Role of Chemistry and Chemical Engineering in Human Life and Safety

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Role of Chemistry and Chemical Engineering

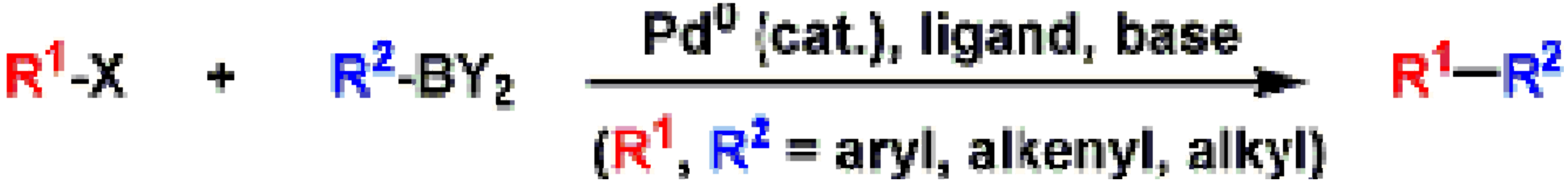
- Chemistry is defined as the science of the composition, structure, properties, and reactions of matter.
- Recently, chemistry has been found to play an important role in life sciences, such as bioinformatic DNA design, effect of SNPs on human diseases, epigenetic transformation, etc.
- Thus, chemistry and life science/biotechnology are closely related each other.

- Chemical Engineering deals with the analysis and design of chemical processes. It includes the study of process safety and management.
- Therefore, chemical engineering gives fundamental concepts on destruction of chemical weapons.
- Biochemical engineering is related to the design and analysis of bio-processes. It is also related to biomedical engineering which deals with human health.

Some examples of the innovation in chemistry and chemical engineering

Cross-couplings for organic synthesis

(Nobel Prize 2010: R. F. Heck, E. Negishi, A. Suzuki)



Applications of Cross-Coupling

Syntheses of:

palytoxin
bio-indole alkaloids
angiotensin II
Vaisartan (Novartis), antihypertensive
Boscalid (BASF), fungicide
liquid crystals,
fluorescents
hole transporting materials

Production of OLED (Cell phone and TV display)

Applications of Ionic Liquids

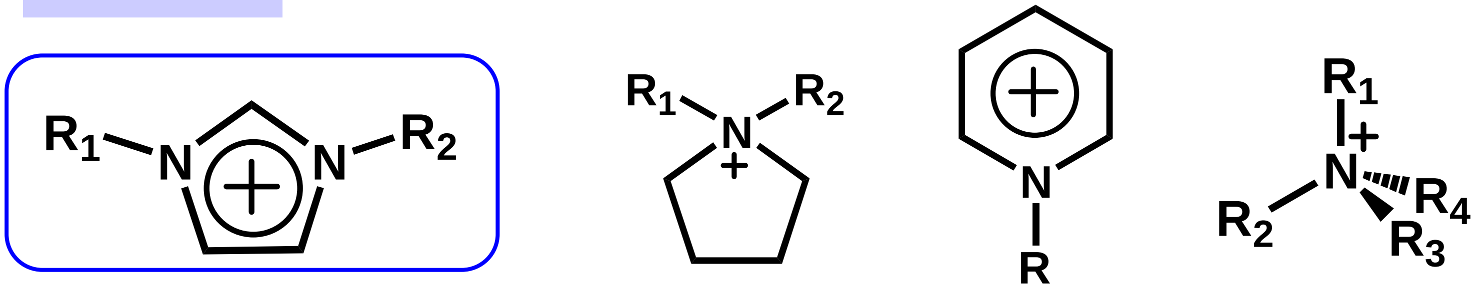
IL can be applied to production of batteries, separation of substances and as an enzyme reaction media.

Here, the following topics will be presented.

