Electrifying Industrial Hydrogen Peroxide Production

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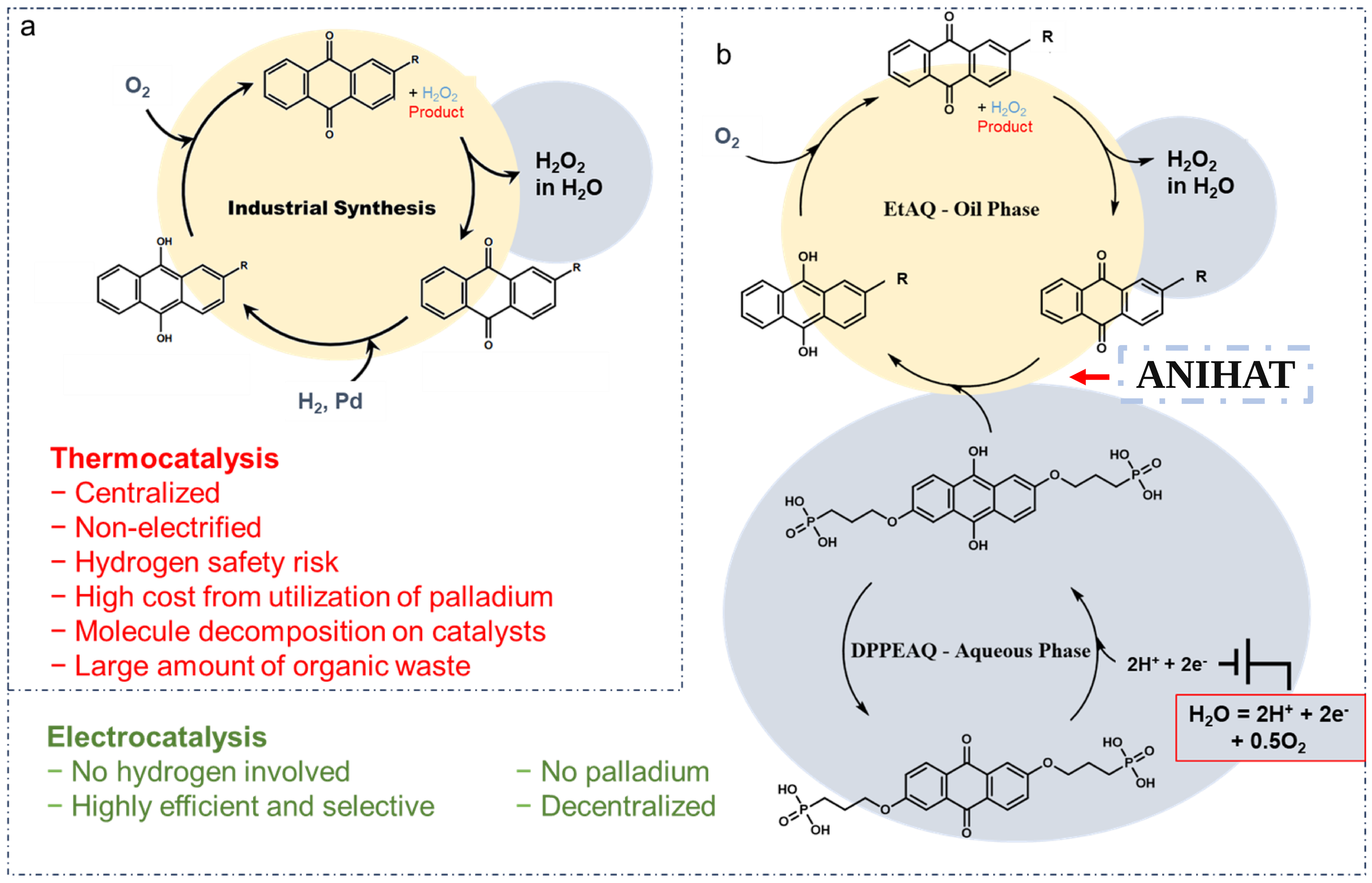
Abstract: Annual global H_2O_2 production is 5 million tons, leading to 15 million tons of CO_2 emissions. The industrial anthraquinone autoxidation (AO) method is the dominant production technology, but it involves high risks of pressurized hydrogen and air input, and requires expensive palladium-based catalysts that can reduce anthraquinone to non-reactive molecules. A considerable amount of energy also has to be put into the distillation and transportation of H_2O_2, providing an opportunity for decentralized electrochemical H_2O_2 production methods. We developed an interface hydrogen atom transfer reaction between an aqueous and a non-aqueous phase to electrify the industrial H_2O_2 production process, avoiding the undesired side-reactions of anthraquinone reduction. The aqueous electrochemical process enables us to produce H_2O_2 with high Faradaic efficiency (>80%) under high current densities (>200 mA cm^{-2}). The system can be free of hydrogen gas and noble metal. The H_2O_2 produced this way can be at high concentration (>10%) and free of electrolyte. This method can facilitate the electrification and decentralization of industrial H_2O_2 production, reducing the major capital cost associated with the decomposition of anthraquinone molecules and major energy cost associated with concentrating and transporting H_2O_2.

