

Some Electrochemistry Basics and an Idea!

Halle Cheeseman

Electrochemical Approaches



- Moderator: Halle Cheeseman Program Director, ARPA-E Notes: Matthew Mattozzi, Tech SETA

A) *IN SITU*

1. Are downhole deployment of electrochemical approaches practical?
2. Are there existing mining or drilling processes which can be readily adapted to incorporate electrochemical manipulation of CO₂ feeds?

B) CHEMISTRY

1. Are there optimal concentrations for CO₂ to accelerate this process/ reaction?
2. Will lower purity CO₂ w/impurities (O₂, H₂S, H₂O, etc.) impact electrochemical processes?
3. Are there other chemical reagents which might enhance dissolution to accelerate mineralization?
4. Could electrochemical mineralization approaches reduce or eliminate comminution?
5. How will mineralization impact the extraction of target metals? (purity, oxidation state, etc)

C) SCALING

1. What are the challenges associated with electrochemical mining and geo-mineralization, in terms of marketability and scale-up?
2. What engineering or chemical work or approaches are being done that should make electrochemical mining and geo-mineralization more profitable and scalable?

Electrochemical Approaches (response)



▸ Moderator: Halle Cheeseman Program Director, ARPA-E

Notes: Matthew Mattozzi, Tech SETA

A) *IN SITU*

1. Downhole deployment of electrochemical approaches is challenging at best: **Much of the geology is not known at sufficient detail, and electrochemical approaches can be fouled by trace contaminants.**
2. Are there existing mining or drilling processes which can be readily adapted to incorporate electrochemical manipulation of CO₂ feeds? **Some low-concentration ores, tailings bodies**

B) CHEMISTRY

1. Are there optimal concentrations for CO₂ to accelerate this process/ reaction? **Unknown. Supercritical CO₂ might be used at some sites, as could CO₂ in solution depending on underlying geology and TEA/LCA**
2. Will lower purity CO₂ w/impurities (O₂, H₂S, H₂O, etc.) impact electrochemical processes? **May foul electrodes; limit utility *in situ***
3. Are there other chemical reagents which might enhance dissolution to accelerate mineralization? **Unclear, depends on ore body. Processes will differ with Ni-rich olivine/serpentine vs lower-value basalts**
4. Could electrochemical mineralization approaches reduce or eliminate comminution? **Perhaps lower the C footprint of generation of acids/bases, regeneration of redox reagents *ex situ*, but the scales needed may differ by orders of magnitude.**
5. How will mineralization impact the extraction of target metals? (purity, oxidation state, etc). **Again, depending on the ore body, but the CO₂ might be fixed downhole as a carbonate.**

C) SCALING

1. What are the challenges associated with electrochemical mining and geo-mineralization, in terms of marketability and scale-up? **Unclear how practical electrochemical approaches are to fix CO₂ underground or extract metals, given energy and scale required.**
2. What engineering or chemical work or approaches are being done that should make electrochemical mining and geo-mineralization more profitable and scalable? **Use existing boreholes and establish aggressive metrics to determine successes of this approach.**

Electrochemical Approaches (Key takeaways)



▶ Moderator: Halle Cheeseman Program Director, ARPA-E

Notes: Christina Leggett, Tech SETA

- ▶ Halle's idea of doing in-situ electrochemistry in groundwater-containing boreholes to convert CO₂ to carbonate was well received by breakout session participants.
- ▶ Several ideas resulted from this proposal:
 - One suggestion to build on Halle's idea was to use bimetal combinations in which one metal functions as a cathode and the other as an anode to initiate a galvanic (as opposed to an electrolytic) reaction, making it truly a passive process. In fact, the coupled cathode and anodic materials need not be metals.
 - Halle's idea to use an in-situ process is similar to what was proposed in Joe's session on Tuesday. One way you can make Halle's concept more modular and compact is to use bipolar membranes to generate acid and base on each side. A catalyst could be added speed of the reactions.
- ▶ • Drawbacks from Halle's proposal:
 - The volume of groundwater you need to process may be an issue.
 - Electrolysis of water is quite energy intensive.
- ▶ • It may be worth looking at membrane-less electrolyzers. You could configure them such that O₂ comes out of one end, and H₂ comes out of the other end.
- ▶ • Capital costs associated with CO₂ mineralization in boreholes (?) largely include the costs of drilling the holes. One way to drive down cost is to try to use newly (or already) drilled holes multiple times. You'd need to make sure that these holes are already encased to mitigate the possibility of collapse. If you can find existing holes that have significant Ni or other minerals, perhaps drill out horizontally from those existing holes.

