

# Contents

Preface	page ix
Acknowledgements	x
<b>I Introduction to chemical oceanography</b>	<b>1</b>
<b>I   Oceanography background: dissolved chemicals, circulation and biology in the sea</b>	<b>3</b>
1.1 A chemical perspective	3
1.2 Constituents of seawater	5
1.3 Ocean circulation	17
1.4 Ocean biology	24
<b>2   Geochemical mass balance: dissolved chemical inflow and outflow from the ocean</b>	<b>33</b>
2.1 Mass balance between input from land and authigenic mineral formation	34
2.2 Reverse weathering	43
2.3 Hydrothermal circulation	46
2.4 Summary and conclusions	57
Appendix 2.1 An extremely brief review of rocks and minerals	58
Appendix 2.2 The meaning of residence time	59
<b>3   Thermodynamics background</b>	<b>63</b>
3.1 The properties of water and ions	64
3.2 Ion-ion interactions and activity coefficients	70
3.3 Thermodynamic basics	73
3.4 Equilibrium constraints on chemical activities	77
3.5 Redox reaction basics	89
<b>4   Carbonate Chemistry</b>	<b>101</b>
4.1 Acids and bases in seawater	103
4.2 Carbonate equilibria: calculating the pH of seawater	112
4.3 Kinetics of CO <sub>2</sub> reactions in seawater	116
4.4 Processes that control the alkalinity and DIC of seawater	118



Appendix 4.1 Carbonate system equilibrium equations in seawater	127
Appendix 4.2 Equations for calculating the equilibrium constants of the carbonate and borate buffer system	130
<b>5   Stable and radioactive isotopes</b>	134
5.1 Stable isotopes	137
5.2 Radioactive isotopes	153
Appendix 5.1 Relating $K$ , $\alpha$ , $\delta$ , and $\epsilon$ in stable isotope terminology	169
Appendix 5.2 Derivation of the Rayleigh distillation equation	170
<b>6   Life processes in the ocean</b>	173
6.1 A simple model of ocean circulation and biological processes	174
6.2 The euphotic zone	179
6.3 Biologically driven export from the euphotic zone	188
6.4 Respiration below the euphotic zone	203
<b>7   Paleoceanography and paleoclimatology</b>	219
7.1 The marine sedimentary record: 0–800 ky	220
7.2 The ice core record: 0–800 ky	243
7.3 Abrupt (millennial-scale) climate change	249
<b>II Advanced topics in marine geochemistry</b>	259
<b>8   Marine organic geochemistry</b> <i>Co-author: Kenia Whitehead</i>	261
8.1 The nature of organic matter	264
8.2 Methods of characterizing organic matter	266
8.3 Major organic carbon compounds as biomarkers	277
8.4 Dissolved organic matter in seawater	294
<b>9   Molecular diffusion and reaction rates</b>	303
9.1 Molecular diffusion	304
9.2 Reaction rates	310
9.3 Reaction rate catalysis	326



<b>10</b>	<b>Gases and air–water exchange</b>	<b>340</b>
10.1	Air–sea gas transfer models	343
10.2	Measurements of gas exchange rates in nature	350
10.3	Gas saturation in the oceans	357
10.4	Surface films and chemical reactions	366
<b>11</b>	<b>The global carbon cycle: interactions between the atmosphere and ocean</b>	<b>372</b>
11.1	The global carbon cycle	373
11.2	The biological and solubility pumps of the ocean	376
11.3	The fate of anthropogenic CO <sub>2</sub> in the ocean	384
<b>12</b>	<b>Chemical reactions in marine sediments</b>	<b>404</b>
12.1	Diagenesis and preservation of organic matter	406
12.2	Diagenesis and preservation of calcium carbonate	419
12.3	Diagenesis and preservation of silica	428
12.4	Diagenesis and preservation of metals	433
12.5	Conclusions	439
	<b>Index</b>	<b>445</b>

*The color plates are between pp. 212 and 213.*