

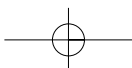
TALC

The mineral talc is a magnesium silicate $[\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2]$, density: 2.5 to 2.8] that occurs as foliated to fibrous masses with a waxlike or pearly color, white to gray or green translucent to opaque. It has a distinctly greasy feel.

Talc is found chiefly in the metamorphic rocks, often those of a more basic type because of the alteration of the minerals mentioned above.

A coarse grayish-green talc rock has been called soapstone or steatite and was formerly much used for stoves, sinks, and electrical switchboards. Talc is used as a cosmetic, for lubricants, and as a filler in paper manufacturing. Most tailor's *chalk* consists of talc.

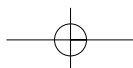
2.511



TALL OIL

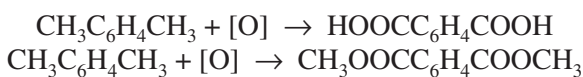
Tall oil is the generic name for the oil obtained upon acidification of the black liquor residue from kraft pulp digesters. Kraft processing dissolves the fats, fatty acids, rosin, and rosin acids contained in pinewoods in the form of sodium salts and when the black liquor is concentrated to make it possible to recover some of its chemical and heating value, the soaps become insoluble and can be skimmed off. The brown, frothy curd thus obtained is then made acidic with sulfuric acid, converting the constituents to a dark-brown fluid (tall oil).

Tall oil is used as a source of turpentine. Tall oil fatty acids are mostly normal C_{18} acids, 75% mono- and diunsaturated, with lesser amounts of saturated and triunsaturated constituents. Tall oil is also used for water-proofing agents, dimer acids, polyamide resins for printer's ink, adhesives, detergents, and agricultural emulsifiers.



TEREPHTHALIC ACID

Terephthalic acid (boiling point: 300°C) and dimethyl terephthalate (melting point: 141°C) are derived from *p*-xylene by oxidation of *p*-xylene in acetic acid as a solvent in the presence of a variety of catalysts such as cobalt and manganese salts of heavy metal bromides as catalysts at 200°C and 400 psi (Fig. 1).



The crude terephthalic acid is cooled and crystallized followed by evaporation of the acetic acid and xylene. The terephthalic acid is washed with hot water to remove traces of the catalyst and acetic acid. If *p*-formylbenzoic acid is present as an impurity from incomplete oxidation, it can be

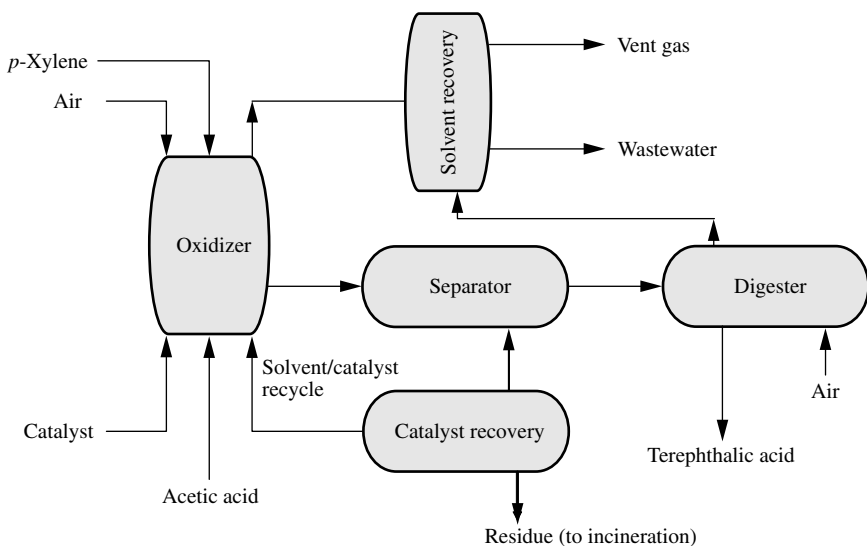
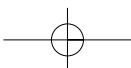


FIGURE 1 Manufacture of terephthalic acid from *p*-xylene.



