The influence of sulfide ion on viscosity of HPAM solution used in oil recovery and the concerning mechanisms

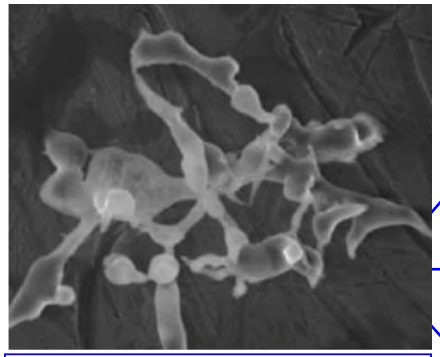
East China University of Science and Technology

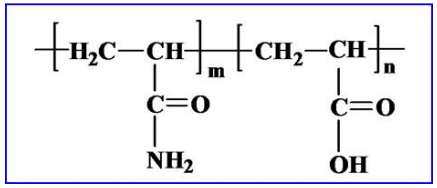
Jinfeng Liu

21th July, 2016

Sulfide influence on HPAM viscosity and the concerning mechanism

Background of this research





Clasification

- Anionic / Cationic
- Nonionic
- Zwitterionic

Properties

- M_W : 0.2-20×10^6 Da
- Hydrophilic, Good water solubility
- Flow property, Flocculation……

Applications

- Oil-displacing agent
- Regulator / stabilizer of drilling fluid
- Water treatment agent

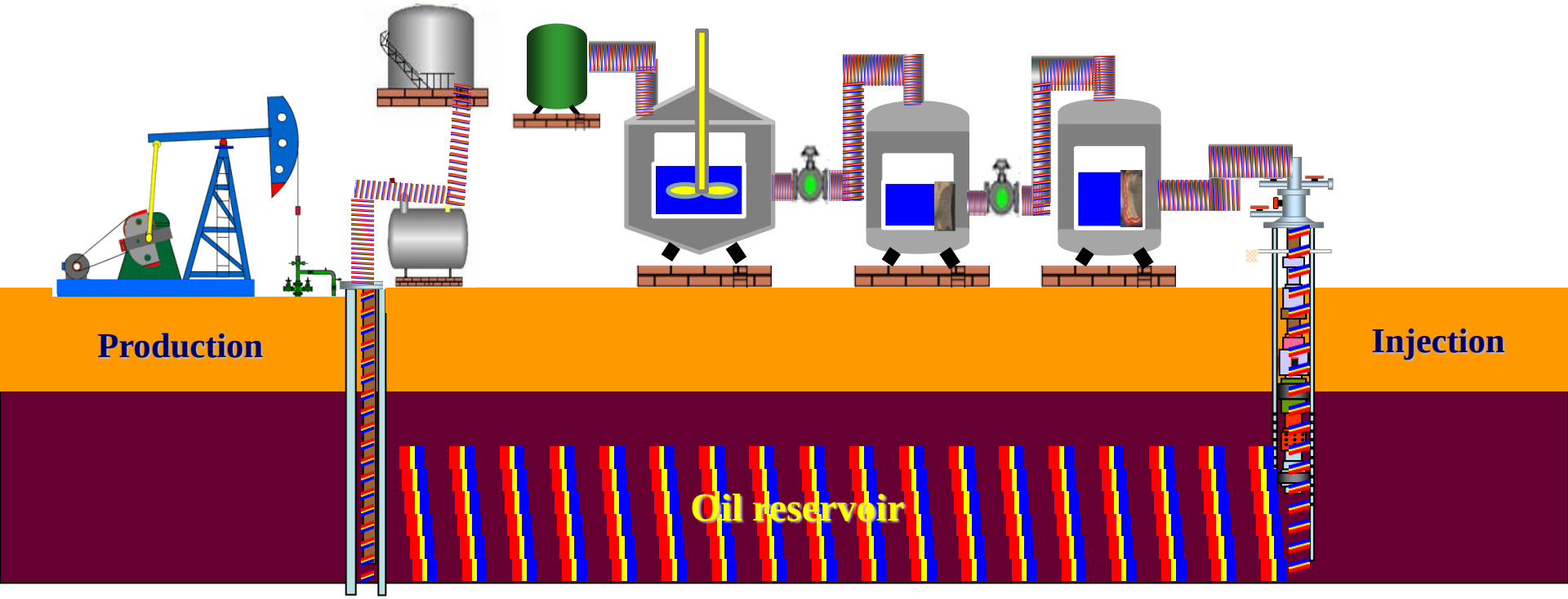
The structure and property of HPAM

Feng Y, *et al*. Polymer International, 2002, 51(51):931-938

Sulfide influence on HPAM viscosity and the concerning mechanism

Background of this research

- **Viscosity reduction negatively and notably influenced the HPAM flooding effect**
  - **Physical factors**: pH, Temperature, Salinity, Shearing and etc
  - **Biological factors**: Biodegradation …



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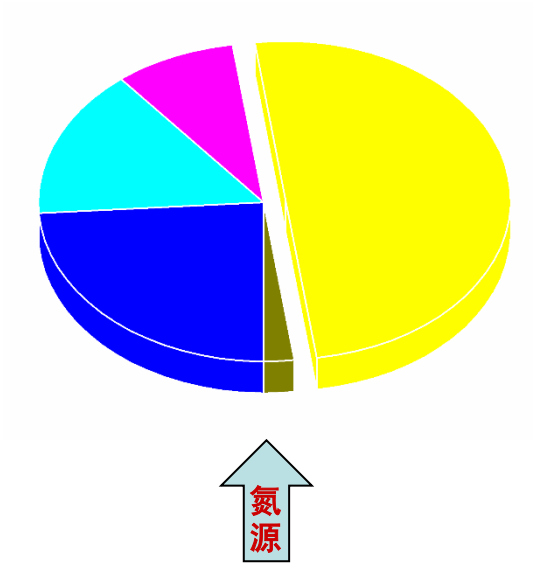

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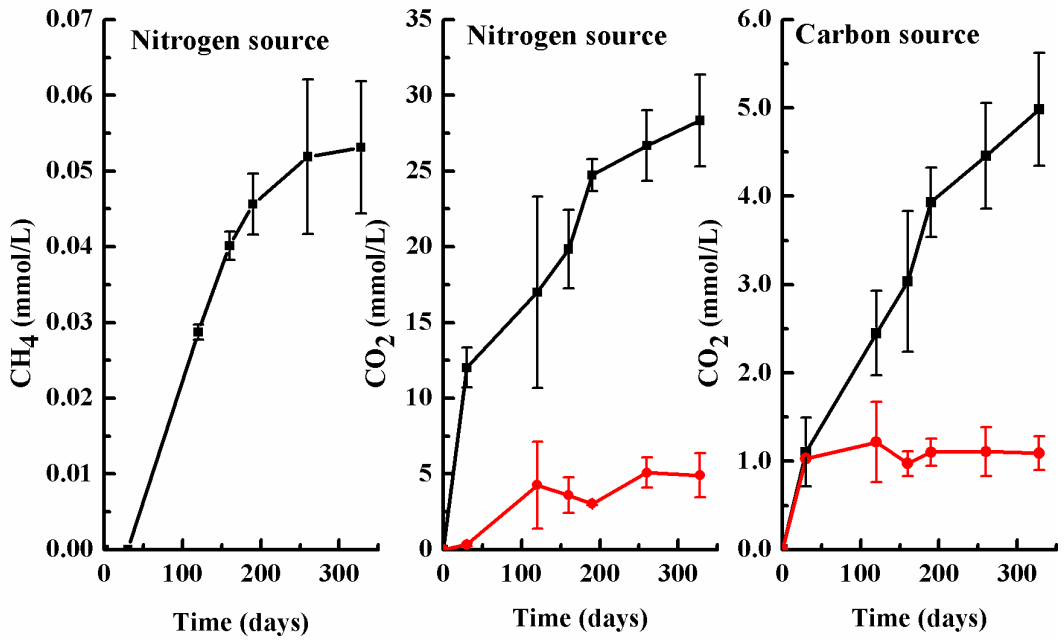

