

## **Supporting Information *for***

# **A Comparative Study on Enhancing Oil Recovery under High Temperature and High Salinity: Polysaccharides versus Synthetic Polymer**

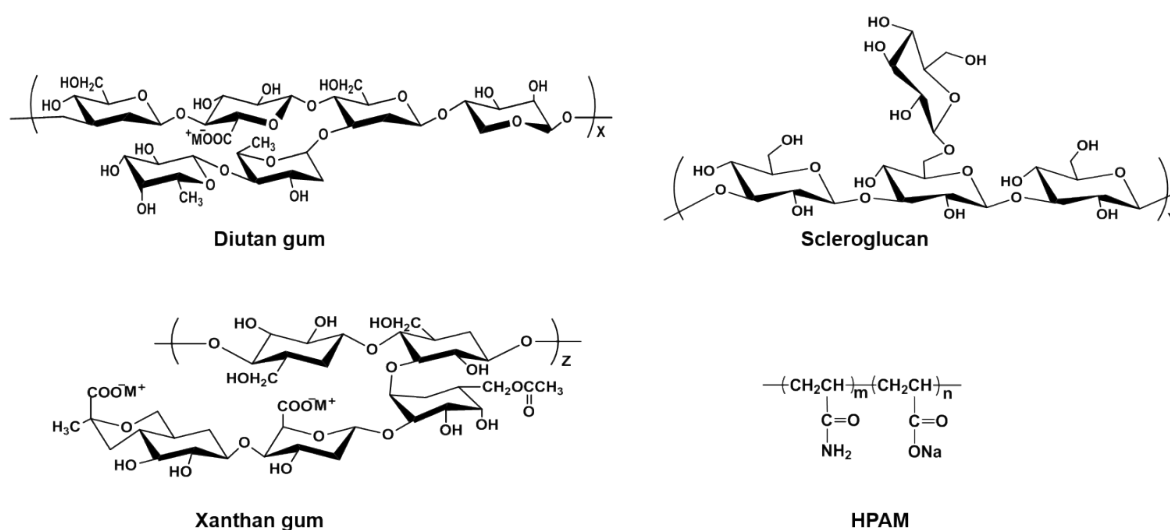
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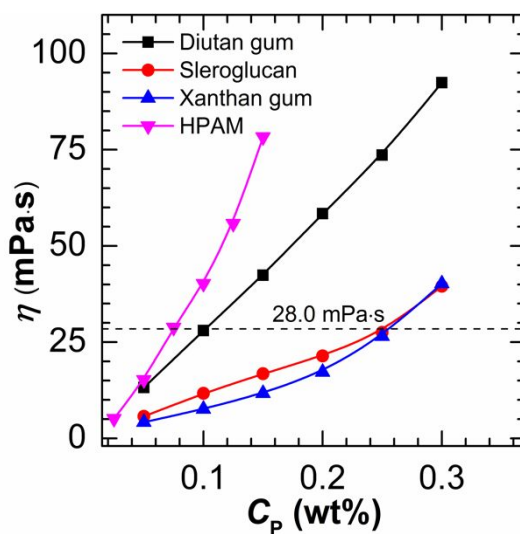
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## Molecular structures



**Scheme S1.** Molecular structures of the polysaccharides and HPAM used in this work. M<sup>+</sup> represents the metal cations of xanthan gum and diutan gum.

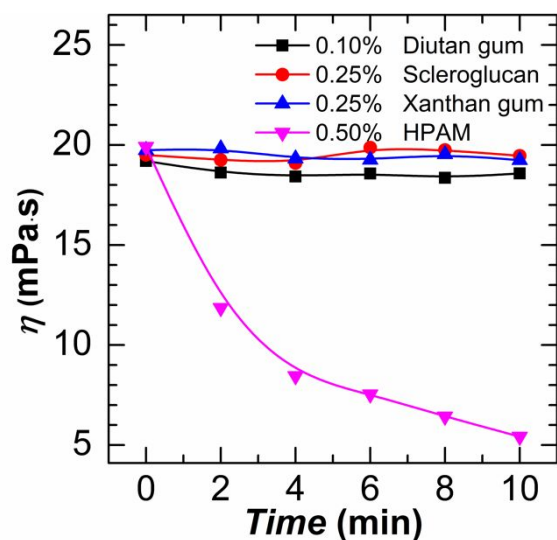


**Figure S1.** Apparent viscosity plotted as a function of concentration for different polymer solutions in pure water. ( $T = 25$  °C,  $\dot{\gamma} = 100$  s<sup>-1</sup>).

