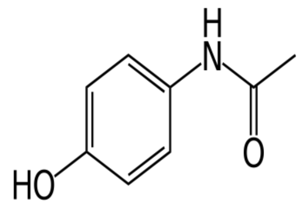
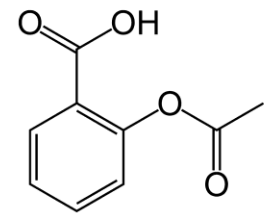
Green Chemistry

CHEMISTRY & SOCIETY

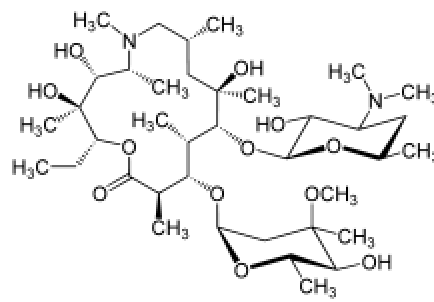
Pharmaceutical – manufacture of drugs (pain killers, antibiotics, heart and hypertensive drugs)



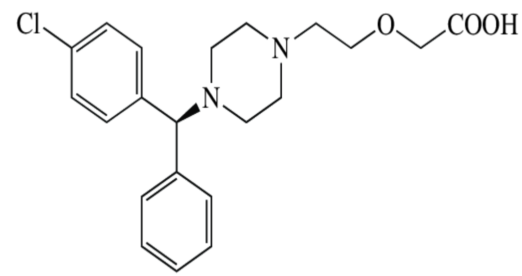
Paracetamol



Aspirin



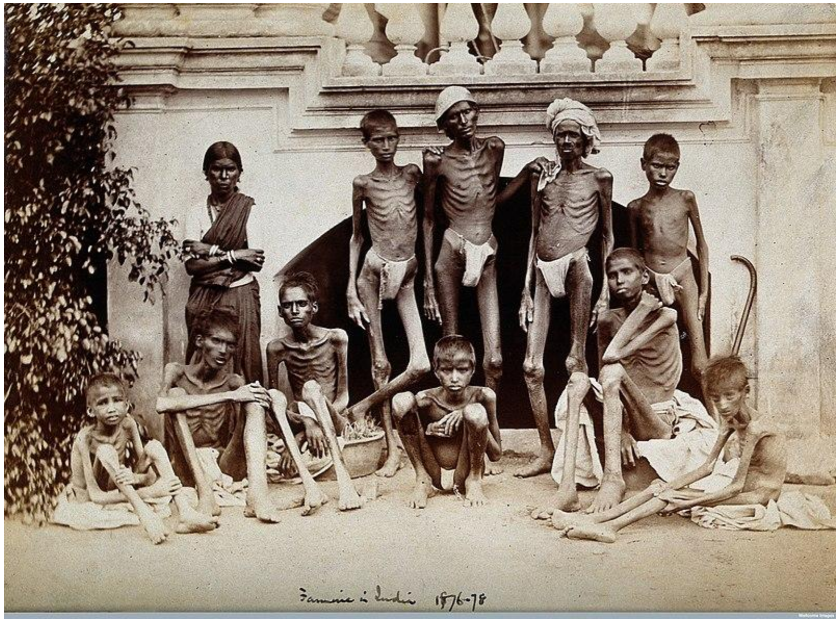
Azithromycin



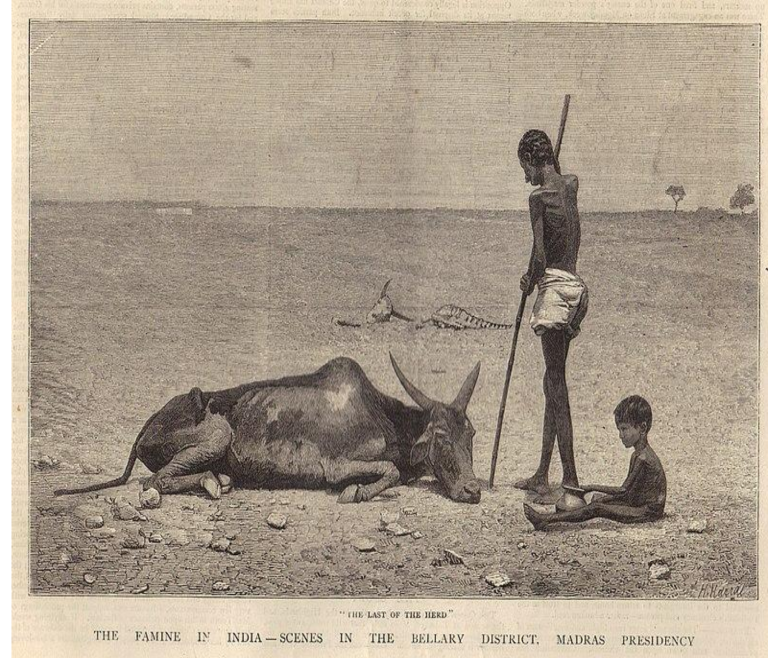
Levocetirizine

Agriculture –production of fertilizers, pesticides

Ammonium sulphate,
$(NH_4)_2SO_4$
Ammonium phosphate,
$(NH_4)_3PO_4$
Ammonium nitrate,
NH_4NO_3.
Urea, $CO(NH_2)_2$
Ammonium chloride,
NH_4Cl
Super phosphate,
$CaH_4P_2O_8$



Famine stricken people during the famine of 1876-78 in Bangalore



Engraving from *The Graphic*, October 1877, showing the plight of animals as well as humans in Bellary district.

Dead bodies line the streets of Calcutta shortly after the Bengal famine. On the rooftops overhead, vultures swoop in.

Calcutta, India. 1946.

Any substance or mixture of substances intended for preventing, destroying, or controlling any pest, unwanted species of plants or animals, causing harm during or otherwise interfering with the production, processing, storage, transport, or marketing of food, agricultural commodities, wood and wood products or animal feedstuffs, or substances that may be administered to animals for the control of insects, arachnids, or other pests in or on their bodies.

Type of pesticide	Target pest group
Algicides or algaecides	Algae
Avicides	Birds
Bactericides	Bacteria
Fungicides	Fungi and oomycetes
Herbicides	Plant
Insecticides	Insects
Lampricides	Lampreys[3]
Miticides or acaricides	Mites
Molluscicides	Snails
Nematicides	Nematodes
Rodenticides	Rodents
Slimicides	Algae, Bacteria, Fungi, and Slime molds
Virucides	Viruses

Type	Chemical group	Examples with name
Insecticides	Chlorinated Hydrocarbons / Organochlorines	Heptachlor, Aldrin, Dieldrin, BHC, DDT, Endrin, Chlordane, Toxaphene.
	Organophosphates	Diazinon, Parathion, Dursban, Malathion, Phosphomidan, Schradan, Disulfoton, Phorate, Fenitrothion, Dimethoate, Dichlorvos
	Carbonates	Carbonyl, Carbofuran, Methomyl, Aminocarb
	Pyrethroids	Cypermethrin, Fenvalerate
Herbicides	Phenoxyalkyl acids	2, 4-D, 2, 4, 5,-T, MCPA
	Triazineas	Atrizine, Simazine, Propazine
	Phenylureas	Diuron, linuron, Fluometuron
	Aliphatic acids	Dalapon.
	Carbonates	Butylate, Vernolate
	Di-nitro anilines	Trifluralin, Benefin
	Di-pyridyl	Paraquat, Diquat
	Amides	Alachlor, Propachlor, Propanil, Alanap
	Benzoies	Amiben, Dicambra
Fungicides	Thio-carbamates	Ferbam, Maneb
	Mercurial	Ceresin
	Others	Copper sulphate, Chlorothalonial