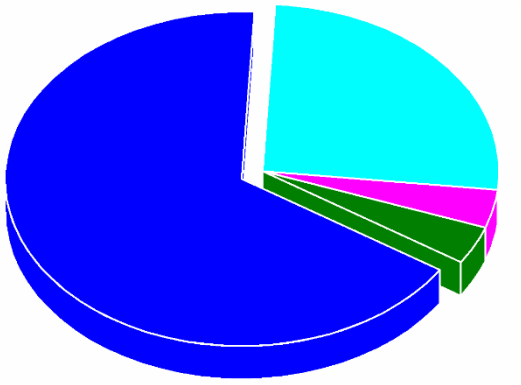

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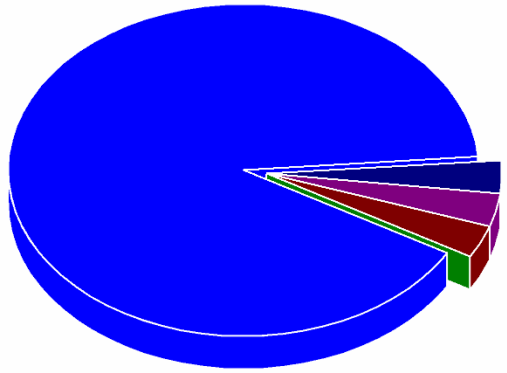
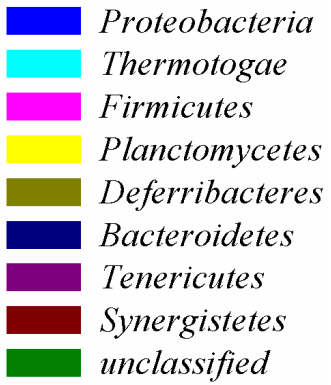
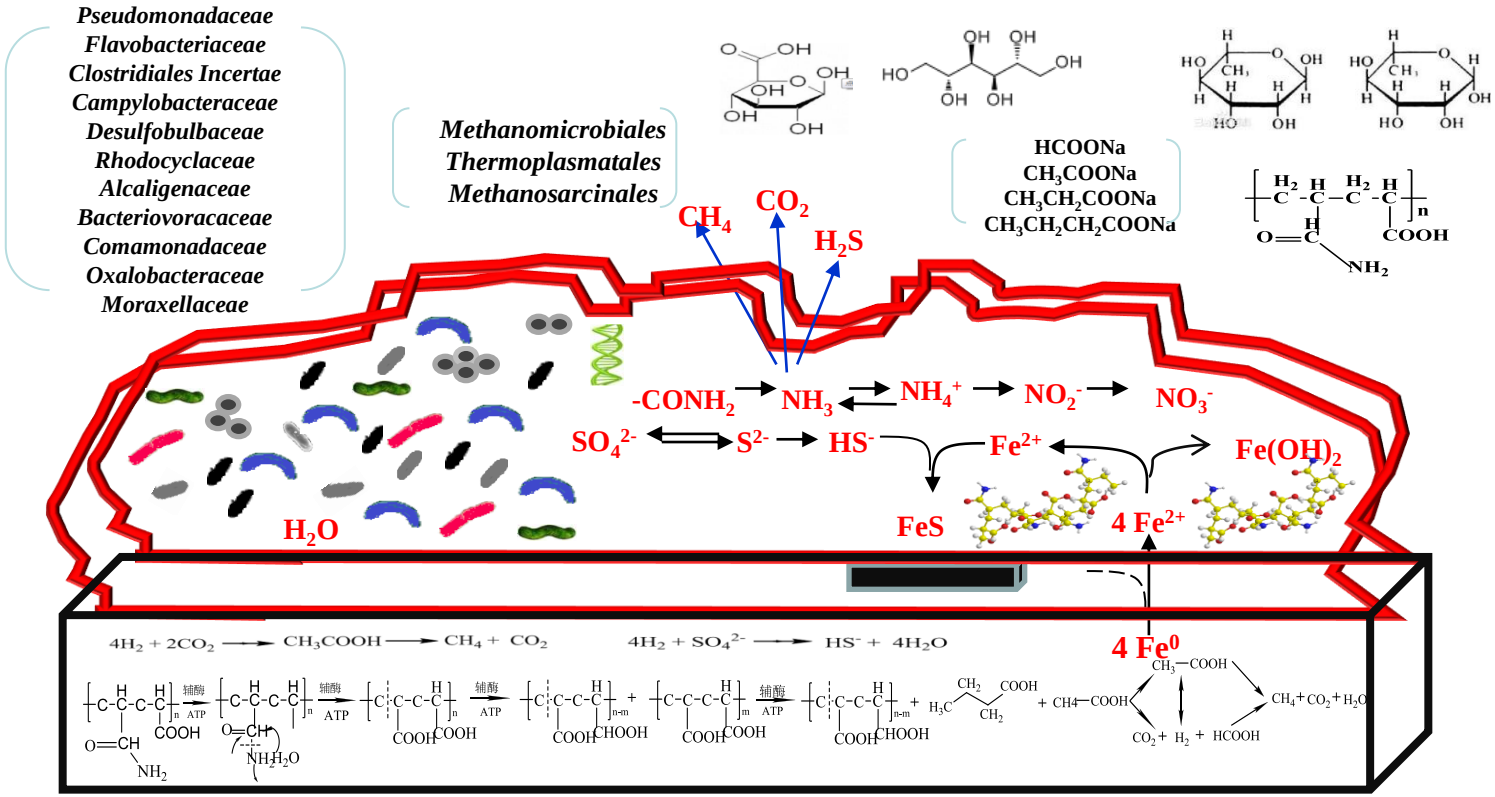




