IBUPROFEN

Ibuprofen, which is sold under trade names such as Motrin® and Advil®, is an alternative to aspirin and acetaminophen because of its analgesic and antiinflammatory properties.

Ibuprofen can be synthesized from isobutylbenzene by a Friedel-Crafts acylation with acetyl chloride, followed by formation of a cyanohydrin. Treatment with hydrogen iodide and phosphorus reduces the benzylic hydroxyl to a hydrogen and hydrolyzes the nitrile to a carboxylic acid.

INSECTICIDES

Insecticides are chemical compounds that are used for the control of insects either through death of the insect or through interference with the reproductive cycle of the insect.

Early insecticides also included organic natural products such as nicotine, rotenone, and pyrethrin. Rotenone is used as a method of killing rough fish when a lake has been taken over completely by them. In a couple of weeks after treatment the lake is then planted with fresh game fish. The pyrethrins, originally obtained from Asian or Kenyan flowers, can now also be synthesized. Nicotine is no longer used as an insecticide because it is not safe for humans.

Dichlorodiphenyltrichloroethane (DDT) is no longer being used in large amounts because of its persistence in the environment, although for many uses there were no good substitutes available. DDT was first made in 1874 but its insecticidal properties were not discovered until 1939.

Second-generation insecticides are of three major types: chlorinated hydrocarbons, organophosphorus compounds, and carbamates. Synthetic pyrethroids are a recent fourth type. A very dramatic decline of the chlorinated hydrocarbons in the late 1960s and the 1970s, while the use of organophosphates and carbamates increased.

The use of chlorinated hydrocarbons has declined worldwide and is banned in many countries for three main reasons: (1) concern over the buildup of residues, (2) the increasing tendency of some insects to develop resistance to the materials, and (3) the advent of insecticides that can replace the organochlorine compounds.

In the 1970s, organophosphorus compounds became the leading type of insecticide. Over 40 such compounds have been registered in the United States as insecticides. The first organophosphorus insecticide was synthesized in 1938 and is known as tetraethyl pyrophosphate (TEPP). Another phosphate insecticide, Malathion is synthesized by condensing diethyl maleate with the *o*,*o*-dimethyl phosphorodithioic acid.

The 1950s saw the development of carbaryl (Sevin®), the first major carbamate and is manufactured by condensing l-naphthol with methyl

isocyanate. The l-naphthol is made from naphthalene by hydrogenation, oxidation, and dehydrogenation. The 1-naphthol is made from naphthalene, which is obtained from coal tar distillation or from petroleum.

Methyl isocyanate can be made from phosgene ($COCl_2$) and methylamine (CH_3NH_2), which would circumvent use of the isocyanate. Methyl isocyanate is a very dangerous chemical and was responsible for the deaths of over 2500 people in the worst industrial accident ever, that of the carbamate insecticide plant in Bhopal, India on December 3, 1984.

INSULIN

Insulin, a hormone, plays a key role in catalyzing the processes by which glucose (carbohydrates) furnishes energy or is stored in the body as glycogen or fat. The absence of insulin not only interrupts these processes, but produces depression of essential functions and, in extreme cases, even death. Insulin protein is characterized by a high sulfur content in the form of cystine and it is unstable in alkaline solution.

Insulin is isolated from the pancreas of beef or pigs and by extraction with acidified alcohol, followed by purification. In the process (Fig. 1), the crude alcoholic extract is run from two strong extraction-centrifuge units into a collection tank from which the extract is neutralized with ammonia and filter aid added. In a continuous precoat drum filter, the cake is separated and washed, the clear liquor going to the reacidification tank. In evaporators, the first stage removes alcohol, with subsequent waste-fat separation. The extract goes to a chill tank, with filter aid added, through a filter press and into the second evaporator. From the second evaporator, the concentrated extract is filtered and conducted to the first salting-out tank, followed by filter-press filtration with filtrate to sewer and salt cake to purification for the second salting out. The second-salting-out product is crystallized twice to furnish Iletin® (insulin) crystals.