Source: [22,23]

Food –manufacture of preservatives, packaging and food wraps, refrigerants

- Sorbic acid, sodium sorbate, sorbates: cheese, wine, baked goods, and more
- Benzoic acid, sodium benzoate, benzoates: jams, salad dressing, juices, pickles, carbonated drinks, soy sauce, and more
- Sulfur dioxide, sulfites: fruits, wines, and more
- Nitrites, nitrates: meats

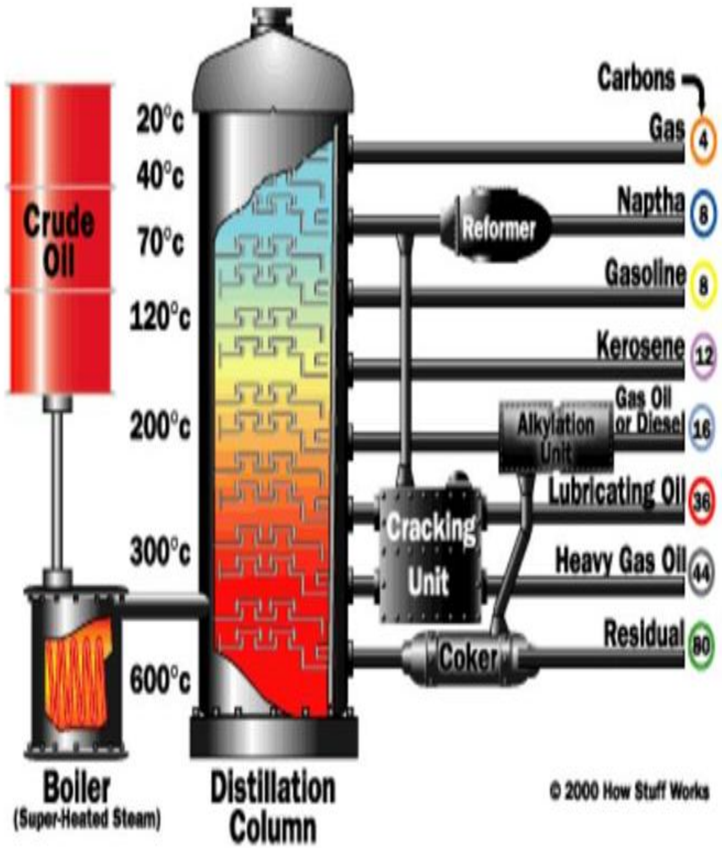
lactic acid: yogurt, kefir, cottage cheeses, and more

- Propionic acid, sodium propionate: baked goods, and more

A refrigerant is a substance used in a heat cycle to transfer heat from one area, and remove it to another.
Chlorofluorocarbons (CFCs
Hydrochlorofluorocarbons (HCFCs
Hydrofluorocarbons (HFCs),

Transportation –production of petrol and diesel, catalytic converters to reduce exhaust emissions