1. Saccharification of cellulose to produce biofuel
2. Separation of rare earth metals

Ionic liquid: a new class cellulose-dissolving solvent

cations



anions

X^{-} = Cl^{-} Br^{-} BF_4^{-} CH_3COO^{-} $(RO)(R')PO_2^{-}$

Chemical properties of solvent can be tuned by the combination of cations and anions.

cation : $R_1 = CH_3$, $R_2 = C_4H_9$
anion : Cl^-
→ 10wt% cellulose dissolution at 100℃

Swatloski et al., *JACS.*, **124**, 4974 (2002)

cation : $R_1 = CH_3$, $R_2 = C_2H_5$
anion : $(MeO)(H)PO_2$
→ 10wt% cellulose dissolution at 55℃

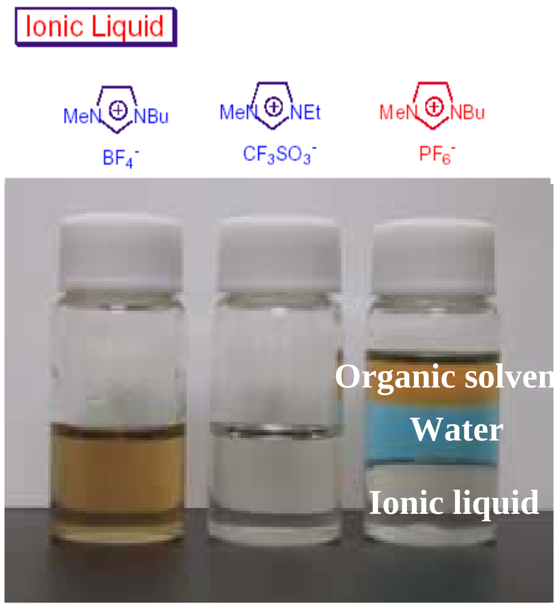
Fukaya et al.,*Green Chem.*, **10**, 44 (2008)

Properties

◎Negligible vapor pressure → Doesn't diffuse into environment

◎Miscible to water or organic solvents, or immiscible to both of them

→ Prospective "third" solvent



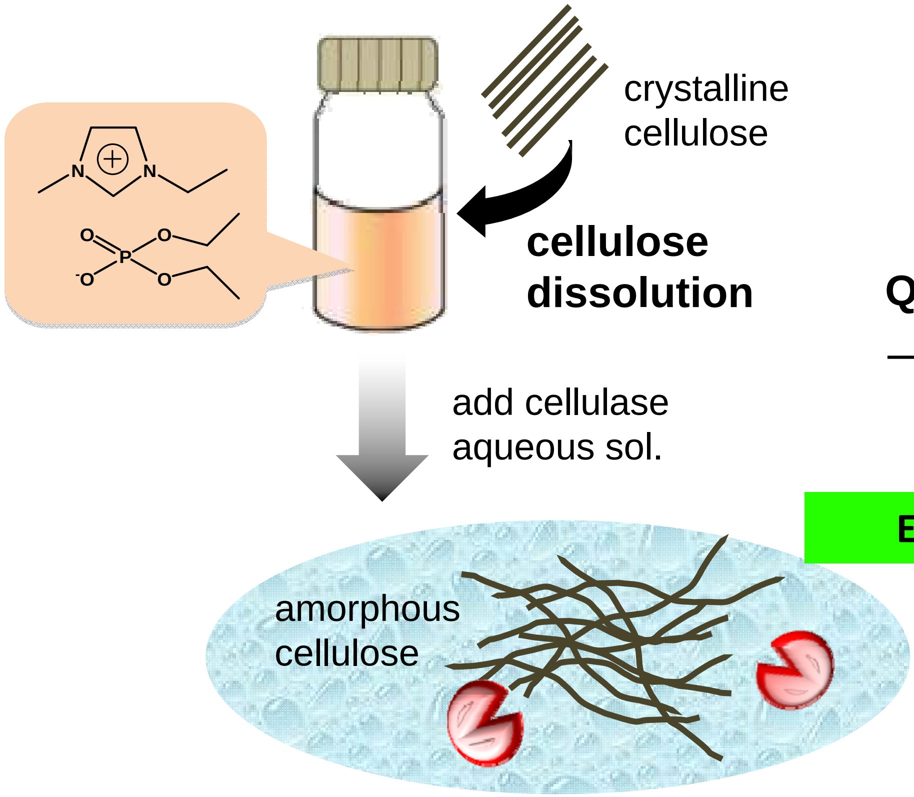
Miscible to organic solvents | Miscible to water | Immiscible to both

Saccharification of cellulose using an ionic liquid

One-batch saccharification process

Combination of regeneration and enzymatic saccharification processes:

Cellulase works in ***aqueous-ionic liquid media***



Q: Overall process can be simplified?

