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Research on Molecular Diffusion Coefficient of Gas-Oil System Under High Temperature and High Pressure

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1. Introduction

As the technology of enhanced oil recovery by gas injection has already been applied worldwide, the research of the transmit mechanism between injected-gas and oil is important to the optimization of gas injection plan. Diffusion is an important phenomenon during the process of gas injection displacement. Because of diffusion, gas molecules will penetrate into the oil phase, while the oil will penetrate into the gas phase. Oil and gas could get balance with time. Diffusion affects the parameters of system pressure, component properties and balance time, which thus affect the efficiency of displacement. Molecular diffusion, which we usually refer to, includes mass transfer diffusion and self-diffusion. Mass transfer diffusion mainly occurs in non-equilibrium condition of the chemical potential gradient (μ_i) .The moleculars move from high chemical potential to low chemical potential of molecular diffusion until the whole system reaching equilibrium. The self-diffusion refers to free movement of molecules (or Brownian motion) in the equilibrium conditions. Mass transfer diffusion and self-diffusion can be quantitatively described by the diffusion coefficient. Up till now, there is no way to test the molecular diffusion coefficient directly. As for the question how to obtain the diffusion coefficient, it is a requirement to establish the diffusion model firstly, and then obtain the diffusion coefficient by analysis of experiments' results.

2. Traditional diffusion theory

2.1 Fick's diffusion law

Fick's law is that unit time per through unit area per the diffusive flux of materials is proportional directly to the concentration gradient, defined as the diffusion rate of that component A during the diffusion.

$$J_A \propto \frac{dc_A}{dz} \quad \text{or} \quad J_A = -D_{AB}\frac{dc_A}{dz} \tag{1}$$

Where, J_A — mole diffusive flux, $kmol \cdot m^{-2} \cdot s^{-1}$;
z — distance of diffusion direction;

$\frac{dc_A}{dz}$ —concentration gradient of component A at z-direction, $\left(kmol/m^3\right)/m$;

D_{AB} —the diffusion coefficient of component A in component B, $m^2 \cdot s^{-1}$.

Therefore, Fick's law says diffusion rate is proportional to concentration gradient directly and the ratio coefficient is the molecular diffusion coefficient. The Fick's diffusion law is called the first form.

Gas diffusion:

$$N_A = J_A = -D\frac{dc_A}{dz} \tag{2}$$

For:

$$c_A = \frac{n_A}{v} = \frac{p_A}{RT} \tag{3}$$

We can obtain:

$$N_A = -\frac{D}{RT}\frac{dp_A}{dz} \tag{4}$$

$$N_A \int_0^z dz = -\frac{D}{RT}\int_{p_A}^{p_i} dp_A \tag{5}$$

$$N_A \cdot z = \frac{D}{RT}\left(p_A - p_i\right) \tag{6}$$

$$N_A = \frac{D}{RTz}\left(p_A - p_i\right) \tag{7}$$

Define $\frac{D}{RTz} = k_G$ (k_G -mass transfer coefficient) ,then:

$$N_A = k_G\left(p_A - p_i\right) \tag{8}$$

Similarly, we can obtain the liquid phase diffusion, which is written as follows:

$$N_A = k_L\left(c_i - c_A\right) \tag{9}$$

Where $k_L = \frac{D}{z}$

Fick also presented a more general conservation equation:

$$\frac{\partial c_1}{\partial t} = D\left(\frac{\partial^2 c_1}{\partial z^2} + \frac{1}{A}\frac{\partial A}{\partial z}\frac{\partial c_1}{\partial z}\right) \quad t > 0, 0 < x < L \tag{10}$$

When area A is constant, eq. 10 become a basic equation of one-dimensional unsteady state diffusion, which is also known as Fick's second law.

Fick's second law describes the concentration change of diffusion material during the process of diffusion. From the first law and the second law, we can see that the diffusion coefficient D is independent of the concentration. At a certain temperature and pressure, it is a constant. Under such conditions, the concentration of diffusion equation can be obtained by making use of initial conditions and boundary conditions in the diffusion process, and then the diffusion coefficient could be gotten by solving the concentration of diffusion equation.

3. Molecular diffusion coefficient model

3.1 Establishment of diffusion model

In 2007, through the PVT experiments of molecular diffusion, Southwest Petroleum University, Dr. Wang Zhouhua established a non-equilibrium diffusion model and obtained a multi-component gas diffusion coefficient. The establishment of the model is shown in fig.1, with the initial composition of the known non-equilibrium state in gas and liquid phase. During the whole experiment process, temperature was kept being constant. The interface of gas - liquid always maintained a balance, considering the oil phase diffuses into the vapor phase. When the diffusion occurs, the system pressure, volume and composition of each phase will change with time until the system reaches balance.

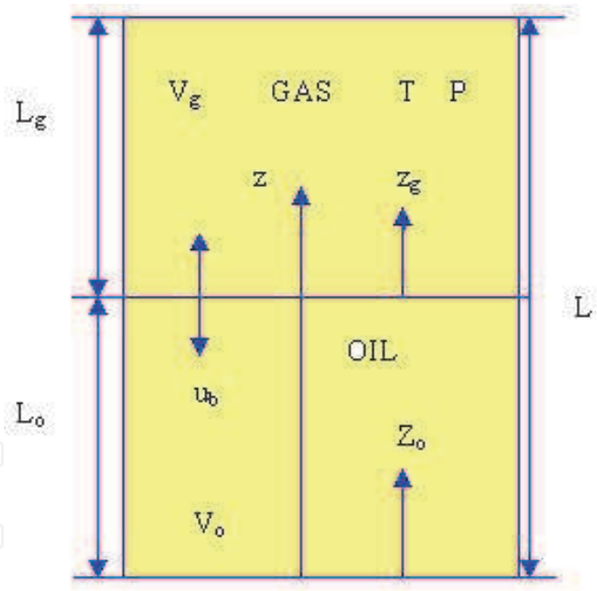


Fig. 1. Physical model schematic drawing

As shown in fig.1, x_i and y_i are i-composition molar fraction of liquid and gas phase respectively. C_{oi} and C_{gi} are i-composition mass fraction of liquid and gas phase respectively. ni is the total mole fraction of i-composition, mi is the total mass fraction of i-composition. L_o and L_g are the height of liquid and gas phase respectively. μ_b, defined as $\partial L_o / \partial t$, is the rate of movement of gas-liquid interface. z, z_o and z_g are coordinate axis as shown in fig.1.

