water MDPI

Experimental study on the kinetics of the natural gas hydration process with a NiMnGa micro-/nanofluid in a static suspension system

Qiong Wu [1,2,3,4], Nengyu Lin [1,4], Li Li [2,3,*], Feng Chen [2,3], Baoyong Zhang [1,4,*], Qiang Wu [1,4], Xianfu Xv, [2,3] and Xinyan Wang [1,4]

1. Department of Safety Engineering, Heilongjiang University of Science and Technology, Harbin, China, 150022.
2. International Joint Laboratory of Advanced Bulk Nanomaterials for Innovative Applications, Harbin Engineering University, Harbin, China, 150001.
3. Institute of Materials Processing and Intelligent Manufacturing, College of Materials Science and Chemical Engineering, Harbin Engineering University, Harbin, China, 150001.
4. National Central Laboratory of Hydrocarbon Gas Transportation Pipeline Safety, Heilongjiang University of Science and Technology, Harbin, China, 150022.
*Corresponding Author: Email address: lili_heu@hrbeu.edu.cn (L. Li); zhangbaoyong2017@outlook.com (B.Y. Zhang)

Table of Content

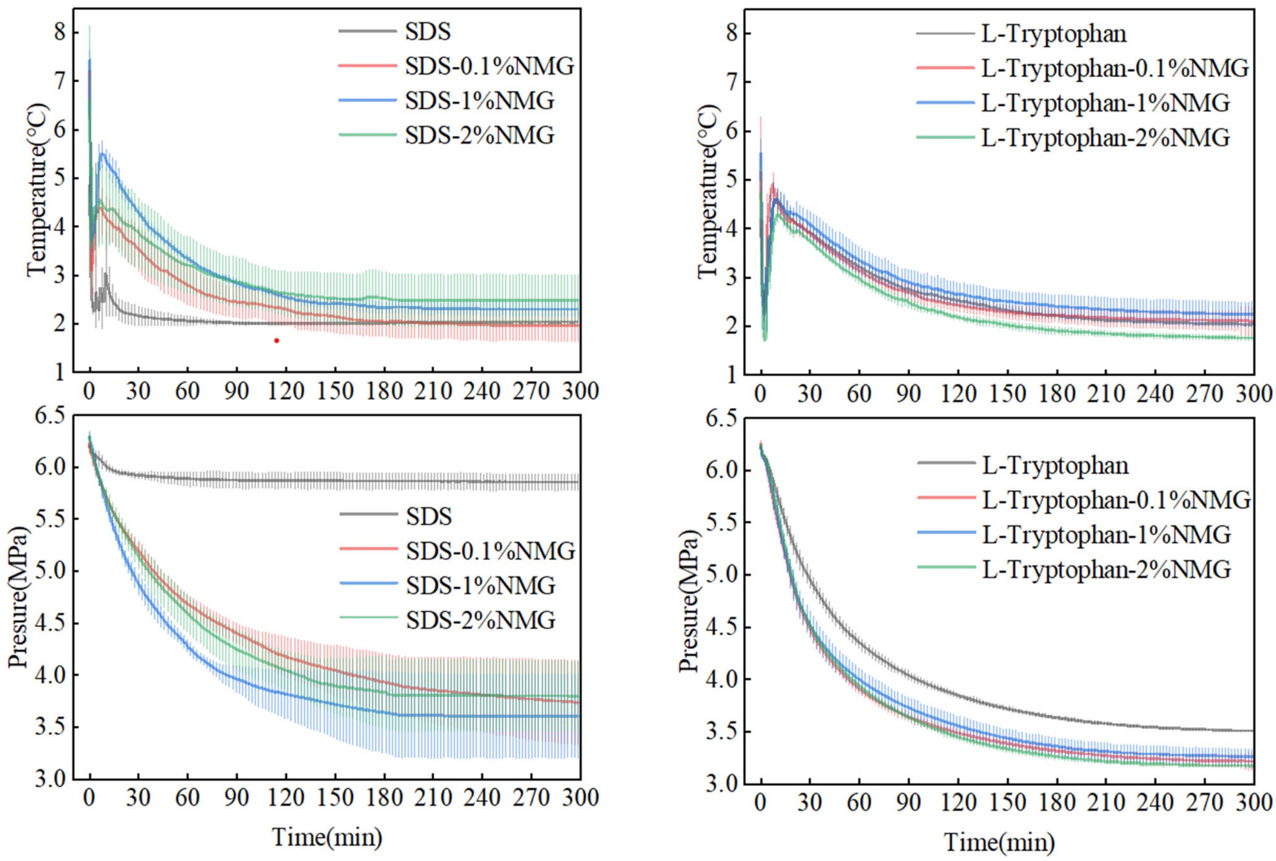
Table S1. Experimental conditions and results of methane hydrate in different systems(P=6.2MPa，T=2°C)......................................2

Figure S1. Temperature and pressure curves of the gas hydration process under different systems……………………........................3

Experimental section...4

Table S1. Experimental conditions and results of methane hydrate in different systems(P=6.2MPa，T=2℃).

