December 18, 2019

Direct Air Capture (DAC): CO_2-Selective Absorbents in Air

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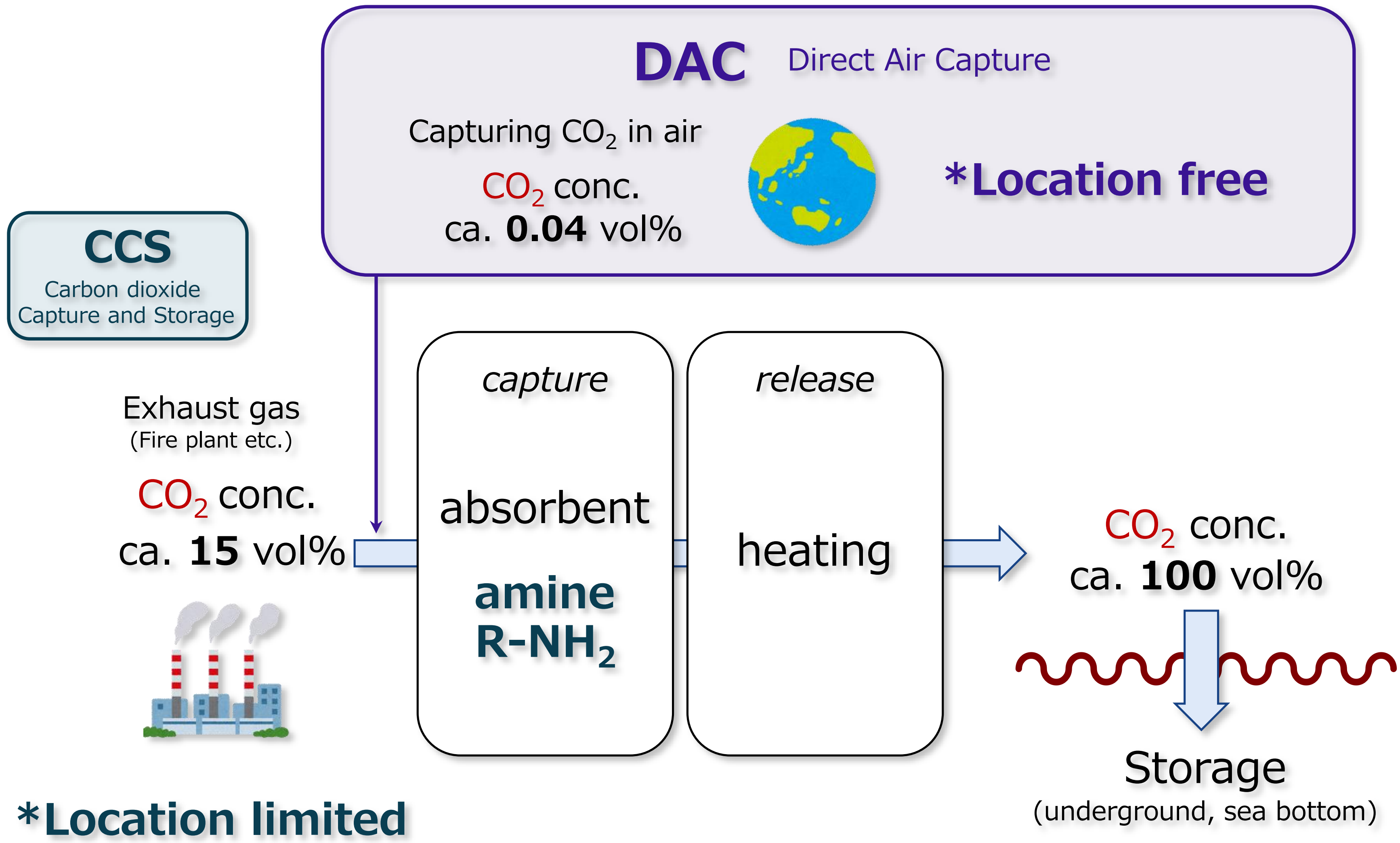
CO_2 Capturing Technology



