

Gems & Gemology Data Depository: Electron-microprobe analyses of tourmaline from the Canary mining area, Zambia^a

From Laurs B.M., Simmons W.B., Rossman G.R., Fritz E.A., Koivula J.I., Anckar B., Falster A.U. (2007)
Yellow Mn-rich tourmaline from the Canary mining area, Zambia. G&G, Vol. 43, No. 4, pp. 314-331.

Color	Deep yellow- brown ^b	Greenish yellow	Deep yellow- brown	Bright yellow	Brownish yellow	Pale yellow
Data point	mt2-19	mt1-4	mt1-11-4	mt2-14-3	mt1-9	mt1-7-2
Sample	Grain mt.	Grain mt.	Grain mt.	Grain mt.	Grain mt.	Grain mt.
No. points	2	3	3	1	3	1
Oxides (wt.%)						
SiO ₂	36.25	36.26	36.30	36.39	36.37	36.13
TiO ₂	0.30	0.37	0.28	0.34	0.53	0.42
B ₂ O ₃ calc.	10.81	10.69	10.68	10.84	10.72	10.74
Al ₂ O ₃	38.42	37.55	37.48	38.89	37.54	38.01
Bi ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00
V ₂ O ₃	0.02	0.10	0.02	0.07	0.02	0.03
FeO	0.10	0.00	0.19	0.00	0.05	0.09
MnO	7.37	7.14	6.94	6.85	6.76	6.70
MgO	0.00	0.00	0.00	0.00	0.00	0.01
CaO	0.08	0.07	0.00	0.11	0.14	0.34
ZnO	0.00	0.00	0.00	0.00	0.00	0.00
Li ₂ O calc.	1.29	1.34	1.36	1.32	1.43	1.40
Na ₂ O	2.54	2.42	2.62	2.31	2.52	2.37
K ₂ O	0.03	0.05	0.02	0.02	0.02	0.04
H ₂ O calc.	3.26	3.18	3.44	3.24	3.19	3.28
F	1.00	1.09	0.52	1.05	1.07	0.90
Subtotal	101.47	100.25	99.85	101.43	100.35	100.46
-O=F	0.42	0.46	0.22	0.44	0.45	0.38
Total	101.05	99.79	99.63	100.99	99.90	100.09
Ions per 31 (O,OH,F)						
Si	5.828	5.892	5.904	5.829	5.894	5.847
Al	0.172	0.108	0.096	0.171	0.106	0.153
Tet. sum	6.000	6.000	6.000	6.000	6.000	6.000
B calc.	2.999	2.999	2.999	2.999	2.999	2.999
Al (Z)	6.000	6.000	6.000	6.000	6.000	6.000
Al (Y)	1.108	1.084	1.090	1.172	1.065	1.096
R _i ³⁺	0.000	0.000	0.000	0.000	0.000	0.000
V ³⁺	0.003	0.012	0.002	0.009	0.003	0.004
Ti	0.036	0.046	0.034	0.041	0.065	0.051
F _e ²⁺	0.014	0.000	0.026	0.000	0.006	0.012
Mn	1.004	0.983	0.957	0.930	0.928	0.919
Mg	0.000	0.000	0.000	0.000	0.000	0.003
Li calc.	0.834	0.873	0.890	0.847	0.932	0.914
Zn	0.000	0.000	0.000	0.000	0.000	0.000
Y sum	2.999	2.999	2.999	2.999	2.999	2.999
Ca	0.014	0.012	0.000	0.019	0.024	0.058
Na	0.793	0.762	0.825	0.718	0.791	0.744
K	0.006	0.010	0.004	0.003	0.004	0.008
Vacancy	0.187	0.215	0.171	0.260	0.181	0.190
X sum	1.000	1.000	1.000	1.000	1.000	1.000
F	0.509	0.558	0.266	0.534	0.549	0.461
OH calc.	3.491	3.442	3.734	3.466	3.451	3.539
Elb	79.8	77.1	82.8	72.0	79.5	75.0
Ross	18.8	21.7	17.2	26.1	18.1	19.1
Lidd	1.4	1.2	0.0	1.9	2.4	5.9