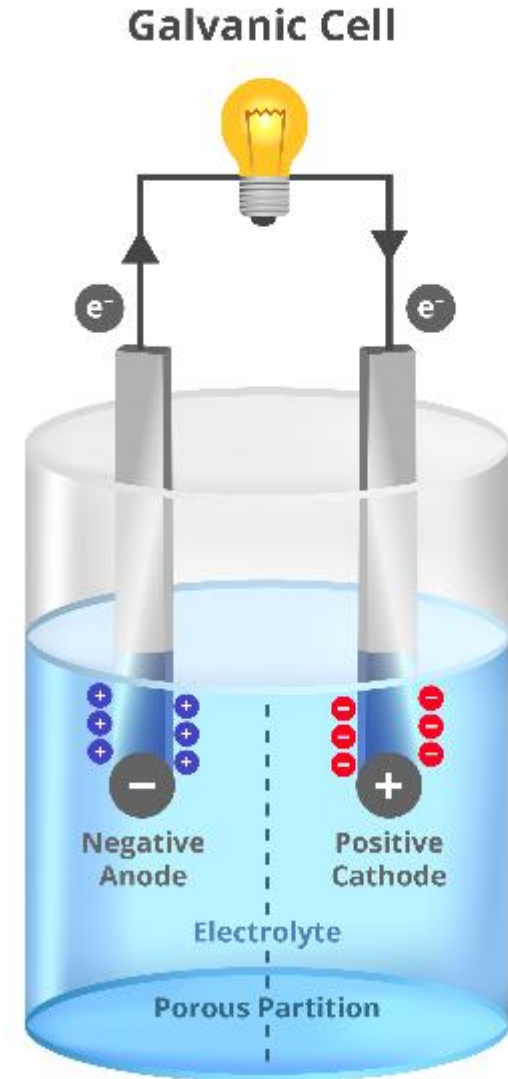
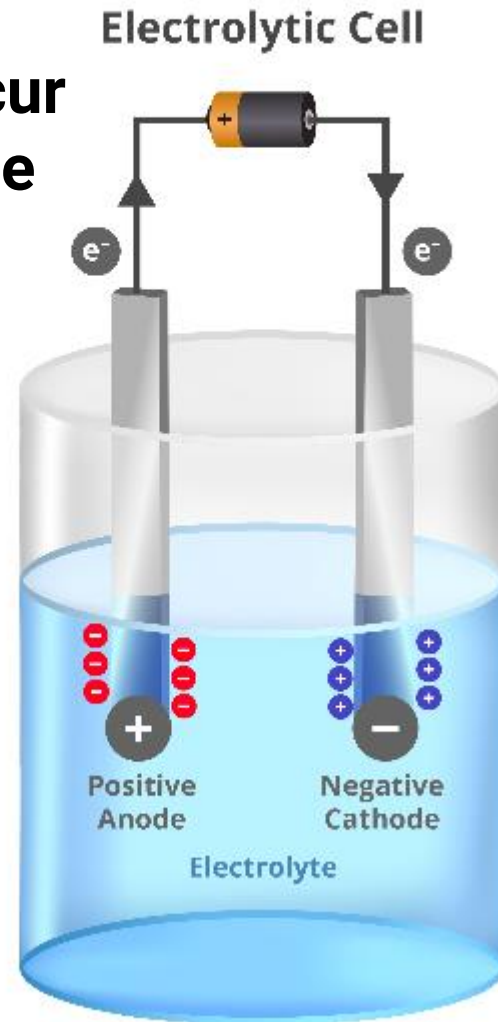
CATHODE AND ANODE