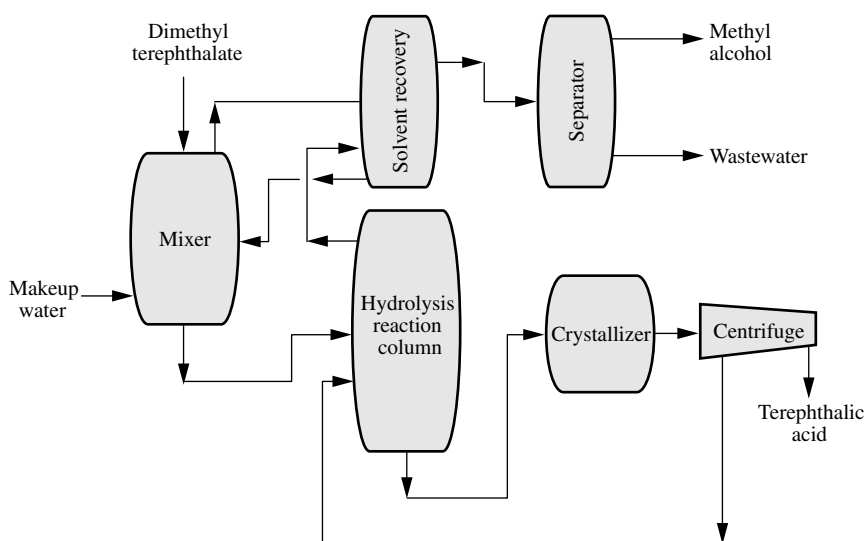


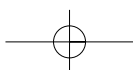
FIGURE 2 Manufacture of terephthalic acid from dimethyl terephthalate.

removed by hydrogenation to *p*-methylbenzoic acid and recrystallization of the pure terephthalic acid, melting point 300°C.

The dimethyl terephthalate can be converted to terephthalic acid by hydrolysis (Fig. 2).

Dimethyl terephthalate is manufactured from terephthalic acid or directly from *p*-xylene. Esterification of terephthalic acid with methanol occurs with sulfuric acid as the acid catalyst. Direct oxidation of *p*-xylene with methanol present also produced dimethyl terephthalate; copper salts and manganese salt are catalysts for this reaction. The dimethyl terephthalate (boiling point 288°C, melting point 141°C) must be carefully purified via a five-column distillation system.

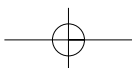
Terephthalic acid and dimethyl terephthalate are used to produce polyester fibers, polyester resins, and polyester film. Terephthalic acid or dimethyl terephthalate is usually reacted with ethylene glycol to give poly(ethylene terephthalate) but sometimes it is combined with 1,4-butanediol to yield poly(butylene terephthalate). Polyester fibers are used in the textile industry. Films find applications as magnetic tapes, electrical insulation, photographic film, packaging, and polyester bottles.



TETRACHLOROETHYLENE

See Perchloroethylene.

2.515

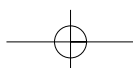


TETRACYCLINES

Tetracycline compounds are efficient antibacterial agents and have the broadest effects of any antibacterial discovered.

The tetracyclines are manufactured by fermentation procedures or by chemical modifications of the natural product. Controlled catalytic hydrogenolysis of chlortetracycline, a natural product, selectively removes the 7-chloro atom and produces tetracycline, the most important member of the group.

The hydrochloride salts are used most commonly for oral administration and are usually encapsulated because of their bitter taste.



TETRAHYDROFURAN

Tetrahydrofuran (freezing point: -108°C , boiling point: 67°C , density: 0.8892) can be manufactured from butane by using circulating solids technology in which butane is oxidized to maleic acid and thence to tetrahydrofuran (Fig. 1).

See Liquefied Petroleum Gas.

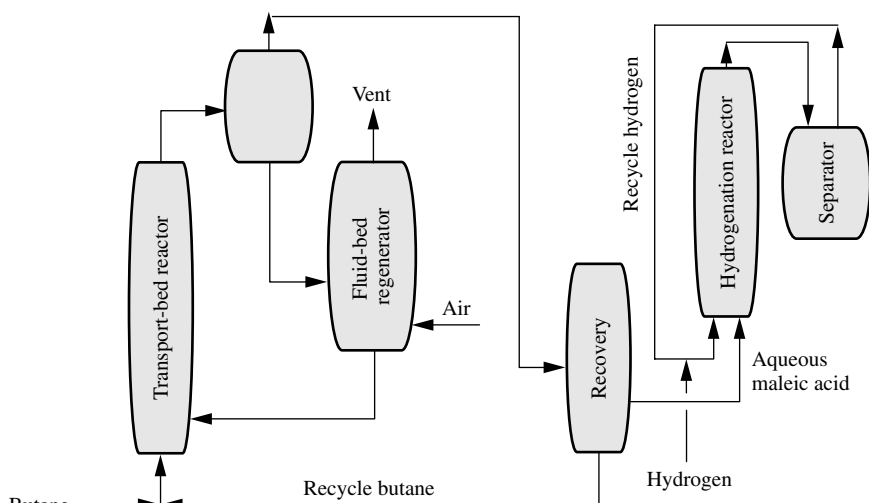
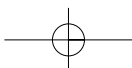


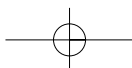
FIGURE 1 Manufacture of tetrahydrofuran from butane.