→ Can be directly linked to fermentation?

Enzymatic *in situ* saccharification (EISS)

→ **glucose**

→ **Direct link to fermentation?**

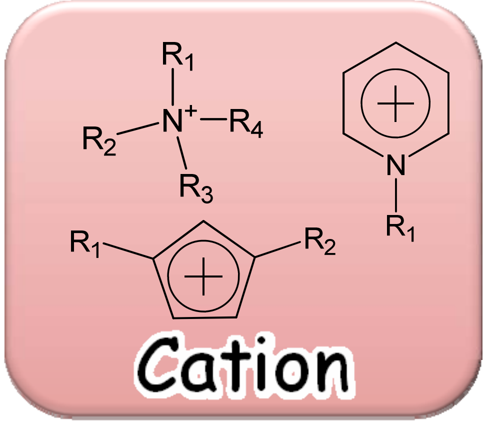
Regeneration & saccharification of cellulose in aqueous-IL media

SEPARATION OF RARE METALS USING IONIC LIQUIDS

M. Goto, Y. Baba and F. Kubota: PASIFICHEM 2010, Honolulu

Application of ILs to separation

- Ionic liquids (ILs)



PF_6^- Br^-

$(CF_3SO_2)_2N^-$

$CF_3SO_3^-$

Anion

Green alternative to organic solvents

✔ liquid state at room temperature

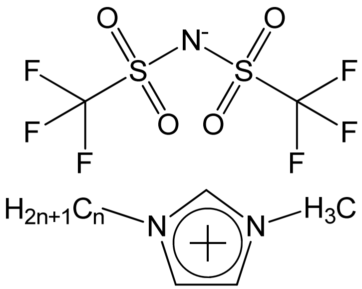
✔ negligible vapor pressure

✔ high tunability of the properties

(hydrophobicity and viscosity etc.)

<u>ILs are salt in the liquids state consists of cation and anion</u>

- ILs used in this research

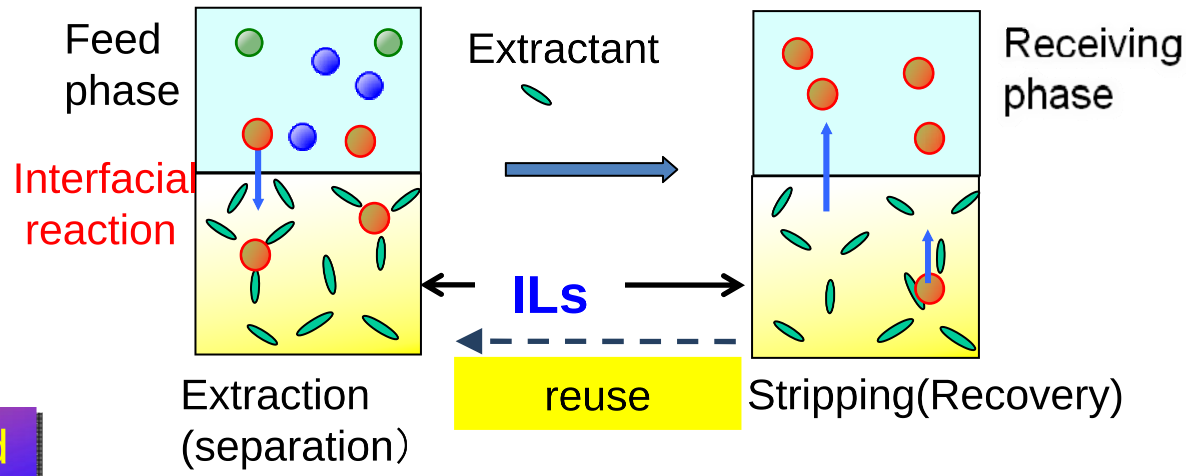


[$C_n$mim][Tf_2N]

