Reinventing the chemical industry

Handbook of Green Chemistry and Technology

edited by James Clark & Duncan

Macquarrie

Blackwell Publishing: 2002. 540pp. £149

Martyn Poliakoff & Peter Licence

Across the world, chemical manufacture is unsustainable. Its petroleum-based feedstocks are dwindling and the problems and cost of waste disposal are increasing rapidly. Environmental legislation is becoming ever more restrictive, and the industry has a poor public image. But modern society is almost totally reliant on the products of the chemical industry, and rising living standards in developing countries are increasing demand. We cannot just stop making chemicals. How then is chemical manufacturing to be transformed into a sustainable, non-polluting activity before the price of oil becomes prohibitive?

'Green chemistry' (see *Nature* **413**, 257; 2001) is a relatively new approach to resolving this impasse by removing the hazards of chemical usage through the design of safer manufacturing processes and safer chemicals. It aims to achieve sustainability by increasing the use of biologically derived, renewable feedstocks and by minimizing waste. Such broad aims require a correspondingly wide range of skills; consequently, green chemistry involves toxicology and life-cycle assessment as well as chemistry and process engineering. Reaching these goals also demands unusually close collaboration between academia and industry.

The *Handbook of Green Chemistry and Technology* is a multi-authored book that aims to illustrate the state of the art across

a wide range of green chemistry. It is not a revolutionary manifesto but rather a 'practical and rigorous' collection of reviews with references up to the end of 2000. The 23 chapters are the work of 28 authors from eight different countries but, disappointingly, only four of them are from industry. The coverage is broad, with chapters on most key aspects of green chemistry, including catalysis, solvents, reagents, life-cycle assessment and unconventional technologies such as ultrasound or microwaves for promoting reactions.

The chapter on 'Hydrogen Peroxide in Waste Minimization' quotes an industrial chemist who maintained that "almost all the chemistry really used was at least 50 years old". This is a key problem of green chemistry. Often, what is new is the way that reactions are used, rather than the reactions themselves. The most enlightening chapters are those such as 'Waste Minimization in Pharmaceutical Process Development', in which particular examples explain the logic and science behind cleaner chemistry. Other chapters fail to highlight the 'green' aspects of their topic and are little more than convenient summaries of catalysis or technology. The chapter on 'Green Chemistry in Practice' is the only one to tackle the problems of non-petroleum feedstocks in any detail. Processing such feedstocks is an area in which biocatalysis is likely to have a major role, so it is disappointing to find biocatalysis discussed in only 21 pages, hardly more than are devoted in another chapter to the solid catalysts from a single company.

There is a useful introduction to electrochemistry, albeit with an unnecessary overlap with the chapter on fuel cells, and a succinct description of the use of high-pressure (supercritical) carbon dioxide as an environmentally less harmful replacement for conventional solvents. Ionic liquids — salts that melt below room temperature — are also

being widely promoted as alternative solvents. Although these liquids are mentioned briefly in the context of phase-transfer catalysis, they warrant a chapter of their own. The book has an intriguing, abstract photograph on the cover, but readers have to wait until page 367 to discover that it is a "view of sheared thin films in a spinning disc reactor". This reactor is briefly covered in a chapter on process intensification, which involves making chemicals in small, high-throughput equipment — another subject that deserved more space. The final chapter, on the extraction of green products, ends with the intriguing statement that the extraction of green (unroasted) coffee beans with superheated water "produced a brown liquid with the aroma of coffee".

Overall, the book is a useful resource for those working in the area; it is not a guide for the novice green chemist. But it does show that there is more to green chemistry than merely using hydrogen peroxide to bleach your waste water so that people do not notice when you pour it into a river.

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Setting the record straight

Rossiiskaya Nauchnaya Emigratsiya: Dvadsat' Portretov (The Russian Scientific Emigration: Twenty Portraits)

edited by G. M. Bongard-Levin & V. E. Zakharov

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18 euros

Valery N. Soyfer

In 1564, the Russian prince Andrei Mikhailovich Kurbsky quit the service of Tsar Ivan the Terrible (Ivan IV) and emigrated to Poland. An educated courtier, a military commander and later a historian and literary figure, Kurbsky was highly regarded by the Polish king Sigismund II Augustus. From 1564 to 1579, Kurbsky and Ivan the Terrible corresponded: Kurbsky accused the tsar of cruelty and tried to explain to him why he preferred voluntary exile over ordeals and possible death, while the tsar accused him of betraying the motherland and of anti-Russian attitudes.