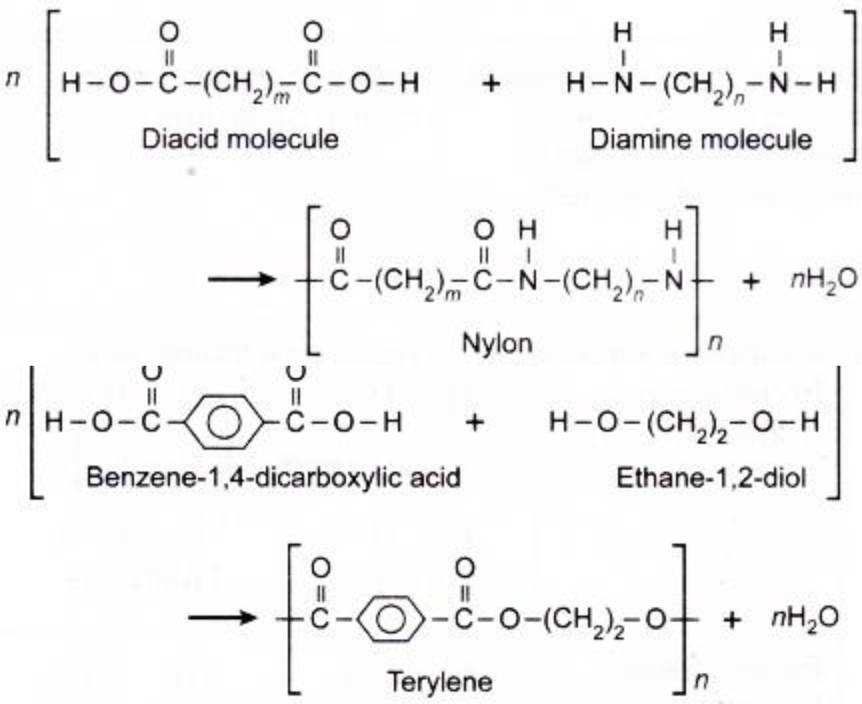
Fractional distillation in oil refining

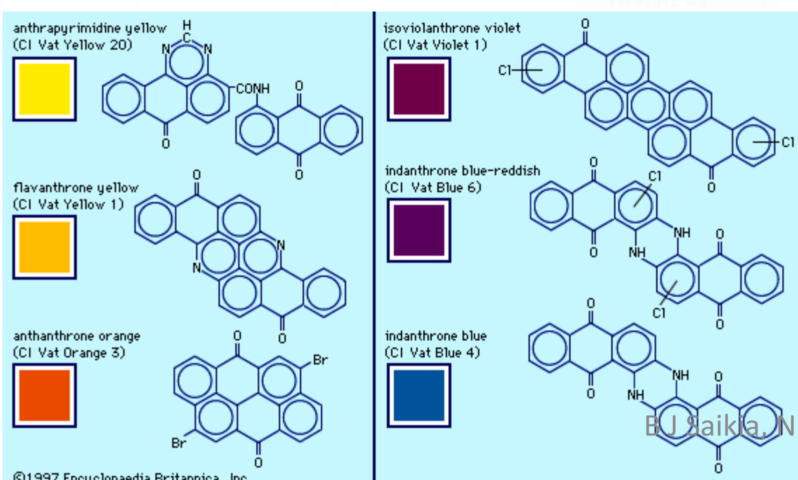


Principal reactions in fluid catalytic cracking

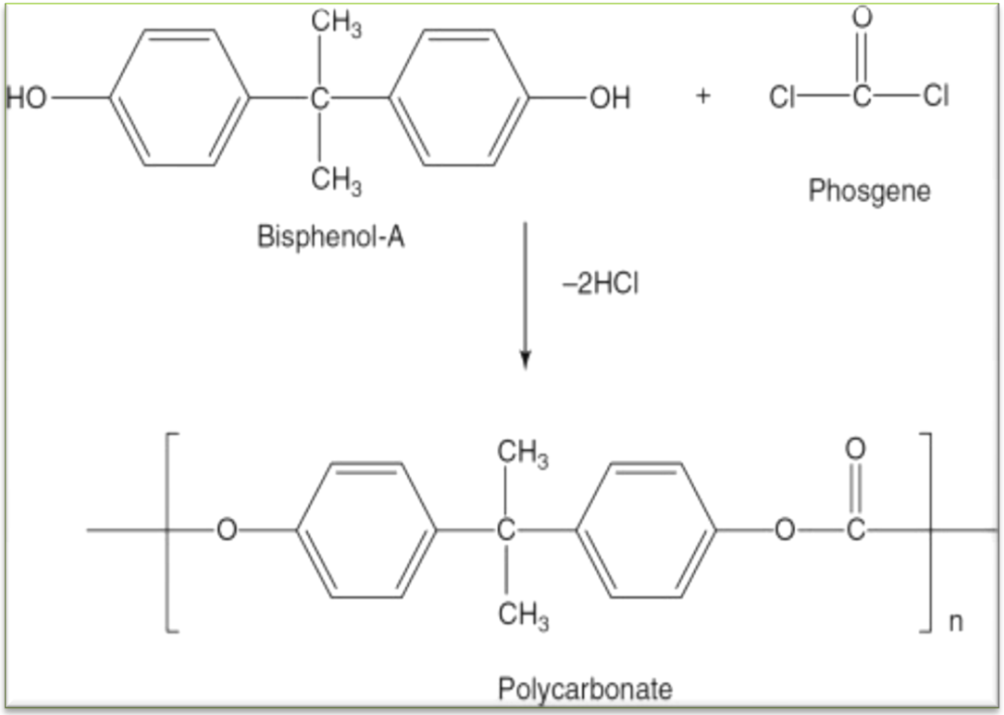
feed	reaction	product
paraffins	cracking	paraffins and olefins
olefins	cracking	LPG olefins
	cyclization	naphthenes
	isomerization	branched olefins (H transfer → branched paraffins)
	H transfer	paraffins
	cyclization, condensation, dehydrogenation	coke
naphthenes	cracking	olefins
	dehydrogenation	cyclo-olefins (dehydrogenation → aromatics)
	isomerization	naphthenes with different rings
aromatics	side-chain cracking	unsubstituted aromatics and olefins
	transalkylation	different alkylaromatics
	dehydrogenation, condensation	polyaromatics (alkylation, dehydrogenation, condensation → coke)