Comparison between current industrial H_2O_2 production and our electrochemical method



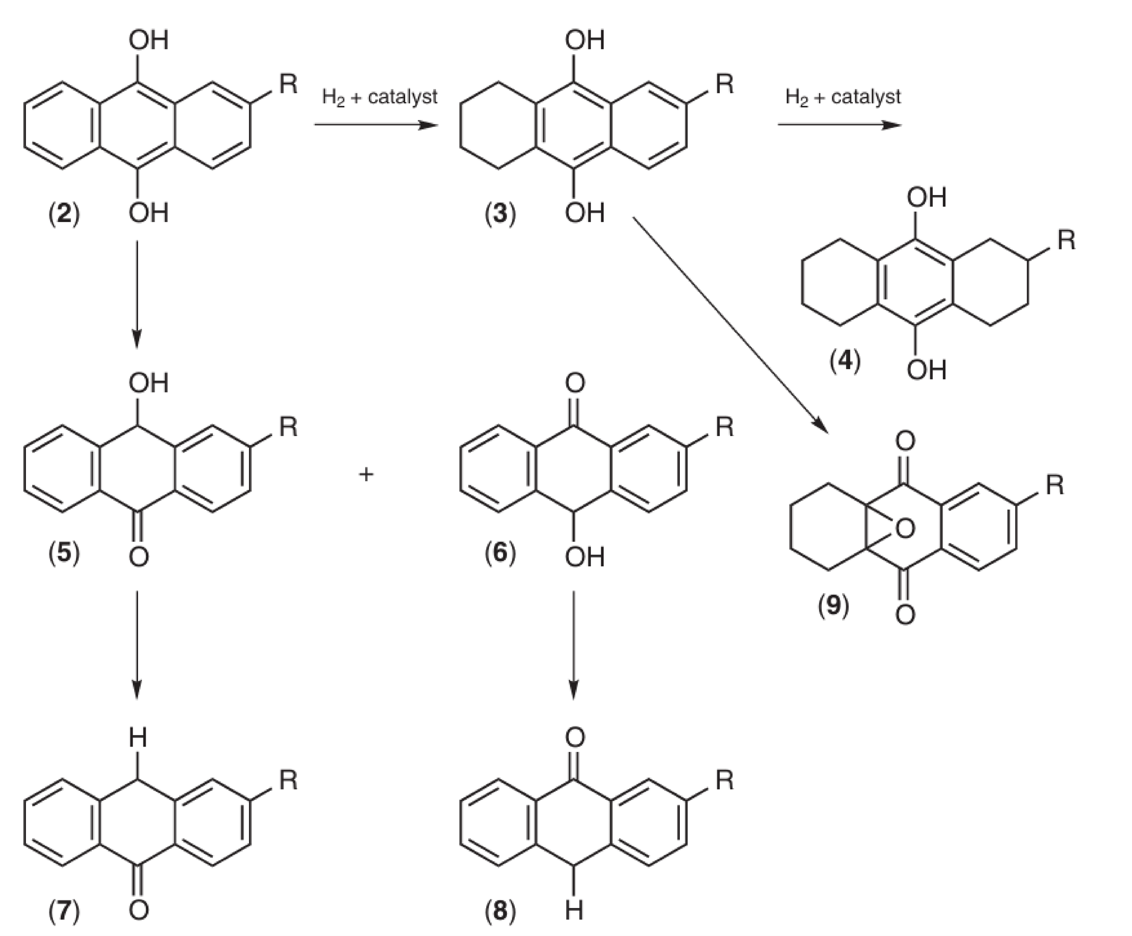
Real pain point for current industrial H_2O_2 production