TETRAZINE

See Explosives.

2.518



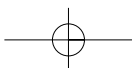
TETRYL

Tetryl [2,4,6-trinitrophenylmethylnitramine, $\text{C}_6\text{H}_2(\text{NO}_2)_3\text{NCH}_3\text{NO}_2$] is manufactured by the action of mixed sulfuric and nitric acid on dimethylaniline in a multiple-stage nitration.

It may also be manufactured by alkylating 2,4-dinitrochlorobenzene with methylamine followed by nitration.

Tetryl is a high explosive with intermediate sensitivity and is used as a base charge in blasting caps, as the booster explosive in high-explosive shells, and as an ingredient of binary explosives.

2.519



TITANIUM DIOXIDE

Titanium dioxide (TiO_2 , density: 4.26) occurs in two crystalline forms, *anatase* and the more stable *rutile*. Anatase can be converted to rutile by heating to 700 to 950°C. It is variously colored, depending upon source, decomposes at about 1640°C before melting, and is insoluble in water but soluble in sulfuric acid or alkalis.

The two methods for producing titanium dioxide are the *sulfate process* and the *chloride process*. The sulfate process is a batch process introduced by European makers in the early 1930s, and the chloride process, a continuous process, was introduced in the late 1950s. The sulfate process can handle both rutile and anatase, but the chloride process is limited to rutile.

The *sulfate process* (Fig. 1) involves the reaction of ilmenite (an ore containing 45 to 60% by weight titanium dioxide) and treating it with sul-

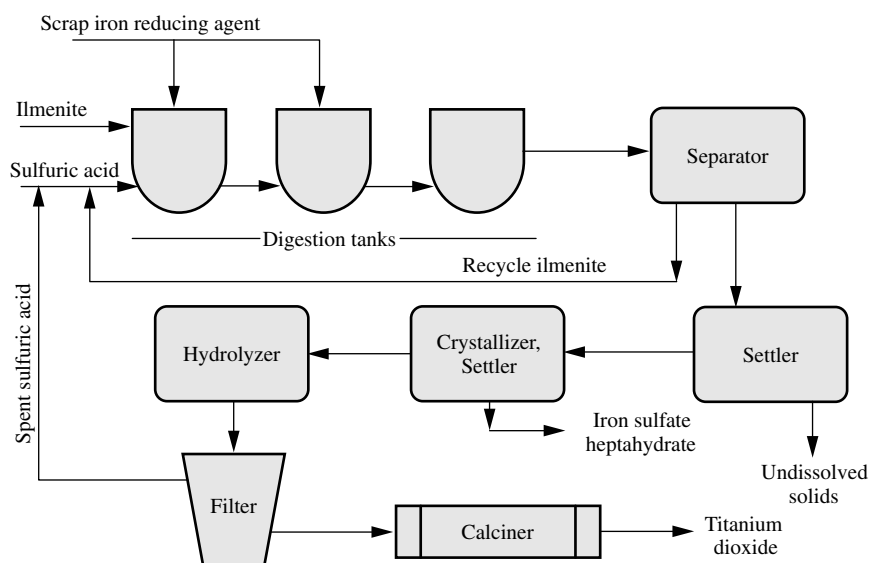
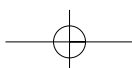
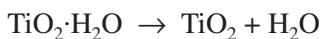
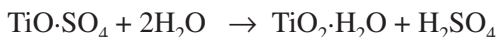


FIGURE 1 Titanium dioxide manufacture by the sulfate process.



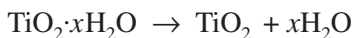
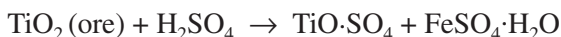
furic acid for digestion and filtration. Hydrolysis of the sulfate and heating gives pure titanium dioxide.



