

Brief Contents

	Preface	xi
Chapter 1	The Essence of Mineralogy	1
Chapter 2	Hand Sample Identification	19
Chapter 3	Crystal Chemistry	47
Chapter 4	Crystallography	69
Chapter 5	Optical Mineralogy	81
Chapter 6	Systematic Mineralogy	103
Chapter 7	Chemistry of the Elements	121
Chapter 8	Bonding and Packing in Minerals	149
Chapter 9	Chemical Analysis of Minerals	169
Chapter 10	Mineral Formulas	197
Chapter 11	Introduction to Symmetry	225
Chapter 12	Symmetry	251
Chapter 13	Mathematical Crystallography	309
Chapter 14	Representation of Crystal Structures	335
Chapter 15	Diffraction	363
Chapter 16	Introduction to Optics	401
Chapter 17	Optical Crystallography	435
Chapter 18	Optical Crystal Chemistry	481
Chapter 19	Mineral Identification	515
Chapter 20	Environments of Mineral Formation	535
Chapter 21	Nomenclature and Classification	555
Chapter 22	Silicate Minerals	577
Chapter 23	Non-Silicate Minerals	641
Chapter 24	Mineralogy Outside of Geology	683

Contents

Preface	xi	Ionic Sizes	57
Introduction	xi	References	68
How This Book Differs from the Others	xi		
Who Cares About Mineralogy?	xii	Chapter 4 Crystallography	69
Our Reasons for Writing this Book	xii	Introduction	70
Using this Book: Professors Take Note!	xiii	Two-Dimensional Space	70
Course Goals	xiv	Symmetry Operations	71
How to Accomplish the Goals	xv	Three-Dimensional Space	72
Finally...	xx	Isometric System	74
Acknowledgments	xx	Tetragonal System	75
References	xxii	Orthorhombic System	76
		Hexagonal System	77
Chapter 1 The Essence of Mineralogy	1	Monoclinic System	77
What's a Mineral?	2	Triclinic System	77
Chemical Elements	4	References	80
Crystal Systems	7		
Optical Classes	11	Chapter 5 Optical Mineralogy	81
The Big Ten Minerals	12	Introduction	82
Concluding Remarks	17	Macroscopic View of Polarized Light and Minerals	82
References	17	Making a Thin Section	84
		Meet Your Microscope	84
Chapter 2 Hand Sample Identification	19	Wave Theory of Light	87
Introduction	20	Optical Classes and Refractive Index	87
Mineral Properties	22	Reflection vs. Refraction: Snell's Law	91
Color and Streak	23	Wavelength and Refractive Index	93
Luster	26	Visual Representations of Refractive Index	93
Hardness	28	Birefringence and Retardation	95
Fracture and Tenacity	30	Interference Figures	98
Crystal Form	32	Concluding Remarks	100
Crystal System	34	References	101
Crystal Shape and Habit	34		
Cleavage and Parting	39	Chapter 6 Systematic Mineralogy	103
Twinning	40	Introduction	104
Specific Gravity	43	Framework Silicates	104
Other Properties	44	Layer Silicates	108
A Concluding Analogy	45	Chain Silicates: Amphiboles and Pyroxenes	111
References	46	Ring Silicates	113
		Disilicates	115
Chapter 3 Crystal Chemistry	47	Orthosilicates	116
Introduction	48	Non-Silicates	117
Structures of Atoms	48	Concluding Remarks	119
From Atoms to Ions	51		
Atomic Bonds	53		