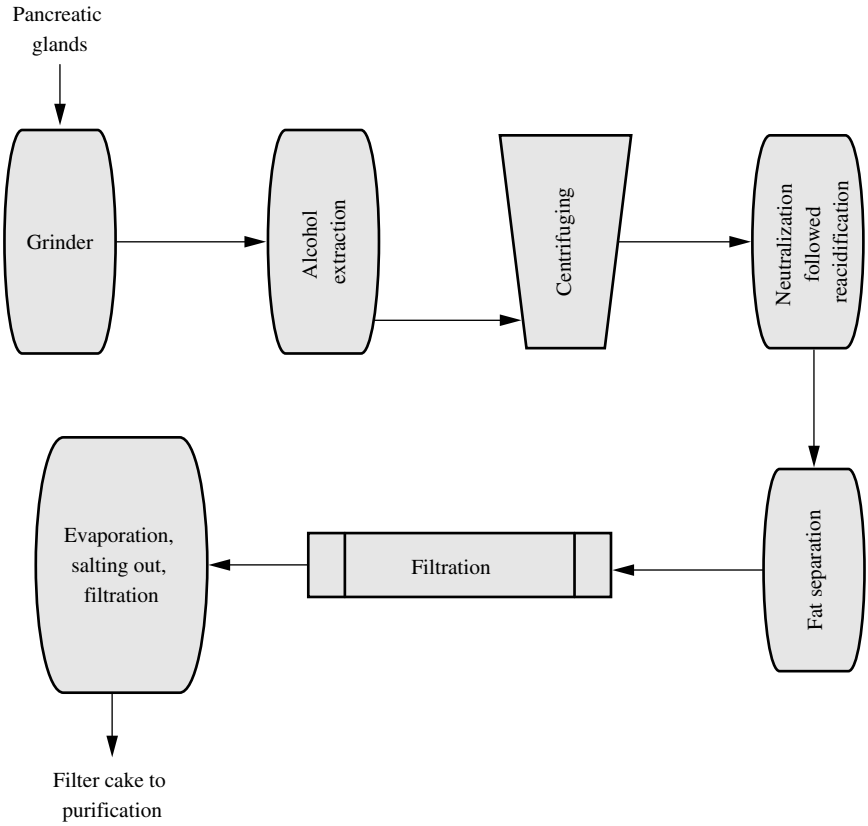

FIGURE 1 Manufacture of insulin.

IODINE

Iodine (melting point: 113.5°C, boiling point: 184.4°C, density: 4.93) is a red to purple solid that sublimes readily under ambient conditions. Iodine can be produced from iodates (Fig. 1):

$$IO_3^- + 3SO_2 + 3H_2O \rightarrow I^- + 3SO_4^{2-} + 6H^+$$

$$IO_3^- + I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$$

Iodine can also be produced from brine. This process (Fig. 2) consists of cleaning the solution (of clays and other materials), adding sulfuric acid to a pH <2.5 followed by treatment with gaseous chlorine:

$$2I^- + Cl_2 \rightarrow I_2 + 2Cl^-$$

after which the iodine is recovered by a countercurrent air blow out step. process.

Iodine is used for the manufacture of organic compounds, for the manufacture of potassium iodide and sodium iodide, and for the manufacture of other inorganic compounds. Iodine is used as a catalyst in the chlorination of organic compounds and in analytical chemistry for determination of the *iodine numbers* of oils. Iodine for medicinal, photographic, and pharmaceutical purposes is usually in the form of alkali iodides, prepared through the agency of ferrous iodide.

In addition, iodine is also used for the manufacture of dyes and as a germicide. Simple iodine derivatives of hydrocarbons, such as iodoform (CHI_3), have an antiseptic action. Organic compounds containing iodine have been used as rubber emulsifiers, chemical antioxidants, and dyes and pigments.

