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Highly alkaline Zn batteries

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Abstract

Rechargeable aqueous Zn batteries are promising energy storage devices owing to the high capacity of Zn anode, high safety and cost-effectiveness¹, but they all suffer from severe hydrogen evolution at the anode². Here, we explore the use of highly alkaline electrolytes to reduce the activity of water and suppress the hydrogen evolution. In a near-saturation 15 M KOH electrolyte, spectroscopic characterizations reveal distinct the solvation structure associated with the low water activity. Despite the high viscosity, the highly alkaline electrolyte retains high ionic conductivity due to the unique hydroxide transfer mechanism, which enables a high-power Zn-air battery that is stable for over 110 hours.

Results & Discussion

The evolution of KOH electrolyte structure

- Solvation structure changes with C_{KOH} increasing (Fig. 3a, b), and the breakage of hydrogen bond networks occurs in 15 M KOH electrolyte (Fig. 3c, d).
- The unique proton motion in $\text{H}_2\text{O}-\text{OH}^-$ species may give rise to the high ionic conductivity of KOH electrolyte with salt concentration increasing.

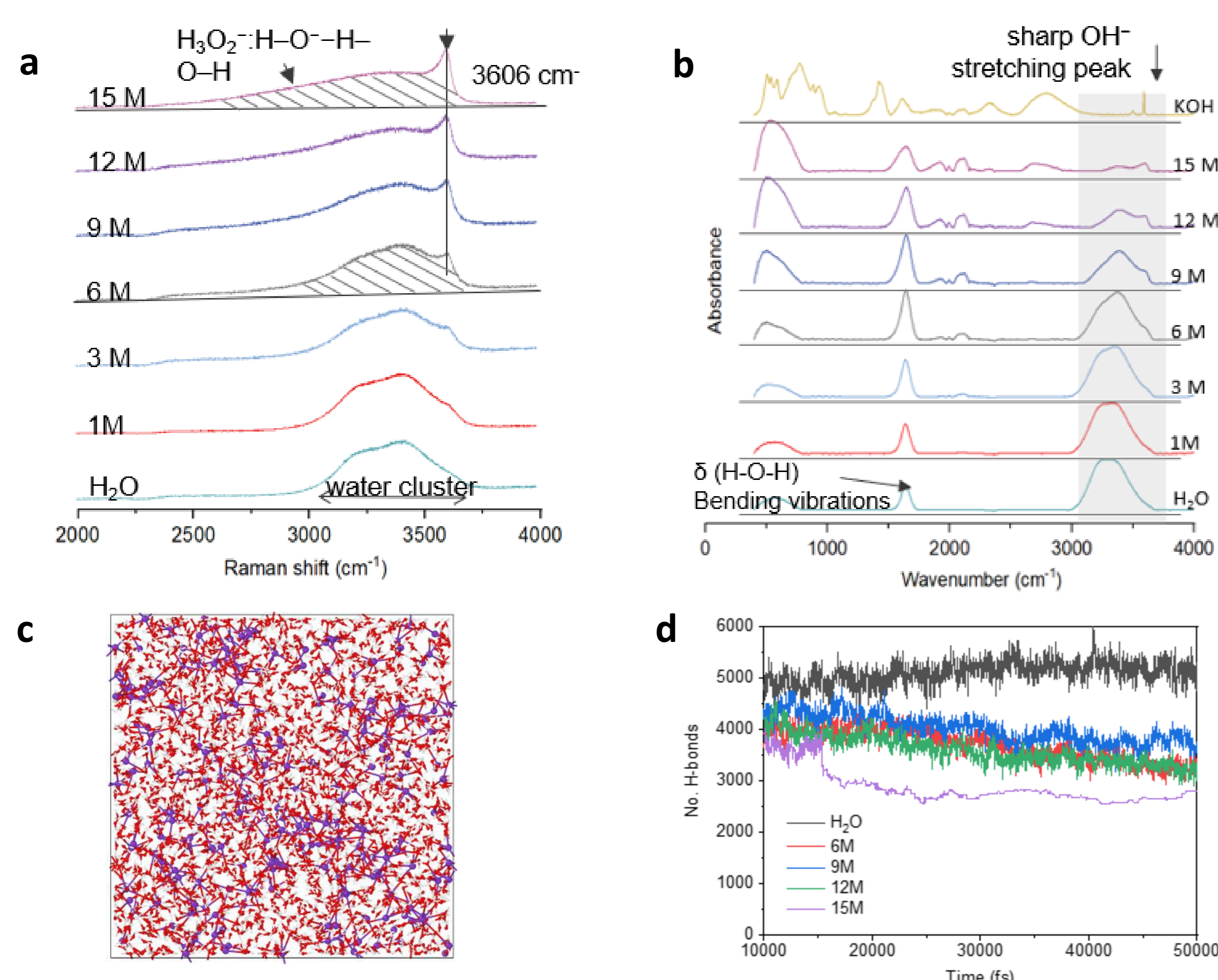


Fig.3: (a) Raman spectra of KOH electrolytes in different concentrations; (b) FT-IR spectra of KOH electrolytes in different concentrations; (c) Snapshot of KOH electrolyte in MD simulations; (d) The number of hydrogen bonds in different concentrated KOH electrolytes.

The physicochemical properties

- Compared with other water-in-salt electrolyte, the KOH electrolyte shows slower reduction of ionic conductivity with concentration increasing (Fig. 4a).
- The near-saturation 15M KOH electrolyte remains high ionic conductivity in wide temperature range (Fig. 4b).

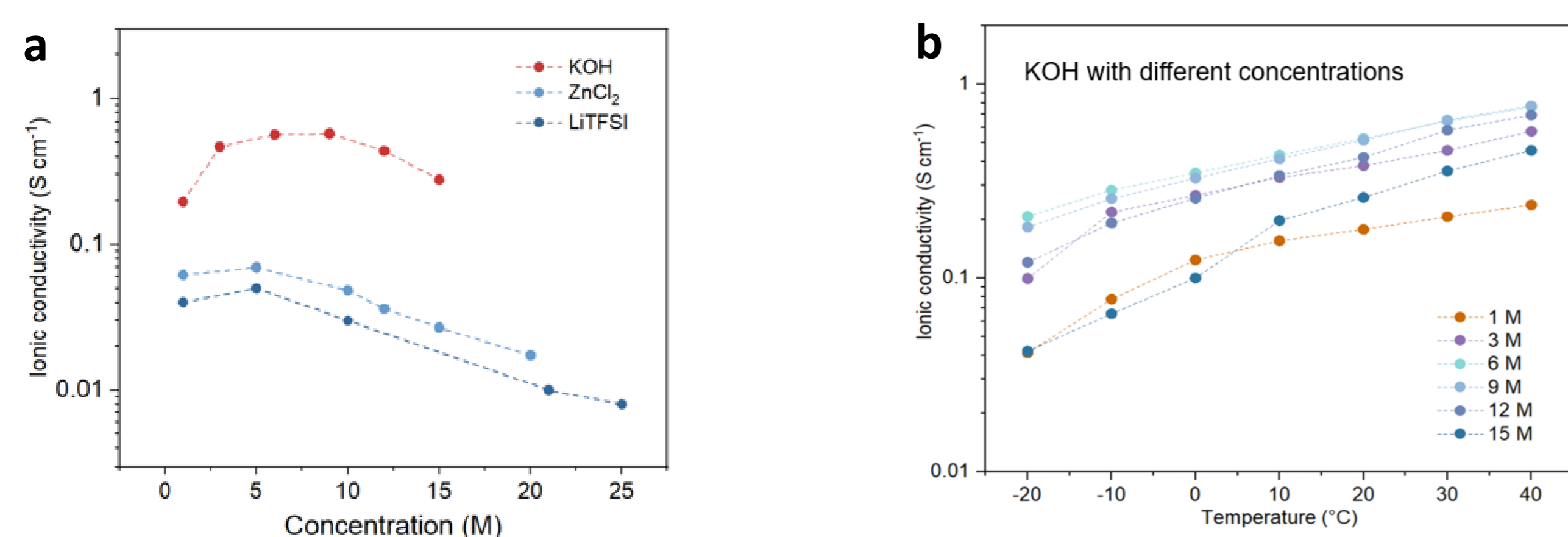


Fig.4: (a) Ionic conductivity of KOH, ZnCl_2 , LiTFSI electrolytes with different concentrations in room temperature; (b) Ionic conductivity of KOH electrolytes in wide temperature range.