-- Hydrogenation selectivity.

-- Utilization of solvent with high polarity.

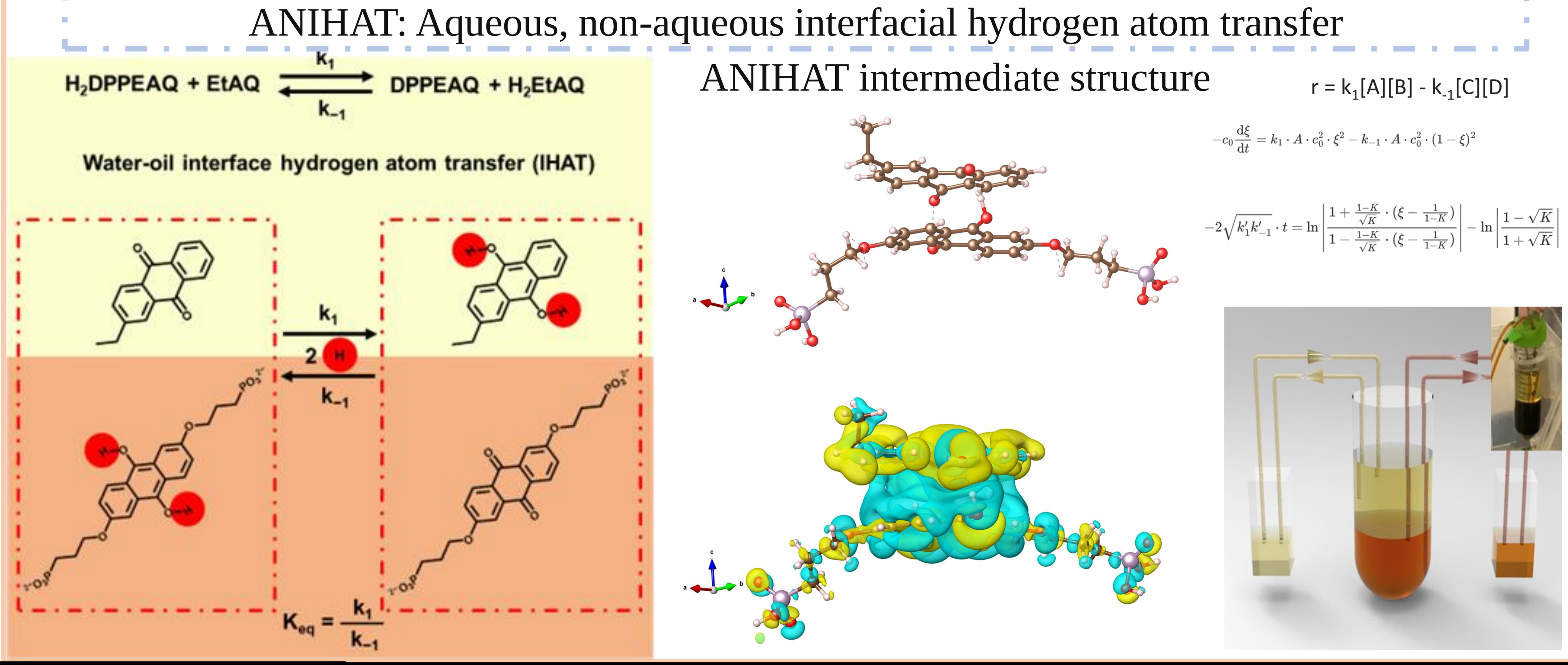
-- High polarity solvents are used to help the selectivity and efficiency of hydrogenation.

