Ionic Liquids
&
Green Chemistry

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Part I: Overview

Part II: Applications as solvents

Part I: Overview

Part II: Applications as solvents

Part I: Overview

- Green Chemistry & the need for alternative solvents.
- What are ionic liquids? Properties
- The “issues”

Green Chemistry

- the utilization of set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products.

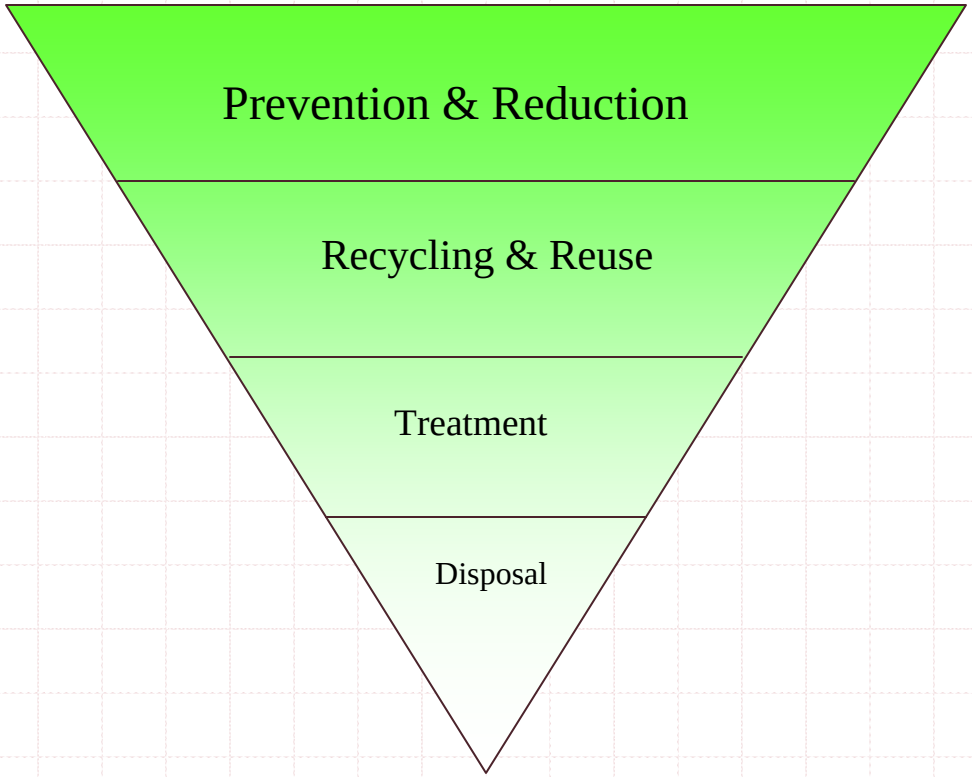
Green Chemistry – Theory and Practice, P. T. Anastas & J. C. Warner, Oxford, 1998

Green Chemistry

A.k.a

- Environmentally benign chemical synthesis
- Alternative synthetic pathways for pollution prevention
- Benign by design

Pollution Prevention Hierarchy



Increasing Greenness

www.chemsoc.org/gcn

Twelve Priciples of Green Chemistry

1) Prevention
2) Atom Economy
3) Less Hazardous
4) Design safer & better chemicals
5) Safer solvents and auxiliaries
6) Design for energy efficiency
7) Use renewable feedstocks
8) Reduce derivatives
9) Use catalysts where ever possible
10) Design for degradation
11) Real-time analysis for pollution prevention
12) Inherently Safer Chemistry for Accident Prevention

The Sheldon E-factor*

{ratio (by weight) of by-products to desired product}

Industry	Production (tons pa)	*E* – factor	Actual waste tonage
Oil refining	$10^6 – 10^8$	0.1	$10^5 – 10^7$
Bulk Chemicals	$10^4 – 10^6$	1 – 5	$10^4 – \sim10^7$
Fine Chemicals	$10^2 – 10^4$	5 – 50	$\sim10^3 – \sim10^6$
Pharmaceuticals	$10^1 – 10^3$	25 - 100	$250 - 10^5$

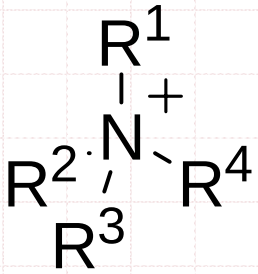
* Sheldon, R. A. Catalysis: the key to waste minimization. *J. Chemical Tech. Biotech.* (1997), **68**: 381-388

