DRIVE

Deep Removal of CO2 &
InnoVative Electrification concepts

Two-step regeneration system for hydroxide-based solvents

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DRIVE project

Aim – To test deep removal with thermal regeneration and electrochemical regeneration processes.

• Operates at mild conditions (ambient temperature, lower pressure)
• Compatible with renewable electricity → enabling green electrification

Key Technologies:

- CESAR1 → Deep removal [refer to Dr. Peter Moser presentation ; Session 6C]
- ZEUS → Zero-emission solvent regeneration using electrochemical cells
  - Aims for higher energy efficiency, reduced solvent degradation
- CODEC → Direct electrochemical conversion/regeneration

DRIVE Target:

• Develop & model ZEUS and CODEC up to TRL 5–6
• Benchmark against thermal regeneration for energy and cost

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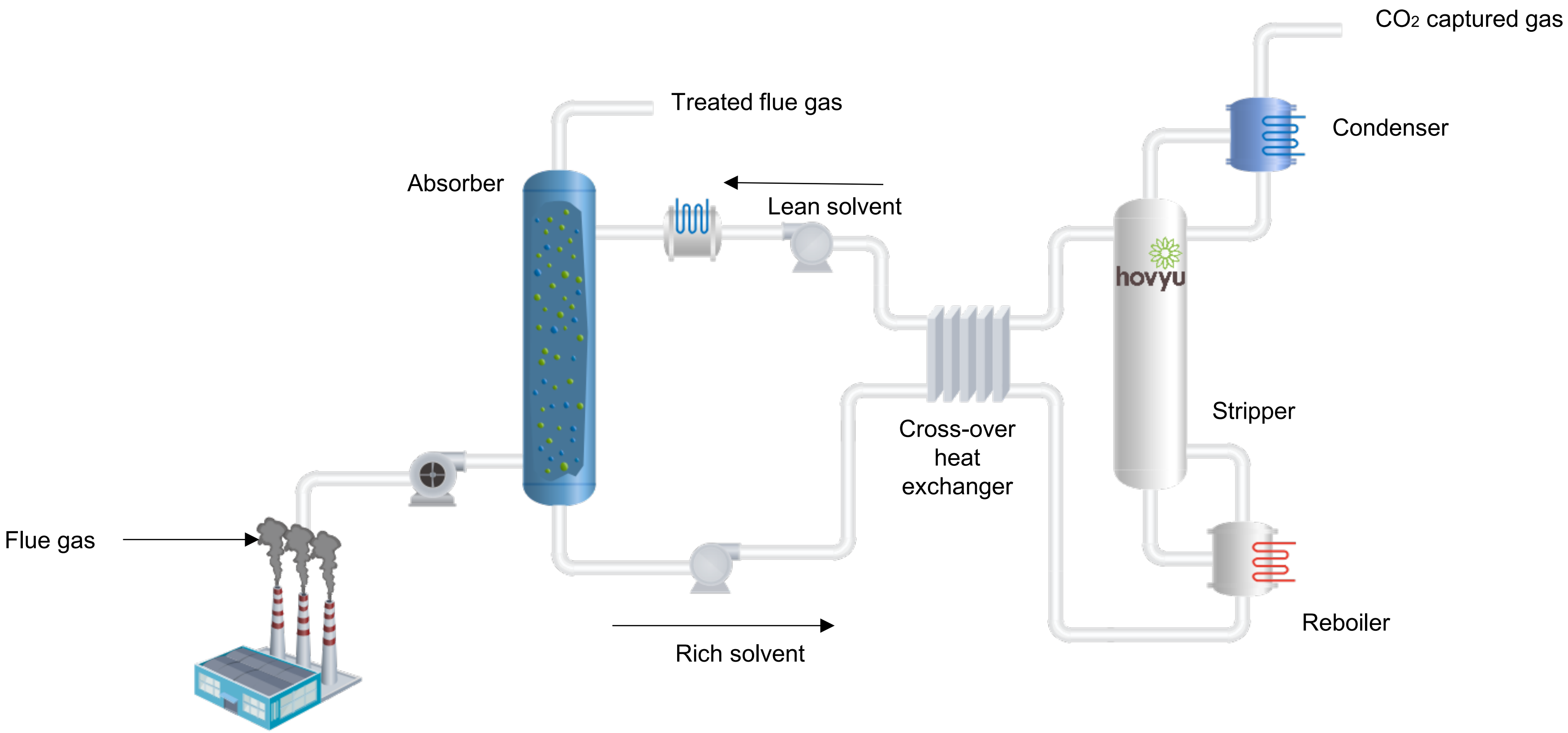
Traditional amine-based process



