Technical Mineralogy and Petrography Part B

TECHNICAL MINERALOGY AND PETROGRAPHY

AN INTRODUCTION TO MATERIALS TECHNOLOGY

PART B

ANDRZEJ SZYMAŃSKI

Institute of Electronic Materials Technology, Warszawa, Poland

PWN – POLISH SCIENTIFIC PUBLISHERS
Warszawa
ELSEVIER
Amsterdam - Oxford - New York - Tokyo
1989

Revised and enlarged translation from the Polish original *Mineralogia stosowana*, published in 1976 by Wydawnictwa Geologiczne, Warszawa

Cover design by *Zygmunt Ziemka*

Distribution of this book is being handled by the following publishers:

For the USA and Canada
ELSEVIER SCIENCE PUBLISHING CO., INC.
52, Vanderbilt Avenue
New York, N. Y. 10017

For Albania, Bulgaria, Cuba, Czechoslovakia, German Democratic Republic, Hungary, Korean People's Democratic Republic, Mongolia, People's Republic of China, Poland, Romania, the USSR, Vietnam and Yugoslavia
ARS POLONA
Krakowskie Przedmieście 7, 00-068 Warszawa 1, Poland

For all remaining areas
ELSEVIER SCIENCE PUBLISHERS
Sara Burgerhartstraat 25
P. O. Box 211, 1000 AE Amsterdam, The Netherlands

ISBN 83-01-07548-1 (Part A)
ISBN 83-01-07318-7 (Part B)

Printed in Poland by D. R. P.

TECHNICAL MINERALOGY AND PETROGRAPHY

AN INTRODUCTION TO MATERIALS TECHNOLOGY

Part B

Contents

Appendix A —Basic Physicochemical Characteristics of Raw Materials, Minerals and Industrial Processes Phases

The COMPARATIVE ANALYSIS of physicochemical properties of the phase is the basis for determination of the technical characteristics for the mineral body application.

That COMPARATIVE ANALYSIS compared with raw materials genetic characteristics, as "in situ" and after processing, is the basis for the improvement of industrial process flow-sheets.

That COMPARATIVE AND GENETIC ANALYSIS is the basis for investigation of new mineral phases or bodies with future industrial application.

That COMPARATIVE ANALYSIS is finally the basis for technogenic raw materials deposits reprocessing for their industrial application.

TABLE A.1. DIAGNOSTIC DATA FOR TRANSPARENT MICROSCOPY

No	Refractive Indices[1] Optical Signature[2] Birefringence[3]	Name Crystal System[4] Chemical Formula or Composition	Axial angle 2V and dispersion of optical axes	Morphological characteristics of crystals and grains (crystal habit, twinning, etc.)
1	2	3	4	5
1	$n_\omega = 1.3225$ $n_\varepsilon = 1.3089$ $\ominus, \Delta = 0.0036$	Mallardite ortho. $Na_2[SiF_6]$	—	Prismatic
2	$n = 1.3246$ Δ weak	Villiaumite iso. NaF		
3	$n_\gamma = 1.3396$ $n\beta = 1.3389$ $n_\alpha = 1.3385$ $\oplus, \Delta = 0.0011$	Cryolite mono. $Na_3[AlF_6]$	43° $r < v$	Equant, polysynthetic twinning
4	$n = 1.3391$ Δ weak	Hieratite iso. $K_2[SFi_6]$		
5	$n_\omega = 1.3486$ $n_\varepsilon = 1.3424$ $\ominus, \Delta = 0.0062$	Chiolite tetrag. $Na_5[Al_3F_{14}]$	—	
6	$n_\varepsilon = 1.3897$ $n_\omega = 1.3780$ $\oplus, \Delta = 0.012$	Sellaite tetrag. MgF_2	—	Prismatic
7	$n_\gamma = 1.398$ $n_\alpha = 1.396$ $\oplus \Delta = 0.023$	Mirabilite mono. $Na_2SO_4 \cdot 10H_2O$	76°	Prismatic, short
8	$\bar{n} = 1.409$—1.466 Δ none or trace	Opal amor. $SiO_2 \cdot nH_2O$		Irregular
9	$n = 1.434$ Δ weak	Fluorite iso. CaF_2		Square, octahedral, twinned
10	$n_\gamma = 1.440$ $n_\beta = 1.425$ $n_\alpha = 1.405$ $\ominus, \Delta = 0.035$	Natron mono. $Na_2CO_3 \cdot 10H_2O$	71°	Tabular