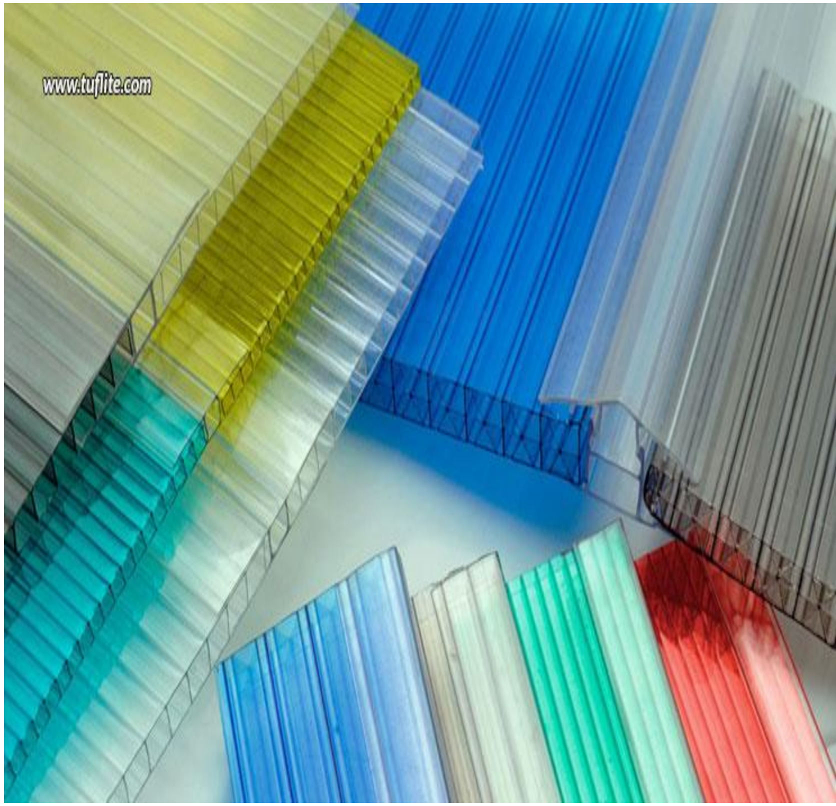
Clothing –synthetic fibers, dyes



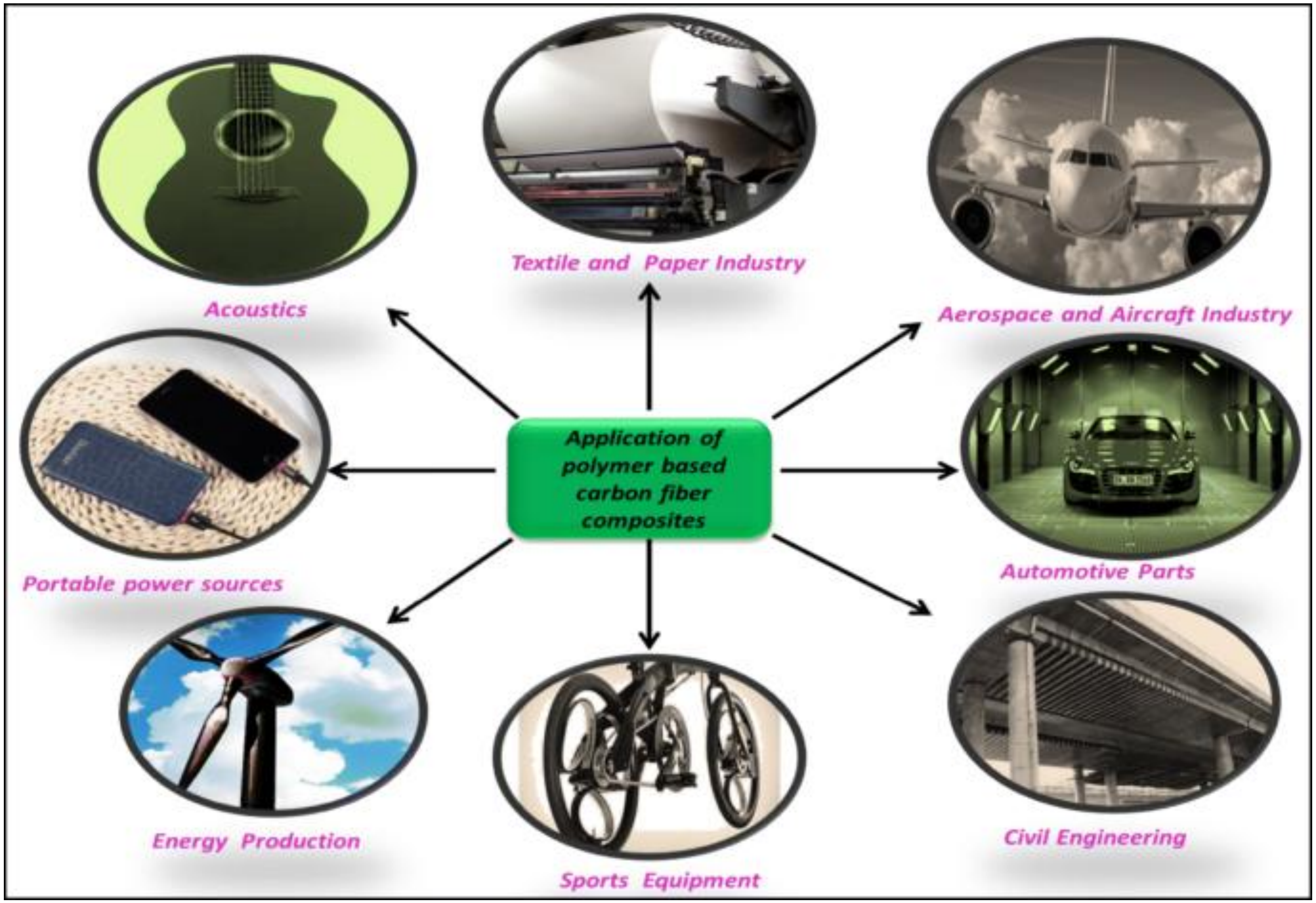


Safety –polycarbonate materials for crash helmets, sunglass, roofing etc





Composite materials for tailor made applications

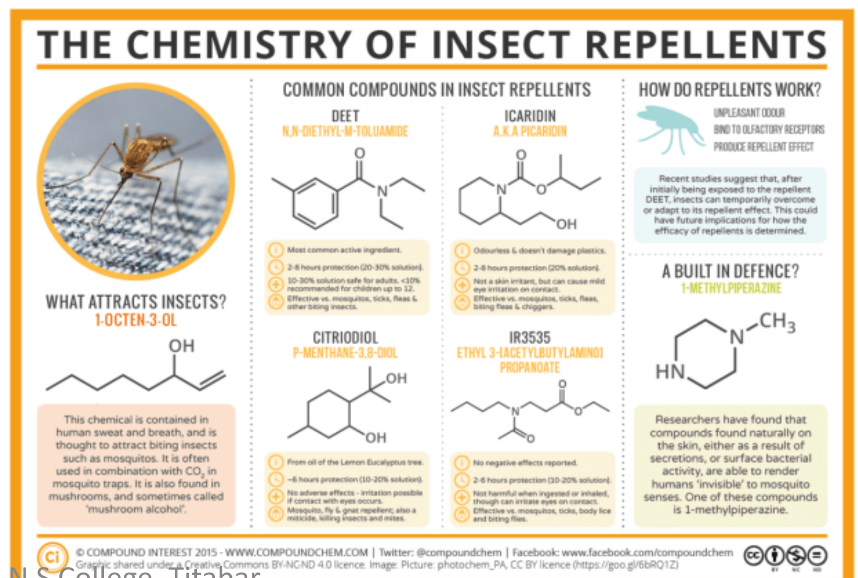


Homes –paints, vanishes and polish

Pigments by elemental composition

- Cadmium pigments: cadmium yellow, cadmium red, cadmium green, cadmium orange, cadmium sulfoselenide
- Chromium pigments: chrome yellow and chrome green (viridian)
- Cobalt pigments: cobalt violet, cobalt blue, cerulean blue, aureolin (cobalt yellow)
- Copper pigments: Azurite, Han purple, Han blue, Egyptian blue, Malachite, Paris green, Phthalocyanine Blue BN, Phthalocyanine Green G, verdigris
- Iron oxide pigments: sanguine, caput mortuum, oxide red, red ochre, yellow ochre, Venetian red, Prussian blue, raw sienna, burnt sienna, raw umber, burnt umber
- Lead pigments: lead white, cremnitz white, Naples yellow, red lead, lead-tin-yellow
- Manganese pigments: manganese violet, YInMn blue
- Mercury pigments: vermilion
- Titanium pigments: titanium yellow, titanium beige, titanium white, titanium black
- Zinc pigments: zinc white, zinc ferrite, zinc yellow
- Aluminum pigment: Aluminum powder
- Carbon pigments: carbon black (including vine black, lamp black), ivory black (bone charcoal)
- Ultramarine pigments (based on sulfur): ultramarine, ultramarine green shade

Detergents, pest killers, cosmatics



Soaps are made from natural ingredients, such as plant oils (coconut, vegetable, palm, pine) or acids derived from animal fat. Detergents, on the other hand, are synthetic, man-made derivatives. While soap is limited in its applications, detergents can be formulated to include other ingredients for all sorts of cleaning purposes.

Dark Side
Soil pollution

Polluting air

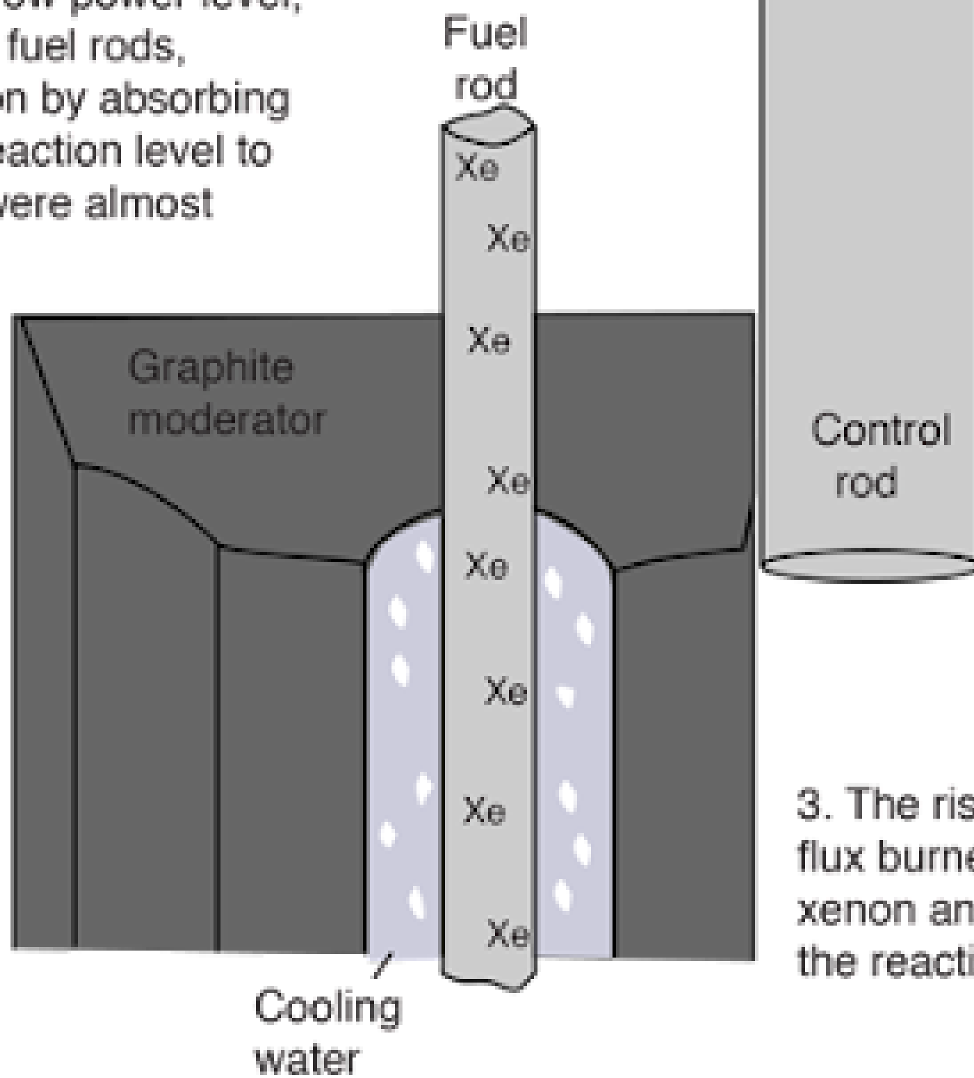
Polluting Air

Chernobyl City(before-26 April 1986)

Critical Final Stages Leading to the Explosion

1. With the extremely low power level, xenon builds up in the fuel rods, "poisoning" the reaction by absorbing neutrons. To get the reaction level to rise, the control rods were almost completely withdrawn.

2. When the turbine was switched off to start the test, the number of feedwater pumps dropped from eight to four. Less pumping caused heating and steam voids in the cooling water. Absorbing fewer neutrons, these voids caused the reaction rate to rise rapidly.