Electrolytic:

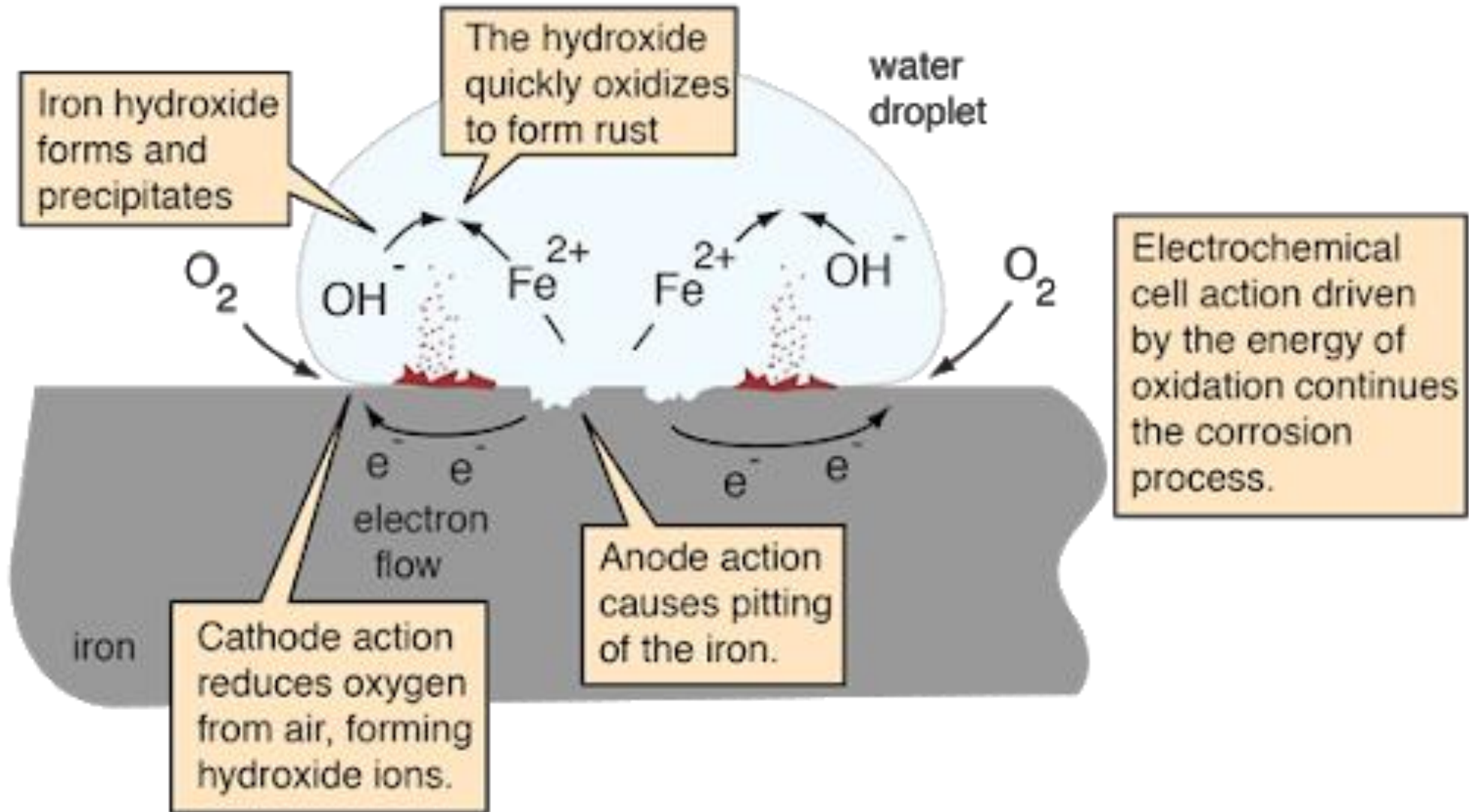
- i) Non-Spontaneous reactions Occur
- ii) Requires external voltage source

