynamite, Privileged by Alfred Nobel) was founded by

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Figure 2. Paintings related to dynamite and explosions in mines, quarrying, and civil engineering. From left to right: *Two Blasters* (Antonio García Mencía, 1905), *Lighting a Wick* (Julio Romero de Torres, 1924), and *The Project* (Ángel Mateo Charris, 2003). Reproduced with permission of Maxam.

Figure 3. Paintings related to fireworks and firecrackers. From left to right: *Young Lady with Rocket* (Cecilio Plá, 1906), *Valencian Group Celebrating* (Cecilio Plá, 1907), and *Firecrackers* (Manuel Benedito Vives, 1910). Reproduced with permission of Maxam.

Nobel in Galdácano, Spain. In 1896 the company joined with eight societies creating the *Unión Española de Explosivos* (UEE, Spanish Union of Explosives) that initiated in 1899 the manufacturing of cartridges for sports and hunting. In 1970 UEE and the *Compañía Española de Minas Río Tinto* merged to create *Unión Explosivos Río Tinto* (known as ERT). After a worldwide development, in 2006 the Group changed its name and corporate identity to Maxam, now one of the oldest chemical company in Spain.[16] The motto of the company, "shaping the world you live in", assumes the idea that explosives are used to remove the soil in order to construct important infrastructure as indicated above.

Excellent histories of Alfred Nobel detailing his biography and his role in the invention of dynamite can be found in a good number of sources.[13,17−19]

■ MAXAM'S COLLECTION OF PAINTINGS

In 1899, UEE commissioned a prestigious artist, Arturo Mélida, to elaborate a watercolor to be reproduced on the cover of the almanac for the turn of the century, which subsequently would be used for the first time to promote the company's products.[20]

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Figure 4. Paintings related to chemistry and the chemical industry. From left to right: *Galdácano* (Clara Gangutia, 1998), *Saint Barbara* (Sigfrido Martín Begué, 2005), and *Chemical Circuit* (Dis Berlin, 2014). Reproduced with permission of Maxam.

This initiative has since repeated itself year after year until today (with the exception of the period of the Spanish Civil War, 1936−1939), giving rise to a unique collection by its conception and style. Popularly known as *Calendarios de Explosivos* (Explosives' Calendars), it turned into a familiar medium for bringing art to the whole of society. These calendars included reproductions of renowned Spanish artists, such as Alcalá-Galiano, Cecilio Plá, Romero de Torres, Sáenz de Tejada, and Eduardo Úrculo. Corresponding biographies can be seen at the section of "artists" in the Maxam Foundation Web page.[20] The collection can be visited on the Internet, as a virtual tour.[20] Moreover, some paintings have been on display at well reputed worldwide art galleries and museums as part of temporary exhibitions.

It is now a collection of more than 100 pieces that makes up a representative part of Spanish art history. It is a witness of its time, for example, through scenes related to explosives and their applications in hunting (Figure 1). Also, there are interesting scenes about mining, quarrying, and civil engineering (Figure 2), fireworks and firecrackers (very popular in Spain and particularly in the Valencian Community) (Figure 3), the army, and chemistry and chemical industry (Figure 4).

The third picture of Figure 2 refers to the construction of the Aswan High Dam in Egypt during the 1960s. One of the paintings shown in Figure 4 refers to Saint Barbara, traditionally the patron of gunsmiths, miners, and anyone else who works with cannon and explosives. In the field of chemistry in general, it should be noted the picture painted by Dis Berlin (the artistic name of Mariano Carrera; see Figure 4) served for the calendar of 2014.

On the other hand, one of the famous portraits of Alfred Nobel is the one that was painted in 1915, 19 years after his death, by Emil Österman (Figure 5), now held by the Nobel Foundation in Stockholm. The painting selected for the 2015 edition of the Maxam Calendar is by Isabel Quintanilla, a leading figure of the Madrid realistic school (Figure 5). Her painting refers to the origin of the company as it aims to represent the atmosphere in which Nobel might have worked. Therefore, Quintanilla "mixes the historical views of the past with the optimistic outlook towards the future with her characteristically intimate atmosphere and exquisite study of light".[20]

Figure 5. Left: *Alfred Nobel's Landscape*, by Isabel Quintanilla. Reproduced with permission of Maxam. Right: *Painting of Alfred Nobel*, by Emil Österman. Image provided by the Nobel Foundation and used with permission.