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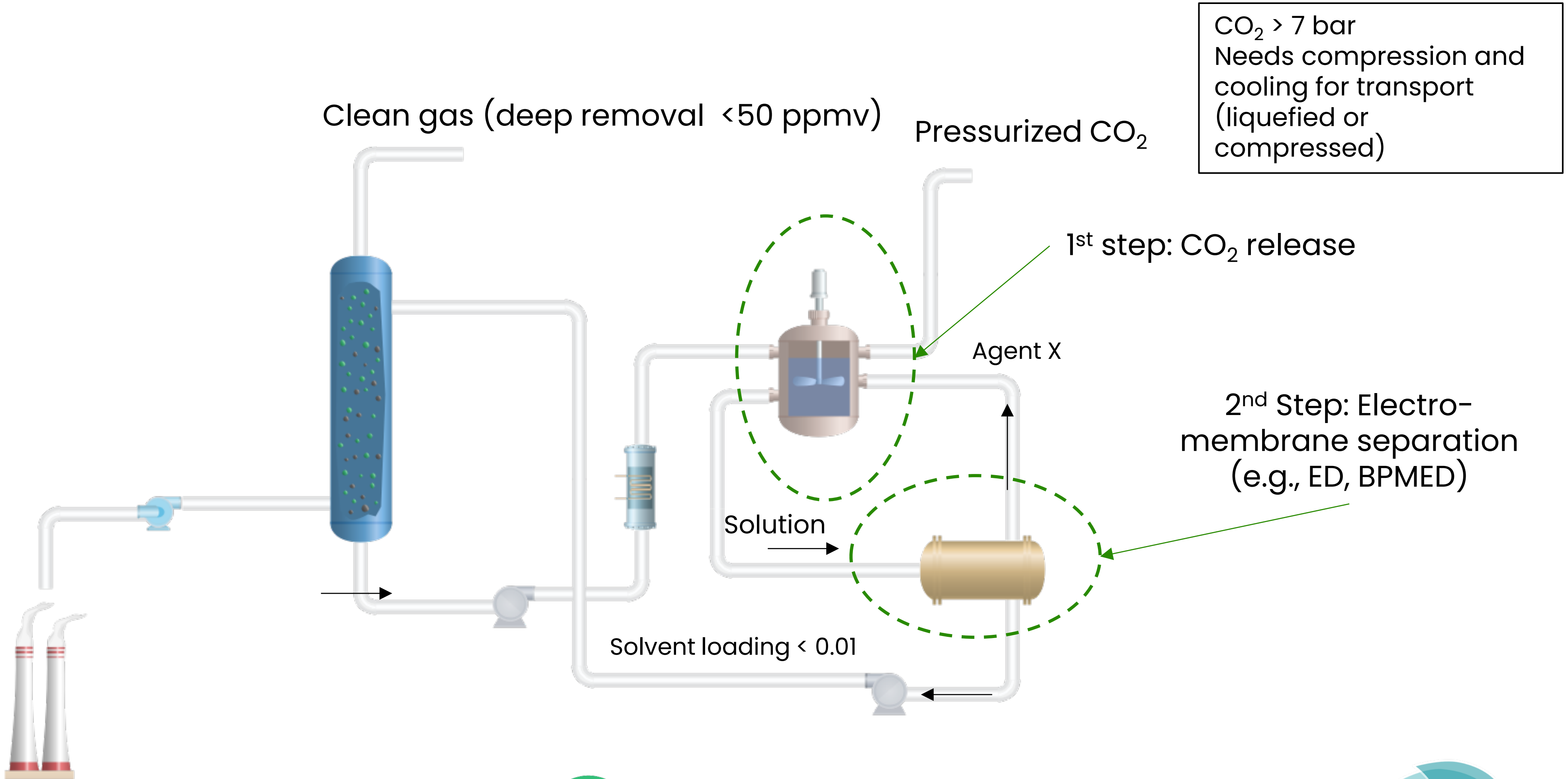
The ZEUS (Zero Emission-Ultra Stripping) process



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Advantages of ZEUS process

- Energy required for regeneration of solvent in conventional amine-based capture process is normally provided by steam
- Requirement of additional CHP unit to supply energy (in a few industries) – higher CAPEX
- ZEUS eliminates the need for this additional unit

- Unlike amines, hydroxides are stable

- CO_2 released is at higher pressure (up to 10bar)

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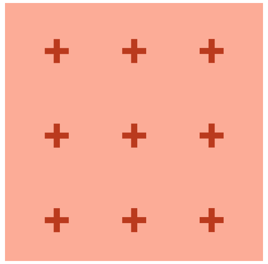
Electrochemistry concept

Ion exchange membranes

Anion exchange membrane



Cation exchange membrane

Anion Exchange Membranes (AEMs):

- Contain fixed positive charges (e.g., NR_4^+ groups)
- Allow passage of anions (counter-ions)
- Block cations (co-ions)

Cation Exchange Membranes (CEMs):

- Contain fixed negative charges (e.g., SO_3^- groups)
- Allow passage of cations (counter-ions)
- Block anions (co-ions)

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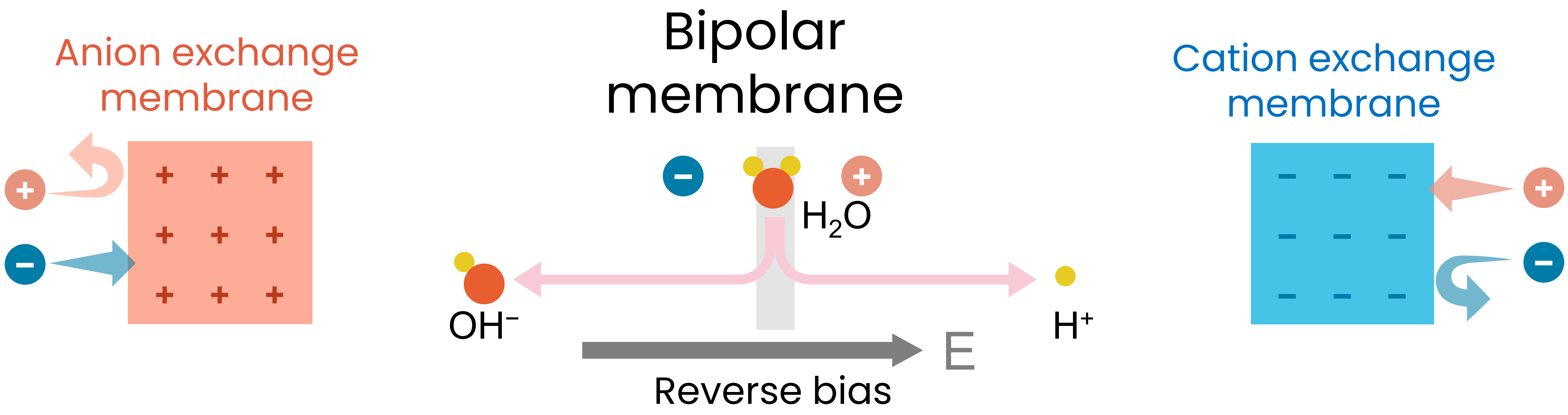
Bipolar membrane (BPM) for acid & base production



- Water dissociation rate in bipolar membrane is about **7 orders of magnitude** higher than in bulk solution