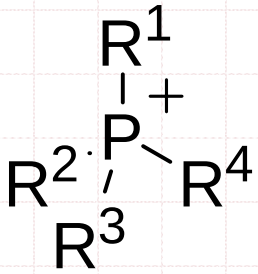
Strategies to reduce waste solvent production in chemical processes:

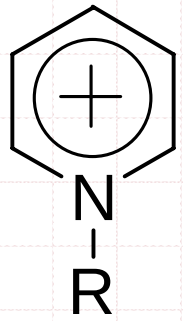
- Solvent-free synthesis
- Use of water as a solvent
- Use of supercritical fluids as solvents
- Use of ionic liquids as solvents

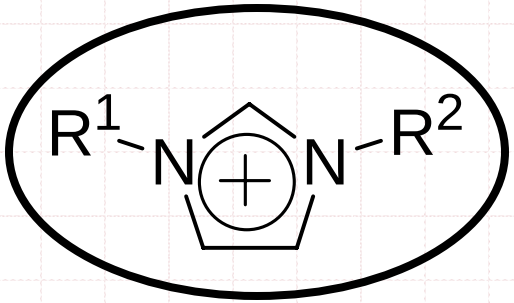
Ionic Liquids

CATIONS









ANIONS

$^{-}AlCl_4$ $^{-}Al_2Cl_7$

$^{-}BF_4$ $CF_3CO_2^{-}$

Cl^{-}, Br^{-} $CF_3SO_3^{-}$

$^{-}PF_6$ $^{-}N(CF_3SO_3)_2$

$^{-}SbF_6$ $^{-}BR_4$

Ionic Liquids
General Properties

- melt <100°C; high thermal capacities
- highly polar and non-coordinating
- excellent solvents for a wide range of inorganic, organic, and polymeric materials
- broad liquid range
- extremely low vapor pressure @ ambient
- renewable & reusable
- may be air & water stable; otherwise inert
- non-flammable
- may be water immiscible
- may exhibit Brönsted, Lewis, and super-acidity

The “Neglected Issues”