Common Task

REDUCTION OF CO_2 SEPARATION ENERGY

CCS

Center for Low Carbon Society Strategy (LCS)
Survey on the Carbon Capture and Storage process, 2016

	current		future
CO_2 separation energy	2.5 MJ/kg-CO_2	⇨	1.5 MJ/kg-CO_2

DAC

Climeworks
900 ton/year

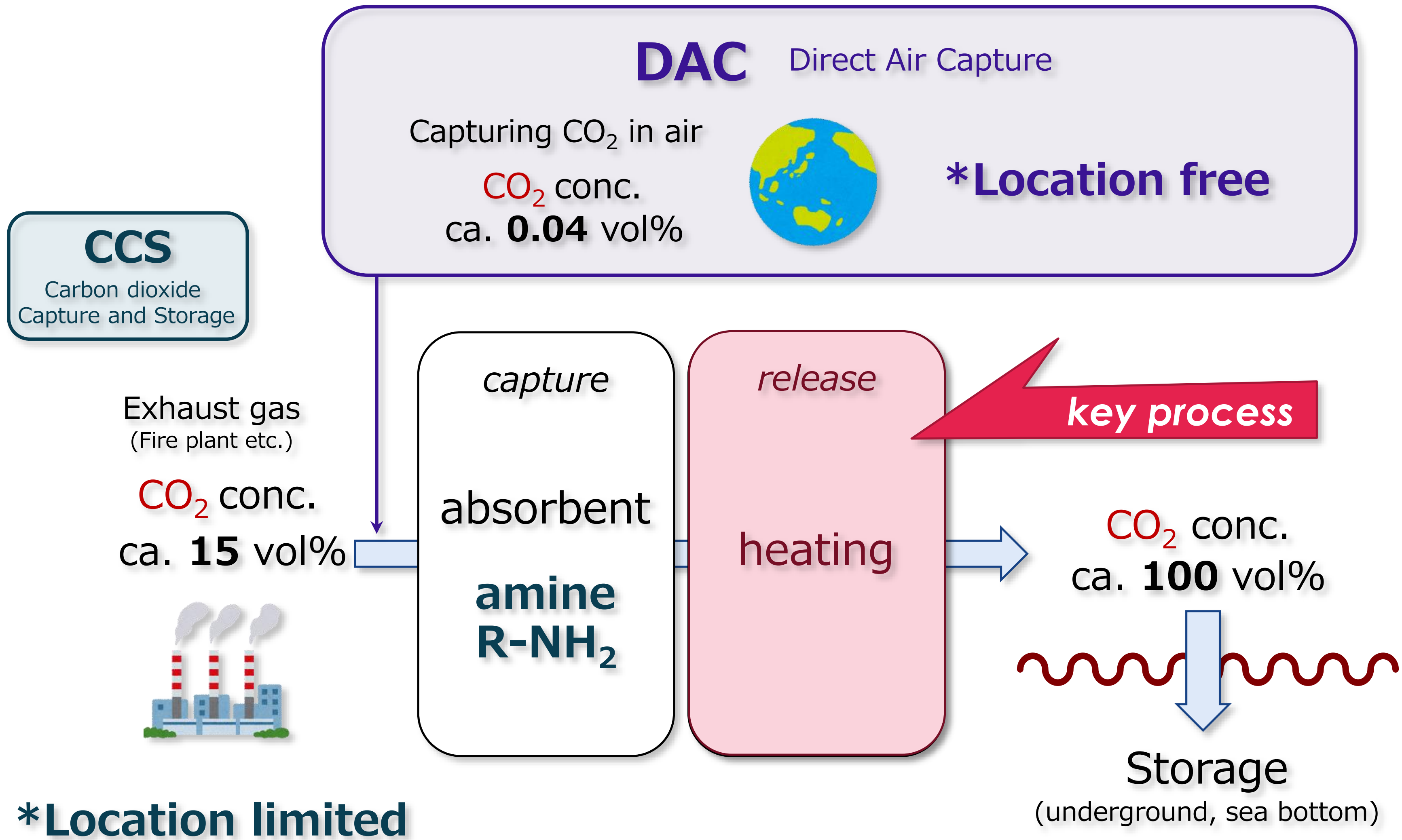
Carbon Engineering
365 ton/year

Global Thermostat
4,000 ton/year

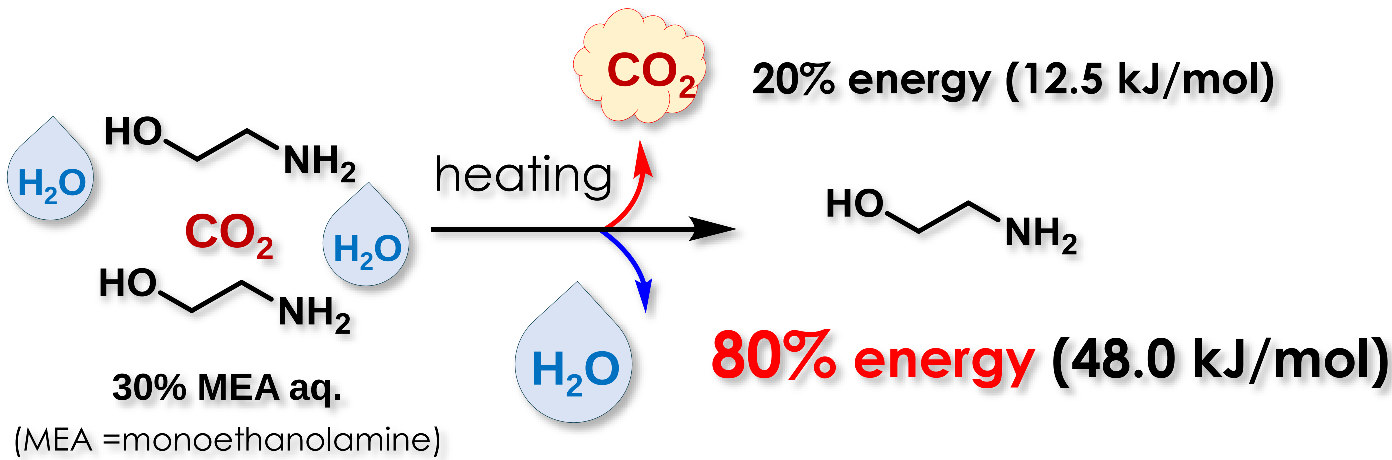
DAC possesses a highly potential for CO_2 reduction

Smith, P. et al. *Nature Climate Change* **2016**, 6, 42-50.

CO_2 Capturing Technology



Bottleneck Issue = Water Separation?



Need for extra thermal energy of water!

Weiland, R. H. *et. al. J. Chem. Eng. Data* **1997**, *42*, 1004-1006.
