Atomic Table, Number 9

By Yukitoshi Nonaka

The chemical industry is an important industrial sector that, along with metallurgy and ceramics, forms a country's industrial materials infrastructure.

After World War II, the Japanese chemical industry was mainly engaged in the development and production of chemical fertilizers and agricultural chemicals to resolve the critical postwar food shortage. During the high economic growth period that followed, Japan built up the second-largest petrochemical industry in the non-communist world and became a leader in promoting the industrial switchover from conventional materials to synthetic resins. At the same time, it was providing a stable supply of fine-quality, low-priced chemical materials to world markets.

After the 1973 oil crisis, not only the petrochemical industry but also other Japanese chemical industries faced difficulties in obtaining essential supplies of raw materials and energy: Japan lacks the hydrocarbons and other resources necessary for its chemical industry.

Given this situation, the Japanese chemical industry has concentrated efforts on diversifying its sources of imported raw materials and energy and on developing energy- and resource-saving technologies. It also devised the strategy of switching over to the development and production of high-value-added fine chemicals, which depend less on imported materials and energy. This switchover is still in process, but results have already been yielded, as the following description of the fluorine chemical industry shows.

Fluoroplastic is used in domed stadiums like the new Korakuen under construction in Tokyo.

Fluorine: a nonmetallic halogen

Fluorine, discovered in France about 100 years ago, is a very interesting element. It reacts directly with almost all elements in the periodic table, bonding particularly well with hydrogen. When it bonds chemically with another element, fluorine creates a highly stable substance and is therefore used to produce a variety of compounds with such

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properties as strong resistance to heat, electricity and corrosion.

After the mid-20th century, when the chemical industry and related technology had developed and diversified, the fluorine chemical industry began to take off. Because of its powerful chemical activity, fluorine bonded with other elements can create a surprising variety of compounds with excellent characteristics and functions.

The raw materials of fluorine chemical products are fluorite and cryolite. Fluorite has been used for over 100 years as a flux in glass and aluminum production, and today these industries are important sources of supply of hydrogen fluorides and other materials. Although most of Japan's needs for these are met through imports, high-value-added fluorine chemical products use only a small volume of raw materials

A high-tech chemical

As in the U.S. and Western Europe, industrial restructuring and reorganization of key corporations are now underway in Japan. This restructuring aims to change conventional industries into high-tech or tertiary ones. For example, one of the world's top steelmakers has ventured into new businesses, such as the development of minicomputer mainframes, the development and manufacture of fine ceramics and the production of VLSI (very large-scale integration). Fluorine industrial products are essential in almost all branches of such high-tech industry.

In its standard form, fluorine is a yellowish-green, gaseous substance. Relatively simple compounds created by fluorine through bonding with hydrogen or nitrogen are also gaseous substances with strong chemical affinity and bond energy. They are poisonous and highly corrosive; however, when bonded with other elements, particularly with carbon, fluorine creates extremely stable compounds strongly resistant to corrosion and electricity, with heat resistance, weather durability, noncohesion, surface activity and low friction. Moreover, because they possess a multiplicity of these outstanding characteristics they are irreplaceable materials in high-tech industrial fields.