## Mechanical stability of polymer solutions

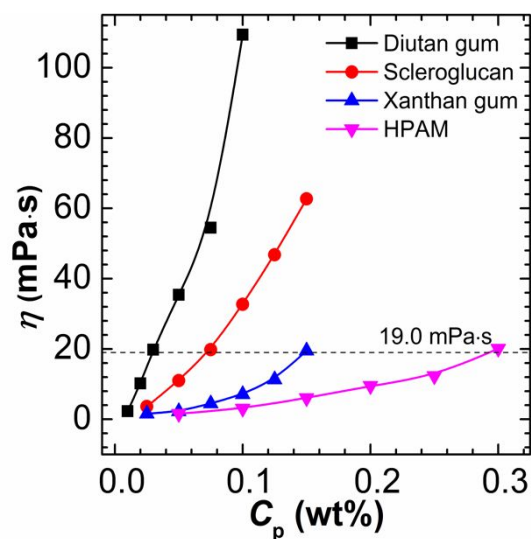
The aqueous solutions of diutan gum, scleroglucan, xanthan gum and HPAM were sheared using high-speed blender (JRJ300-SH, Shanghai Specimen Factory) at a speed rate of 3000 rpm. At every two-minute interval, polymer solution was taken out for viscosity measurement.

Mechanical stability of polymer solutions under high flowing velocity region close to the wellbore is a significant property for water-soluble polymer used in EOR process. Under strong shear stress, the large molecules would be broken into fragments and thus decrease in viscosity of polymer solutions.<sup>1</sup> Especially for HPAM,<sup>2</sup> it is very sensitive to shear degradation. The longer the polymer chain of HPAM is, the easier the mechanical degradation will occur.

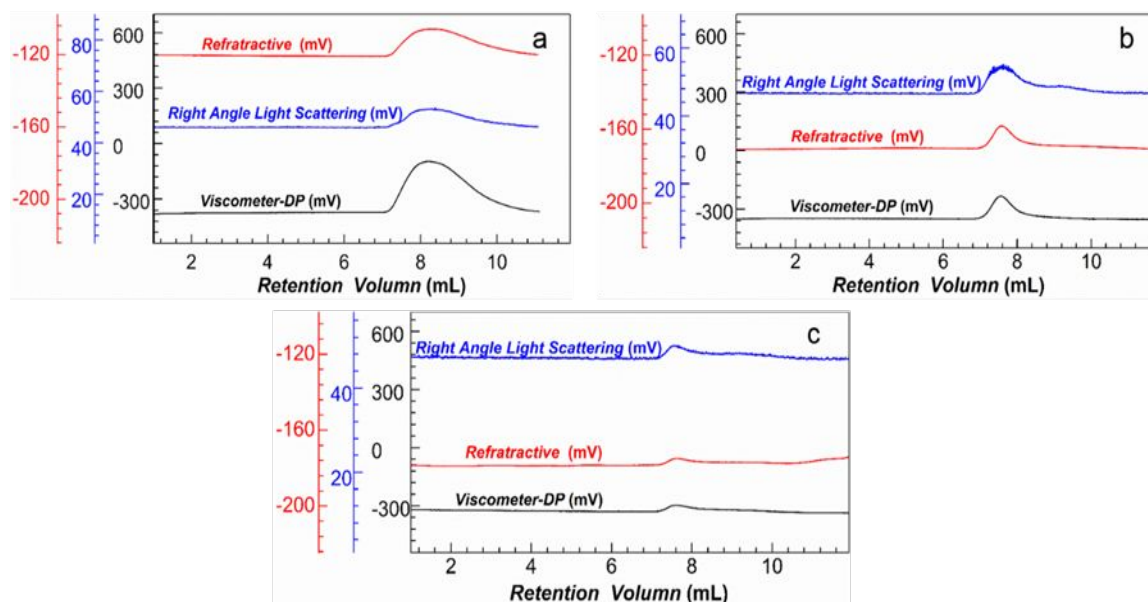


**Figure S2.** Apparent viscosity plotted as a function of shearing time for different polymer solutions in brine ( $\text{TDS} = 10.1 \times 10^4 \text{ mg}\cdot\text{L}^{-1}$ ,  $[\text{Ca}^{2+}] = 1.0 \times 10^3 \text{ mg}\cdot\text{L}^{-1}$ ,  $\dot{\gamma} = 100 \text{ s}^{-1}$ ) at  $85 \text{ }^\circ\text{C}$ , polymer solutions were sheared through high-speed blender at a rotation rate of 3000 rpm.

