CHEMISTRY: OUR LIFE, OUR FUTURE

Ferruccio Trifirò*
Accademia delle Scienze dell'Istituto di Bologna
Bologna, Italy

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1. Introduction

In this note, we report some innovations in chemistry considered to be important, as they have changed the world; they include: the discovery of the additive for gasoline, tetraethyl lead; the discovery of the first synthetic rubber, the first synthetic fiber (nylon) and the catalytic converters that remove pollutants from petrol engines. We also report on the various interventions of the chemical industries in restoring historic buildings around the world. Finally, mention must be made of the ethical principles and code of conduct signed by the International Union of Pure and Applied Chemistry (IUPAC, the global agency of chemical companies) and by the Organization for the Prohibition of Chemical Weapons (OPCW) and also signed by the Italian Chemical Society (SCI).

2. The Chemistry that has changed the world we live in

The December issue of the business magazine Forbes Global 2000 reported the innovations that from 1917-2000 changed the world, including the chemicals that have played an important part in our lives [1]. For each year, with a few exceptions, one innovation was selected from among the total of 85 reported, many of which might easily have been suggested by any one of us, such as television, the Xerox copier, the Internet, the transistor, penicillin, the polio vaccine, recombinant DNA technology, fiber optics. However, there are four, and this can only happily surprise us, that are the result of chemistry alone.

The first innovation was the discovery of lead tetraethyl (year 1921), an anti-knock agent for petrol engines (eliminated from the market only a few years ago), which enabled the use of a higher compression ratio in the engine, resulting in increased efficiency. The product was discovered by Thomas Midgley, after a focused five-year search, using a research methodology of 'trial and error'.

The second innovation was that of synthetic rubber (1929) based on chloroprene, the first synthetic rubber for industrial use and the first to have a commercial success. It was developed jointly by Newland, a professor at the University of Notre Dame, who had discovered the synthesis of vinyl acetylene which started as acetylene (he had observed the formation of vinyl acetylene as a by-product), with researchers at Dupont. In the Dupont research laboratories under the guidance of Carothers, research was

* Corresponding author: ferruccio.trifiro@unibo.it

continued with the aim of producing vinyl acetylene, which led to the accidental discovery of chloroprene, formed by adding HCl to both vinyl acetylene and its subsequent polymerization. The elastomer, at first called Duprene, then changed to Neoprene, was produced industrially in 1931. In truth, the discovery of the first synthetic rubbers (with inferior properties however) was made in Germany in 1910 by Bayer, following research conducted on the polymerization of isoprene.

The third innovation was nylon, one of the first synthetic fibers to be produced (1934). The discovery was made in the organic research center base specially created by Dupont. Carothers, director of the laboratories, had been doing some basic research since 1928 on polymerization reactions, concentrating on polycondensation (between different molecules), unlike Staudinger, a future Nobel Prize in chemistry who, in Germany, was studying polyadditions (starting from the same molecule). After several years of research on this class of reactions, Carothers came upon the polycondensation of adipic acid with hexamethylene diamine, research which led to the discovery of polyamide 6.6.

Production of the first fiber, known as nylon, started in 1938.

The most recent innovation was that of the catalytic converter (1974), developed by Corning Glass Works where, in three years and with 300 researchers,15 thousand different catalysts were tested before arriving at the final result of platinum and palladium supported on a ceramic monolith in the form of a honeycomb. The catalyst production plant, opened in 1975, was the largest facility in the world built of stainless steel. Over the years the catalyst has become increasingly more complex to meet ever more stringent regulations and currently operates under the most extreme reaction conditions that can be encountered in a chemical synthesis: low contact times and low reactant concentrations, reduction of nitrogen oxides at the same time as oxidation of CO and residual hydrocarbons, the need for activity in a broad temperature range, to avoid slowing down the flow of exhaust gas from the engine and increasing the life of the catalyst and so decrease the need to stop for spare parts. All these objectives were achieved by assembling various chemical products with specific functions.

