

Acrylic Acid

Technology and Cost Estimates for Production Via Propylene Oxidation, 3HP Fermentation, (Glycerol Derived) Acrolein, (Ethylene-Oxide Derived) β -Propiolactone, Acetylene Complex. Regional supply, demand and trade forecasts.

PERP 08/09

Report Abstract
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INTRODUCTION

Acrylic acid (also known as propenoic acid) is a colorless transparent liquid with a pungent smell. This corrosive chemical is miscible in water, alcohol, and esters and polymerizes readily in the presence of oxygen forming acrylic resins. For this reason, the product is usually stabilized with polymerization inhibitors such as methyl ethyl hydroquinone (MEHQ).

There are two grades of acrylic acid commercially available:

Technical Grade Acrylic Acid which usually has about 94 percent acrylic acid content (the remainder being mainly maleic anhydride, propionic acid, acetic acid and furfural). Technical (also referred to as crude) acrylic acid is suitable for the production of commodity acrylate esters. Major markets for the commodity esters include surface coating, adhesives and sealants, textiles, plastic additives, and paper treatment.

Glacial Grade Acrylic Acid is generally used to designate grades of the acid with acrylic acid content between 98 to 99.7 percent; although in the literature of many companies selling the product, glacial grade is typically listed as having 99.5 to 99.7 percent acrylic acid content. Glacial acrylic acid is suitable for the production of super absorbent polymers (for disposable diapers), detergents, water treatment and dispersants.

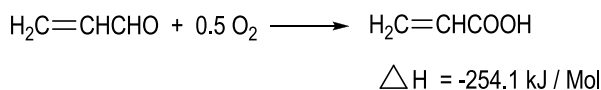
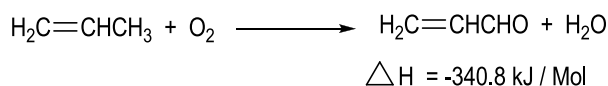
The outline of this report is as follows.

- Current production technology is discussed including processes for upgrading crude to glacial product.
- Developing technologies are discussed and an overview of key historical processes is given.
- Economics for the established propylene oxidation process, dehydration of (fermentation derived) 3HP, oxidation of (glycerol derived) acrolein, and catalytic conversion of (ethylene oxide derived) β -propiolactone developing processes, as well as the historical (gas-derived) acetylene based process are evaluated.
- Commercial end-use applications and regional market overview analysis is given.

CURRENT TECHNOLOGY

Today virtually all acrylic acid is manufactured in two stages via propylene-based oxidation processes, where separate optimization of each step leads to a higher overall yield of acrylic acid.

The chemistry of the fundamental oxidation process is summarized by the following chemical equations:



A family of catalysts has been developed and modified over the last several years, based on promoted molybdenum-bismuth systems for the primary oxidation step and promoted molybdenum-vanadium for the secondary oxidation step.

As with crude acrylic acid synthesis, purification technology varies enormously. Both crystallization and distillation are used.

EMERGING TECHNOLOGIES

Much work has been carried out on development of a microbe that is capable of producing 3-hydroxypropionic acid (3HP) by a fermentation process, with subsequent dehydration to acrylic acid. According to the companies involved, this process could be commercially available within the next three years.

Catalysts have been developed to produce acrylic acid from glycerol and according to the companies involved, pilot/demonstration plants could be in operation anytime between now and the next four years.

There is developing technology to produce acrylic acid via a β -propiolactone intermediate produced by carbonylation of ethylene oxide using a patented catalyst.

A method of producing acrylic acid involving initial fermentation of a sugar to fumaric acid followed by cross-metathesis with ethylene is being investigated.

Various companies have independently been working on routes to acrylic acid from propane feedstock.

ECONOMICS

The following cost estimates have been developed and discussed in the report:

- production of crude acrylic acid via propylene oxidation
- production of glacial acrylic acid from crude acrylic acid via additive enhanced distillation
- production of glacial acrylic acid from crude acrylic acid via dynamic/static crystallization
- production of 3-hydroxypropionic acid (3HP) via fermentation of dextrose
- production of glacial acrylic acid via catalytic dehydration of 3HP
- production of crude acrylic acid via dehydration of glycerol to acrolein followed by oxidation

- production of crude acrylic acid via ethylene oxide carbonylation to β -propiolactone followed by catalytic conversion
- production of crude acrylic acid via gas-derived acetylene complex.

