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Prediction of gas hydrate formation conditions in Khangiran and Sarkhun gas fields in the presence of potassium chloride inhibitor

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ABSTRACT

Gaseous hydrates are composed of light gases that are formed under certain temperature and pressure conditions. The formation of gas hydrate in the transmission lines causes clogging of the lines. To prevent the formation of gas hydrates, various solutions such as increasing the temperature, reducing the pressure and dehumidification can be mentioned and also using kinetic and chemical inhibitors. The aim of this study was to investigate the thermodynamic prediction of hydrate formation conditions of Khangiran and Sarkhun gas fields in Iran in the presence of KCl inhibitors and without inhibitors. The results were performed using Hydoff software and combining real percentages of gas fields. In order to validate them, the results were compared with experimental values. The results showed that with increasing temperature and also adding 5% potassium chloride inhibitor, gaseous hydrates are formed at higher pressures, and in order to predict the formation behavior of hydrates, mathematical models were presented for both cases.

1. Introduction

Demand for natural gas and its main component, which is methane, is increasing day by day due to their high storage capacity and clean fuel. The composition of natural gas varies depending on the type of field, and the amounts of its components will vary. Gas hydrate research has increased in recent decades as a result of the large deposits and extensive applications of gas hydrates exceptional physiochemical qualities dictate their major roles in a variety of fields, including energy and the environment. Gas hydrates, in particular, are an appealing option for gas production, gasification, wastewater treatment, and other applications.In underground reservoirs, natural gas and crude oil are in contact with water, and in the deep sea, the pressure is very high and the temperature is very low. Under these conditions, water, due to its strong

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hydrogen bonds, forms porous structures (actually a lattice structure) known as hydrated lattices.

Depending on the type of hydrate, three different structures can be formed:

Type 1: In this structure, the hydrate network is filled with smaller molecules such as CH_4, C_2H_6, CO_2, H_2S.

Type 2: In this structure, compounds such as C_3H_8, i-C_4H_{10}, n-C_4H_{10} form a diamond-like network.

Type 3: In these structures, solid paraffin molecules larger than n-C_4H_{10} together form a large lattice, also called the H structure [1].

Therefore, the important point in determining the type of structure of hydrates is that in examining the type of structure of hydrates, it is the combination of gases that determines the type of structure.

Figure 1 shows a diagram of the three main types of hydrates formed in the gas industry.

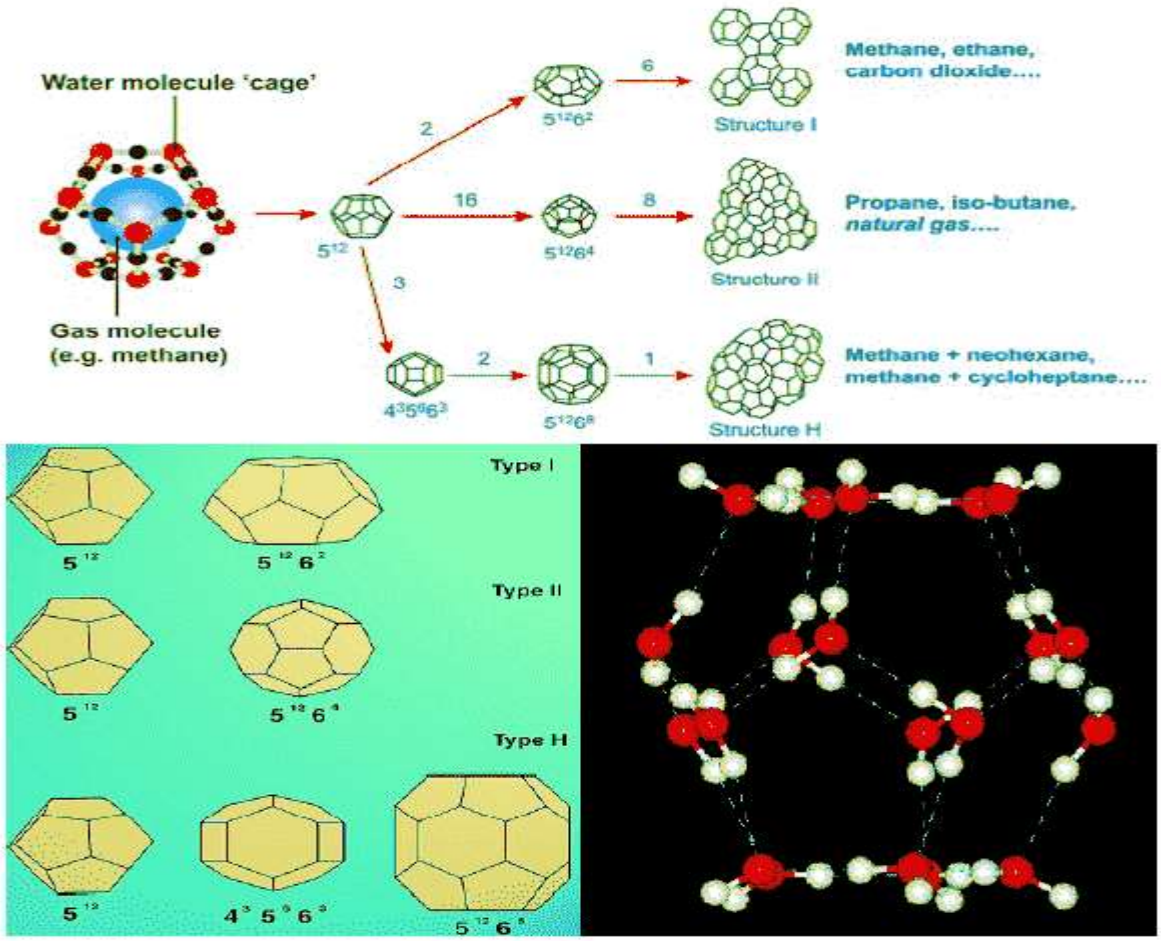

Figure 1. Main types of hydrates formed in the gas industry

Natural-gas hydrates can cause many problems if formed in processes in the gas refining industry. These can cause clogged pipelines and devices or explosions behind control valves. In fact, the formation of hydrates in the transmission lines indicates the acute state of condensate inside the pipes and, therefore, its effects will be worse. The first two factors in the formation of hydrates are present in gas refining processes, and the third factor that must be eliminated is humidity. In gas refineries, in the dehumidification process, the amount of moisture removed must be such that the remaining moisture in the gas is so low that there is no potential for hydrate formation in the gas [2-7].

Hydrate formation experiments, according to Maiti et al., revealed that the addition of sediment solution greatly reduced the pressure required for hydrate formation when compared to formation in distilled water alone. Because salt is a hydrate inhibitor, it was discovered that salinity slowed the development of hydrates. The frequency of hydrate formation in sediment aqueous solution was found to be higher than in pure water. In comparison both to purified water and sediment aqueous solution, the formation rate of sediment solution with salinity is lower [8]. According to Zaare et al., the proposed CFD model is capable of accurately forecasting hydrate formation behaviors in the jumper. The number of hydrates generated in the jumper is reduced as the liquid intake speed and inlet temperature increase. Increases in subcooling and gas volume percentage, on the other hand, lead to increased hydrate formation. The suggested CFD model may be used to successfully predict hydrate formation in pipes under a variety of process and thermodynamic circumstances, assisting in the development of reliable and effective hydrate management approaches [9].