If there is component concentration gradation, diffusion between gas and liquid phase will occur. Under the specific physical conditions of PVT cell, when gas phase diffuses into oil phase, the density of oil phase will decrease. According to the physical characteristics of diffusion, the concentration of light component in oil phase at the gas-liquid interface is higher than that of oil phase at the bottom of PVT cell, that is to say, the vector direction of concentration gradient of light component in oil phase is consistent with the coordinate direction of oil phase z_o. From the above analysis, we can see oil density along the coordinate direction is gradually decreasing, so there is no natural convection. The established models with specific boundary condition are as follows:
Oil phase:

$$\begin{cases} \dfrac{\partial C_{oi}}{\partial t} = \dfrac{\partial}{\partial z_o}\left[D_{oi} \dfrac{\partial C_{oi}}{\partial z_o} \right] \\ C_{oi}\left(z_o, 0\right) = C_{oi}^{1}\left(z_o\right) \\ \dfrac{\partial C_{oi}\left(0,t\right)}{\partial z_o} = 0 \\ C_{oi}\left(L_o, t\right) = C_{obi} \end{cases} \tag{11}$$

Gas phase:

$$\begin{cases} \dfrac{\partial C_{gi}}{\partial t} = \dfrac{\partial}{\partial z_g}\left[D_{gi} \dfrac{\partial C_{gi}}{\partial z_g} \right] \\ C_{gi}\left(z_g, 0\right) = C_{gi}^{1}\left(z_g\right) \\ C_{gi}\left(0,t\right) = C_{gbi} \\ \dfrac{\partial C_{gi}\left(L_g,t\right)}{\partial z_g} = 0 \end{cases} \tag{12}$$

C_{oi}^{1}, C_{gi}^{1} are i-component initial molar concentration of oil and gas phase, respectively, $kmol/m^3$.
C_{obi}, C_{gbi} are i-component molar concentration of oil and gas phase at oil-gas interface respectively, $kmol/m^3$.
In order to study the law of mutual diffusion between components, eq. 11 and 12 need to be solved. Because the velocity of gas-oil interface movement during the diffusion process is rather slow, we introduce a time step Δt. Then, we assume that gas-oil interface doesn't move, the height of oil and gas phase keeps the same, molar concentration at boundary and C_{obi}, C_{gbi} are constant during the whole time step,. And in the next time step, refresh the L_o, L_g and their values are the calculated result of the former time step, so each component concentration of oil and gas phase can be calculated. Continue the circular calculation like this way till gas and liquid phase reach balance. The detailed calculation procedure is as follows in fig. 2.