- Cost effectiveness
- Stability
- Toxicity
- Biodegradability
- Recyclability

P. J. Scammells, J. Scott, R. D. Singer *Aust. J. Chem.* **2005**, 58, 158 – 169.

Part I: Overview

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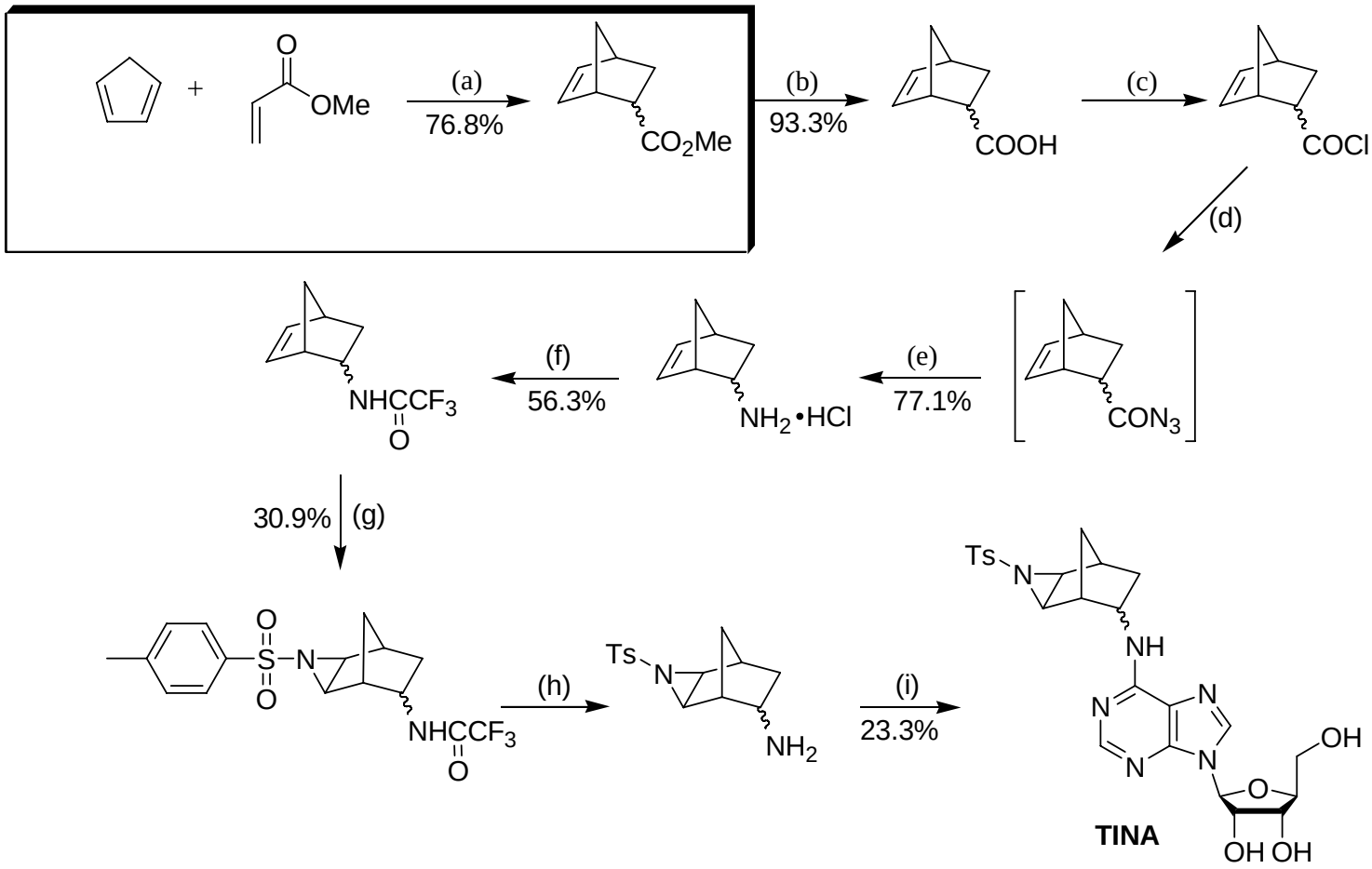
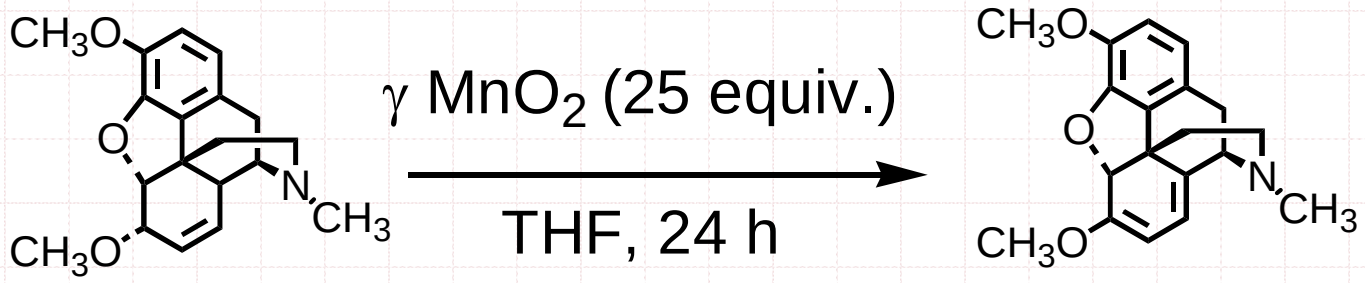
Part II: Applications as solvents

Synthesis of an adenosine agonist



a) neat, room temp. or $BMimBF_4$, room temp. b) LiOH, 5:4 THF:H_2O, room temp. c) $SOCl_2$, room temp.
d) acetone, NaN_3/H_2O, 0°C e) $CHCl_3$, 2M HCl, reflux f) $(CF_3CO)_2O$, CH_2Cl_2, NEt_3, 0°C to room temp.
g) PhINTs, $Cu(acac)_2$, CH_3CN, room temp. h) K_2CO_3, MeOH/H_2O, room temp.
i) 6-chloropurine riboside, $EtN(iPr)_2$, t-BuOH, reflux

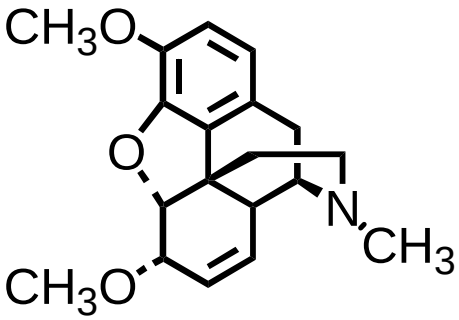


Codeine Methyl Ether

Thebaine
(25%, best try)

Barber and Rapoport J. Med. Chem. 1975, 18, 1074.

