Pre	face		xix
In	trod	uction	
Ac		as Injection: Past, Present, and Future n J. Carroll	xxi
Se	ctio	n 1: Data and Correlation	
1.	Aci	uilibrium Water Content Measurements For d Gas Mixtures A. Marriott, E. Fitzpatrick, F. Bernard, H. H. Wan	3
		L. Lesage, P. M. Davis, and P. D. Clark	
		Introduction Available Literature Data	4
		Equilibration Vessels / Techniques	6
	1.0	1.3.1 The Visual Dew Point Cell, VDP	10
		1.3.2 The Stirred Autoclave, SA, and	10
		Basic Equilibrium Cell, EQ	11
		1.3.3 The Isolated Floating Piston with	•
		Micro Sampler, IFP/µS	13
	1.4	· · · · · · · · · · · · · · · · · · ·	14
	1.5	1 0	15
	1.6		17
	Ref	erences	19
2.	The	e Performance of State of the Art Industrial ermodynamic Models for the Correlation	24
		l Prediction of Acid Gas Solubility in Water rco A. Satyro and James van der Lee	21
	2.1		21
	2.2		22
		Water Content	28
		Conclusions and Recommendations	31
		knowledgements	33
		menclature	-33
	Sub	oscripts	34

	•	erscrip		34
		ek Lette		34
	Refe	erences		34
3.	The	Resea	rch on Experiments and Theories about	
			n High-Sulfur Gas Reservoirs	37
	•		Zhang Guangdong, Ye Changqing,	
	-		g and Liu Yanli	
			duction	38
		3.1.1	The Progress of Experimental Test in	
			High-CO, or H ₂ S-containing System	38
		3.1.2	- -	
			High-CO, or H,S-containing System	39
	3.2	Exper	rimental Tests	40
		3.2.1		40
		3.2.2	Experimental Samples	40
		3.2.3	Experimental Results	40
		3.2.4	Alcohol and Glycol Systems	41
		3.2.5	Electrolytes Systems	43
	3.3	Therr	nodynamic Model	44
		3.3.1	The Improvement of Chemical Potential	
			of Hydration Phase	44
		3.3.2	Calculation of Activity of Water Phase	47
		3.3.3		
			Water-gas- Electrolytes- Alcohols	47
		3.3.4	The Definition of Freezing Point in	
			Inhibitors-containing System	51
		3.3.5	Improved Prediction Model of Hydrate	51
	3.4	-	rimental Evaluation	52
		3.4.1	Experimental Evaluation of Thermodynamics	
			Prediction Model of Hydrate	52
		3.4.2	The Error Evaluation of the Improved	
			Model for Experimental Data	53
		3.4.3		53
	•	3.4.4	<u> </u>	54
		3.4.5	The Electrolytes Solution is Water-rich	
			in System	55
		3.4.6	The Mixed of Electrolytes and Methanol	_
			Solution is Water-rich in System	56
	3.5		lusions	57
			dgements	58
	Ref	erences	S	58

4.	An Association Model for the Correlation of the	
	Solubility of Elemental Sulfur in Sour Gases	61
	Bian Xiaoqing, Du ZHimin and Chen Jing	
	4.1 Introduction	61
	4.2 Derivation of an Association Model	62
	4.3 Calculation and Analysis of Solubility	67
	4.4 Conclusions	72
	Acknowledgements	73
	References	73
5.	Properties of CO ₂ Relevant To Sequestration – Density	75
	Sara Anwar and John J. Carroll	
	5.1 Introduction	75
	5.2 Review and Correlation	78
	5.2.1 Equations of State	78
	5.3 Density	80
	References	80
_	The Experimental Study of the Effect of the CO	
6.	The Experimental Study of the Effect of the CO ₂ Content on Natural Gas Properties at	
	_	04
	Gathering Conditions	81
	Du Jianfen, Hu Yue, Guo Ping, Deng Lei,	
	and Yang Suyun	
	6.1 Introduction	82
	6.2 Experimental Test Process	82
	6.3 Experimental Principles and Methods	83
	6.4 Experimental Conditions	83
	6.5 Analysis of Experimental Results	84
	6.6 Conclusions	102
Se	ction 2: Process Engineering	
7.	Dehydration of Acid Gas Prior	
	to Injection	107
	Eugene W. Grynia, John J. Carroll, and Peter J. Griffin	
	7.1 Introduction	107
	7.2 Acid Gas Phase Diagrams	108
	7.3 Water Content of Acid Gas	109
	7.4 Water Content of Acid Gas for Different Isotherms	111
	7.5 Effect of Impurities on Water Content of	
	Acid Gas	115
	7.6 Acid Gas Dehydration	116