Galvanic:

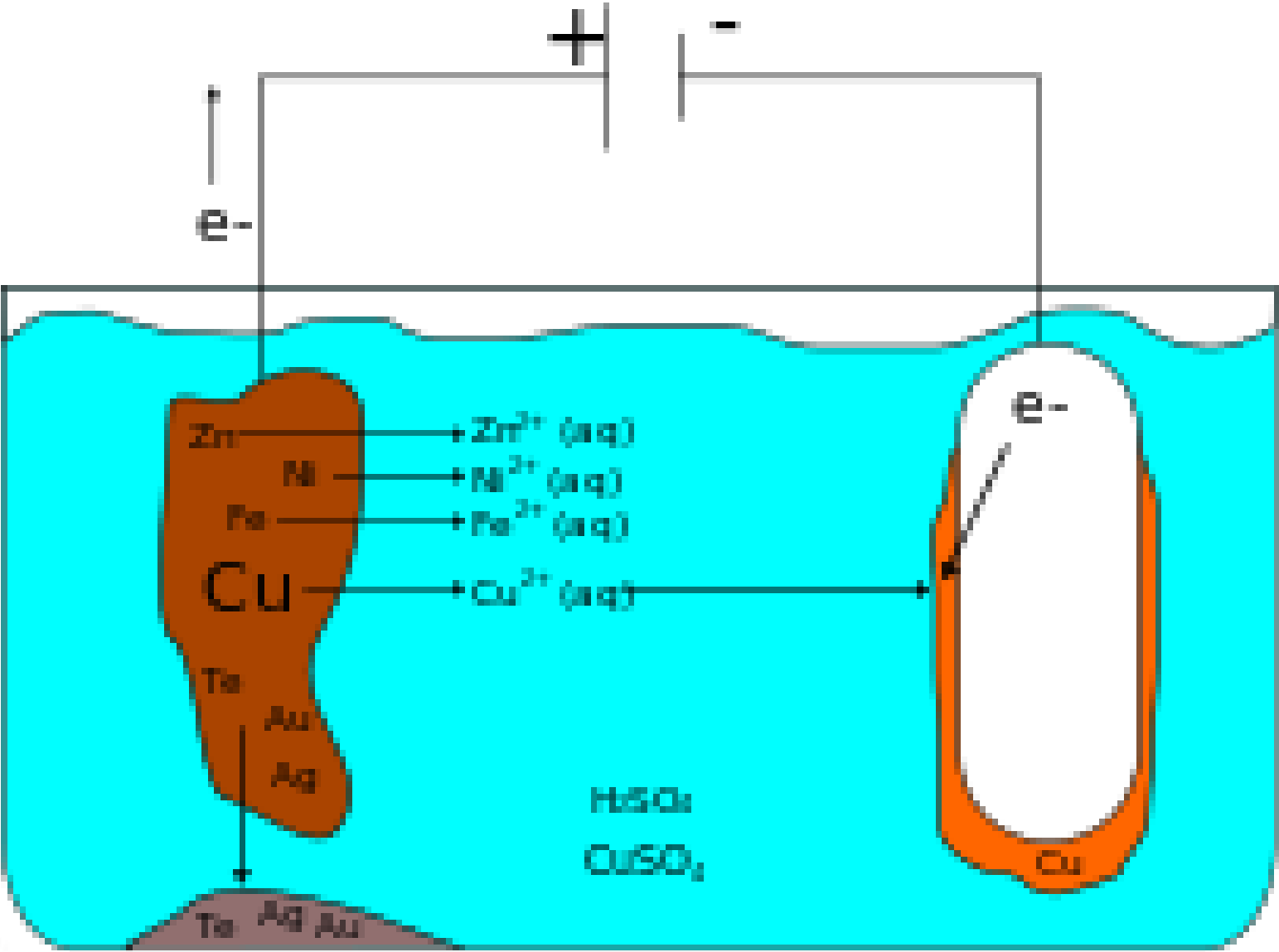
- i) Spontaneous reactions occur
- ii) Does not require external voltage source