Sulfide influence on HPAM viscosity and the concerning mechanism

Background of this research



Li Cai-Yun *et al*. Journal of Hazardous Material, 2016

Sulfide influence on HPAM viscosity and the concerning mechanism

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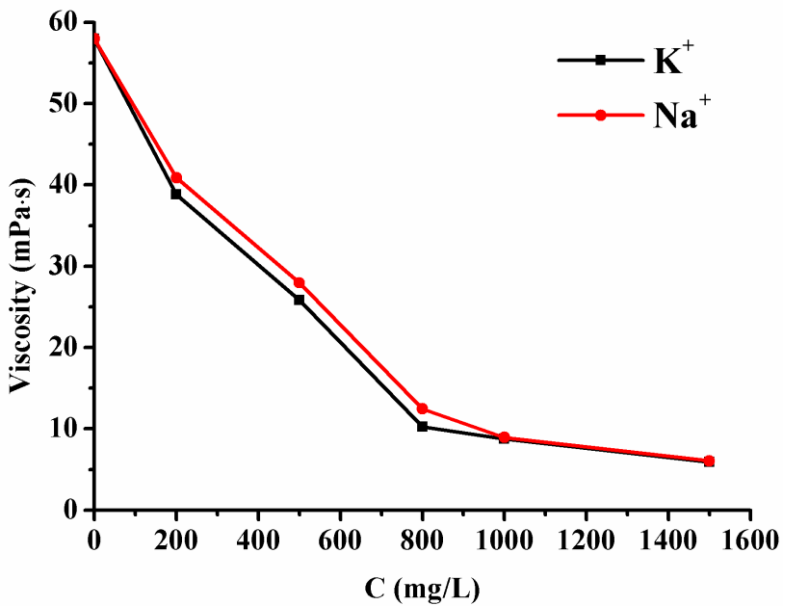
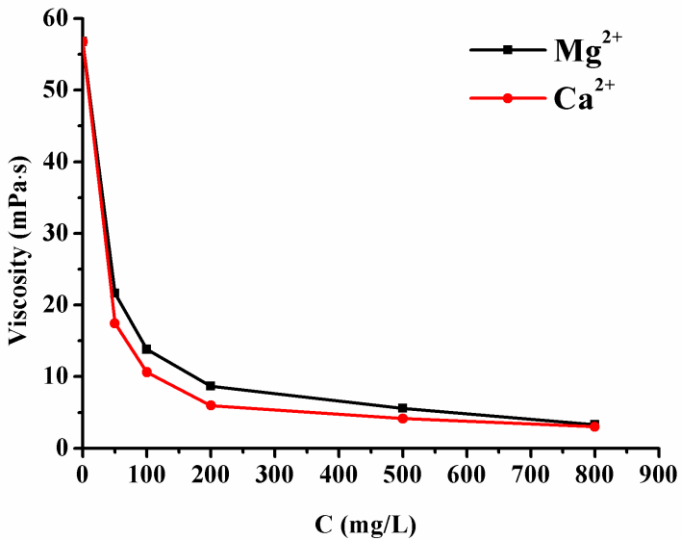
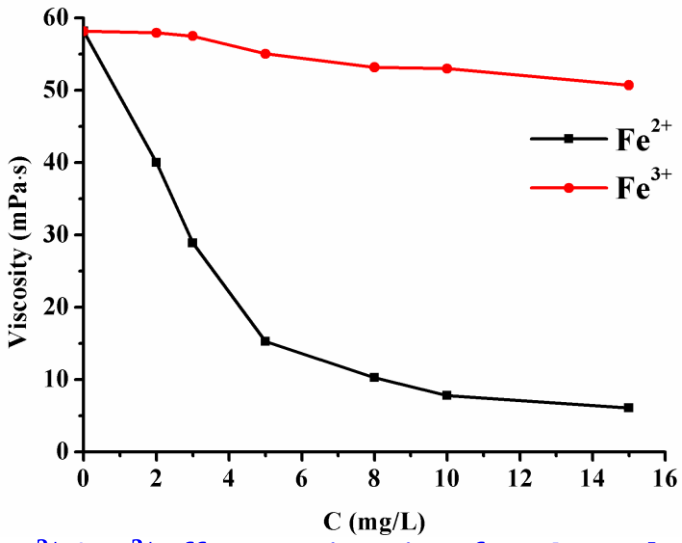


Na^+ / K^+ effect on viscosity of HPAM solution



Mg^{2+} / Ca^{2+} effect on viscosity of HPAM solution



Fe^{2+} / Fe^{3+} effect on viscosity of HPAM solution

Sulfide influence on HPAM viscosity and the concerning mechanism

Background of this research

Mechanical shear force exceeds the range of tolerance force of HPAM / **Well Characterised**

Viscosity decreases with increasing temperature. Dramatically under acidic conditions / **Well Characterised**

Shearing | **Ions** | **Tem & pH** | **Microorganisms**

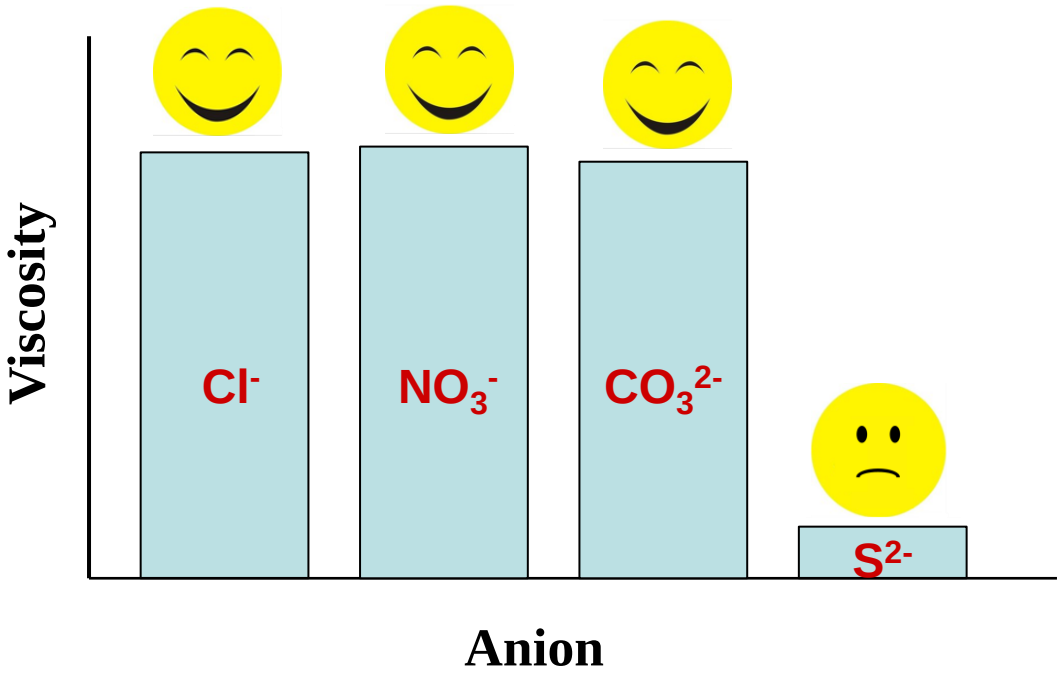
The higher cation valence, the greater effect on the viscosity, / **Well Characterised**

Biodegradation reduces the viscosity via scission of HPAM backbone chain / **Characterised**