In another study, Li et al. investigated hydrate formation conditions, and to investigate hydrate dissociation behavior, the size, number, and size distribution of fragmented methane bubbles were quantitatively studied. The methane-brine system had dramatically different hydrate dissociation than the methane-pure water system. Multiple methane hydrate formation-dissociation processes were also explored. Multiple formation-dissociation processes, according to the findings, can have a considerable impact on the features of the gas-liquid interface, which could influence hydrate formation and dissociate behaviors [10]. An experiment looked at the

$$\mu_W^H = \mu_W^L \quad (1)$$

The water chemical potential in an empty hydrate network can be obtained from Equation 2:

$$\mu_W^\beta - \mu_W^H = \mu_W^\beta - \mu_W^L \quad (2)$$

The potential difference between water in the situation of an empty hydrate lattice and a stabilized hydrate lattice (H), according to the van der Waals and Plateau models, is $\Delta\mu_W^{\beta-H}$, which illustrates the stabilizing impact of gas molecule adsorption inside the hydrate lattice (Formula 3).

effects of NaCl, KCl, $MgCl_2$, and $CaCl_2$ on the kinetic variables of CO_2 crystal growth, including incubation time, the quantity of gas consumed, rate of gas usage, and storage capacity. All of the studies were conducted at 274.15 K and 3.5 MPa, with aqueous solutions containing the same ion concentration as the Persian Gulf Seawater. According to the findings, salts decrease the kinematic characteristics of carbon dioxide hydrate formation by lowering carbon dioxide solubility in water and the electrostatic interaction between water and ions. The strength of ion inhibition is influenced by ion size, charge, concentration, and kosmotropic and chaotropic properties. In comparison to pure water, Mg^{2+} has the biggest inhibition activity on the kinetic variables of carbon dioxide hydrate in saline solution with such a continual concentration (10 mg/L of each ion), increasing the reaction rate by 110.71 percent and lowering gas consumption, percentage of gas usage, and storage capabilities by 48.21 percent, 82.14 percent, and 68.75 percent, respectively. The results revealed that the inhibitory action of salt ions on the production of carbon dioxide hydrate is in the correct sequence: $Mg^{2+} > Ca^{2+} > Na^+ > K^+$ [11]. Other studies have also been done on hydrate formation conditions and important factors that have a high influence [12–38].

Gas hydrate formation is one of the most common operational problems in natural gas exploitation and transmission operations, and the knowledge of gas analysis is vital to predicting the conditions for hydrate formation, preventing clogging of pipelines, and using inhibitory methods.

The hydrate formation equilibrium pressure and the potential for chemical reactions between the two phases of water and hydrate are the same.

$$\Delta\mu_W^{\beta-H} = \mu_W^\beta - \mu_W^H = RT\sum_{i=1} V_i(1 - \sum_{i=1}^{N} Y_{ki} \quad (3)$$

The study of gas hydrates is done from both thermodynamic and kinetic perspectives. Thermodynamic investigation of hydrate formation temperature and pressure conditions, as well as kinetic investigation of the rate of formation and growth of gaseous hydrate crystals in recent years, due to the use of thermodynamic

air inhibitors in industry, engineers have focused on the thermodynamic study of gaseous hydrates. The conditions for hydrate formation are the appropriate pressure and temperature, the presence of water molecules, and the presence of gas molecules. The process of hydrate formation has completely similar steps to the crystallization process and includes two stages of nucleation and growth. Studies have shown that when the necessary conditions are met, the hydrate crystal does not form immediately, but it takes a while for the necessary arrangement to form between the water molecules, resulting in the formation of cages.

In the results section, the hydrate formation conditions of Sarkhun and Khangiran gas fields have been investigated. These fields are located in Iran and the percentage composition related to their feed is shown in Table 1.

Table 1. Feed composition of Sarkhun and Khangiran gas fields

Formula	Components	Sarkhun	Khangiran
CH_4	Methane	0/8809	0/98555
C_2H_6	Ethane	0/0342	0/0065
C_3H_8	Propane	0/0127	0/0007
I-C_4H_{10}	Iso-Butane	0/0029	0/0002
n-C_4H_{10}	n-Butane	0/0037	0/0004
I-C_5H_{12}	Iso-Pentane	0/0012	0/0002
n-C_5H_{12}	n-Pentane	0/0007	0/0002
C_6H_{14}	Hexane	0/0009	0/0014
N_2	Nitrogen	0/0575	0/005
CO_2	Carbon dioxide	0/0053	0

The results were first evaluated in the case without the use of inhibitors, which showed that with increasing temperature, the amount of equilibrium pressure will also increase. Figures 1 and 2 show the results of equilibrium pressure for the Sarkhun and Khangiran gas fields, respectively.