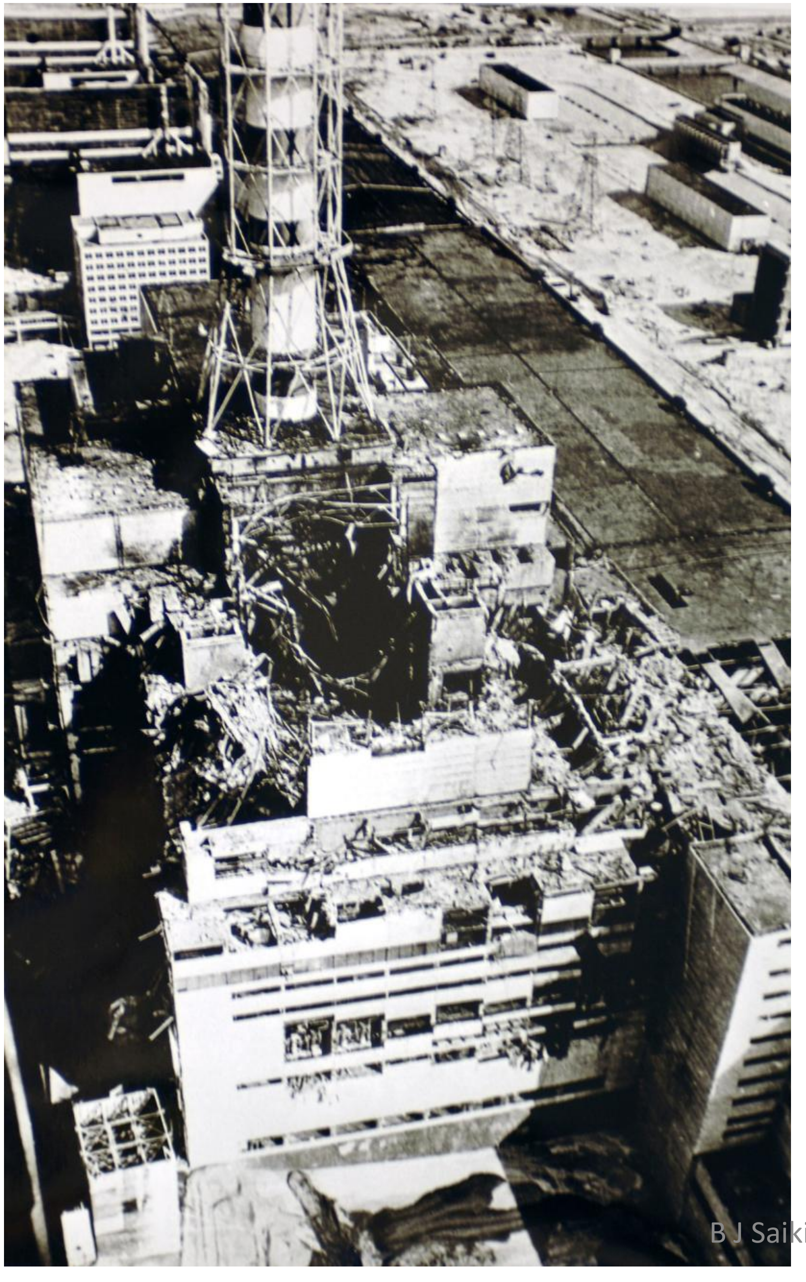


5. Power surges to 100 times the normal operating power!!

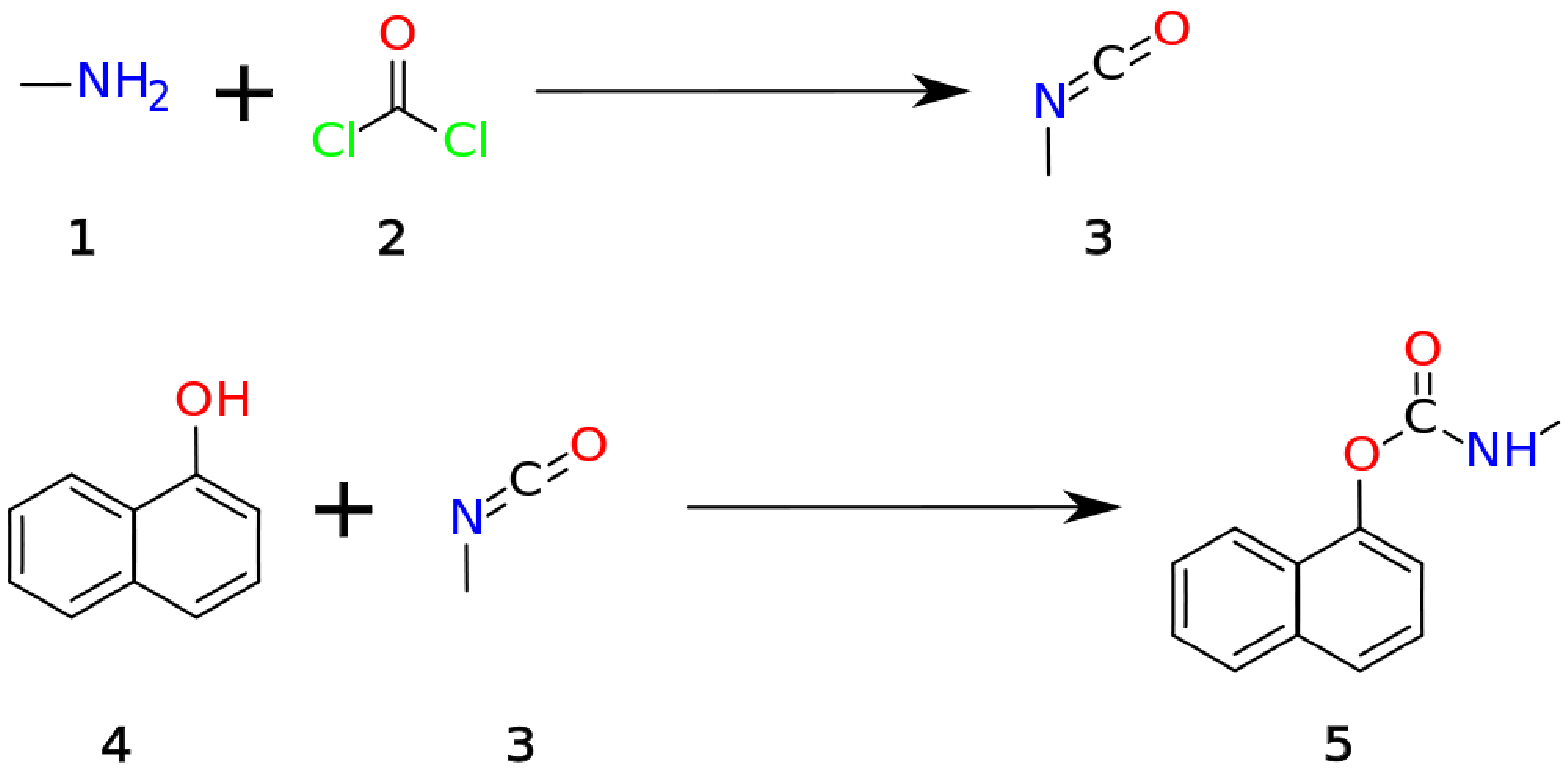
4. Manual control rod insertion comes too late, because it displaces water and actually increases the reaction rate before it can begin to absorb neutrons.

