

Oxo Alcohols

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INTRODUCTION

Oxo alcohols refer to any of the alcohols produced via the oxo process. The oxo process, more formally known as hydroformylation, is the common name for the reaction of an alkene (olefin) with syngas (i.e., carbon monoxide (CO) and hydrogen (H₂)) in the presence of a catalyst; the product of this reaction are aldehyde isomers. Subsequently, the aldehyde is hydrogenated to obtain an alcohol (with a carbon number one higher than the reacting alkene).

An intermediate step of adding two aldehydes together (to obtain an alkenal via an aldol condensation reaction) can precede the hydrogenation.

Oxo alcohols typically lie in the C₃-C₁₅ range and are clear liquids with characteristic odors. Their end-use markets include solvents, plasticizers, coatings, adhesives and specialty chemicals, and demand drivers are broadly tied to the construction, housing, automotive and electrical sectors.

The major oxo alcohols of commercial importance include:

- *n*-butanol (a C₄ alcohol)
- *iso*-butanol (a C₄ alcohol)
- 2-ethylhexanol (2-EH, a C₈ alcohol)
- isononanol (INA, a C₉ alcohol)
- 2-propylheptanol (2-PH, a C₁₀ alcohol)

Collectively these five oxo alcohols account for the vast majority of total oxo alcohol demand; with *n*-Butanol and 2-ethylhexanol accounting for about three-quarters of oxo alcohol production.

COMMERCIAL TECHNOLOGY

Currently used in approximately two-thirds of global capacity, the Dow-Davy Low Pressure (LP) OxoSM SELECTORSM technology is used to produce *n*- and *iso*- butanal (butyraldehyde) and pentanals (valeraldehydes). The SELECTOR technology has two catalyst options, the SELECTORSM 10 and the SELECTORSM 30, which uses the NORMAXTM catalyst. These different catalysts achieve different *n*-butanal to *iso*-butanal ratios (10:1 for SELECTORSM 10 and 30:1 for SELECTORSM 30) in the products produced from the hydroformylation process. SELECTORSM 10 uses a rhodium catalyst modified with a triphenylphosphine (TPP) ligand. This technology has widespread use in many of the older oxo-alcohol plants.

While many of the producers of oxo alcohols are licensees of the LP Oxo SELECTORSM technologies, some of the large producers of oxo aldehydes, including Oxea and BASF, have their own oxo-technology that is not available for license.

DEVELOPING TECHNOLOGY

A review of recent patents indicates that developments in oxo alcohol production technology have focused on two areas of development:

- Streamlined manipulation of the *n/iso* ratios depending on market demands
- Further simplification of the process in terms of catalyst separation and recycle

Eastman has recently indicated its intention to license the technology it uses in its plants in Longview (Texas, USA), Singapore and Zibo (China). In recently awarded patents, Eastman revealed novel rhodium catalyst systems that enable the production of variable *n-* to *iso*-alkanal (*iso*-aldehyde) ratios by modest changes in process conditions. Eastman's technology claims to allow flexibility in selectivity, with an *n*-butanal to *iso*-butanal ratio that can range from 1:1 to 25:1. This would allow producers the option of producing *iso*-butanol in greater quantities when the economics of doing so are favorable and then entering the increasing *iso*-butanol market.

In addition, Dow seems to be actively investigating the potential of gas phase hydroformylation in the presence of a heterogeneous rhodium organophosphite ligand complex catalyst. It is still premature to assess the commercial viability of the process, however, it will be a major drift in the hydroformylation art should these development plans come to fruition.

PROCESS ECONOMICS

Nexant has estimated costs of production for world scale, state-of-the-art, oxo plants built in China, N.W. Europe, and the United States Gulf Coast (USGC). The selected cases are:

- *n*-butanol by LP OxoSM SELECTORSM 10 process
- *n*-butanol by LP OxoSM SELECTORSM 30 process
- 2-ethylhexanol by LP OxoSM SELECTORSM 10 process
- 2-ethylhexanol by LP OxoSM SELECTORSM 30 process
- 2-propylheptanol by LP OxoSM SELECTORSM 30 process
- Isononanol by Johnson Matthey process

In addition, the sensitivity of the economics for oxo alcohols production has been developed for feed price and economy of scale.

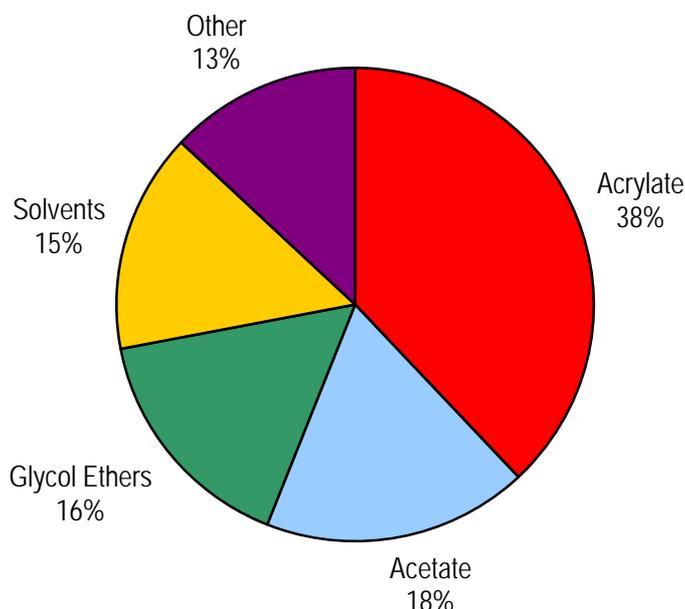
All cost tables given in this report include a breakdown of the cost of production in terms of raw materials, utilities, and direct and allocated fixed costs. These categories are presented annually by unit consumption and per metric ton. The contribution of depreciation is also included to arrive at a cost estimate.

COMMERCIAL MARKET REVIEW

The butanols business is driven by solvent applications particularly in emulsion and lacquers business. These water-based systems have benefited from environmental considerations and are

closely allied to the construction business. Other uses are illustrated in the figure below displaying global *n*-butanol consumption by application.

Global *n*-butanol consumption by end-use



The major use for 2-EH is in plasticizers, especially diisooctyl phthalate (DOP). DOP is the “workhorse” of the PVC plasticizer industry. 2-EH is also used in specialty plasticizers such as adipates, trimellitates, phosphates, etc., where a higher performance is needed, (e.g., high temperature resistance). A smaller but significant and growing use is in the production of 2-ethylhexyl acrylate, a monomer used in acrylic copolymers for pressure sensitive adhesives and impact modifiers.

Global Supply, Demand and Trade

Global Supply, Demand and Trade data is given for:

- *n*-butanol
- isobutanol
- 2-EH
- 2-PH
- INA

Regional Supply/Demand/Trade

Further regional supply, demand and trade data for North America, Western Europe and Asia Pacific is given and discussed for:

- *n*-Butanol

- 2-EH

Plant Capacity Listings

A listing of specific plant capacities denoted by company, location and annual tonnage produced is also provided for:

- *n*-butanol (North-America, Western Europe, Asia Pacific)
- 2-EH (North-America, Western Europe, Asia Pacific)
- Isobutanol (North-America, Western Europe, Asia Pacific, Rest of the World)
- 2-PH (North-America, Western Europe, Asia Pacific)
- INA (North-America, Western Europe, Asia Pacific)



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