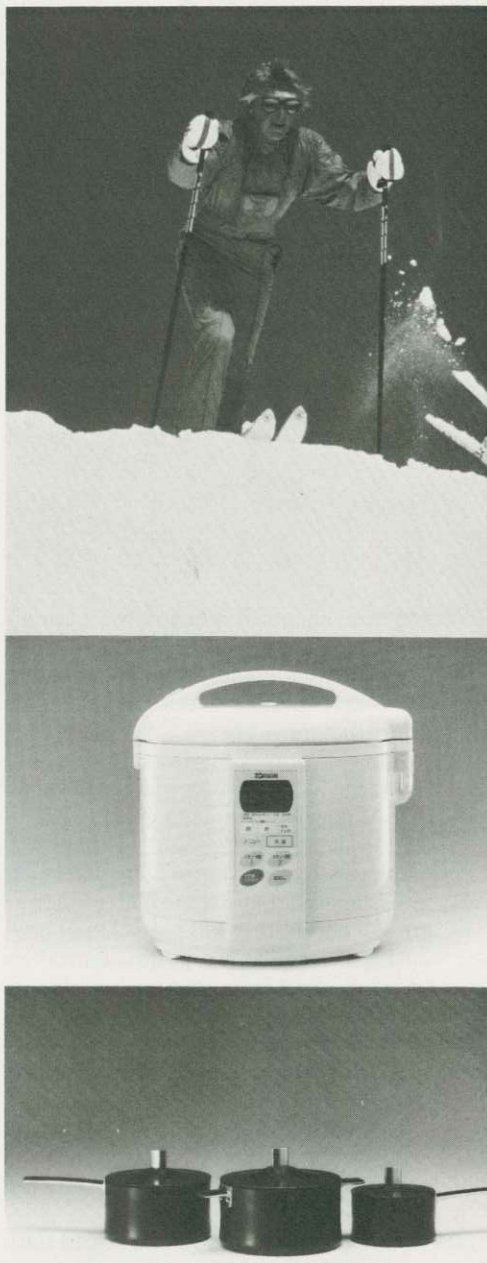
The fluorine chemical industry requires precise and elaborate manipulations of chemical reactions. Because of its wide applications, highly sophisticated science and technology and a high level of industrial technology in related fields are essential. Lacking natural energy and raw material resources, the Japanese chemical industry has had to switch from mass-production-type petrochemical products and chemical fertilizers to high-value-added fine chemicals. Fortunately, the necessary science, technology and related industrial capabilities were available, allowing the chemical industry to develop and produce precision chemical products. Fluorine chemistry was a particularly important sector in this development process.

Because of their chemical bonding power, the normally gaseous fluorine products are used as initial raw materials or chemicals in making a great variety of fluorine chemical products, including high-purity nitrogen trifluoride, flon 14, sulfur hexafluoride, perfluoropropane and silicon tetrafluoride that are used as gases for etching and cleaning in the manufacture of ultra-LSIs and as components in gas lasers.

Fluorine can partially or totally replace the hydrogen in many organic and inorganic compounds, creating a great variety of substances and improving the properties of the original substances so that entirely new uses can be developed.

Fluorine cools and cleans

Relatively low-molecule compounds created by fluorine through bonding with carbon and chlorine come in liquid form of various kinds, depending on the molecular quantity and composition. They are nonflammable, nonexplosive and chemically stable. Because they do not corrode metals and plastics, they are used as cooling media, aerosol spray agents, fire extinguishants, solvents and foaming agents. E.I. du Pont de Nemours and Co. was the first to develop these types of products under its trademark "Freon." Flon gas (fluorocarbon gas) is used as the cooling agent in refrigerators and in air-conditioners. Ammonium gas served this purpose in the past in large refrigeration chambers and cold storage food warehouses, but today more flon than ammonium gas is used because flon gas performs better and it is not harmful if it leaks.



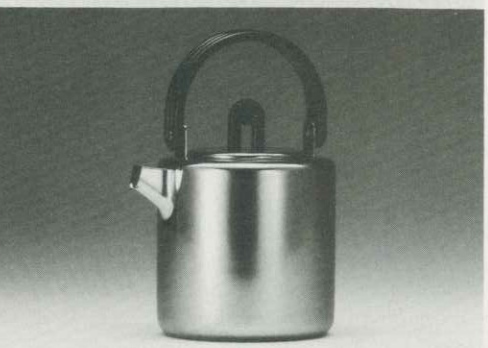
Fluorine goes into easy-care kitchen utensils and waterproof, thermal-exchange outdoor clothing.

Skyrocketing Demand for Fluorine

(¥billion)

	1984	1985 estimate
Fluorine pharmaceuticals	211	220
Flon gas	57	65
Fluoroplastics	31.7	38
Hydrofluoric acid	25	30
Construction material for domed stadiums	0.5	1

Source: Research Institute for Industry and Technology



Flon gas turbine generator technology is nearing commercialization. In this technology, electric power is generated using flon gas as the heating medium in a geothermal generator or in an ocean thermal-difference power generator. Flon is also the heating medium used in the recovery of low-temperature, abundant waste thermal energy discharged from thermal power plants.