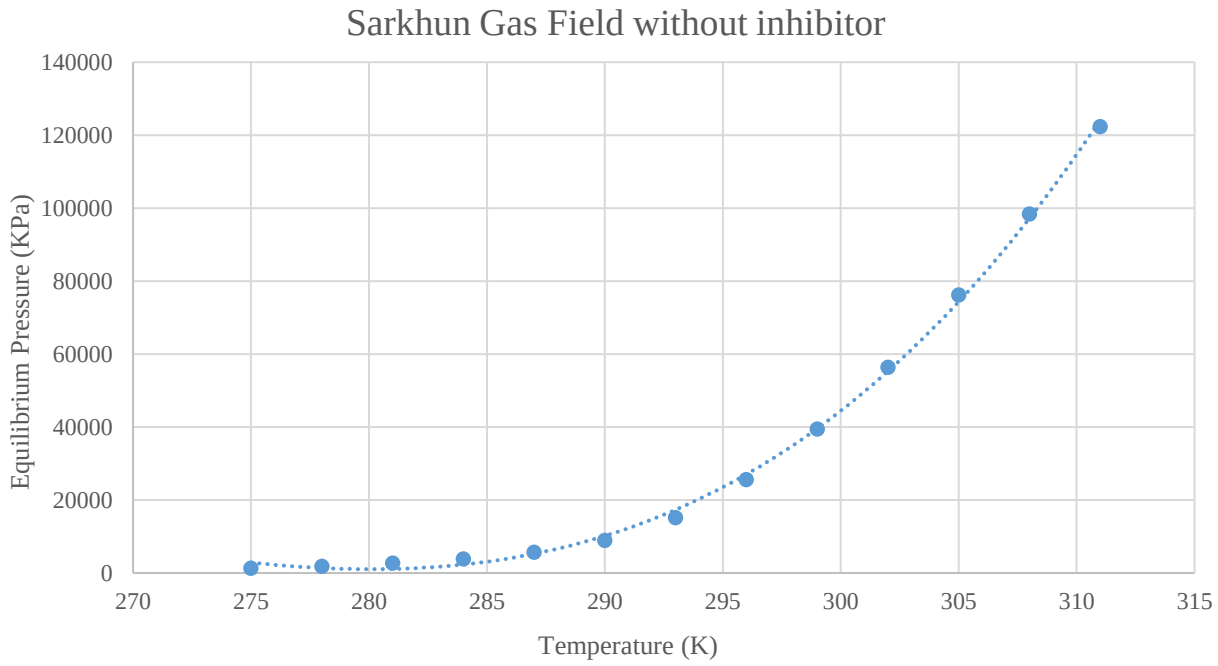

Figure 1. Sarkhun gas field hydrate formation graph without inhibitor

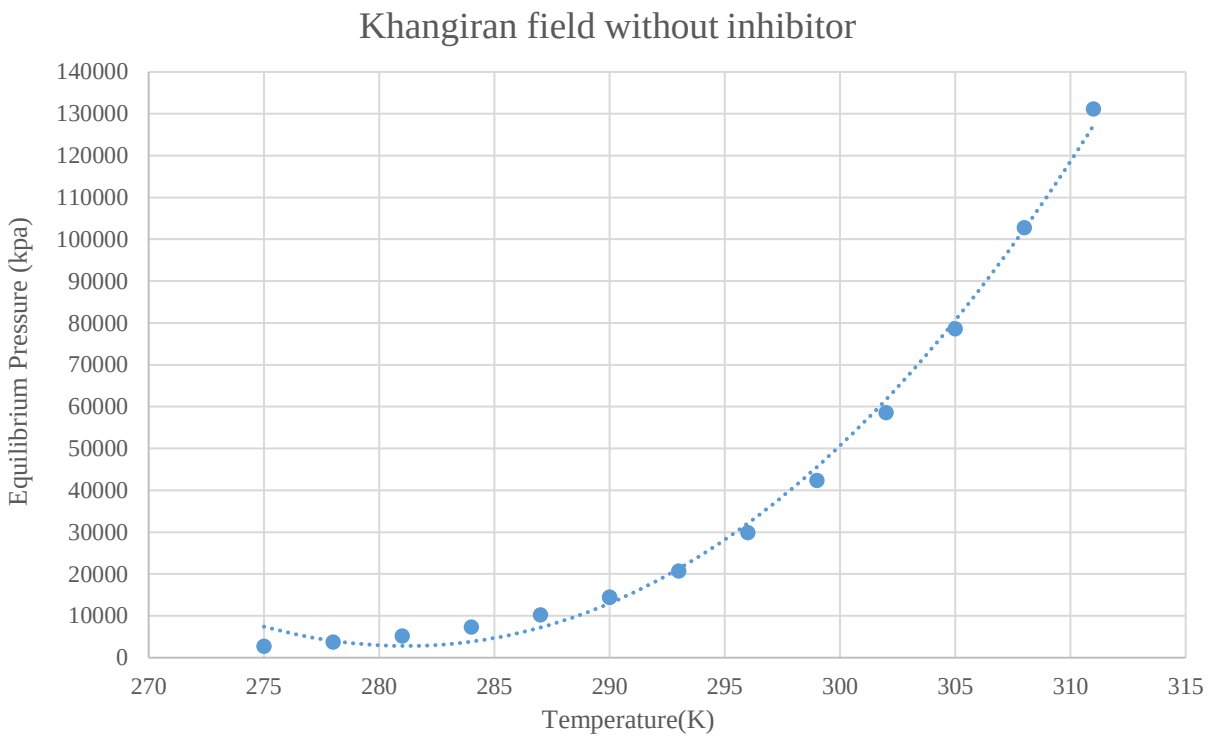

Figure 2. Khangiran gas field hydrate formation graph without inhibitor

In order to validate the present modeling, the results are compared with the experimental outcomes of Jager and Sloan, shown in Figure 3.

The percentage composition of the gas investigated by Jager and Sloan is listed in Table 2 [39].

Table 2- Composition of the gas investigated by Jager and Sloan [39]

CH_4	C_2H_6	C_3H_8	i-C_4H_{10}	n-C_4H_{10}	i-C_5H_{12}	n-C_5H_{12}	C_6H_{14}	C_7H_{16}	N_2	CO_2
97.53	0.8797	0.1397	0.0149	0.0248	0.0180	0.0203	0.0222	0.0126	0.9303	0.410

According to the results and their comparison, it can be concluded that the present modeling is able to predict the formation of gaseous hydrates with high accuracy. Regarding the existing difference, it can be explained that the composition of the percentage in the input feed has a slight difference, and therefore there is a slight deviation in the results.

According to the validation performed and ensuring the existing modeling, in order to predict the equilibrium pressure for the formation of gas hydrate at different temperatures, two mathematical equations were presented; equation 4 related to the formation of hydrate for Sarkhun field and equation 5 to predict equilibrium pressure for hydrate formation in Khangiran field.

$$P(KPa) = 0.00454T^4 - 3.4807T^3 + 897.58T^2 - 7654T \text{ , } R^2 = 0/9987 \quad (4)$$

$$P(KPa) = 0.4488T^3 - 252.37T^2 + 35491T \text{ , } R^2 = 0/9954 \quad (5)$$

The results of modeling hydrate formation in the temperature range between 275- and 311-degrees Kelvin are comprehensively mentioned in Tables 3 and 4, respectively, for Sarkhon and Khangiran fields.

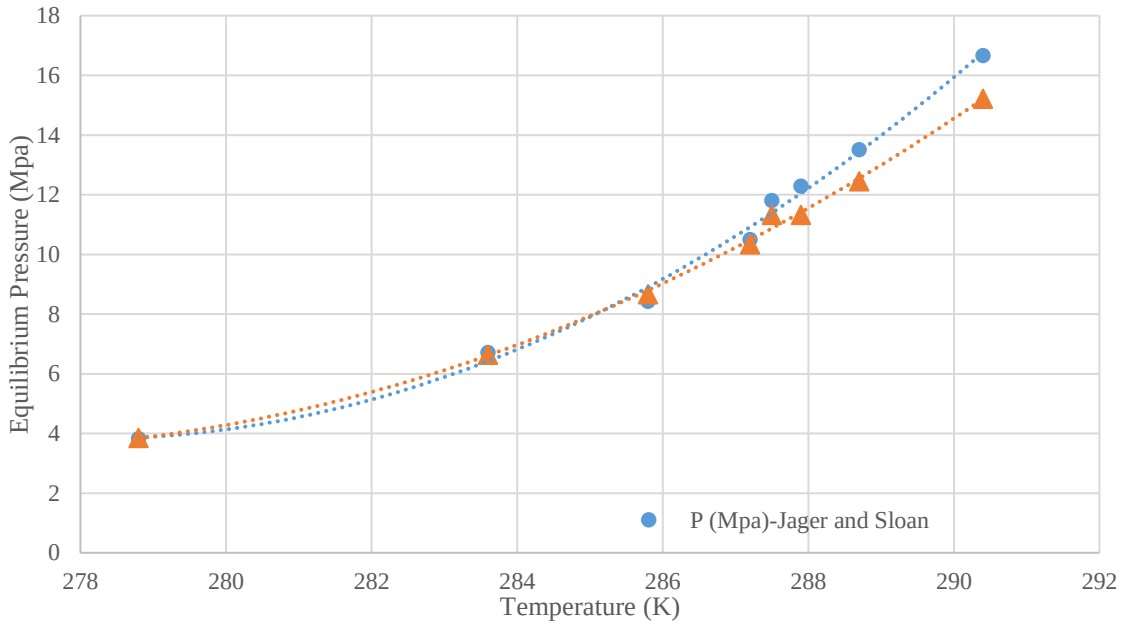

Figure 3. Comparison the present model with Jager & Sloan's results.

Table 3. Sarkhun field modeling result without inhibitor

Temperature (K)	Equilibrium Hydrate:	Composition of Phases at Equilibrium (moles)				Equilibrium Pressure (kpa)	Fractional Occupancy of Cages	
		FEED	Water	Liquid	Hydrate		Small	Large
275	CH4	0/8809	0/0004	0/8809	0/6191	1334/127	0/689	0/0881
	C2H6	0/0342	0	0/0342	0/0321		0	0/0761
	C3H8	0/0127	0	0/0127	0/2513		0	0/595
	I-C4H10	0/0029	0	0/0029	0/0871		0	0/2062
	n-C4H10	0/0037	0	0/0037	0/0104		0	0/0246
	I-C5H12	0/0012	0	0/0012	0		0	0
	n-C5H12	0/0007	0	0/0007	0		0	0
	C6H14	0/0009	0	0/0009	0		0	0
	N2	0/0575	0	0/0575	0		0	0
	CO2	0/0053	0/0001	0/0053	0		0	0
278	CH4	0/8809	0/0005	0/8809	0/6376	1892/663	0/7342	0/0997
	C2H6	0/0342	0	0/0342	0/0326		0	0/0801
	C3H8	0/0127	0	0/0127	0/2389		0	0/5876
	I-C4H10	0/0029	0	0/0029	0/081		0	0/1993
	n-C4H10	0/0037	0	0/0037	0/0099		0	0/0244
	I-C5H12	0/0012	0	0/0012	0		0	0
	n-C5H12	0/0007	0	0/0007	0		0	0
	C6H14	0/0009	0	0/0009	0		0	0
	N2	0/0575	0	0/0575	0		0	0
	CO2	0/0053	0/0001	0/0053	0		0	0