If these innovations fail to coincide with the most important discoveries in chemistry, it is necessary to consider that the innovations indicated are, according to observers outside the field of chemistry, those that have most changed the world we live in, even if merely from the point of view of habits and commercial impact. Those outside the world of chemistry judge chemical products on their behavioral properties and their usefulness: this we must accept if we are to bridge the gap between chemistry and society. But these behavioral properties can only be studied if scientists are involved in the application of the products, which are typically external to the academic world; this is the great challenge facing chemistry and these the difficulties in which it is obliged to operate. At this point we cannot help but add a fifth innovation: the stereo-specific polymerization of propylene, discovered by Natta in 1954 [2], that led to the production of polymers with similar properties to natural polymers, among the most widely used products of organic chemical synthesis in the world. Besides, with Natta's discovery, a new opening was created for innovation stemming from a deep scientific knowledge in the various fields of chemistry, accompanied by detailed knowledge of the problems in the chemistry industry. Natta used to say that "when a research topic has a solid scientific basis and when you are careful about the possible applications of the products you are working on, sooner or later there is innovation".

3. Chemical technologies for cultural Heritage

The chemical industry is involved in cultural heritage conservation and preservation strategies for the development of optimal technologies, for its dedication in sponsoring restoration work and for the opportunity to present a chemistry that is easily understood and accepted by all. It is worth highlighting the commitment of several chemical companies such as Eni, Mapei, 3M, Rhône-Poulenc and Syremont in the recovery, consolidation and restoration of numerous works of art [2].

Chemistry has a part in all phases of restoration and conservation of a work of art, architectural heritage or an ancient artifact, from diagnosis and interventions of stabilization and consolidation to prevent further deterioration, cleaning of damaged and / or contaminated parts, to restoration of the original aesthetics or functionality. What is, however, the chemical industry's specific relationship with technologies involved in restoring the cultural heritage of a country? Three definite areas can be identified in which the chemical industry is directly involved. The first, the most natural, is that of developing new products and technologies for the different phases of restoration. The second is the opportunity the sponsorship of the restoration of a work of art offers a company to show their commitment to social issues and the ability to know how to create strong links with the territory. The third is the chance a company is given to speak of its activities in the restoration, to come up with a chemical whose utility is easily understandable to all.

There have been several chemical industries in Italy in recent years that have used their products and / or have offered their services and skills to sponsor restoration work.

Rhône-Poulenc (now with the name of Rhodia for the chemical sector and Aventis for the pharmaceutical sector), has restored the facade of the Palazzo Senatorio (Senate Palace) at the Campidoglio (Capitoline Hill) in Rome [3] and the Galleria Vittorio Emanuele in Milan [4], employing among other products, ethyl silicate for consolidation work, biocides for cleaning operations and silicone-based resins for the final treatment of all surfaces, all of which are produced by the company.

Mapei oversaw the consolidation of some damaged structures in the church of San Francesco in Assisi, following the recent earthquake, using composite materials based on epoxy resins and aramid fibers [5].

Syremont, among others worked on the restoration of the frescoes by Masaccio and Masolino in the Brancacci Chapel in Florence and the Scrovegni Chapel in Padua by developing formulations based on ion exchange resins for cleaning sulphur compounds (desulfurization) and the removal of limescale and other unwanted layers [6]. It has also followed the restoration of archaeological areas and various monumental buildings using aggregates, binders and protective agents, in general, based on fluorinated compounds. Lastly, Syremont, has taken care of the design and implementation of the special sophisticated system of conservation and museum exhibition of the Similaun Man Mummy (Ötzi) in the archaeological museum in Bolzano.

3M has sponsored restoration activities in Pompei by providing its protective film, and finally Eni, with its own financial and technical resources, has recently cleaned the façade of St. Peter's at the Vatican in Rome [7].

One last aspect regarding the links of the chemical industry with the restoration of cultural heritage is what was learned in one of the first conferences on Sustainable Development organized by the Association of European Chemical Industries, held in Paris several years ago. At the conference, while other representatives from the different chemical industries presented the success of their companies in producing processes that were safe and clean and products whose use posed no risk to living beings and the environment, Rhône-Poulenc's president chose to speak only about his group's activities in the restoration and conservation of heritage in different parts of the world. The French company, in addition to the interventions mentioned in Italy, undertook the restoration of a wooden building in the Imperial Citadel of Hue in Vietnam [8], the Taj Mahal in India [9], the cathedral of Burgos and old manuscripts in France. The initiative of the President of Rhône-Poulenc to speak only of the activities of his company in saving European and world cultural heritage must be interpreted as a precise strategic choice in wishing to present a chemistry that is positive.

This is a chemistry that is no longer on the defensive, straining to try to explain that chemical production no longer alters the ecosystem, but on the offensive, in other words available to explain how it is useful to humanity and how it can help to preserve our existing heritage for future generations. In addressing the public it is not enough to talk about the sustainability of processes and products, it is necessary to commit oneself to explaining the usefulness and non-substitutability of synthetic products for society.