Principal factors impacting on HPAM viscosity

Sulfide influence on HPAM viscosity and the concerning mechanism

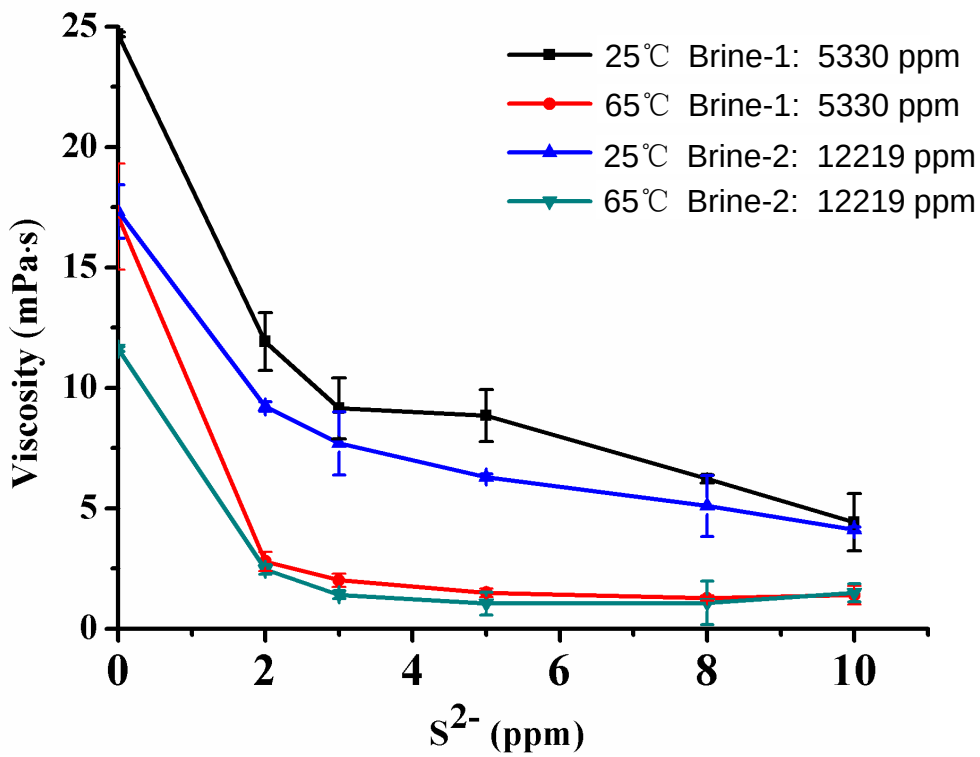
Background of this research



Influence of S^{2-} on HPAM viscosity

Sulfide influence on HPAM viscosity and the concerning mechanism

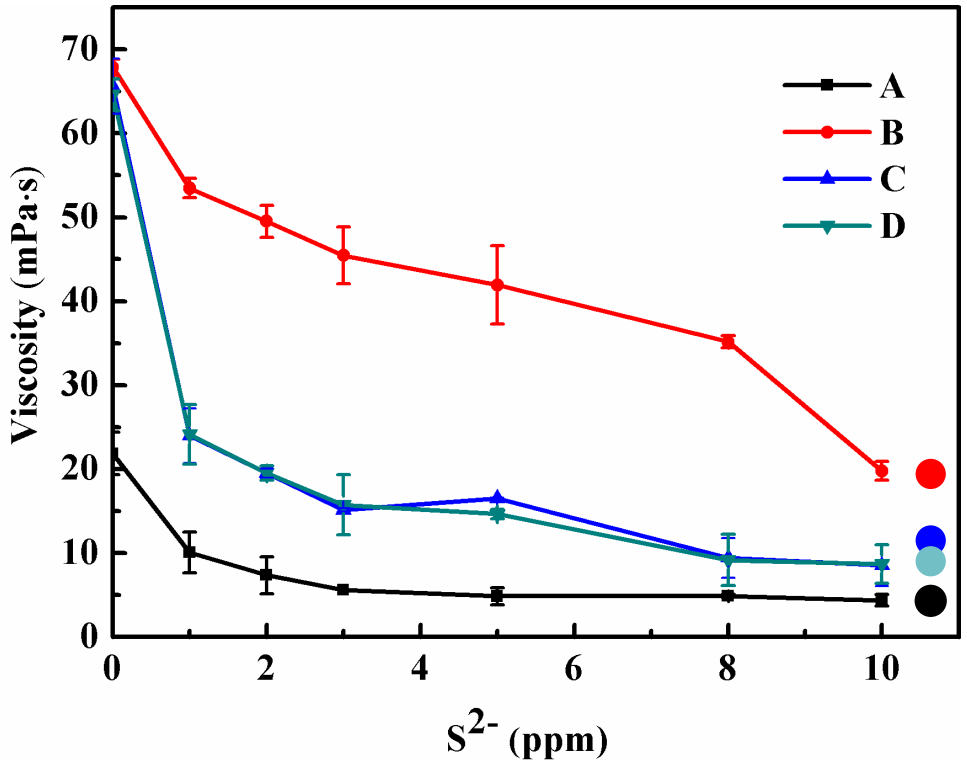
The influence of sulfide ions on viscosity of HPAM solution



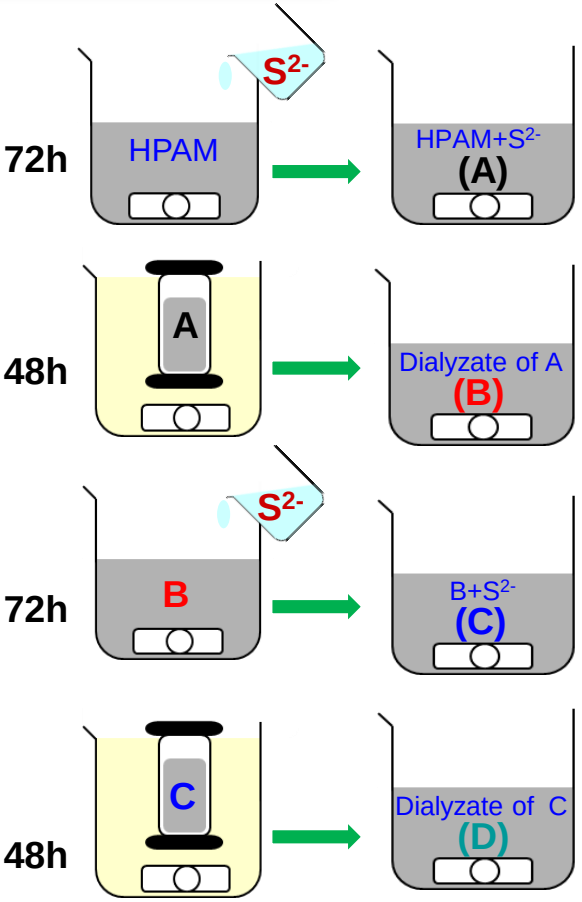
The effect of S^{2-} on viscosity of HPAM solution prepared with simulated formation water

Sulfide influence on HPAM viscosity and the concerning mechanism

The influence of sulfide ions on viscosity of HPAM solution



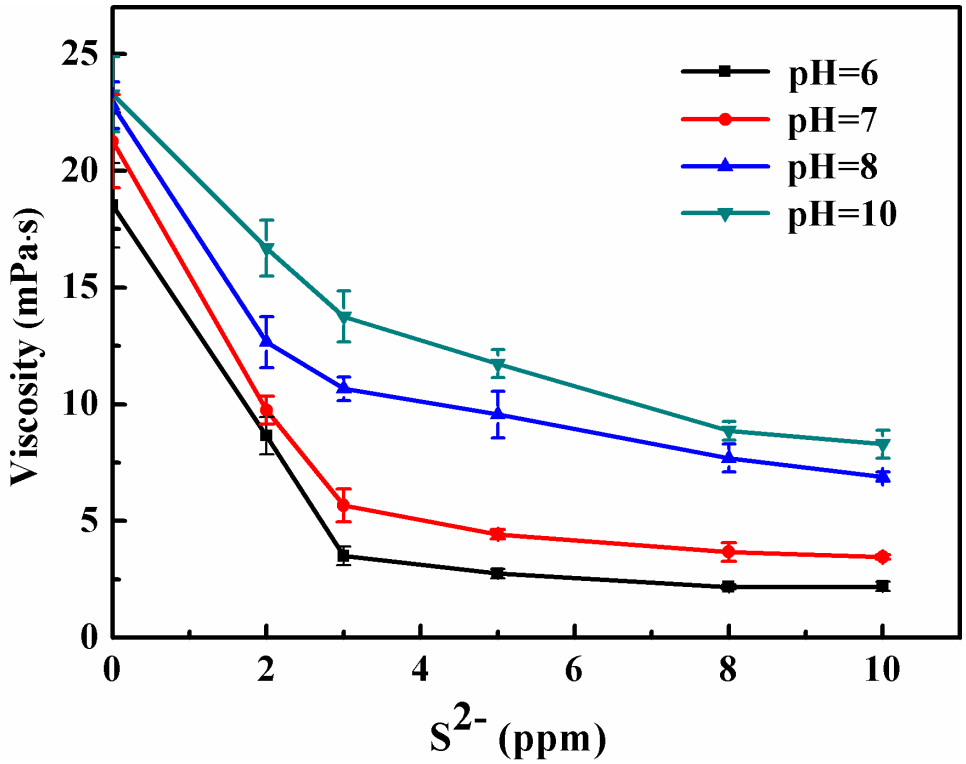
The viscosity of HPAM solution with different concentration of S^{2-} before and after dialysis treatment