Color	Pinkish brown	Bright yellow	Light brown	Yellow	Light brownish yellow	Deep yellow
Data point	mt1-8	mt5-3	mt1-10	Average	mt2-15	mt2-16
Sample	Grain mt.	Grain mt.	Grain mt.	1.38 ct	Grain mt.	Grain mt.
No. points	3	2	3	5	3	2
Oxides (wt.%)						
SiO ₂	36.22	36.26	36.35	36.64	36.19	36.21
TiO ₂	0.25	0.42	0.43	0.43	0.47	0.43
B ₂ O ₃ calc.	10.70	10.80	10.78	10.90	10.94	10.81
Al ₂ O ₃	37.88	38.53	37.99	38.87	39.31	39.21
Bi ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00
V ₂ O ₃	0.02	0.01	0.02	0.00	0.08	0.03
FeO	0.00	0.00	0.00	0.00	0.00	0.00
MnO	6.56	6.33	6.28	6.21	5.79	5.78
MgO	0.00	0.00	0.01	0.00	0.00	0.00
CaO	0.04	0.29	0.62	0.00	0.40	0.01
ZnO	0.00	0.00	0.00	0.00	0.00	0.00
Li ₂ O calc.	1.42	1.46	1.57	1.51	1.65	1.40
Na ₂ O	2.62	2.45	2.47	2.40	2.39	2.34
K ₂ O	0.04	0.03	0.03	0.02	0.03	0.01
H ₂ O calc.	3.23	3.27	3.45	3.22	3.34	3.22
F	0.97	0.96	0.57	1.15	0.93	1.08
Subtotal	99.95	100.83	100.55	101.36	101.50	100.52
-O=F	0.41	0.41	0.24	0.48	0.39	0.46
Total	99.54	100.42	100.32	100.88	101.11	100.06
Ions per 31 (O,OH,F)						
Si	5.883	5.833	5.856	5.840	5.746	5.821
Al	0.117	0.167	0.144	0.160	0.254	0.179
Tet. sum	6.000	6.000	6.000	6.000	6.000	6.000
B calc.	2.999	2.999	2.999	3.000	2.999	2.999
Al (Z)	6.000	6.000	6.000	6.000	6.000	6.000
Al (Y)	1.136	1.139	1.069	1.142	1.103	1.249
Ri ³⁺	0.000	0.000	0.000	0.000	0.000	0.000
V ³⁺	0.003	0.001	0.002	0.000	0.011	0.003
Ti	0.031	0.051	0.052	0.052	0.056	0.052
Fe ²⁺	0.000	0.000	0.000	0.000	0.000	0.000
Mn	0.903	0.863	0.857	0.838	0.778	0.787
Mg	0.000	0.000	0.002	0.000	0.000	0.000
Li calc.	0.927	0.945	1.017	0.967	1.051	0.908
Zn	0.000	0.000	0.000	0.000	0.000	0.000
Y sum	2.999	2.999	2.999	3.000	2.999	2.999
Ca	0.007	0.051	0.106	0.000	0.068	0.002
Na	0.825	0.765	0.771	0.743	0.734	0.730
K	0.007	0.006	0.005	0.005	0.006	0.002
Vacancy	0.160	0.178	0.118	0.253	0.192	0.267
X sum	1.000	1.000	1.000	1.000	1.000	1.000
F	0.499	0.490	0.289	0.577	0.465	0.550
OH calc.	3.501	3.510	3.711	3.423	3.535	3.450
Elb	83.1	77.0	77.5	74.6	73.9	73.1
Ross	16.1	17.9	11.8	25.4	19.3	26.8
Lidd	0.7	5.1	10.7	0.0	6.8	0.2