Maxam's collections of paintings and related calendars have been well-known in the past, especially among specific communities, such as hunters and professionals in the field of explosives. In the next section, we highlight the use of this collection in chemistry classrooms.

■ INCORPORATING DISCUSSION OF THE PAINTINGS COLLECTION IN CHEMISTRY CLASSROOMS

The idea of using paintings to discuss chemistry topics is not original. For example, on the occasion of National Chemistry Week 2001, entitled Celebrating Chemistry and Art, Jacobsen selected the best "pictures" of chemistry and art from previous issues of the *Journal*.[21] Among other sources, Beyer also provided a very interesting view of the relationship between chemistry and art.[22]

Similarly, in previous contributions, one of us (G.P.) illustrated how two postage stamps released in Spain[23,24] and

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a monument such as the Atomium in Brussels[25] could serve as opportunities to link chemistry with history and art at the classroom, and to introduce and to discuss different concepts in general chemistry. The Maxam collection of paintings offers students the opportunity to inquire about topics such as

a. History of science, technology, and industrial chemistry
b. History of explosives
c. Manufacturing, properties, and chemistry of explosives
d. Reaction of synthesis of nitrate esters
e. The origin of Nobel prizes
f. Properties and the history of the discovery of nobelium
g. Chemistry of fireworks
h. The physiological influence of nitroglycerin
i. Ethics of chemistry
j. Environmental chemistry

More details about these topics are included in the following activities that should be considered merely as starting points. After the teacher has briefly introduced the class to the Maxam collection of paintings and its relationship with explosives, students should be ready to explore these activities. To further motivate students, development of additional activities and questions, or use of other materials (artistic or informational), could be undertaken by local chemical companies.

Related Activities for Students

We outline several activities for middle or high school students and first-year college students. The teacher should select or draw on some of the proposed activities according to the students' level and course objectives.

1. Visit the Maxam collection of paintings online and: (i) describe the history of the collection; (ii) select three (or more, as determined by the teacher) paintings for each topic (e.g., hunting, mining explosives, civil engineering, dynamite, fireworks, chemical industry, etc.); and (iii) describe three (or more, as determined by the teacher) favorite paintings and discuss connections between the paintings and some aspect of chemistry.
2. With the help of appropriate literature, summarize: (i) the biography of Alfred Nobel; (ii) the most important contributions of Nobel in the manufacture of explosives; (iii) the origin of Nobel prizes.
3. Search the Internet or chemistry books to find information about the history of explosives, and Maxam (or another) chemical company.
4. Look for typical chemicals used as explosives.
5. Describe the chemical structure of typical explosives such as trinitrotoluene and nitroglycerin.
6. Search for information about the following concepts related to explosives: detonation, propellant, blaster, wick, rocket, dynamite, fireworks, and so on. Look for illustrations of these concepts within the Maxam collection.
7. Describe military and civilian applications of explosives and discuss the advantages and disadvantages of their use. Illustrate several of these applications with some paintings of the Maxam collection.
8. Write the simplified balanced reaction that occurs in the explosion of a conventional explosive (e.g., trinitrotoluene or nitroglycerin). Consider that in explosion, carbon and oxygen of the explosive give CO; hydrogen and oxygen give water; nitrogen transforms in its natural state (N_2); the remaining oxygen will combine with the CO to give CO_2; and finally the excess of oxygen, hydrogen, and carbon produce O_2, H_2, and C, respectively.
9. Calculate by stoichiometry the quantity of gases, measured in L at STP, produced by chemical reaction during explosion, as described in the previous question.
10. On the basis of the balanced equations in Activity 8 and with the use of adequate values for standard enthalpies of formation, estimate the standard enthalpy for the corresponding reactions of explosion.
11. Write the corresponding balanced reaction for the synthesis of nitroglycerin (or other explosive as determined by the instructor) and provide explanation about it.
12. On the basis of the information supplied on the Maxam Web site, describe the painting entitled *Alfred Nobel's Landscape* by Isabel Quintanilla, selected for the illustration of the 2015 calendar of the company.
13. Search for the element nobelium on a periodic table. Justify its position on the periodic table with relationship with its electronic configuration. Describe briefly its history and properties.
14. Chemicals always have many uses. So, according to the information given in different sources, describe uses of nitroglycerin other than the manufacture of explosives.
15. Discuss how the uses of civil explosives, compared with mechanical means, can reduce hydrocarbon consumption and minimize greenhouse gas emissions.

