Contents

1 Introduction

1.1 Molecules between the stars	1
1.2 The Galaxy	2
1.3 The structure and morphology of the interstellar medium	3
1.4 Representative well studied objects	6 21
Further reading	21
2 Introduction: Chemistry	
2.1 On the origin of interstellar molecules	22
2.2 The nature of the problem of interstellar chemistry	24
2.3 Observational constraints on rates of reactions	26
2.4 Molecular hydrogen and the initiating chemical reactions	28
Problems	32
Further reading	33
3 Gas Phase Reactions	
3.1 Cosmic ray ionization	34
3.2 Ion–molecule reactions	36
3.3 Charge transfer reactions	41
3.4 Radiative association	44
3.5 Neutral exchanges	48
3.6 Radiative recombination	54
3.7 Dissociative recombination	56
3.8 Negative ion reactions	59
3.9 Summary	63
Problems	63
Further reading	64
4 Photophysics of Interstellar Molecules	
4.1 Basic processes	66
4.2 Absorption and emission of radiation	70
4.3 The interstellar radiation field	72
4.4 Photodissociation	73
4.5 Photoionization	76
4.6 Photodissociation of H ₂	76
4.7 Molecular excitation	78
Problems	84
Further reading	85

viii CONTENTS

5 Grain Surface Chemistry

5.1 Evidence for interstellar grains	86 87			
5.2 Space density of grains				
5.3 The nature of grain surfaces				
5.4 Molecular formation on grains				
5.5 Depletion of atoms and molecules on grains	111			
Problems	113			
Further reading	114			
6 The Molecular Hydrogen Problem				
6.1 Introduction	115			
6.2 Required formation rate	120			
6.3 Formation of H ₂ in diffuse clouds	121			
6.4 Molecular hydrogen in dark clouds	132			
Problems	133			
Further reading	134			
7 Modelling the Chemistry in Interstellar Clouds				
7.1 Introduction	135			
7.2 Time-dependent or equilibrium chemistry	137			
7.3 Setting up the problem	138			
7.4 Obtaining the solutions	141			
7.5 A test calculation	142			
7.6 Results of some illustrative calculations	145			
7.7 The modelling exercise	153			
Problems	157			
Further reading	157			
8 Interstellar Chemistry in Special Situations				
· · · · · · · · · · · · · · · · · · ·	159			
8.1 Introduction to interstellar shocks8.2 The chemical effects of a non-magnetic shock	162			
8.3 Dissociative and non-dissociative shocks	164			
8.4 Procedures for modelling shock chemistry	168			
8.5 Illustrative results of some non-magnetic shock chemistry models	168			
8.6 Introduction to interstellar isotopes	173			
8.7 Isotopes in interstellar molecules	175			
8.8 Molecule formation in stellar atmospheres	182			
8.9 Molecules in circumstellar shells	186			
8.10 Maser sources	191			
Problems	194			
Further reading	195			
9 The Present State and Future Prospects of Interstellar Chemistry	196			
	199			
Solutions to Problems Appendix: Library of chemical reactions Index				