| Hey Number | Mineral Name | Other Names | Chemical Formula | Moh's Hardness | Tenacity | H&S Data | Notes |
|---|---|---|---|---|---|---|---|
| **1** | **Elements & Alloys** | | | | | | |
| 1.1 | copper | | Cu | 2.5-3 | malleable | | |
| 1.2 | silver | | Ag | 2.5-3 | malleable | | |
| 1.24 | diamond | | C | 10 | brittle | | |
| 1.29 | tin | | Sn | 1.5-2 | malleable | | |
| 1.30 | lead | | Pb | 1.5 | malleable | | easily scratched |
| 1.33 | arsenic | | As | 3.5 | brittle | | |
| 1.37 | domeykite | | $Cu_3As$ | 3-3.5 | | | |
| 1.38 | algodonite | | $(Cu_{1-x}As_x)$; x≈0.15 | 4 | | | |
| 1.41 | antimony | | Sb | 3-3.5 | very brittle | | |
| 1.42 | stibarsen | allemontite | AsSb | 3-4 | | | |
| 1.48 | dyscrasite | stibiotriargentite | $Ag_3Sb$ | 3.5-4 | sectile, but brittle | | |
| 1.49 | bismuth | | Bi | 2-2.5 | sectile | | |
| 1.51 | sulfur | α-sulfur; brimstone | $S_8$ | 1.5-2.5 | brittle | | "negatively charged when rubbed" (Schumann 1992: 38) |
| 1.54 | tellurium | | Te | 2-2.5 | brittle | | |
| 1.57 | iron | | Fe | 4.5 | malleable | | |
| 1.61 | nickel | | Ni | 3.5 | | | |
| 1.62 | kamacite | | α-(Fe,Ni) | 4 | | | |
| 1.63 | taenite | | γ-(Ni,Fe) | 5-5.5 | | | |
| 1.82 | platinum | | Pt | 4 | malleable | | Non-magnetic to distinctly magnetic when rich in iron |
| **2** | **Carbides, Nitrides, Silicides and Phosphides** | | | | | | |
| 2.3 | osbornite | | TiN | 8.5 | brittle | | |
| 2.14 | schreibersite | rhabdite, shepardite | $(Fe,Ni)_3P$ | 6.5-7 | very brittle | | strongly magnetic |
| **3** | **Sulfides, Selenides, Tellurides, Arsenides and Bismuthides** | | | | | | |
| 3.1.1 | chalcocite | cuprein | $Cu_2S$ | 2.5-3 | brittle | | |
| 3.1.8 | covellite | | CuS | 1.5-2 | flexible | | |
| 3.1.9 | berzelianite | selencuprite | $Cu_2Se$ | 2 | somewhat malleable | | |
| 3.1.11 | umangite | | $Cu_3Se_2$ | 3 | | | |
| 3.1.14 | klockmannite | | CuSe | 2-2.5 | | | |
| 3.1.16 | weissite | | $Cu_{2-x}Te$ | 3 | | | |
| 3.1.17 | rickardite | | $Cu_7Te_5$ | 3.5 | | | |
| 3.1.22 | cubanite | barracanite | $CuFe_2S_3$ | 3.5 | | | |
| 3.1.23 | bornite | erubescite | $Cu_5FeS_4$ | 3 | brittle | | |
| 3.1.25 | chalcopyrite | cupropyrite | $CuFeS_2$ | 3.5-4 | brittle | | |

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|---|---|---|---|---|---|---|---|
| 3.2.1 | acanthite | | $Ag_2S$ | 2-2.5 | sectile | | |
| 3.2.3 | naumannite | | $Ag_2Se$ | 2.5 | sectile | | |
| 3.2.4 | aguilarite | | $Ag_4SeS$ | 2.5 | sectile | | |
| 3.2.5 | hessite | | $Ag_2Te$ | 2-3 | sectile | | |
| 3.2.8 | cervelleite | | $Ag_4TeS$ | 2 | | | |
| 3.2.10 | stromeyerite | | AgCuS | 2.5-3 | brittle | | |
| 3.2.11 | mckinstryrite | | $(Ag,Cu)_2S$ | 1.5-2.5 | | | |
| 3.2.12 | jalpaite | | $Ag_3CuS_2$ | 2-2.5 | | | |
| 3.2.13 | eucairite | | AgCuSe | 2.5 | brittle | | |
| 3.2.17 | argentopyrite | | $AgFe_2S_3$ | 3.5-4 | brittle | | |
| 3.3.1 | calaverite | | $AuTe_2$ | 2.5-3 | brittle | | |
| 3.3.2 | krennerite | müllerine | $Au_3AgTe_8$ | 2-3 | | | |
| 3.3.7 | petzite | | $Ag_3AuTe_2$ | 2.5-3 | brittle | | |
| 3.3.9 | sylvanite | | $(Au,Ag)_2Te_4$ | 1.5-2 | brittle | | |
| 3.4.2 | oldhamite | | (Ca,Mg)S | 4 | | | |
| 3.4.4 | sphalerite | blende | ZnS | 3.5-4 | brittle | | soft |
| 3.4.5 | wurtzite | spiauterite | (Zn,Fe)S | 3.5-4 | brittle | | |
| 3.4.7 | greenockite | | CdS | 3-3.5 | brittle | | |
| 3.5.1 | cinnabar | vermilion | HgS | 2-2.5 | sectile | | |
| 3.6.5 | galena | | PbS | 2.5 | brittle | | |
| 3.6.7 | altaite | | PbTe | 2-3 | sectile | | |
| 3.7.4 | realgar | ruby sulfur | $As_4S_4$ | 1.5-2 | sectile | | |
| 3.7.8 | orpiment | | $As_2S_3$ | 1.5-2 | sectile | | |
| 3.7.14 | stibnite | | $Sb_2S_3$ | 2 | flexible | | soft |
| 3.7.17 | bismuthinite | | $Bi_2S_3$ | 2-2.5 | flexible | | |
| 3.7.29 | tetradymite | | $Bi_2Te_2S$ | 1.5-2 | | | |
| 3.7.30 | joséite | oruetite | $Bi_4TeS_2$ | 2 | flexible | | |
| 3.8.4 | daubréelite | | $Fe^{2+}Cr^{3+}{}_2S_4$ | 4.5-5 | brittle | | |
| 3.8.6 | molybdenite | | $MoS_2$ | 1-1.5 | flexible | | |
| 3.8.12 | alabandite | | MnS | 3.5-4 | brittle | | |
| 3.8.13 | hauerite | | $MnS_2$ | 4 | brittle | | |
| 3.9.1 | pyrrhotite | magnetic iron pyrites | $Fe_7S_8$ | 3.5-4 | | | strongly magnetic |
| 3.9.3 | pyrite | fool's gold | $FeS_2$ | 6-6.5 | brittle | | sensitive to shock |
| 3.9.4 | marcasite | | $FeS_2$ | 6-6.5 | brittle | | |
| 3.9.5 | greigite | melnikovite | $Fe^{2+}Fe^{3+}{}_2S_4$ | 4-4.5 | | | |
| 3.9.6 | mackinawite | kansite | $(Fe,Ni)_9S_8$ | 2.5 | | | |
| 3.9.7 | smythite | | $(Fe,Ni)_{3+x}S_4$; x≈0-0.3 | 4.5 | brittle | | |

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| 3.9.9 | ferroselite | hastite | $FeSe_2$ | 6-6.5 | very brittle | | |
| 3.9.11 | löllingite | Imohsine | $FeAs_2$ | 5-5.5 | brittle | | |
| 3.9.12 | arsenopyrite | | FeAsS | 5.5-6 | brittle | | |
| 3.9.NI | troilite | | FeS | 3.5-4.5 | | | |
| 3.10.2 | linnaeite | | $Co^{2+}Co^{3+}{}_2S_4$ | 4.5-5.5 | | | |
| 3.10.10 | safflorite | | $(Co,Ni,Fe)As_2$ | 4.5-5 | brittle | | |
| 3.10.12 | skutterudite | smaltite; modumite | $CoAs_3$ | 5.5-6 | | | |
| 3.10.13 | cobaltite | | CoAsS | 5.5 | brittle | | |
| 3.10.17 | glaucodot | | $(Co_{0.5}Fe_{0.5})AsS$ | 5 | brittle | | |
| 3.10.18 | carrollite | sychnodymite | $Cu(Co,Ni)_2S_4$ | 4.5-5.5 | very brittle | | |
| 3.11.3 | millerite | | NiS | 3-3.5 | brittle | | |
| 3.11.4 | polydymite | grünauite | $Ni^{2+}Ni^{3+}{}_2S_4$ | 4.5-5.5 | | | |
| 3.11.5 | vaesite | | $NiS_2$ | 4.5-5.5 | | | |
| 3.11.8 | violarite | beyrichite | $Fe^{2+}Ni^{3+}{}_2S_4$ | 4.5-5.5 | | | |
| 3.11.9 | pentlandite | lillehammerite | $(Fe,Ni)_9S_8$ | 3.5-4 | brittle | | |
| 3.11.10 | bravoite | | $(Fe,Ni)S_2$ | 6.5 | brittle | | |
| 3.11.19 | penrosite | blockite | $(Ni,Co,Cu)Se_2$ | 2.5-3 | brittle | | |
| 3.11.22 | melonite | | $NiTe_2$ | 1-1.5 | | | |
| 3.11.26 | maucherite | placodine, temiskamite | $Ni_{11}As_8$ | 5 | | | |
| 3.11.27 | nickeline | niccolite | NiAs | 5-5.5 | brittle | | |
| 3.11.28 | rammelsbergite | | $NiAs_2$ | 5.5-6 | brittle | | |
| 3.11.29 | pararammelsbergite | | $NiAs_2$ | 5.5 | | | |
| 3.11.30 | nickelskutterudite | chloanthite | $(Ni,Co,Fe)As_3$ | 5.5-6 | | | |
| 3.11.34 | gersdorffite | | NiAsS | 5.5 | brittle | | |
| 3.11.36 | breithauptite | | NiSb | 5.5 | brittle | | |
| 3.11.38 | ullmannite | | NiSbS | 5-5.5 | brittle | | |
| **4** | **Oxysulfides** | | | | | | |
| 4.2 | kermesite | | $Sb_2S_2O$ | 1-1.5 | | | |
| **5** | **Sulfosalts: Sulfarsenites & Sulfobismuthites** | | | | | | |
| 5.1.4 | chalcostibite | guejarite; rosite; wolfsbergite | $CuSbS_2$ | 3-4 | brittle | | |
| 5.1.7 | emplectite | tannenite | $CuBiS_2$ | 2 | brittle | | |
| 5.1.9 | wittichenite | | $Cu_3BiS_3$ | 2-3 | brittle | | |
| 5.1.10 | hodrušite | | $Cu_8Bi_{12}S_{22}$ | 4-5 | very brittle | | |
| 5.2.1 | smithite | | $AgAsS_2$ | 1.5-2 | brittle | | |
| 5.2.2 | trechmannite | | $AgAsS_2$ | 1.5-2 | | | |