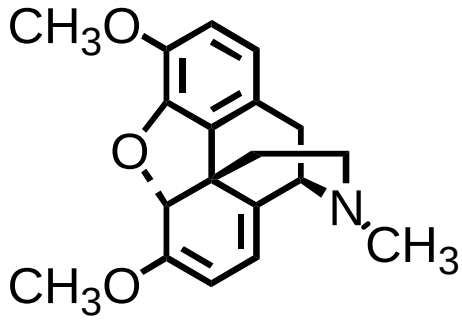
Ionic Liquid as extractant



Codeine Methyl Ether

1) γ MnO_2 , 10 equiv.
THF, sonicate 96 h

2) 5 mL $bmimBF_4$ / EtOAc
(extraction)

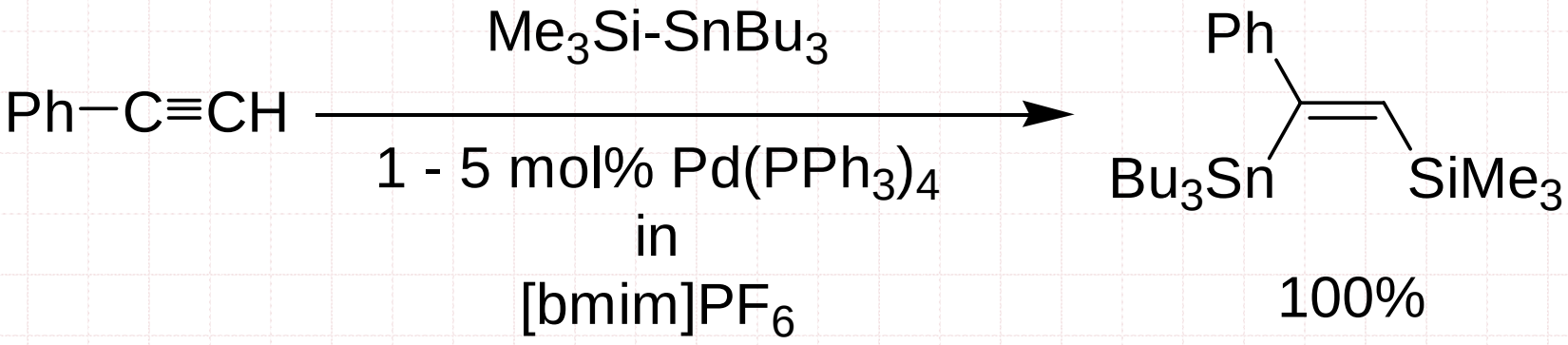


Thebaine
(100% recovery)
(>82% conversion)

P.J. Scammells, J.A. Ripper, R.D. Singer, *Australian Provisional Patent*, **2000** "Novel Syntheses of Commercially Important Opiates."

Robert D. Singer and Peter J. Scammells "Alternative methods for the MnO_2 oxidation of codeine methyl ether to thebaine utilizing ionic liquids." *Tetrahedron Letters*, **2001**, 42: 6831.