		7.6.1	Compression and Cooling Alone	117
		7.6.2		118
	7.7	Hydra	ates of Acid Gas	125
	7.8	Concl	lusions	127
	Refe	rences		127
8.	Lim	itation	s And Challenges Associated With	
			sal Of Mercaptan-Rich Acid Gas Streams	
			on – A Case Study	129
	-	•	ı and John J. Carroll	
	8.1		erties of Mercaptans	130
			Pure Component Properties	130
		8.1.2	* -	131
		8.1.3	Water Content and Solubility	131
			Hydrates	131
	8.2	Limit	ations of Process Simulation Tools and	
		Proce	ess Design	132
		8.2.1	Vapour-Liquid Equilibria and	
			Hydrate Formation	133
		8.2.2	Water Content and Dehydration	
			Processes	133
	8.3	Case	Study	134
			Injection Pressures	136
		8.3.2	Phase Envelopes and Compression	136
		8.3.3	Dehydration	137
	8.4	Conc	lusions	139
	Refe	erences		139
9.	Aci	d Gas:	When to Inject and When to Incinerate	141
	Aud		ascarenhas	
	9.1		eration Technology	142
	9.2	Conc	lusion	145
10.	Dyı	namics	of Acid Gas Injection Well Operation	147
	R.N	Mireau	lt, R. Stocker, D. Dunn,	
	and	М. Ро	ooladi-Darvish	
	10.1	Intro	oduction	148
	10.2	Effe	ects of Gas Composition	152
	10.3	Dete	ermining Wellhead Operating Pressure	154
	10.4		nputing Wellbore Pressure Changes	156

	10.5	Examp	ole 1		157
	10.6	Examp	ole 2		159
	10.7	Sensiti	vity Analy	ysis	161
	10.8	Conclu	isions		163
	Ackn	owledg	ements		164
	Refer	rences			164
Sec	ction	3: CO ₂	Enhanc	ed Oil Recovery	
11.	Learı	nings fr	om CO ₂ N	Aiscible Floods Provides	
	Desi	gn Guid	lelines fo	r CO ₂ Sequestration	167
	Jim I	Louie			
		Introdu			167
	11.2	Encana	a Weyburi	n and Apache	
		Midale	Projects		169
			CO ₂ for EO		177
			ties of CC		178
			ehydratio		179
	11.6		als Selecti		182
				Carbon Dioxide Pipeline	182
				on Pipelines	183
		Merca			184
			Hazards o	of CO ₂	185
		Capita			187
		Summ	ary		189
	Refe	rences			189
12.				of CO ₂ Injection after Water	
		_	Xinli Oil		191
		•		Guo Xiao	
		Introd			192
			nli Field		192
	12.3		ooding Pa		193
		12.3.1		Dil Properties	193
			12.3.1.1	Fluid Properties under Surface	
				Condition	193
			12.3.1.2	Underground Fluid Properties	194
			12.3.1.3	Crude Oil Property after	
		4005	60 F	CO ₂ Flooding	194
		12.3.2		oding Displacement	
			Efficienc	cy .	195