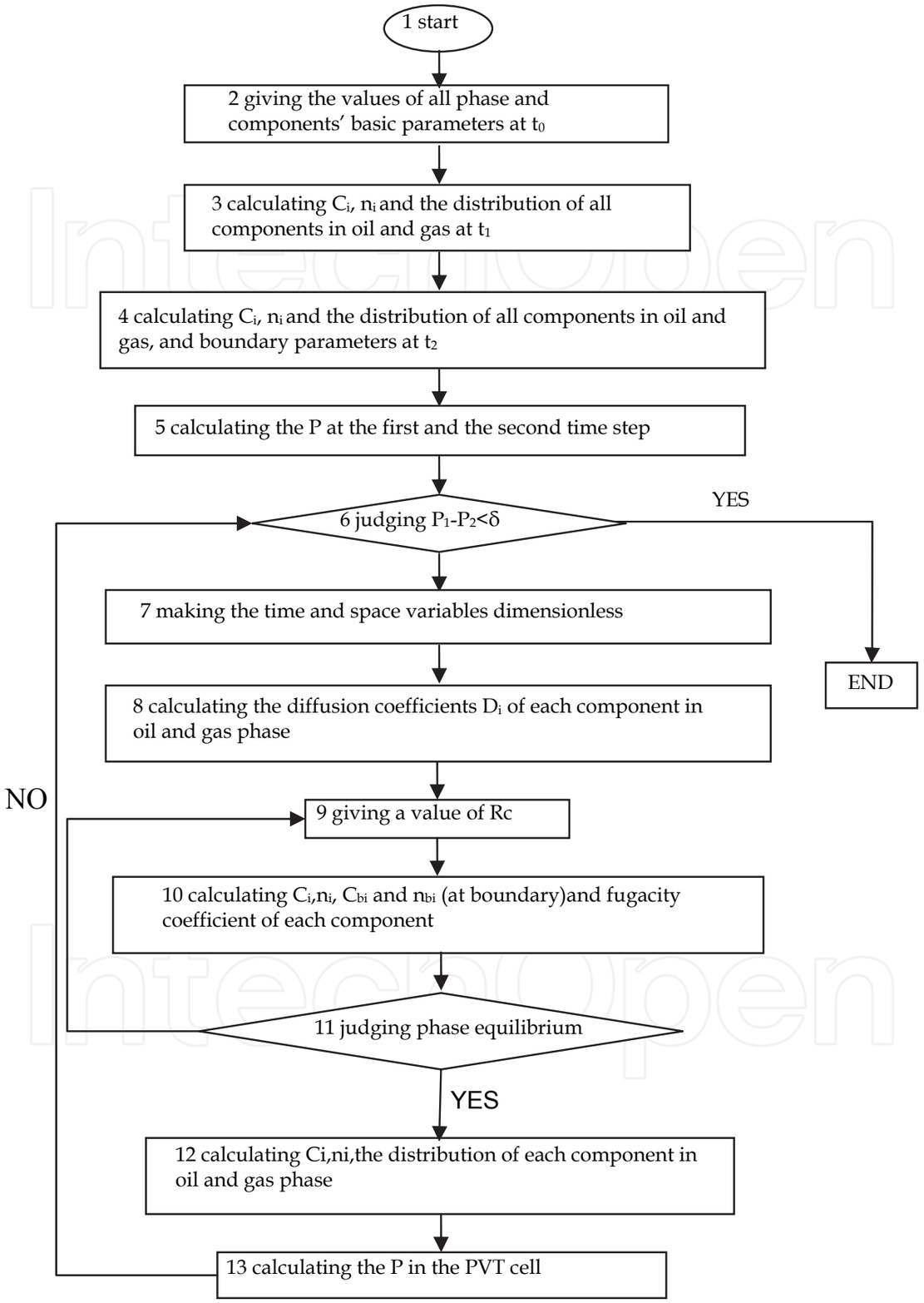


Fig. 2. Flow chart of calculation procedure

3.2 Model solution

Effective diffusion coefficient of each component directly affects the time to reach the balance for the whole system during the calculation procedure. There is no absolutely accurate general calculation equation to calculate the diffusion coefficient of i-component in oil phase and gas phase, except using the empirical equation which is a relatively accurate method. The diffusion factor of i-component in oil phase usually is usually calculated by Will—Chang(1955) and that in gas phase by Chapman-Enskog empirical formula (1972). The initial K value of each component is calculated by Wilson function, and corrected by fugacity coefficient in every time step, while fugacity coefficient is calculated by PR-EOS. Compared with the computation model proposed for single component, the model is much closer to the actual simulation, since it has taken interaction among the components into consideration.

4. The molecule diffusion experiment

The experiment tested the three different diffusion coefficients of hree different N_2, CH_4 and CO_2 gases and the diffusion coefficient of the actual oil separator. Using the mathematical model, we obtained diffusion coefficient of the gas molecules by fitting the experimental pressure changes or gas-oil interface position change.

4.1 Experimental fluid samples

The composition of gas sample is shown in Tab-1. The composition of oil sample is shown in Tab-2. The oil sample is taken from surface separator. The average molecular weight of oil sample is 231.5 and the density is 0.8305, g / cm^3 .

name	component name and molar percentage,%									
	N_2	CO_2	C_1	C_2	C_3	iC_4	nC_4	iC_5	nC_5	C_6
N_2	98.23	—	1.67	—	—	—	—	—	—	—
CO_2	0.0796	98.181	1.6939	—	—	—	—	—	—	—
Dry gas	3.1951	2.5062	92.7098	1.3957	0.1182	0.0141	0.0278	0.0129	0.0032	0.0169

Table 1. Components of gas samples

name	volume fraction,%	molar mass,kg/kmol	critical temperature,K	critical pressure,MPa	acentric factor
iC_4	0.057	58.124	408.1	3.600	0.1840
nC_4	0.094	58.124	425.2	3.750	0.2015
iC_5	0.405	72.151	460.4	3.340	0.2286
nC_5	0.337	72.151	469.6	3.330	0.2524
C_6	5.073	86.178	507.5	3.246	0.2998
C_7	4.578	100.250	543.2	3.097	0.3494
C_8	5.125	114.232	570.5	2.912	0.3513
C_9	3.625	128.259	598.5	2.694	0.3908
C_{10}	3.683	142.286	622.1	2.501	0.4438
C_{11+}	77.020	156.313	643.6	2.317	0.4775

Table 2. Components of oil samples used in diffusion experiments

4.2 Experimental temperature and pressure

Three groups of gas diffusion tests are conducted. The first one is the diffusion test of CO_2-Oil (20*MPa*, 60℃); the second is the diffusion test of CH_4-oil (20 *MPa*, 60℃); the third is the diffusion test of N_2-Oil (20 *MPa*, 60℃).

4.3 Experimental apparatus and experimental procedures

4.3.1 Experimental apparatus

Diffusion experiments are conducted mainly in DBR phase behavior analyzer. The other equipments include injection pump system, PVT cell, flash separator, density meter, temperature control system, gas chromatograph, oil chromatograph, electronic balance and gas booster pump. The flow chart is shown in fig.3.

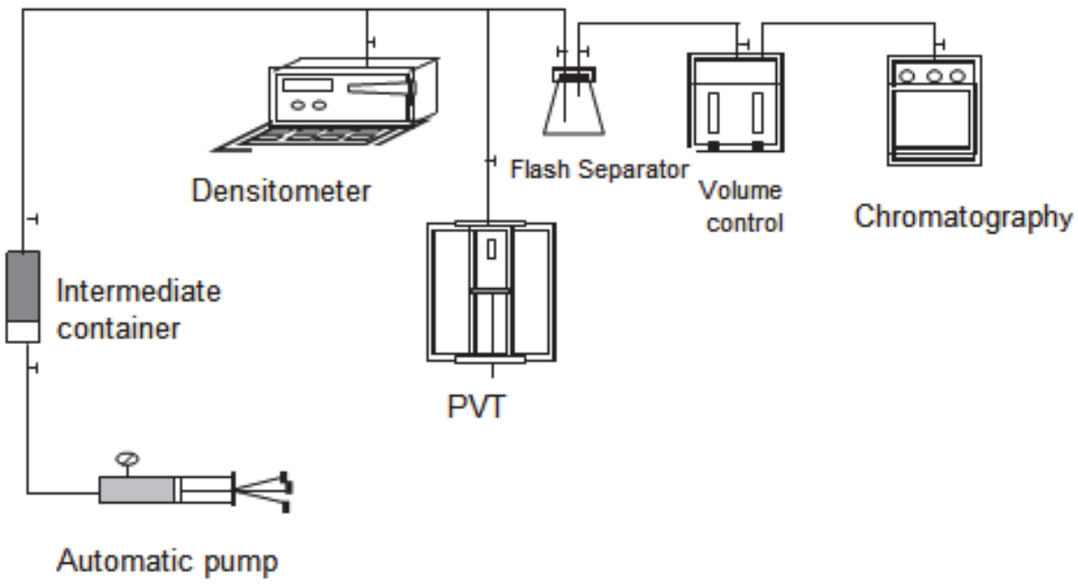


Fig. 3. The flow chart of diffusion experiment

4.3.2 Experimental procedures

Before testing, firstly, oil and gas sample under normal temperature are transferred into the intermediate container and put the middle container in a thermostatic oven. Then the oven is being heated up to 60℃ for 24 hours in general. The pressure of oil and gas sample under high-temperature is increased to the testing pressure—20*MPa*. Meanwhile, the temperature and pressure of PVT cell is increased to the experimental temperature and pressure, and then, the height of plunger is recorded. Secondly, transfer the oil sample into PVT cell and record the height of plunger again when the oil sample becomes steady. The difference of the two recorded heights is the oil volume. Thirdly, transfer the gas sample into PVT cell from the top of PVT cell. During the transferring process, it is necessary to keep a low sample transfer rate so that it would not lead to convection. Record the height of plunger and liquid level once completing sample transfer. Fourthly, start the diffusion test and make a record of time, pressure and liquid level. If variation of pressure is less than 1 psi during an interval of 30 minutes, it means gas-oil have reached the diffusive equilibrium and the

diffusion test is finished. And then, test the composition and density of oil phase and the composition of gas phase at different positions. Finally, wash the equipments with petroleum ether and nitrogen gas to prepare for the next experiment.