281	CH4	0/8809	0/0007	0/8809	0/6549	2694/82	0/7754	0/1154
	C2H6	0/0342	0	0/0342	0/0333		0	0/0847
	C3H8	0/0127	0	0/0127	0/2274		0	0/5783
	I-C4H10	0/0029	0	0/0029	0/075		0	0/1906
	n-C4H10	0/0037	0	0/0037	0/0094		0	0/0239
	I-C5H12	0/0012	0	0/0012	0		0	0
	n-C5H12	0/0007	0	0/0007	0		0	0
	C6H14	0/0009	0	0/0009	0		0	0
	N2	0/0575	0	0/0575	0		0	0
	CO2	0/0053	0/0001	0/0053	0		0	0
284	CH4	0/8809	0/0009	0/8809	0/6725	3885/078	0/8131	0/1348
	C2H6	0/0342	0	0/0342	0/0345		0	0/0903
	C3H8	0/0127	0	0/0127	0/2159		0	0/5655
	I-C4H10	0/0029	0	0/0029	0/0684		0	0/1791
	n-C4H10	0/0037	0	0/0037	0/0087		0	0/0229
	I-C5H12	0/0012	0	0/0012	0		0	0
	n-C5H12	0/0007	0	0/0007	0		0	0
	C6H14	0/0009	0	0/0009	0		0	0
	N2	0/0575	0	0/0575	0		0	0
	CO2	0/0053	0/0002	0/0053	0		0	0
287	CH4	0/8809	0/0011	0/8809	0/6922	5744/947	0/8481	0/1653
	C2H6	0/0342	0/0001	0/0342	0/0362		0	0/0973
	C3H8	0/0127	0	0/0127	0/2031		0	0/5462
	I-C4H10	0/0029	0	0/0029	0/0607		0	0/1632
	n-C4H10	0/0037	0	0/0037	0/0078		0	0/0211
	I-C5H12	0/0012	0	0/0012	0		0	0
	n-C5H12	0/0007	0	0/0007	0		0	0
	C6H14	0/0009	0	0/0009	0		0	0
	N2	0/0575	0	0/0575	0		0	0
	CO2	0/0053	0/0002	0/0053	0		0	0
290	CH4	0/8809	0/0015	0/8809	0/7187	8961/104	0/8816	0/2178
	C2H6	0/0342	0/0001	0/0342	0/0386		0	0/1064
	C3H8	0/0127	0	0/0127	0/1856		0	0/5116
	I-C4H10	0/0029	0	0/0029	0/0506		0	0/1394
	n-C4H10	0/0037	0	0/0037	0/0065		0	0/018
	I-C5H12	0/0012	0	0/0012	0		0	0
	n-C5H12	0/0007	0	0/0007	0		0	0
	C6H14	0/0009	0	0/0009	0		0	0
	N2	0/0575	0/0001	0/0575	0		0	0
	CO2	0/0053	0/0002	0/0053	0		0	0
290	CH4	0.8809	0.0015	0.8809	0.7187	8961.225	0.8816	0.2178
	C2H6	0.0342	0.0001	0.0342	0.0386		0.0000	0.1064
	C3H8	0.0127	0.0000	0.0127	0.1856		0.0000	0.5116

	I-C4H10	0.0029	0.0000	0.0029	0.0506		0.0000	0.1394
	n-C4H10	0.0037	0.0000	0.0037	0.0065		0.0000	0.0180
	I-C5H12	0.0012	0.0000	0.0012	0.0000		0.0000	0.0000
	n-C5H12	0.0007	0.0000	0.0007	0.0000		0.0000	0.0000
	C6H14	0.0009	0.0000	0.0009	0.0000		0.0000	0.0000
	N2	0.0575	0.0001	0.0575	0.0000		0.0000	0.0000
	CO2	0.0053	0.0002	0.0053	0.0000		0.0000	0.0000
293	CH4	0.8809	0.0020	0.8809	0.7578	15181.784	0.9132	0.3104
	C2H6	0.0342	0.0001	0.0342	0.0409		0.0000	0.1152
	C3H8	0.0127	0.0000	0.0127	0.1587		0.0000	0.4474
	I-C4H10	0.0029	0.0000	0.0029	0.0378		0.0000	0.1067
	n-C4H10	0.0037	0.0000	0.0037	0.0048		0.0000	0.0136
	I-C5H12	0.0012	0.0000	0.0012	0.0000		0.0000	0.0000
	n-C5H12	0.0007	0.0000	0.0007	0.0000		0.0000	0.0000
	C6H14	0.0009	0.0000	0.0009	0.0000		0.0000	0.0000
	N2	0.0575	0.0001	0.0575	0.0000		0.0000	0.0000
	CO2	0.0053	0.0003	0.0053	0.0000		0.0000	0.0000
296	CH4	0.8809	0.0027	0.8809	0.7933	25605.766	0.9375	0.4009
	C2H6	0.0342	0.0001	0.0342	0.0405		0.0000	0.1162
	C3H8	0.0127	0.0000	0.0127	0.1334		0.0000	0.3826
	I-C4H10	0.0029	0.0000	0.0029	0.0292		0.0000	0.0837
	n-C4H10	0.0037	0.0000	0.0037	0.0037		0.0000	0.0105
	I-C5H12	0.0012	0.0000	0.0012	0.0000		0.0000	0.0000
	n-C5H12	0.0007	0.0000	0.0007	0.0000		0.0000	0.0000
	C6H14	0.0009	0.0000	0.0009	0.0000		0.0000	0.0000
	N2	0.0575	0.0002	0.0575	0.0000		0.0000	0.0000
	CO2	0.0053	0.0003	0.0053	0.0000		0.0000	0.0000
299	CH4	0.8809	0.0033	0.8809	0.8092	39464.871	0.9544	0.4412
	C2H6	0.0342	0.0001	0.0342	0.0388		0.0000	0.1128
	C3H8	0.0127	0.0000	0.0127	0.1217		0.0000	0.3535
	I-C4H10	0.0029	0.0000	0.0029	0.0269		0.0000	0.0780
	n-C4H10	0.0037	0.0000	0.0037	0.0034		0.0000	0.0099
	I-C5H12	0.0012	0.0000	0.0012	0.0000		0.0000	0.0000
	n-C5H12	0.0007	0.0000	0.0007	0.0000		0.0000	0.0000
	C6H14	0.0009	0.0000	0.0009	0.0000		0.0000	0.0000
	N2	0.0575	0.0002	0.0575	0.0000		0.0000	0.0000
	CO2	0.0053	0.0003	0.0053	0.0000		0.0000	0.0000
302	CH4	0.8809	0.0038	0.8809	0.8115	56433.594	0.9668	0.4444
	C2H6	0.0342	0.0001	0.0342	0.0371		0.0000	0.1089