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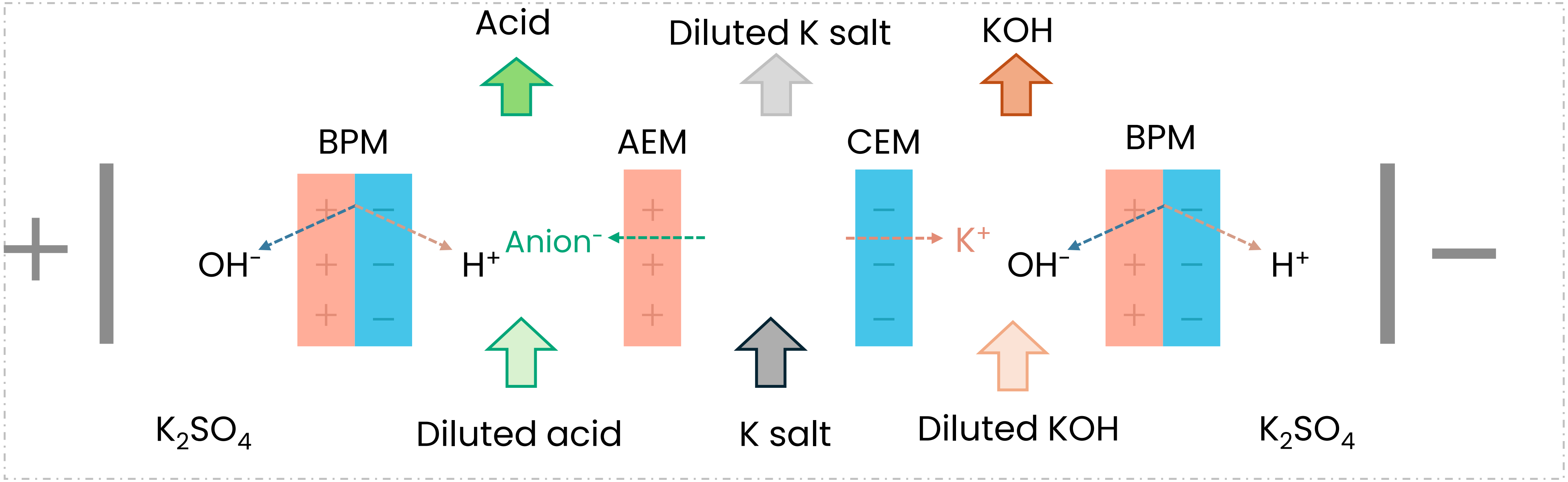
Typical BPM configuration for acid and base production



- Catalyst is the determining factor for water dissociation

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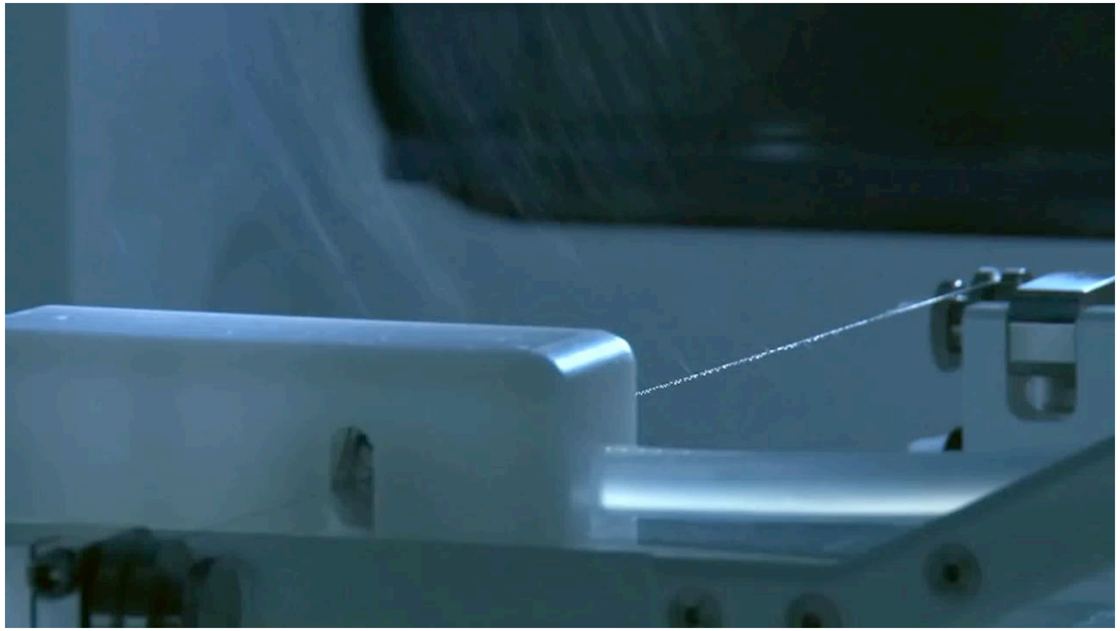
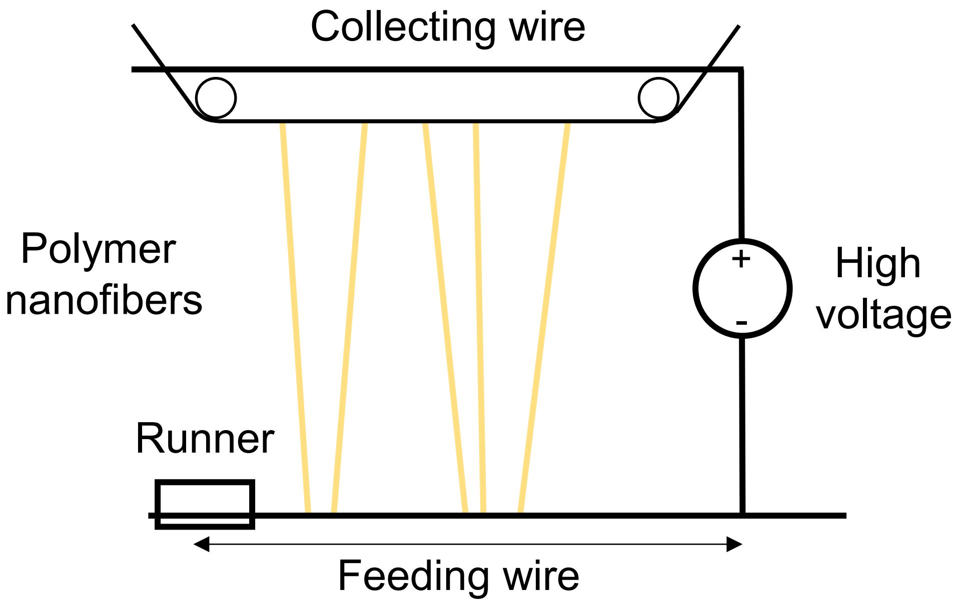
Electrospinning technique





- Nano-fibre structure created by Electrospinning provides more surface area for catalyst.