Cleavage	Colour in thin section, pleochroism	Density $\times 10^3$kg/m^3	Mohs hardness / Vickers hardness number	Melting point[5] K	Remarks
6	7	8	9	10	11
	Colourless	2.75			
	Red		2.8	1268	
None	Colourless, brown, red	2.97	2.5	1293	Goes to isometric phase near 833 K
	Colourless	2.66			
Good	White	2.99	3.5—4.0		
	Colourless	3.15	5.0 270—320	1494	
Good	Colourless, green	1.49	1.5—2.0		
None	Colourless, yellow, brown, red	2.0—2.2	5.5—6.5		As impurities in clays. 28% H_2O
Perfect (*111*)	Colourless or coloured	3.18	4.0 194	1613—1623	
Good	Colourless	1.46	1.0—1.5	34.5	

TABLE A. 1. (*continued*)

1	2	3	4	5
11	$\bar{n} = 1.447-1.455$	Halloysite mono. $Al_2O_3 \cdot SiO_2 \cdot 2H_2O$		Embedded, gelaty
12	$\bar{n} = 1.458$	Lechatelierite amor. (quartz glass) SiO_2		Irregular
13	$n_\omega = 1.464$ $n_\varepsilon = 1.458$ $\triangle = 0.006$	α-Cristobalite tetrag. (pseudoiso.) SiO_2	—	Elongated needles, flaky, spherolites, octagons
14	$n = 1.466$	iso. (tetrag.?) $3CaSO_4 \cdot 31H_2O$		
15	$n_\omega = 1.466$ $n_\varepsilon = 1.461$ $\triangle = 0.005$	Ettringite hex. $3CaO \cdot Al_2O_3 \cdot 3CaSO_4 \cdot \cdot 3H_2O$	—	Needles
16	$\bar{n} = 1.470-1.500$	Allophane amor. $mAl_2O_3 \cdot nSiO_2 \cdot pH_2O$		Gelaty
17	$n_\gamma = 1.473$ $n_\beta = 1.470$ $n_\alpha = 1.469$ $\oplus, \triangle = 0.004$	γ-Tridymite ortho. SiO_2	35°	Needles, prisms, tablets, agrowhead twins, skeletal forms
18	$\bar{n} = 1.480$	Silica gel amor. SiO_2		Irregular
19	$n_\gamma = 1.482$ $n_\alpha = 1.477$ $\oplus, \triangle = 0.005$	? $K_2O \cdot 4SiO_2$	large	Plates, twinning
20	$n = 1.483-1.487$	Sodalite iso. $Na_8[AlSiO_4]_6Cl_2$	—	Twinning, grains,
21	$n_\gamma = 1.485$ $n_\beta = 1.474$ $n_\alpha = 1.464$ $\triangle = 0.021$	Thenardite ortho. Na_2SO_4	83°	Prismatic grains
22	$n = 1.485$ $\triangle = 0.001$ (possible)	Leucite iso. $\alpha-K_2O \cdot Al_2O_3 \cdot 4H_2O$	—	Grains, complex lamellar twinning
23	$n_\omega = 1.487$ $n_\varepsilon = 1.484$ $\triangle = 0.003$	β-Crystobalite tetrag. (pseudoiso.) SiO_2	40°	Irregular scaly twinning, euhedral needles

6	7	8	11	10	11
	Colourless	~ 2.6	2.5—3.0		
None	Colourless	2.19			
		2.32	6.5	1993	
	Colourless				
	Colourless	1.85—1.89	3		
Poor	Colourless	2.32	6.5	1943	Transforms to crystobalite at 1743K
	Colourless		< 1.0		
	Colourless			1038	
	Colourless yellow, blue	2.35	5.5—6.0	1400—1523	
	White	2.66	2.5—3.0	1153	
	Colourless	2.47	5.5—6.0	1959	Stable above 893K
None	Colourless	2.32	6.5	1986	

TABLE A.1 (*continued*)