4.4 Experimental results and analysis

4.4.1 Experimental results

The test results are shown in Tab 3 and Fig 4.

Tab 3 has shown that the property of upper oil is different from that of lower oil in a certain extent. The component concentration of C_{11+} and flash density of the oil at upper position (upper oil) are lower than those at lower position (lower oil), but GOR of upper oil is obviously higher than that of the lower oil. Comparing the oil property of the three groups of experiment, it is found that the CO_2 concentration in oil phase and GOR in CO_2–oil diffusion experiment is higher than those of the other two gases diffusion experiments when the gas-oil system reaches balance. It shows that the high diffusion velocity, strong dissolving power and extraction to heavy components of CO_2 are the theory to explain the above phenomena.

component	upper oil phase			lower oil phase		
	N_2	CH_4	CO_2	N_2	CH_4	CO_2
CO_2	— —	1.1115	66.6284	— —	0.7231	66.3558
N_2	16.7464	0.8037	0.1354	10.8768	1.9091	0.0549
C_1	0.0256	34.3391	2.8402	0.0711	30.6201	1.9226
C_2	0.0052	0.7732	0.0231	0.0045	0.3081	0.0000
C_3	0.0394	0.1065	0.0397	0.0279	0.0240	0.0245
iC_4	0.1532	0.2481	0.1208	0.1084	0.1225	0.1035
nC_4	0.1981	0.3724	0.1715	0.1594	0.2431	0.1499
iC_5	0.4111	0.9540	0.4520	0.4545	0.4554	0.2850
nC_5	0.3091	0.7560	0.3594	0.3594	0.5611	0.2056
C_6	1.2669	5.6477	2.6848	1.6267	2.4097	0.8201
C_7	1.9029	5.6401	2.2140	2.9228	3.3796	1.0394
C_8	4.3693	7.1465	3.5759	5.7419	3.8080	2.1943
C_9	3.4355	5.2515	2.1883	4.9054	2.7312	1.6908
C_{10}	3.9898	4.6165	1.5017	4.5018	2.6389	1.9596
C_{11+}	67.1475	32.2331	17.0647	68.2393	50.0661	23.1940
GOR（m3/m3)	13.62	71.78	255	11.53	61	232.8
ρ_o（kg/m3）	822.6	821.9	825	823.8	822.9	830.2

Table 3. Comparision of oil component and composition at different position at the end of test

Fig4 has shown that system pressure drawdown curve due to diffusion displays that pressure is declining gradually with time. The pressure history curve of CO_2-oil diffusion test lies below, CH_4-oil lies middle, N_2-oil lies above. Hence, we can see that different diffusion tests have different rates of pressure drawdown. It shows that the diffusion velocity of CO_2 is the fastest, CH_4 is slower and N_2 is the slowest. For each group of diffusion experiment, the pressure drawdown is also different. The pressure drop of N_2-oil is 1.14MPa, CH_4-oil is 4.55*MPa* and CO_2-oil is 3.9*MPa*.

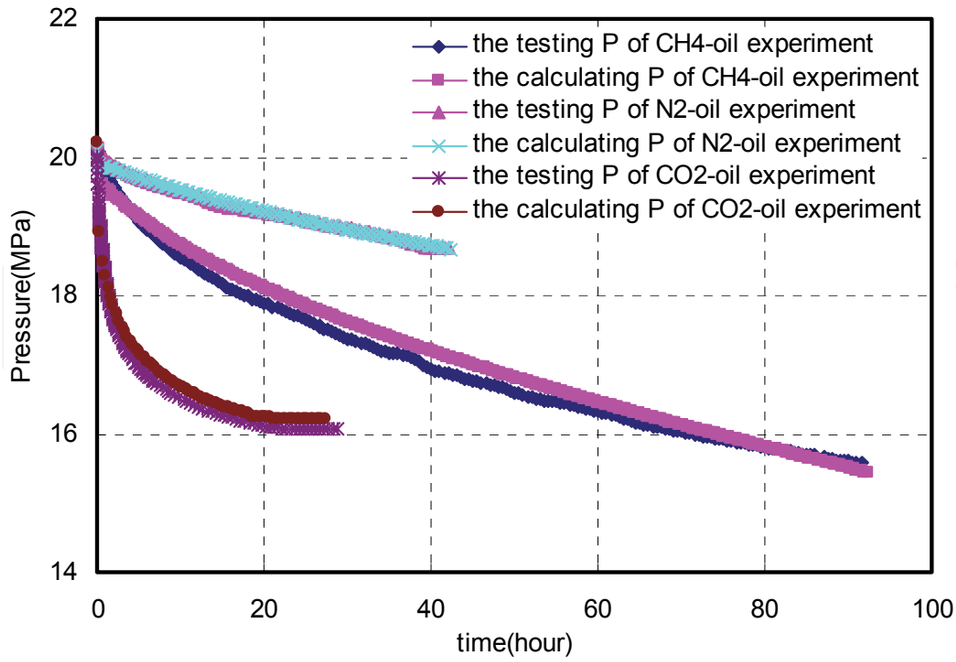


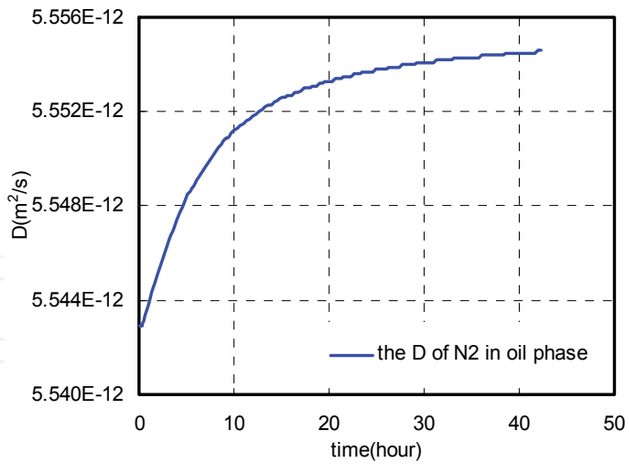
Fig. 4. Contrast of pressure variation of three groups of experiments