Such animosity endured in Russia towards those who abandoned their country, reaching a peak during the Soviet period. After the 1917 revolution, nearly 2 million educated and talented Russians emigrated to the West. The names of many Russian émigrés have entered the history of the twentieth century, including Vladimir Zworykin,

Green chemistry: zeolite minerals provide an environmentally friendly route to refining petroleum.

the inventor of television; Igor Sikorsky, the creator of the helicopter; and the composers Igor Stravinsky, Sergei Rachmaninov and Nikolai Metner. But the communist rulers did not recognize that these people were bringing glory not only to the countries that gave them shelter, but also to their motherland. The émigrés were slandered and declared to be traitors and enemies.

When, in the 1920s and 1930s, several leading scientists did not return to the USSR after travelling abroad, they began to be persecuted. The communists applied a harsh strategy to the most eminent scientists: elected members of the Russian (or Soviet) Academy of Sciences who emigrated were excluded from the list of members. This happened to the historian Mikhail Rostovtsev in 1927, and to the chemists Alexei E. Chichibabin and Vladimir N. Ipatiev later. Their names and those of the great majority of Russian émigrés were struck from the memory of Russians for nearly half a century.

However, a remarkable book has now been published in Russia on the lives and affairs of 20 of the most important Russian scientific émigrés who achieved worldwide renown not in their homeland, but in exile. Most of the protagonists of this book shared similar fates. They began in their new environments with difficulty, and none expected a warm reception. But possessing enormous creative potential and unusual strength of character, they made their way to the peak of the scientific Olympus in the West.

A number of Russian scientists went to America, among them the astronomer Otto Lyudvigovich Struve. Struve graduated from university in Russia in 1914. He fought in the White Army against the Bolsheviks but was seriously wounded and escaped to the West. His uncle, Paul Gutnik of the Babelsberg Observatory in Berlin, wrote to the director of the Yerkes Observatory at the University of Chicago, encouraging him to take his nephew

The eye of the beholder

Much of the world around us cannot be seen by the naked eye — we need techniques such as scanning electron microscopy or satellite imaging. For instance, the fine detail shown here of the coiled shell of the tun (*Tonna galea*), a marine carnivore, was obtained using false-colour X-ray

techniques. In *Heaven & Earth: Unseen by the Naked Eye* (Phaidon, £29.95, \$49.95, 49.95 euros), David Malin has compiled a stunning collection of images, which without such techniques would be lost to us, of objects ranging in size from a tiny gold atom to galaxies billions of light years away.

on. Once there, Struve began to use spectral methods in astronomy, pioneering work in several directions, especially in stellar spectroscopy (using absorption lines). He also discovered interstellar calcium and hydrogen. He became director of the Yerkes Observatory before heading the new Leuschner Observatory in Berkeley, California.

The physicist Georgiy Antonovich Gamow became a well known and colourful figure in world science. Gamow contributed

to three fundamental scientific fields of the twentieth century: physics (he discovered the quantum nature of α -decay), cosmology (he created the theory of a hot Universe, and on the basis of that he predicted the existence of the Big Bang) and genetics (he guessed the essential nature of the universal genetic code). Gamow and his wife were allowed to leave Russia for two weeks in 1933 to attend a Solvay Congress on physics, but never returned. At that time, failure to return to the USSR was regarded by the Soviet authorities as espionage, betrayal of the motherland, and conspiracy with the goal of seizing power. The death penalty was prescribed for such actions (this statute was removed in Russia only in 1995). Thus, Gamow would often tell acquaintances in America: "I am living under a sentence of death."

The physical chemist Georgiy Kistya-kovsky was a professor at Harvard University and also worked on the Manhattan Project to create the American atomic bomb. He became an important figure in the White House, advising President Eisenhower on issues of national security.

Other émigrés settled in Europe. Sergei N. Vinogradsky, considered to be the founder of modern soil microbiology, came to France in 1923. He organized a laboratory in the Pasteur Institute near Paris but stayed in contact with Soviet scientists and remained an honorary member of the Soviet Academy

Russian reunion: scientists gathered in Berlin for Russian Science Week in 1927 included the chemists Vladimir N. Ipatiev (standing, eighth from right) and Alexei E. Chichibabin (standing, fourth from right).

of Sciences. The author of the essay on Vinogradsky, G. A. Zavarzin, claims that he "continued to take an interest in scientific life in Soviet Russia", which meant maintaining friendly relations with the bosses of Soviet science, in contrast to other Russian émigrés. But this singling out of Vinogradsky is perhaps unjustified. As the other essays in this book show, most émigré scientists remained Russian patriots and helped many of their friends who remained in the USSR. They simply could not reconcile themselves with the morals and behaviour of the communists. They condemned the repressions and terror in their motherland, and tried to avoid the retribution of the Bolshevik hangmen.