CONTENTS

		12.3.3	The Com	parison between Different	
				ding Mode	196
	12.4	Numer	rical Śimu		197
				itional Model of Xinli Unit	197
				serve Matching	198
				Oil Distribution Prediction	198
	12.5			Simulation of Xinli	
		Distric			198
		12.5.1		meter Optimization of	
			WAG In		198
				Water-Gas Ratio	
				Optimization	202
			12.5.1.2		202
			12.5.1.3	0 1	
				Optimization	203
		12.5.2	Develop	ment Scheme	204
	12.6	Conclu			208
		rences			208
				•	
13.	Stud	y on De	evelopme	nt Effect of CO ₂	
	Huff and Puff Process in Horizontal Well in				
	Normal Heavy Oil Reservoir				
	Guo Ping, Huang Qin, Li Min, Zhang Wei,				
	Du I	u Jianfen and Zhao Binbin			
		Óverv			210
	13.2	Stimu	lation Med	chanism of CO ₂ Huff and	
		Puff Process		211	
		13.2.1	Crude C	Oil PVT Test	211
		13.2.2	CO ₂ -Oil	Swelling Test	211
		13.2.3		Carbon dioxide Huff and	
			Puff Pro	cess in the Long Core	214
	13.3	Single		nerical Simulation of CO ₂ Huff	
			uff Proces		218
		13.3.1	Built Sir	ngle Well Geological Model	218
		13.3.2		ehavior and History Matching	218
				of Development Program of	
				ff and Puff Process	220
		13.3.4		s of Numerical Simulation	
			Results		223
	13.4	Concl	usions		228
		rences			229
	References				

14.		-		natic Models of Multi-Phase Orive in Ultra-Low	
				Application	231
		_		Chen Jiecheng	201
		Liu Jinzi		enen freeneng	
		Introd			231
				odel of Oil Displacement with CO ₂	201
	17.2			Jltra-low Permeability Reservoir	232
		14.2.1		the Mathematical Model	232
			_	eristic Equation	235
		· - · -	14.2.2.1	•	235
			14.2.2.2	Concentration Equation for	200
				All-components	235
			14.2.2.3		236
				Effective Viscosity	236
	14.3	Experi		udy of Ultra-low	
				servoir CO ₂ Flooding	236
	14.4		rical Šimu		238
		14.4.1	Numerio	cal Simulation of an Ideal Model	238
			14.4.1.1	Numerical Simulation	
				Programming	238
			14.4.1.2	Design of Mathematically	
				Geological Models	239
			14.4.1.3	Characteristics of the Physical	
				Properties Change	239
		14.4.2		cal Simulation of the Experiment	
			Pilot Are		242
			14.4.2.1	Experimental Zone	242
			14.4.2.2	History Matching and	
				Production Forecasting	242
			14.4.2.3	0 1	244
			14.4.2.4	Comparison and Prediction of	
	a	<i>c</i> 1	•	the Production	244
		Conclu	asion		248
	Keter	rences			249
15.	Expe	rimenta	l Apprais	al and Single-well Simulation for	
				lity in Liaohe Light Oil Blocks	251
				ui, Sun Lei and Wu Yi	_01
	15.1	Introd	_	,	251
	15.2	Phase	Behavior	of Formation Crude	252