	C3H8	0.0127	0.0000	0.0127	0.1195		0.0000	0.3501
	I-C4H10	0.0029	0.0000	0.0029	0.0282		0.0000	0.0827
	n-C4H10	0.0037	0.0000	0.0037	0.0037		0.0000	0.0107
	I-C5H12	0.0012	0.0000	0.0012	0.0000		0.0000	0.0000
	n-C5H12	0.0007	0.0000	0.0007	0.0000		0.0000	0.0000
	C6H14	0.0009	0.0000	0.0009	0.0000		0.0000	0.0000
	N2	0.0575	0.0003	0.0575	0.0000		0.0000	0.0000
	CO2	0.0053	0.0003	0.0053	0.0000		0.0000	0.0000
305	CH4	0.8809	0.0042	0.8809	0.8052	76221.422	0.9761	0.4230
	C2H6	0.0342	0.0001	0.0342	0.0355		0.0000	0.1046
	C3H8	0.0127	0.0000	0.0127	0.1228		0.0000	0.3622
	I-C4H10	0.0029	0.0000	0.0029	0.0323		0.0000	0.0952
	n-C4H10	0.0037	0.0000	0.0037	0.0043		0.0000	0.0127
	I-C5H12	0.0012	0.0000	0.0012	0.0000		0.0000	0.0000
	n-C5H12	0.0007	0.0000	0.0007	0.0000		0.0000	0.0000
	C6H14	0.0009	0.0000	0.0009	0.0000		0.0000	0.0000
	N2	0.0575	0.0004	0.0575	0.0000		0.0000	0.0000
	CO2	0.0053	0.0004	0.0053	0.0000		0.0000	0.0000
308	CH4	0.8809	0.0050	0.8809	0.7930	98366.297	0.9829	0.3851
	C2H6	0.0342	0.0001	0.0342	0.0336		0.0000	0.0996
	C3H8	0.0127	0.0000	0.0127	0.1293		0.0000	0.3832
	I-C4H10	0.0029	0.0000	0.0029	0.0388		0.0000	0.1149
	n-C4H10	0.0037	0.0000	0.0037	0.0054		0.0000	0.0159
	I-C5H12	0.0012	0.0000	0.0012	0.0000		0.0000	0.0000
	n-C5H12	0.0007	0.0000	0.0007	0.0000		0.0000	0.0000
	C6H14	0.0009	0.0000	0.0009	0.0000		0.0000	0.0000
	N2	0.0575	0.0005	0.0575	0.0000		0.0000	0.0000
	CO2	0.0053	0.0004	0.0053	0.0000		0.0000	0.0000
311	CH4	0.8809	0.0055	0.8809	0.7773	122324.281	0.9829	0.3367
	C2H6	0.0342	0.0001	0.0342	0.0313		0.0000	0.0932
	C3H8	0.0127	0.0000	0.0127	0.1369		0.0000	0.4072
	I-C4H10	0.0029	0.0000	0.0029	0.0476		0.0000	0.1417
	n-C4H10	0.0037	0.0000	0.0037	0.0068		0.0000	0.0203
	I-C5H12	0.0012	0.0000	0.0012	0.0000		0.0000	0.0000
	n-C5H12	0.0007	0.0000	0.0007	0.0000		0.0000	0.0000
	C6H14	0.0009	0.0000	0.0009	0.0000		0.0000	0.0000
	N2	0.0575	0.0006	0.0575	0.0000		0.0000	0.0000
	CO2	0.0053	0.0004	0.0053	0.0000		0.0000	0.0000

Table 4. Khangiran field modeling result without inhibitor

Temperature (K)	Equilibrium Hydrate	Composition of Phases at Equilibrium (moles)				Equilibrium Pressure (kpa)	Fractional Occupancy of Cages	
		FEED	Water	Liquid	Hydrate		Small	Large
275	CH4	0/98555	0/0009	0/9855	0/8687	2728/959	0/8308	0/6224
	C2H6	0/0065	0	0/0065	0/8322		0	0/0047
	C3H8	0/0007	0	0/0007	0/0682		0	0/1793
	I-C4H10	0/0002	0	0/0002	0/0257		0	0/0677
	n-C4H10	0/0004	0	0/0004	0/0052		0	0/0136
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
278	CH4	0/98555	0/0011	0/9855	0/8838	3755/024	0/8548	0/6604
	C2H6	0/0065	0	0/0065	0/8305		0	0/0019
	C3H8	0/0007	0	0/0007	0/0595			0/1596
	I-C4H10	0/0002	0	0/0002	0/0217		0	0/0582
	n-C4H10	0/0004	0	0/0004	0/0044		0	0/0119
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
281	CH4	0/98555	0/0013	0/9855	0/8997	5210/328	0/8764	0/7022
	C2H6	0/0065	0	0/0065	0/0285		0	0/8779
	C3H8	0/0007	0	0/0007	0/0505		0	0/1378
	I-C4H10	0/0002	0	0/0002	0/0176		0	0/0479
	n-C4H10	0/0004	0	0/0004	0/0037		0	0/01
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0/0004	0	0		0	0
284	CH4	0/98555	0/0016	0/9855	0/9167	7322/106	0/8957	0/7484
	C2H6	0/0065	0	0/0065	0/8261		0	0/0722
	C3H8	0/0007	0	0/0007	0/041		0	0/1137
	I-C4H10	0/0002	0	0/0002	0/01134		0	0/0371
	n-C4H10	0/0004	0	0/0004	0/0028		0	0/007
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0/0004	0	0		0	0

287	CH4	0/98555	0/002	0/9855	0/9724	10234/618	0/9319	0/9511
	C2H6	0/0065	0	0/0065	0/8276		0	0/035
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0/0004	0	0		0	0
290	CH4	0/98555	0/0024	0/9855	0/9771	14434/882	0/9428	0/9591
	C2H6	0/0065	0	0/0065	0/0229		0	0/0299
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0/0001	0/005	0		0	0
	CO2	0	0/0005	0	0		0	0
290	CH4	0/9855	0/0024	0/9855	0/9771	14434.888	0/9428	0/9591
	C2H6	0/0065	0	0/0065	0/0229		0	0/0299
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
293	CH4	0/9855	0/0029	0/9855	0/981	20739.547	0/953	0/966
	C2H6	0/0065	0	0/0065	0/019		0	0/0249
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0

296	CH4	0/9855	0/0035	0/9855	0/9836	29872.537	0/9625	0/9712
	C2H6	0/0065	0	0/0065	0/0164		0	0/0216
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
299	CH4	0/9855	0/0041	0/9855	0/985	42366.992	0/971	0/9747
	C2H6	0/0065	0	0/0065	0/015		0	0/0198
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
302	CH4	0/9855	0/0048	0/9855	0/9855	58549.496	0/9784	0/9767
	C2H6	0/0065	0	0/0065	0/0145		0	0/0192
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
305	CH4	0/9855	0/0056	0/9855	0/9853	78643.406	0/9845	0/9776
	C2H6	0/0065	0	0/0065	0/0147		0	0/0194
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0

	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
308	CH4	0/9855	0/0064	0/9855	0/9846	102811.250	0/9893	0/9775
	C2H6	0/0065	0	0/0065	0/0154		0	0/0205
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
311	CH4	0/9855	0/0073	0/9855	0/9832	131178.703	0/9929	0/9763
	C2H6	0/0065	0	0/0065	0/0168		0	0/0224
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0

2. Simulation results using inhibitors

The ionic materials utilized operate as inhibitors thermodynamically by altering the equilibrium three-phase equilibrium graph. In fact, hydrates develop at lower temperatures and greater pressures in the presence of these materials than in the absence of any additions. The saline characteristics of these chemicals are thought to be the cause of their inhibitory effect. When the thermodynamic effects of two ionic liquids on hydrate are compared, the ionic liquid is found to be the higher inhibitor.

Adding a chemical inhibitor is one of the best ways to prevent hydrate formation. It is certainly preferable to add small amounts of inhibitors, and therefore, a potassium chloride inhibitor with a weight percentage of 5% has been used to investigate the formation of gaseous hydrates at temperatures between 275 and 311 K, which, according to the results, gases at higher temperatures. were formed relative to the state without additives. Figures 4 and 5 show the hydrate formation conditions for the Khangiran and Sarkhun fields with 5% potassium chloride, respectively.