The iron sulfate crystallizes out from the titanium persulfate solution and can be recycled to make more sulfuric acid. The sulfate process uses the ore ilmenite as a raw material, while the chloride process requires rutile. Ilmenite can be converted to synthetic rutile.

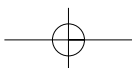
The sulfate process has traditionally used batch ore digestion, in which concentrated sulfuric acid is reacted with ilmenite. This reaction is very violent and causes the entrainment of sulfur oxides (SO_x) and sulfuric acid in large amounts of water vapor. In an effort to reduce the particulate emissions, scrubbers have been installed at most plants, but these, in turn, have necessitated the treatment of large quantities of scrubbing liquid before discharge. Other waste-disposal problem products are spent sulfuric acid and copperas ($\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$).

The sulfate process has, in some cases, been supplanted by the chloride process because of by-product character and disposal. However, a continuous process that uses relatively dilute sulfuric acid (25 to 60%) to temper the violent, original reaction and to reduce the amount of water-vapor-entrained particulates is available. As the process uses more dilute acid than the older batch process, more of the spent acid can be recycled.



The hydrolysis reaction is dependent upon several factors: quantity and quality of the seeds added to the colloidal suspension of titanium dioxide, concentration, rate of heating, and pH. Introduction of seeds prior to hydrolysis ensures production of the desired form. Using anatase seeds, 6 hours of boiling is needed. and with rutile seeds, the time can be shortened to 3 hours.

The *chloride process* (Fig. 2) involves the reaction of rutile (an ore containing approximately 95% by weight titanium dioxide, TiO_2) with chlorine to give titanium tetrachloride (TiCl_4), a liquid that can be purified by



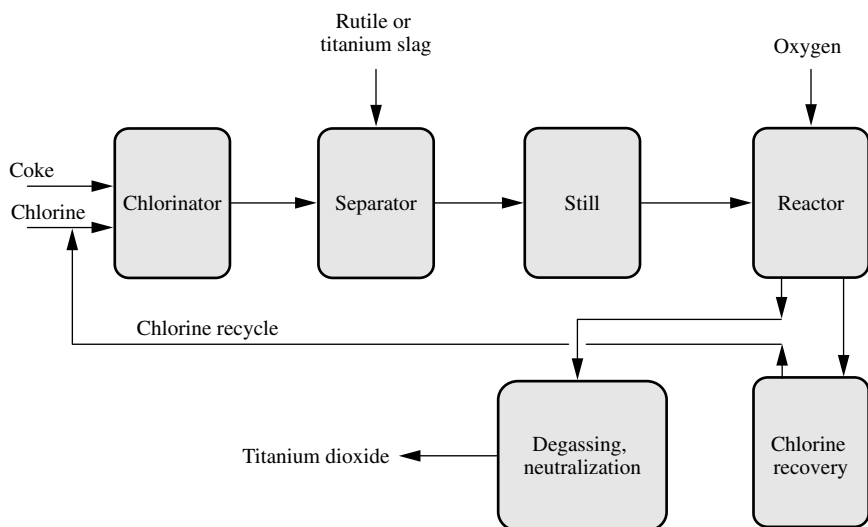
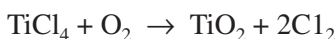
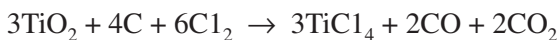


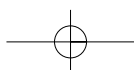
FIGURE 2 Titanium dioxide manufacture by the chloride process.

distillation, boiling point 136°C . The titanium tetrachloride is then oxidized to pure titanium dioxide and the chlorine is regenerated.



The chloride process utilizes the treatment of rutile (natural or synthetic) with chlorine gas and coke to produce titanium tetrachloride (TiCl_4). The titanium tetrachloride is distilled to remove impurities and then reacted with oxygen or air in a flame at about 1500°C to produce chlorine and very fine particle titanium dioxide. The chlorine is recycled (Fig. 1).

Titanium dioxide is the principal white pigment of commerce. The compound has an exceptionally high refractive index, great inertness, and a negligible color, all qualities that make it close to an ideal white pigment. The major uses of titanium dioxide pigments are: paint, paper, plastics, floor coverings, printing inks, and various applications including rubber, ceramics, roofing granules, and textiles. Almost all of the titanium dioxide used in paints is the rutile form.



