Trends in Analytical Chemistry 77 (2016) 122–138

Contents lists available at ScienceDirect

Trends in Analytical Chemistry

journal homepage: www.elsevier.com/locate/trac

Ionic liquids for mass spectrometry: Matrices, separation and microextraction

Hani Nasser Abdelhamid *

Department of Chemistry, Assuit University, Assuit 71515, Egypt

ARTICLE INFO

Keywords:
Ionic liquids
Mass spectrometry
Matrices
Liquid-liquid microextraction
Proteomics
Pathogenic bacteria
Quantification

ABSTRACT

Applications of ionic liquids (ILs) for mass spectrometry (MS) are a burgeoning area and are promising for real applications. However, the research of ILs for MS is in its infancy and there are a large potential for further applications under the ashes. This review article provided an overview of the current state and the research progress of ILs applications for MS. ILs offered several advantages, such as low vapor pressure, soft ionization, high sensitivity, better separation and microextraction, effectively disperse nanoparticles for nanoprobe technologies, and stable under vacuum and for storage in solution form, that leaded to several applications for MS and assured that ILs carry a brilliant future for analytical purposes. A plethora of ILs with different properties can be designed by various combinations of acid and base moieties and were applied as multifunctional materials. Thus, ILs provided many platforms such as green solvents for microextraction, stationary phases for separation and matrices for laser desorption/ionization mass spectromery (LDI-MS). Comparison among the organic matrices, ILs and nanoparticles were also highlighted.

Contents

Abbreviations: [C_8MIM][PF_6], 1-octyl-3-methylimidazolium hexafluorophosphate; TCIL-DLLME, Temperature-controlled ionic liquid dispersive liquid–liquid microextraction; US-IL-DLLME, Ultrasound-assisted ionic liquid dispersive liquid–liquid microextraction; LC–QqLIT–MS/MS, High-performance liquid chromatography with a hybrid triple quadrupole-linear ion trap–mass spectrometer; [CMIM][PF_6], 1-Hexyl-3-methylimidazolium hexafluorophosphate; [C_4MIM][PF_6], 1-butyl-3-methylimidazolium hexafluorophosphate; [C_6MIM][$N(SO_2CF_3)_2$], 1-Hexyl-3-methyl imidazolium bis(trifluoromethylsulfonylimide); IL-USA-ME, Ionic-liquid based ultrasound-assisted emulsification microextraction; USA-TC-IL-DLME, ultrasound-assisted temperature-controlled ionic-liquid dispersive liquid-phase microextraction; HPLC, High-performance liquid chromatography; [HMIM][PF_6], 1-hexyl-3methylimidazolium hexafluorophosphate; FAAS, Fame atomic absorption spectrometry; [C_4MIM][PF_6], 1-butyl-3-methylimidazolium hexafluorophosphate; APDC, Ammonium pyrroldine dithiocarbamate; ETAAS, Electrothermal atomic absorption spectrometry; GFAAS, Graphite furnace atomic absorption spectrometry; [BMIM][NTf_2], 1butyl-3-methylimidazolium bis(trifluormethylsulfonyl) imide; CYPHOS IL101, tetradecyl(trihexyl) phosphonium chloride ionic liquid; BmimBr, 1-butyl-3-methylimidazolium bromide; MAILE, Microwave-assisted ionic liquid extraction; SPME, Solid phase microextraction; GC-MS, Gas chromatography-mass spectrometry; VOCs, Volatile organic compounds; MPIHS, 1-methyl-3-phenethyl-1H-imidazolium hydrogen sulfate ionic liquid; MMHg, Monomethyl mercury; IHg, Inorganic mercury; HF-LPME, Hollow fiber supported liquid phase microextraction; [emin]Br, 1-ethyl-3-methylimidazolium bromide; [hmin]Br, 1hexyl-3-methylimidazolium bromide; [bmim]SO_4, 1-butyl-3-methylimidazolium methanesulfonate; [bmin]BF_4, 1-butyl-3-methylimidazolium tetrafluoroborate; [Cmim]Cl, 1-dodecyl-3-ethylimidazolium chloride; [C_{12}mim]Br, 1-dodecyl-3-methylimidazolium bromide; [C_{12}mim] CF_3SO_4, 1-dodecyl-3-methylimidazolium trifluoromethanesulfonate; [C_{12}mim]NO_3, 1-dodecyl-3-methylimidazolium nitrate; [C_{12}mim]HSO_4, 1-dodecyl-3-methylimidazolium hydrogen sulfate; RRLC-ESI-MS/MS, Rapid resolution liquid chromatography-electrospray tandem mass spectrometry; [C_4MIM][PF_6], 1-Butyl-3-methylimidazolium hexafluorophosphate; [C_6MIM][PF_6], 1-hexyl-3-methylimidazolium hexafluorophosphate; [C_8MIM][PF_6], 1-octyl-3-methylimidazolium hexafluorophosphate; [C_4MIM][BF_4], 1-butyl-3-methylimidazolium tetrafluoroborate; [EMIM][BF_4], 1-ethyl-3-methylimidazole tetrafluoroborate; [C_4MIM]NO_3, 1-butyl-3-methylimidazoliumnitrate; ETV-ICP-MS, Electrothermal vaporization inductively coupled plasma mass spectrometry; HS-SDME, Headspace- Single-Drop Microextraction; DUNE, Dynamic ultrasonic nebulisation extraction; PLE, Pressurized liquid extraction; UA-DLLME, Ultrasonic-assisted dispersive liquid–liquid microextraction.