Color	Light brown	Yellow	Yellowish green	Light brownish yellow	Yellow	Orangy yellow
Data point	mt2-18-3	Average	Average	mt2-17	Average	Average
Sample	Grain mt.	1.17 ct	2.16 ct	Grain mt.	0.69 ct	1.79 ct
No. points	1	5	5	2	4	5
Oxides (wt.%)						
SiO ₂	36.27	36.55	36.56	36.23	36.56	36.65
TiO ₂	0.40	0.20	0.17	0.39	0.40	0.43
B ₂ O ₃ calc.	10.90	10.86	10.82	10.90	10.91	10.89
Al ₂ O ₃	39.58	39.46	39.13	39.71	39.67	39.64
Bi ₂ O ₃	0.00	0.01	0.00	0.00	0.01	0.01
V ₂ O ₃	0.03	0.00	0.00	0.05	0.00	0.00
FeO	0.00	0.00	0.00	0.01	0.00	0.00
MnO	5.66	5.64	5.64	5.45	5.44	4.66
MgO	0.00	0.00	0.00	0.00	0.00	0.00
CaO	0.61	0.00	0.00	0.85	0.02	0.10
ZnO	0.00	0.02	0.01	0.00	0.00	0.01
Li ₂ O calc.	1.51	1.44	1.45	1.52	1.47	1.57
Na ₂ O	2.14	2.40	2.39	1.84	2.38	2.30
K ₂ O	0.01	0.02	0.02	0.01	0.02	0.03
H ₂ O calc.	3.60	3.19	3.22	3.32	3.24	3.25
F	0.34	1.18	1.08	0.93	1.11	1.07
Subtotal	101.04	100.96	100.50	101.20	101.24	100.59
-O=F	0.14	0.50	0.46	0.39	0.47	0.45
Total	100.90	100.47	100.04	100.81	100.77	100.14
Ions per 31 (O,OH,F)						
Si	5.781	5.846	5.870	5.777	5.825	5.850
Al	0.219	0.154	0.130	0.223	0.175	0.150
Tet. sum	6.000	6.000	6.000	6.000	6.000	6.000
B calc.	2.999	3.000	3.000	2.999	3.000	3.000
Al (Z)	6.000	6.000	6.000	6.000	6.000	6.000
Al (Y)	1.217	1.285	1.275	1.238	1.275	1.307
Ri ³⁺	0.000	0.000	0.000	0.000	0.000	0.000
V ³⁺	0.003	0.000	0.000	0.006	0.000	0.000
Ti	0.048	0.024	0.021	0.047	0.048	0.051
Fe ²⁺	0.000	0.000	0.000	0.001	0.000	0.000
Mn	0.764	0.763	0.768	0.736	0.735	0.630
Mg	0.000	0.000	0.000	0.000	0.000	0.000
Li calc.	0.967	0.925	0.934	0.972	0.942	1.009
Zn	0.000	0.002	0.002	0.000	0.000	0.001
Y sum	2.999	3.000	3.000	2.999	3.000	3.000
Ca	0.105	0.000	0.000	0.146	0.003	0.016
Na	0.663	0.743	0.744	0.568	0.736	0.712
K	0.002	0.004	0.004	0.003	0.005	0.007
Vacancy	0.231	0.253	0.251	0.284	0.256	0.265
X sum	1.000	1.000	1.000	1.000	1.000	1.000
F	0.171	0.596	0.551	0.468	0.559	0.541
OH calc.	3.829	3.404	3.449	3.532	3.441	3.458
Elb	66.4	74.6	74.7	57.0	74.0	71.7
Ross	23.1	25.4	25.3	28.4	25.7	26.7
Lidd	10.5	0.0	0.0	14.6	0.3	1.7

Color	Yellowish green	Light yellow	Yellowish green	Yellowish green	Brownish yellow	Yellow-green
Data point	Average	mt9-9	Average	Average	mt9-7	mt9-3
Sample	2.32 ct	Grain mt.	2.72 ct	1.92 ct	Grain mt.	Grain mt.
No. points	5	3	5	5	2	4
Oxides (wt.%)						
SiO ₂	36.57	36.52	36.69	36.54	36.55	36.60
TiO ₂	0.15	0.17	0.14	0.10	0.12	0.15
B ₂ O ₃ calc.	10.84	10.83	10.87	10.85	10.95	10.97
Al ₂ O ₃	39.71	39.68	39.88	40.02	41.17	41.62
Bi ₂ O ₃	0.00	0.00	0.00	0.00	0.00	0.00
V ₂ O ₃	0.00	0.00	0.00	0.00	0.01	0.00
FeO	0.00	0.00	0.00	0.00	0.00	0.00
MnO	4.40	4.40	4.34	4.00	2.74	1.82
MgO	0.00	0.00	0.00	0.00	0.00	0.00
CaO	0.00	0.03	0.00	0.00	0.03	0.02
ZnO	0.01	0.00	0.00	0.00	0.00	0.00
Li ₂ O calc.	1.57	1.59	1.59	1.60	1.75	1.84
Na ₂ O	2.37	2.43	2.40	2.36	2.52	2.50
K ₂ O	0.04	0.02	0.02	0.01	0.01	0.03
H ₂ O calc.	3.23	3.27	3.23	3.19	3.26	3.27
F	1.06	1.00	1.09	1.17	1.10	1.09
Subtotal	99.95	99.93	100.26	99.85	100.20	99.89
-O=F	0.45	0.42	0.46	0.49	0.46	0.46
Total	99.50	99.51	99.80	99.36	99.74	99.43
Ions per 31 (O,OH,F)						
Si	5.865	5.857	5.864	5.856	5.801	5.796
Al	0.135	0.143	0.136	0.144	0.199	0.204
Tet. sum	6.000	6.000	6.000	6.000	6.000	6.000
B calc.	3.000	2.999	3.000	3.000	2.999	2.999
Al (Z)	6.000	6.000	6.000	6.000	6.000	6.000
Al (Y)	1.370	1.358	1.375	1.414	1.501	1.566
Ri ³⁺	0.000	0.000	0.000	0.000	0.000	0.000
V ³⁺	0.000	0.000	0.000	0.000	0.001	0.000
Ti	0.018	0.021	0.017	0.013	0.015	0.018
Fe ²⁺	0.000	0.000	0.000	0.000	0.000	0.000
Mn	0.597	0.597	0.588	0.543	0.369	0.244
Mg	0.000	0.000	0.000	0.000	0.000	0.000
Li calc.	1.014	1.023	1.019	1.030	1.115	1.171
Zn	0.001	0.000	0.001	0.000	0.000	0.000
Y sum	3.000	2.999	3.000	3.000	2.999	2.999
Ca	0.000	0.005	0.000	0.000	0.004	0.003
Na	0.737	0.755	0.743	0.734	0.776	0.767
K	0.007	0.004	0.004	0.002	0.003	0.005
Vacancy	0.256	0.236	0.253	0.263	0.217	0.225
X sum	1.000	1.000	1.000	1.000	1.000	1.000
F	0.540	0.507	0.552	0.594	0.550	0.545
OH calc.	3.460	3.493	3.448	3.405	3.450	3.455
Elb	74.2	75.8	74.6	73.6	77.8	77.1
Ross	25.8	23.7	25.4	26.4	21.7	22.7
Lidd	0.0	0.5	0.0	0.00	0.4	0.3