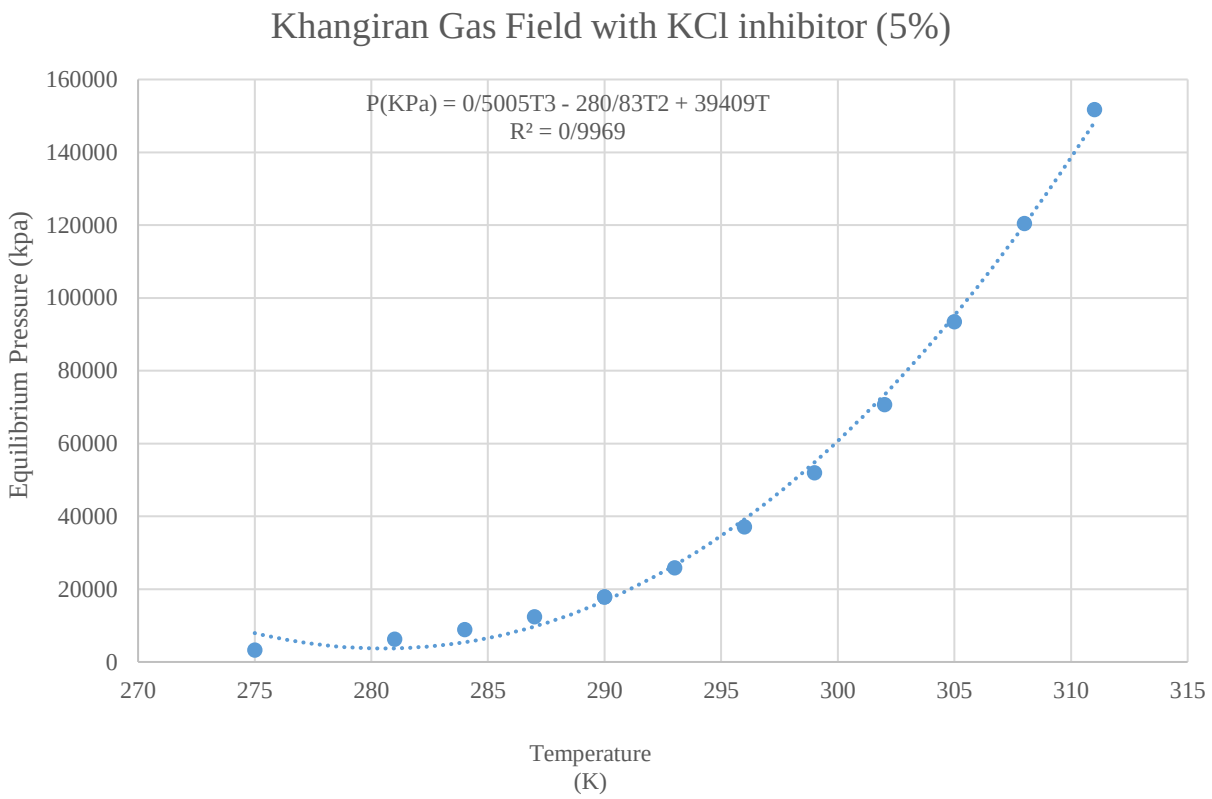

Figure 4. Khangiran gas field hydrate formation with KCl inhibitor (5%).

The presence of salts, due to the strengthening of the electric charge and the increase of surface tension, has a positive synergistic effect in preventing the formation of gas hydrates. The smaller the ions released and the higher the charge accumulation, the better the inhibitory effect and the greater the synergy. Since the hydrate network is formed by the formation of hydrogen bonds between water molecules, adding an inhibitor to this structure disrupts the hydrate network by creating stronger hydrogen bonds between the water molecules, thus inhibiting the formation of hydrate crystals. The degree of inhibition of salts is directly related to the number of ions released and inversely proportional to the radius of the ions, so the best inhibitors are those that release the maximum number of cations with the minimum ionic radius.

Of course, the use of salts has disadvantages, including corrosion and deposition in cold areas where there is a possibility of hydration. A mathematical equation was also proposed to predict hydrate formation in the temperature range of 275 to 311 K using a 5% potassium chloride inhibitor, equations 6 and 7 for the Khangiran and Sarkhon gas fields, respectively.

$$P(KPa) = 0.5005T^3 - 280.83T^2 + 39409T \quad , \quad R^2 = 0/9969 \qquad (6)$$

$$P(KPa) = 0.001T^4 - 0.3624T^3 + 20.727T^2 + 13346T, \; R^2=0/9989 \qquad (7)$$

Also, in Tables 5 and 6, the complete results related to hydrate formation in Khangiran and Sarkhun fields are mentioned, respectively.

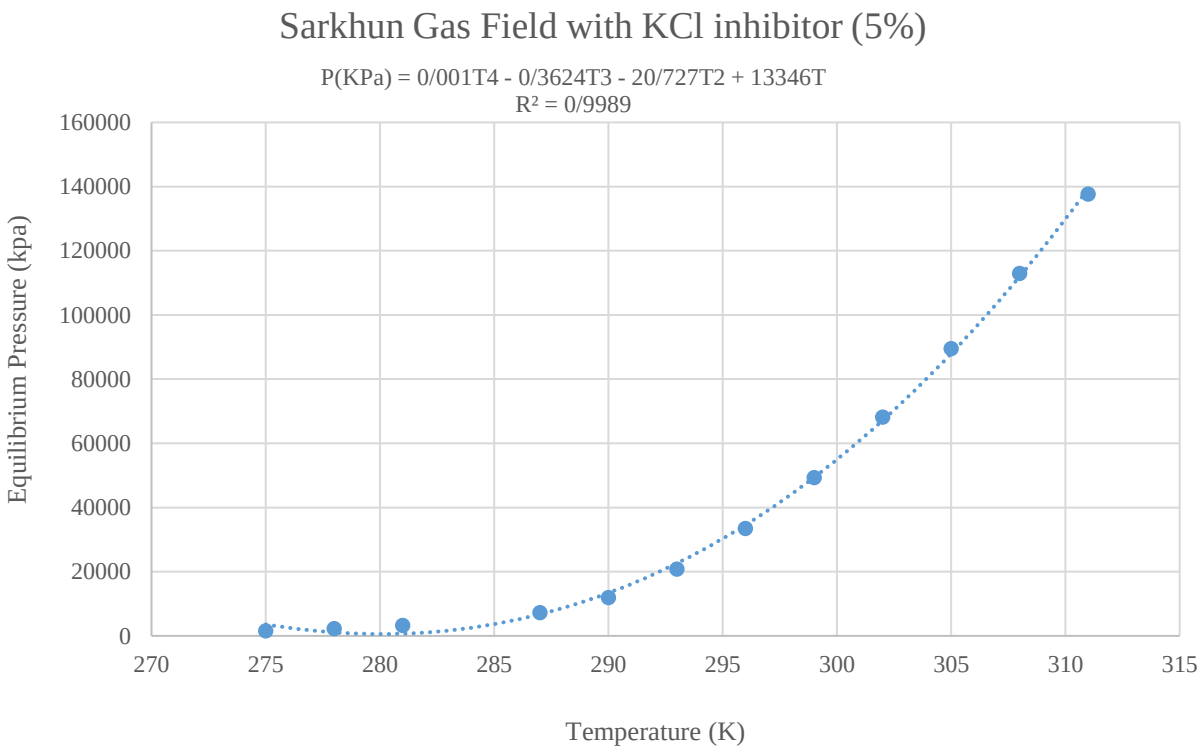

Figure 5. Sarkhun gas field hydrate formation with KCl inhibitor (5%).