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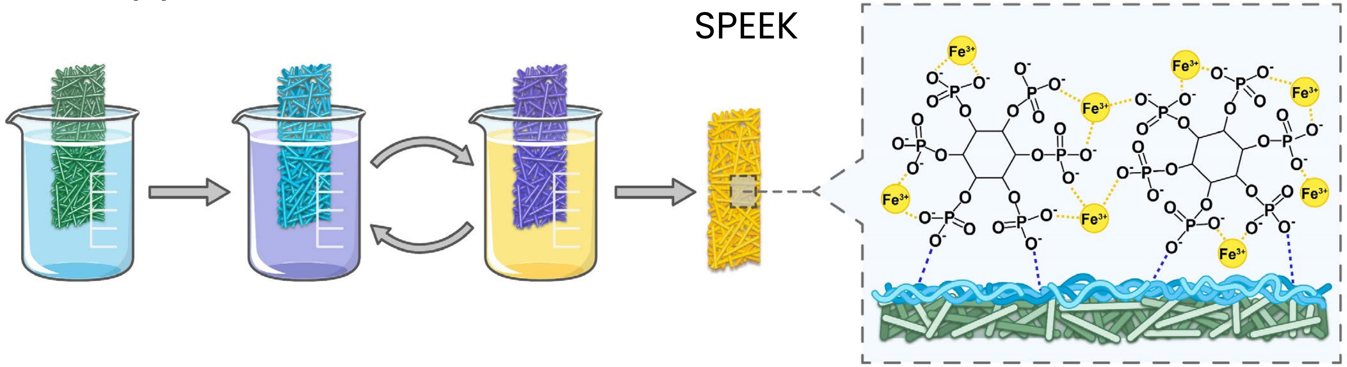
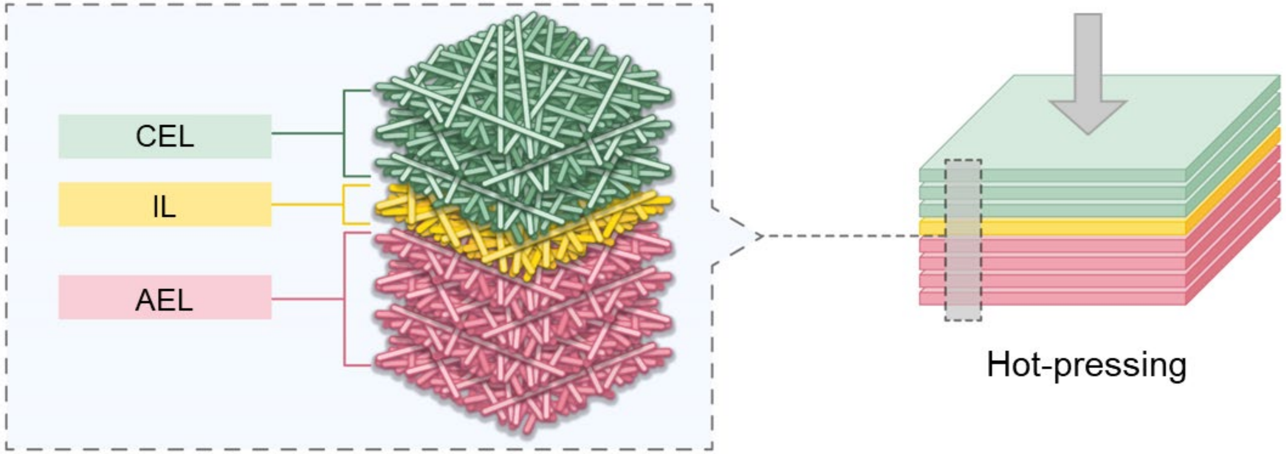
Fabrication of Bipolar-membrane



- Layer-by-layer to introduce catalyst, Phytic acid-Fe^{3+} complex

- Hot pressing to transform porous nanofiber structure into dense bipolar membranes