References

- Wang, F.; Borodin, O.; Gao, T.; Fan, X.; Sun, W.; Han, F.; Faraone, A.; Dura, J. A.; Xu, K.; Wang, C. *Nature Materials*, 2018, 17, 543–549.
- Fu, J.; Cano, Z. P.; Park, M. G.; Yu, A.; Fowler, M.; Chen, Z. *Advanced Materials*, 2017, 29, 1604685.

Background & Objective

The inherent interfacial issues of Zn anode is highly related with electrolyte properties (Fig. 1). Therefore, the aim of this work is to regulate the electrolyte structure and water activity to achieve highly reversible Zn anode via near-saturation 15 M KOH electrolyte (Fig. 2).

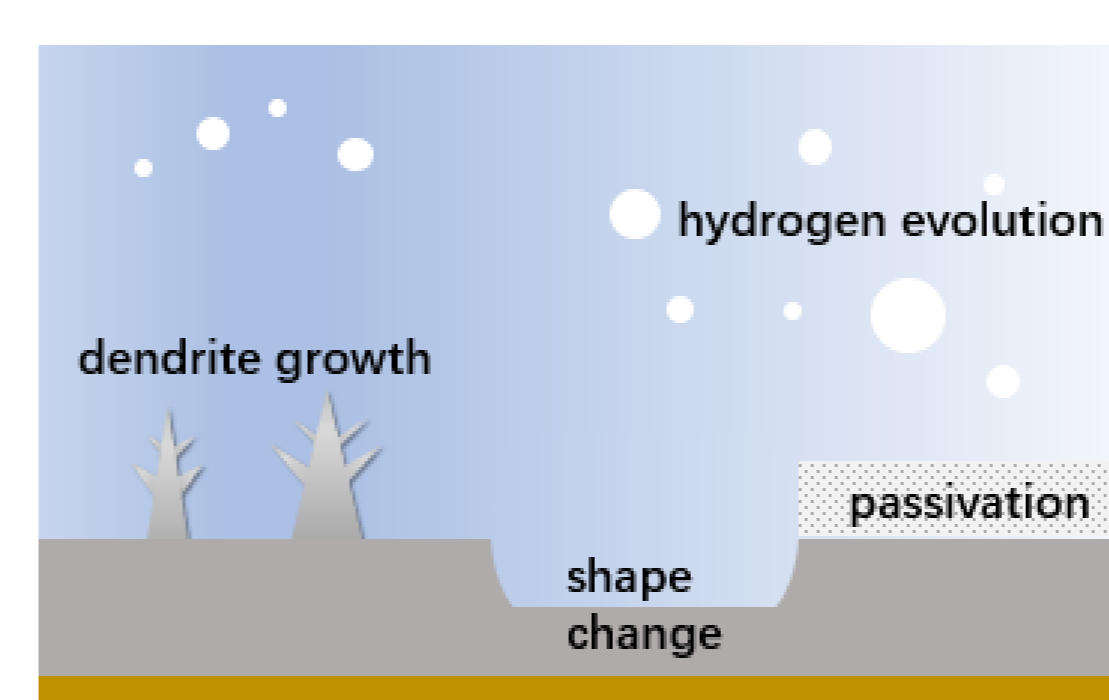


Fig.1: interfacial issues of Zn anode

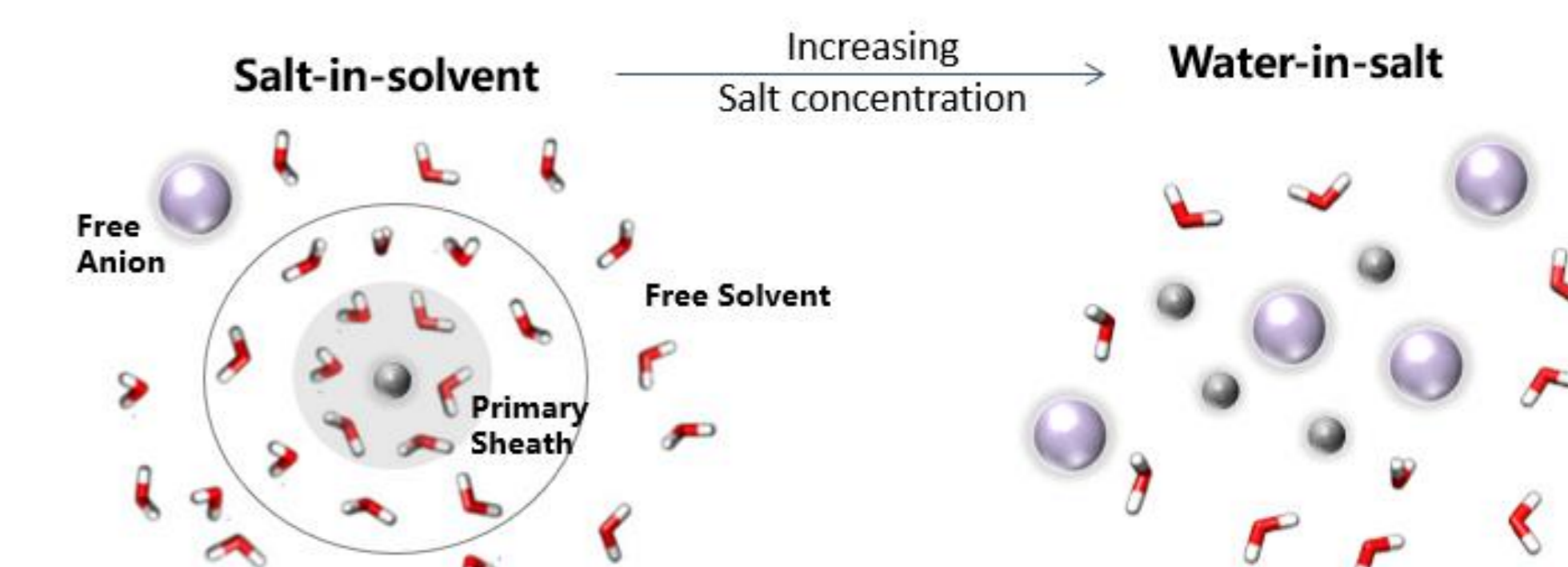


Fig. 2: Schematic representation of electrolyte structure

Results & Discussion

The inhibition of hydrogen evolution reactions

- The anodic stability of water increases with the KOH concentration, which is independently of the electrode material (Pt, Zn or GC) (Fig. 5a, b, c).