References	120	Formula Recalculations Based on Oxides	206
Chapter 7 Chemistry of the Elements	121	Graphical Depictions of Mineral Chemistry	209
Introduction	122	Compositional Variation in Minerals	212
The Big Bang	122	Assigning Cations to Structural Sites	213
Atomic Structure	126	The “Grammar” Rules for Mineral Formula	221
Size	132	Concluding Remarks	223
Color in Minerals	133	References	223
Chemical Substitution	141		
Phase Diagrams	144	Chapter 11 Introduction to Symmetry	225
References	146	Introduction	226
Chapter 8 Bonding and Packing in Minerals	149	Operations in Two Dimensions	226
Introduction	150	Combinations of Operations:	
The Forces that Bind	150	Planar Point Groups	230
A Dog-Gone Good Analogy for Chemical Bonding	152	Plane Lattices: Combinations of Rotations and Translations	232
Metallic Bonds	153	Plane Groups = Translation + Rotation + Reflection + Glide	235
Covalent Bonds	156	Operations in Three Dimensions	242
Intermediate Covalent-Ionic Bonding	156	Combinations of Operations in 3-D Crystal Classes	244
Ionic Bonds	160	Space Lattices	245
Van der Waals Bonds	165	Space Groups	247
Hydrogen Bonds	166	Summary	247
References	168	References	249
Chapter 9 Chemical Analysis of Minerals	169	Chapter 12 Symmetry	251
Introduction	170	Introduction	252
Analysis of Minerals	171	Stereographic Projections	252
Wet Chemical Analysis	171	Point Symmetry Operations	258
“Water Content” of Minerals and Hydrogen Extraction	172	Groups of Point Symmetry Operations	261
Introduction to Spectroscopic Methods	173	Relating Point Symmetry Operations to Crystal Systems	264
Inductively-Coupled Plasma (ICP) and Atomic Absorption Spectrometry (AAS)	175	Naming Point Groups	271
X-ray Fluorescence (XRF)	177	The 32 Point Groups: Organizing Collections of Point Groups into Crystal Systems	273
Electron Microprobe and the Scanning Electron Microscopy	179	Unit Cells	282
Ion Microprobes	181	Bravais Lattices	283
Proton-Induced Emission Spectroscopy	182	Naming Planes and Lines in Crystals	286
Neutron Activation Analysis	183	Space Symmetry	292
Mössbauer Spectroscopy	187	Space Groups	301
Visible and Infrared Spectroscopy	188	Summary	305
Raman Spectroscopy	190	References	307
Common Themes	191		
References	193	Chapter 13 Mathematical Crystallography	309
Chapter 10 Mineral Formulas	197	Introduction	310
Introduction	198	Matrix Representation of Symmetry Operations	310
Mineral Formula Calculation	198	Rotoinversion Axes	315
Complete Chemical Analysis (Minerals without Oxygen)	198	Derivation of Space Group Symmetry	
Formula Recalculations Based on Oxides	201	Group Operations: Symmetry	
The Trouble with Iron	204	Propagation of Atoms	315
What about Hydrogen?	206		

The Metric Tensor	319	Systematic Absences	383
Volume Calculations	320	Instrumentation for Single-Crystal	
Bond Distances	320	Diffraction	388
Bond Angles	321	Diffraction by Example Structures	390
d-spacings and Reciprocal Space	321	Identification by Powder Diffraction	395
Angles Between Two Axes	322	Integration of Powder and	
Angles Between Two Planes	322	Single-Crystal Diffraction	398
Angles Between an Axis and a Plane		Historical Thoughts & Conclusions	399
Normal	323	References	400
Derivation of the 32 Crystallographic			
3-D Point Groups and Collection		Chapter 16 Introduction to Optics	401
into Six Crystal Systems	323	Introduction	402
Proper Point Groups	323	The Electromagnetic Spectrum and	
Improper Point Groups	323	Wave Nomenclature	403
Determining the Angles Between the		Refractive Index	403
Rotation and Rotoinversion		Refraction vs. Reflection of Light	404
Axes and Grouping the 32 Point		Refractometer	406
Groups into the Six Crystal		Dispersion of Refractive Index	407
Systems	324	Back to the Prism and the Rainbow	408
Appendix A: Brief Introduction to		Refraction by Lenses	408
Linear Algebra and Matrix		Estimation and Determination of	
Manipulation as Applied to		Refractive Index	410
Mineralogy	327	Correcting Vision	411
Multiplication of Matrices	327	Relief	412
Transpose of a Matrix	328	Anisotropic Materials	413
Inversion (“Division”) of Matrices	328	Interference Colors	418
The Determinant of a Matrix	329	Polarization by Reflection	428
Addition and Subtraction of Matrices	329	Polarization by Absorption	429
Dot Products	329	Light Interaction with a Quartz Sphere	430
Cross Products	330	Polarized Sunglasses	431
Appendix B: The General Cartesian		Gem Refractometer: Anisotropic	
Rotation Matrix and Its Use to		Minerals	433
Arrive at Matrix Representation		Summary	434
for Rotations and Rotoinversions	330	References	434
Non-Cartesian Case	331		
References	333	Chapter 17 Optical Crystallography	435
Chapter 14 Representation of Crystal		Introduction	436
Structures	335	The Polarizing Light Microscope (PLM)	436
Introduction	336	Sample Types and Preparations	439
Visualizations of Crystal Structures	336	Birefringence, Retardation, and	
Andalusite Story	340	Orientation of N and n	442
Building Computer-Based and Physical		Accessory Plates	443
Model of Minerals	345	Interference Figures	446
Examples	348	The Indicatrix Revisited	454
Conclusions and Final Thoughts	358	Dispersion	457
References	361	Indicatrix on “Stage”	459
Chapter 15 Diffraction	363	Interference Figures in Practice	460
Introduction	364	Orientational Dependence of Images	466
Light Diffraction	366	Other Optical Phenomena	469
Reciprocal Lattices and d-spacings	371	References	480
“Reflection” of X-rays	373	Chapter 18 Optical Crystal Chemistry	481
Diffraction Theory	376	Introduction	482
Generation of X-rays	378	Refractive Indices and Minerals	482
Diffraction by Lattices	380	Measuring Refractive Indices	485
		Spindle Stage	496