1	2	3	4	5
24	$n = 1.4904$	Sylvite iso. KCl	—	Grains
25	$n_\omega = 1.492$ $n_\varepsilon = 1.487$ $\triangle = 0.005$	Aphthitalite hex. $(NaK)_2O \cdot SO_3$		Blades, rhombohedral grains
26	$n_\gamma = 1.497$ $n_\beta = 1.495$ $n_\alpha = 1.494$ $\oplus, \triangle = 0.003$	Arcanite ortho. K_2SO_4	67°	Equant crystals and blades
27	$n = 1.501$	iso. $K_2O \cdot MgO \cdot 5SiO_2$		Squares, hexagons, octagons
28	$n_\gamma = 1.50$ average	Sepiolite mono. $6SiO_2 \cdot 4MgO \cdot 2H_2O$	variable	Microcrystalline fibres
29	$n_\omega = 1.504$ $n_\varepsilon = 1.488$ $\ominus, \triangle = 0.016$	hex. $3CaO \cdot Al_2O_3 \cdot CaSO_4 \cdot \cdot 12H_2O$	—	Star-like aggregates
30	$n_\gamma = 1.508$ $n_\alpha = 1.505$ $n_\beta = 1.497$ $\triangle = 0.011$	ortho. $Na_2O \cdot 2SiO_2$	50°	Prisms, blades according to (*100*)
31	$\bar{n} = 1.508$	Kaliophilite amor. (glass) $K_2O \cdot Al_2O_3 \cdot 2SiO_2$		Irregular
32	$n = 1.508$ $n = 1.486$ $\triangle = 0.022$	Noserite hex. $2MgO \cdot MgF_2 \cdot 3CaF_2$		Needles
33	$n_\gamma = 1.509$ $n_\beta = 1.508$ $n_\alpha = 1.508$ $\oplus, \triangle = 0.001$	Leucite ortho. β-$K_2O \cdot Al_2O_3 \cdot 4SiO_2$	small	Equal grains, twinned, pseudoisometric
34	$\bar{n} = 1.510$	Nepheline glass amor. $Na_2O \cdot Al_2O_3 \cdot 2SiO_2$	—	Irregular
35	$n_\gamma = 1.510-1.604$ $n_\alpha = 1.490-1.527$	Hydrated aluminas hex. (α, β, γ and others) $3CaO \cdot Al_2O_3 \cdot xH_2O$		Tablets, needles

6	7	8	9	10	11
	Colourless or coloured	1.99	1.5—2.0	1043	
Perfect (*1010*) Distinct (*0001*)	Coloured	2.7	3.0		
		2.66			Inverts to uniaxial at 923 K
	Colourless				Occasional birefringence
Basal	Colourless		2.0—2.5		Decomposes above 623 K
Distinct according to (*100*) and (*010*)	Colourless	2.49		1147	
	Colourless	2.60	6.0		
	White				
	Colourless	2.47	5.6—6.0	1954	At 773—973 K, inverts to isometric form
	Colourless				
	White				

TABLE A.1 (*continued*)

1	2	3	4	5
36	$n = 1.512$ $n = 1.498$ $\triangle = 0.016$	Hydrotalcite hex. $6MgO \cdot Al_2O_3 \cdot CO_2 \cdot 12H_2O$	small	Basal plates
37	$n = 1.513-1.610$ $n = 1.488-1.589$ $\triangle = 0.021$	Montmorillonite mono. $Mg \cdot Al_2O_3 \cdot 5SiO_2 \cdot nH_2O$	10–15°	Microcrystalline aggregates
38	$n_\gamma = 1.513$ $n_\alpha = 1.503$ $\ominus, \triangle = 0.010$	ortho. $K_2O \cdot SiO_2$	large	Plates, hexagons, lamellar twinning
39	$n_\gamma = 1.514$ $n_\beta = 1.510$ $n_\alpha = 1.509$ $\ominus, \triangle = 0.005$	α-Carnegieite $Na_2O \cdot Al_2O_3 \cdot 2SiO_2$	15°	Lath-like, needles, polysynthetic twinning
40	$n_\gamma = 1.516$ $n_\alpha = 1.504$ $\oplus, \triangle = 0.012$	Petalite mono. $Li[AlSi_4O_{10}]$	83° $r > v$	Laths or needles
41	$n_\varepsilon = 1.522$ $n_\omega = 1.516$ $\oplus, \triangle = 0.006$	β-Spodumene tetrag.? $Li_2O \cdot Al_2O_3 \cdot 4SiO_2$	58°	Anhedral grains
42	$n_\gamma = 1.522-1.555$ $n_\alpha = 1.508-1.542$ $\ominus, \triangle = 0.010$	Chrysotile ortho. $3MgO \cdot 2SiO_2 \cdot 2H_2O$	large	Fibrous
43	$n = 1.523$	? $Na_2O \cdot MgO \cdot SiO_2$		Square tablets
44	$n_\gamma = 1.523$ $n_\alpha = 1.517$ $\ominus, \triangle = 0.006$	Sanidine mono. $K_2O \cdot Al_2O_3 \cdot 6SiO_2$		Tablets, prisms
45	$n = 1.524$ $n = 1.420$	Thermonatrite ortho. $Na_2CO_3 \cdot H_2O$		Tablets, prisms
46	$n_\omega = 1.524$ $n_\varepsilon = 1.520$ $\triangle = 0.004$	β-Eucryptite hex.? $Li_2O \cdot Al_2O_3 \cdot 2SiO_2$		Hexagonal dipyramidal
47	$n_\omega = 1.523$ $n_\varepsilon = 1.530$ $\oplus, \triangle = 0.006$	Berlinite hex. α-$AlPO_4$		Isotypic with Quartz α-SiO_2 Isomorphic with $AlAsO_4$