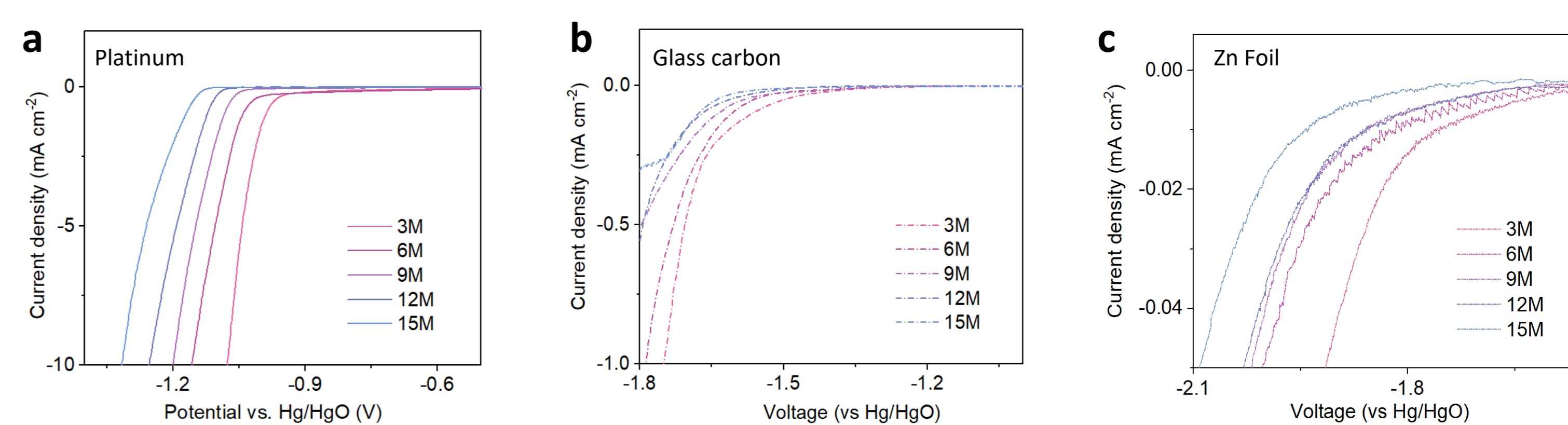


Fig.5: Linear sweep voltammograms for the reductive stability in different concentrated KOH electrolytes on (a) platinum electrode; (b) glass carbon electrode; (c) Zn foil.

Electrochemical performance

- A considerable amount of H_2 (4.51 μmol) in 6M KOH electrolyte generated during charging process. By contrast, the emission of H_2 was completely suppressed in 15M KOH electrolyte (Fig. 6a).
- Coin-type Zn-air batteries based on 15 M KOH without any additions shows the best cycle performance, the total cycling time is more than 110 h (Fig. 6b).

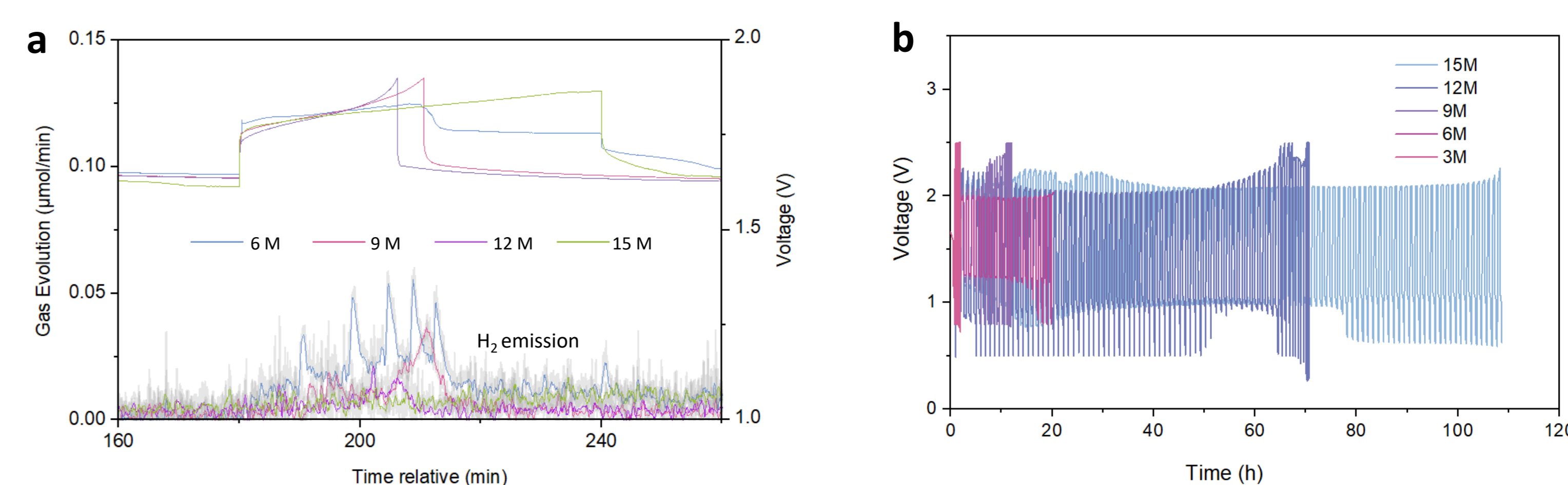


Fig.6: (a) Differential electrochemical mass spectrometry tests in Zn-NiOOH batteries based on different concentrated KOH electrolytes; (b) Cycling performance of Zn-air batteries based on different concentrated KOH electrolytes.

Conclusions

- The breakage of initial HB network in electrolyte occurs with C_{KOH} increasing, leads to the proton motion in new solution configurations, which influence its unique ionic transportation properties.
- The modified electrolyte structure in 15M KOH electrolyte effectively inhibited the HER side reactions, give rise to a high-power Zn-air battery which is stable for over 110 hours.

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