

### Inhibition effects of urea, choline chloride, and their mixture on CH<sub>4</sub> hydrate formation

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Pipeline blockages due to the hydrate formation in deep ocean surroundings with cold temperature is now severe problems in oil and gas industries. Using hydrate inhibitors is one of the ideas to resolve these phenomena. Urea and choline chloride are potential hydrate inhibitors and considered as suitable materials in industries because these substances are ecologically harmless and economically reasonable. Carbonyl group and -NH<sub>2</sub> groups in urea will have hydrogen bonds with hydrate water molecules, and ionic nature of ChCl will influence gas hydrate formation. Furthermore, their synergetic effects are also expected because of their different roles in hydrate inhibition. In this study, their thermodynamic and kinetic inhibition effects on CH<sub>4</sub> hydrate formation were examined by autoclave experiments. The hydrate equilibrium shift due to the addition of urea, ChCl, and their mixture was measured by adopting a temperature ramping method. In addition, CH<sub>4</sub> hydrate growth pattern in the presence of these inhibitors were observed using in-situ Raman spectroscopy. From these experimental results, we can suggest another way to avoid pipeline blockage problems with new hydrate inhibitors.