The diffusion coefficient is obtained by using established model to match the variation in pressure. Pressure matching is shown in fig.4. The matching result is fairly good. Normally, diffusion coefficient of gas in oil phase is most practical problem in engineering project; the diffusion coefficients of gas in oil phase of the three diffusion tests are shown in fig.5. Fig. 5 indicates that the diffusion coefficient, which increases with the decrease of pressure till the system reaches balance, is variable. The final calculated mole fraction of N_2 in oil phase when in balance is 12.86%, testing value varies from 16.7464%—10.8767% in the different positions at the end of the experiment; For CH_4-oil, the calculated result of CH_4 is 35.34%, the testing value ranges from 34.3391% to 37.6201%; and for CO_2-oil, the calculated result of CO_2 is 67.262% and the testing value ranges from 66.6284% to 66.3558%. The calculated value of component is close to the actual tested ones, which shows the established model and testing method are both reasonable.

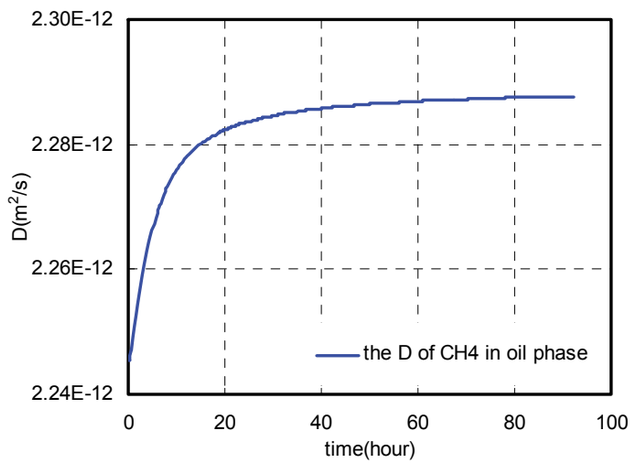
4.4.2 Experimental analysis

4.4.2.1 Equilibrium time

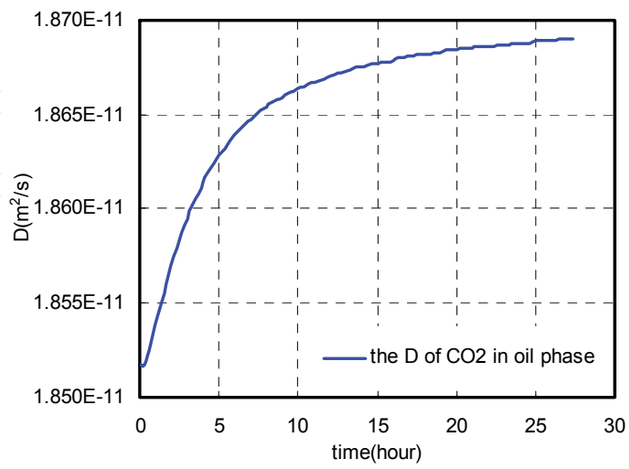
The comparison of the equilibrium time of N_2-oil, CO_2-oil and CH_4-oil system under the condition of 20MPa, 60℃ is displayed in Tab 4 which shows that the equilibrium time of CO_2-oil system is obviously less than that of N_2-oil and CH_4-oil system, because the diffusion velocity of CO_2-oil is higher than that of the other two gases. The equilibrium time of N_2-oil is less than that of CH_4-oil; however, it doesn't mean that the diffusion velocity of N_2-oil is higher than CH_4-oil. In fact the main reason is that the solubility of N_2 in the oil is lower, and after a certain time, N_2-oil has reached saturated at the testing temperature and pressure so it appears that the equilibrium time of N_2 is less than that of CH_4. Another reason is that dry gas is used in the experiment instead of CH_4 and there are some heavy components, such as N_2 and C_3H_8 in the dry gas, so the diffusion equilibrium time increases.



(a)



(b)



(c)

Fig. 5. Diffusion coefficient in liquid phase

The diffusion experiments of CO_2-dead oil have been conducted under the pressure of 1.36MPa, 0.8*MPa* and temperature of 20℃. abroad and the final equilibrium time was 35 and 27 minutes respectively. Compared with our test at high temperature and pressure, there is a great difference. It shows that pressure, temperature and oil composition have a dramatic influence on diffusion velocity. For the actual case of reservoir gas injection, the accurate shut-in time for the maximum oil recovery can be determined according to the testing results.

dissuasive gas	experimental condition	balance time, hour
N_2-oil	20*MPa*,60℃	42
CH_4-oil	20*MPa*,60℃	91.5
CO_2-oil	20*MPa*,60℃	27.33

Table 4. Balance time for different gas-oil systems

4.4.2.2 Pressure comparison

The comparison of pressure variation of the four diffusion experiments is shown in fig.6. It can be seen from fig.6, the pressure drop curve caused by the diffusion shows the pressure curve for CO_2 lies in the bottom, CH_4 lies in the middle, N_2 lies at the top. From the first phase of each pressure history curve, we can see, speed differences of different gases' pressure drop are significant. Therefore, the CO_2 diffusion rate is the fastest, CH_4 is second and N_2 is the slowest. Each diffusion experiment didn't have the same degree of pressure drop. The diffusion pressure drop of N_2-oil diffusion was 1.14MPa, diffusion pressure drop of CH_4-oil was 4.55MPa. CO_2-crude oil reduced to 3.7MPa; CO_2-crude oil diffusion pressure under the condition of 20MPa 80 ℃ reduced to 3.9MPa. The equilibrium pressure of four experiments was 18.68MPa, 15.57MPa, 16.4MPa and 16.3MPa respectively. CO_2-crude oil under the condition of 20MPa, 60 ℃, had a tendency of a period of diffusion pressure upward phase. From the two pressure curves of CO_2-crude oil, we can see that temperature on the early diffusion of CO_2 has some influence, the higher the temperature, the higher the rate of diffusion, but the final balance pressure has almost no difference. The shape of the pressure curves, except that of the pressure curve of CO_2-crude oil under the condition of 20MPa, 60℃ has abnormal pressure trend, the other three are essentially the same.