-- Both introduce large amount of organic wastes.

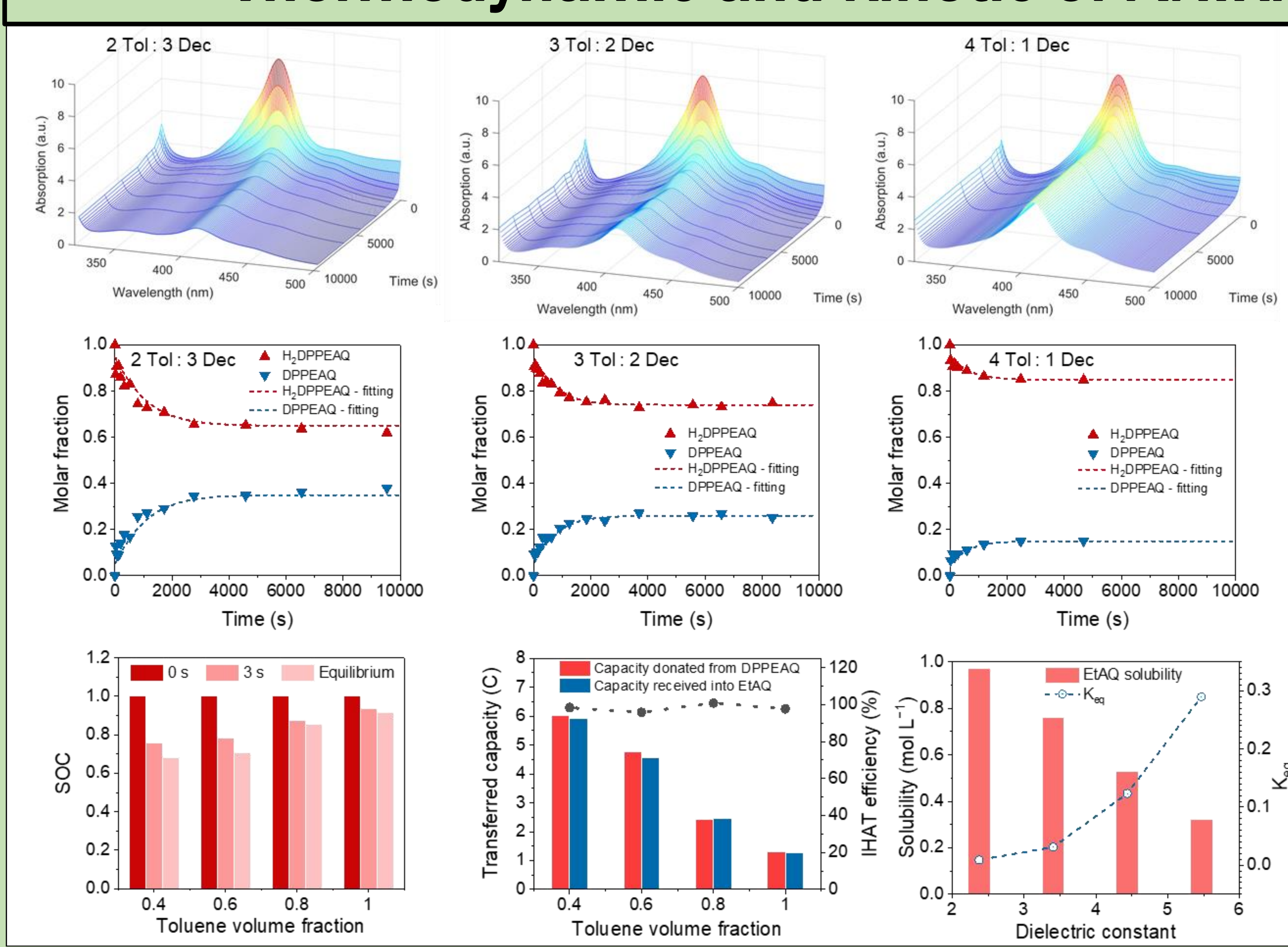


ANIHAT for non-aqueous hydrogenation

ANIHAT: Aqueous, non-aqueous interfacial hydrogen atom transfer



