

## Contents

<i>Preface to the second edition</i>	<i>page</i> ix
<i>Foreword to the first English edition</i>	x
<i>Foreword to the French edition</i>	xii
<i>Acknowledgments</i>	xiv
<b>Introduction</b>	<b>1</b>
<b>1 The properties of elements</b>	<b>5</b>
1.1 The periodic table	7
1.2 Chemical bonding	11
1.3 States of matter and the atomic environment of elements	15
1.4 Geochemical classifications	17
1.5 The different reservoirs and their compositions	19
1.6 The nucleus and radioactivity	20
Exercises	22
<b>2 Mass conservation and elemental fractionation</b>	<b>25</b>
2.1 Conservation of mass	26
2.2 Elemental fractionation	31
2.3 Films and interfaces	36
2.4 Distillation processes	37
Exercises	41
References	44
<b>3 Fractionation of stable isotopes</b>	<b>45</b>
3.1 Principles of stable isotope fractionation	46
3.2 Delta notation and stuff	56
3.3 Hydrogen	59
3.4 Oxygen	60
3.5 Carbon	64
3.6 Sulfur	66
3.7 Nitrogen	67
3.8 Other elements	68
Exercises	68
References	70

<b>4</b>	<b>Geochronology and radiogenic tracers</b>	<b>71</b>
4.1	Dating by radioactive nuclides	78
4.1.1	Carbon-14	78
4.1.2	Beryllium-10	79
4.1.3	The thorium-230 excess method	81
4.2	Systems with high parent/daughter ratios	83
4.2.1	The potassium–argon method	83
4.2.2	Dating zircons by the uranium–lead method	84
4.3	The isochron method	86
4.4	Radiogenic tracers	90
4.5	Helium isotopes	93
	Exercises	94
	References	99
<b>5</b>	<b>Element transport</b>	<b>101</b>
5.1	Advection	102
5.2	Diffusion	103
5.2.1	Closure temperature: chronometers, thermometers, and barometers	106
5.2.2	Other applications	110
5.3	Chromatography	110
5.4	Reaction rates	113
5.5	Adsorption	115
	Exercises	116
	References	118
<b>6</b>	<b>Geochemical systems</b>	<b>120</b>
6.1	Single-reservoir dynamics	120
6.2	Interaction of multiple reservoirs and geochemical cycles	127
6.3	Mixing and stirring	131
	Exercises	134
	References	137
<b>7</b>	<b>The chemistry of natural waters</b>	<b>138</b>
7.1	Basic concepts	138
7.2	Dominance diagrams	141
7.3	Speciation in solutions	143
7.4	Water–solid reactions	144
7.5	Electrolyte chemistry	146
7.6	Biological activity	147
7.7	The carbonate system	148
7.8	Precipitation, rivers, weathering, and erosion	152
7.9	Elements of marine chemistry	156

	Exercises	163
	References	167
<b>8</b>	<b>Biogeochemistry</b>	<b>168</b>
8.1	The geological record	168
8.2	Some specifics of biological activity	170
8.3	The chemistry of life	172
8.4	Biominerals	176
8.5	Biological controls on the ocean–atmosphere system	177
8.6	Diagenetic transformation of organic material	178
8.7	Biomarkers	181
8.8	Metals in organic matter	182
	References	183
<b>9</b>	<b>Environments</b>	<b>184</b>
9.1	Phanerozoic climates	185
	9.1.1 Quaternary climates	186
	9.1.2 Mesozoic and Cenozoic climatic trends	187
	9.1.3 Biogeochemical catastrophes in the Phanerozoic	191
9.2	The rise of atmospheric oxygen	193
	9.2.1 The 2.1 Ga crisis	193
	9.2.2 The Snowball Earth and the emergence of Metazoans	196
9.3	The geochemical environment of the origin of life	198
	Exercises	200
	References	201
<b>10</b>	<b>Mineral reactions</b>	<b>202</b>
10.1	Early diagenesis	204
10.2	Hydrothermal reactions	205
10.3	Metamorphism	211
10.4	Water/rock ratios	214
	Exercises	215
	Reference	217
<b>11</b>	<b>The solid Earth</b>	<b>218</b>
11.1	The geochemical variability of magmas	221
	11.1.1 Melting of the mantle and crust	221
	11.1.2 Differentiation of magmatic series	225
11.2	Magmatism of the different tectonic sites	229
11.3	Mantle convection	237
11.4	The growth of continental crust	241
	References	246

<b>12 The Earth in the Solar System</b>	<b>248</b>
12.1 The formation of elements	249
12.2 The formation of the Solar System	255
12.3 Condensation of planetary material	258
12.4 The composition of the Earth and its core, and the origin of seawater	261
12.5 The early Solar System	265
12.6 The Moon	272
12.7 Mars	276
12.8 Venus	278
12.9 Planetary atmospheres	279
Exercises	283
References	287
<b>13 The element barn</b>	<b>288</b>
13.1 Silicon	288
13.2 Aluminum	290
13.3 Potassium	291
13.4 Sodium	292
13.5 Magnesium	293
13.6 Calcium	294
13.7 Iron	295
13.8 Sulfur	298
13.9 Phosphorus	299
13.10 Carbon	300
References	302
<i>Appendix A Composition of the major geological units</i>	303
<i>Appendix B The mixing equation for ratios</i>	306
<i>Appendix C A refresher on thermodynamics</i>	308
<i>Appendix D The geological time scale</i>	315
<i>Appendix E An overview of analytical methods</i>	316
<i>Appendix F Physical and geophysical constants</i>	322
<i>Appendix G Some equations relative to residence time</i>	323
<i>Appendix H The adiabatic atmosphere</i>	325
<i>Further reading</i>	327
<i>Index</i>	330