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|---|---|---|---|---|---|---|---|
| 5.2.3 | proustite | light red silver ore | $Ag_3AsS_3$ | 2-2.5 | brittle | | |
| 5.2.4 | xanthoconite | | $Ag_3AsS_3$ | 2-3 | brittle | | |
| 5.2.5 | pearceite | arsenpolybasite | $[Ag_9CuS_4][(Ag,Cu)_6(As,Sb)_2S_7]$ | 2.5-3 | | | 2 known polymorphs, both formerly known as arsenpolybasite; forms solid solution series with polybasite-Tac |
| 5.2.8 | miargyrite | hypargyrite; kenngottite | $AgSbS_2$ | 2.5 | | | |
| 5.2.9 | pyrargyrite | dark red silver ore; argyrythrose | $Ag_3SbS_3$ | 2.5 | brittle | | |
| 5.2.10 | pyrostilpnite | fireblende; pyrochrotite; pyrichrolite | $Ag_3SbS_3$ | 2 | | | |
| 5.2.11 | stephanite | goldschmidtine; psaturose; röschwächs | $Ag_5SbS_4$ | 2-2.5 | brittle | | |
| 5.2.12 | polybasite | antimonpearcite | $[(Ag,Cu)_6(Sb,As)_2S_7][Ag_9CuS_4]$ | 2.5-3 | very brittle | | 3 known polymorphs, including polybasite-Tac (formerly known as antimonpearcite); forms solid solution series with pearceite |
| 5.2.16 | aramayoite | | $Ag_3Sb_2(Bi,Sb)S_6$ | 2.5 | | | |
| 5.2.17 | matildite | argentobismuthutite; morocochite; peruvite; plenargyrite | $AgBiS_2$ | 2.5 | brittle | | |
| 5.2.19 | pavonite | | $AgBi_3S_5$ | 2 | | | |
| 5.2.24 | volynskite | | $AgBiTe_2$ | 2.5-3 | | | |
| 5.2.NI | fettelite | sanguinite | $[Ag_6As_2S_7][Ag_{10}HgAs_2S_8]$ | 3.5 | brittle | | |
| 5.3.1 | nagyágite | | $[Pb_3(Pb,Sb)_3S_6](Au,Te)_3$ | 1-1.5 | flexible | | |
| 5.5.1 | lorándite | | $TlAsS_2$ | 2-2.5 | elastic | | |
| 5.5.7 | hutchinsonite | | $TlPbAs_5S_9$ | 1.5-2 | brittle | | |
| 5.5.10 | vrbaite | urbaite | $Hg_3Tl_4As_8Sb_2S_{20}$ | 3.5 | brittle | | |
| 5.6.1 | sartorite | binnite; rathite-V | $PbAs_2S_4$ | 3 | very brittle | | |
| 5.6.2 | dufrénoysite | plumbobinnite; rathite-1a; scleroclase | $Pb_2As_2S_5$ | 3 | brittle | | |
| 5.6.4 | baumhauerite | | $Pb_3As_4S_9$ | 3 | | | |
| 5.6.6 | jordanite | reniforite; reniformite | $Pb_{14}(As,Sb)_6S_{23}$ | 3 | brittle | | |
| 5.6.7 | fülöppite | | $Pb_3Sb_8S_{15}$ | 2.5 | brittle | | |
| 5.6.8 | zinkenite | keeleyite | $Pb_9Sb_{22}S_{42}$ | 3-3.5 | | | |
| 5.6.13 | semseyite | | $Pb_9Sb_8S_{21}$ | 2.5 | brittle | | |

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| 5.6.15 | boulangerite | embrithite; mullanite; yenerite | $Pb_5Sb_4S_{11}$ | 2.5-3 | brittle | | |
| 5.6.23 | galenobismutite | bismutoplagionite | $PbBi_2S_4$ | 2.5-3.5 | flexible | | |
| 5.7.2 | bournonite | berthonite; endellione; rädlerz; tripelglanz; wölchite | $PbCuSbS_3$ | 2.5-3 | brittle | | |
| 5.7.3 | meneghinite | | $Pb_{13}CuSb_7S_{24}$ | 2.5 | brittle | | |
| 5.7.9 | aikinite | belonite; nadelerz; patrinite | $PbCuBiS_3$ | 2-2.5 | | | |
| 5.7.20 | marrite | | $AgPbAsS_3$ | 3 | brittle | | |
| 5.7.22 | andorite | sundtite; webnerite | $AgPbSb_3S_6$ | 3.5 | brittle | | |
| 5.7.23 | ramdohrite | | $Pb_{5.9}Fe_{0.1}Mn_{0.1}In_{0.1}Cd_{0.2}Ag_{2.8}Sb_{10.8}S_{24}$ | 2 | brittle | | |
| 5.7.27 | fizélyite | | $Ag_5Pb_{14}Sb_{21}S_{48}$ | 2 | very brittle | | |
| 5.7.28 | owyheeite | | $Ag_3Pb_{10}Sb_{11}S_{28}$ | 2.5 | brittle | | |
| 5.7.29 | freieslebenite | donacargyrite | $AgPbSbS_3$ | 2.5 | | | |
| 5.7.30 | diaphorite | brongniardite; ultrabasite | $Ag_3Pb_2Sb_3S_8$ | 2.5-3 | brittle | | |
| 5.7.39 | benjaminite | | $Ag_3Bi_7S_{12}$ | 3.5 | | | |
| 5.7.40 | lengenbachite | | $Ag_4Cu_2Pb_{18}As_{12}S_{39}$ | 1-2 | malleable | | |
| 5.7.47 | rathite | arsenomelane; wiltshireite | $Ag_2Pb_{12-x}Tl_{x/2}As_{18+x/2}S_{40}$ | 3 | | | |
| 5.8.1 | samsonite | | $Ag_4MnSb_2S_6$ | 2.5 | | | |
| 5.8.4 | berthierite | anglarite; chazellite; martourite | $FeSb_2S_4$ | 2-3 | brittle | | |
| 5.8.5 | jamesonite | comuccite; pfaffite | $Pb_4FeSb_6S_{14}$ | 2.5 | brittle | | |
| **6** | **Sulfosalts** | | | | | | |
| 6.1.6 | stannite | bolivianite; volfsonite | $Cu_2FeSnS_4$ | 4 | | | |
| 6.1.18 | franckeite | llicteria | $Fe^{2+}(Pb,Sn^{2+})_6Sn^{4+}{}_2Sb_2S_{14}$ | 2.5-3 | malleable | | |
| 6.2.1 | germanite | | $Cu_{13}Fe_2Ge_2S_{16}$ | 4 | brittle | | |
| 6.2.4 | argyrodite | plusinglanz | $Ag_8GeS_6$ | 2.5-3 | brittle | | |
| 6.2.5 | canfieldite | | $Ag_8SnS_6$ | 2.5 | brittle | | |
| 6.3.1 | enargite | garbyite; guayacanite | $Cu_3AsS_4$ | 3 | brittle | | |
| 6.4.1 | sulvanite | | $Cu_3VS_4$ | 3.5 | | | |
| 6.5.1 | corderoite | | $\alpha\text{-}Hg^{2+}{}_3S_2Cl_2$ | 3 | | | |
| 6.5.NI | kenhsuite | | $\gamma\text{-}Hg^{2+}{}_3S_2Cl_2$ | 2-3 | | | |

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| **7** | **Oxides & Hydroxides** | | | | | | |
| 7.3.1 | cuprite | ruberite | $Cu_2O$ | 3.5-4 | brittle | | |
| 7.3.2 | tenorite | melaconite | CuO | 3.5 | brittle | | |
| 7.4.7 | periclase | | MgO | 5.5 | brittle | | |
| 7.4.8 | brucite | hydrate of/native magnesia, shepardite, texalite | $Mg(OH)_2$ | 2.5-3 | sectile | | |
| 7.5.1 | zincite | spartalite, sterlingite (of Alger) | ZnO | 4 | brittle | | |
| 7.5.12 | montroydite | | HgO | | | | |
| 7.6.1 | corundum | spath adamantin | $Al_2O_3$ | 9 | brittle | | |
| 7.6.4 | gibbsite | gibbsitogelite; hydrargillite; zirlite | $Al(OH)_3$ | 2.5-3 | brittle | | hygroscopic; porous |
| 7.8.1 | quartz | | $SiO_2$ | 7 | brittle | | var. chalcedony "always somewhat porous" (Schumann 1974) |
| 7.8.5 | cristobalite | | $SiO_2$ | 6-7 | brittle | | |
| 7.8.8 | opal | | $SiO_2 \cdot nH_2O$ | 5.5-6.5 | brittle | | porous; water content varies with conditions, composition, and porosity, but can be up to 30% $H_2O$; sensitive to pressure & stress |
| 7.9.2 | rutile | crispite; dicksbergite; titanite | $TiO_2$ | 6-6.5 | brittle | | |
| 7.10.10 | thorianite | | $ThO_2$ | 6.5-7 | brittle | usually radioactive | |
| 7.11.20 | massicot | chrysitin | PbO | 2 | | | |
| 7.11.21 | litharge | | PbO | 2 | | | |
| 7.11.22 | minium | red lead | $Pb_3O_4$ | 2.5 | | | |
| 7.11.23 | plattnerite | diplasites plumbicus | $PbO_2$ | 5.5 | brittle | | |
| 7.12.8 | navajoite | | $(V^{5+},Fe^{3+})_{10}O_{24} \cdot 12H_2O$ | 1.5 | sectile | | |
| 7.12.10 | bariandite | | $Al_{0.6}(V^{5+},V^{4+})_8O_{20} \cdot 9H_2O$ | | | | |
| 7.13.1 | arsenolite | | $As_2O_3$ | 1.5 | | very poisonous | |
| 7.13.4 | valentinite | exitèlite; white antimony | $Sb_2O_3$ | 2.5-3 | brittle | | hygroscopic; porous |
| 7.13.6 | stibiconite | arsenostibite; hydroroméite; stibanite; volgerite | $Sb^{3+}Sb^{5+}{}_2O_6(OH)$ | 5.5-7 | | | |
| 7.16.1 | uraninite | ulrichite; uranatemnite | $UO_2$ | 5-6 | brittle | highly radioactive | |
| 7.16.2 | schoepite | epiianthinite | $(UO_2)_8O_2(OH)_{12} \cdot 12H_2O$ | 2.5 | brittle | | |

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| 7.16.3 | paraschoepite | | $UO_3 \cdot 2H_2O$ | | | | existance questionable; probably a mixture of metaschoepite, paulscherrerite, and ianthinite |
| 7.16.4 | metaschoepite | | $(UO_2)_8O_2(OH)_{12} \cdot 10H_2O$ | | | | |
| 7.16.7 | ianthinite | | $U^{4+}(UO_2)_5O_7 \cdot 10H_2O$ | 2-3 | | | |
| 7.16.21 | davidite-(La) | | $La(Y,U)Fe_2(Ti,Fe,Cr,V)_{18}(O,OH,F)_{38}$ | 6 | | | |
| 7.16.22 | davidite-(Ce) | | $Ce(Y,U)Fe_2(Ti,Fe,Cr,V)_{18}(O,OH,F)_{38}$ | 6 | | | |
| 7.16.28 | vandendriesscheite | | $PbU_7O_{22} \cdot 12H_2O$ | 3 | | radioactive | |
| 7.17.2 | tellurite | tellurige säure; tellurocker | $TeO_2$ | 2 | | | |
| 7.18.1 | manganosite | | MnO | 5.5 | brittle | | |
| 7.18.3 | pyolusite | lapis manganensis; pseudomanganite; varvicite | $Mn^{4+}O_2$ | 2; 6-6.5 | brittle | | hygroscopic; porous |
| 7.18.7 | manganite | newkirkite; sphenomanganite | $Mn^{3+}O(OH)$ | 4 | brittle | | |
| 7.18.10 | pyrochroite | eisenpyrochroite | $Mn(OH)_2$ | 2.5-3 | elastic | | |
| 7.20.4 | hematite | hematitogelite; iron glance | $Fe_2O_3$ | 5-6 | brittle | | |
| 7.20.5 | goethite | allcharite; brown hematite/ironstone; chileit; ehrenwerthite; hydrohematite; mesabite; przibramite | $\alpha$-$Fe^{3+}O(OH)$ | 5-5.5 | brittle | | |
| 7.20.6 | akaganeite | | $(Fe^{3+},Ni^{2+})_8(OH,O)_{16}Cl_{1.25} \cdot nH_2O$ | | | | hygroscopic |
| **8** | **Halides** | | | | | | |
| 8.1.2 | villiaumite | | NaF | 2-2.5 | brittle | highly toxic; irritant; see MSDS for further information | |
| 8.1.3 | halite | common salt; martinsite; natrikalite; rock salt; saltspar | NaCl | 2.5 | brittle | | hygroscopic 'when contaminated' (Schumann 1992) |
| 8.1.4 | hydrohalite | | $NaCl \cdot 2H_2O$ | | | | |
| 8.1.5 | carobbiite | | KF | 2-2.5 | | | |
| 8.1.6 | sylvite | hoevelite | KCl | 1.5-2 | brittle | | hygroscopic 'when contaminated' (Schumann 1992) |
| 8.1.7 | salammoniac | chlorammonium | $NH_4Cl$ | 1-2 | sectile | | porous |
| 8.2.1 | nantokite | | CuCl | 2-2.5 | sectile | | |