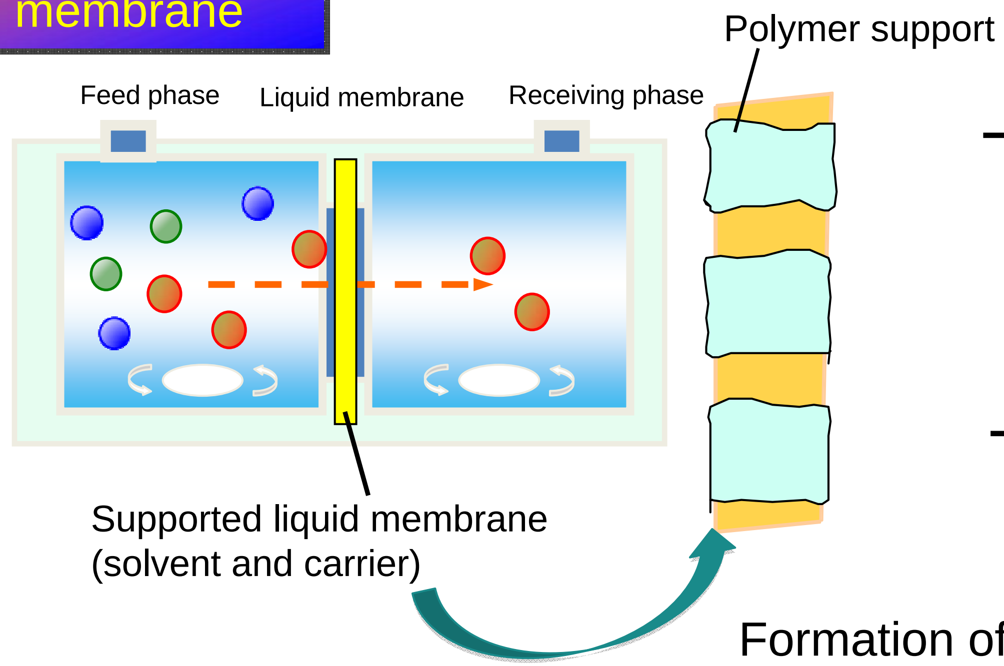
- Tf_2N^- are involved hydorophobicity
- Immidazolium based ILs