Color	Light brownish yellow	Yellowish brown	Brownish orange	Pale brownish yellow	Dark brownish orange
Data point	mt9-2	mt9-1	mt9-5	mt9-4	mt9-6
Sample	Grain mt.	Grain mt.	Grain mt.	Grain mt.	Grain mt.
No. points	2	6	3	3	2
Oxides (wt.%)					
SiO ₂	36.59	36.56	36.61	36.55	36.57
TiO ₂	0.08	0.11	0.13	0.18	0.15
B ₂ O ₃ calc.	10.96	10.97	10.97	10.96	10.96
Al ₂ O ₃	41.83	41.74	41.80	41.67	41.85
Bi ₂ O ₃	0.00	0.00	0.00	0.00	0.01
V ₂ O ₃	0.00	0.00	0.00	0.00	0.00
FeO	0.00	0.00	0.00	0.00	0.00
MnO	1.71	1.60	1.48	1.47	1.35
MgO	0.00	0.00	0.03	0.00	0.00
CaO	0.00	0.13	0.03	0.03	0.00
ZnO	0.03	0.03	0.02	0.00	0.01
Li ₂ O calc.	1.80	1.85	1.85	1.87	1.85
Na ₂ O	2.35	2.42	2.45	2.47	2.35
K ₂ O	0.00	0.02	0.01	0.02	0.02
H ₂ O calc.	3.26	3.29	3.29	3.30	3.20
F	1.11	1.04	1.05	1.01	1.22
Subtotal	99.73	99.89	99.72	99.54	99.52
-O=F	0.47	0.44	0.44	0.43	0.51
Total	99.26	99.45	99.28	99.12	99.01
Ions per 31 (O,OH,F)					
Si	5.798	5.789	5.795	5.797	5.799
Al	0.202	0.211	0.205	0.203	0.201
Tet. sum	6.000	6.000	6.000	6.000	6.000
B calc.	2.999	2.999	2.999	2.999	2.999
Al (Z)	6.000	6.000	6.000	6.000	6.000
Al (Y)	1.611	1.577	1.596	1.585	1.621
Ri ³⁺	0.000	0.000	0.000	0.000	0.000
V ³⁺	0.000	0.000	0.000	0.000	0.000
Ti	0.010	0.013	0.015	0.022	0.017
Fe ²⁺	0.000	0.000	0.000	0.000	0.000
Mn	0.230	0.214	0.198	0.198	0.181
Mg	0.000	0.000	0.007	0.000	0.000
Li calc.	1.145	1.177	1.181	1.194	1.178
Zn	0.004	0.003	0.002	0.000	0.002
Y sum	2.999	2.999	2.999	2.999	2.999
Ca	0.000	0.021	0.005	0.005	0.000
Na	0.721	0.743	0.751	0.758	0.723
K	0.000	0.005	0.002	0.005	0.003
Vacancy	0.279	0.231	0.242	0.233	0.274
X sum	1.000	1.000	1.000	1.000	1.000
F	0.558	0.521	0.525	0.508	0.611
OH calc.	3.442	3.479	3.475	3.492	3.389
Elb	72.1	74.6	75.2	76.2	72.5
Ross	27.9	23.2	24.3	23.4	27.5
Lidd	0.0	2.1	0.5	0.5	0.0

^a Samples consist of grain mounts and faceted stones, and are arranged by decreasing Mn content. Average analyses are given except where only one analysis point was available. Detection limits (wt.% oxide): 0.009 Mg, 0.006 Fe, 0.018 K, 0.010 Bi, 0.014 Zn. Analyzed, but not detected, were Cr (0.014), Cu (0.009), Ba (0.012), and Pb (0.011). Total Fe reported as FeO.

^b This sample had the highest manganese content obtained in this study: 7.59 wt.% MnO.