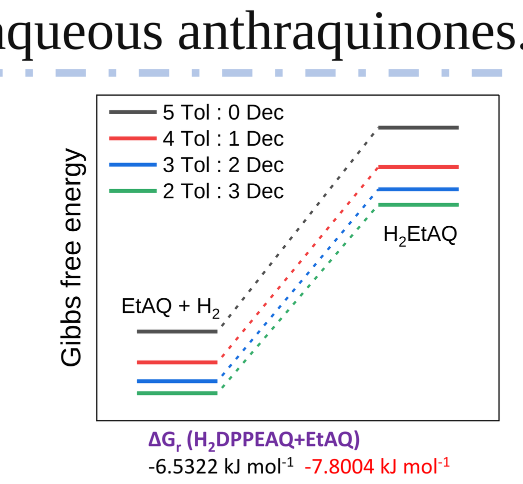
Thermodynamic and kinetic of ANIHAT



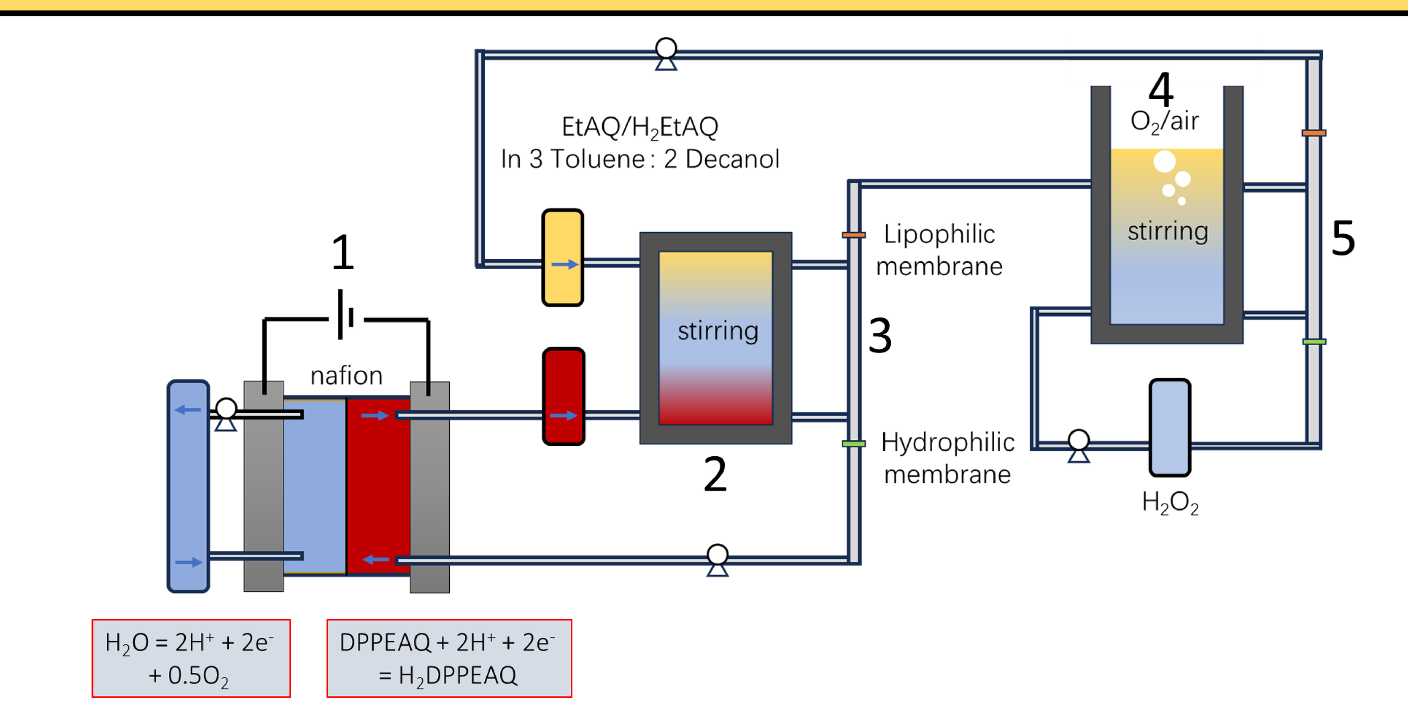
-- ANIHAT is generally fast interfacial reaction.