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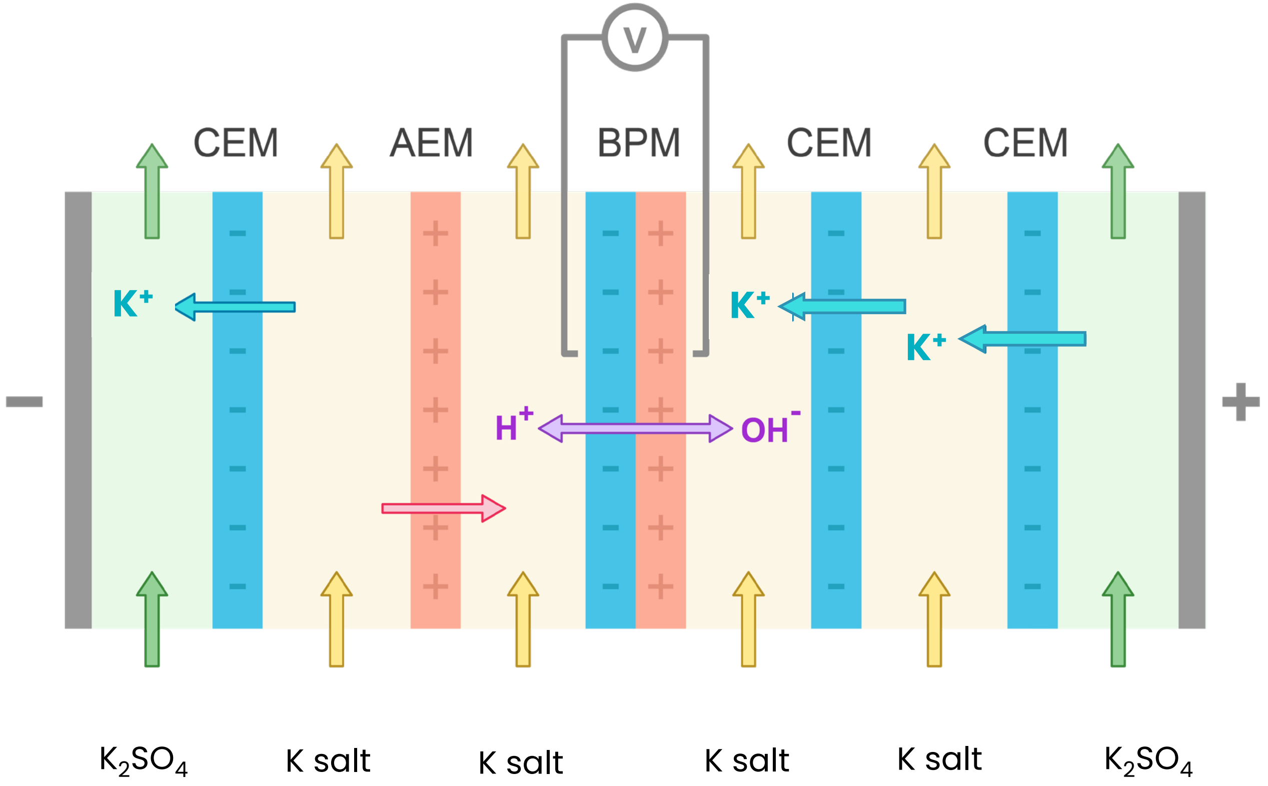
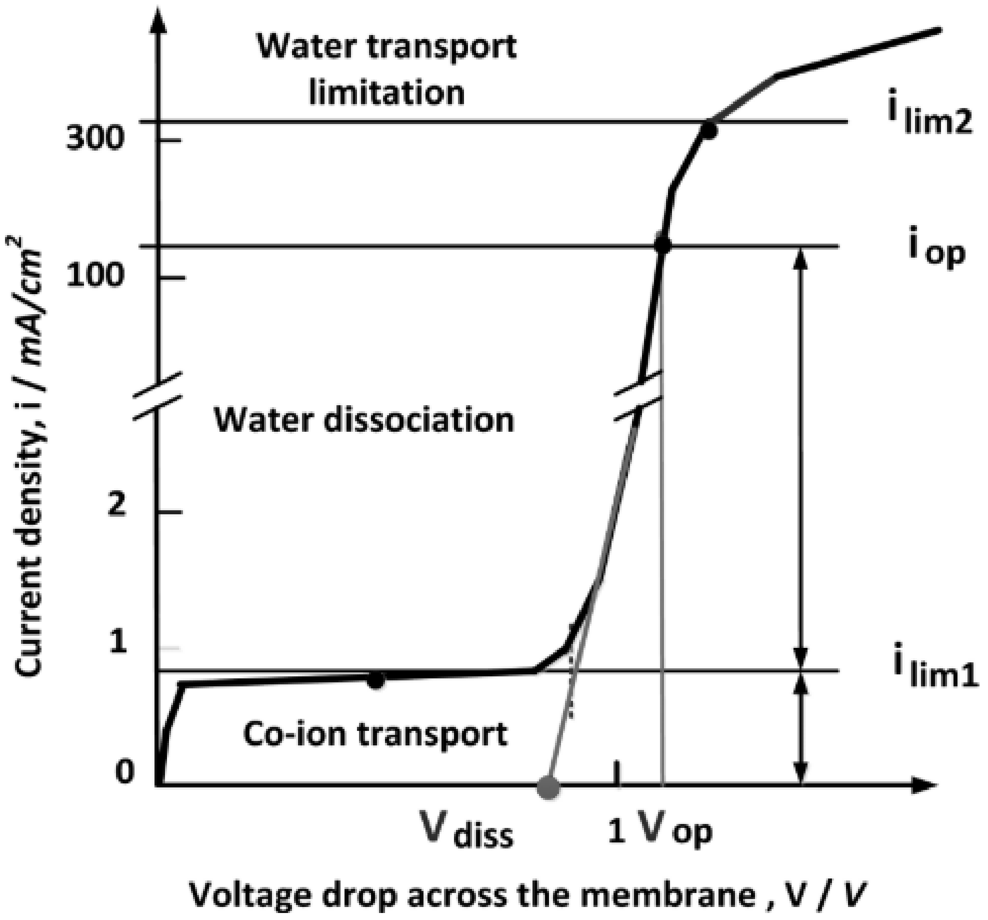
I–V curve of a Bipolar membrane





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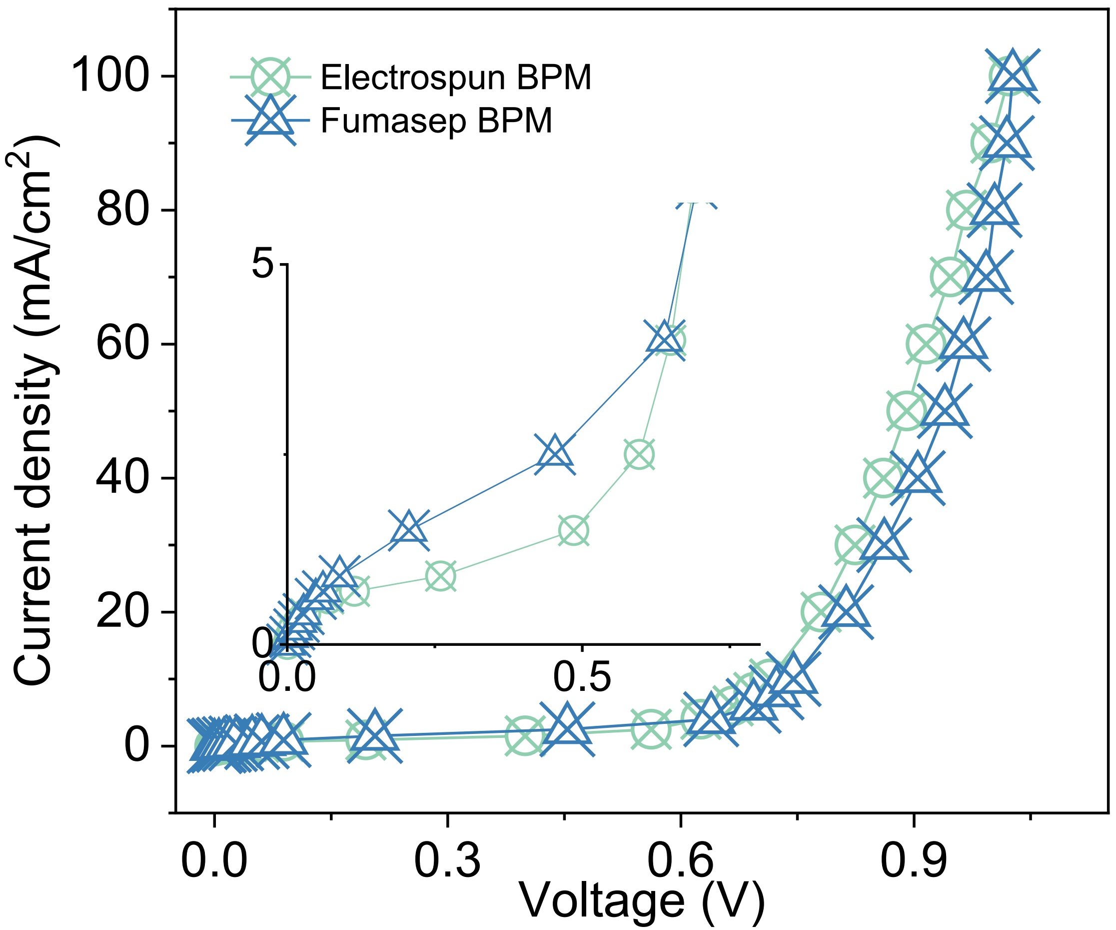
Resistance (I-V curves) measurement