TOLUENE

Toluene ($\text{C}_6\text{H}_5\text{CH}_3$, boiling point: 110.8°C , density: 0.8548, flash point: 4.4°C , ignition temperature: 552°C) is a colorless, flammable liquid with a benzenelike odor that is essentially insoluble in water but is fully miscible with alcohol, ether, chloroform, and many other organic liquids. Toluene dissolves iodine, sulfur, oils, fats, resins, and phosgene. When ignited, toluene burns with a smoky flame. Unlike benzene, toluene cannot be easily purified by crystallization.

Toluene is generally produced along with benzene, xylenes, and C_9 aromatics by the catalytic reforming of C_6 – C_9 naphthas. The resulting crude reformate is extracted, most frequently with sulfolane (Fig. 1) or tetraethylene glycol and a cosolvent, to yield a mixture of benzene, toluene, xylenes, and C_9 -aromatics, which are then separated by fractionation.

The principal source of toluene is catalytic reforming of refinery streams. This source accounts for about 79% of the total toluene produced. An additional 16% is separated from pyrolysis gasoline produced in steam

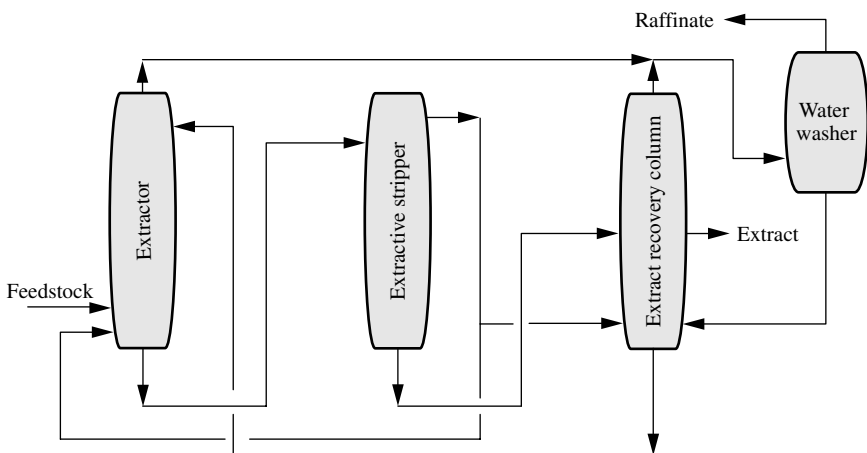
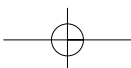


FIGURE 1 Toluene or aromatics recovery by sulfolane extraction.



crackers during the manufacture of ethylene and propylene. Other sources are an additional 1% recovered as a by-product of styrene manufacture and 4% entering the market via separation from coal tars. The reactions taking place in catalytic reforming to yield aromatics are dehydrogenation or aromatization of cyclohexanes, dehydroisomerization of substituted cyclopentanes, and the cyclodehydrogenation of paraffins.

One toluene production process commences with mixed hydrocarbon stocks and can be used for making both toluene and benzene, separately or simultaneously. The process is a combination of extraction and distillation. An aqueous dimethyl sulfoxide (DMSO) solution is passed countercurrently against the mixed hydrocarbon feed. A mixture of aromatic and paraffinic hydrocarbons serves as reflux.

Catalytic reforming is the major source of benzene and xylenes as well as of toluene. There are three basic types of processes: semiregenerative, cyclic, and continuous.

In the semiregenerative process (Fig. 2), feedstocks and operating conditions are controlled so that the unit can be maintained on stream from 6 months to 2 years before shutdown and catalyst regeneration. In cyclic process (Fig. 3), a swing reactor is employed so that one reactor can be regenerated while the other three are in operation. Regeneration, which may be as frequent as every 24 hours, permits continuous operation at high severity. In the continuous process (Fig. 4), the catalyst is continuously withdrawn, regenerated, and fed back to the system.