APS Physics, *Direct Air Capture of CO_2 with Chemicals*, **2011**, pp 59.

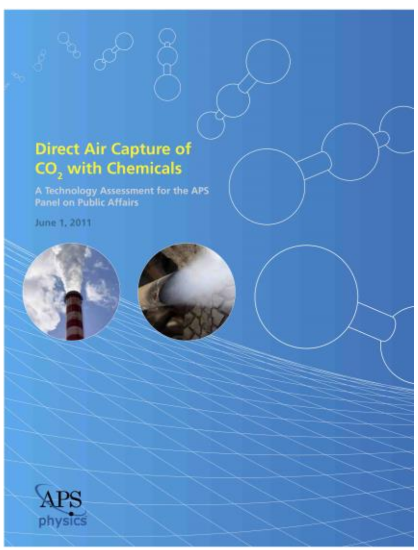
General : **Hydration** is **inevitable**

$$R\text{-}NH_2 + CO_2 + H_2O \rightarrow R\text{-}\overset{+}{N}H_3\,\overset{-}{O}\text{-}C(=O)\text{-}OH \rightleftarrows \text{hydration}$$

amine — 親水性

CO_2 — 水溶性

bicarbonate



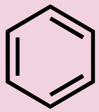
Direct Air Capture of CO_2 with Chemicals, 2011

American Physical Society (APS)

"Water vapor can compete with CO_2 for the reactive sites on sorbents, degrading capture performance. Water vapor can add to the thermal mass of a sorption system that must be heated during regeneration, adding to operating costs."