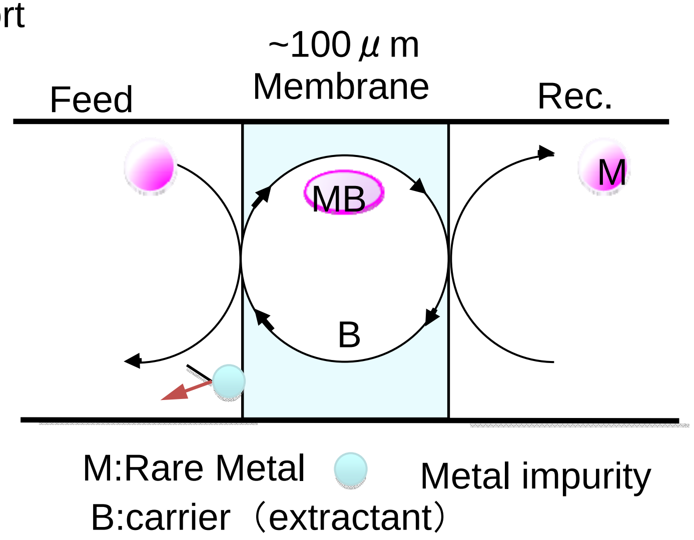
n=4,8,12

Liquid liquid extraction



Supported liquid membrane





Formation of stable SLM by using ILs

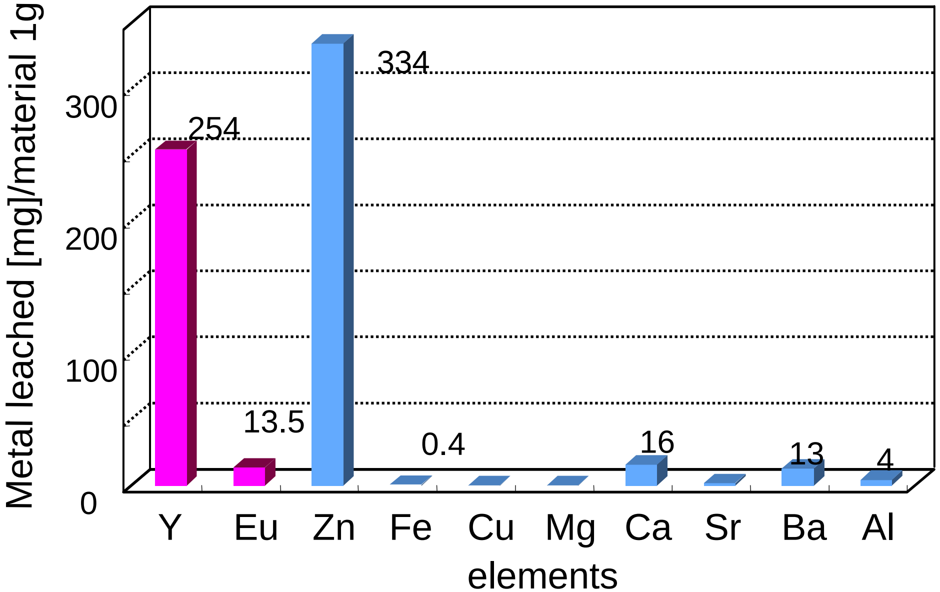
Example

Recovery of fluorescent material from CRT panel

Scraping

Fluorescent material

Leaching
by acid solution



Analysis of the leaching solutions

Amount of metals leached from 1g a fluorescent material

M. Goto, Y. Baba and F. Kubota: PASIFICHEM 2010, Honolulu

Future of chemical science

- Interdisciplinary fields are becoming more important.
- Cooperation with other fields such as life science and/or material science will result in opening of new innovation in application.
- Medical field, e.g. diagnosis and therapy, will be considerably developed by introducing chemical science and technology. Personalized medicine is one of the prospective fruits of the cooperation.

Safety of chemical plants

- Responsible care

  responsible to environment and society

  responsible to consumers

  responsible to workers and stockholders

- Safety is most important.

  risk assessment and analysis

  fault-tree analysis, hazard mapping

  information and analysis of accidents that occurred in the past (horizontal development)

International cooperation in safety

Security and safety should be promoted by international cooperation. Two examples are given here.

1. Environmental standard for destruction of chemical weapons
2. Detoxification of As

Summary of Airborne Limits of Chemical Warfare Agents

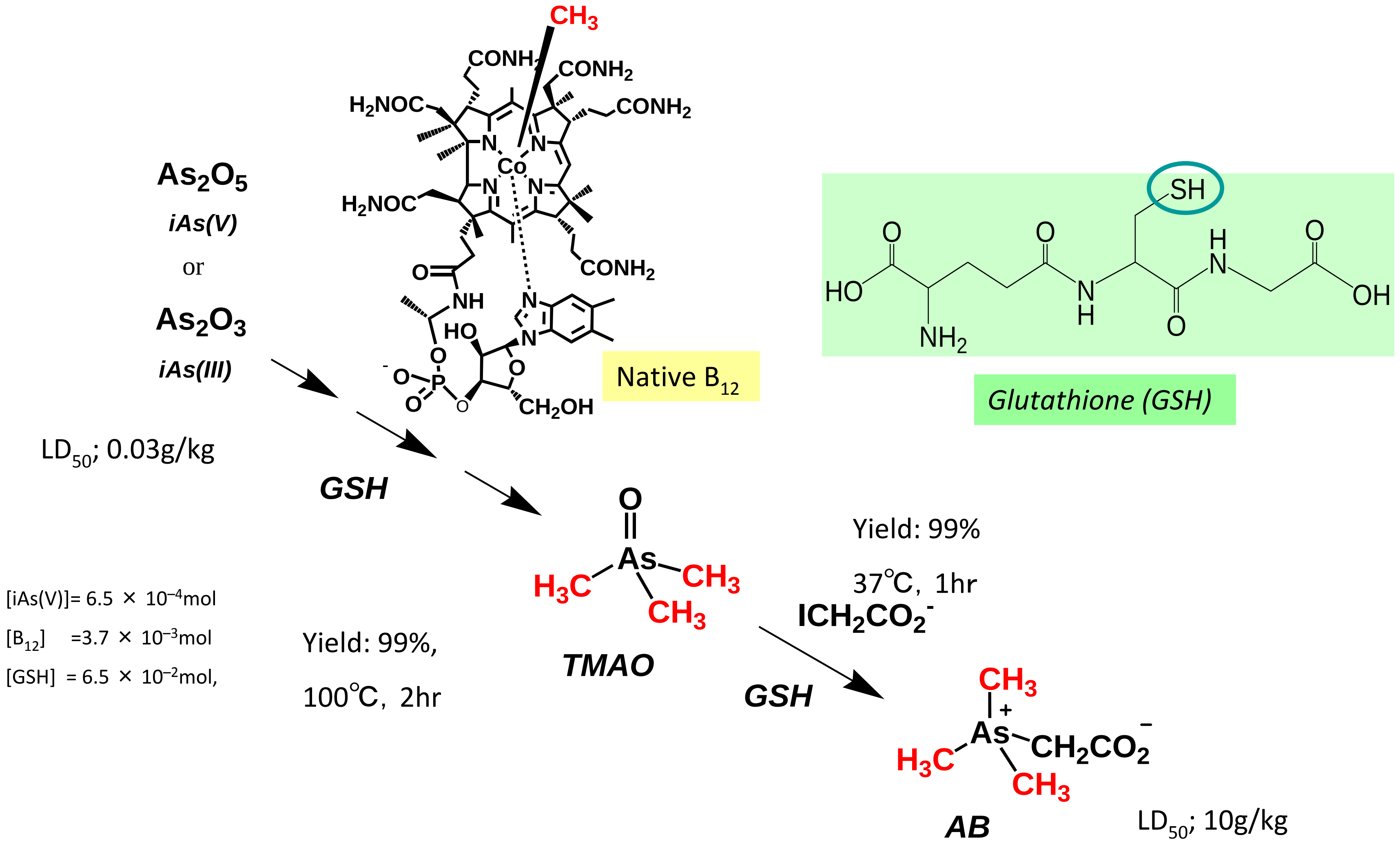
(mg/m^3)