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|---|---|---|---|---|---|---|---|
| 8.2.2 | tolbachite | | $CuCl_2$ | | | | hygroscopic |
| 8.2.3 | eriochalcite | antofagasite; eriocalcite; erythrocalcite | $CuCl_2 \cdot 2H_2O$ | 2.5 | | | |
| 8.2.4 | atacamite | marcylite, muriate of copper, remolinite | $Cu_2(OH)_3Cl$ | 3-3.5 | brittle | | |
| 8.2.6 | botallackite | | $Cu_2Cl(OH)_3$ | | | | |
| 8.2.8 | calumetite | | $CaCu_4(OH)_8Cl_2 \cdot 3.5H_2O$ | 2 | brittle | | |
| 8.2.9 | anthonyite | vondechenite | $Cu(OH,Cl)_2 \cdot 3H_2O$ | 2 | sectile | | |
| 8.2.11 | marshite | | CuI | 2.5 | brittle | | |
| 8.2.12 | mitscherlichite | | $K_2CuCl_4 \cdot 2H_2O$ | 2.5 | | | |
| 8.3.1 | chlorargyrite | argyroceratite; cerargyrite; iodembolite; kerate | AgCl | 1.5-2.5 | sectile | | |
| 8.3.2 | bromargyrite | bromyrite; chlorobromite | AgBr | 2.5 | sectile | | |
| 8.3.3 | bromian chlorargyrite | embolite; orthobromite | Ag(Cl, Br) | 1.5-2 | | | IMA discredited species; considered variety of chloragyrite |
| 8.3.4 | iodargyrite | iodyrite | AgI | 1.5-2 | | | |
| 8.3.5 | miersite | | (Ag, Cu)I | 2.5-3 | brittle | | |
| 8.4.3 | bischofite | | $MgCl_2 \cdot 6H_2O$ | 1-2 | | | |
| 8.4.5 | carnallite | | $KMgCl_3 \cdot 6H_2O$ | 2.5 | | | highly hygroscopic |
| 8.4.6 | tachyhydrite | | $CaMg_2Cl_6 \cdot 12H_2O$ | 2 | | | |
| 8.4.7 | fluorite | bruiachite; cand; lithophosphorus suhlensis | $CaF_2$ | 4 | brittle | | |
| 8.4.8 | sinjarite | | $CaCl_2 \cdot 2H_2O$ | 1.5 | | | hygroscopic |
| 8.4.9 | antarcticite | | $CaCl_2 \cdot 6H_2O$ | 2-3 | brittle | | |
| 8.4.10 | chlorocalcite | baeumlerite | $KCaCl_3$ | 2.5-3 | | | |
| 8.4.11 | rorisite | | CaFCl | 2 | | | hygroscopic |
| 8.4.NI | chloromagnesite | | $MgCl_2$ | | | | A doubtful species; natural magnesium chloride is regarded as very unlikely. |
| 8.5.2 | calomel | | $[Hg_2]^{2+}Cl_2$ | 1.5-2 | sectile | | |
| 8.5.3 | terlinguaite | | $Hg_2OCl$ | 2-3 | brittle | | |
| 8.5.6 | eglestonite | | $([Hg^{1+}]_2)_3OCl_3(OH)$ | 2.5 | brittle | | |
| 8.6.2 | chloraluminite | | $AlCl_3 \cdot 6H_2O$ | | | | |
| 8.6.3 | cadwaladerite | lesukite | $AlCl(OH)_2 \cdot 4H_2O$ | | | | |
| 8.6.5 | cryolite | | $Na_2NaAlF_6$ | 2.5 | brittle | | |

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|---|---|---|---|---|---|---|---|
| 8.6.10 | koenenite | justite | $Na_4Mg_9Al_4Cl_{12}(OH)_{22}$ | 1.5 | flexible | | |
| 8.7.1 | fluocerite-(Ce) | | $(Ce,La)F_3$ | 4.5-5 | brittle | | |
| 8.8.4 | cotunnite | | $PbCl_2$ | 1.5-2 | sectile | | |
| 8.8.17 | bideauxite | | $Pb_2AgCl_3(F,OH)_2$ | 3 | brittle | | |
| 8.8.18 | boleite | argentopercylite | $KPb_{26}Ag_9Cu_{24}(OH)_{48}Cl_{62}$ | 3-3.5 | | | |
| 8.10.1 | scacchite | | $MnCl_2$ | | | | hygroscopic |
| 8.10.3 | chloromanganokalite | | $K_4MnCl_6$ | 2.5 | brittle | | |
| 8.11.1 | molysite | | $FeCl_3$ | | | | |
| 8.11.2 | hydromolysite | | $FeCl_3 \cdot 6H_2O$ | | | | |
| 8.11.3 | rokühnite | | $FeCl_2 \cdot 2H_2O$ | | flexible | | |
| 8.11.4 | douglasite | | $K_2Fe^{2+}Cl_4 \cdot 2H_2O$ | | | | |
| 8.11.5 | erythrosiderite | | $K_2Fe^{3+}Cl_5 \cdot H_2O$ | | | | |
| 8.11.6 | rinneite | | $K_3NaFe^{2+}Cl_6$ | 3 | | | |
| 8.11.7 | kremersite | kopeiskite | $(NH_4,K)_2Fe^{3+}Cl_5 \cdot H_2O$ | | | | |
| 8.11.9 | nickelbischofite | | $NiCl_2 \cdot 6H_2O$ | 1.5 | | | |
| 8.11.10 | lawrencite | | $(Fe^{2+},Ni)Cl_2$ | | | | |
| 8.12.4 | hieratite | | $K_2SiF_6$ | 2.5 | | | |
| **9** | **Borates** | | | | | | |
| 9.1.1 | sassolite | sal sedativum | $H_3BO_3$ | 1 | | | hygroscopic; porous |
| 9.1.6 | kernite | rasorite | $Na_2[B_4O_6(OH)_2] \cdot 3H_2O$ | 2.5 | flexible | | |
| 9.1.8 | tincalconite | | $Na_2(B_4O_7) \cdot 5H_2O$ | 2 | | | |
| 9.1.9 | borax | bauracia; tincal; tinkar | $Na_2(B_4O_5)(OH)_4 \cdot 8H_2O$ | 2-2.5 | brittle | | porous |
| 9.1.14 | larderellite | borocalcite | $(NH_4)B_5O_7(OH)_2 \cdot H_2O$ | | | | |
| 9.2.16 | kaliborite | heintzite; paternoite | $KMg_2H[B_6O_8(OH)_5]_2(H_2O)_4$ | 4-4.5 | | | |
| 9.2.17 | iquiqueite | | $K_3Na_4Mg(CrO_4)B_{24}O_{39}(OH) \cdot 12H_2O$ | 2 | brittle | | somewhat hygroscopic |
| 9.3.12 | inyoite | | $Ca(H_4B_3O_7)(OH) \cdot 4H_2O$ | 2 | brittle | | |
| 9.3.14 | colemanite | borspar | $Ca[B_3O_4(OH)_3] \cdot H_2O$ | 4.5 | very brittle | | |
| 9.3.20 | probertite | kramerite | $NaCaB_5O_7(OH)_4 \cdot 3H_2O$ | 3.5 | brittle | | |
| 9.3.21 | ulexite | borocalcite; franklandite; hayesine; tv stone | $NaCa[B_5O_6(OH)_6] \cdot 5H_2O$ | 2.5 | brittle | | |
| **10** | **Borates with othe anions** | | | | | | |
| 10.1.2 | bandylite | | $Cu[B(OH)_4]Cl$ | 2.5 | elastic | | |
| 10.1.5 | boracite | | $Mg_3(B_7O_{13})Cl$ | 7-7.5 | | | |
| 10.1.12 | hydrochlorborite | | $Ca_4B_8O_{15}Cl_2 \cdot 21H_2O$ | 2.5 | | | |

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| 10.1.13 | ekaterinite | | $Ca_2(B_4O_7)(Cl,OH)_2 \cdot 2H_2O$ | 1-1.5 | | | hygroscopic |
| 10.3.1 | sulfoborite | | $Mg_3[B(OH)_4]_2(SO_4)(OH,F)_2$ | 4-4.5 | brittle | | |
| **11** | **Carbonates** | | | | | | |
| 11.1.2 | natrite | | $Na_2CO_3$ | 1-1.5 | | | |
| 11.1.3 | nahcolite | thermokalite | $NaHCO_3$ | 2.5 | | | |
| 11.1.5 | thermonatrite | | $Na_2CO_3 \cdot H_2O$ | 1-1.5 | sectile | | |
| 11.1.6 | trona | | $Na_3H(CO_3)_2 \cdot 2H_2O$ | 2.5 | | | |
| 11.1.7 | natron | | $Na_2CO_3 \cdot 10H_2O$ | 1-1.5 | brittle | | |
| 11.1.10 | nyerereite | natrofairchildite | $Na_2Ca(CO_3)_2$ | | | | |
| 11.1.13 | pirssonite | | $Na_2Ca(CO_3)_2 \cdot 2H_2O$ | 3-3.5 | brittle | | |
| 11.1.14 | gaylussite | | $Na_2Ca(CO_3)_2 \cdot 5H_2O$ | 2.5 | very brittle | | |
| 11.1.16 | fairchildite | | $K_2Ca(CO_3)_2$ | 2.5 | | | |
| 11.1.17 | bütschliite | | $K_2Ca(CO_3)_2$ | | | | |
| 11.1.18 | teschemacherite | | $(NH_4)HCO_3$ | 1.5 | brittle | | |
| 11.1.NI | gregoryite | | $(Na_2,K_2,Ca)CO_3$ | | | | |
| 11.2.1 | malachite | | $Cu_2(CO_3)(OH)_2$ | 3.5-4 | brittle | | |
| 11.2.2 | azurite | chessylite; lasur | $Cu_3(CO_3)_2(OH)_2$ | 3.5-4 | brittle | | |
| 11.3.1 | magnesite | baldissérite; giobertite | $MgCO_3$ | 3.5-4.5 | brittle | | porous |
| 11.3.3 | nesquehonite | | MgCO3 · 3H2O | 2.5 | | | |
| 11.3.4 | lansfordite | | $MgCO_3 \cdot 5H_2O$ | 2.5 | | | |
| 11.3.7 | hydromagnesite | | $Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O$ | 3.5 | brittle | | |
| 11.4.1 | calcite | | $CaCO_3$ | 3 | brittle | | |
| 11.4.2 | aragonite | chimborazite; conchite; ktypéite | $CaCO_3$ | 3.5-4 | brittle | | |
| 11.4.4 | monohydrocalcite | | $CaCO_3 \cdot H_2O$ | 2-3 | | | |
| 11.4.5 | ikaite | (sub-/tri-/penta-) hydrocalcite | $CaCO_3 \cdot 6H_2O$ | | | | |
| 11.4.6 | dolomite | magnesiodolomite; pearl/rhomb spar; ridolphite | $CaMg(CO_3)_2$ | 3.5-4 | brittle | | |
| 11.6.1 | smithsonite | bonamite | $ZnCO_3$ | 4-4.5 | brittle | | |
| 11.6.2 | hydrozincite | earthy calamine; marionite; zinc bloom | $Zn_5(CO_3)_2(OH)_6$ | 2-2.5 | very brittle | | hygroscopic; porous |
| 11.6.5 | aurichalcite | buratite, messingite, risséite | $(Zn,Cu)_5(CO_3)_2(OH)_6$ | 1-2 | fragile | | |
| 11.7.1 | scarbroite | | $Al_5(CO_3)(OH)_{13} \cdot 5H_2O$ | | | | hygroscopic; porous |

