Integration of Green Chemistry and Engineering for Industrial Applications

Santiago V. Luis,

Dept. of Inorganic and Organic Chemistry, University Jaume I, Avda Sos Baynat s/n, E-12071 Castellón, Spain, luiss@uji.es

Keywords: Flow chemistry, Catalysis, Ionic Liquids, Biocatalysis.

The origin of the Green Chemistry can be dated to the pioneering work by Anastas and Warner and the elaboration of the *principles of Green Chemistry*.[1] Thus, most research efforts in the last decades involved the study of specific individual techniques for the *toolbox for Green Chemistry*. Although useful, this approach has limitations to provide the proper answers to current challenges of the Chemical Industry and related industrial fields. As a matter of fact, sometimes the efforts have been wasted in the search for the *Holy Grial of Green Chemistry*. Such simplistic answers do not exist, in particular for the complex problems raised even by the more simple industrial chemical transformation.

In this regard, we need to shift our focus towards the development of an integrated vision of the field being able to combine the proper usage of the Green Chemistry toolbox with Green Engineering aspects and, particularly, with the knowledge of other elements often disregarded and including economic, environmental or social issues.

The efforts of our research group in the last years have evolved from the study of the application of individual Green Chemistry principles to the analysis of integrated chemical platforms being able to incorporate, in a synergistic approach, several of those principles. The development of materials containing covalently-bound Ionic Liquid-Like fragments (*SILLPs*) and the study and understanding of their unique properties and potential represents a significant step forward in this line and illustrates the advantages of such a vision.[2]

Although ILs are one of the most impressive contributions to the Green Chemistry toolbox, there are a variety of drawbacks associated to their use. The high cost of many of them, makes prohibitive their use for industrial applications, while recent toxicological reports have raised important concerns. On the other hand, their use and manipulation is not always simple and is often carried out at the expenses of additional environmental impacts, sometimes bigger than the expected benefits.

Incorporation of IL-like moieties into solid supports allows developing materials that maintaining all the essential features and advantages of bulk ILs do not present their drawbacks. This provides new opportunities for optimizing the involved processes, implementing their potential application.

The modular design of ILs is one of their key features. For SILLPs, the polymeric matrix itself represents an additional design vector in this regard. The covalent attachment eliminates the possibility of leaching and accordingly the environmental concerns and facilitates the work-up and the incorporation of the required engineering elements, in particular for flow applications, representing, nowadays, a prerequisite for future chemical processes of industrial interest.

The multifaceted character of IL moieties has led to the preparation of different materials, from functional beads to nanostructured polymeric monoliths, being able to act as superadsorbents, as conducting materials and solid electrolites, or as efficient organo-, MNP-based or bio-catalysts with improved efficiencies and stabilities. Moreover, they are compatible with other environmentally friendly conditions like solventless processes, supercritical fluids or the use of microwave heating, facilitated by the chemical nature of IL-like fragments.

Solid functional SILLPs, in particular those prepared in the form of porous monoliths inside tubular molds, facilitate the preparation of tubular catalytic mini-reactors with extraordinary space-time productivity. Besides, different catalytic systems (including chemo- and bio-catalysts) can be combined in a single reactor to achieve a multifunctional catalytic system, and different catalytic reactors can be combined in a successive arrangement to obtain a multicatalytic process. When the necessary stoichiometric and separation steps are incorporated, the ultimate goal of the integrated nano-, micro-, mini-chemical factory becomes closer.

References

1 P.T. Anastas, J.C. Warner, Green Chemistry: Theory and Practice, Oxford University Press, NY, 1998.

2 M.I. Burguete, E. García-Verdugo, N. Karbass, S.V. Luis, V. Sans, M. Sokolova, Pure Appl.Chem., 2009, **81**, 1991. P.Lozano E. Garcia-Verdugo, S.V. Luis, M. Pucheault, M. Vaultier, Curr. Org. Synth., 2011, **8**, 810.