A cost comparison discussion of the processes producing crude acrylic acid has been made. The total cost of production from raw material to crude product and upgrading crude to glacial product has been made for all the non-fermentation processes (via the crystallization upgrading process) and compared to the cost of the glacial product produced via fermentation.

COMMERCIAL APPLICATIONS

Acrylic acid and its esters are among the most versatile monomers for providing performance properties to a wide variety of polymers. The major application for acrylic acid is a feedstock for commodity acrylate esters, which include methyl, ethyl, *n*-butyl, and 2-ethylhexyl acrylate. Acrylate esters impart many desirable qualities to polymeric materials, such as color stability and clarity when exposed to light, heat and aging resistance, good weatherability, low temperature flexibility, and acid and base resistance.

In addition to the commodity esters, smaller quantities of other alkyl acrylates are produced for specialized applications. Functional acrylate oligomers and multifunctional acrylate esters are consumed as raw materials in radiation curable coatings, inks, electronics manufacturing processes, and adhesives.

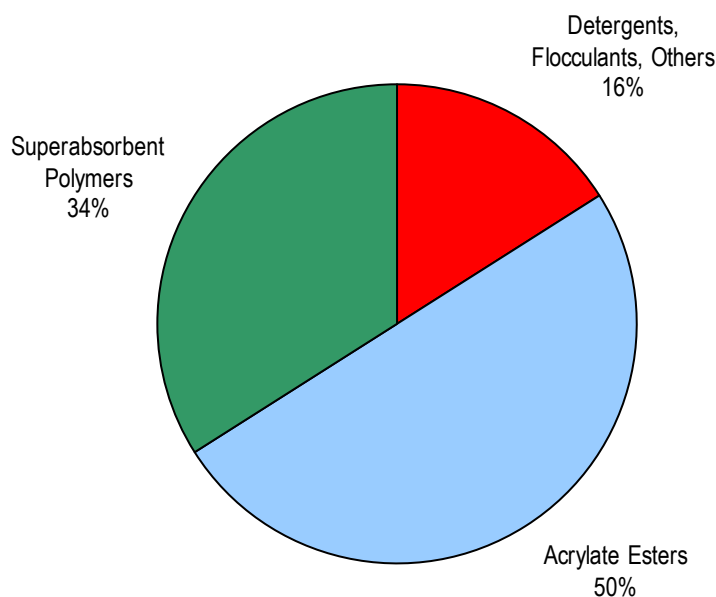
While a relatively large portion of acrylic acid is consumed for production of acrylate esters, a significant portion is upgraded (purified) into glacial acrylic acid and subsequently utilized for the production of polyacrylic acid or copolymers which find applications in superabsorbents, detergent co-builders, dispersants, flocculants, and thickeners. Superabsorbent polymers are used in a number of applications where rapid absorbance of liquids is needed such as in diapers, training pants, adult incontinence products, and feminine hygiene products. Polyacrylic acid, generally as the sodium acrylate homopolymer, is used in replacing phosphates in laundry detergents. It may be used alone or in conjunction with zeolite builders. Acrylic acid based dispersants are used with a variety of solid materials, particularly clay, titanium dioxide, and calcium carbonate. Thickeners are used in cosmetics, personal care products, and textile warp sizing. Flocculants induce aggregation of suspended colloidal particles.

Commercial applications for commodity acrylates, specialty acrylates, polyacrylic acid, super absorbent polymers, and detergent are discussed further in this section of the report.

REGIONAL MARKET ANALYSIS

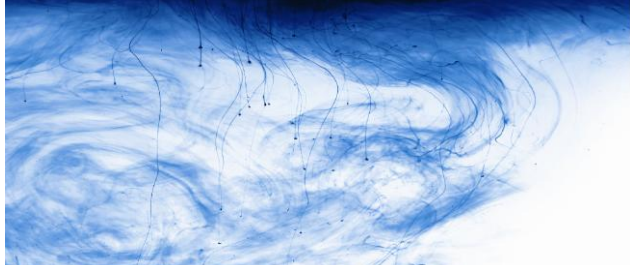
The acrylic acid industry is mature in the United States and Western Europe, but still developing rapidly in some parts of Asia and the Middle East. End-use demand for acrylic acid in a mature market is exemplified below.

U.S. Acrylic Acid Consumption by End-Use



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- Acrylic Acid Production Capacity for the United States, Western Europe and Asia Pacific is tabulated by company, specific plant location and capacity
- Supply, Demand and Trade (including forecast to 2014) for each of these regions is given and discussed



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