3. The rising neutron flux burned away the xenon and increased the reaction rate.

Chernobyl City (after-26 April 1986)

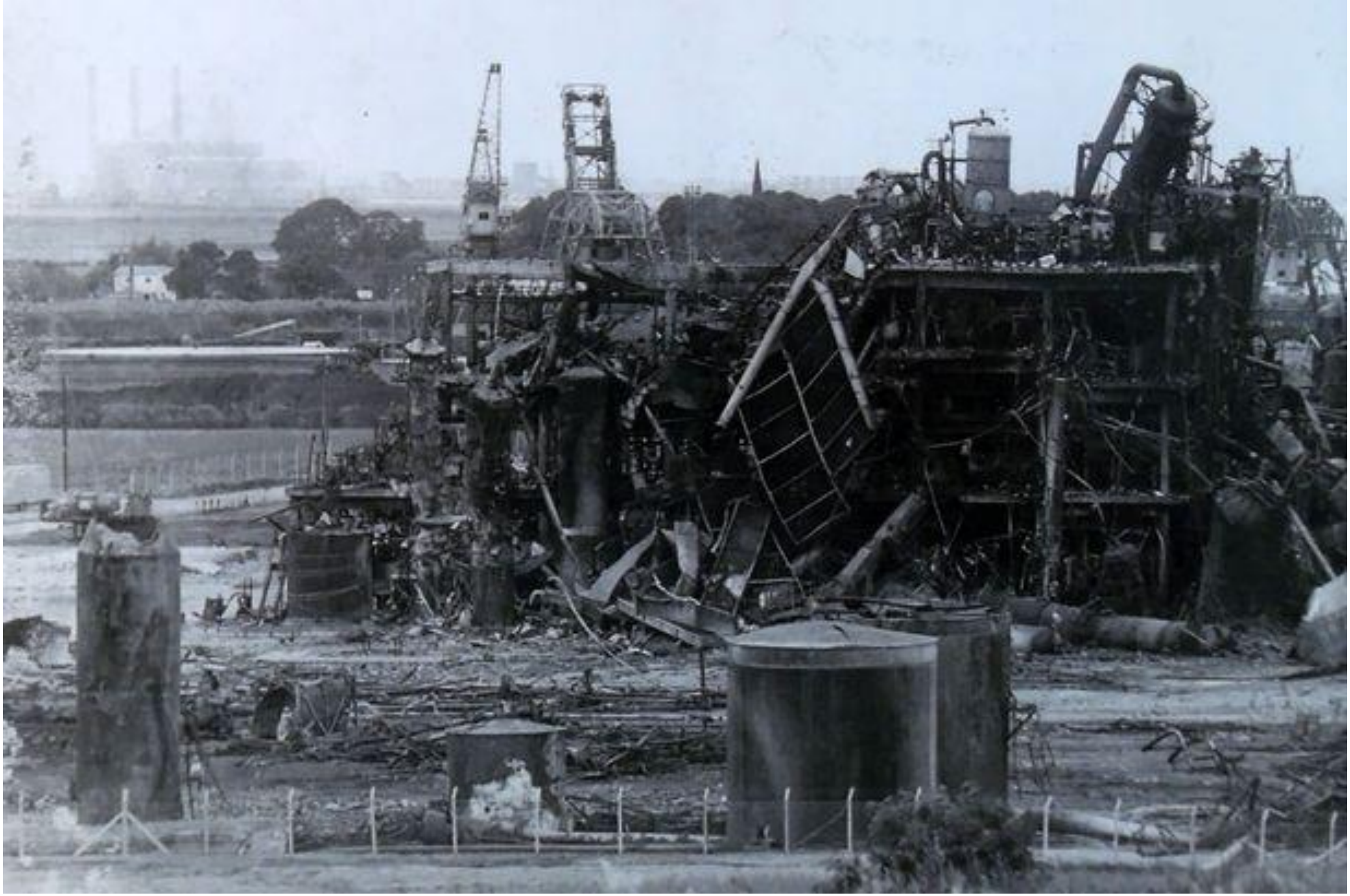


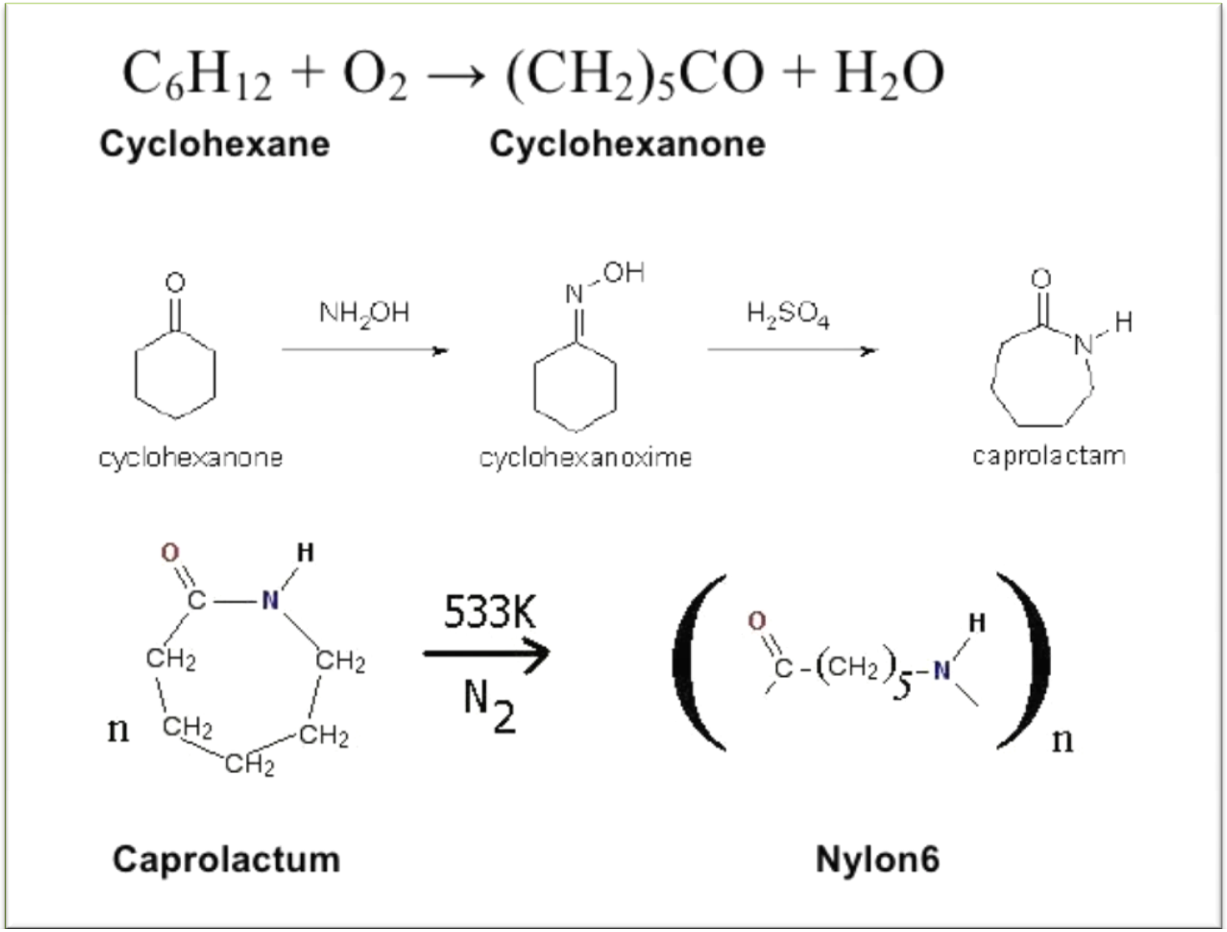
Bhopal Gas Tragedy (1984)



Methylamine (1) reacts with phosgene (2) to produce methyl isocyanate (3), which in turn reacts with 1-naphthol (4) to yield carbaryl (5).