**Figure S2** depicts the variation in viscosity of polysaccharides and HPAM solutions with shearing time, and polymer solutions with the same initial viscosity were sheared at a rotation of 3000 rpm. The most striking feature concerning the shearing stability is that polysaccharides solutions appeared to be extremely shear stable and their viscosity barely changed with shearing time; conversely, HPAM solutions was very sensitive to shear stress with the viscosity retention of only 20.5% after being sheared for 10 min. For the great many rigid groups and stronger hydrogen bonds existing in three polysaccharides, the viscosity of polysaccharides solutions can recover rapidly when shear stress is removed.<sup>3</sup>



**Figure S3.** Apparent viscosity plotted as a function of concentration for different polymer solutions in brine. ( $T = 85\text{ }^\circ\text{C}$ ,  $\text{TDS} = 10.1 \times 10^4\text{ mg}\cdot\text{L}^{-1}$ ,  $[\text{Ca}^{2+}] = 1.0 \times 10^3\text{ mg}\cdot\text{L}^{-1}$ ,  $\dot{\gamma} = 10\text{ s}^{-1}$ )



**Figure S4.** The GPC curves for polysaccharides. a, diutan gum; b, xanthan gum; c, scleroglucan. ( $T = 45\text{ }^\circ\text{C}$ )

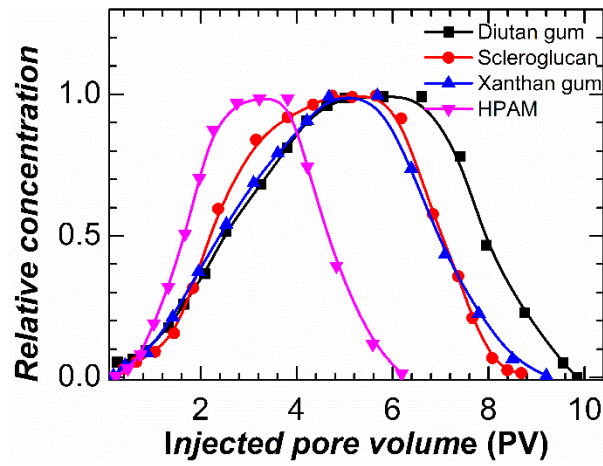
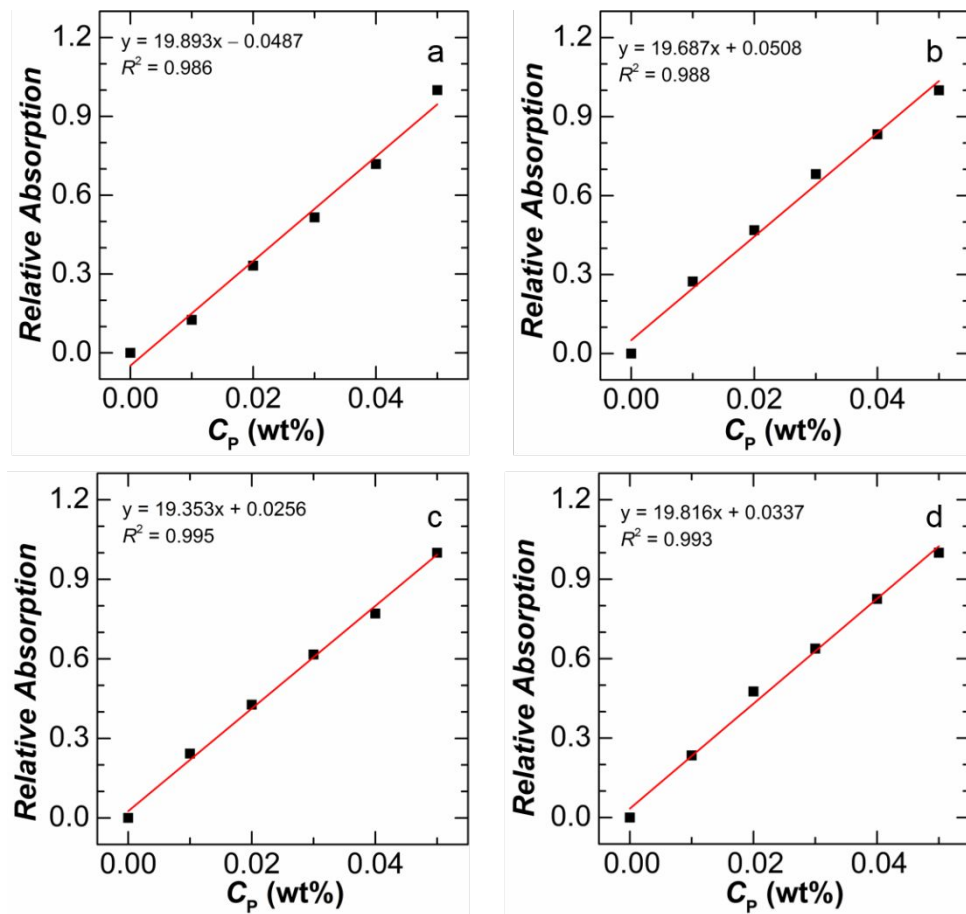