Gas sample	System		Gellan gum /%	SDS /%	L-Tryptophan /%	NMG /%	No.	Induction time /min	Gas consumption/mmol of gas /mol of water	Gas consumption rate/mmol of gas/mol of water/min	
										V_{15min}	V_{avg}
99.99% CH_4	**I**	**SG**	**0.3**	**0.05**	**0**	**0**	**1**	**3**	2.763	0.175	0.125
							2	6	5.105	0.215	0.083
							3	8.83	2.673	0.151	0.062
		SNG				0.1	4	1.83	30.969	0.699	0.167
							5	2.67	32.458	0.593	0.116
							6	1.67	39.135	0.612	0.152
		SNG				1	7	1.17	43.797	0.896	0.238
							8	1.67	37.864	0.831	0.199
							9	1.87	30.612	0.951	0.177
		SNG				2	10	1.67	32.779	0.637	0.179
							11	1.33	40.090	0.707	0.220
							12	1.5	30.848	0.699	0.153
	II	LG		0	1	0	1	2.67	38.417	0.889	0.151
							2	3.67	38.718	0.775	0.153
							3	3.33	38.295	0.798	0.146
		LNG				0.1	4	2.50	41.948	1.071	0.198
							5	3.17	41.116	1.112	0.189
							6	2.67	42.165	1.241	0.180
		LNG				1	7	2.17	40.662	1.170	0.190
							8	3.50	41.221	1.024	0.190
							9	3.67	42.022	1.242	0.195
		LNG				2	10	2.83	43.114	1.190	0.210
							11	3.00	43.013	1.098	0.210
							12	3.00	42.853	1.075	0.198



(a) SDS system (b) L-tryptophan system

Figure S1. Curve of temperature and pressure change with time in different systems.

Experimental section

Materials

(1) High-purity nickel lump, electrolytic manganese, and pure gallium metal were melted in the vacuum medium frequency arc melting furnace (SR830, Beijing Zhongke Keji Co., Ltd.) according to the ratio of Ni52.5Mn22.5Ga25. In order to make the alloy melt more uniform, the ingots were turned over and melted 6 times with electromagnetic stirring during the melting process, and finally, button-shaped ingots were obtained.

(2) The melted ingots were polished for oxidation and cut by a wire cutting machine (BDR7725, Beijing Dimeng Hengda Company). The cut ingots are homogenized in a heat treatment chamber resistance heating furnace (SX-4-10, Harbin E. Excel Heat Treatment Equipment Manufacturing Co., Ltd.), and the surface oxidized skin is polished after water cooling.

(3) The homogenized solid solution treated ingots were prepared into small particles of uniform size and ball milled in a high-speed vibrating ball mill (GB-80, Nanjing Boynton Instruments Technology Co., Ltd.) for 30 min-90 min. Various particle sizes could be prepared by controlling the ball milling time and finally annealed to produce the desired NiMnGa micro-nano particles.

Test Results

In order to grasp the degree of influence of different NMG and different pressure conditions on the phase change conditions, the parameters of phase change temperature, inverse phase change temperature, and their latent heat were measured. The results of μDSCVII high-pressure differential scanning calorimeter (HP DSC) tests are shown in Table S2. NMG phase change temperature and inverse phase change latent heat diagram are shown in Figure S2. From the test results, it can be seen that the NMG inverse phase change temperature is 1.794°C in the pressure range of 6~8 MPa, and the latent heat of inverse phase change is 2.493J/g.

Table S2. The results of μDSCVII high-pressure differential scanning calorimeter (HP DSC) tests

NO.	Pressure /MPa	$Ni_{52.5}Mn_{22.5}Ga_{25}$				
		M/g	M_s~M_f	A_s~A_f	△h_1	△h_2
1.	0	0.0440	-18.343~-20.1	-0.967~1.245	-0.94	1.7
2.	6	0.0485	-18.612~-20.378	-0.976~1.794	-0.814	2.493
3.	10	0.0475	-18.747~20.506	-0.998~1.636	-0.859	2.666
4.	15	0.0554	-19.562~21.3	-1.036~-1.685	-0.748	2.569
5.	20	0.0601	-20.171~21.849	-2.014~-0.264	-0.614	0.684
6.	26	0.0615	-20.142~21.805	-1.878~-0.111	-0.559	0.661

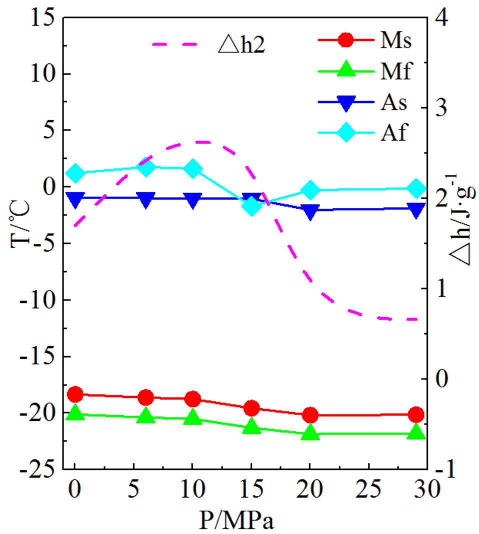


Figure S2. NMG phase change temperature and inverse phase change latent heat diagram

Where, M−phase change start temperature/°C

M_f−end of phase change temperature/°C

A_s−reverse phase change start temperature/°C

A_f−the end of the reverse phase change temperature/°C

△h_1−the latent heat of phase change J/g

△h_2−inverse phase change latent heat J/g

M−sample mass/g