Other Russian émigrés featured include Vladimir A. Kostitsyn, an astrophysicist who

also worked in mathematics and ecology, the mathematician Dmitry P. Ryabushinsky and Chichibabin, who all emigrated to France. Also profiled here are geneticist and evolutionist Theodosius G. Dobzhansky, mathematician Yakov (Jacob) Tamarkin, engineer Stepan P. Timoshenko and Ipatiev.

The final section is devoted to biographies of eminent specialists in the fields of economics and the humanities: the Nobel laureate Vasily Leontiev, the historians Rostovtsev, Georgiy Vernadsky and Pavel Milyukov, and the philologist Roman Yakobson, a Harvard University professor who had great influence in many fields of the humanities.

The book is full of detailed descriptions of the degrees, prizes and awards bestowed on the subjects of the essays, but unfortunately

there are no name or subject indexes and no bibliography. Only some of the authors indicate the sources from which they obtained their materials. These materials would be useful not only to researchers of Russian history, but also to show more fully how the history of Russia was viewed in the West.

Nevertheless, this book is the first work in which the lives and activities of representatives of those who achieved significant success during their lives outside Russia are discussed without any political subtext. Although it is primarily addressed to a Russian audience, it would be good to see it translated into European languages. ■

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Science in culture

Shingu's showers

Technology and nature at Fiat's Lingotto factory in Turin.

Martin Kemp

On the face of it, there seems to be something incompatible between high-tech components in gleaming metal, obviously precision-engineered, and an insistence upon a total harmony with nature in all its living complexity. But any incompatibility is triumphantly dissolved by the kinetic sculpture of Susumu Shingu, the Japanese constructor of devices driven by natural forces.

His large-scale constructions grace public spaces throughout the world, including Queens Criminal Court in New York and the New England Aquarium in Boston. His travelling installations of sculptures, *Windcircuit*, which toured urban sites in the late 1980s, and *Wind Caravan*, which was encamped in stunning natural locations in Japan, New Zealand, Finland, Morocco, Mongolia and Brazil during 2000 and 2001, are at once forceful and light, strong and elegant, large and delicate — evoking the power and sensitivity inherent in natural systems.

There could be no more telling context for him than Fiat's classic Lingotto factory in Turin, Italy, one of the paradigmatic structures of the modern era. Built to the master-plan of engineer Giacomo Mattè Trucco, starting in 1916, it is a great hollow rectangle 500 metres long. High on its roof is an automobile test-track with parabolic banking. Having reluctantly abandoned it as a manufacturing base in 1982, Fiat has progressively brought new life into the great space. Now, with the recent opening of the Giovanni and Marella Agnelli Art Gallery in a 'pod' extruded from the roof, the rehabilitation is complete. Renzo Piano — who came to world prominence when he and Richard Rogers won the design competition for the Pompidou Centre in Paris — is the architectural mastermind, and it was at his instigation that Shingu was invited to provide a water sculpture to stand in front of one of the building's long facades.

The 11.2-metre central column of Shingu's *Locus of Rain* consists of a hollow tube from which a water spray spouts high into the air. Around this revolve a series of arms, trumpet-shaped vessels and counterweights. Each of the two units on either side of the axis revolve in vertical planes around three pivots, the first on their shared axle, the second at the point where the lateral arms intersect with the poles that support the 'trumpets', and the third in the necks of trumpets themselves.

The ensemble is driven by water that falls into the trumpets, affecting not only their own rotation, but those of the poles that support them and the primary arms. Each mouth drinks from the spray when it swings towards the vertical, and turns gracefully aside as it becomes replete. Sometimes it will swing out of the nourishing spray before it is full, pulled away by the accumulating weight of water in the other trumpets. At other times, it will spin gently to disgorge into the pool below. Sometimes, two trumpets spill their waters almost simultaneously. At others, one performs its climactic act alone before rising to drink again.

Watching the hypnotic effect of the planetary cycles and epicycles is like witnessing a ballet choreographed according to nature's own laws of complexity. Compared to that classic of chaotic motion, the coupled pendulum, the variables are multiple, combining the unpredictability of the water spout — both in itself and as affected by the breeze — with the interactive ensemble of the rotating components. The two rotational ensembles work according to the same principles, as we can intuitively sense, yet they never perfectly repeat the same phase, either in themselves or in concert.

The design is uncompromisingly abstract. Yet there is an elusive feeling of things remembered from nature — of fish rising to the surface to gulp air, of elegant water birds drinking at a waterfall, of flowers dipping their heads in the wind and rain. Through his artistic

insights and constructional skill, Shingu is involved in a quest to ensnare the patterns underlying the variousness of nature in motion. Many a scientist will share the motivation behind this quest.

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Susumu Shingu's *Locus of Rain*, located at Fiat's Lingotto factory in Turin, Italy.