All Electrochemical Systems have a Cathode, Anode, Electrolyte and Electronic Conductors



Electrowinning



Electrochemical CO₂ Capture via Electrolysis

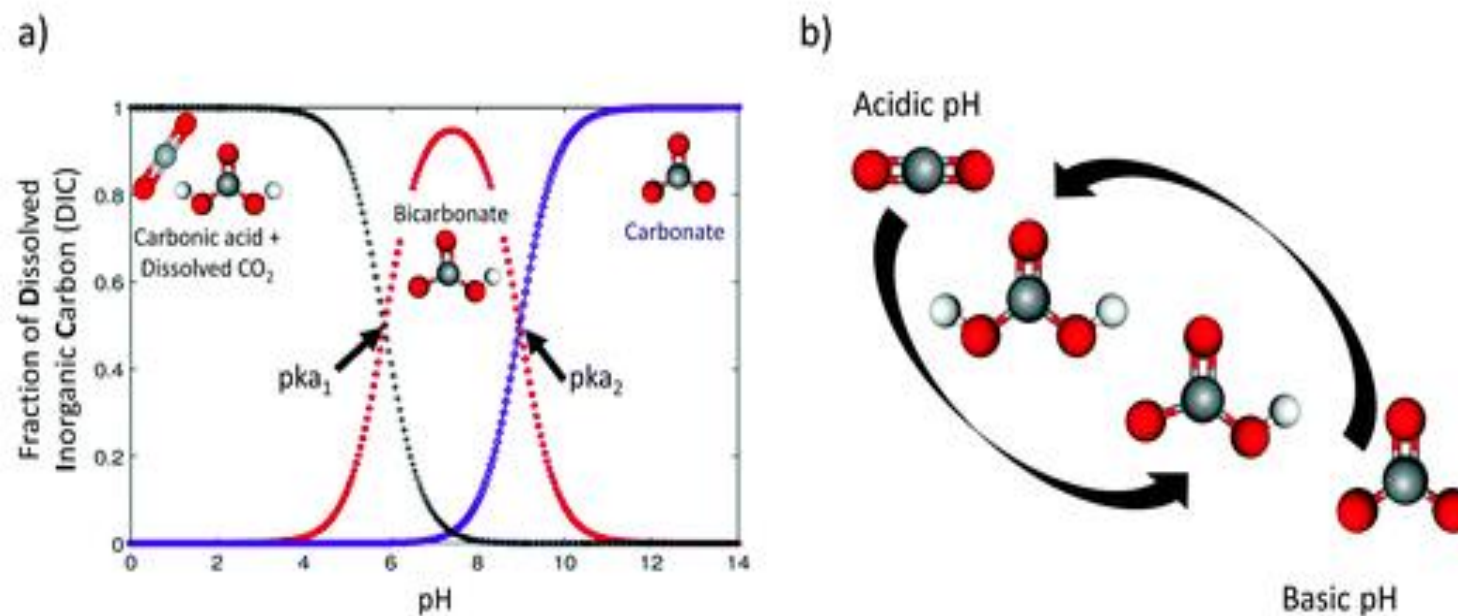


Fig. 2 (a) Effect of pH on the CO₂ equilibrium (for a closed system at temperature of 25 °C and salinity of 35 ppt). The solution is

buffered around two pK values. (b) Schematic of the equilibrium concept.