Flixborough disaster

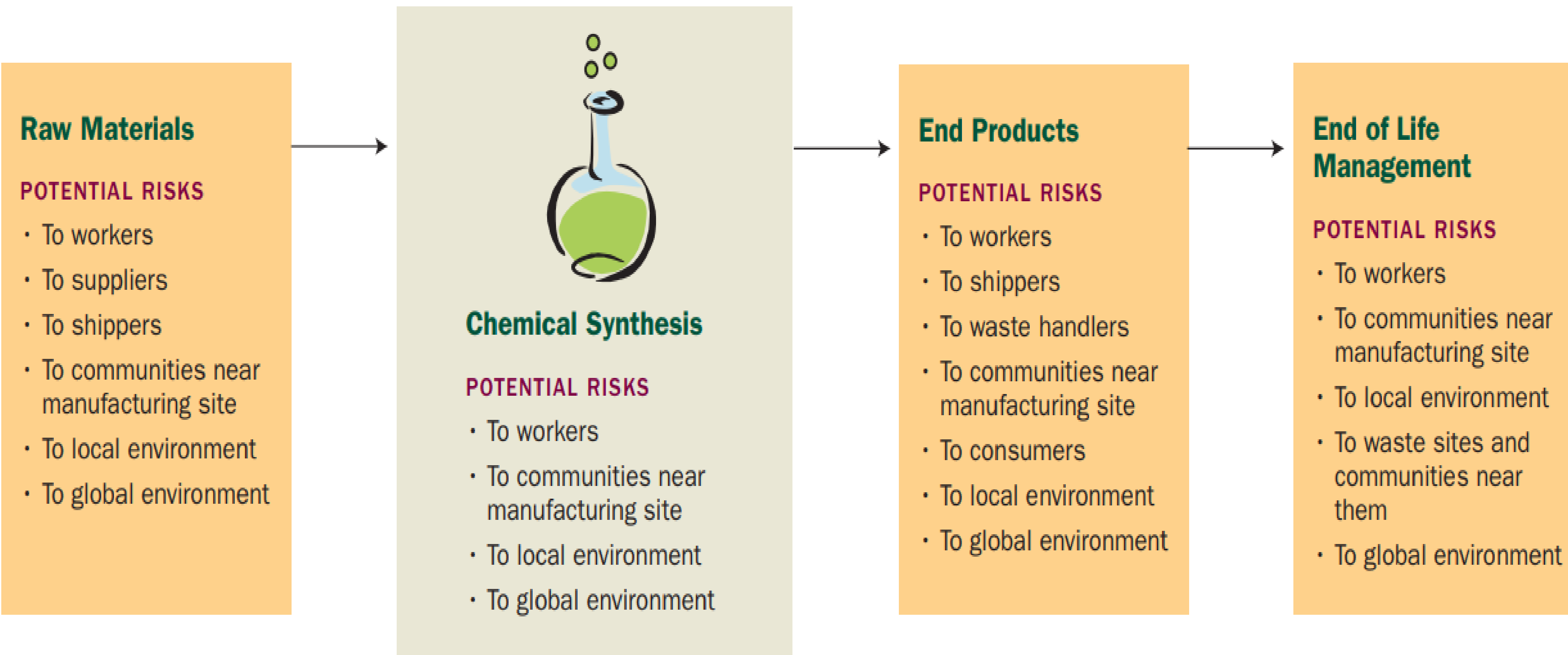




The Flixborough disaster was an explosion at a chemical plant close to the village of Flixborough, North Lincolnshire, England on Saturday, 1 June 1974. It killed 28 people and seriously injured 36 out of a total of 72 people on site at the time. Cyclohexane was leaked from ruptured pipe which caused the disaster.

•Chemistry is undeniable a very prominent part of our daily lives.

•Chemical developments also associated with new environmental problems and harmful unexpected side effects which results in need for greener chemical products



Beginning of consciousness …

- **Silent Spring** is an environmental science book by Rachel Carson. The book was published on September 27, 1962, documenting the adverse environmental effects caused by the indiscriminate use of pesticides.
- Book was so popular that it was the best-seller and the most talked about book in decades.
- Silent Spring was probably the book that had changed the scientific world the most, after the Origin of Species by Charles Darwin.
- This book brought environmental awareness to the public and lead to nationwide band of DDT.

History of green chemistry

The concept of green chemistry was formally established at the Environmental Protection Agency(EPA) in response to Pollution Prevention Act of 1990.

The Law

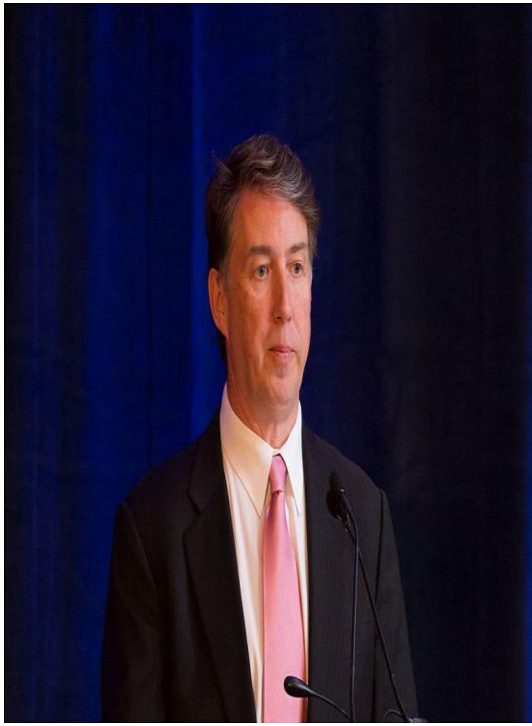
The Federal Pollution Prevention Act of 1990 established pollution prevention as the public policy of the United States. The Federal Act declares that pollution should be prevented or reduced at the source wherever feasible, while pollution that cannot be prevented should be recycled in an environmentally safe manner. In the absence of feasible prevention or recycling opportunities, pollution by-products should be treated. Disposal or other releases into the environment should be used only as a last resort and should be conducted in an environmentally safe manner.

- By 1991, the EPA Office of Pollution Prevention and Toxics had launched a research grant program encouraging redesign of existing chemical products and processes to reduce impacts on human health and the environment. The EPA, in partnership with the U.S. National Science Foundation (NSF), then proceeded to fund basic research in green chemistry in the early 1990s.

- The introduction of the annual Presidential Green Chemistry Challenge Awards in 1996 drew attention to both academic and industrial green chemistry success stories.

- Paul T. Anastas and John Warner conceive the two letter word "green chemistry" and developed the twelve principles of green chemistry in 1998.

- In 2005 Ryoji Noyori identified three key developments in green chemistry: use of supercritical carbon dioxide as green solvent, aqueous hydrogen peroxide for clean oxidations and the use of hydrogen in asymmetric synthesis.



GREEN CHEMISTRY

DEFINITION

Green Chemistry is the utilisation of a set of principles that reduc or eliminates the use or generation of hazardous substances in t design, manufacture and application of chemical products .

GREEN CHEMISTRY IS ABOUT

- **Waste Minimisation at Source**
- **Use of Catalysts in place of Reagents**
- **Using Non-Toxic Reagents**
- **Use of Renewable Resources**
- **Improved Atom Efficiency**
- **Use of Solvent Free or Recyclable Environmentally Benign Solvent systems**

Green Chemistry Is About...