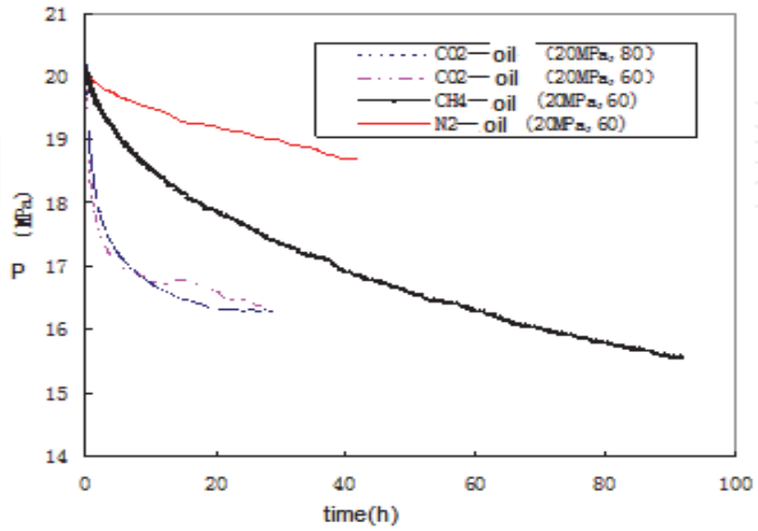


Fig. 6. The comparison of pressure variation of four diffusion experiments

4.4.2.3 Composition changes

The C_2-C_6 hydrocarbon compositions of four group of experiments are shown in Table 5, the comparison of oil phase composition is shown in Table 6.

experiment	upper gas,%	lower gas,%	remark
N_2—oil	0.3142	0.4740	20MPa,60℃
CH_4—oil	1.4974	5.5255	
CO_2—oil	1.1392	1.1524	
CO_2—oil	0.9445	1.7420	20MPa,80℃

Table 5. C_2—C_6 content contrast of gas phase

composition	upper oil				lower oil			
	N_2	CH_4	CO_2	CO_2 (80℃)	N_2	CH_4	CO_2	CO_2 (80 ℃)
CO_2		1.1115	74.6707	66.6284		0.7231	66.3558	66.5355
N_2	16.7464	0.8037	0.0606	0.1354	10.8768	1.9091	0.0549	0.0564
C_1	0.0256	34.3391	2.8120	2.8402	0.0711	37.6201	1.9226	1.8397
C_2	0.0052	0.7732	0.0000	0.0231	0.0045	0.3081	0.0000	0.0000
C_3	0.0394	0.1065	0.0252	0.0397	0.0279	0.0240	0.0245	0.0229
iC_4	0.1532	0.2481	0.1155	0.1208	0.1084	0.1225	0.1035	0.1274
nC_4	0.1981	0.3724	0.1666	0.1715	0.1594	0.2431	0.1499	0.1856
iC_5	0.4111	0.9540	0.3145	0.4520	0.4545	0.4554	0.2850	0.3851
nC_5	0.3091	0.7560	0.2260	0.3594	0.3594	0.5611	0.2056	0.2813
C_6	1.2669	5.6477	0.7177	2.6848	1.6267	2.4097	0.8201	0.7089
C_7	1.9029	5.6401	0.7219	2.2140	2.9228	3.3796	1.0394	0.8206
C_8	4.3693	7.1465	1.5241	3.5759	5.7419	3.8080	2.1943	1.9411
C_9	3.4355	5.2515	1.1743	2.1883	4.9054	2.7312	1.6908	1.5711
C_{10}	3.9898	4.6165	1.3611	1.5017	4.5018	2.6389	1.9596	1.8674
C_{11+}	67.1475	32.2331	16.1098	17.0647	68.2393	43.0661	23.1940	23.6572
GOR（m3/m3)	13.62	71.78	363.2	255	11.53	61	232.8	208.2
ρ_o（kg/m3）	822.6	821.9	827.7	825	823.8	822.9	830.2	831.4

Table 6. Oil content contrast of oil phase

4.4.2.4 Influence of system on diffusion coefficient

The calculated results of diffusion coefficient show that the diffusion coefficients of a certain component in different systems are not the same under the same temperature and pressure. Taking the injected gas for an example, as shown in Tab7, diffusion coefficient of each component of gas and liquid phase in the CO_2-oil system is higher than that of N_2-oil and CH_4-oil system, which is consistent with the diffusion phenomenon observed within the experiment. In the same system, diffusion coefficients of the identical component in different phases are not the same. The diffusion coefficient of gas phase is higher than that of liquid phase. For the phenomena above, there are two reasons, one is interaction between components; the other is the influence caused by the system's state. Molecular motion in gas phase is quicker than that in liquid phase, so diffusive velocity in gas phase is faster.

component	diffusion coefficient in gas phase (final value)			diffusion coefficient in oil phase (final value)		
	N_2-oil	CH_4-oil	CO_2-oil	N_2-oil	CH_4-oil	CO_2-oil
N_2	1.932E-11	8.281E-11	2.403E-10	5.555E-12	3.978E-12	1.082E-11
C_1	1.944E-11	6.081E-11	2.690E-10	3.559E-12	2.287E-12	1.263E-11
CO_2	——	6.743E-11	2.723E-10	——	3.985E-12	1.869E-11

