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PII: S2095-4956(16)30415-6  
DOI: [10.1016/j.jechem.2017.04.001](https://doi.org/10.1016/j.jechem.2017.04.001)  
Reference: JECHEM 295

To appear in: *Journal of Energy Chemistry*

Received date: 8 December 2016  
Revised date: 5 April 2017  
Accepted date: 7 April 2017

Please cite this article as: Anatoliy N. Nesterov , Aleksey M. Reshetnikov , Andrey Yu. Manakov , Tatyana P. Adamova , Synergistic effect of combination of surfactant and oxide powder on enhancement of gas hydrates nucleation, *Journal of Energy Chemistry* (2017), doi: [10.1016/j.jechem.2017.04.001](https://doi.org/10.1016/j.jechem.2017.04.001)

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## **Synergistic effect of combination of surfactant and oxide powder on enhancement of gas hydrates nucleation**

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### **Abstract**

In the present work we studied the induction periods of hydrate formation of natural gas in pure water, aqueous solutions of surfactants, and in the presence of surfactant together with aluminum oxide nanopowder, the activity of which as hydrate formation inducer was studied previously. Sodium dodecyl sulphate (SDS) or neonol AF-9-12 were used as the surfactants. It was demonstrated that the addition of either surfactants or aluminum oxide powder under our experimental conditions causes a decrease in the induction period of hydrate formation from ~105 min for pure water to 30–35 min for water with additives. In the case of the simultaneous presence of surfactants and aluminum oxide powder in the system, induction period decreased to ~20 min. So, the synergistic effect of the combination of surfactant and oxide powder on gas hydrate nucleation was demonstrated. Possible reasons of this effect have been discussed.

**Key words:** Gas hydrate; Hydrate formation; Nucleation; Induction period; Surfactant; Nanopowder

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### **1. Introduction**

Gas hydrates are clathrate compounds formed due to inclusion of the molecules of hydrate forming agent (guest) into the cavities of the framework formed by water molecules (host) [1]. Substantial accumulations of natural gas hydrates exist in the sediments of seas and oceans, as well as in permafrost. According to different estimations, the world resources of hydrocarbon raw material in the form of gas hydrates account for  $10^{14}$  to  $10^{16}$  m<sup>3</sup> [2]. In many cases the accumulations of natural gas hydrates exist close to the boundary of their thermodynamic stability, which ensures their possible participation in the global scenarios of climate changes [1,3]. In addition to the resource-related and global ecological problems connected with natural gas hydrates, these compounds possess technological potential in the area of storage and transportation of natural gas (for example, Ref. [4,5]), separation of gas mixtures [6–9], water desalination [10].

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