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| 11.7.2 | hydroscarbroite | | $Al_{14}(CO_3)_3(OH)_{36} \cdot nH_2O$ | | | | |
| 11.7.13 | hydrodresserite | | $BaAl_2(CO_3)_2(OH)_4 \cdot 3H_2O$ | 3-4 | | | |
| 11.8.3 | lanthanite-(Ce) | | $(Ce,La,Nd)_2(CO_3)_3 \cdot 8H_2O$ | 2.5 | | | |
| 11.9.1 | cerussite | white lead (ore) | $PbCO_3$ | 3-3.5 | very brittle | | |
| 11.9.2 | hydrocerussite | | $Pb_3(CO_3)_2(OH)_2$ | 3.5 | brittle | | |
| 11.9.3 | dundasite | | $PbAl_2(CO_3)_2(OH)_4 \cdot H_2O$ | 2 | | | |
| 11.11.3 | swartzite | | $MgCa(UO_2)(CO_3)_3 \cdot 12H_2O$ | | | | |
| 11.11.4 | grimselite | | $K_3Na(UO_2)(CO_3)_3 \cdot H_2O$ | | | | |
| 11.11.5 | bayleyite | | $Mg_2(UO_2)(CO_3)_3 \cdot 18H_2O$ | | | | |
| 11.11.7 | zellerite | | $Ca(UO_2)(CO_3)_2 \cdot 5H_2O$ | 2 | | radioactive | |
| 11.11.8 | wyartite | | $CaU^{5+}(UO_2)_2(CO_3)O_4(OH) \cdot 7H_2O$ | 3-4 | | | |
| 11.12.1 | rhodochrosite | dialogite; villaurite | $MnCO_3$ | 3.5-4 | brittle | | sensitive to shock |
| 11.13.1 | siderite | chalybite; junckérite; spathic/spathose iron | $FeCO_3$ | 3.5-4.5 | brittle | | paramagnetic |
| 11.14.4 | hellyerite | | $NiCO_3 \cdot 5.5H_2O$ | 2.5 | brittle | | |
| **12** | **Carbonates with other anions: with halides or sulfate** | | | | | | |
| 12.1.2 | barentsite | | $Na_7Al(HCO_3)_2(CO_3)_2F_4$ | 3 | brittle | | |
| 12.1.23 | phosgenite | corneous lead (ore), cromfordite, galenoceratite | $Pb_2CO_3Cl_2$ | 2-3 | sectile | | |
| 12.2.1 | burkeite | | $Na_6(CO_3)(SO_4)_2$ | 3.5 | brittle | | |
| 12.2.2 | hanksite | | $Na_{22}K(SO_4)_9(CO_3)_2Cl$ | 3-3.5 | brittle | | |
| 12.2.11 | leadhillite | maxite | $Pb_4(CO_3)_2(SO_4)(OH)_2$ | 2.5-3 | brittle | | |
| 12.2.18 | schröckingerite | dakeite | $NaCa_3(UO_2)(CO_3)_3(SO_4)F \cdot 10H_2O$ | 2.5 | | | |
| **13** | **Nitrates** | | | | | | |
| 13.1 | nitratine | natronitrite; natronsalpeter | $NaNO_3$ | 1.5-2 | sectile | | hygroscopic |
| 13.2 | niter | saltpeter | $KNO_3$ | 2 | brittle | | |
| 13.3 | gerhardtite | | $Cu_2(NO_3)(OH)_3$ | 2 | flexible | | |
| 13.4 | nitromagnesite | | $Mg(NO_3)_2 \cdot 6H_2O$ | | | | hygroscopic |
| 13.5 | nitrocalcite | | $Ca(NO_3)_2 \cdot 4H_2O$ | 1-2 | | | |
| 13.6 | nitrobarite | | $Ba(NO_3)_2$ | 3 | | | |
| 13.8 | sveite | | $KAl_7(NO_3)_4(OH)_{16}Cl_2 \cdot 8H_2O$ | | | | hygroscopic |
| 13.9 | darapskite | | $Na_3(SO_4)(NO_3) \cdot H_2O$ | 2.5 | | | |
| 13.12 | hydrombobomkulite | | $(Ni,Cu)Al_4((NO_3)_2,SO_4)(OH)_{12} \cdot 13\text{-}14H_2O$ | | | | |

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|---|---|---|---|---|---|---|---|
| 13.NI | gwihabaite | nitrammite | $(NH_4,K)NO_3$ | 2 | | | |
| **14** | **Silicates not containing aluminum** | | | | | | |
| 14.2.1 | dioptase | | $CuSiO_3 \cdot H_2O$ | 5 | brittle | | |
| 14.2.5 | chrysocolla | | $Cu_{2-x}Al_x(H_{2-x}Si_2O_5)(OH)_4 \cdot nH_2O$, x < 1 | 2.5-3.5 | brittle | | hygroscopic; porous |
| 14.3.1 | phenakite | | $Be_2SiO_4$ | 7.5-8 | brittle | | |
| 14.4.11 | sepiolite | | $Mg_4(Si_6O_{15})(OH)_2 \cdot 6H_2O$ | 2 | brittle | | hygroscopic; porous |
| 14.5.1 | wollastonite | donegalite, gjellebäckite | $CaSiO_3$ | 4.5-5 | brittle | | |
| 14.5.6 | larnite | | $Ca_2SiO_4$ | 6 | | | |
| 14.9.6 | titanite | sphene | $CaTi(SiO_4)O$ | 5-5.5 | brittle | | |
| 14.10.1 | zircon | | $Zr(SiO_4)$ | 7.5 | brittle | U- and Th-bearing zircon is radioactive | |
| 14.12.4 | pabstite | | $Ba(Sn,Ti)(Si_3O_9)$ | 6 | | | |
| 14.13.8 | barysilite | | $Pb_8Mn^{2+}[Si_2O_7]_3$ | 3 | | | |
| 14.16.10 | uranophane | lambertite | $Ca(UO_2)_2(SiO_3OH)_2 \cdot 5H_2O$ | 2-3 | brittle | | |
| 14.17.1 | rhodonite | | $Mn^{2+}SiO_3$ | 5.5-6.5 | | | very sensitive to shock |
| 14.17.8 | bementite | | $Mn_7Si_6O_{15}(OH)_8$ | 6 | flexible | | |
| 14.18.21 | inesite | | $Ca_2(Mn,Fe)_7Si_{10}O_{28}(OH)_2 \cdot 5H_2O$ | 5.5-6 | brittle | | |
| 14.19.1 | fayalite | | $Fe^{2+}{}_2SiO_4$ | 7 | | | |
| 14.19.8 | hisingerite | canbyite | $Fe^{3+}{}_2(Si_2O_5)(OH)_4 \cdot 2H_2O$ | 2.5-3 | brittle | | |
| **15** | **Silicates of aluminum** | | | | | | |
| 15.6 | dickite | | $Al_2(Si_2O_5)(OH)_4$ | 2-2.5 | flexible | | hygroscopic & porous |
| 15.7 | nacrite | | $Al_2(Si_2O_5)(OH)_4$ | 2-2.5 | | | hygroscopic & porous |
| 15.11 | allophane | ilbaite; razoumofskyn | $(Al_2O_3)(SiO_2)_{1.3\text{-}2} \cdot 2.5\text{-}3H_2O$ | 3 | brittle | | |
| 15.NI | halloysite-10Å | endellite; (hydrated /hydro-)halloysite | $Al_2Si_2O_5(OH)_4 \cdot 2H_2O$ | | | | hygroscopic; porous; Halloysite-10Å is not a polytype of halloysite. It is also a different species from halloysite-7Å, which does not contain molecular water. |
| **16** | **Silicates containing aluminum & other metals** | | | | | | |
| 16.1.2 | spodumene | triphane | $LiAlSi_2O_6$ | 6.5-7 | brittle | | |
| 16.2.2 | analcime | eudnophite | $Na(AlSi_2O_6) \cdot H_2O$ | 5-5.5 | brittle | | |
| 16.2.5 | natrolite | apoanalcite, laubanite, | $Na_2Al_2Si_3O_{10} \cdot 2H_2O$ | 5-5.5 | brittle | | |
| 16.2.7 | paranatrolite | | $Na_2Al_2Si_3O_{10} \cdot 3H_2O$ | 5-5.5 | | | |

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| 16.3.8 | muscovite | amphilogite; oncosine; white mica | $KAl_2(AlSi_3O_{10})(OH)_2$ | 2.5 | elastic | | variety illite = hygroscopic & porous |
| 16.4.1 | nepheline | sommite | $Na_3K(Al_4Si_4O_{16})$ | 5.5-6 | brittle | | |
| 16.6.1 | beryl | | $Be_3Al_2Si_6O_{18}$ | 7.5-8 | brittle | | |
| 16.7.6 | palygorskite | | $(Mg,Al)_2Si_4O_{10}(OH) \cdot 4H_2O$ | 2-2.5 | | | hygroscopic; highly porous |
| 16.7.7 | saponite | mauritzite; soapstone | $Ca_{0.25}(Mg,Fe)_3((Si,Al)_4O_{10})(OH)_2 \cdot nH_2O$ | 1.-2 | | | hygroscopic; porous |
| 16.7.9 | montmorillonite | amagorsite | $(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2 \cdot nH_2O$ | 1-2 | | | hygroscopic; porous |
| 16.8.6 | phlogopite | | $KMg_3(AlSi_3O_{10})(OH)_2$ | 2-3 | flexible | | |
| 16.9.2 | anorthite | | $Ca(Al_2Si_2O_8)$ | 6-6.5 | brittle | | |
| 16.9.23 | laumontite | schneiderite | $CaAl_2Si_4O_{12} \cdot 4H_2O$ | 3.5-4 | brittle | | |
| 16.11.NI | chabazite | | $(Ca,K_2,Na_2)_2[Al_2Si_4O_{12}]_2 \cdot 12H_2O$ | 4-5 | brittle | | Chabazite-Ca is the most common member of the Chabazite series of the Zeolite Group. Other members include chabazite-K, chabazite-Mg, chabazite-Na, and chabazite-Sr. |
| 16.16.5 | carpholite | | $Mn^{2+}Al_2(Si_2O_6)(OH)_4$ | 5-5.5 | | | |
| 16.18.1 | nontonite | chloropal; hydroferripyrophyllite | $Na_{0.3}Fe_2((Si,Al)_4O_{10})(OH)_2 \cdot nH_2O$ | 1.5-2 | | | hygroscopic; porous |
| 16.19.22 | vermiculite | brodrickite | $Mg_{0.7}(Mg,Fe,Al)_6(Si,Al)_8O_{20}(OH)_4 \cdot 8H_2O$ | 1.5-2 | | | |
| 16.23.3 | vesuvianite | idocrase | $Ca_{19}Fe^{3+}Al_4(Al_6Mg_2)(\square_4)\square[Si_2O_7]_4[(SiO_4)_{10}]O(OH)_9$ | 6.5 | brittle | | |
| **17** | **Silicates containing other anions** | | | | | | |
| 17.2.1 | topaz | pyrophysalite | $Al_2SiO_4(F,OH)_2$ | 8 | brittle | | |
| 17.2.9 | zinnwaldite | | $KFe2^{2+}Al(Al_2Si_2O_{10})(OH)_2 – KLi_2Al(Si_4O_{10})(F,OH)_2$ | 2-3 | elastic | | discredited; series of trioctahedral micas on/close to the siderophyllite-polylithionite series; -1M, -2M, and -3T polytypes are known |
| 17.2.NI | trilithionite | | $K(Li,Al)_3(AlSi_3O_{10})(F,OH)_2$ | 2.5-3.5 | elastic | | forms polylithionite-trilithionite series; mediaries are considered *lepidolite* , an IMA discredited species |
| 17.3.3 | sodalite | glaucolite | $Na_4(Si_3Al_3)O_{12}Cl$ | 5.5-6 | brittle | | |
| 17.4.2 | spurrite | paraspurrite | $Ca_5(SiO_4)_2(CO_3)$ | 5 | | | |
| 17.5.3 | searlesite | | $Na(H_2BSi_2O_7)$ | 3.5 | brittle | | hygroscopic; porous |
| 17.10.4 | haüyne | | $(Na,K)_3(Ca,Na)(Al_3Si_3O_{12})(SO_4,S,Cl)$ | 5.5-6 | brittle | | |