Fluorocarbon gas mixed with bromine is used as special fire extinguishant to put out flames in such diverse locations as aircraft engines, art museums and computer rooms. This agent changes free oxygen in the air into nonflammable compounds and thus is especially effective in extinguishing fires. Unlike water, it does not cause damage to objects in the fire area.

Semiconductor devices, electronic parts and precision instruments are sensitive to dirt, dust and oil which affect their performance and inspection ratings. Fluoric solvents, such as flon 113, are superior cleaning agents for electronic parts and precision instruments. Their strong selective solvency means they can be used to clean whole finished products and they are indispensable in high-tech industries. The oil of the fluorine family is nonflammable and highly lubricative. It makes excellent hydraulic fluid for hydraulic machinery and devices and grease for machinery friction parts. Fluoric oil sprinkled with fine particles of magnetic material makes an excellent sealant to prevent air and fluid from leaking between high-speed revolving shafts and bearings.

If the molecular weight of fluorine-bonded substances is increased, they become organic high polymers, such as plastics, synthetic rubber and synthetic fibers. Organic high polymer material containing fluorine has high heat resistance, corrosion resistance, low friction, self-lubrication and weather durability, and also has good piezoelectric, pyroelectric and dielectric characteristics. Therefore, they are being increasingly used in every industrial field. Fluoroplastic and fluororubber are indispensable for high-grade applications such as sheathing of electric wires used in computers, printed circuit substrates and condensers. Piezoelectric and pyroelectric materials are used in microphones, pickups and sensors. Organic high polymers containing fluorine are used in bearings of high-speed revolving bodies as sealants, gaskets, packing, sliders for heavy machinery and bridges and super-weather-resistant paint in high-rise structures. Glass-fiber membrane covered with fluoroplastic is used as roofing material for ultra-large domed stadiums, such as the Houston Astrodome and the new Korakuen Baseball Stadium in Tokyo. In the semiconductor, chemical and food industries, it is used for jigs and containers for strongly corrosive and adhesive substances, reverse osmosis membranes, separation membranes like ultra filtration membranes and diaphragms for the manufacture of caustic soda. Moisture-permeable waterproof clothing worn by mountaineers and skiers allows perspiration to evaporate while keeping out rain and snow and cannot be made without fluorine. Pots and pans and food manufacturing machinery are coated with fluororesin to prevent fat, starch and proteins from sticking to them.

On the medical front

Today, fluorine is applied in the fight against cancer. One drawback of most anti-tumor agents is that while they kill cancerous cells, they also damage normal healthy cells. If molecular elements, for example, hydrogen, in these anti-tumor agents are partially replaced with fluorine, few side effects accompany the cancer-killing action.

Selective permeable membranes of extremely thin fluororesin film can extract only the desired gas from a mixture of gases. Because fluororesin is highly heat resistant it is safe even at high temperatures. A device using a selective permeable membrane to extract from air the oxygen needed by patients suffering from breathing difficulties has already been marketed in Japan.

Fluorine compound colloids carry oxygen efficiently to human extremities and because they are harmless are used as temporary artificial blood in emergency treatment. Because it does not react with human organic matter like blood and is stable and harmless, it is used as material for artificial organs and veins.

The debut of physiological activators using fluorine, such as medicines, insecticides and bactericides, is being awaited with high hopes, along with anti-cancer agents. Research is now underway on agents with better anti-tumorial effects and fewer side effects by replacing hydrogen and other elements in the molecular composition of these medicines with forms of fluorine. "Futraful" is one such drug now commercially available in Japan and similar medicines will be developed in the future.

The ultimate objective of energy technology is nuclear power. The separation and refining of nuclear fuel central to the process would not have been possible without diaphragms made from fluorine compounds like ethylene tetrafluoride polymer which withstands the violent corrosion of uranium compounds.

Fluorine's characteristics are being exploited in research and development on substances to be used in industrial activities covering all aspects of human life. Spectacular progress and development are foreseen in the field of inorganic fluorine compounds. Glass for high-performance optical fibers and for high-refraction power lenses and the electrolytes needed to produce high-performance batteries have already been developed and commercialized in Japan. ●