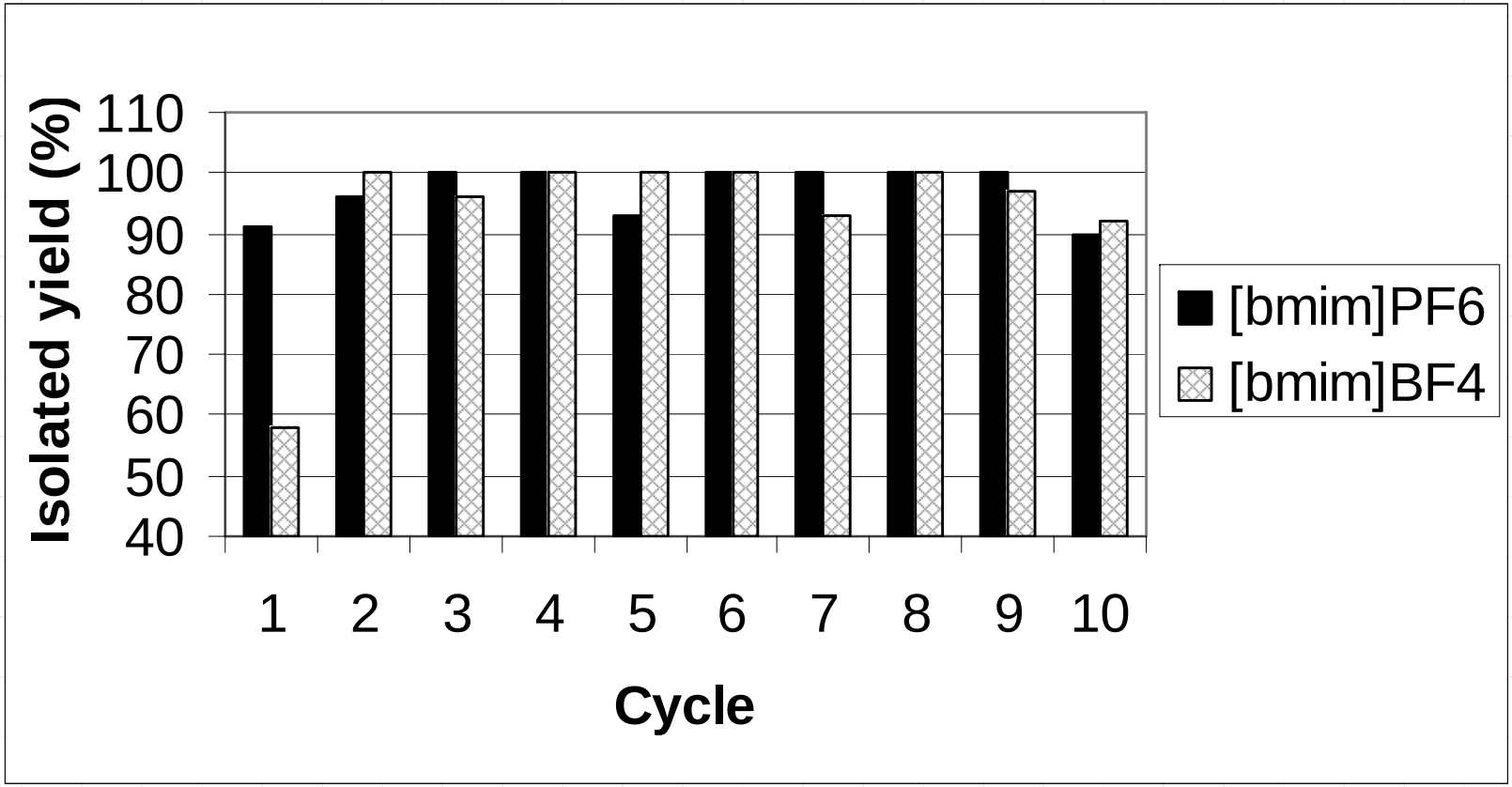
Silylstannation of terminal alkynes



Ivan Hemeon and Robert D. Singer*, *Chem. Commun.*, **2002, 1884 - 1885.**

Ivan Hemeon and Robert D. Singer* *J. Mol. Cat. A* **2004, 214, 33-44.**

Recycling study



Exploited advantages of I.L.'s

- enhanced yields
- enhanced selectivity
- enhanced reaction rates
- renewable
- reusable
- limited solvent loss due to evaporation

Take home messages

- Ionic Liquids are alternative "green" solvents for a wide variety of applications
- "issues" must be resolved

Take home messages

- Ionic Liquids are alternative "greener" solvents for a wide variety of applications
- "issues" must be resolved

Outlook – *The Future*

- Task Specific Ionic Liquids
- Environmentally benign Ionic Liquids
  - Biodegradable
  - Non-toxic
  - Inexpensive
  - Recyclable

Acknowledgements

Researchers

- Peter Scammells
- Kristy McCamley
- Gavin Beck
- Elizabeth Turner
- Jeremy Finden
- Michael Strümpel
- Andrea Lantz
- Tara Lantz
- Caroline DeAmicis
- Laine Green
- Bonnie MacLean
- Jackie Surette
- Annegret Stark
- Ivan Hemeon
- Steve Dickson
- Kim Hennigar
- Kevin Kells
- Whitfield Lewis
- Darrell Dean
- Jitendra Harjani
- Haiwen Zhang
- Dexiang Li
- Amy Holland
- Jeff Farrell
- Ryan Boudreau
- Mike Zaworotko

Funding - $$$

- NSERC Discovery
- NSERC – CRD
- NSERC - RCD
- PRAC
- Saint Mary's
- GSK Australia
- C.F.I.

ARMRC

- Mike Lumsden

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Reduce
Recycle
Reuse