Table 7. Diffusion coefficient of identical component in different systems

Table 5 and Table 6 shows that the contents of intermediate hydrocarbon components in lower gas is higher than those in upper gas. The content of C_{11+} components in upper oil, density of single-off oil is lower than the latter, but the upper part of the oil phase gas-oil ratio was significantly higher than the lower oil phase. From the component data of different locations, we can see that the oil and gas properties are not the same, the concentration difference of C_{11+} components of N_2, CH_4, CO_2 and CO_2 (80℃) between the upper and lower oil is respectively 10.8330%, 7.0842 % and 6.5924%, so during the phase calculation, we must consider physical heterogeneity which is caused by molecular diffusion and others of the oil and gas. From the content of the pseudo-component, we can also see that solubility in oil and extraction capacity of N_2 are very low. Since the cause, the property of N_2-oil experiment between upper and lower oil have little difference. Because of CH_4 and CO_2 have the higher solubility in the oil and powerful extraction capacity, the property between the upper and lower oil has great difference. In addition, the content of the diffusion gas are not the same, and their content of the same diffusion experiment in upper oil is higher than that in lower oil. For different experiments,CO_2 gas diffusion experiments is the highest content of gas diffusion(66% -74%), which is followed by CH_4 (34%-37%) and a minimum of N_2 (10%-16%), the final molar concentration differences of the gas diffusion reflect the size of the gas diffusion capacity, the stronger the diffusion capacity is, the higher the molar concentration would be, whereas the lower.

4.4.2.5 Influence of molar concentration on diffusion coefficient

According to literature review, there are two different opinions about the problem whether component concentration has an influence on diffusion coefficient or not at present. Some scholars think that there is an influence of component concentration on diffusion coefficient while others think that there is no influence. Taking the component of injected gas diffusing into liquid phase at 60℃ as an example, the relationship of content and diffusion coefficient is shown in fig7, 8 and 9. These figures show that diffusion coefficient of gas changes with the concentration variation of gas diffusing in the liquid phase. Compared with the initial values, the molar concentration changing level of N_2,CH_4,CO_2 are 12.86%,34.087% and 67.262% respectively and the changing level of the diffusion coefficient of the three gases is 0.211%,1.88% and 0.934% respectively at the end of tests. The data above show that the rate of change of concentration differs from that of diffusion coefficient in different systems. N_2 has the smallest rate of change while the rate of change of CH_4 diffusion coefficient is the largest. Theoretically, the component concentration does have a certain impact on diffusion coefficient. But in engineering application, the impact on the diffusion coefficient can be ignored due to the small rate of change (<2%) under this experimental condition.

The gas injection is applied widely not only in oil-field, but also in condensate gas-field. Hence, further researches need to be done to make sure whether the diffusion phenomena of gas-gas and gas-volatile oil agree with the research result in this paper. The porous media has impact on the phase state of oil and gas, the diffusion in porous media should be the

first step for the study of diffusion issue. The molecular diffusion coefficient tested in the paper is under static condition; nevertheless, how to evaluate the molecular diffusion under dynamic condition needs to develop new theories and testing method further.

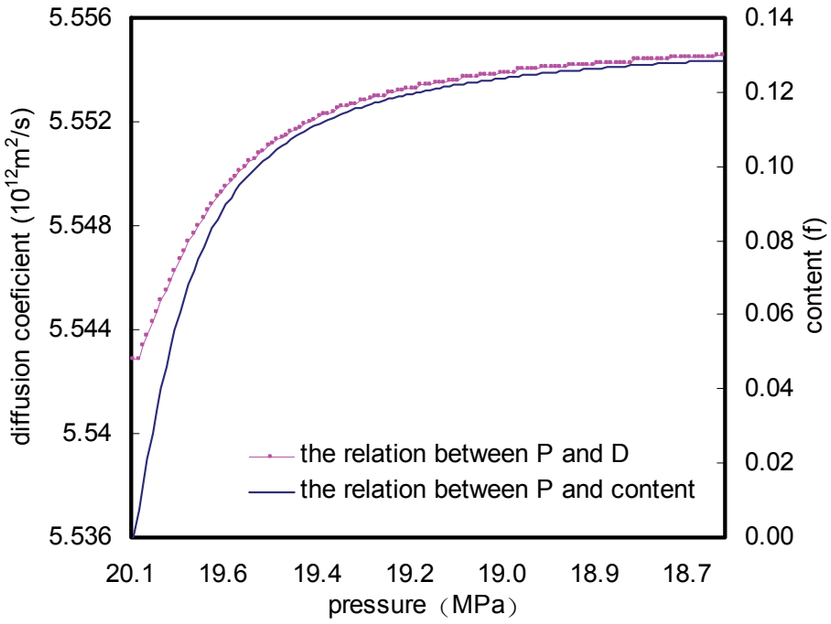


Fig. 7. Relationship of N_2 mole fraction in liquid phase and its diffusion coefficient in N_2-oil diffusion experiment

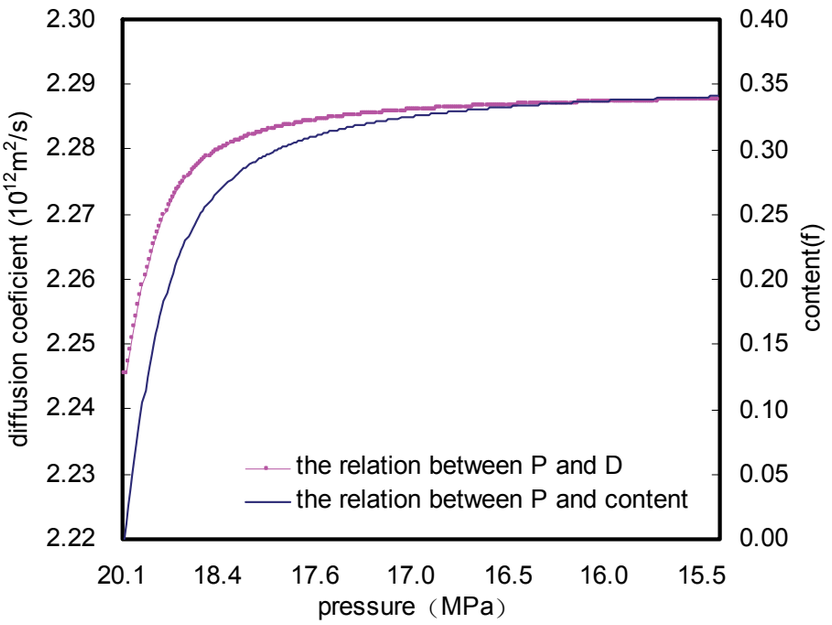


Fig. 8. Relationship of CH_4 mole fraction in liquid phase and its diffusion coefficient in CH_4-oil diffusion experiment