A: Viscosity at 72 hrs after addition of S^{2-}
B: Viscosity of the 48 hrs dialysate from A
C: Viscosity of B after addition of S^{2-} for 72 hrs;
D: Viscosity of the 48 hrs dialysate from C

Sulfide influence on HPAM viscosity and the concerning mechanism

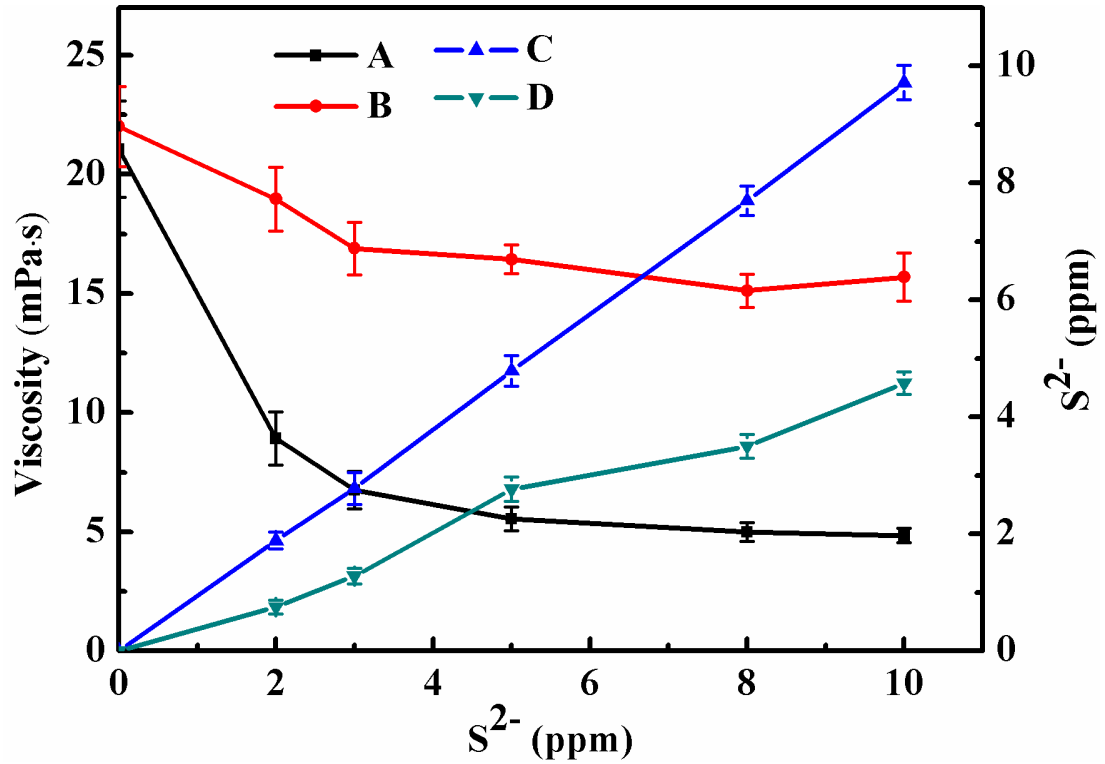
The influence of sulfide ions on viscosity of HPAM solution



The viscosity of HPAM solution under different concentration of S^{2-} and pH conditions

Sulfide influence on HPAM viscosity and the concerning mechanism

The influence of sulfide ions on viscosity of HPAM solution



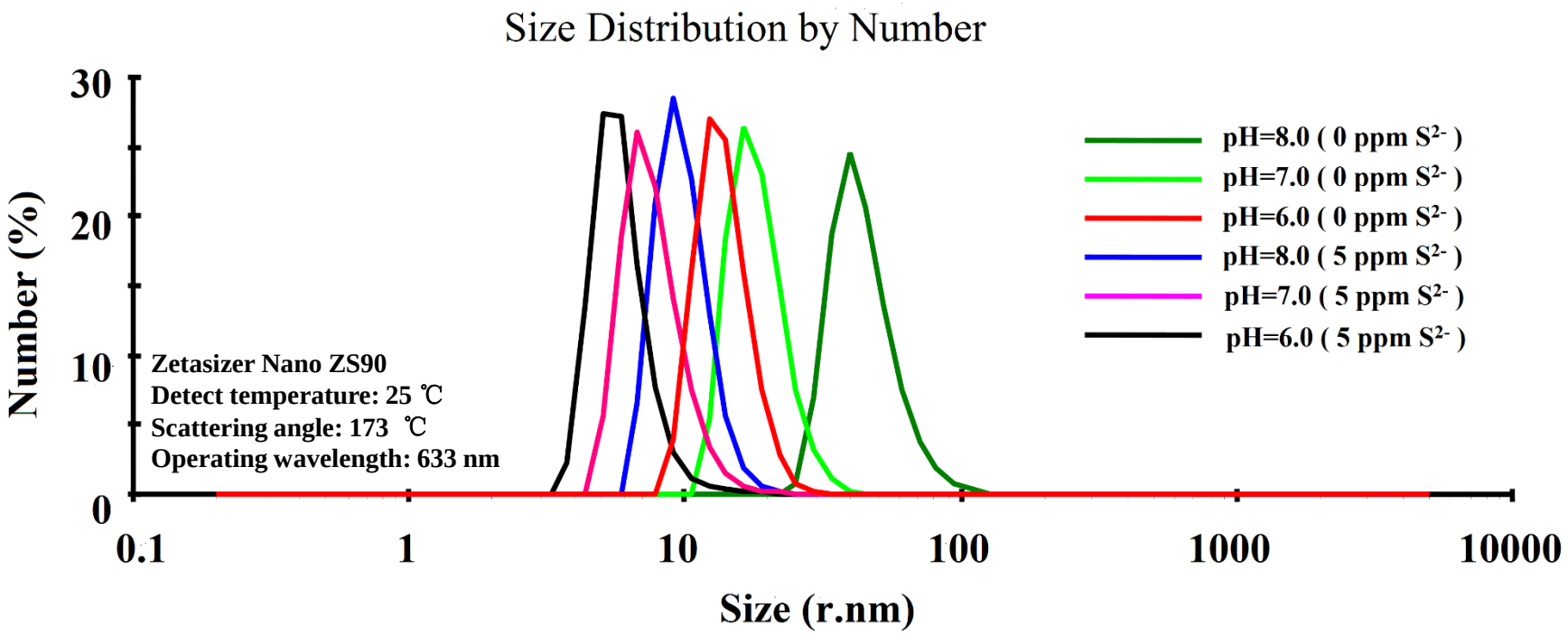
Stronger influence of S^{2-} on viscosity of HPAM was observed under DO conditions than that without DO; So, this influence is proposed to be oxygen dependent.