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|---|---|---|---|---|---|---|---|
| **18** | **Niobates & Tantalates** | | | | | | |
| 18.1.4 | franconite | | $Na(Nb_2O_5)(OH) \cdot 3H_2O$ | 4 | | | |
| 18.1.11 | microlite | haddamite; metasimpsonite; neotantalite; niobtantalpyrochlor; tantalpyrochlor | $(Ca,Na)_2Ta_2(O,OH,F)_7$ | 5-5.5 | brittle | | Microlite is now a group name for Ta-dominant minerals within the pyrochlore supergroup (nomenclature revised: 2010) |
| 18.2.1 | fergusonite-(Y) | | $YNbO_4$ | 5.5-6.5 | brittle | | Risörite = titaniferous variety |
| 18.2.7 | formanite-(Y) | | $YTaO_4$ | 5.5-6.5 | | | |
| 18.2.8 | pyrochlore | endeiolite; fluochlor; hydrochlor; niobpyrochlor | $A_2Nb_2(O,OH)_6Z$; where A = Na, Ca, $Sn^{2+}$, Sr, $Pb^{2+}$, $Sb^{3+}$, Y, $U_4^+$, $H_2O$ or □; & Z = OH, F, O, $H_2O$ or □ | | | | Pyrochlore is now a group name for a number of minerals within the pyrochlore supergroup (nomenclature recently revised ~2010-2013); analysis is necessary to identify a specimen's species |
| 18.3.3 | betafite | blomstrandite; hatchettolite | $(Ca,Na,U)_2(Ti, Nb,Ta)_2O_6Z(OH)$ | 3-5.5 | brittle | strogly radioactive | IMA discredited species; many historically labelled specimens are no longer part of the betafite group due to replacement and or alteration; analysis is necessary to identify a specimen's species; Betafite is also now a group name for a number of minerals within the pyrochlore supergroup (nomenclature recently revised ~2010-2013) |
| 18.4.1 | uranpyrochlore | ellsworthite; U-rich oxynatropyrochlore | $(Ca,U,Ce)_2(Nb,Ti,Ta)_2O_6(OH,F)$ | 4-5 | | | IMA discredited species (due to lack of acceptable analyses); considered a variety of the pyrochlore group |
| 18.4.5 | euxenite | | $(Y,Ca,Ce,U,Th)(Nb,Ta,Ti)_2O_6$ | 5.5-6.5 | | radioactive | |
| 18.4.8 | polycrase-(Y) | | $Y(Ti,Nb)_2(O,OH)_6$ | 5-6 | | | |
| 18.4.12 | samarskite-(Y) | adelpholite; ampangabéite; eytlandite; nuevite; uranoniobit; uranotantal | $YFe^{3+}Nb_2O_8$ | 5-6 | brittle | radioactive | |
| **19** | **Phosphates** | | | | | | |
| 19.1.2 | olympite | | $Na_5Li(PO_4)_2$ | 4 | brittle | | |
| 19.1.3 | nahpoite | | $Na_2HPO_4$ | 1-2 | brittle | | |
| 19.1.4 | dorfmanite | | $Na_2HPO_4 \cdot 2H_2O$ | 1-1.5 | | | |
| 19.1.NI | schertelite | muellerite | $(NH_4)_2MgH_2(PO_4)_2 \cdot 4H_2O$ | | | | |

| Hey Number | Mineral Name | Other Names | Chemical Formula | Moh's Hardness | Tenacity | H&S Data | Notes |
|---|---|---|---|---|---|---|---|
| 19.2.8 | turquoise | calaite; chalchihuitl; chalchuite; hydrargillite; johnite | $CuAl_6(PO_4)_4(OH)_8 \cdot 4H_2O$ | 5-6 | brittle | | hygroscopic; porous |
| 19.3.18 | phosphorrösslerite | | $Mg(HPO_4) \cdot 7H_2O$ | 2.5 | brittle | | |
| 19.3.23 | struvite | guanite | $(NH_4)Mg(PO_4) \cdot 6H_2O$ | 1.5-2 | brittle | | |
| 19.4.1 | monetite | | $Ca(HPO_4)$ | 3.5 | brittle | | |
| 19.4.3 | brushite | epiglaubite; stoffertite | $Ca(HPO_4) \cdot 2H_2O$ | 2.5 | brittle | | |
| 19.5.6 | nabaphite | | $NaBaPO_4 \cdot 9H_2O$ | 2 | | | |
| 19.5.8 | nastrophite | | $Na(Sr,Ba)PO_4 \cdot 9H_2O$ | 2 | brittle | | |
| 19.7.5 | variscite | lucinite; peganite; sphaerite; utahlite | $AlPO_4 \cdot 2H_2O$ | 3.5-4.5 | | | |
| 19.8.2 | brazilianite | | $NaAl_3(PO_4)_2(OH)_4$ | 5.5 | brittle | | |
| 19.9.3-5 | monazite | cryptolite, urite | $REE(PO_4)$; REE = Ce, La, Nd, Sm, or Gd | | | Monazite usually contains small amounts of Th or sometimes U, both making it radioactive. | The name monazite, without a elemental suffix, was the accepted name for all material in this group, regardless of the REE-bearing components' relative abundance. The great majority of "monazite" is monazite-(Ce); the other members are all very rare. |
| 19.10.10 | sincosite | | $Ca(VO)_2(PO_4)_2 \cdot 5H_2O$ | 1-2 | brittle | | |
| 19.11.10 | torbernite | uranite; uran-mica | $Cu(UO_2)_2(PO_4)_2 \cdot 12H_2O$ | 2-2.5 | brittle | highly radioactive | |
| 19.11.14 | meta-autunite | | $Ca(UO_2)_2(PO_4)_2 \cdot 6\text{-}8H_2O$ | 2-2.5 | brittle | | |
| 19.11.15 | autunite | | $Ca(UO_2)_2(PO_4)_2 \cdot 11H_2O$ | 2-2.5 | sectile | radioactive | |
| 19.11.22 | uranocircite | | $Ba(UO_2)_2(PO_4)_2 \cdot 10H_2O$ | 2-2.5 | | radioactive | |
| 19.11.32 | uranospathite | | $(Al,\square)(UO_2)_2(PO_4)_2F \cdot 20(H_2O,F)$ | 2-2.5 | | radioactive | |
| 19.11.40 | lehnerite | | $Mn^{2+}(UO_2)_2(PO_4)_2 \cdot 8H_2O$ | 2-3 | | | |
| 19.11.41 | bassetite | | $Fe^{2+}(UO_2)_2(PO_4)_2 \cdot 10H_2O$ | 2.5 | brittle | radioactive | |
| 19.12.10 | heterosite | ferripurpurite; heterozite; pseudotriplite | $(Fe^{3+}, Mn^{3+})PO_4$ | 4-4.5 | brittle | | |
| 19.12.11 | purpurite | manganipurpurite | $Mn^{3+}PO_4$ | 4-4.5 | brittle | | |
| 19.12.16 | rockbridgeite | kobokobite | $Fe^{2+}Fe^{3+}_4(PO_4)_3(OH)_5$ | 3.5-4.5 | brittle | | |
| 19.12.22 | hureaulite | baldaufite; (pseudo)palaite | $(Mn,Fe)_5(PO_4)_2(HPO_4)_2 \cdot 4H_2O$ | 5 | brittle | | |
| 19.12.35 | ludlamite | lehnerite | $Fe^{2+}_3(PO_4)_2 \cdot 4H_2O$ | 3.5 | brittle | | diamagnetic |
| 19.12.36 | graftonite | repossite | $Fe^{2+}Fe^{2+}_2(PO_4)_2$ | 5 | brittle | | |
| 19.12.40 | messelite | | $Ca_2Fe^{2+}(PO_4)_2 \cdot 2H_2O$ | 3.5 | brittle | | |
| 19.13.2 | strengite | | $FePO_4 \cdot 2H_2O$ | 3.5-4 | brittle | | |

| Hey Number | Mineral Name | Other Names | Chemical Formula | Moh's Hardness | Tenacity | H&S Data | Notes |
|---|---|---|---|---|---|---|---|
| 19.13.11 | vivianite | anglarite; mullicite | $Fe^{2+}_3(PO_4)_2 \cdot 8H_2O$ | 1.5-2 | sectile | | |
| 19.12.19 | phosphoferrite | reddingite | $Fe^{2+}_3(PO_4)_2 \cdot 3H_2O$ | 3-3.5 | brittle | | |
| 19.14.14 | anapaite | tamanite | $Ca_2Fe^{2+}(PO_4)_2 \cdot 4H_2O$ | 3.5 | flexible | | |
| 19.14.28 | koninckite | | $Fe^{3+}PO_4 \cdot 3H_2O$ | 3.5-4 | | | |
| 19.14.29 | lazulite | berkeyite; klaprothite; voraulite | $MgAl_2(PO_4)_2(OH)_2$ | 5.5-6 | brittle | | |
| **20** | **Arsenates** | | | | | | |
| 20.1.2 | olivenite | | $Cu_2(AsO_4)(OH)$ | 3 | brittle | | |
| 20.1.8 | euchroite | | $Cu_2(AsO_4)(OH) \cdot 3H_2O$ | 3.5-4 | brittle | | |
| 20.1.13 | liroconite | | $Cu_2Al(AsO_4)(OH)_4 \cdot 4H_2O$ | 2-2.5 | | | |
| 20.2.3 | rösslerite | | $Mg(HAsO_4) \cdot 7H_2O$ | 2-3 | brittle | | |
| 20.2.12 | ferrarisite | | $Ca_5(AsO_4)_2(HAsO_4)_2 \cdot 9H_2O$ | | brittle | | |
| 20.2.14 | phaunouxite | | $Ca_3(AsO_4)_2 \cdot 11H_2O$ | | | | |
| 20.7.1 | trögerite | | $(H_3O)(UO_2)(AsO_4) \cdot 3H_2O$ | 2-3 | brittle | | |
| 20.7.6 | metaováčekite | | $Mg(UO_2)_2(AsO_4)_2 \cdot 8H_2O$ | 2.5 | | | |
| 20.7.7 | nováčekite-I | | $Mg(UO_2)_2(AsO_4)_2 \cdot 12H_2O$ | 2.5 | | | |
| 20.7.9 | metauranospinite | | $Ca(UO_2)_2(AsO_4)_2 \cdot 8H_2O$ | 2-3 | very brittle | | |
| 20.7.10 | uranospinite | | $Ca(UO_2)(AsO_4)_2 \cdot 10H_2O$ | 2-3 | flexible | radioactive | |
| 20.7.12 | heinrichite | | $Ba(UO_2)_2(AsO_4)_2 \cdot 10H_2O$ | 2.5 | | radioactive | |
| 20.7.14 | arsenuranospathite | | $Al(UO_2)_2(AsO_4)_2F \cdot 20H_2O$ | 2 | | | |
| 20.9.2 | scorodite | loaisite | $Fe^{3+}AsO_4 \cdot 2H_2O$ | 3.5-4 | | | |
| 20.9.6 | symplesite | | $Fe^{2+}_3(AsO_4)_2 \cdot 8H_2O$ | 2.5 | flexible | | |
| 20.10.1 | erythrite | | $Co_3(AsO_4)_2 \cdot 8H_2O$ | 1.5-2.5 | sectile | | |
| 20.10.9 | annabergite | cordillerite; nickel bloom/green/ocher | $Ni_3(AsO_4)_2 \cdot 8H_2O$ | 1.5-2.5 | sectile | | |
| **21** | **Vanadates** | | | | | | |
| 21.2.1 | metarossite | | $Ca(V_2O_6) \cdot 2H_2O$ | 1-2 | flexible | | hygroscopic; porous |
| 21.2.2 | rossite | | $Ca(VO_3)_2 \cdot 4H_2O$ | 2-3 | brittle | | |
| 21.2.3 | metahewettite | | $CaV_6O_{16} \cdot 3H_2O$ | | friable | | |
| 21.2.4 | hewettite | | $CaV_6O_{16} \cdot 9H_2O$ | | | | |
| 21.2.5 | pintadoite | | $Ca_2(V_2O_7) \cdot 9H_2O$ | | | | |
| 21.2.7 | fernandinite | | $(Ca,K)(V^{5+},V^{4+},Fe^{2+})_8O_{20} \cdot 10H_2O$ | 2-3 | waxy | | |
| 21.2.8 | pascoite | | $Ca_3(V_{10}O_{28}) \cdot 17H_2O$ | 2.5 | | | |
| 21.2.9 | sherwoodite | | $Ca_{4.5}(AlV^{4+}_2V^{5+}_{12}O_{40}) \cdot 28H_2O$ | 2 | | | |
| 2.2.10 | melanovanadite | | $Ca(V^{5+},V^{4+})_4O_{10} \cdot 5H_2O$ | 2.5 | brittle | | |