	15.3	CO ₂ Injection Experiment and Fluid Properties	254
	15.4	CO ₂ Injection Feasibility Analysis and Parameter	
		Optimization of XB-S ₃	257
		15.4.1 Geological Features	257
		15.4.2 Reservoir Characteristics	257
		15.4.3 Numerical Simulation and Parameter	
		Optimization	258
	15.5	Conclusion	262
	Refer	ences .	262
16.		riment Study about Phase Transition	
	Char	acteristics of CO ₂ in Low-permeable	
	Porou	as Media	263
	Guo I	Ping, Wang Juan, Fan Jianming and Luo Yuqiong	
		Introduction	264
	16.2	Testing System	265
		16.2.1 Principles of Ultrasonic Testing	265
		16.2.2 Testing Procedure [11]	265
	16.3	Testing Devices	266
	16.4		268
		16.4.1 26°C	268
		16.4.2 48°C	270
	16.5	Experiment Phenomenon	270
		Conclusions	272
		rences	272
17.	Mecl	nanism Evaluation of Carbon Dioxide Miscible	
	Flood	ling - Caoshe Oilfield, a Case Study	275
		Yong, Du Zhimin, Sun Lei, Yu Kai, Liu Wei	
	_	Chen Zuhua	
	17.1	Introduction	276
		Phase Behavior Experiment Simulation of	
		CO ₂ Injection in CS Oilfield	277
		17.2.1 Reservoir Introduction	277
		17.2.2 Fluid Composition	277
		17.2.3 Match the Fluid PVT Phase Behavior	
		Experiment and CO ₂ Injection	
		Swelling Test	278
	17.3	Evaluation of CO ₂ Injection Minimum	
		Miscibility Pressure	279
		17.3.1 Determination of MMP by Slim Tube	,
		Test and Numerical Simulation	279

		17.3.2	Determin	nation of Injecting CO ₂	
				ty Pressure by Pseudo-ternary	
			Phase Di	agram	282
		17.3.3	Miscibili	ty Evaluation at Current	
				on Pressure	284
	17.4	Mecha	nism Eval	uation of CO2 Miscible Flooding	
		by One	e-dimensi	onal Simulation	284
		17.4.1	Compon	ent Changing Law	284
	17.5	Miscib	le Floodin	g Processes in Profile Model	
		of Injec	ctor-produ	icer Well Group	285
		17.5.1	The CO,	Sweeping Area Increasing	286
		17.5.2		il Viscosity Reduces Sharply in	
			CO, Swe	pt Region	286
		17.5.3	Miscible	Bank Formation Around the	
			Produce	r after CO ₂ Injection	289
	17.6	Conclu			291
	Refer	ences			292
18.				nance Evaluating of Surfactant in	
				Flooding in Caoshe Oil Field	293
	Yi Xiangyi, Zhang Shaonan, Lu Yuan, Li Chun,				
	Jiao 1		Liu Wei		
	18.1	Introd	uction		294
	18.2			acteristics in Taizhou Formation	
			she Oil Fi		295
				Summary	295
		18.2.2		eristics of Reservoir Geology	
			and Flui		295
		18.2.3	Heterog	-	296
	18.3			nprove the Effect of CO ₂ Flooding	298
	18.4			valuating of Surfactant	299
		18.4.1		ture-enduring and Salt-resistant	
				nt Selecting	299
				Foaming Agent Selecting	299
				Foaming Agent Concentration	301
			18.4.1.3		302
			18.4.1.4	Rheological Property	302
		18.4.2	Main Pe	rformance Evaluating of	
					202
			Surfacta		303
			Surfacta 18.4.2.1	Experiment Materials	
					303

		18.4.2.3 Influencing Factors on the Foam Stability	304
		18.4.2.4 Sealing Characteristics	306
	18.5	Conclusions	308
	Refer		309
Sec	ction	4: Materials and Corrosion	
19.	Casir	ng and Tubing Design for Sour Oil & Gas Field	313
		ongxing, Lin Yuanhua, Wang Zhongsheng,	0.20
		aihe, You Xiaobo, Zhang Guo, Liu Hongbin,	
		Chu Dajiang	
	19.1	Introduction	314
		SSC Testing	315
		Casing and Tubing Design in	
		Fracture Mechanics	316
		19.3.1 Material Yield Strength and Hardness19.3.2 Design Equation for Fracture of the	316
		Pipe Body	317
		19.3.3 Anti-fracture Capability Assessment of	
		Casing C110 and T95 in Sour	
		Environments	320
		Conclusions	324
	Refer	rences	325
20.		rial Evaluation and Selection of OCTG and	
	Gath	ering Lines for High Sour Gas Fields in China	327
	Zeng	Dezhi, Huang Liming, Gu Tan, Lin Yuanhua,	
		hide, Yuan Xi, Zhu Hongjun, Huo Shaoquan,	
	and 2	Xiao Xuelan	
		Introduction	328
	20.2	Material Evaluation and Selection of	
		OCTG for High Sour Gas Fields	328
	20.3	Indoor Corrosion Evaluation	329
		20.3.1 Anti-SSC Performance Evaluation of OCTG	329
		20.3.2 Electrochemical Corrosion Resistance	
	20.4	Evaluation of OCTG	329
	20.4	Field Corrosion Evaluation in Tian Dong 5-1	332
		20.4.1 Evaluation of Electrochemical Corrosion	333
		20.4.2 Evaluation of Stress Corrosion	334