- Solution concentration: 0.5M
- Membrane area: 0.786 cm^2



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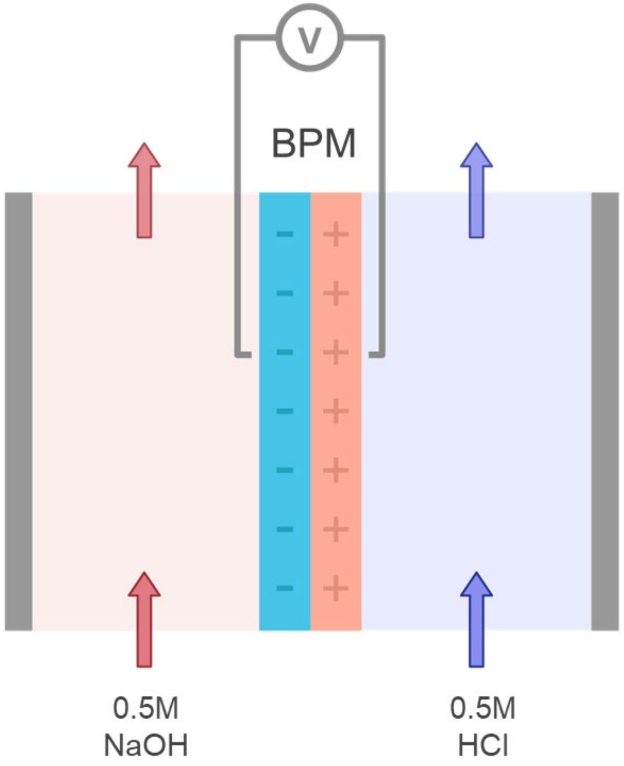
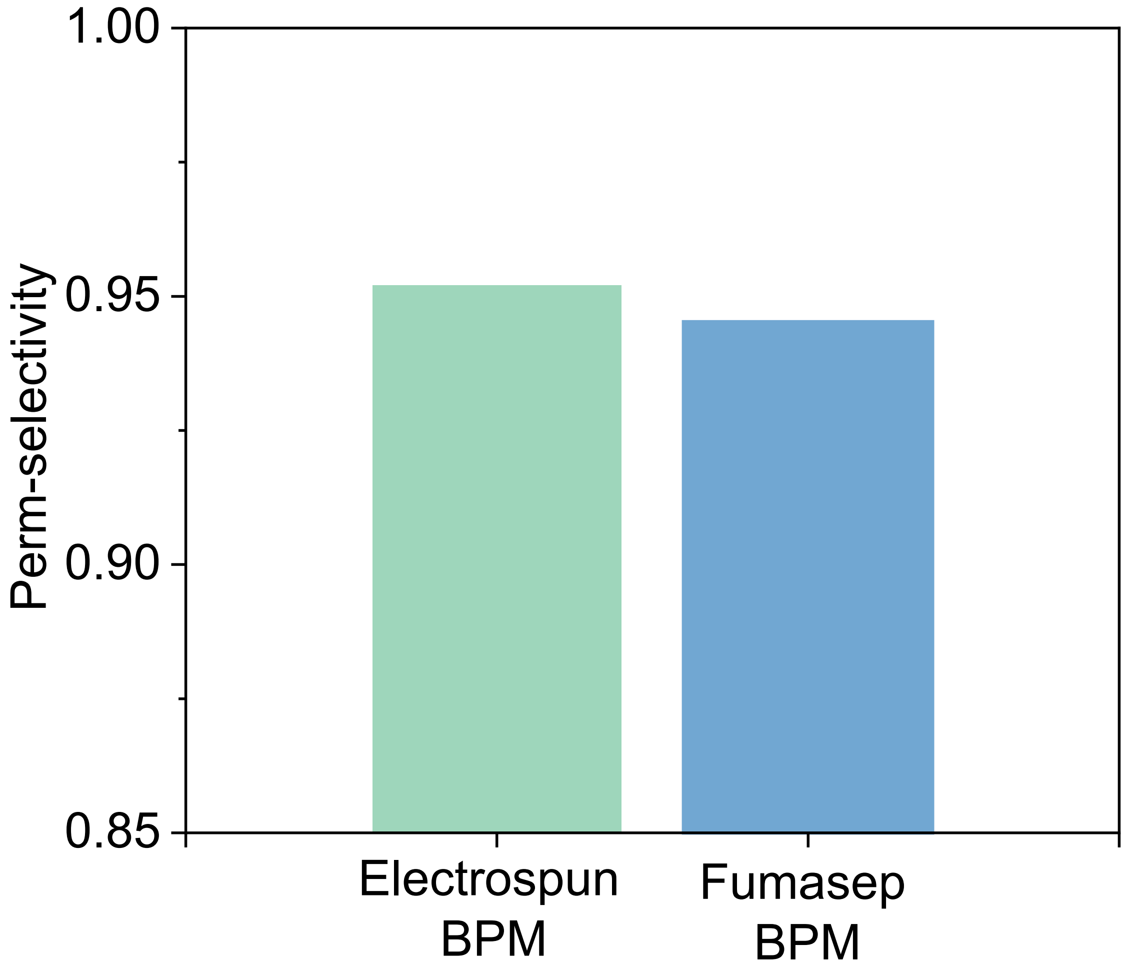
Perm-selectivity measurement