A: Viscosity with S^{2-} under DO conditions
B: Viscosity with S^{2-} under anoxic condition;
D: S^{2-} concentration under DO conditions
C: S^{2-} concentration under oxygen-free conditions

The viscosity of HPAM solution with different concentration of S^{2-} with and without DO

Sulfide influence on HPAM viscosity and the concerning mechanism

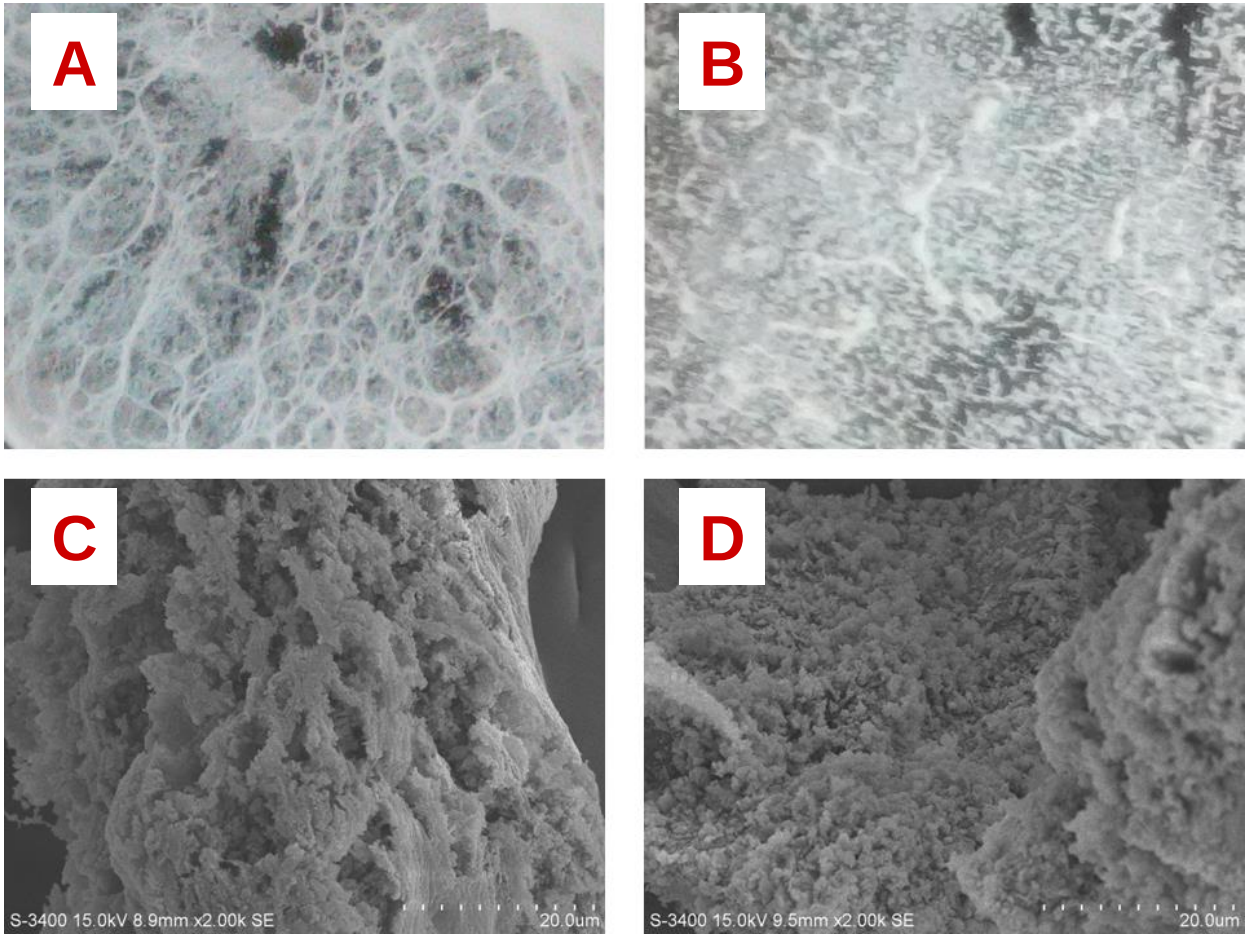
The influence of sulfide ions on hydrodynamic radius of HPAM



The change in particle size of HPAM under different concentration of S^{2-} and pH conditions

Sulfide influence on HPAM viscosity and the concerning mechanism

The influence of sulfide ions on microstructure of HPAM



A&C: 0 ppm S^{2-}

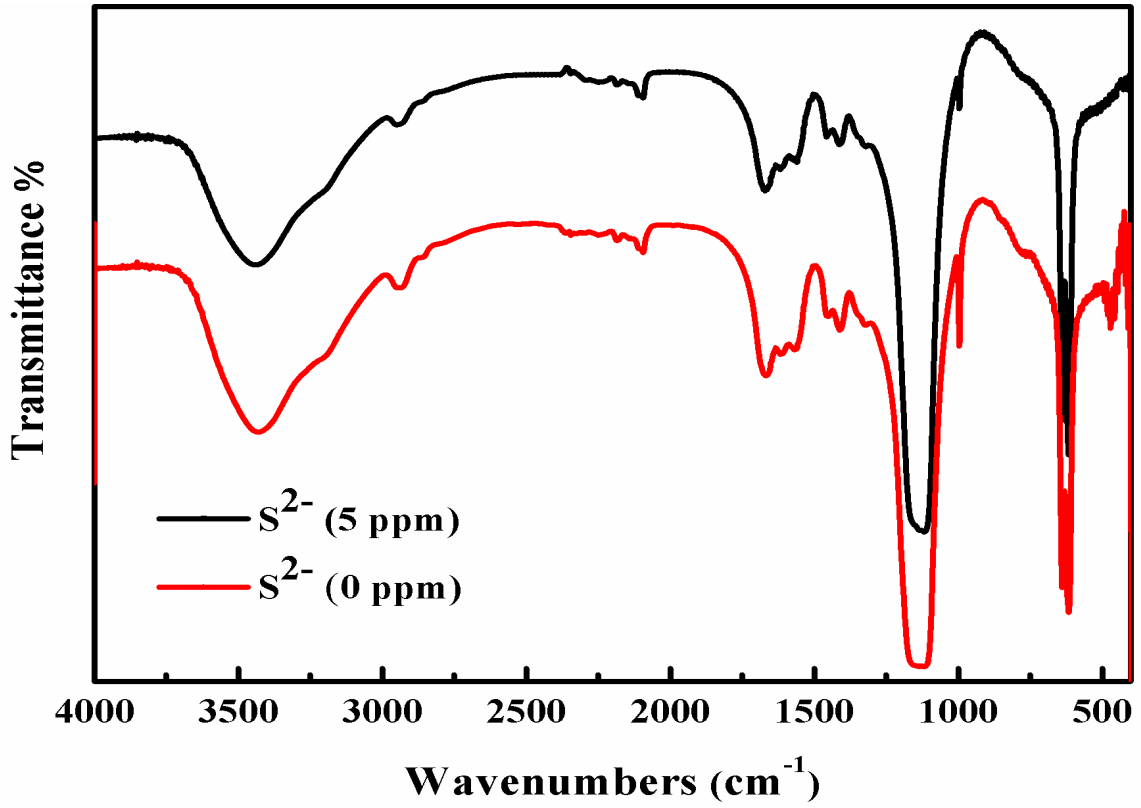
B&D: 5 ppm S^{2-}

Without S^{2-} (A and C), HPAM forms a network structure, resulting in high viscosity; while S^{2-} added (B and D), the network structure is significantly damaged, thus the viscosity be greatly reduced.