	20.5 Material Evaluation and Selection of Gathering		
		Lines for High Sour Gas Fields	334
	20.6	Indoor Corrosion Evaluation	335
		20.6.1 Anti-SSC Performance Evaluation of	
		Gathering and Transportation Pipelines	
		and its Welded Joints	335
		20.6.2 Electrochemical Corrosion Resistance	000
		Evaluation of Gathering and Transportation	
		Pipelines and its Welded Joints	337
		20.6.3 Corrosion Evaluation of X52/825 Clad	337
			337
	20.7	Field Corrosion Evaluation in Tian Dong 5-1	340
	20.8	Conclusion	342
	Refere	•	
	Keren	ERCES	343
_			
Sec	ction	5: Reservoir Engineering, Geology,	
and	d Geo	chemistry	
21.		entration Gradients Associated With	
	Acid	Gas Injection	347
	S. J. T	alman and E.H. Perkins	
	21.1	Introduction	348
	21.2		350
		ALAN MEN A LINE A	350
			350
			351
			352
	21.3		358
			358
	Refere	. •	358
	reier	Sirects	<i>3</i> 36
22	A NT	or Community and a Matheway Co. 134 J. 1. C.	
22.		w Comprehensive Mathematical Model of	
		ation Damage in Fractured Gas Reservoirs with	
	_	-	361
		kui, Guo Xiao, Du Zhimin, Fu Yu, Zhang Yong,	
	Deng	Shenghui, and Liu Linqing	
	22.1		362
	22.2	Mathematical Model	364
		22.2.1 Mass Conservation Formulation	365
		00 0 0 To	366
		1	

	22.2.3	Prediction Model of Sultur Solubility in	
		Sour Gas	367
	22.2.4	Sulfur Adsorption Model	368
	22.2.5		368
	22.2.6	Calculation of Migration Velocity of	
		Sulfur Particle in Gas Mixture	369
	22.2.7	Calculation of Deposition Velocity of	
		Sulfur Particle in Gas Mixture	369
	22.2.8	Auxiliary Equation	370
22.3	Case A	Application	371
			371
	22.3.2	Set up and Division of Grid Model	371
	22.3.3		372
22.4	Concli	usions	375
Nom	enclatu	re	376
Ackn	owledg	ments	377
Refer	rences		377
Evalu	ation o	of Formation Damage Due to	
Sulfu	ır Depo	osition	379
Guo.	Xiao, D	u Zhimin, Yang Xuefeng, Zhang Yong,	
			380
			380
23.3	Depos	sited Sulfur of Core Samples	381
			381
			384
			384
	-	,	384
Num	erical S	Simulation Studies on Sour Gas	
	_		387
-			507
and?	Yang Xu	iefeng	
24.1	Introd	uction	388
24.2	Phase	Behavior Characteristics of Highly Sour	
			389
			007
	24.2.1	Sulfur Dissolution and Precipitation in	00)
	,	Sulfur Dissolution and Precipitation in the Sour Gas	389
	,	Sulfur Dissolution and Precipitation in	
	22.4 Nom Ackn Refer Evalue Sulfu Guo and I 23.1 23.2 23.3 23.4 23.5 Ackn Refer Num Flow H ₂ S O Zhan and I 24.1	22.2.5 22.2.6 22.2.7 22.2.8 22.3.1 22.3.2 22.3.3 22.4 Conclustion of Sulfur Deporation of	Sour Gas 22.2.4 Sulfur Adsorption Model 22.2.5 Permeability Damage Model 22.2.6 Calculation of Migration Velocity of Sulfur Particle in Gas Mixture 22.2.7 Calculation of Deposition Velocity of Sulfur Particle in Gas Mixture 22.2.8 Auxiliary Equation 22.3.1 Case Application 22.3.2 Set up and Division of Grid Model 22.3.3 Result Analysis 22.4 Conclusions Nomenclature Acknowledgments References Evaluation of Formation Damage Due to Sulfur Deposition Guo Xiao, Du Zhimin, Yang Xuefeng, Zhang Yong, and Fu Dekui 23.1 Introduction 23.2 Experimental Investigation of Sulfur Deposition 23.3 Deposited Sulfur of Core Samples 23.4 Experimental Results 23.5 Conclusions Acknowledgments References Numerical Simulation Studies on Sour Gas Flowing Mechanisms in Gas Reservoirs with High H ₂ S Content Zhang Yong, Du Zhimin, Guo Xiao, and Yang Xuefeng 24.1 Introduction