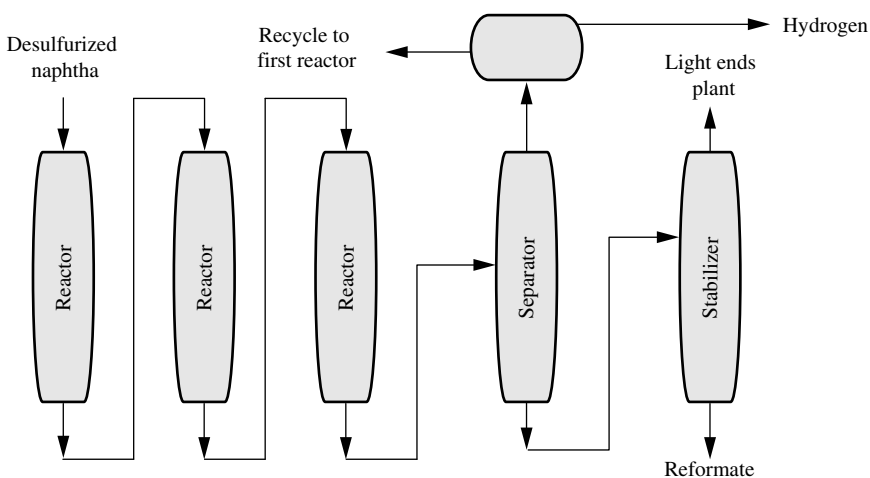


FIGURE 2 Toluene manufacture by a semiregenerative reforming process.

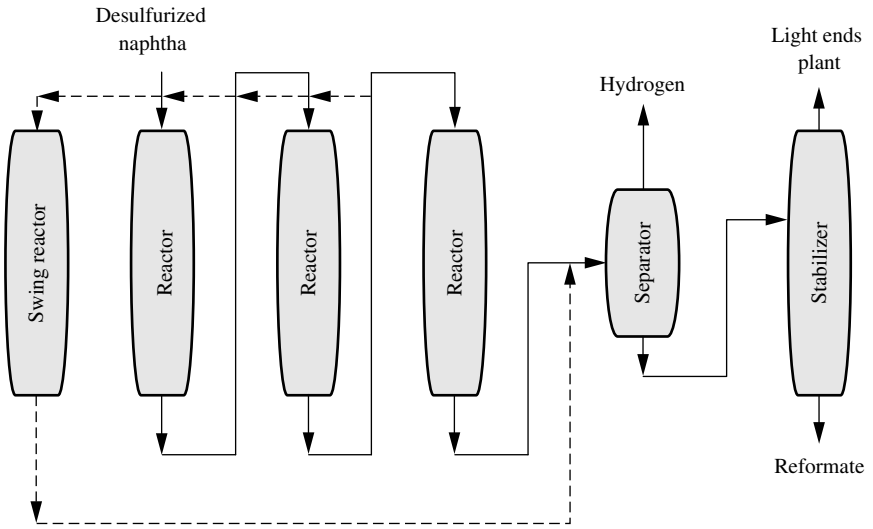


FIGURE 3 Toluene manufacture by a cyclic reforming process.

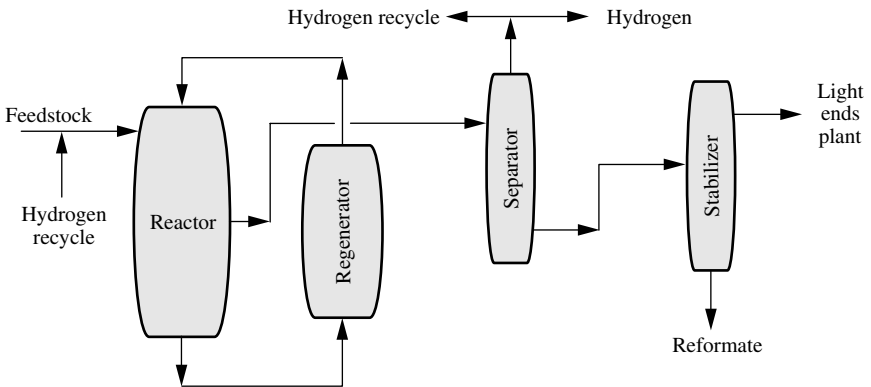
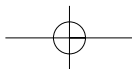


FIGURE 4 Toluene manufacture by a continuous reforming process.

The dealkylation of toluene is a prime source of benzene, accounting for about one-half of toluene consumption. The production of diisocyanates from toluene is increasing. As a component of fuels, the use of toluene is lessening. Toluene takes part in several industrially important syntheses. The hydrogenation of toluene yields methyl cyclohexane ($C_6H_{11}CH_3$), a solvent for fats, oils, rubbers, and waxes. Trinitrotoluene [TNT, $CH_3C_6H_2(NO_2)_3$] is a major component of several explosives. When reacted with sulfuric acid, toluene yields *o*- and *p*-toluene sulfonic acids



($\text{CH}_3\text{C}_6\text{H}_4\text{SO}_3\text{H}$). Saccharin is a derivative of the ortho acid; chloramine T (an antiseptic) is a derivative of the para acid.