As can be seen, apart from details about the collection of paintings presented in this paper, these activities are related to one or several of the 10 topics referred before (a–j). In particular, topics are covered by the following activities expressed in parentheses: a (1–3 and 12), b (2, 3, and 12), c (4–6 and 8–10), d (11), e (2), f (13), g (6), h (14), i (7), and j (15).

Information and Answers for Suggested Activities for Students

In this section, we briefly offer answers and comments related to the activities, including some teaching strategies, as well as connections instructors may want to highlight to facilitate class discussion.

Regarding the first three activities, information about Alfred Nobel, explosives, and an explosives company (Maxam), was summarized in this paper and a good number of references have been collected to facilitate the incorporation of these questions into the classroom. With regard to activity 2 (iii), it must be noted that, according to the Official Web site of the Nobel Prize, when Alfred Nobel's will was opened, it came as a surprise that his fortune was to be used for prizes in Physics, Chemistry, Physiology or Medicine, Literature, and Peace.[17] On the basis of his will, the Nobel Foundation was established in 1900.

In response to activities 4–8, students must conclude initially that an explosive is a compound or mixture that, upon the application of heat or shock, decomposes with extreme rapidity, yielding much gas and heat. There are excellent references about the history, theory and chemical types of explosives.[12,26] A thorough work about using the chemistry of fireworks to engage students in learning basic chemical principles was published by Steinhauser and Klapötke recently.[27] It is interesting to emphasize that the discovery of fireworks and gunpowder occurred by chance more than 2000 years ago in

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China. An English scholar by the name of Roger Bacon (1214–1294)[28] was one of the first Europeans to study gunpowder and write about it.

In Figure 6, the chemical structures of nitroglycerin, the chemical constituent of dynamite and trinitrotoluene (or TNT)

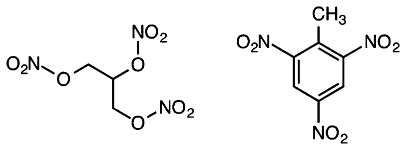

Figure 6. Chemical formulas of nitroglycerin (left) and trinitrotoluene, TNT (right).

(another typical chemical used for explosives manufacturing) are included, as examples for answers to activity 5.

As an example of ethics and chemistry, for activity 7 and similar activities, we recommend a paper by Essex and Howes in which they discuss the complicated ethical history underlying World War I, including information about the ethical history of the Nobel's invention of explosives.[29]

As an example response to activity 8, the decomposition of nitroglycerin is highly exothermic, and the overall process can be written by the balanced equation:

$$4C_3H_5N_3O_9(l) \rightarrow 12CO_2(g) + 10H_2O(l) + 6N_2(g) + O_2(g)$$

Explosives usually have less potential energy than fuels, but their high rate of gas release produces a great blast pressure. For example, using stoichiometry and thermochemistry (with data of standard enthalpies of formation for all substances), respectively, it is easy to calculate that, according to the previous chemical equation, every mole (227.1 g) of nitroglycerin that detonates produces around 106.4 L (at STP) of gases (activity 9) and releases about 1.5 MJ of heat (activity 10).

As a particular case of manufacture of an explosive (activity 11), the chemical reaction of the synthesis of nitrate esters (such as nitroglycerin) can be discussed, with information easily available in general and organic chemistry textbooks.

Information about activity 12 was given above, when the Maxam's collection was introduced.