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|---|---|---|---|---|---|---|---|
| 21.2.13 | metadelrioite | | $CaSr(V_2O_6)(OH)_2$ | 2 | | | |
| 21.2.14 | delrioite | | $CaSr(V_2O_6)(OH)_2 \cdot 3H_2O$ | 2 | | | |
| 21.3.3 | metaschoderite | | $Al_2(PO_4)(VO_4) \cdot 6H_2O$ | 2 | | | |
| 21.3.4 | schoderite | | $Al_2(PO_4)(VO_4) \cdot 8H_2O$ | | | | |
| 21.3.10 | descloizite | eusynchite, ramirite | $PbZn(VO_4)(OH)$ | 3-3.5 | brittle | | |
| 21.4.4 | carnotite | | $K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$ | 2 | fragile | radioactive | |
| 21.4.7 | metatyuyamunite | | $Ca(UO_2)_2(VO_4)_2 \cdot 3\text{-}5H_2O$ | 2 | sectile | | |
| 21.4.8 | tyuyamunite | calicocarnotite | $Ca(UO_2)_2(VO_4)_2 \cdot 5\text{-}8H_2O$ | 1.5-2 | sectile | radioactive | |
| 21.4.9 | rauvite | | $Ca(UO_2)_2(V_{10}O_{28}) \cdot 16H_2O$ | | sectile | | |
| 21.4.11 | metavanuralite | | $Al(UO_2)_2(VO_4)_2(OH) \cdot 8H_2O$ | | brittle | | |
| 21.4.12 | vanuralite | | $Al(UO_2)_2(V_2O_8)(OH) \cdot 8.5\text{-}11H_2O$ | 2 | | | |
| **22** | **Phosphates, Arsenates, & Vanadates with other anions** | | | | | | |
| 22.1.1 | amblygonite | | $LiAl(PO_4)F$ | 5.5-6 | brittle | | |
| 22.1.23 | triplite | | $Mn^{2+}{}_2(PO_4)F$ | 5-5.5 | | | |
| 22.2.9 | pyromorphite | | $Pb_5(PO_4)_3Cl$ | 3.5-4 | brittle | | |
| 22.2.10 | mimetite | petterdite | $Pb_5(AsO_4)_3Cl$ | 3.5-4 | brittle | | |
| 22.2.14 | vanadinite | | $Pb_5(VO_4)_3Cl$ | 2.5-3 | brittle | | |
| 22.2.NI | apatite | estramadurite; kietyöite; pyroguanite; sombrerite | $Ca_5(PO_4)_3(Cl/F/OH)$ | 5 | very brittle | | *Apatite* is a field term for unidentified members of the apatite group. Most apatite is fluorapatite. |
| 22.3.6 | chalcophyllite | copper mica, erinite, tamarite | $Cu_{18}Al_2(AsO_4)_4(SO_4)_3(OH)_{24} \cdot 36H_2O$ | 2 | | | |
| 22.3.21 | sasaite | | $(Al,Fe^{3+})_{14}(PO_4)_{11}(SO_4)(OH)_7 \cdot 83H_2O$ | | | | |
| 22.4.5 | tyrolite | kupaphrite, trichalcite | $Ca_2Cu_9(AsO_4)_4(CO_3)(OH)_8 \cdot 11H_2O$ | 1.5-2 | sectile | | |
| **25** | **Sulfates** | | | | | | |
| 25.1.1 | metathénardite | pyrotechnite; thénardite | $Na_2SO_4$ | 2.5-3 | brittle | | |
| 25.1.2 | matteuccite | | $NaHSO_4 \cdot H_2O$ | | | | |
| 25.1.3 | mirabilite | exanthalose; glauber salt; reussin | $Na_2SO_4 \cdot 10H_2O$ | 1.5-2 | | | |
| 25.1.4 | arcanite | taylorite | $K_2SO_4$ | 2 | | | |
| 25.1.5 | mercallite | | $KHSO_4$ | | | | |
| 25.1.6 | misenite | | $K_8H_6(SO_4)_7$ | | | | |
| 25.1.7 | aphthitalite | glaserite | $(K,Na)_3Na(SO_4)_2$ | 3 | brittle | | |

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|---|---|---|---|---|---|---|---|
| 25.1.8 | mascagnite | | $(NH_4)_2SO_4$ | 2.5 | sectile | | |
| 25.1.NI | lecontite | | $(NH_4,K)NaSO_4 \cdot 2H_2O$ | 2-2.5 | | | |
| 25.2.1 | chalcocyanite | hydrocyanite | $CuSO_4$ | 3.5 | | | hygroscopic |
| 25.2.2 | bonattite | | $CuSO_4 \cdot 3H_2O$ | | | | |
| 25.2.3 | chalcanthite | blue/copper vitriol | $CuSO_4 \cdot 5H_2O$ | 2.5 | brittle | | |
| 25.2.4 | boothite | | $CuSO_4 \cdot 7H_2O$ | 2-2.5 | brittle | | |
| 25.2.5 | dolerophanite | | $Cu_2(SO_4)O$ | 3 | | | |
| 25.2.7 | brochantite | brogniartine (of Huot), kamarezite, königine, waringtonite | $Cu_4(SO_4)(OH)_6$ | 3.5-4 | | | |
| 25.2.11 | kröhnkite | salvadorite | $Na_2Cu(SO_4)_2 \cdot 2H_2O$ | 2.5-3 | | | |
| 25.2.12 | natrochalcite | | $NaCu_2(SO_4)_2(OH) \cdot 2H_2O$ | 4.5 | | | |
| 25.2.13 | piypite | | $K_4Cu_4O_2(SO_4)_4 \cdot (Na,Cu)Cl$ | 2.5 | | | |
| 25.2.14 | fedotovite | | $K_2Cu_3(SO_4)_3O$ | 2.5 | | | |
| 25.2.15 | cyanochroite | | $K_2Cu(SO_4)_2 \cdot 6H_2O$ | 2-2.5 | | | |
| 25.2.20 | cyanotrichite | lettsomite, namaqualite | $Cu_4Al_2(SO_4)(OH)_{12} \cdot 2H_2O$ | 1-3 | | | |
| 25.2.24 | ransomite | | $CuFe_2(SO_4)_4 \cdot 6H_2O$ | 2.5 | | | |
| 25.2.27 | poitevinite | | $(Cu,Fe)SO_4 \cdot H_2O$ | 3.5 | | | |
| 25.3.1 | kieserite | martinsite | $MgSO_4 \cdot H_2O$ | 3.5 | fragile | | |
| 25.3.2 | sanderite | | $MgSO_4 \cdot 2H_2O$ | | | | |
| 25.3.3 | starkeyite | | $MgSO_4 \cdot 4H_2O$ | 2-3 | brittle | | |
| 25.3.4 | pentahydrite | | $MgSO_4 \cdot 5H_2O$ | 2.5 | | | |
| 25.3.5 | hexahydrite | | $MgSO_4 \cdot 6H_2O$ | 2-2.5 | brittle | | |
| 25.3.6 | epsomite | seelandite | $MgSO_4 \cdot 7H_2O$ | 2-2.5 | fragile | | |
| 25.3.8 | vanthoffite | | $Na_6Mg(SO_4)_4$ | 3.5 | fragile | | |
| 25.3.9 | blödite | astrakhanite | $Na_2Mg(SO_4)_2 \cdot 4H_2O$ | 2.5-3 | brittle | | |
| 25.3.10 | konyaite | | $Na_2Mg(SO_4)_2 \cdot 5H_2O$ | 2.5 | | | |
| 25.3.11 | löweite | | $Na_{12}Mg_7(SO_4)_{13} \cdot 15H_2O$ | 2.5-3 | | | |
| 25.3.13 | langbeinite | | $K_2Mg_2(SO_4)_3$ | 3.5-4 | brittle | | |
| 25.3.14 | leonite | | $K_2Mg(SO_4)_2 \cdot 4H_2O$ | 2.5-3 | | | |
| 25.3.15 | picromerite | schönite | $K_2Mg(SO_4)_2 \cdot 6H_2O$ | 2.5 | | | |
| 25.3.17 | boussingaultite | | $(NH_4)_2Mg(SO_4)_2 \cdot 6H_2O$ | 2 | | | |
| 25.3.18 | pickeringite | picralluminite; sonomaite | $MgAl_2(SO_4)_4 \cdot 22H_2O$ | 1.5-2 | brittle | | |
| 25.3.NI.1 | alpersite | | $(Mg,Cu)(SO_4) \cdot 7H_2O$ | 2 | brittle | | |
| 25.3.NI.2 | meridianite | | $MgSO_4 \cdot 11H_2O$ | | | | |

| Hey Number | Mineral Name | Other Names | Chemical Formula | Moh's Hardness | Tenacity | H&S Data | Notes |
|---|---|---|---|---|---|---|---|
| 25.4.1 | anhydrite | | $CaSO_4$ | 3-3.5 | brittle | | moderately high mechanical sensitivity |
| 25.4.3 | gypsum | marmor fugax; montmartrite | $CaSO_4 \cdot 2H_2O$ | 2 | flexible | | |
| 25.4.4 | glauberite | | $Na_2Ca(SO_4)_2$ | 2.5-3 | brittle | | |
| 25.4.8 | syngenite | kaluszite | $K_2Ca(SO_4)_2 \cdot H_2O$ | 2.5 | | | |
| 25.4.10 | polyhalite | | $K_2Ca_2Mg(SO_4)_4 \cdot 2H_2O$ | 2.5-3.5 | | | |
| 25.4.11 | koktaite | ammonium-syngenite | $(NH_4)_2Ca(SO_4)_2 \cdot H_2O$ | | | | |
| 25.4.12 | ye'elimite | kruzhevite | $Ca_4Al_6(SO_4)O_{12}$ | | | | |
| 25.4.13 | ettringite | woodfordite | $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26H_2O$ | 2-2.5 | | | |
| 25.4.15 | celestine | eschwegite; sicilianite | $SrSO_4$ | 3-3.5 | brittle | | very fragile |
| 25.4.17 | baryte | baroselenite; calstronbarite; dréelite; (fetid) heavy spar | $BaSO_4$ | 3 | brittle | | very fragile |
| 25.5.2 | goslarite | galiznite; white/zinc vitriol | $ZnSO_4 \cdot 7H_2O$ | 2-2.5 | brittle | | |
| 25.5.6 | boyleite | | $(Zn,Mg)SO_4 \cdot 4H_2O$ | 2 | | | |
| 25.5.7 | serpierite | | $Ca(Cu,Zn)_4(SO_4)_2(OH)_6 \cdot 3H_2O$ | 2 | brittle | | |
| 25.5.11 | gunningite | | $ZnSO_4 \cdot H_2O$ | 2.5 | | | |
| 25.5.13 | bianchite | | $(Zn,Fe)SO_4 \cdot 6H_2O$ | 2.5 | | | |
| 25.5.15 | zincmelanterite | | $(Zn,Cu,Fe)SO_4 \cdot 7H_2O$ | 2 | | | |
| 25.6.3 | mendozite | natrumalaun; soda-alum | $NaAl(SO_4)_2 \cdot 11H_2O$ | 3 | | | |
| 25.6.5 | aluminite | hallite; native argill | $Al_2(SO_4)(OH)_4 \cdot 7H_2O$ | 1-2 | | | fragile; hygroscopic; porous |
| 25.6.7 | alunogen | davite; keramohalite; saldanite; solfatarite | $Al_2(SO_4)_3 \cdot 17H_2O$ | 1.5-2 | | | |
| 25.6.8 | alunite | aluminilite; alumite; calafatite; ignatiewite; lœwigite | $KAl_3(SO_4)_2(OH)_6$ | 3.5-4 | brittle | | |
| 25.6.10 | hydrobasaluminite | | $Al_4(SO_4)(OH)_{10} \cdot 12\text{-}36H_2O$ | | | | |
| 25.6.11 | zaherite | | $Al_{12}(SO_4)_5(OH)_{26} \cdot 20H_2O$ | 3.5 | | | |
| 25.6.12 | tamarugite | | $NaAl(SO_4)_2 \cdot 6H_2O$ | 3 | | | |
| 25.6.14 | alum-(Na) | | $NaAl(SO_4)_2 \cdot 12H_2O$ | 3 | | | |
| 25.6.16 | kalinite | potassalumite | $KAl(SO_4)_2 \cdot 11H_2O$ | 2 | | | |
| 25.6.17 | alum-(K) | | $KAl(SO_4)_2 \cdot 12H_2O$ | 2 | | | |
| 25.6.20 | tschermigite | ammonalun; ammonia alum | $(NH_4)Al(SO_4)_2 \cdot 12H_2O$ | 1.5-2 | | | |
| 25.7.3 | anglesite | lead vitriol | $PbSO_4$ | 2.5-3 | brittle | | very fragile |