CO_2 Selective Absorbent in Air without Hydration

H_2N—R
アミン



Pairing!
Phenyl (Ph)
hydrophobicity

※Commercial sources
(Already mass-production)

Tips

capture

a) CO_2 selectivity (CO_2 vs. water) up!!
※Some compounds absorb CO_2 only

b) Similar absorption ability with MEA

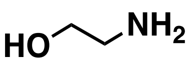
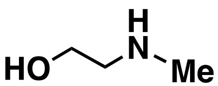
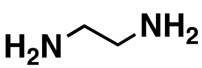
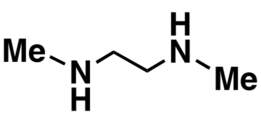
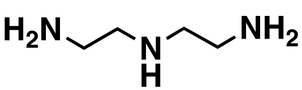
release

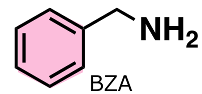
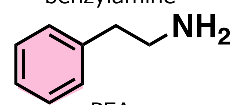
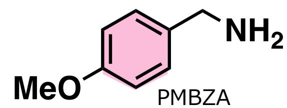
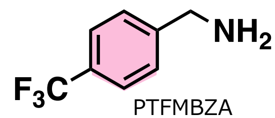
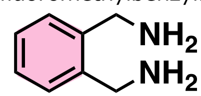
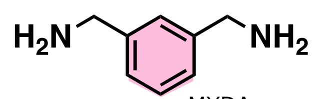
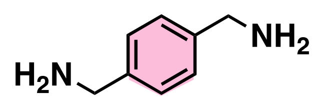
c) Similar heating temperature with MEA (100-120 °C)
※ Some compounds under 100 ℃

d) Pure CO_2 gas production

a) CO_2 selectivity

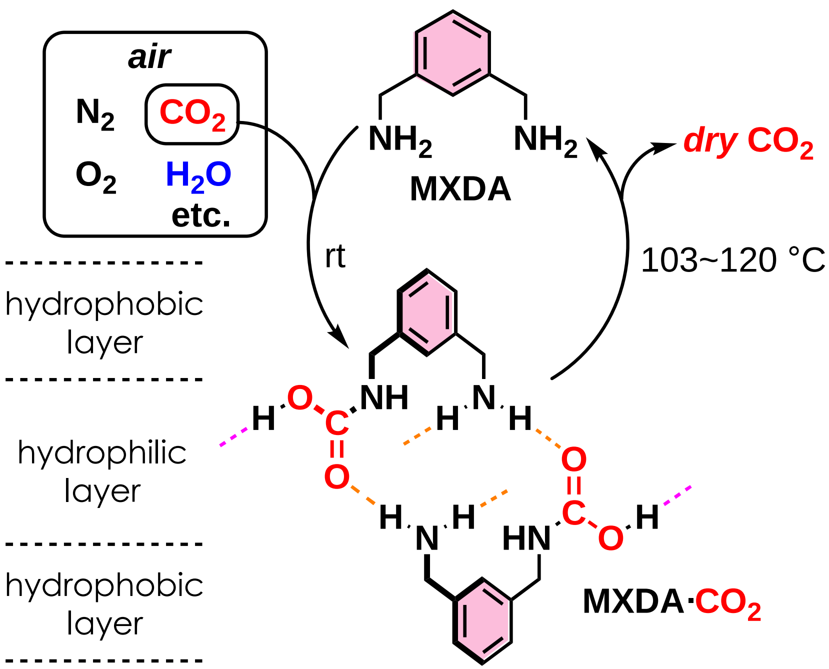
amine in air at room temperature (ca. 1 week) → **amine·X(CO_2)·Y(H_2O)** (elemental analysis)