* Tel.: +00201279744643; Fax: +202342708.
E-mail address: hany.abdelhameed@science.au.edu.eg.

http://dx.doi.org/10.1016/j.trac.2015.12.007
0165-9936/

1. Introduction

Ionic liquids (ILs) are salts in liquid phase at room temperature. ILs have low melting point below 100°C (212°F). The main reason for the low melting point is due to the charge diffuse of ILs ions. ILs consists of ions and can be called as liquid electrolytes, ionic melts, ionic fluids, fused salts, liquid salts, or ionic glasses. The first prototype represented the ionic liquids was ethyl ammonium nitrate with chemical formula $[C_2H_5NH_3]^+[NO_3]^-$ and melting point 12°C [1]. Ionic liquids offered several features such as low vapor pressure, non-flammable, electrically conducting, offered a wide numbers of different structures, were stable under vacuum, and have good thermal stability. There are several review articles [2–16], book chapters [17–20] that discussed the properties and applications of ILs as solvent, catalysis or chemical engineering. Because of the unique properties of ILs, they are integrated in many trends such as analytical chemistry [21–29], electrochemistry [30], catalysis [31,32], and others [33]. The wide applications of ILs can be confirmed by the increase of publication when a search was run with "ionic liquids" (Fig. 1A). These interests are varied for many aspects such as analytical chemistry, chromatography/separation/microextraction, material chemistry, environmental, catalysis, electrochemistry, energy

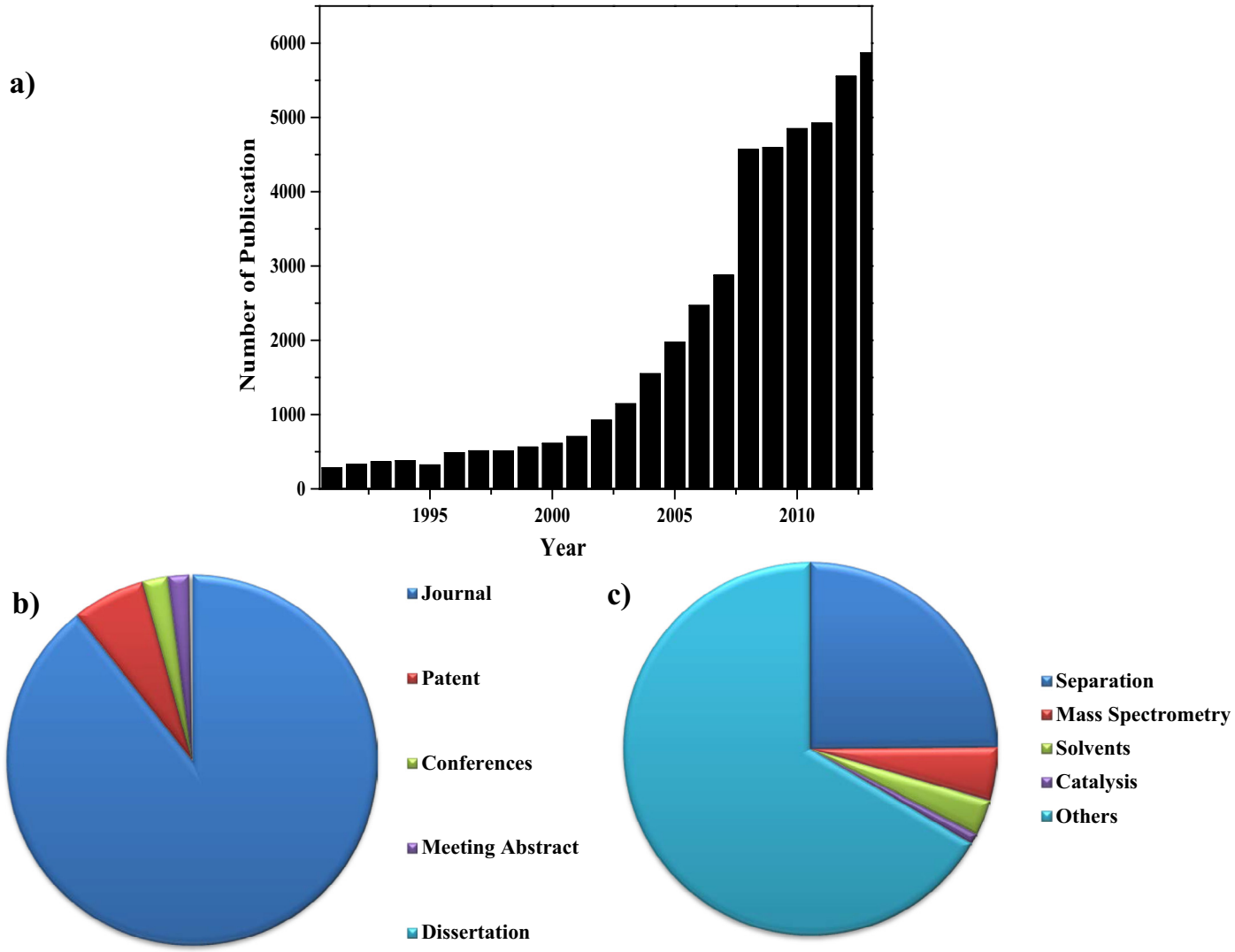

Fig. 1. a) Scientific publication of ionic liquids over the years. Data were collected from Web of Science by using the word 'ionic liquids'; b) types of the scientific publications and c) the applications of ILs.