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|---|---|---|---|---|---|---|---|
| 25.7.6 | linarite | | $PbCu(SO_4)(OH)_2$ | 2.5 | brittle | | |
| 25.8.5 | minasragrite | | $(V^{4+}O)(SO_4) \cdot 5H_2O$ | 1–2 | | | |
| 25.8.7 | redingtonite | | $(Fe^{2+},Mg,Ni)(Cr,Al)_2(SO_4)_4 \cdot 22H_2O$ | 2 | | | |
| 25.8.9 | uranopilite | uranocher | $(UO_2)_6(SO_4)O_2(OH)_6 \cdot 12\text{-}14H_2O$ | | | | |
| 25.9.1 | szmikite | | $MnSO_4 \cdot H_2O$ | 1.5 | | | |
| 25.9.2 | jôkokuite | | $MnSO_4 \cdot 5H_2O$ | 2.5 | | | |
| 25.9.3 | mallardite | | $MnSO_4 \cdot 7H_2O$ | 2 | | | |
| 25.9.5 | chvaleticeite | | $(Mn,Mg)SO_4 \cdot 6H_2O$ | 1.5 | | | |
| 25.9.7 | apjohnite | | $Mn^{2+}Al_2(SO_4)_4 \cdot 22H_2O$ | 1.5-2 | | | |
| 25.9.9 | ilesite | | $(Mn,Zn,Fe)SO_4 \cdot 4H_2O$ | 2-3 | | | |
| 25.9.13 | dietrichite | | $(Zn,Fe^{2+},Mn^{2+})Al_2(SO_4)_4 \cdot 22H_2O$ | 2 | brittle | | |
| 25.10.1 | szomolnokite | ferropallidite | $FeSO_4 \cdot H_2O$ | 2.5 | brittle | | |
| 25.10.2 | rozenite | | $FeSO_4 \cdot 4H_2O$ | 2-3 | | | |
| 25.10.3 | siderotil | | $FeSO_4 \cdot 5H_2O$ | 2.5 | | | only forms when > 1.2% Cu present |
| 25.10.4 | ferrohexahydrate | | $FeSO_4 \cdot 6H_2O$ | 2 | | | |
| 25.10.5 | melanterite | green/iron vitriol | $FeSO_4 \cdot 7H_2O$ | 2 | brittle | | |
| 25.10.6 | rhomboclase | | $(H_5O_2)Fe^{3+}(SO_4)_2 \cdot 2H_2O$ | 2 | elastic | | |
| 25.10.8 | kornelite | | $Fe_2(SO_4)_3 \cdot 7H_2O$ | | | | |
| 25.10.9 | coquimbite | blakeite | $AlFe^{3+}{}_3(SO_4)_6(H_2O)_{12} \cdot 6H_2O$ | 2.5 | brittle | | |
| 25.10.10 | paracoquimbite | | $Fe^{3+}{}_4(SO_4)_6(H_2O)_{12} \cdot 6H_2O$ | 2.5 | | | |
| 25.10.11 | quenstedtite | | $Fe^{3+}{}_2(SO_4)_3 \cdot 11H_2O$ | 2.5 | brittle | | |
| 25.10.14 | hohmannite | castanite | $Fe^{3+}{}_2(SO_4)_2O \cdot 8H_2O$ | 3 | | | |
| 25.10.17 | amarantite | castanite; paposite | $Fe^{3+}{}_2(SO_4)_2O \cdot 7H_2O$ | 2.5 | brittle | | |
| 25.10.18 | fibroferrite | | Fe3+(SO4)(OH) · 5H2O | 2-2.5 | | | |
| 25.10.20 | römerite | louderbackite | $Fe^{2+}Fe^{3+}{}_2(SO_4)_4 \cdot 14H_2O$ | 3-3.5 | | | |
| 25.10.21 | bílinite | | $Fe^{2+}Fe^{3+}{}_2(SO_4)_4 \cdot 22H_2O$ | 2 | | | |
| 25.10.22 | copiapite | janosite | $Fe^{2+}Fe^{3+}{}_4(SO_4)_6(OH)_2 \cdot 20H_2O$ | 2.5-3 | fragile | | |
| 25.11.2 | sideronatrite | urusite | $Na_2Fe(SO_4)_2(OH) \cdot 3H_2O$ | 1.5-2 | elastic | | hygroscopic; porous |
| 25.11.3 | metasideronatrite | | $Na_2Fe(SO_4)_2(OH) \cdot H_2O$ | 1.5-2 | | | |
| 25.11.4 | ferrinatrite | gordaite; leucoglaucite | $Na_3Fe(SO_4)_3 \cdot 3H_2O$ | 2.5 | brittle | | |
| 25.11.7 | krausite | | $KFe(SO_4)_2 \cdot H_2O$ | 2.5 | brittle | | |
| 25.11.9 | jarosite | moronolite | $KFe^{3+}{}_3(SO_4)_2(OH)_6$ | 2.5-3.5 | brittle | | |
| 25.11.10 | voltaite | monsmedite; pettkoite | $K_2Fe^{2+}{}_5Fe^{3+}{}_3Al(SO_4)_{12} \cdot 18H_2O$ | 3-3.5 | | | |

| Hey Number | Mineral Name | Other Names | Chemical Formula | Moh's Hardness | Tenacity | H&S Data | Notes |
|---|---|---|---|---|---|---|---|
| 25.11.12 | metavoltine | metavoltaite | $Na_6K_2Fe^{2+}Fe^{3+}_6(SO_4)_{12}O_2 \cdot 18H_2O$ | 2.5 | | | |
| 25.11.17 | lonecreekite | | $(NH_4)Fe^{3+}(SO_4)_2 \cdot 12H_2O$ | 2-3 | | | |
| 25.11.18 | godovikovite | | $(NH_4)Al(SO_4)_2$ | 2 | | | |
| 25.11.19 | botryogen | kubeite; palacheite; quetenite; red iron vitriol | $MgFe^{3+}(SO_4)_2(OH) \cdot 7H_2O$ | 2-2.5 | brittle | | |
| 25.11.26 | halotrichite | | $Fe^{2+}\ Al_2(SO_4)_4 \cdot 22H_2O$ | 1.5-2 | brittle | | |
| 25.11.NI | mikasaite | | $Fe^{3+}_2(SO_4)_3$ | 2 | | | |
| 25.12.1 | bieberite | cobalt/red vitriol | $CoSO_4 \cdot 7H_2O$ | 2 | | | |
| 25.12.3 | aplowite | | $(Co,Mn,Ni)SO_4 \cdot 4H_2O$ | 3 | | | |
| 25.12.4 | moorhouseite | | $(Co,Ni,Mn)SO_4 \cdot 6H_2O$ | 2.5 | | | |
| 25.12.5 | retgersite | | $NiSO_4 \cdot 6H_2O$ | 2.5 | brittle | | |
| 25.12.6 | morenosite | | $NiSO_4 \cdot 7H_2O$ | 2-2.5 | | | |
| 25.12.13 | nicklehexahydrite | | $(Ni,Mg,Fe)SO_4 \cdot 6H_2O$ | 2 | | | |
| 25.12.NI | wupatkiite | | $(Co,Mg,Ni)Al_2(SO_4)_4 \cdot 22H_2O$ | 1.5-2 | | | |
| **26** | **Sulfates with Halide** | | | | | | |
| 26.2 | sulphohalite | | $Na_6(SO_4)_2FCl$ | | | | |
| 26.3 | schairerite | | $Na_{21}(SO_4)_7ClF_6$ | | | | |
| 26.7 | kamchatkite | | $KCu_3(SO_4)_2OCl$ | 3.5 | | | hygroscopic |
| 26.9 | aubertite | | $CuAl(SO_4)_2Cl \cdot 14H_2O$ | 2–3 | | | |
| 26.14 | kainite | | $KMg(SO_4)Cl \cdot 3H_2O$ | 2.5-3 | | | |
| 26.15 | mosesite | | $(Hg_2N)(Cl, SO_4, MO_4) \cdot H_2O$ | | | | |
| 26.16 | kleinite | | $(Hg_2N)(Cl, SO_4) \cdot nH_2O$ | | | | |
| 26.23 | pseudograndreefite | | $Pb_6(SO_4)F_{10}$ | 2.5 | brittle | | |
| 26.25 | caracolite | | $Na_3Pb_2(SO_4)_3Cl$ | 4.5 | | | |
| **27** | **Sulfites, Chromates, Molybdates, & Tungstates** | | | | | | |
| 27.2.1 | tarapacáite | | $K_2(CrO_4)$ | | | | |
| 27.2.5 | crocoite | beresofite; lehmannite | $PbCrO_4$ | 2.5-3 | brittle | | very fragile |
| 27.2.6 | phoenicochroite | subsesquichromate of lead | $Pb_2(CrO_4)O$ | 2.5 | | | |
| 27.2.NI | edoylerite | | $Hg^{2+}_3(CrO_4)S_2$ | | brittle | | |
| 27.3.3 | wulfenite | | $Pb(MoO_4)$ | 2.5-3 | brittle | | |
| 27.3.14 | ferrimolybdite | molybdenic acid/ocher; molybdite | $Fe^{3+}_2(Mo^{6+}O_4)_3 \cdot 7H_2O$ | 1-2 | | | |
| 27.4.15 | wolframite | | $(Fe^{2+})WO_4 – (Mn^{2+})WO_4$ | 4-4.5 | brittle | | |