Table 5. Khangiran gas field hydrate formation conditions with KCl inhibitor (5%)

Temperature (K)	Equilibrium Hydrate:	Composition of Phases at Equilibrium (moles)				Equilibrium Pressure (kpa)	Fractional Occupancy of Cages	
		FEED	Water	Liquid	Hydrate		Small	Large
275	CH4	0/9855	0/001	0/9855	0/8744	3237/955	0/852	0/63559
	C2H6	0/0065	0	0/0065	0/0315		0	0/08433
	C3H8	0/0007	0	0/0007	0/0651		0	0/1742
	I-C4H10	0/0002	0	0/0002	0/0241		0	0/0646
	n-C4H10	0/0004	0	0/0004	0/0048		0	0/0129
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
281	CH4	0/9855	0/0015	0/9855	0/9074	6273/828	0/8931	0/7227
	C2H6	0/0065	0	0/0065	0/8274		0	0/0759
	C3H8	0/0007	0	0/0007	0/0464		0	0/1283
	I-C4H10	0/0002	0	0/0002	0/0156		0	0/0431
	n-C4H10	0/0004	0	0/0004	0/0032		0	0/0009
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0

	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
284	CH4	0/9855	0/0019	0/9855	0/97	8872/807	0/9309	0/9478
	C2H6	0/0065	0	0/0065	0/83		0	0/0389
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
287	CH4	0/9855	0/0023	0/9855	0/9749	12448/504	0/9415	0/9561
	C2H6	0/0065	0	0/0065	0/0251		0	0/0327
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
290	CH4	0/9855	0/0028	0/9855	0/9793	17836/09	0/9515	0/9637
	C2H6	0/0065	0	0/0065	0/0207		0	0/027
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
290	CH4	0/9855	0/0028	0/9855	0/9793	17836.262	0/9515	0/9637
	C2H6	0/0065	0	0/0065	0/0207		0	0/027
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
293	CH4	0/9855	0/0033	0/9855	0/9826	25859/135	0/9609	0/9697

	C2H6	0/0065	0	0/0065	0/0174		0	0/0229
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
296	CH4	0/9855	0/0039	0/9855	0/9845	37102/363	0/9695	0/9837
	C2H6	0/0065	0	0/0065	0/0155		0	0/0205
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
299	CH4	0/9855	0/0046	0/9855	0/9853	51969.277	0/977	0/9762
	C2H6	0/0065	0	0/0065	0/0147		0	0/0195
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
302	CH4	0/9855	0/0054	0/9855	0/9853	70707.625	0/9833	0/9774
	C2H6	0/0065	0	0/0065	0/0147		0	0/0194
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
305	CH4	0/9855	0/0062	0/9855	0/9848	93500.313	0/9883	0/9776
	C2H6	0/0065	0	0/0065	0/0152		0	0/0202
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0

	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
308	CH4	0/9855	0/007	0/9855	0/9836	120479.047	0/9922	0/9767
	C2H6	0/0065	0	0/0065	0/0164		0	0/0218
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0
311	CH4	0/9855	0/0079	0/9855	0/9817	151754.469	0/9949	0/9747
	C2H6	0/0065	0	0/0065	0/0183		0	0/0243
	C3H8	0/0007	0	0/0007	0		0	0
	I-C4H10	0/0002	0	0/0002	0		0	0
	n-C4H10	0/0004	0	0/0004	0		0	0
	I-C5H12	0/0002	0	0/0002	0		0	0
	n-C5H12	0/0002	0	0/0002	0		0	0
	C6H14	0/0014	0	0/0014	0		0	0
	N2	0/005	0	0/005	0		0	0
	CO2	0	0	0	0		0	0

Salts in solution act by absorbing dipoles from water molecules. The ionic materials utilized operate as inhibitors thermodynamically by altering the equilibrium three-phase equilibrium graph. In fact, hydrates develop at lower temperatures and greater pressures in the presence of these materials than in the absence of any additions. The saline characteristics of these chemicals are thought to be the cause of their inhibitory effect. When the thermodynamic effects of two ionic liquids on hydrate are compared, the ionic liquid is found to be the higher inhibitor.

Table 6. Sarkhun gas field hydrate formation conditions with KCl inhibitor (5%)

Temperature (K)	Equilibrium Hydrate:	Composition of Phases at Equilibrium (moles)				Equilibrium Pressure (kpa)	Fractional Occupancy of Cages	
		FEED	Water	Liquid	Hydrate		Small	Large
275	CH4	0/8809	0/0005	0/8809	0/6331	1599/843	0/7253	0/0905
	C2H6	0/0342	0	0	0/0315		0	0/077
	C3H8	0/0127	0	0	0/2438		0	0/5952
	I-C4H10	0/0029	0	0	0/0837		0	0/2043
	n-C4H10	0/0037	0	0	0/01		0	0/0243

	I-C5H12	0/0012	0	0	0		0	0
	n-C5H12	0/0007	0	0	0		0	0
	C6H14	0/0009	0	0	0		0	0
	N2	0/0575	0	0	0		0	0
	CO2	0/0053	0/0001	0/0001	0		0	0
278	CH4	0/0005	0/0006	0/6331	0/6481	2273/071	0/7669	0/1033
	C2H6	0	0	0/0315	0/0322		0	0/0814
	C3H8	0	0	0/2438	0/2324		0	0/5871
	I-C4H10	0	0	0/0837	0/0778		0	0/1964
	n-C4H10	0	0	0/01	0/0095		0	0/024
	I-C5H12	0	0	0	0		0	0
	n-C5H12	0	0	0	0		0	0
	C6H14	0	0	0	0		0	0
	N2	0	0	0	0		0	0
	CO2	0/0001	0/0001	0	0		0	0
281	0/0005	0/0006	0/0008	0/6331	0/6648	3255/267	0/8047	0/1204
	0	0	0	0/0315	0/0333		0	0/0865
	0	0	0	0/2438	0/2215		0	0/5763
	0	0	0	0/0837	0/0716		0	0/1863
	0	0	0	0/01	0/0089		0	0/0232
	0	0	0	0	0		0	0
	0	0	0	0	0		0	0
	0	0	0	0	0		0	0
	0	0	0	0	0		0	0
	0/0001	0/0001	0/0001	0	0		0	0
284	0/0005	0/0006	0/001	0/6331	0/6827	4760/274	0/8398	0/1452
	0	0	0/0001	0/0315	0/0348		0	0/093
	0	0	0	0/2438	0/2098		0	0/5608
	0	0	0	0/0837	0/0645		0	0/1725
	0	0	0	0/01	0/0082		0	0/0218
	0	0	0	0	0		0	0
	0	0	0	0	0		0	0
	0	0	0	0	0		0	0
	0	0	0	0	0		0	0
	0/0001	0/0001	0/0002	0	0		0	0
287	0/0005	0/0006	0/0014	0/6331	0/705	7238/849	0/8726	0/1856
	0	0	0/0001	0/0315	0/037		0	0/1014
	0	0	0	0/2438	0/1953		0	0/5348
	0	0	0	0/0837	0/0556		0	0/1524
	0	0	0	0/01	0/0071		0	0/0194
	0	0	0	0	0		0	0
	0	0	0	0	0		0	0
	0	0	0	0	0		0	0