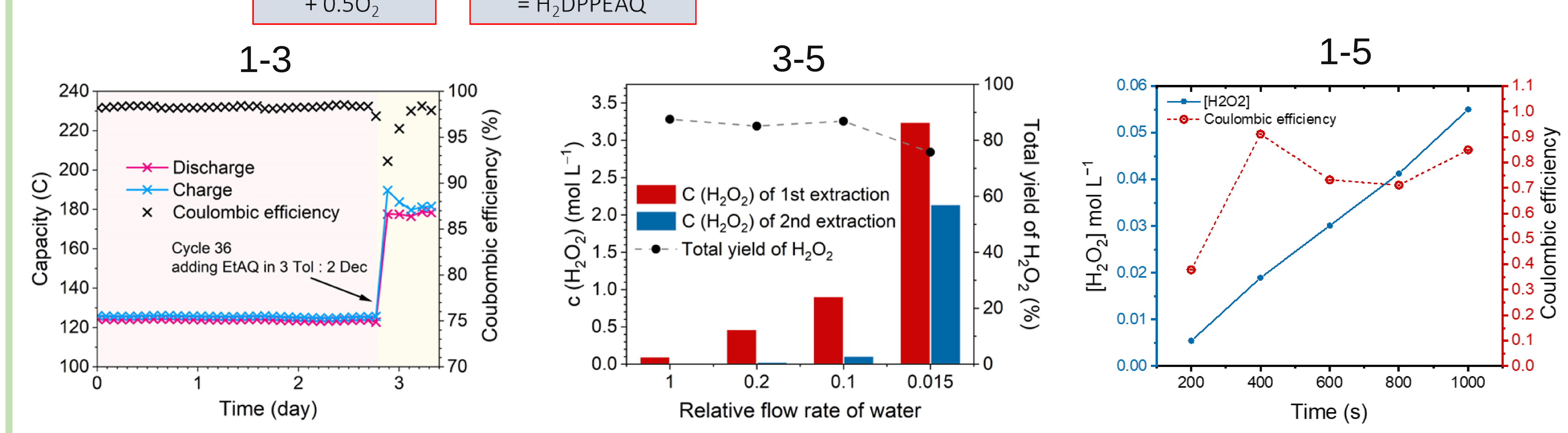
-- ANIHAT is highly efficient and selective.

-- Organic solvent polarity mainly affects the thermodynamic of ANIHAT by influencing the redox potential of non-aqueous anthraquinones.