The presentation of the President of the Rhône-Poulenc at this conference was a useful example in this direction, just as presenting the involvement of the chemistry industry in the field of world heritage restoration and preservation is.

4. Ethics and chemistry

Recently, the two organizations, IUPAC and OPCW, have once again presented a code of conduct recommending to those involved in the chemistry industry to review their code of ethics and / or develop new standards to promote the safe and correct use of chemicals in the interest of everyone, the development of science and verification of whether these principles are in accordance with national laws and international conventions [10-13].

It is the responsibility of all chemists, regardless of their field of work, in industry, academia or government establishments, to assess ethical aspects to prevent the misuse of chemicals which could lead to the production of toxic substances harmful to humans, animals and the environment. All chemists have their own ethical principles, from which derive codes of conduct and moral codes of responsibility that respect work safety procedures and comply with national laws and international conventions.

In 2006 the Italian Chemical Society (SCI) approved a charter of ethical principles for chemical sciences, becoming one of the first chemical companies in the world to do so [14, 15]. For SCI members, ethical principles are a binding force, acting as a link between procedures, national laws and international conventions and rules of conduct in the workplace.

IUPAC suggests that chemists should guarantee the following ethical principles: ensure that their work is ethical and defend the dignity and continuing repute and integrity of their profession; ensure that their knowledge and technology may be used for the benefit and betterment of humanity and the environment; ensure that their work is in accordance with the principles of sustainable development and preservation of the earth's ability to guarantee life in all its diversity; ensure that the chemicals and equipment used under their responsibility are not used for illegal or destructive purposes or subsequently cause harm to people or the environment; always inform the competent authorities if they become aware of any improper use of chemicals, either for criminal or destructive purposes; minimize risk to workmates and colleagues, to any citizen, to the environment, with respect to any intended and accidental consequences of their actions; regularly assess the effects of activities for which they are responsible on health and safety; that their work complies with national and international regulations on chemicals; ensure they cooperate with governments and organizations to identify any shortcomings in safety laws and try to help to improve them; ensure they keep up-to-date with knowledge on the latest developments in health and environment control, and chemical risk, and use it to make the public understand the benefits derived from chemicals, as well as the risks associated with their misuse.

Finally, it is useful to remember that the code of ethics of the Italian Chemical Society [14] ends with the following commitment that every graduate should subscribe to at the end of his educational curriculum: “I pledge to apply the aims of the chemical sciences to: safeguard the environment and its ecosystems; improve the quality of life without harming the surrounding world; to keep in check the misuse of chemistry; spread knowledge of the advantages and benefits of the chemical sciences in the public opinion”.

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Biographical notes

Prof. Ferruccio Trifirò was born in Barce (Libya) on 17 June 1938. He graduated in chemical engineering at the Polytechnic of Milan in 1963 under Prof. Giulio Natta

(Nobel Prize in Chemistry 1963). In 1966 he then went to work in Prague at the Institute of Physical Chemistry of the Academy of Sciences of Czechoslovakia. In 1968 he obtained a scholarship to work at the Department of Chemistry at the University of Reading (UK) and in 1974 won a scholarship to study Alexander von Humboldt and work at the Institute of Industrial Chemistry of the University of Erlangen (Germany). In November 1975 he was appointed professor of Industrial Chemistry at the Faculty of Engineering of Cosenza; in November 1976 he was called to Bologna to the Faculty chair of Industrial Chemistry. His main research activity was for the most part in the field of heterogeneous catalysis applied to the synthesis of the major intermediates with oxidation and hydrogenation and to a lesser degree in the field of homogeneous catalysis, environmental catalysis and transformation of biomass into raw materials for chemistry by gasification. He is the author of 517 scientific publications, 24 patents, five books published abroad in English, in the field of oxidation processes; editor of 8 books, 17 reviews about teaching and has presented 400 communications in congresses. He is a professor emeritus of the University of Bologna; director of the journal, *La chimica e l'industria* since 1996; president of the Academy of Sciences of the Institute of Bologna; scientific member of the Organization for the Prohibition of Chemical Weapons (OPCW) and scientific consultant for *Tecnologie Innovative per il Controllo Ambientale e lo Sviluppo Sostenibile* (TICASS), a consortium in Liguria.