	0	0	0/0001	0	0		0	0
	0/0001	0/0001	0/0002	0	0		0	0
290	0/0005	0/0006	0/0018	0/6331	0/7388	11947/504	0/9047	0/2614
	0	0	0/0001	0/0315	0/0398		0	0/1117
	0	0	0	0/2438	0/1725		0	0/4834
	0	0	0	0/0837	0/0434		0	0/1218
	0	0	0	0/01	0/0055		0	0/0154
	0	0	0	0	0		0	0
	0	0	0	0	0		0	0
	0	0	0	0	0		0	0
	0	0	0	0	0		0	0
	0/0001	0/0001	0/0003	0	0		0	0
290	CH4	0.8809	0.0018	0.8809	0.7388	11947.620	0.9047	0.2614
	C2H6	0.0342	0.0001	0.0342	0.0398		0.0000	0.1117
	C3H8	0.0127	0.0000	0.0127	0.1725		0.0000	0.4834
	I-C4H10	0.0029	0.0000	0.0029	0.0434		0.0000	0.1218
	n-C4H10	0.0037	0.0000	0.0037	0.0055		0.0000	0.0154
	I-C5H12	0.0012	0.0000	0.0012	0.0000		0.0000	0.0000
	n-C5H12	0.0007	0.0000	0.0007	0.0000		0.0000	0.0000
	C6H14	0.0009	0.0000	0.0009	0.0000		0.0000	0.0000
	N2	0.0575	0.0001	0.0575	0.0000		0.0000	0.0000
	CO2	0.0053	0.0003	0.0053	0.0000		0.0000	0.0000
293	CH4	0.8809	0.0025	0.8809	0.7803	20819.506	0.9320	0.3661
	C2H6	0.0342	0.0001	0.0342	0.0409		0.0000	0.1168
	C3H8	0.0127	0.0000	0.0127	0.1431		0.0000	0.4090
	I-C4H10	0.0029	0.0000	0.0029	0.0318		0.0000	0.0909
	n-C4H10	0.0037	0.0000	0.0037	0.0039		0.0000	0.0113
	I-C5H12	0.0012	0.0000	0.0012	0.0000		0.0000	0.0000
	n-C5H12	0.0007	0.0000	0.0007	0.0000		0.0000	0.0000
	C6H14	0.0009	0.0000	0.0009	0.0000		0.0000	0.0000
	N2	0.0575	0.0001	0.0575	0.0000		0.0000	0.0000
	CO2	0.0053	0.0003	0.0053	0.0000		0.0000	0.0000
296	CH4	0.8809	0.0031	0.8809	0.8039	33491.090	0.9507	0.4272
	C2H6	0.0342	0.0001	0.0342	0.0395		0.0000	0.1144
	C3H8	0.0127	0.0000	0.0127	0.1259		0.0000	0.3648
	I-C4H10	0.0029	0.0000	0.0029	0.0273		0.0000	0.0789
	n-C4H10	0.0037	0.0000	0.0037	0.0034		0.0000	0.0098
	I-C5H12	0.0012	0.0000	0.0012	0.0000		0.0000	0.0000
	n-C5H12	0.0007	0.0000	0.0007	0.0000		0.0000	0.0000
	C6H14	0.0009	0.0000	0.0009	0.0000		0.0000	0.0000
	N2	0.0575	0.0002	0.0575	0.0000		0.0000	0.0000
	CO2	0.0053	0.0003	0.0053	0.0000		0.0000	0.0000
299	CH4	0.8809	0.0037	0.8809	0.8108	49364.129	0.9641	0.4429

	C2H6	0.0342	0.0001	0.0342	0.0378		0.0000	0.1104
	C3H8	0.0127	0.0000	0.0127	0.1206		0.0000	0.3527
	I-C4H10	0.0029	0.0000	0.0029	0.0274		0.0000	0.0802
	n-C4H10	0.0037	0.0000	0.0037	0.0035		0.0000	0.0101
	I-C5H12	0.0012	0.0000	0.0012	0.0000		0.0000	0.0000
	n-C5H12	0.0007	0.0000	0.0007	0.0000		0.0000	0.0000
	C6H14	0.0009	0.0000	0.0009	0.0000		0.0000	0.0000
	N2	0.0575	0.0003	0.0575	0.0000		0.0000	0.0000
	CO2	0.0053	0.0003	0.0053	0.0000		0.0000	0.0000
302	CH4	0.8809	0.0043	0.8809	0.8072	68182.047	0.9741	0.4296
	C2H6	0.0342	0.0001	0.0342	0.0361		0.0000	0.1063
	C3H8	0.0127	0.0000	0.0127	0.1222		0.0000	0.3600
	I-C4H10	0.0029	0.0000	0.0029	0.0306		0.0000	0.0900
	n-C4H10	0.0037	0.0000	0.0037	0.0040		0.0000	0.0116
	I-C5H12	0.0012	0.0000	0.0012	0.0000		0.0000	0.0000
	n-C5H12	0.0007	0.0000	0.0007	0.0000		0.0000	0.0000
	C6H14	0.0009	0.0000	0.0009	0.0000		0.0000	0.0000
	N2	0.0575	0.0004	0.0575	0.0000		0.0000	0.0000
	CO2	0.0053	0.0004	0.0053	0.0000		0.0000	0.0000
305	CH4	0.8809	0.0049	0.8809	0.7969	89543.523	0.9815	0.3969
	C2H6	0.0342	0.0001	0.0342	0.0343		0.0000	0.1015
	C3H8	0.0127	0.0000	0.0127	0.1278		0.0000	0.3784
	I-C4H10	0.0029	0.0000	0.0029	0.0362		0.0000	0.1072
	n-C4H10	0.0037	0.0000	0.0037	0.0048		0.0000	0.0143
	I-C5H12	0.0012	0.0000	0.0012	0.0000		0.0000	0.0000
	n-C5H12	0.0007	0.0000	0.0007	0.0000		0.0000	0.0000
	C6H14	0.0009	0.0000	0.0009	0.0000		0.0000	0.0000
	N2	0.0575	0.0004	0.0575	0.0000		0.0000	0.0000
	CO2	0.0053	0.0004	0.0053	0.0000		0.0000	0.0000
308	CH4	0.8809	0.0055	0.8809	0.7822	112910.578	0.9868	0.3516
	C2H6	0.0342	0.0001	0.0342	0.0321		0.0000	0.0956
	C3H8	0.0127	0.0000	0.0127	0.1352		0.0000	0.4020
	I-C4H10	0.0029	0.0000	0.0029	0.0443		0.0000	0.1316
	n-C4H10	0.0037	0.0000	0.0037	0.0061		0.0000	0.0183
	I-C5H12	0.0012	0.0000	0.0012	0.0000		0.0000	0.0000
	n-C5H12	0.0007	0.0000	0.0007	0.0000		0.0000	0.0000
	C6H14	0.0009	0.0000	0.0009	0.0000		0.0000	0.0000
	N2	0.0575	0.0005	0.0575	0.0000		0.0000	0.0000
	CO2	0.0053	0.0004	0.0053	0.0000		0.0000	0.0000
311	CH4	0.8809	0.0060	0.8809	0.7652	137725.984	0.9906	0.2996
	C2H6	0.0342	0.0001	0.0342	0.0296		0.0000	0.0882
	C3H8	0.0127	0.0000	0.0127	0.1427		0.0000	0.4253
	I-C4H10	0.0029	0.0000	0.0029	0.0546		0.0000	0.1628

	n-C4H10	0.0037	0.0000	0.0037	0.0079		0.0000	0.0235
	I-C5H12	0.0012	0.0000	0.0012	0.0000		0.0000	0.0000
	n-C5H12	0.0007	0.0000	0.0007	0.0000		0.0000	0.0000
	C6H14	0.0009	0.0000	0.0009	0.0000		0.0000	0.0000
	N2	0.0575	0.0006	0.0575	0.0000		0.0000	0.0000
	CO2	0.0053	0.0004	0.0053	0.0000		0.0000	0.0000

As shown in the figures, at higher temperatures, inhibitors are more effective, and as shown in the figures, at a given concentration, the process of change is slower for reduced temperatures, but the slope increases dramatically at higher temperatures.

In the presence of a sodium chloride inhibitor, the following conditions are required for hydrate formation: The presence of these substances lowers the surface tension between liquid and gas, which is a desirable property for two-phase interaction and enhances the likelihood of nucleation at the liquid-gas interface.

3. Conclusion

The phenomenon of hydrate formation in different parts of the oil and gas industry in downstream processes causes production to stop and reduce production, so the study of how it occurs and the conditions for hydrate formation is important and vital. The importance of the study in this field goes back to the issue of the transfer of natural gas as hydrate in order to reduce costs, increase the volume of transferred gas and suitably thermodynamic conditions.

In this study, the hydrate formation conditions of the Khangiran and Sarkhun gas fields in Iran were investigated in terms of the involvement and lack of inhibitors, and the results were compared to experimental results in this field. The introduction of additives such as inhibitors alters the liquid phase behavior, causing it to deviate from the optimum solution. Finally, the findings revealed that the current model was capable of accurately predicting the situation and that the checked results can indeed be relied upon with a high degree of confidence.

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