Figure S5. The relative concentration plotted as a function of injected pore volume. ( $T = 85\text{ }^{\circ}\text{C}$ ,  $\text{TDS} = 10.1 \times 10^4 \text{ mg}\cdot\text{L}^{-1}$ ,  $[\text{Ca}^{2+}] = 1.0 \times 10^3 \text{ mg}\cdot\text{L}^{-1}$ )



**Figure S6.** The relative absorption plotted as a function of polymer concentration. a, diutan gum, wavelength = 207 nm; b, scleroglucan, wavelength = 256 nm; c, xanthan gum, wavelength = 211 nm; d, HPAM, wavelength = 207 nm. ( $T = 25\text{ }^{\circ}\text{C}$ )

**Table S1.** The apparent viscosity and viscosity retention for polysaccharides and HPAM at different temperature (no salt,  $\dot{\gamma} = 100 \text{ s}^{-1}$ ).

Sample	$\eta_{25}^a$ (mPa·s)	$\eta_{85}^a$ (mPa·s)	$\eta_{150}^a$	$\Phi_{85}$ (%) <sup>b</sup>	$\Phi_{150}$ (%) <sup>b</sup>
Diutan gum	28.0	20.6	13.5	73.6	48.3
Xanthan gum	26.5	12.8	2.5	49.8	9.4
HPAM	28.8	9.7	– <sup>c</sup>	42.9	– <sup>c</sup>
Scleroglucan	26.5	20.3	19.9	73.8	72.3

<sup>a</sup>  $\eta_{25}$ ,  $\eta_{85}$ ,  $\eta_{150}$ , viscosity of polymer solutions at 25 °C, 85 °C and 150 °C, respectively;

<sup>b</sup>  $\Phi_{85}$ ,  $\Phi_{150}$ , viscosity retention of polymer solutions at 85 °C and 150 °C, respectively;

$$\Phi_{85} = \frac{\eta_{85}}{\eta_{25}} \times 100\%; \quad \Phi_{150} = \frac{\eta_{150}}{\eta_{25}} \times 100\%$$

<sup>c</sup> “–”, the viscosity of polymer solutions was too low to be measured.

### Calculation of oil recovery efficiency

Mobility ratio ( $M$ ) which can greatly influence the sweep efficiency is defined as<sup>4</sup>

$$M = \frac{\lambda_p}{\lambda_o} = \frac{K_p/\eta_p}{K_o/\eta_o} \quad (1)$$

where  $\lambda_p$  and  $\lambda_o$  refer to the mobility of the polymer solutions and oil severally;  $K_p$  and  $K_o$  represent the polymer solution permeability and oil permeability, respectively.

**Table S2.** Recovery factors of polysaccharides and HPAM solutions in porous media at 85 °C

Core number	Sample	$\phi^a$ (%)	1 PV (mL)	Saturated oil volume (mL)	$K_w^b$ (mD)	$\eta_p^c$ (mPa·s)	$M^d$	$E_w^e$ (%)	$E_p^f$ (%)	$E_r^g$ (%)
5	Diutan gum	20.6	30.3	12.8	271	18.7	0.15	68	16	84
6	Xanthan gum	21.1	31.1	13.1	303	19.2	0.21	64	11	75
7	HPAM	20.2	29.7	12.4	204	19.1	0.11	64	10	74
8	Scleroglucan	20.5	30.2	12.4	255	19.2	0.23	69	13	82

<sup>a</sup> $\phi$ , the porosity of artificial cores;

<sup>b</sup> $K_w$ , the water permeability of the artificial cores;

<sup>c</sup> $\eta_p$ , the viscosity of polymer solutions at 85°C,  $\dot{\gamma} = 10 \text{ s}^{-1}$ ;

<sup>e</sup> $E_w$ , the oil recovery efficiency of water flooding;

<sup>f</sup> $E_p$ , the oil recovery efficiency of polymer flooding;

<sup>g</sup> $E_r$ , the total oil recovery efficiency of core flooding.

## References

- (1) Sorbie, K. S. *Polymer-Improved Oil Recovery*. Blackie and Son Ltd., Bishopbriggs, Glasgow, 1991. Chapter 3.
- (2) Liu, P.; Zhang, S.; Yang, N.; Xiong, C. A novel surface active polymer oil displacement agent. *Pet. Explor. Dev.* **2012**, *39*, 619–623.
- (3) Chen, C. S. H.; Sheppard, E. W. Conformation and shear stability of xanthan gum in solution. *Polym. Eng. Sci.* **1980**, *20*, 512–516.
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