Type of Standard/Guideline	Exposure scenario	Agent name/Code name					
		Sulfur Mustard	Lewisite	Hydrogen cyanide	Arsine	Phosgene	Chloroaceto-phenone
		H/HD/HT	L	AC	As	CG	CN
IDLH (Immediately Dangerous to Life or Health Level)	**worker; acute** 30 minutes	0.7	NA	55 (NIOSH)	9.6 (NIOSH)	8.1	15 (NIOSH)
STEL (Short Term Exposure Limit)	**worker; acute-intermittent** 15-min exposure (<4 x day)	0.003	NA	5 (NIOSH, skin)	0.002 (NIOSH 15-min ceiling REL)	0.8 (NIOSH 15-min ceiling)	
WPL, PEL, TLV, or OEL (Worker Population Limit)	**worker; chronic** 8-hr, daily/30 yr, time-weighted average	0.0004	(0.003)	11 (OSHA PEL), 5.5 (OEL)	0.2 (OSHA PEL, NIOSH REL, ACGIH TLV)	0.4 (OSHA PEL, ACGIH TLV)	0.3 (OSHA PEL, NIOSH REL, ACGIH TLV)
GPL,RfC or OEL (General Population Limit)	**civilian population; chronic** 24-hr/day, lifetime, time-weighted average	0.00002	(0.003)	0.003 (IRIS RfC)	0.00005 (IRIS RfC), 0.0003 (OEL: cancer)	NA	0.00003 (NIOSH RfC, Inhalation)

Source: U. S. Army Center for Health Promotion & Preventive Medicine
OEL: Recommendation of Occupational Exposure Limits, Japan

Detoxification of inorganic arsenic (As)