In connection with nobelium (activity 13), it is a synthetic element with atomic number 102 and symbol No. It is named in honor of Alfred Nobel, as established by IUPAC in 1997. The discovery was claimed in the 1950s and 1960s from different laboratories in Sweden (at the Nobel Institute of Physics in Stockholm), the former Soviet Union (the team led by Flyorov), and the United States (at the Lawrence Berkeley Laboratory).[30] Fortunately, the names of other elements, flerovium (Fl) and lawrencium (Lr), honor the memory of physicists Goergy Flyorov and Ernest Lawrence, respectively. This is another example of how the instructor can introduce various topics inspired by a certain painting (as the two shown in Figure 5).

A curious application of nitroglycerin different from explosives (activity 14) relates the story of the synthesis and discovery of the vasodilator action of this compound, one of the little-known events of the pioneer days of medicinal chemistry.[31] Concerning its use—for example, as treatment for the relief of angina pain—Marsh and Marsh describe a short history of this substance and nitric oxide in pharmacy and physiology.[32]

Finally, apart from other questions, teachers can suggest that students look for information and discuss how the use of civil explosives, compared with mechanical means, may reduce hydrocarbon consumption and greenhouse gas emissions (activity 15). As pointed out by several authors, energy savings from the use of explosives instead of mechanical excavation and grinding are significant.[33] Therefore, according to Workman and Eloranta, it reduces CO_2 emissions by up to 8 times compared with mechanical excavation and up to 40 times compared with rock grinding.[34]

■ STUDENTS' RESPONSES

Some of the above items have been used by us for first-year undergraduate civil, industrial, and chemical engineering students. These activities were used as individual out-of-class assignments for students. Thus, only a short period of time was needed for the introduction of different activities and for final class discussions. Obviously, there are other possibilities to use these activities. For example, the teacher can suggest activities, followed by class discussions; students can also form groups and work on several activities.

Our experience has shown that, in general terms, students' responses to the questions are aligned with the expectations. Generally, they seem motivated and interested during discussions of results. As engineering students, they specifically appreciated the significance of explosives on the construction of civil works.

We have used the Maxam Web sites in our classrooms. Although almost none of students knew the collection of paintings, most of them appreciated finding out about this and learning that an important chemical company devotes resources to the promotion of art.

Students have expressed keen interest in this type of "tangible" chemistry in which examples of everyday life put chemistry in context. In fact, during discussions with students, new issues arose: for example, noting other practical applications of explosives, such as the use of air bags in cars.[35]

Regarding the significance of explosives in civil engineering, students find two case studies of great infrastructure projects particularly engaging. The first relates to submarine blasting in which Maxam's predecessor company (UEE) participated in the 1960s construction of the Aswan High Dam, as illustrated in the painting entitled *The Project* (Figure 2). Students were also interested to learn about Maxam's involvement in work on the ambitious expansion of the Suez Canal, recently initiated.[36] The second case is the underwater blasting performed by Maxam for the expansion in progress of the Panama Canal.[37] Both are examples of the importance of explosives for civil works on historical projects that change the world. Curiously, in gratitude for contribution to the work on the Aswan High Dam, the Egyptian state donated the temple of Debod to Spain in 1968. Thus, the temple was removed from the flood zone of the dam and it is currently located in Madrid. It is one of the few works of ancient Egyptian architecture that can be seen outside Egypt. Our students discussed this case as another example of relationships among science, technology, art, and history.

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Table 1. Analysis Model of the Learning Activity Based on Maxam Paintings in Accordance with the Sjöström Tetrahedron[10]