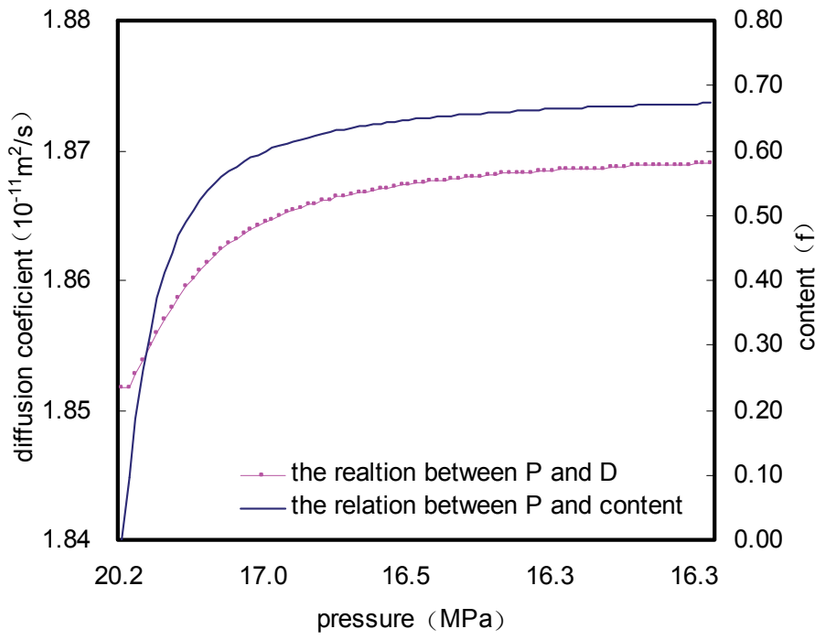


Fig. 9. Relationship of CO_2 mole fraction in liquid phase and its diffusion coefficient in CO_2-oil diffusion experiment

5. References

Reamer, H.H., Duffy, C.H., and Sage, B.H., Diffusion coefficients in hydrocarbon systems: methane – pentane in liquid phase[J]. Industrial Engineering Chemistry, 1958, 3:54-59

Gavalas, G.R., Reamer, H.H., Sage, B.H., Diffusion coefficients in hydrocarbon system. Fundaments, 1968, 7,306-312

Schmidt, T., Leshchyshyn, T.H., Puttagunta, V.R., Diffusion of carbon dioxide into Alberta bitumen.33d annual technical meeting of the petroleum society of CIM, Calgary, Canada,1982

Renner T A. Measurement and correlation of diffusion for CO_2 and rich gas applications[J]. SPE Res Eng, 1988,517-523

Nguyen, T.A., Faroup-Ali,S.M.,Role of diffusion and gravity segregation in oil recovery by immiscible carbon dioxide wag progress[C].In:UNITER international conference on heavy crude and tar sand, 1995, 12:393-403

Wang L S,Lang Z X and Guo T M. Measurements and correlation of the diffusion coefficients of carbon dioxide in liquid hydrocarbons under Elevated pressure[J]. Fluid phase equilibrium, 1996, 117:364-372

Riazi, M.R. A new method for experimental measurement of diffusion coefficients in reservoir fluids[J].SPEJ,1996,14 (5):235-250

Zhang, Y.P, Hyndman, C.L, Maini, B.B. Measuement of gas diffusivity in heavy oils[J]. SPEJ, 2000, 25 (4):37-475

Oballa, V.; Butler, R.M. An experimental-study of diffusion in the bitumen-toluene system. J. Can. Pet. Technol. 1989, 28 (2), 63-90

Das, S.K.; Butler, R.M. Diffusion coefficients of propane and butane in Peace River bitumen. Can. J. Chem. Eng. 1996, 74, 985-992

Wen, Y.; Kantzas, A.; Wang, G.J. Estimation of diffusion coefficients in bitumen solvent mixtures using low field NMR and X-ray CAT scanning, The 5th International Conference on Petroleum Phase Behaviour and Fouling, Banff, Alberta, Canada, June 13-17th, 2004

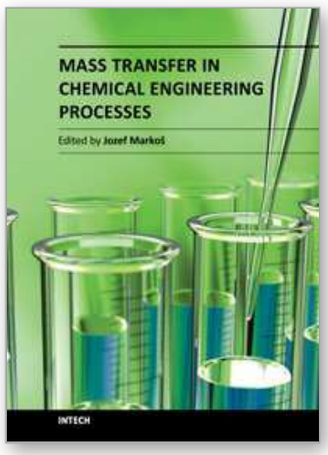
Chaodong Yang, Yongan GU.A new method for measuring solvent diffusivity in heavy oil by dynamic pendant drop shape analysis. SPE 84202,2003

R. Islas-Juarez, F. Samanego V., C. Perez-Rosales, et al. Experimental Study of Effective Diffusion in Porous Media.SPE92196,2004

Wilke C R and Chang P. Correlation of diffusion coefficients in dilute solutions[J]. AIChE Journal, 1955, 1(2):264-269

Chapman, EnskogThe Chapman-Enskog and Kihara approximations for isotopic thermal diffusion in gases[J]. Journal of Statistical Physics, 1975, 13(2):137-143

Riazi, M.R. A new method for experimental measurement of diffusion coefficients in reservoirfluids. SPEJ, 1996, 14(3-4): 235-250



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This book offers several solutions or approaches in solving mass transfer problems for different practical chemical engineering applications: measurements of the diffusion coefficients, estimation of the mass transfer coefficients, mass transfer limitation in separation processes like drying, extractions, absorption, membrane processes, mass transfer in the microbial fuel cell design, and problems of the mass transfer coupled with the heterogeneous combustion. I believe this book can provide its readers with interesting ideas and inspirations or direct solutions of their particular problems.

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