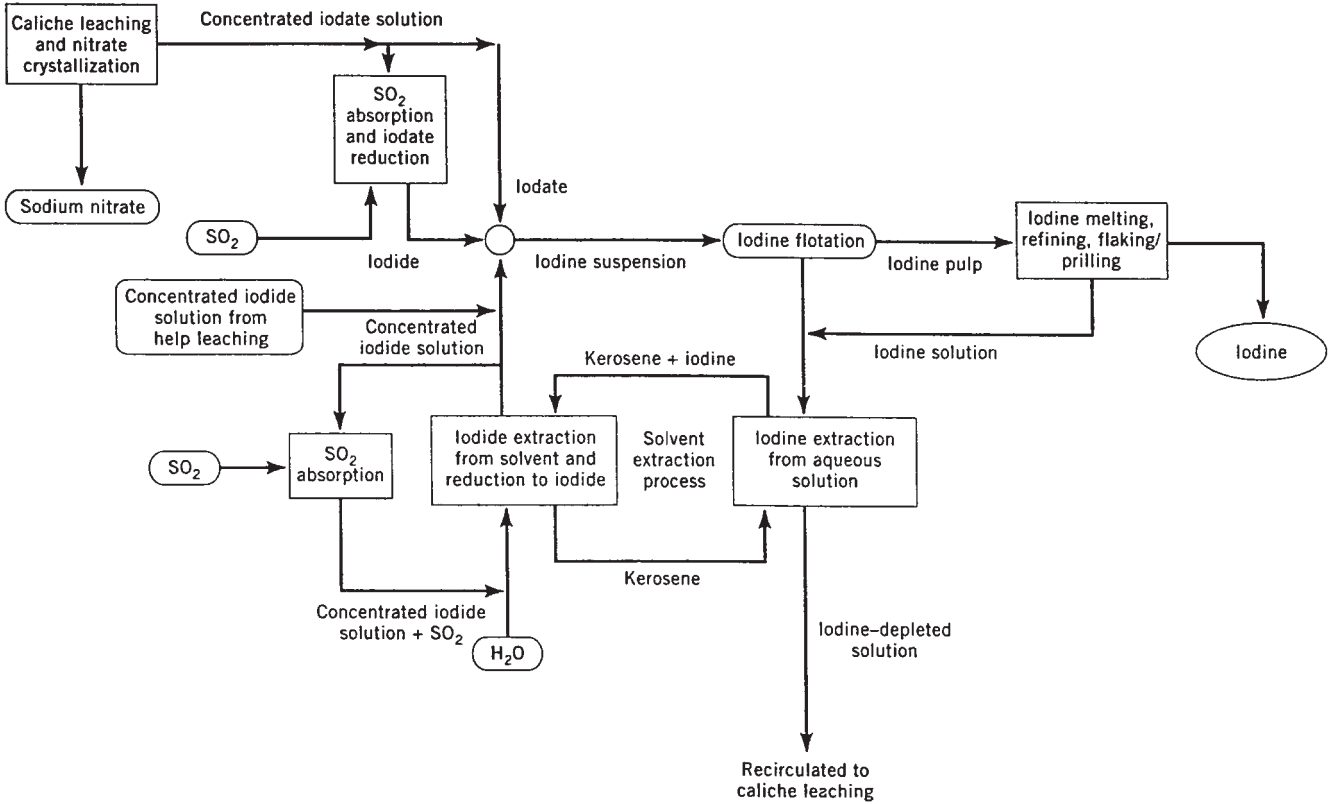

FIGURE 1 Iodine manufacture from iodate solutions.

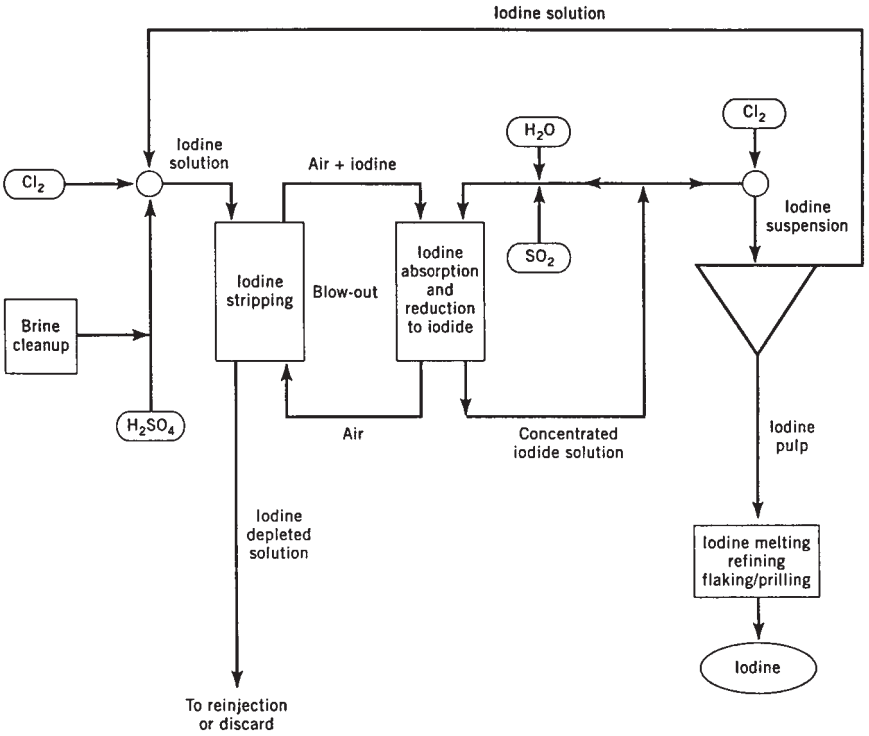

FIGURE 2 Iodine manufacture from brine.