Dimension	Disciplinary Frame of Chemistry[a]	Societal Frame of Chemistry[a]
Contemporary Frame of Chemistry (formal and pragmatic aspects)	*Pure chemistry* (The triplet relationship: macro, submicro, symbolic) Chemical structures; stoichiometry; balanced equations; thermochemical calculations; properties of substances Activities: 4, 5, 8, 9, 10, 11, 13	*Applied chemistry* (Technical−instrumental and everyday-life context) Concepts related to explosives: detonation, propellant, wick, rocket Different uses of chemicals: e.g., use of nitroglycerin as medication Applications of explosives: e.g., hunting, mines, fireworks, civil works, air bags Activities: 6, 7, 14
Critical Frame of Chemistry (reflective aspects)	*Nature of chemistry* (Philosophy of chemistry) Chemistry is both a science and a technology, a "technoscience": e.g., from nitroglycerin to dynamite, solving technical problems Activities: 2, 3, 6	*Socio-chemistry* (Socio-cultural and historical context) Relations between chemistry, technology, and society: e.g., history of explosives, history of Maxam, Maxam collection of paintings Biography of Alfred Nobel, the origin of Nobel prizes Environmental consequences of use of explosives Chemical ethics: e.g., consequences of use of explosives (military and civilian applications) Art and science Activities: 1, 2, 3, 12, 15

[a]Numbers refer to activities discussed in the text.

DISCUSSION OF THE CASE IN RELATION TO THE "CHEMISTRY IN CONTEXT" LITERATURE

The case of classroom teaching practice presented in this paper has certain components of relevance under the concept of Stuckey et al. referred in the introduction:[8]

- At the individual dimension, students can satisfy curiosity and interest (present and intrinsic) by discovering how explosives work or by calculating the amount of gas emitted in an explosion. Students are also prepared to act responsibly (future and extrinsic) with the analysis of topics such as ethics of science or environmental chemistry.
- Within societal dimensions, information about the Maxam collection allows students to consider promotion of their own interest in societal discourse (future and extrinsic).
- At the vocational dimension, students are oriented to potential careers in the field of industrial chemistry (present and intrinsic) and to contributing to society's growth, both economic and arts patronage (future and extrinsic).

In a similar way as Christensson and Sjöström analyzed chemistry videos,[38] based on Sjöström's tetrahedron of chemistry teaching,[10] we have developed for our case the analysis model summarized in Table 1. This analysis captures the multidimensionality of chemistry.

Table 1 consists of four fields, with contemporary and critical frames of chemistry on the left and disciplinary and societal frames of chemistry indicated in the column headings. As will be clear, the division into the four fields is not easy and should be seen only as a way to analyze the education tool. As pointed out by Christensson and Sjöström,[38] an alternative to traditional school chemistry, focused on formal aspects, is a "critical chemistry". The context-based educational questions explained in this work are in this line, as shown in Table 1. Thus, the idea is to emphasize learning *about* chemistry in addition to content knowledge.

Furthermore, the case shown in this paper can be an opportunity to facilitate the chemical literacy among students (and also the general public). In fact, and as explained before, the Maxam calendars have been, in a way, a tool to popularize the applications of explosives, that is, specific products obtained by a field of the chemical industry. For a further discussion of the public images of chemistry, we recommend several papers.[39−41]

CONCLUDING REMARKS

Paintings can be effective education tools if properly presented and used in the classroom or in continuing education. This article summarizes some ideas of how the relationship between art and chemistry can be exploited for pedagogical purposes. We have shown examples from a unique collection of paintings, prepared to illustrate calendars of a Spanish chemical company (founded by Alfred Nobel) as a potential teaching tool. The idea is to incorporate a topic that some chemistry instructors sometimes avoid discussing in class in spite of the interest students often exhibit when viewing chemical reactions that involve explosives. It is suggested as a starting point to explore the science and history of topics related to the explosives industry, and to tackle subjects with varying degrees of depth.

Students can be encouraged to discuss a wide variety of topics of general chemistry and others such as history and ethics of science and technology, chemistry of explosives, the origin of the Nobel prizes, the biography of Alfred Nobel, properties of the nobelium, chemistry of fireworks, environmental chemistry, and the physiological influence of nitroglycerin, among others.

Such context enables students to connect the relevance (under the broad concept for this term of Stuckey et al.[8]) of chemistry outside the classroom environment.

The history of modern explosives is other example of how science and technology are made with collective efforts by research from different countries. This is relevant in view, for example, of the role that the history of chemistry may play in teaching and learning chemistry. Also, students can appreciate art, history, and science (particularly chemistry), coming to understand that they are complementary and not separate fields.

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AUTHOR INFORMATION

Corresponding Author

*E-mail: gabriel.pinto@upm.es.

Notes

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