- Membrane area: 17.34 cm^2

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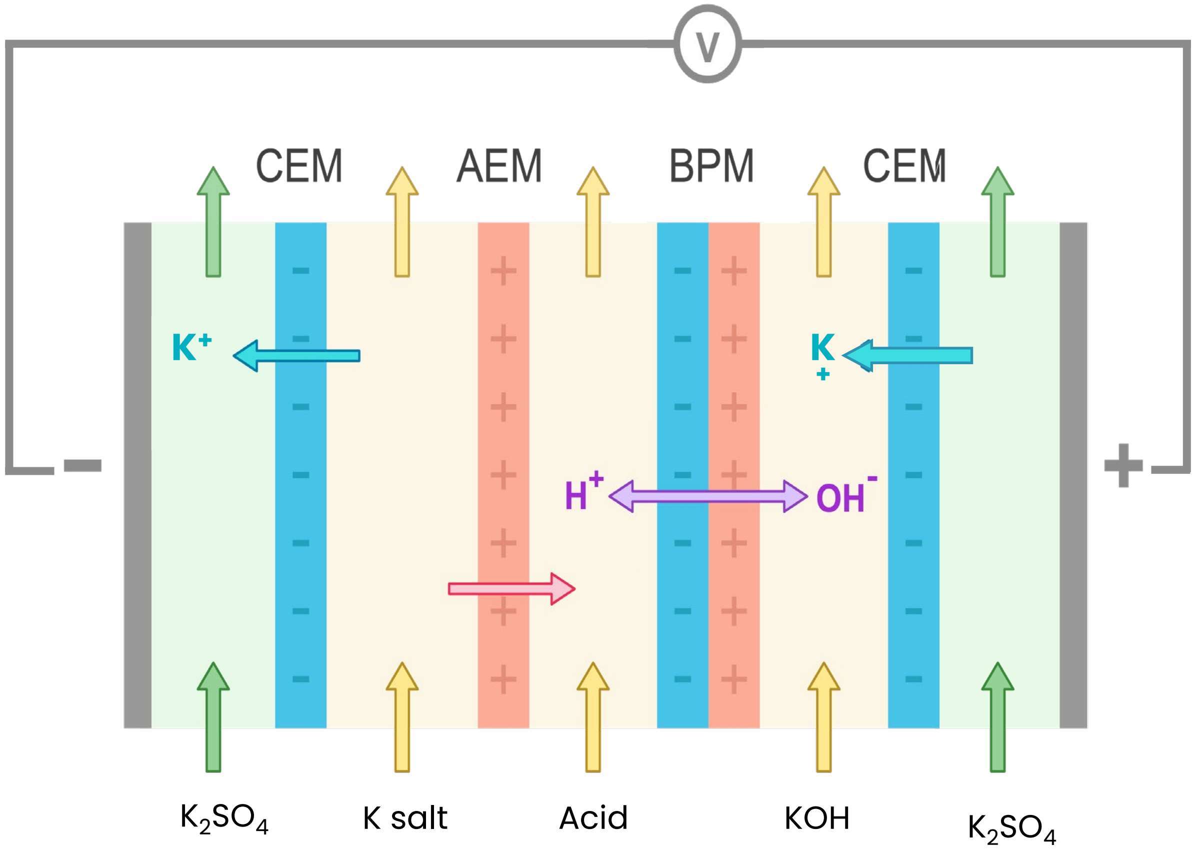
Corresponding Acid Base production



- Solution concentration: 0.05M
- Membrane area: 17.36 cm^2
- Solution volume: 300 mL
- Current density: 3 mA/cm^2

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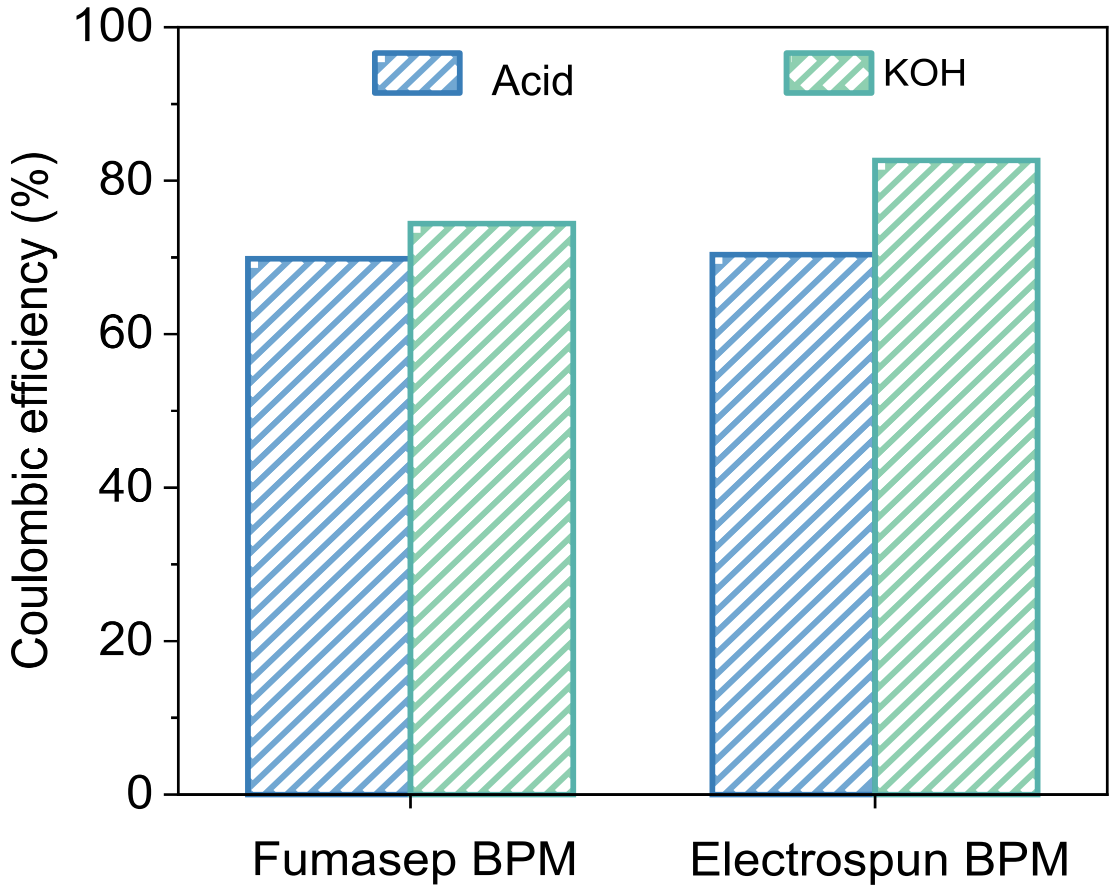
Coulombic efficiency