	CO_2 X	H_2O Y	Moisture content
 MEA monoethanolamine	0.33	1	**300%**
 MAE 2-(methylamino)ethanol	0.34	1.8-2.7	**500-800%**
 EDA ethylenediamine	0.27	4.1-4.4	**1,500-1,600%**
 DMEDA N,N-dimethylethylenediamine	0.86	4.7-4.8	**550-560%**
 DETA diethylenetriamine	0.35	4.8-5	**1,350-1,450%**

	CO_2 X	H_2O Y	Moisture content
 BZA benzylamine	0.5	0.125	25%
 PEA phenetylamine	0.44	0.11	25%
 PMBZA *P*-methoxybenzylamine	0.44	0.11	25%
 PTFMBZA *P*-trifluoromethylbenzylamine	0.5	0.125	25%
 OXDA *o*-xylylenediamine	1	0	0%
 MXDA *m*-xylylenediamine	1	0	0%
 PXDA *p*-xylylenediamine	1	0	0%

Phenyl pairing → CO_2 selectivity up!!

Waterproof Mechanisms

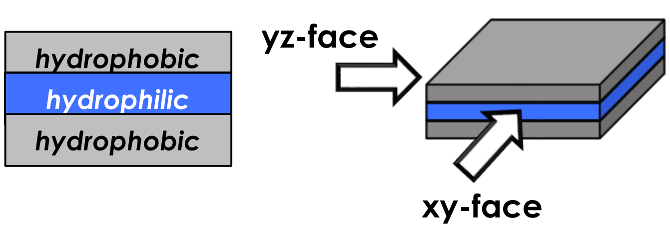


MXDA
water soluble

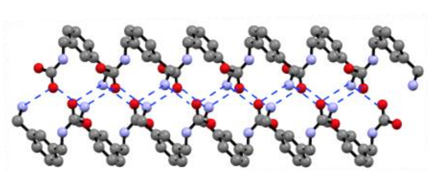
MXDA·CO_2
insoluble

Self-assembled to form a **reverse lipid bilayer** structure
with hydrophobic layers (phenyl groups) on both outer surfaces