Absorption and Pleochroism	500	Silicates and the SiO_4^{4-} Tetrahedron	571
Relating Optic Properties to Crystal Chemistry	503	Concluding Comments on the Evolution of Mineral Classification Schemes	572
LCD's	504	References	573
Calculating Refractive Indices	506		
Relationship to Density and Bonding	506		
Gladstone-Dale Relationship	507	Chapter 22 Silicate Minerals	577
Conclusions	509	Introduction	578
Appendix: How to Build a Spindle Stage and Oil Cell	509	Silica Polymorphs	578
References	512	Feldspars	583
		Feldspathoids	588
Chapter 19 Mineral Identification	515	Zeolites	589
Introduction	516	Layer Silicates (Phyllosilicates)	593
What's in a Name?	516	Polymorphism	599
The Process of Identification	518	Amphiboles	606
Our Database	519	Swimming Octahedra	610
Other Databases	520	Chains with Side Branches or Loops	612
Strategies	524	Pyroxenes	612
New Minerals	529	Other Single-Chain Silicates	617
Conclusions	532	Ring Silicates	617
References	533	Disilicates	621
		Orthosilicates	627
		Borosilicates and Beryllsilicates	634
Chapter 20 Environments of Mineral Formation	535	Concluding Remarks	635
Introduction	536	References	636
Binary Phase Diagrams	538		
Ternary Phase Diagrams	542	Chapter 23 Non-Silicate Minerals	641
Mineral Associations	544	Introduction	642
A Quick Journey to the Center of the Earth	545	A Word About Nomenclature and the Organization of this Chapter	642
The Rock Cycle, Mineralogy-Style	549	Close Packing, Revisited	642
Conclusion	552	Native Elements	644
References	553	Sulfides and Related Structures	648
		Oxides	657
Chapter 21 Nomenclature and Classification	555	Carbonates	667
Introduction	556	Borates	671
Mineral Classification	558	Sulfates	672
The Dana System of Mineralogy	558	Phosphates	675
Strunz Classification	559	Anhydrous Tungstates	680
Structure Classification	561	Salts of Organic Acids	681
AX Compounds	564	Concluding Thoughts	681
A_2X Compounds	564	References	681
AX_2 Compounds	565		
AX_3 Compounds	566	Chapter 24 Mineralogy Outside of Geology	683
A_2X_3 Compounds	567	Introduction	684
ABX_3 Compounds	567	Industry	684
ABX_4 Compounds	569	Health	686
AB_2X_4 Compounds	570	Forensics	686
Other Compounds	570	Conclusions	686
		References	687