			24.2.1.2	Sulfur Solubility Prediction Model	390	
			24.2.1.3	Chrastil's Thermodynamic Model	390	
			24.2.1.4	Phase Equilibrium Calculation		
				Model	391	
	24.3	Sour G	as Flow N	Numerical Model for Highly		
		Sour G	as Reserv	oir	391	
		24.3.1	Mechani	sms and Model Development for		
			Sulfur P	article Movement	391	
		•	24.3.1.1	Mechanisms for Sulfur Particle		
				Movement	391	
			24.3.1.2	Dynamic Model for Gas-Solid		
				Movement	392	
		24.3.2	Formation	on Damage Caused by Sulfur		
			Depositi	on	393	
			24.3.2.1	Gas-Solid Coupled Mathematical		
		•		Model for Highly Sour		
				Gas Reservoir	394	
			24.3.2.2	Sulfur Continuity Equation		
				based on Gas-solid Slip Model	394	
			24.3.2.3	Partial Differential Continuity		
				Equations for Hydrocarbon		
				Components in the Gas	395	
			24.3.2.4	Sulfur Precipitation Model	395	
		24.3.3		n Study for Fluid Flow in		
			Porous I		395	
				Gas Rate Effect	395	
				Initial H ₂ S Concentration Effect	396	
			24.3.3.3	Formation Permeability Effect	397	
	24.4	Conclu	ısions		398	
	Refer	rences			399	
5.	Why Does Shut-In Well Head Pressure of Sour Gas Well Decrease During Formation Testing? 40					
	Gas Well Decrease During Formation Testing?					
	Guo Xiao, Du Zhimin and Fu Dekui					
		Introd			401	
	25.2			lodel of Heavy Gas Fraction	403	
		25.2.1	Assump		403	
		25.2.2		h Mathematical Model of Heavy		
				nents Sedimentation	403	
	25.3			vy Gas Fraction	405	
	25.4			ors Affecting the Pressure		
		Nume	ration in S	Sour Gas Wells	408	

	25.5	Conclusion	409		
	Acknowledgments References				
26.	Impaction of the Stacking Pattern of Sandstone and Mudstone on the Porosity and Permeability of Sandstone Reservoirs in Different Buried Depths				
		g Dekang and Zhu Xiaomin	411		
		Introduction	412		
	26.2	Stacking Pattern of Sandstone and Mudstone	413		
		The Characteristics of Physical Property of			
		Reservoirs in Sandstone-mudstone Interbed	416		
	26.4	The Discussion of Variation Mechanism of			
		Physical Properties of Sandstone – Mudstone			
		Interbed	421		
	26.5	Conclusion	424		
	Acknowledgements				
	References				
T 3	1		429		
inc	Index				