The micromorphology of HPAM

Sulfide influence on HPAM viscosity and the concerning mechanism

The influence of sulfide ions on the structure of HPAM

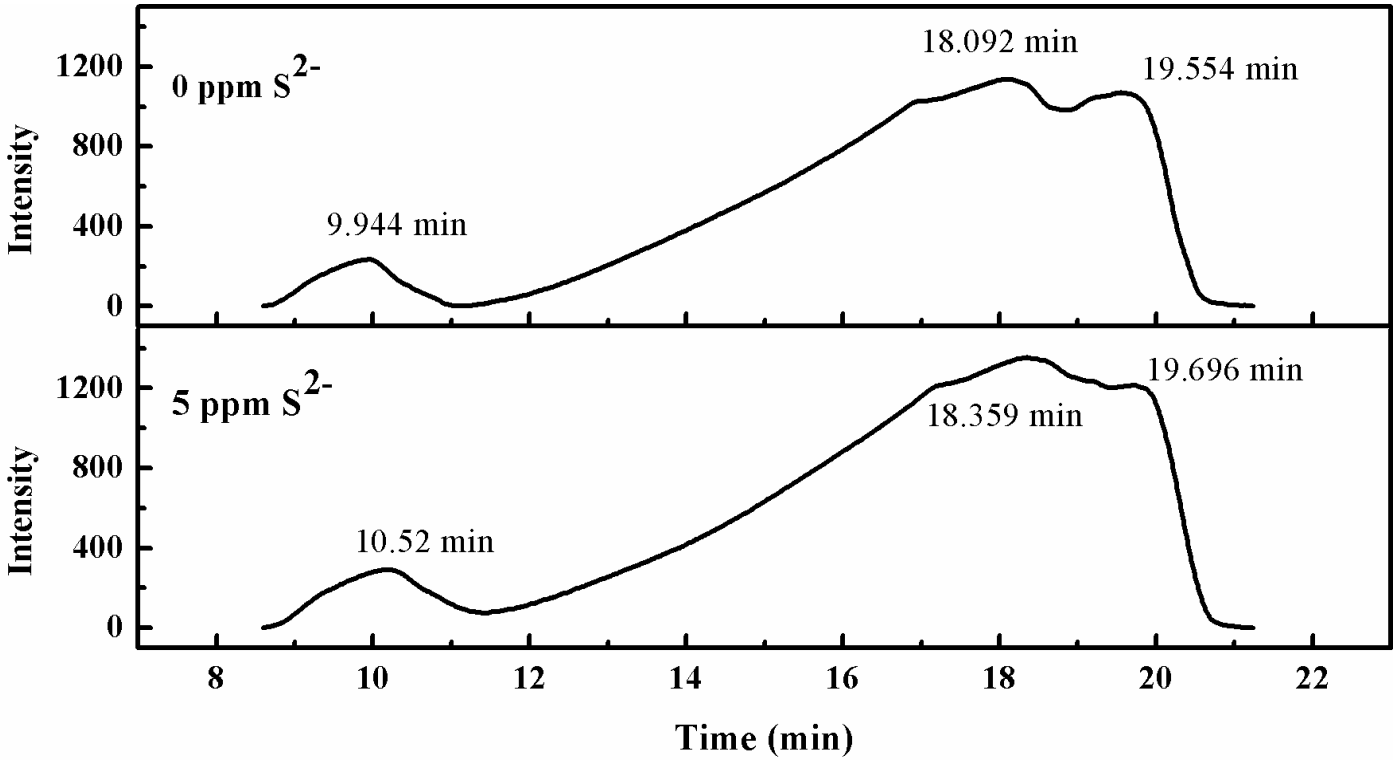


N-H: 3100-3500 cm^{-1} (stretching vibration)
N-H: 1475 cm^{-1} (bending vibration)
C=O: 1615 cm^{-1} (stretching vibration)
C-N: 1415 cm^{-1} (stretching vibration)
C-O: 1130 cm^{-1} (stretching vibration)

The FT-IR spectroscopy of HPAM before and after interaction with S^{2-}

Sulfide influence on HPAM viscosity and the concerning mechanism

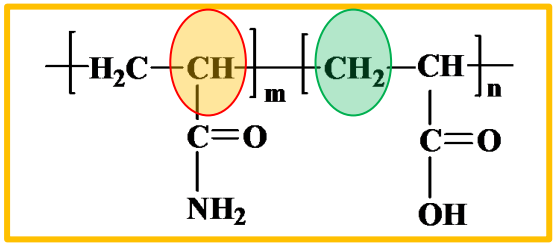
The influence of sulfide ions on Mw of HPAM