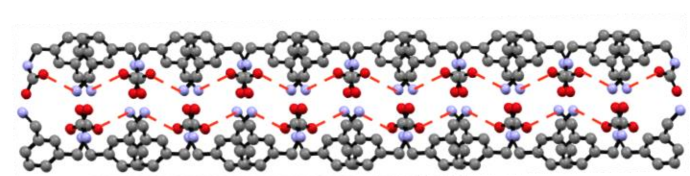
X-ray



xy-face



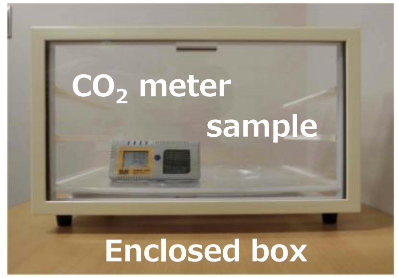
yz-face

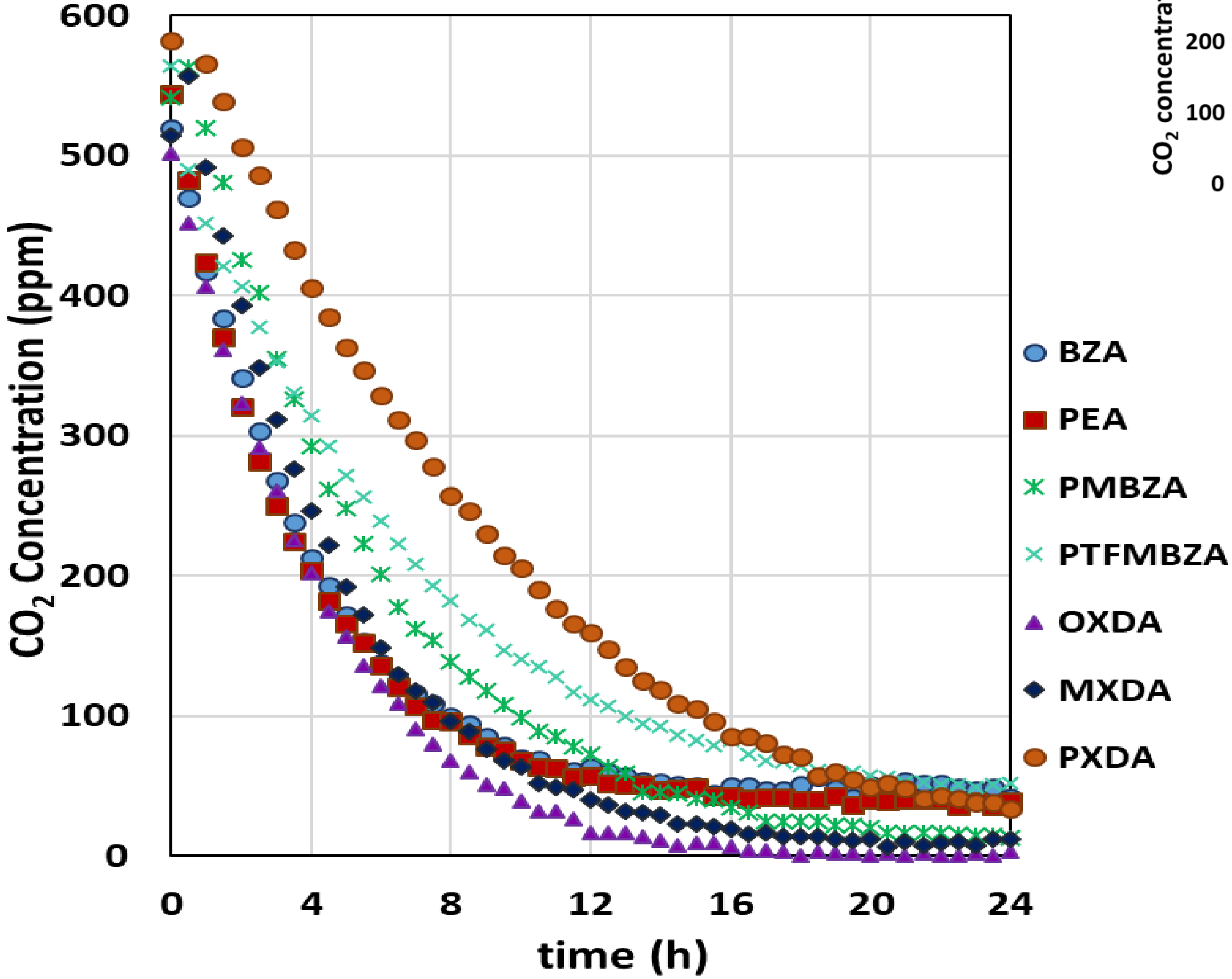


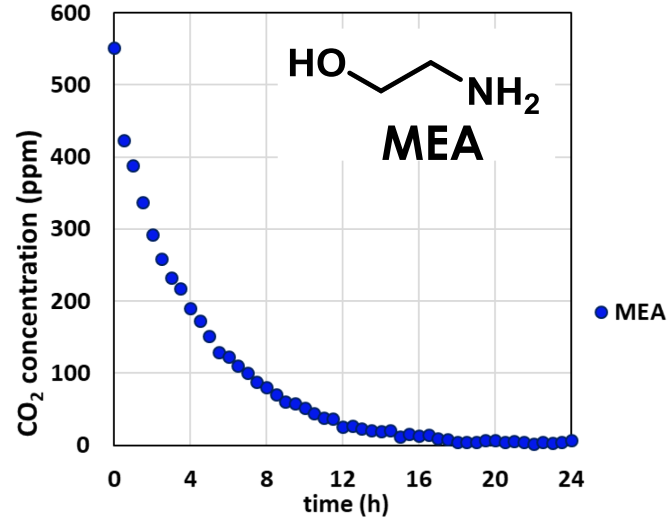
Ball color, grey : carbon, blue : nitrogen, red : oxygen