ISONIAZID

Isoniazid, isonicotinic acid hydrazide, is the most potent and selective of the tuberculostatic antibacterial agents.

ISOPRENE

Isoprene (melting point: –146°C, boiling point: 34°C, density: 0.6810) may be produced by the dehydrogenation of *iso*-pentane in the same plant used for the production of butadiene. However, the presence of 1,3-pentadiene (for which there is very little market) requires a purification step. One method produces isoprene from propylene. Thus, dimerization of propylene to 2-methyl-1-pentene is followed by isomerization of the 2-methyl-1-pentene to 2-methyl-2-pentene, which upon pyrolysis gives isoprene and methane.

$$CH_3CH{=}CH_2 \rightarrow CH_3CH_2CH_2CH(CH_3){=}CH_2$$

$$CH_3CH_2CH_2CH(CH_3){=}CH_2 \rightarrow CH_3CH_2CH{=}C(CH_3)_2$$

$$CH_3CH_2CH{=}C(CH_3)_2 \rightarrow CH_2{=}CHC(CH_3){=}CH_2 + CH_4$$

Isoprene can be also produced from isobutylene and formaldehyde and the product is of exceptional purity when made by this method. The *iso*-butylene is first condensed with formaldehyde to yield the cyclic 4,4-dimethyl-*m*-dioxane, which produces isoprene.

$$(CH_3)_2C{=}CH_2 + 2HCH{=}O \rightarrow (CH_3)_2COCH_2OCH_2CH_2$$

$$(CH_3)_2COCH_2OCH_2CH_2 \rightarrow CH_2{=}CHC(CH_3){=}CH_2 + HCH{=}O + H_2O$$

The production of isoprene from acetylene and acetone is also possible. The acetylene is reacted with acetone to produce 2-methyl-3-butyn-2-ol which, by hydrogenation produces 2-methyl-3-butene-2-ol. Dehydration then yields isoprene.

$$HC{\equiv}CH + (CH_3)_2C{=}O \rightarrow (CH_3)_2C(OH)C{\equiv}CH$$

$$(CH_3)_2C(OH)C{\equiv}CH + H_2 \rightarrow (CH_3)_2C(OH)CH{=}CH_2$$

$$(CH_3)_2C(OH)CH{=}CH_2 \rightarrow CH_2{=}CHC(CH_3){=}CH_2 + H_2O$$

ISO-PROPYL ALCOHOL

Iso-propyl alcohol (2-propanol, *iso*-propanol, rubbing alcohol) is manufactured by the esterification/hydrolysis of propylene to *Iso*-propyl alcohol. Unlike ethanol, for which the esterification/hydrolysis has been replaced by direct hydration, the direct process for *Iso*-propyl alcohol is more difficult for crude propylene.

In the esterification process only the propylene reacts and conditions can be maintained so that ethylene is inert.

$$CH_3CH{=}CH_2 + H_2SO_4 \rightarrow CH_3CH(OSO_3H)CH_3$$

$$CH_3CH(OSO_3H)CH_3 + H2O \rightarrow CH_3CH(OH)CH_3 + H_2SO_4$$

The esterification step occurs with 85% sulfuric acid at 24 to 27°C, and dilution to 20% concentration is done in a separate tank. The *iso*-propyl alcohol is distilled from the dilute acid that is concentrated and returned to the esterification reactor. The *Iso*-propyl alcohol is originally distilled as a 91% azeotrope with water. Absolute *iso*-propyl alcohol, boiling point 82.5°C, is obtained by distilling a tertiary azeotrope with isopropyl ether. A 95% yield is realized.

Iso-propyl alcohol is used to produce acetone, pharmaceuticals, processing solvents, and coatings. Some of the chemicals derived from *iso*-propyl alcohol are *iso*-propyl ether (an industrial extraction solvent), *iso*-propyl acetate (a solvent for cellulose derivatives), *iso*-propyl myristate (an emollient, lubricant, and blending agent in cosmetics, inks, and plasticizers), *t*-butylperoxy *iso*-propyl carbonate (a polymerization catalyst and curing agent), and *iso*-propylamine and *diiso*-propylamine (low-boiling bases).

ISOQUINOLINE

See ***Quinoline.***