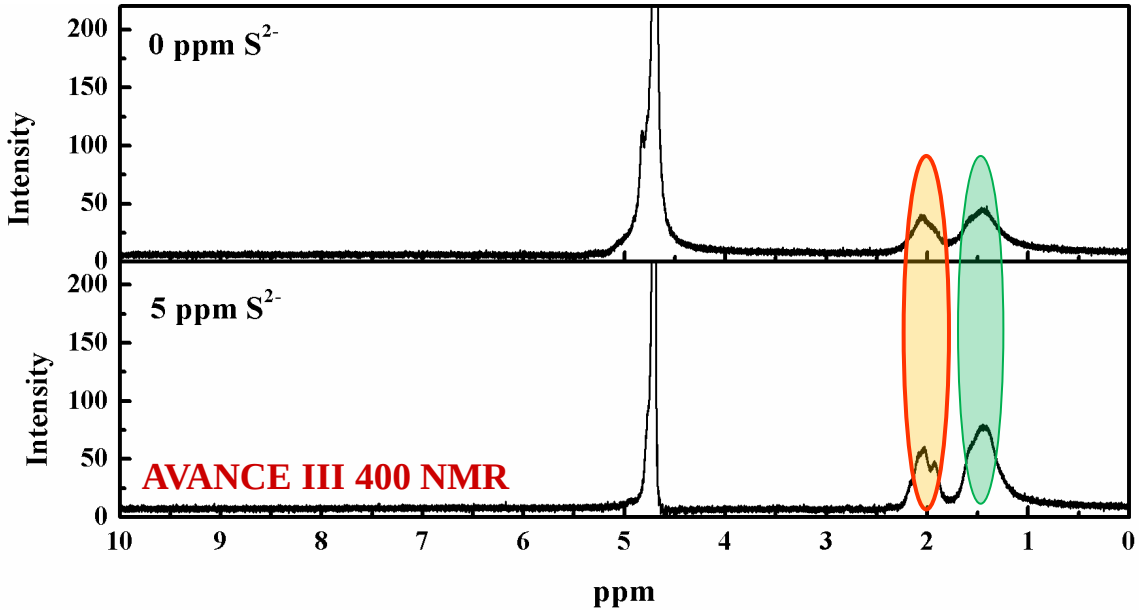


The GPC analysis of HPAM before and after interaction with S^{2-}

Sulfide influence on HPAM viscosity and the concerning mechanism

The interaction site of sulfide ions and HPAM



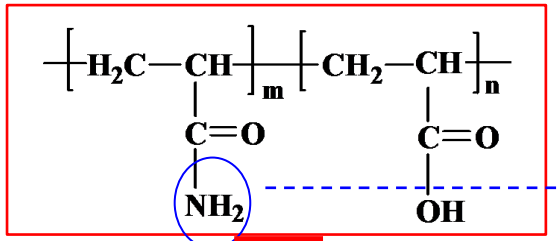


The ^{1}H NMR before and after interaction with S^{2-}

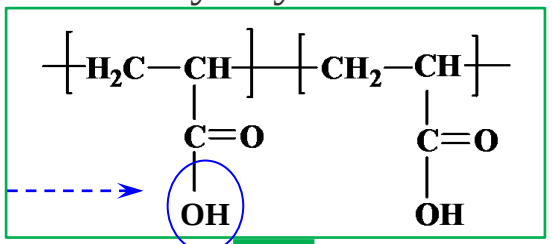
Sulfide influence on HPAM viscosity and the concerning mechanism

The interaction site of sulfide ions and HPAM

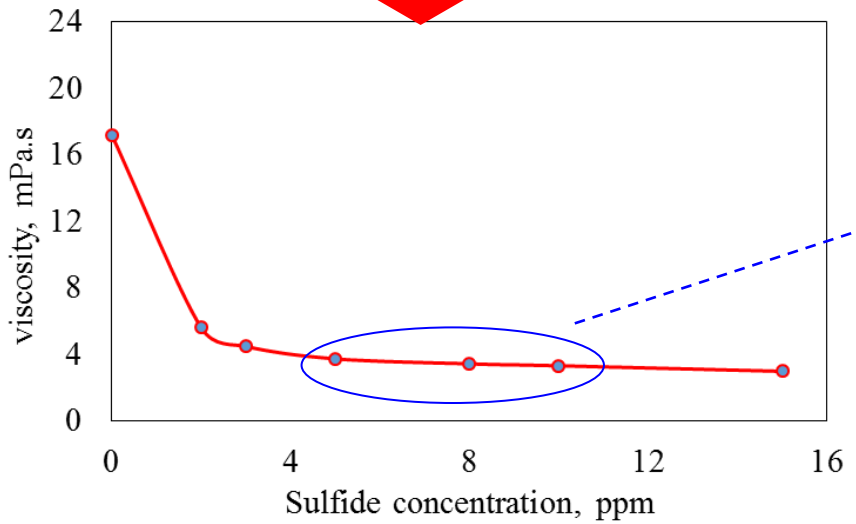
Polyacrylamid



Polyacrylicacid

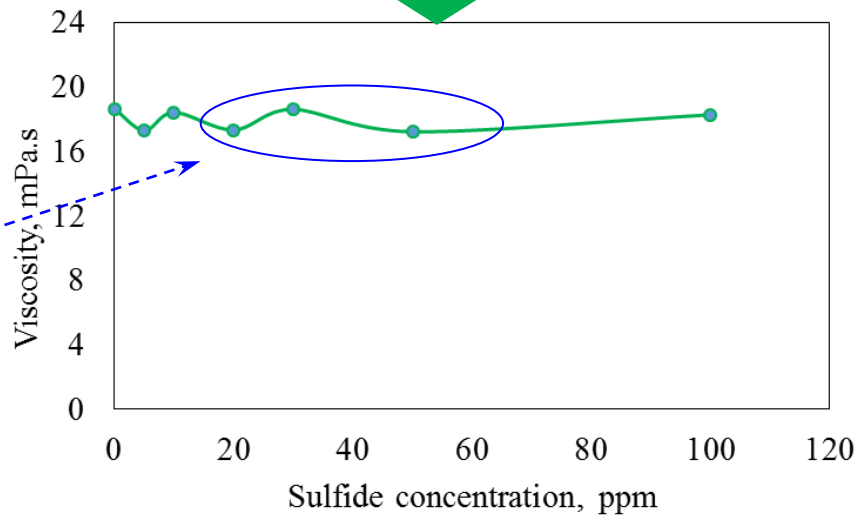


$+S^{2-}$



The viscosity of HPAM solution with different concentration of S^{2-} at pH =7

$+S^{2-}$



The viscosity of HPAA solution with different concentration of S^{2-} at pH =7

Sulfide influence on HPAM viscosity and the concerning mechanism

Summary

- The viscosity of HPAM solution is sensitive to cationic ions, the sensitivity is in this order as: $Fe^{2+} > Ca^{2+} > Mg^{2+} > K^{+} > Na^{+}$; wherein, Fe^{2+} is the most distinguish one which can significantly reduce the viscosity of HPAM solution at a concentration of 5 mg/L.
- Under sufficient oxygen, the lower the pH and the higher the temperature, the more significant the influence of S^{2-} on viscosity of HPAM solution. However, under anaerobic conditions, S^{2-} shows no or not significant effect on the viscosity.
- S^{2-} largely reduce the viscosity through destroying the network structure of HPAM in solution rather than cutting down the HPAM chain, and this action is reasonably related to the amid group of HPAM.

Sulfide influence on HPAM viscosity and the concerning mechanism

INTRODUCTION

Engineering Research Center of Microbial Enhanced Oil Recovery of the Ministry of Education was established in Oct. 2013, and was built based on East China University of Science and Technology. The center consists of four platforms as key Technology Development & Integration, Engineering R&D, Scaling up & Pilot Protocols, and Technology Transfer.

VISION

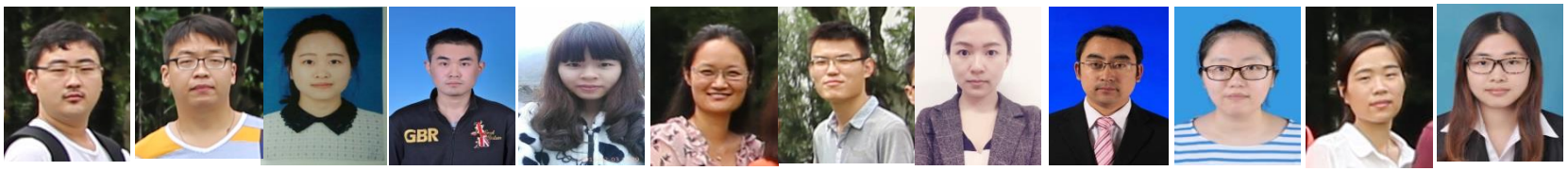
As one of the leading research center, it strives to attract nurture frontiers in green and sustainable technologies in microbial enhanced oil recovery, and to serve as an open platform for research, technical training, technology transfer, information sharing, and international collaboration.

MISSION

The objectives of the center are focus on cost-effective approaches for enhancement of energy recovery. The on-going tasks include (1) roles of microbial community in-situ petroleum, (2) bio-conversion of residues oils into natural gas in oil reservoirs, (3) microbial and bio-based surfactants, and (4) biofixation and bio-conversion of carbon dioxide to methane energy by geo-microorganisms in-situ oil reservoirs.

Sulfide influence on HPAM viscosity and the concerning mechanism

Faculty and students in our group



Biodegradation & Products

Microbial communities

Academic members (including Postdoctors)

Thanks for your attentions

East China University of Science and Technology

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