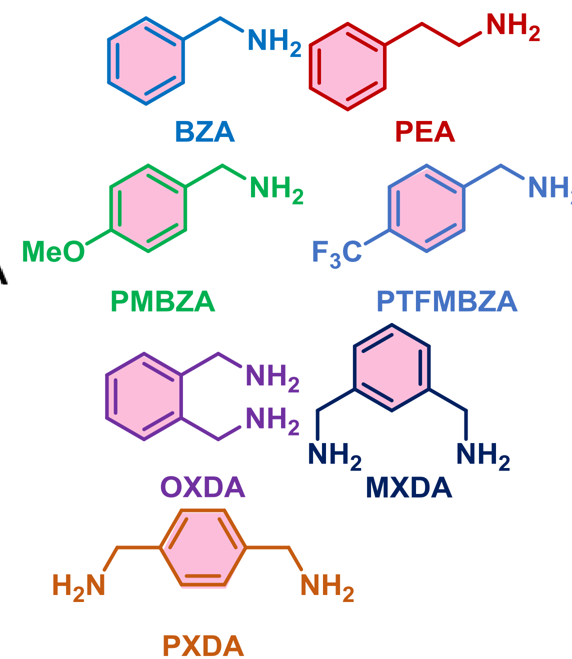
b) Absorption ability

amine 5 mmol, vol. 36 L
initial CO_2 conc. ca. 600 ppm
room temperature



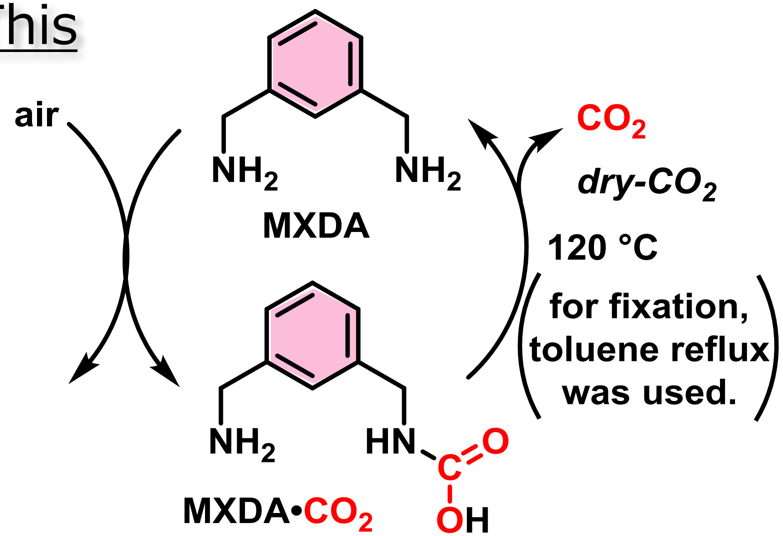




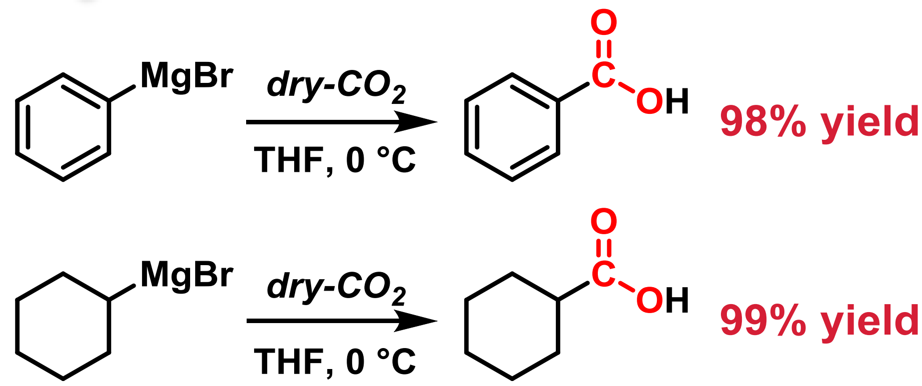


d) Utility of CO_2 gas

This

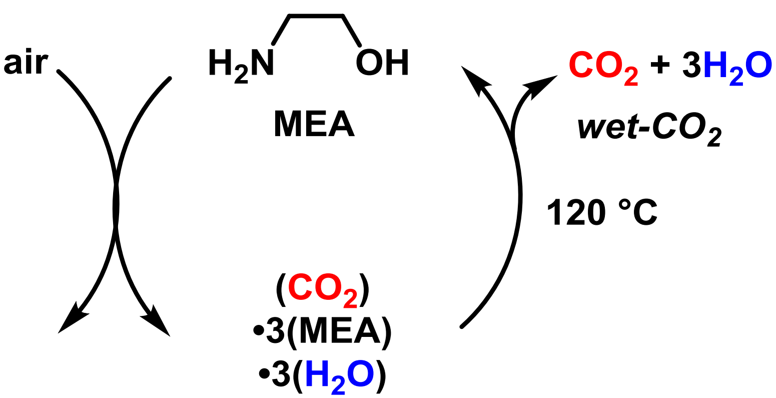


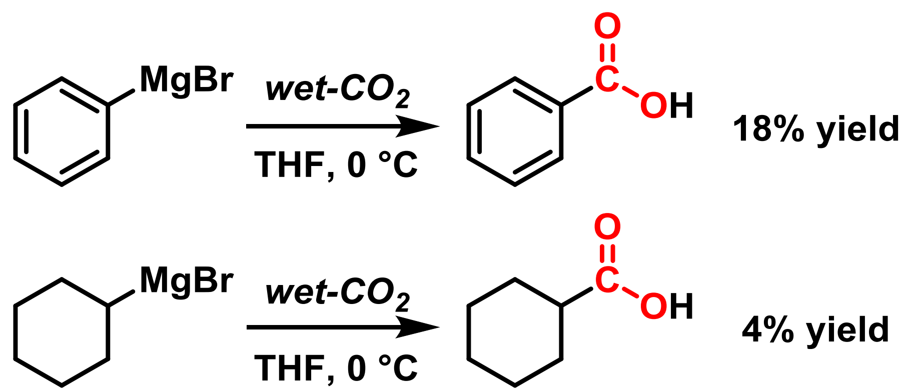
Grignard reaction



Reactive on moisture sensitive condition

General





Unreactive on moisture sensitive condition

Information

【Paper】 **CO_2-Selective Absorbents in Air: Reverse Lipid Bilayer Structure Forming Neutral Carbamic Acid in Water without Hydration**
Inagaki, F.; Matsumoto, C.; Iwata, T.; Mukai, C.
J. Am. Chem. Soc. **2017**, *139*, 4639-4642. DOI: 10.1021/jacs.7b01049

Energyless CO_2 Absorption, Generation, and Fixation Using Atmospheric CO_2