Integrated systems



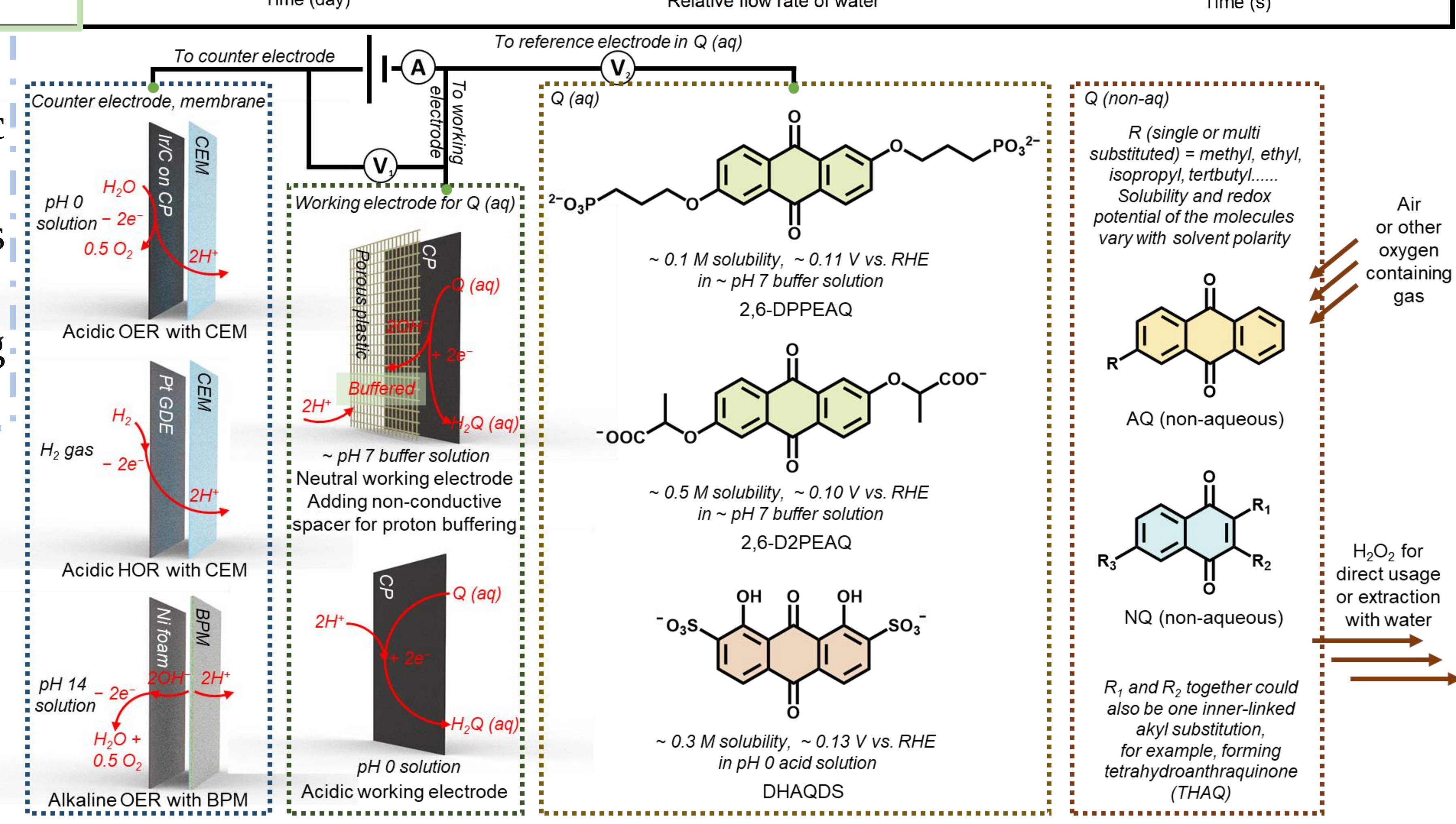


Conclusions:

-- With various molecules and solvents, the ANIHAT can be > 99% selectivity and Faradaic efficiency, with a current density higher than 0.5 A cm^{-2}. Overall peroxide efficiency is ~80%.

-- With various cell structures and counter reactions, we can do noble metal free, hydrogen gas free pure hydrogen peroxide production.

-- With further molecular development, heavy aromatic solvent can be directly used, cutting organic wastes during production.



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Acknowledgements:

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