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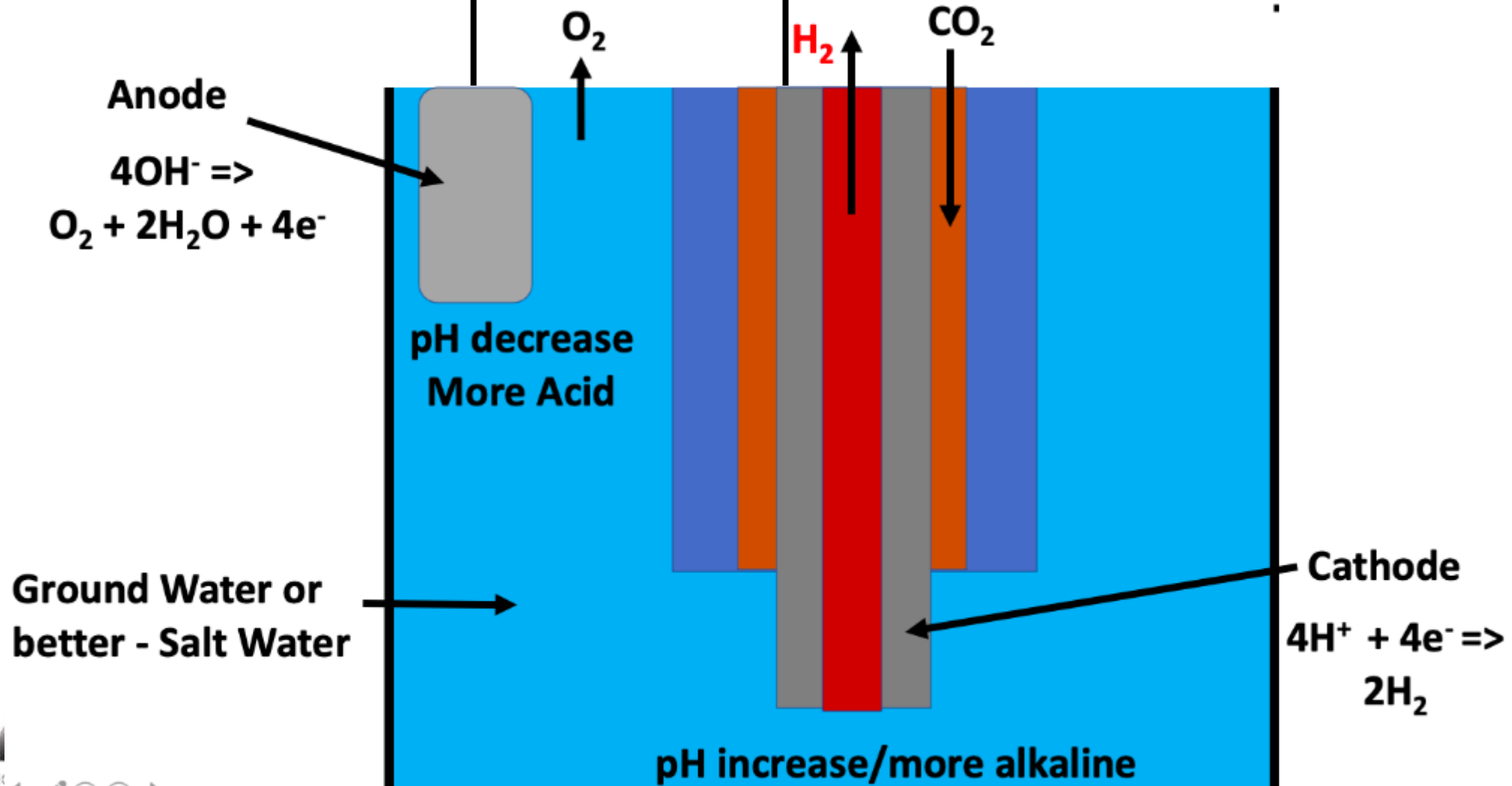
Electrochemical carbon dioxide capture to close the carbon cycle[†]

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DC POWER

An IDEA



Alternative