$$\frac{F\ (c_b\ -\ c_a)\ V}{I\ t} \times 100\ \%$$

- F : Faraday's constant (96485 C/mol)
- c_a: initial concentration of acid or base
- c_b: final concentration of acid or base
- V : volume
- I : current
- T: time

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Scale up process

Pilot plant skid

- Pilot scale
- 10–20 kg/h KOH flow rate
- Commercial BPM used
- Connection with TNO mini-plant (capture capacity ~1kgCO_2/h)

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Conclusions & Upcoming tasks

- The production of base using electrospun membrane is slightly higher compared to commercial membrane.
- The perm-selectivity of both electrospun membrane and commercial membrane are comparable.
- The scaling up of electrospun membrane is not feasible in the laboratory, therefore pilot tests would be conducted using commercial membrane.
- Results to be generated in this upcoming semester.
- TEA will be conducted with the results and benchmarking against thermal regeneration process to be done.

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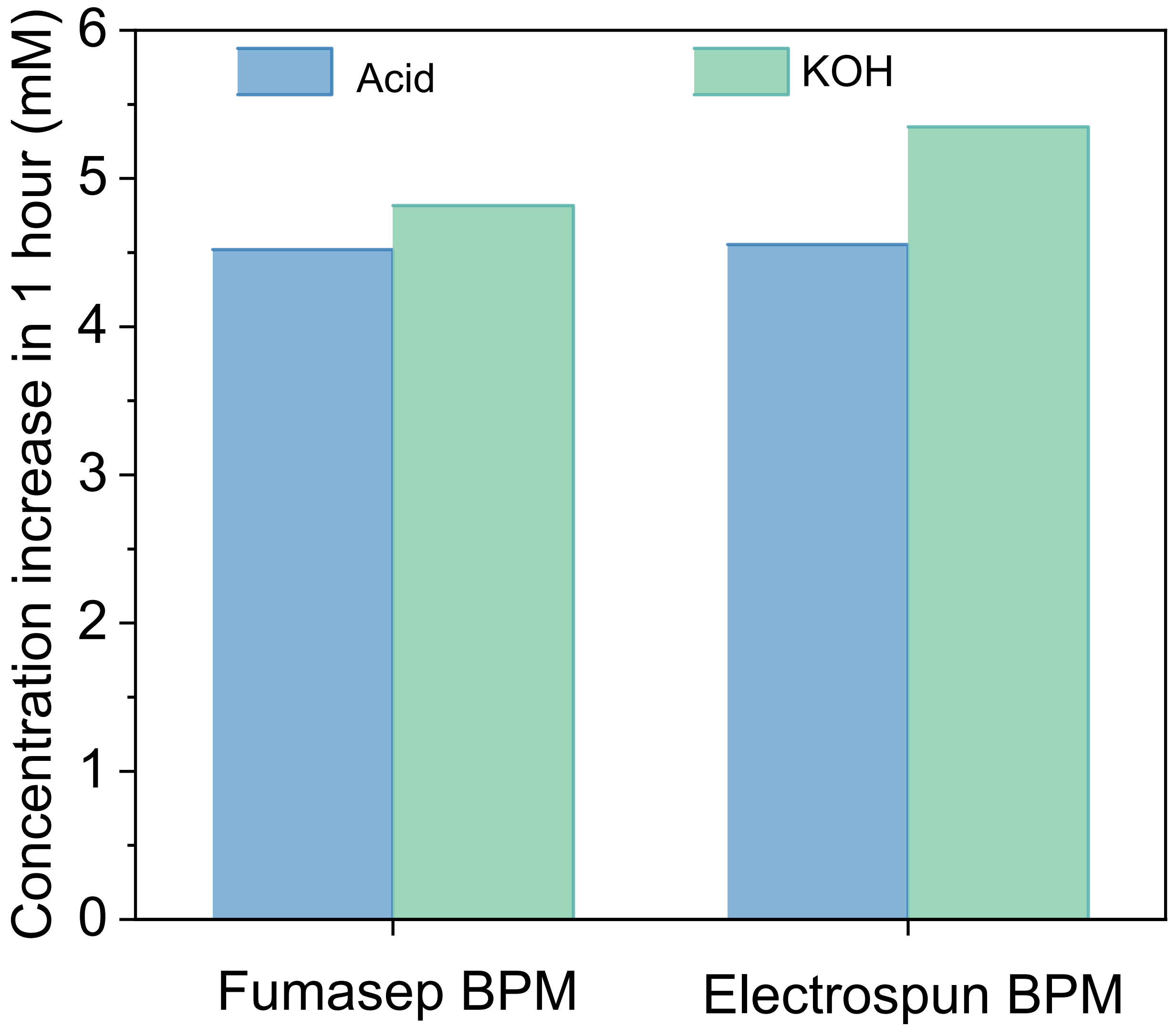

Solution volume: 300 mL
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