Like benzene, which is made from toluene by hydrodealkylation, toluene also provides a source for a variety of chemicals (Fig. 5).

Toluene also provides an alternative source for the manufacture of the xylene isomers, especially *p*-xylene. The last two products provide routes respectively to terephthalic acid and *p*-xylene without the need for an isomer separation, a very appealing use for toluene that is often in excess supply, unlike the xylene isomers.

Another process is the conversion of toluene into caprolactam that provides an alternative basic building block for this chemical other than benzene. Toluene is oxidized to benzoic acid, and hydrogenation to cyclohexanecarboxylic acid is followed by treatment with nitrosylsulfuric acid to form cyclohexanone oxime followed by rearrangement to caprolactam.

Two other derivatives of toluene are the explosive trinitrotoluene (TNT) and the polyurethane monomer toluene diisocyanate (TDI).

The production of trinitrotoluene requires complete nitration of toluene that can be achieved by use of nitric acid.

Toluene diisocyanate is derived from a mixture of dinitrotoluenes (usually 65 to 85% *o,p*-dinitrotoluene and 35 to 15% *o,o*-dinitrotoluene) followed by reduction to the diamine and reaction with phosgene to the diisocyanate.

Toluene diisocyanate is made into flexible foam polyurethanes for cushioning in furniture, automobiles, carpets, bedding, polyurethane coatings, rigid foams, and elastomers.

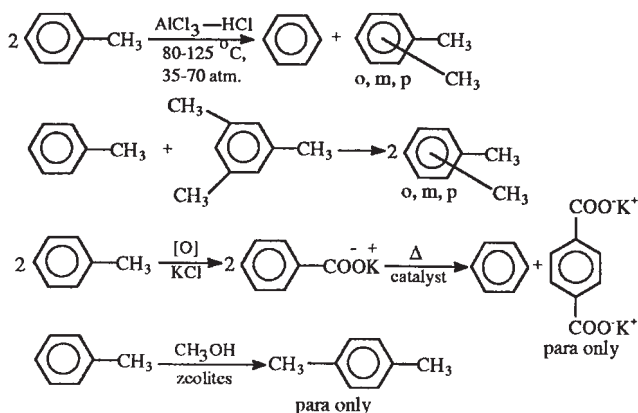
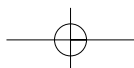


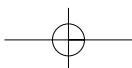
FIGURE 5 Conversion of toluene to other aromatics.



Chlorotoluene ($\text{CH}_3\text{C}_6\text{H}_4\text{Cl}$), a widely used solvent for synthetic resins and rubber, is a derivative of toluene. Toluene also is used in the manufacture of benzoic acid ($\text{C}_6\text{H}_5\text{CO}_2\text{H}$), the latter an important ingredient for phenol ($\text{C}_6\text{H}_5\text{OH}$) production.

In other industrially important processes, toluene is a source of benzyl chloride ($\text{C}_6\text{H}_5\text{CH}_2\text{Cl}$), benzal chloride ($\text{C}_6\text{H}_5\text{CHCl}_2$), benzotrichloride ($\text{C}_6\text{H}_5\text{CCl}_3$), benzyl alcohol ($\text{C}_6\text{H}_5\text{CH}_2\text{OH}$), benzaldehyde ($\text{C}_6\text{H}_5\text{CHO}$), and sodium benzoate ($\text{C}_6\text{H}_5\text{COONa}$).

*See **Benzene**.*

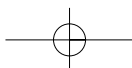


TOLUENE DIISOCYANATE

Toluene diisocyanate (TDI) is made from the reaction of 2,4-toluenediamine and phosgene. The diamine is made by reduction of dinitrotoluene, which in turn is manufactured by nitration of toluene.

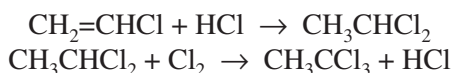
Toluene diisocyanate is used for the production of flexible polyurethane foams for furniture, transportation uses, carpet underlay, and bedding; for coatings; in rigid foams; and elastomers.

2.528



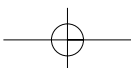
1,1,1-TRICHLOROETHANE

1,1,1-trichloroethane (melting point: -30.4°C , boiling point: 74.1°C , density: 1.3390) is made primarily from vinyl chloride by a hydrochlorination-chlorination process.



It is also be made from vinylidene chloride by hydrochlorination or from ethane by chlorination.