6	7	8	9	10	11
	White	2.6	2.0		
None	Colourless	2.5—2.6	1.5		
Distinct basal	Colourless			1309	
None	Colourless			1799	Isometric above 1521K, at 960K inverts to triclinic form
Good	Colourless	2.42	6.5 681		
None	Colourless	2.37	6.0—7.0 1055		Above 773K inverts to α form
Good	Green, yellow, colourless	2.36	2.0—3.0	1723	Decomposes above 1773K
None	Colourless				
Good in two directions	Colourless	2.57	6.0	1443	Stable above 1173K, decomposes at 1803K
	Colourless, white				
	Colourless				Below 1223K inverts to α form
None	Colourles	2.64 nat. 2.56 synt.	6.5		At 856K inverts to β-$AlPO_4$

TABLE A.1 (*continued*)

1	2	3	4	5
48	$n_\gamma = 1.525$ $n_\beta = 1.525$ $n_\alpha = 1.522$ $\ominus, \Delta = 0.003$	α-Cordierite ortho. (pseudohex.) $2MgO \cdot 2Al_2O_3 \cdot 5SiO_2$		Hexagonal prisms or fibres, occasionally twinned
49	$n_\gamma = 1.525$ $n_\beta = 1.523$ $n_\alpha = 1.519$ $\ominus, \Delta = 0.006$	Orthoclase mono. $K_2O \cdot Al_2O_3 \cdot 6SiO_2$	62° $r > v$	Prismatic grains, simple twinning
50	$n_\gamma = 1.528$ $n_\beta = 1.520$ $n_\alpha = 1.513$ $\ominus, \Delta = 0.015$	ortho. $Na_2O \cdot SiO_2$	80°	Prismatic elongated needles
51	$n_\gamma = 1.528$ $n_\beta = 1.521$ $n_\alpha = 1.520$ $\oplus, \Delta = 0.008$	? $K_2O \cdot SiO_2$	−35°	Grains
52	$n_\gamma = 1.528$ $n_\beta = 1.493$ $n_\alpha = 1.471$ $\oplus, \Delta = 0.057$	α-$Na_2O \cdot 2B_2O_3$	?	Grains
53	$n_\gamma = 1.529$ $n_\alpha = 1.524$ $\oplus ? \Delta = 0.005$	? $6Na_2O \cdot 2SiO_2$		Plates
54	$n = 1.529$ $n = 1.506$ $\ominus, \Delta = 0.023$	Nesquehonite ortho. $MgCO_3 \cdot 3H_2O$	53°	Elongated prisms
55	$n_\omega = 1.530$ $n_\alpha = 1.524$ $\Delta = 0.006$	hex.? α-$K_2O \cdot MgO \cdot 3SiO_2$		Rounded or hexagonal grains
56	$n_\gamma = 1.530$ $n_\beta = 1.523$ $n_\alpha = 1.520$ $\oplus, \Delta = 0.010$	Gypsum mono. $CaSO_4 \cdot 2H_2O$	58°	Tablets, needles, prisms, aggregates, twinnings according (*100*)
57	$n_\gamma = 1.530$ $n_\alpha = 1.522$ $\ominus, \Delta = 0.008$	Microcline tric. $K_2O \cdot Al_2O_3 \cdot 6SiO_2$	77—84° $r > v$	Grains or tablets cross twinnings

6	7	8	9	10	11
None	Colourless	2.57	7.0		May be biaxial. Decomposes at 1723 K
Good (*001*), Distinct (*010*)	Colourless	2.54	6.0 794		Decomposes to Leucite at 1443 K
Prismatic	Colourless	2.61		1361	
Distinct	Colourless			1239	
Good				1015	
Good	Colourless			1395	
	Colourless	1.85	2.5		
None	Colourless				High-temperature phase
Good (*010*)	Colourless	2.32	2.0 58		Dehydration at 398—423 K
Perfect according (*010*) and (*001*)	Colourless	2.54	6.0		