Nanofiltration for Reuse of Sharpless Catalytic Systems

Frederico Castelo Ferreira
Department of Bioengineering, Instituto Superior Técnico, Institute for Bioengineering and Biosciences, Universidade de Lisboa, Lisbon, Portugal

**Nanofiltration for reuse of Sharpless catalytic systems** combines reaction and separation in a single vessel, allowing successive reaction and filtration steps, to recycle the catalytic system in successive batches with isolation of the chiral product on the permeated solution. The Sharpless catalysis is a robust strategy for production of chiral 1,2-diols from olefins at high yields and enantiomer excesses, using a catalytic system based on OsO_4 or K_2OsO_2(OH)_4 salt and a chiral dimeric ligand (Bolm et al. 2000; Kolb et al. 1994). Chiral ligands used are based on a cinchona alkaloid (dihydroquinidine or dihydroquinine) with phthalazina, pyrimidine, or indoline groups. The reaction requires a co-oxidant, which can be organic or inorganic, such as N-methylmorpholine-N-oxide (NMO) or K_2Fe(CN)_6, respectively. The reaction media is conventionally an aqueous/organic (50 v/v% solvent) mixture with tert-butanol, methyl tert-butyl ether, or acetone. The feasibility of Sharpless reaction was also attained for a range of seven different olefins on the absence of organic solvent, using an aqueous system that includes a surfactant, such as sodium dodecyl sulfate and sodium cholate, or an ionic liquid such as hexadecyltrimethylammonium bromide (Branco and Afonso 2002; Branco et al. 2008). Moreover, the use of aqueous/surfactant or ionic liquid systems avoids the continuous gradual slow addition, required to obtain high enantiomer excesses in the aqueous/organic system. Widespread industrial application of the Sharpless system has been restricted by the high cost of the catalyst and toxicity of the osmium species. Aqueous and organic solvent nanofiltration had been assayed to isolate chiral product and recycle the osmium salt and chiral ligand hydroquinidine 1,4-phthalazinediyl diether (molecular weights, MW, of 368 Da and 779 Da, respectively) (Branco et al. 2008; Ferreira et al. 2007) into successive reactions. NMO with a molecular weight of 135 Da was used as co-oxidant for both aqueous/organic and aqueous/surfactant systems. Starmem120, a polyimide membrane with nominal molecular weight cutoff (MWCO) of 200 Da, was used for the aqueous/organic system, composed of a water/acetone (25 v% acetone) mixture, with a lower water content than in the conventional Sharpless system, to improve solvent mixture flux through the membrane (Ferreira et al. 2007). On the other hand, a polyamide membrane, Desal DK, with a MWCO of about 250 Da, was used in the aqueous/surfactant system to retain both catalytic system and sodium.
cholate (Mw 460.6 g.mol⁻¹), the surfactant used (Branco et al. 2008). In both systems, each reaction-membrane filtration cycle included a first reaction step at atmospheric pressure, without permeation, and a second nanofiltration step in which a pressure of 10–20 bar was applied as driving force to promote solution permeation through the membrane. The next cycle started by making up the feed volume with addition of solvent/water or only water in the water/surfactant system. Different steady states, concerning product concentration in the vessel, can be reached according with concentration factors (i.e., the ratio of initial per final volume) used. Product concentration can be important in the final process yield due to reaction inhibition by the product. Diafiltration strategies with feeding of additional solvent/water (or water alone) can also be employed in the nanofiltration step to reach lower product concentrations in the vessel and recovery higher product amounts in the permeate. However, for higher diavolumes, when catalyst and surfactant have rejections lower than 100 %, losses of the catalytic system into the permeate can become significant. Moreover isolation of the more diluted product from permeate is more challenging. Overall, the application of nanofiltration for reuse of the osmium catalytic system as the potential to improve turn over numbers (TON), (i.e., total product obtained by catalyst used) with beneficial impact on Sharpless reaction economics and osmium contamination of the product (Figs 1 and 2).

References