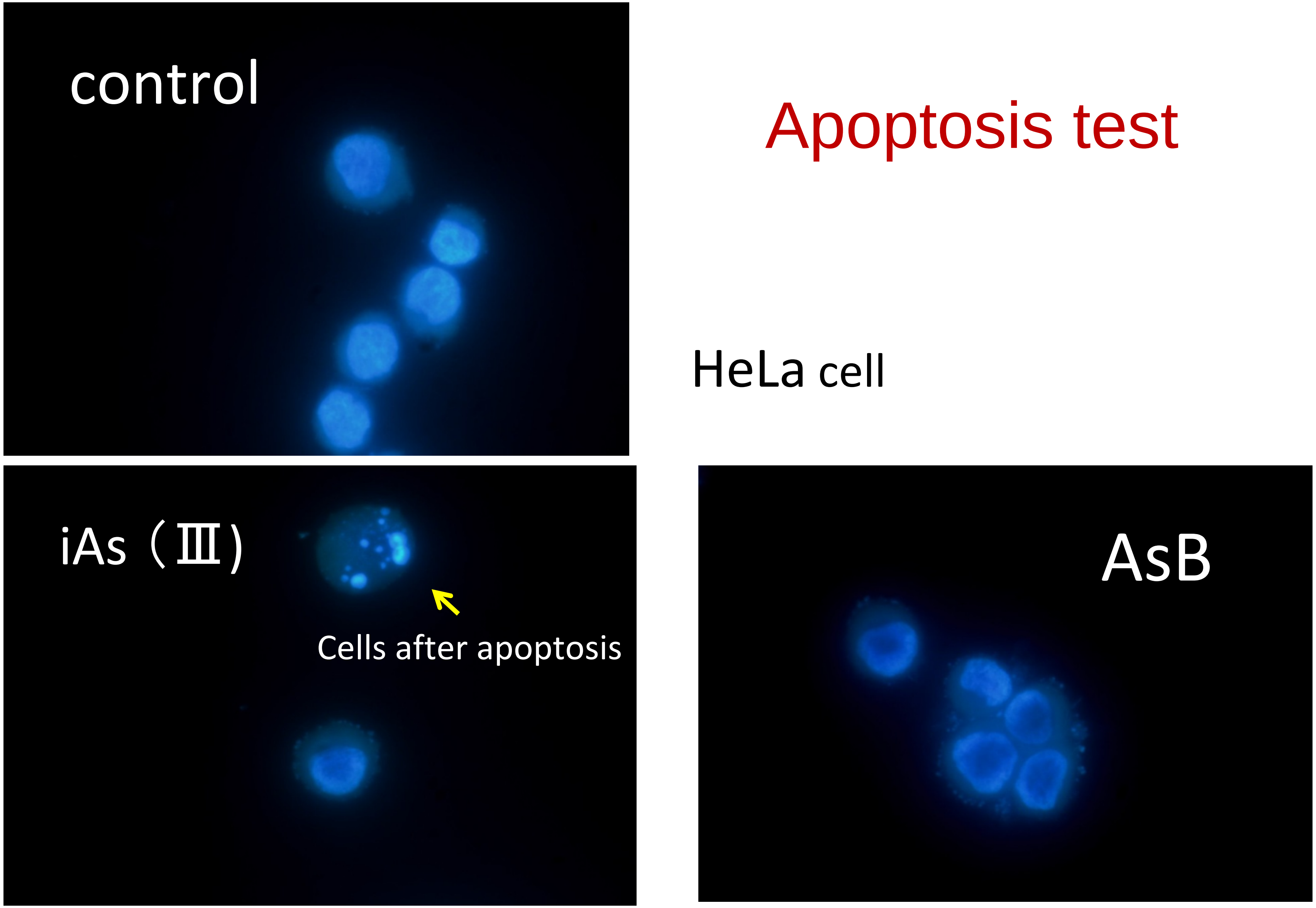
Detoxificatin of Inorganic Arsenic :
Synthesis of Arsenobetaine (AB)



Nakamura K, Yamauchi H. *et al. (2008), Chem. Comm.*, 41: 5122－5124.

Apoptosis test

HeLa cell



Apoptosis of cells in the medium with inorganic arsenic III

No change by arsenobetaine

Courtesy: Prof. H. Yamauchi, Kitasato University

Resilience from disaster

From Asahi Shimbun, www.asahi.com

From NHK TV Program

www.hirobro.com/archives/51458275.html

Fire of a refinery along the Tokyo Bayshore
(https://database.yomiuri.co.jp/shashinkan/)

Resilience from disaster

We thank every assistance from all over the world for recovery from the earthquake and tsunami disaster.

Women’s voluntary contributions were quite important in the resilient management and operation in the disaster. This point is important to think and plan the future rescue operation.

Women in Japan became strong!
(World Championship of FIFA Football Game)

17 July, 2011

AP Photo

Thank you for your kind attention.