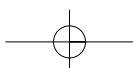
Uses of 1,1,1-trichloroethane are in vapor degreasing, cold cleaning, aerosols, adhesives, intermediates, and coatings.



TRICHLOROETHYLENE

See Perchloroethylene.

2.530



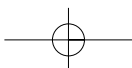
TRIETHYLENE GLYCOL

Triethylene glycol is produced, with diethylene glycol, as a by-product in the manufacture of ethylene glycol from hydrolysis of ethylene oxide.



It is separated from the ethylene glycol and diethylene glycol by vacuum distillation.

See Ethylene Glycol and Diethylene Glycol.

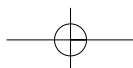


TRINITROTOLUENE

Symmetrical trinitrotoluene (1,3,5-trinitrotoluene, *sym*-trinitrotoluene, TNT) is manufactured by multiple-stage nitration of toluene with a mixture of nitric acid and sulfuric acid.

Three-stage nitration to mono-, di-, and trinitrotoluene was formerly used, but continuous-flow stirred-tank reactors and tubular units using the countercurrent flow of strong acids and toluene permit better yields and reaction control.

2.532



TURPENTINE

Turpentine is a mixture of $C_{10}H_{16}$ volatile terpene hydrocarbons (predominantly α -pinene and β -pinene) made of isoprene units).

Turpentine is produced from various species of pines and balsamiferous woods, and several different methods are applied to obtain the oils leading to different types of turpentine, such as (1) dry-distilled wood turpentine from dry distillation of chopped woods and roots of pine trees, (2) steam-distilled wood turpentine that is steam-distilled from pine wood or from solvent extracts of the wood, and (3) sulfate turpentine, which is a by-product of the production of cellulose sulfate.

Pine oil is a mixture of terpene-derived alcohols. It can be extracted from pine but is also synthetically made from turpentine, especially the α -pinene fraction, by reaction with aqueous acid. It is used in many household cleaners as a bactericide, odorant, and solvent.

Rosin, a brittle solid, melting point 80°C , is obtained from the gum of trees and tree stumps as a residue after steam distillation of the turpentine (Fig. 1). It is made up of 90% resin acids and 10% neutral matter. Resin

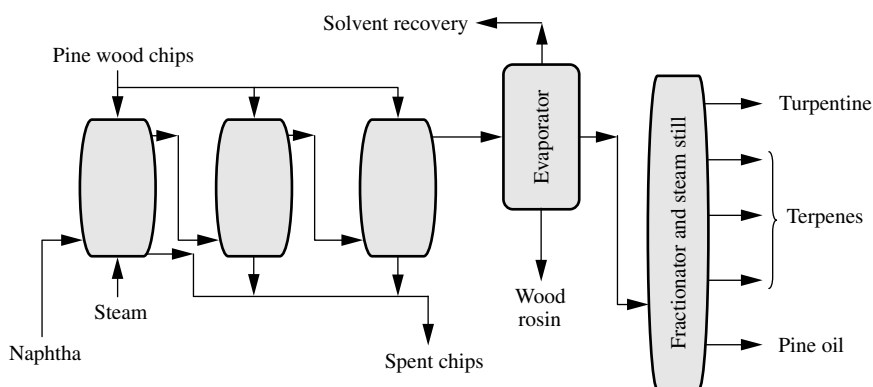
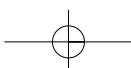


FIGURE 1 Production of turpentine.



acids are tricyclic monocarboxylic acids of formula $C_{20}H_{30}O_2$. The common isomer is 1-abietic acid. About 38% of rosin is used as paper size (its sodium salt), in synthetic rubber as an emulsifier in polymerization (13%), and in adhesives (12%), coatings (8%), and inks (8%).

In addition to turpentine, rosin, and pine oil that can be obtained from pines, directly or indirectly by distillation or extraction, the kraft pulp process now furnishes many related side products. Sulfate turpentine can be obtained from the black kraft liquor. Tall oil rosin and tall oil fatty acids can also be isolated from this liquor. Tall oil rosin is similar to pine rosin and is used in paper sizing, printing inks, adhesives, rubber emulsifiers, and coatings. Tall oil fatty acids are C_{16} and C_{18} long-chain carboxylic acids used in coatings, inks, soaps, detergents, disinfectants, adhesives, plasticizers, rubber emulsifiers, corrosion inhibitors, and mining flotation reagents.