Reducing

- Waste
- Materials
- Hazard
- Risk
- Energy
- Cost

Green chemistry vs Enviromental chemistry

- Environmental chemistry deals with various facets of pollution, degree of pollution and treatment of pollution, while as green chemistry does not lead to pollution at all, hence we say it prevents pollution.

- Green chemistry approach is a prevention approach, while as environmental chemistry approach is a treatment approach.

- Since prevention is better than cure, we may say green chemistry is better than environmental chemistry.

Need for green Chemistry

1. Chemistry, chemical and chemical products have become the most important part of human society which demands sustainability is of chemical products and chemical process is of prime focus.

2. There is increasing pressure from both society and government for chemistry based industries to become more sustainable through development of eco-friendly products and processes that reduce waste and prevent toxic substances from entering the environment.

3. In order to prevent further environmental damage and to encourage more young people into the industry, the public acceptability needs to be raised by adoption of greener and cleaner processes and green product design.

4. With global warming being accepted as the biggest environmental challenge, the chemical industry must also develop more energy efficient process and reduce its reliance on fossil fuels.

5. This can be achieved through development of more environmentally benign products using less hazardous process and raw materials.

6. Green chemistry looks at pollution prevention on the molecular scale.

7. The Green Chemistry program supports the invention of more environmentally friendly chemical processes which reduce or even eliminate the generation of hazardous substances. This program works very closely with the twelve principles of Green Chemistry.

Goals of green chemistry

1. To reduce adverse environmental impact, try appropriate and innovative choice of material & their chemical transformation.
2. To develop processes based on renewable rather than non- renewable raw materials.
3. To develop processes that are less prone to obnoxious chemical release, fires & explosion.
4. To minimize by-products in chemical transformation by redesign of reactions & reaction sequences.
5. To develop products that are less toxic.

6. To develop products that degrade more rapidly in the environment than the current products.

7. To reduce the requirements for hazardous persistent solvents & extractants in chemical processes.

8. To improve energy efficiency by developing low temperature & low pressure processes using new catalysts.

9. To develop efficient & reliable methods to monitor the processes for better & improved controls.

Benefits of Green Chemistry

Human health:

- **Cleaner air**: Less release of hazardous chemicals to air leading to less damage to lungs
- **Cleaner water:** less release of hazardous chemical wastes to water leading to cleaner drinking and recreational water
- Increased safety for workers in the chemical industry; less use of toxic materials; less personal protective equipment required; less potential for accidents (e.g., fires or explosions)
- Safer consumer products of all types: new, safer products will become available for purchase; some products (e.g., drugs) will be made with less waste; some products (i.e., pesticides, cleaning products) will be replacements for less safe products
- Safer food: elimination of persistent toxic chemicals that can enter the food chain; safer pesticides that are toxic only to specific pests and degrade rapidly after use
- Less exposure to such toxic chemicals as endocrine disruptors

Environment:

- Many chemicals end up in the environment by intentional release during use (e.g., pesticides), by unintended releases (including emissions during manufacturing), or by disposal. Green chemicals either degrade to innocuous products or are recovered for further use
- Plants and animals suffer less harm from toxic chemicals in the environment
- Lower potential for global warming, ozone depletion, and smog formation
- Less chemical disruption of ecosystems
- Less use of landfills, especially hazardous waste landfills

Economy and business:

- Higher yields for chemical reactions, consuming smaller amounts of feedstock to obtain the same amount of product
- Fewer synthetic steps, often allowing faster manufacturing of products, increasing plant capacity, and saving energy and water
- Reduced waste, eliminating costly remediation, hazardous waste disposal, and end-of-the-pipe treatments
- Allow replacement of a purchased feedstock by a waste product
- Better performance so that less product is needed to achieve the same function
- Reduced use of petroleum products, slowing their depletion and avoiding their hazards and price fluctuations
- Reduced manufacturing plant size or footprint through increased throughput
- Increased consumer sales by earning and displaying a safer-product label (e.g., Safer Choice labeling)
- Improved competitiveness of chemical manufacturers and their customers

Advantages of Green Processes and Technology

1. Does not release anything harmful into atmosphere
2. Bring economic profits to certain areas
3. Need less maintenance
4. It is renewable which means will never run out
5. Slow the impacts of global warming by reducing CO2 emissions

Limitations of green chemistry

- High implementing costs
- Lack of information
- No known alternative chemical or raw material inputs
- No known alternative process technology
- Uncertainty about performance impacts
- Lack of human resources and skills
- Lesser availability of green technologies
- Problem with Scale-up and commercialization
- Low conversion, poor selectivity, low yield and huge quantities of effluent generated

Obstacles in pursuit of goals of green chemistry:

- Despite this diversity, there are many barriers which appear to be common across large parts of the chemical enterprise

- Regulatory Barriers
- Economic and Financial Barriers
- Technical Barriers
- Organizational Barriers
- Cultural Barriers

Economic and Financial Barriers

- Within the chemical enterprise, a new product or process based on green chemistry must meet two criteria: economic and environmental performance.
- The product or process must not only represent an improvement for health and the environment, but it must also be more profitable, without sacrificing efficacy or quality.
- In the case of an existing product, changes in the production process or formulation must represent enough of a potential cost savings to outweigh upfront costs. But a small decrease in cost of waste, marginal efficiency improvements, or implementation of less dangerous processes may not be enough to justify large investments, especially when exact savings are uncertain or hard to quantify.

Regulatory Barriers

- **While green chemistry is interested in reducing inherent risk through the reduction of hazard, most environmental, health, and safety regulations focus instead on reducing risk through reductions in exposure.**
- **This means that many firms find themselves in situations where they must use their resources on mandated actions and end-of-pipe technologies instead of investing in research and development into inherently safer products and processes.**
- **There are also regulatory barriers that are product sector specific. If a pharmaceutical company wishes to change certain parts of its method of production for a product on the market , it must undergo a time-consuming and expensive recertification process with the FDA(food and drugs administration).**
- **If a company develops a pesticide that is safer, or produced in a less hazardous or more environmentally friendly manner than one in current production, it must go through the process of registration with the EPA.**
- **These regulations, while meant to protect, do not offer any incentives for greener alternatives (such as a fast-track for processes that provide environmental or health benefits) and often take enough time, money, or both, to create a significant barrier to the implementation of green chemistry.**

Technical Barriers

- The science behind green chemistry is often complex and multidisciplinary. While the underlying chemistry has made great progress, there are many reactions and processes for which greener substitutes remain unknown.

- The number of disciplines involved in green chemistry also creates a technical barrier. Organic chemists typically do not have a working knowledge of toxicology, chemical engineering, or ecology. Similarly, toxicologists are not trained as synthetic chemists, and the engineers usually do not have extensive knowledge of environmental systems. This makes it difficult for chemists to anticipate, or take into account, the potential downstream effects of a product or a synthetic pathway

Organizational Barriers.

- A division within an organization may be reluctant to change to a greener production process that may produce costs for their own bottom-line, even if the results benefit the firm as a whole, since this could negatively impact evaluations of the division's performance.

- There can also be occasions where the development of a greener product in one part of a company will hurt the sales of another product, leading to conflicts and difficulty in implementation

Cultural Barriers

- While green chemistry has made significant progress, it is unknown or misunderstood by a large number of chemists.
- It is not part of the standard curriculum in most schools, although this is beginning to change.
- While training is low among chemists, many managers lack even basic awareness of the concept, and its business potential.
- People whose jobs revolve around sales, marketing, and operations have even less exposure to the concepts and potential benefits of green chemistry.

The End

The End