Inagaki, F.; Okada, Y.; Matsumoto, C.; Yamada, M.; Nakazawa, K.; Mukai, C.
Chem. Pharm. Bull. **2016** , 64, 8-13. DOI: 10.1248/cpb.c15-00793

【Patent】 **空気由来の二酸化炭素の吸収剤及び発生剤**
稲垣冬彦, 向　智里, 岡田泰彦,松本千明, 山田将之, 中澤研太
特願2015-149320, 新規国内優先権出願 特願2016-147414, 特開2017-031046

２-オキサゾリジノン誘導体の製造方法
稲垣冬彦, 向　智里, 岡田泰彦, 松本千明, 山田将之, 中澤研太
特許第6607596号

低エネルギー型の二酸化炭素発生方法、及び該方法に使用するための二酸化炭素発生剤
稲垣冬彦, 向　智里, 松本千明
特願2018-010003

【Media】 **金沢大、ＣＯ$_2$のみ吸収・放出する新素材を開発−化学系メーカーに提案**
Nikkan Kogyo Shinbunn, March, 27, 2017

Carbon capture gets a boost from aromatic rings
Chemical & Engineering News, 2017, 16, 7.

CO_2-selective Absorption Using *m*-Xylylenediamine
TCI Topics 2017

Development of an efficient atmospheric CO_2 absorber/release agent -Challenge from medicinal chemistry-
Gendaikagaku, November, 2017

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