| Hey Number | Mineral Name | Other Names | Chemical Formula | Moh's Hardness | Tenacity | H&S Data | Notes |
|---|---|---|---|---|---|---|---|
| **28** | **Selenites, Selenates, Tellurites, & Tellurates** | | | | | | |
| 28.1.8 | marthozite | | $Cu^{2+}(UO_2)_3(SeO_3)_2O_2 \cdot 8H_2O$ | | | | |
| **29** | **Iodates** | | | | | | |
| 29.3 | lautarite | | $Ca(IO_3)_2$ | 3.5-4 | | | |
| 29.5 | dietzeite | | $Ca_2(IO_3)_2(CrO_4) \cdot H_2O$ | 3.5 | | | |
| **30** | **Thiocyanates** | | | | | | |
| 30.2 | kafehydrocyanite | | $K_4[Fe(CN)_6] \cdot H_2O$ | 2-2.5 | | | existance questionable |
| **31** | **Oxalates, Citrates, Mellitates, & Acetates** | | | | | | |
| 31.1.1 | oxammite | | $(NH_4)_2(C_2O_4) \cdot H_2O$ | | | | |
| 31.1.3 | wheatleyite | | $Na_2Cu(C_2O_4)_2 \cdot 2H_2O$ | 1–2 | very brittle | | |
| 31.1.5 | whewellite | oxacalcite, oxalate of lime | $Ca(C_2O_4) \cdot H_2O$ | 2.5-3 | brittle | | |
| 31.1.NI | natroxalate | | $Na_2(C_2O_4)$ | 3 | | | |
| 31.3.1 | mellite | honey stone | $Al_2[C_6(COO)_6] \cdot 16H_2O$ | 2-2.5 | sectile | | |
| **32** | **Crystalline Organics** | | | | | | |
| 32.11 | acetamide | | $CH_3CONH_2$ | 1-1.5 | | | |
| 32.13 | urea | | $CO(NH_2)_2$ | | | | |
| **O** | **'Precious' Non-minerals** | | | | | | |
| O.1 | amber | succinite | approx. $C_{10}H_{16}O$ | 2-2.5 | brittle | flammable | "becomes electrically charged when rubbed, attractnig small particles" (Schumann 1992: 32) like dust, etc. |
| O.2 | pearl | | $CaCO_3$ | | | | |
| O.3 | obsidian | | | | | | |
| O.4 | coral | | $CaCO_3$ | 3-4 | brittle | | |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| **1** | **Elements & Alloys** | | | | | | |
| 1.1 | copper | Cu | light | surficial photo-oxidation | tarnish | | Nassau 1992; Howie 1984 |
| | | | RT, > ~60% RH | oxidation | tarnish | to cuprite, spertiniite, & tenorite | Platzman et al. 2008 |
| | | | sulfur compounds | oxidation | black spots, pitting | to copper sulfides & sulfates | Eggert et al. 2004; Weichert et al. 2004 |
| | | | moisture & chlorides | oxidation | green film or encrustations | initially to nantokite, & eventually to copper trihydroxychloride species | Scott 1990, 2000; Kologo et al. 2007 |
| | | | hydrochloric acid | etching, rapid tarnish | colour change: rose-red; tarnish: dull | | King 1983 |
| | | | acetic acid | oxidation | green encrustation | verdigris formation | Kuhn 1970 |
| 1.2 | silver | Ag | moist air, especially w/ S exposure | oxidation | tarnish: black | | Howie 1992; O'Donoghue 1983 |
| | | | sulfur compounds | oxidation | tarnish | formation of S-bearing compounds | Howie 1992; O'Donoghue 1983 |
| 1.24 | diamond | C | light | colour change | chameleon (yellow): green; chameleon (red): pink | | Nassau 1992 |
| 1.29 | tin | Sn | < 13.2C | structural phase change | colour change: grey; potential blistering, cracking, and disintegration | to α-tin (cubic); reaction only occurs with significant undercooling and/or after a long period of time | Ojima et al. 1993; Zeng et al. 2014 |
| | | | > 13.2C | structural phase change | colour change: white (when T > ~30C ) | to β-tin (tetragonal); reaction only occurs with significant overheating and/or after a long period of time | Ojima et al. 1993; Zeng et al. 2014 |
| 1.30 | lead | Pb | high RH | oxidation | tarnish | | Howie 1992 |
| | | | nitric acid | | | corrosion | O'Donoghue 1983 |
| | | | carboxylic acids | oxidation | corrosion crust | to Pb-bearing carboxylates | Tétreault et al. 1998; Raychaudhuri & Brimblecombe 2000; Tétreault et al. 2003 |
| 1.33 | arsenic | As | moist air | oxidation | tarnish: dark grey | to arsenolite | Howie 1992; King 1985 |
| | | | acids | | | | O'Donoghue 1983 |
| 1.37 | domeykite | $Cu_3As$ | moist air | oxidation | tarnish: grey, yellow, or black | sequential alteration | Howie 1992 |
| | | | moist air | oxidation | tarnish: brown | | Howie 1992 |
| 1.38 | algodonite | $(Cu_{1-x}As_x)$; x≈0.15 | light | tarnish | dull, brown | | Howie 1992; O'Donoghue 1983 |
| | | | moist air | oxidation | tarnish: dull | | Howie 1992 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 1.41 | antimony | Sb | moist air | oxidation | tarnish: grey | | Howie 1992 |
| | | | sulfuric acid | | | formation of S-bearing compounds | O'Donoghue 1983 |
| 1.42 | stibarsen | AsSb | moist air | oxidation | tarnish: grey or brown | | Howie 1992 |
| 1.48 | dyscrasite | $Ag_3Sb$ | moist air | oxidation | tarnish: grey, yellow, or black | | Howie 1992; O'Donoghue 1983 |
| 1.49 | bismuth | Bi | moist air | oxidation | tarnish: pink, brass-yellow | | O'Donoghue 1983; Howie 1992; Schumann 1992 |
| 1.51 | sulfur | $S_8$ | sudden temperature changes | cracking, spawling | | | O'Donoghue 1983 |
| 1.57 | iron | Fe | critical : > ~65% RH | oxidation | | corrosion | Howie 1992; O'Donoghue 1983 |
| 1.61 | nickel | Ni | critical: > ~85% RH | oxidation | tarnish | corrosion | Howie 1992 |
| 1.62 | kamacite | α-(Fe,Ni) | water, oxygen, & chloride | electrochemical oxidation | cracks, pits | akaganeite precipitation | Buchwald & Clarke 1989 |
| 1.63 | taenite | γ-(Ni,Fe) | water, oxygen, & chloride | electrochemical oxidation | cracks, pits | akaganeite precipitation | Buchwald & Clarke 1989 |
| 1.82 | platinum | Pt | | tarnish | colour change: darker | | Schumann 1992 |
| **2** | **Carbides, Nitrides, Silicides and Phosphides** | | | | | | |
| 2.3 | osbornite | TiN | moist air | oxidation | | | Bannister 1937 |
| 2.14 | schreibersite | $(Fe,Ni)_3P$ | moist air | oxidation | tarnish: brassy yellow or brown | | Bannister 1937 |
| **3** | **Sulfides, Selenides, Tellurides, Arsenides and Bismuthides** | | | | | | |
| 3.1.1 | chalcocite | $Cu_2S$ | light | surficial photo-oxidation | tarnish: blue or green | to digenite | Nassau 1992; King 1985 |
| | | | moist air | oxidation | tarnish: dull black | to copper sulfides & ultimately to digenite | Howie 1992; King 1985 |
| 3.1.8 | covellite | CuS | moist air | oxidation | tarnish: blue or purple, iridescent | | Howie 1992; O'Donoghue 1983 |
| 3.1.9 | berzelianite | $Cu_2Se$ | light | photo-oxidation | tarnish: dull | | Howie 1992; Nassau 1992 |
| | | | moist air | oxidation | tarnish: dull grey | | Howie 1992; O'Donoghue 1983 |
| 3.1.11 | umangite | $Cu_3Se_2$ | > 50% RH | oxidation | tarnish: dull violet-blue | to chalcomenite | Howie 1992 |
| 3.1.14 | klockmannite | CuSe | > 50% RH | oxidation | tarnish: blue | | Howie 1992 |
| 3.1.16 | weissite | $Cu_{2-x}Te$ | moist air | oxidation | tarnish: darkens | | Howie 1992 |
| 3.1.17 | rickardite | $Cu_7Te_5$ | light | photo-oxidation | dull | | O'Donoghue 1983 |
| | | | moist air | oxidation | tarnish: darkens | | Howie 1992 |
| 3.1.22 | cubanite | $CuFe_2S_3$ | moist air | oxidation | tarnish: brown or blue | | Howie 1992 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 3.1.23 | bornite | $Cu_5FeS_4$ | moist air | oxidation | tarnish: purple-blue, iridescent | hydrated iron oxide | Howie 1992; O'Donoghue 1983 |
| | | | oxalic acid | | tarnish | | King 1983 |
| 3.1.25 | chalcopyrite | $CuFeS_2$ | low temperatures, > 50% RH | oxidation | tarnish: iridescent blue or red, dull brown, or black | to hydrated ferric oxide & copper sulfate | Howie 1992 |
| | | | hydrochloric acid | | tarnish | | O'Donoghue 1983 |
| 3.2.1 | acanthite | $Ag_2S$ | light | surfical photo-oxidation | darken | sulfide formation | Nassau 1992; O'Donoghue 1983 |
| | | | light | photochemical oxidation | tarnish: lead-grey, eventually grey friable crust | rapid surface degradation | Howie 1992 |
| 3.2.3 | naumannite | $Ag_2Se$ | light | surfical photo-oxidation | tarnish: brown, iridescent | | Nassau 1992 |
| 3.2.4 | aguilarite | $Ag_4SeS$ | light | surfical photo-oxidation | tarnsh: darkens | to silver & cuprian stephanite | Nassau 1992; King 1985 |
| 3.2.5 | hessite | $Ag_2Te$ | light | surfical photo-oxidation | tarnish: dull, yellow or grey | | Howie 1992; Nassau 1992 |
| 3.2.8 | cervelleite | $Ag_4TeS$ | light | photochemical oxidation | | | Howie 1992 |
| 3.2.10 | stromeyerite | AgCuS | light | surfical photo-oxidation | tarnish: dark blue | | Nassau 1992 |
| | | | moist air | oxidation | tarnish: blue | to metallic silver & covelline | Howie 1992; O'Donoghue 1983 |
| 3.2.11 | mckinstryrite | $(Ag,Cu)_2S$ | moist air | oxidation | | | Howie 1992 |
| 3.2.12 | jalpaite | $Ag_3CuS_2$ | light | surfical photo-oxidation | tarnish: darkens or iridescent | to silver & silver sulfosalts | Nassau 1992; King 1985 |
| | | | moist air | oxidation | tarnish: dark grey or yellow | | O'Donoghue 1983 |
| 3.2.13 | eucairite | AgCuSe | moist air | oxidation | tarnish: light yellow | | O'Donoghue 1983 |
| 3.2.17 | argentopyrite | $AgFe_2S_3$ | moist air | oxidation | tarnish: brown, blue, green, or purple | | O'Donoghue 1983 |
| 3.3.1 | calaverite | $AuTe_2$ | light | photo-oxidation | tarnish: brassy-yellow | | Howie 1992 |
| 3.3.2 | krennerite | $Au_3AgTe_8$ | light | photo-oxidation | tarnish: brassy-yellow | | Howie 1992 |
| 3.3.7 | petzite | $Ag_3AuTe_2$ | light | photo-oxidation | tarnish: yellow-gold | | Howie 1992 |
| | | | moist air | oxidation | tarnish: darkens | | O'Donoghue 1983 |
| | | | nitric acid | | | | O'Donoghue 1983 |
| 3.3.9 | sylvanite | $(Au,Ag)_2Te_4$ | high light levels | surfical photo-oxidation | tarnish: brassy-yellow, darkens | to tellurite | Howie 1992; Nassau 1992 |
| 3.4.2 | oldhamite | (Ca,Mg)S | moist air | oxidation | | to calcium sulfate | Howie 1992 |
| 3.4.4 | sphalerite | ZnS | light | photo-oxidation | darkens; metallic tarnish | | Nassau 1992 |
| | | | moist ar | oxidation | | | Howie 1984 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 3.4.7 | greenockite | CdS | moist air | surficial oxidation & hydration | yellow/red: white, fading | to cadmium sulfate monohydrate | Van der Snickt 2009 |
| | | | hydrochloric acid | | | | O'Donoghue 1983 |
| 3.5.1 | cinnabar | HgS | light, moisture, & alkai halogens | surficial photochemical oxidation | darkens & blackens | to metallic mercury & other mercuric halides | Keune & Boon 2005; Radepont et al. 2011; Anaf et al. 2013; Neiman et al. 2015 |
| 3.6.5 | galena | PbS | 20C, > 65% RH | oxidation | tarnish: blue, dark grey | surficial lead enrichment | Howie 1992 |
| | | | moist air | oxidation | | to anglesite | Swartzlow 1933 |
| | | | dilute acids | etching | | | King 1983 |
| 3.6.7 | altaite | PbTe | moist air | oxidation | tarnish: dull brown or bronze | | Howie 1992; O'Donoghue 1983 |
| 3.7.4 | realgar | $As_4S_4$ | light: 500-670nm | structural alteration | red: orange | to pararealgar | Douglass et al. 1992; Kyono et al. 2005; Kyono 2007; Jovanovski & Makreski 2020 |
| 3.7.8 | orpiment | $As_2S_3$ | moist air | oxidation | | to arsenolite | Howie 1992 |
| 3.7.14 | stibnite | $Sb_2S_3$ | light | self-limiting photochemical oxidation | tarnish: dull, blue-black &/or iridescent | | Howie 1992; Nassau 1992 |
| 3.7.17 | bismuthinite | $Bi_2S_3$ | moist air | oxidation | tarnish: yellow or iridescent | to hydrated bismuth oxide | Howie 1992 |
| 3.7.29 | tetradymite | $Bi_2Te_2S$ | moist air | oxidation | tarnish: dull or iridescent | to bismutite & montanite | Howie 1992 |
| 3.7.30 | joséite | $Bi_4TeS_2$ | moist air | oxidation | tarnish: dull or iridescent | to montanite | Howie 1992 |
| 3.8.4 | daubréelite | $Fe^{2+}Cr^{3+}{}_2S_4$ | moist air | oxidation | | | Howie 1984; Bannister 1937 |
| 3.8.6 | molybdenite | $MoS_2$ | high RH | oxidation | | | Howie 1992 |
| 3.8.12 | alabandite | MnS | light | surficial photo-oxidation | tanish: brown | | Nassau 1992 |
| | | | moist air | oxidation | tarnish: brown | to hydrated manganese sulfate | Howie 1992 |
| 3.8.13 | hauerite | $MnS_2$ | hydrochloric acid | | | | O'Donoghue 1983 |
| 3.9.1 | pyrrhotite | $Fe_7S_8$ | 20C, > 50% RH | oxidation | tarnish: dull, pink-gold or iridescent | to iron sulfates & sulfuric acid; some marcasite may form | Howie 1992; Jerz & Rimstidt 2003 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 3.9.3 | pyrite | $FeS_2$ | > 30% RH; critical: > 60% RH | oxidation | tarnish: dull or iridescent; efflorescence | initially to sulfate & iron (hydr)oxides; then to iron sulfates & sulfuric acid | Howie 1992; Guevremont et al. 1998; Rosso et al. 1999; Jerz & Rimstidt 2004 |
| | | | Arsenic compounds, anoxia | alteration | | to an FeAsS surface precipitate, potentially evolving into scorodite or orpiment | Bostick & Fendorf 2003 |
| 3.9.4 | marcasite | $FeS_2$ | light | tarnish | darkens | | O'Donoghue 1983 |
| | | | > 30% RH | oxidses | tarnish: dull or iridescent; efflorescence | to iron sulfates & sulfuric acid | Howie 1992; Lowson 1982 |
| 3.9.5 | greigite | $Fe^{2+}Fe^{3+}{}_2S_4$ | moisture | oxidation | tarnish | | Howie 1992 |
| 3.9.6 | mackinawite | $(Fe,Ni)_9S_8$ | moisture | oxidation | | to sulfates, FeO, & HS | Howie 1992 |
| 3.9.7 | smythite | $(Fe,Ni)_{3+x}S_4$; x≈0-0.3 | moisture | oxidation | tarnish | | Howie 1992 |
| 3.9.9 | ferroselite | $FeSe_2$ | moisture | oxidation | | | Howie 1984 |
| 3.9.11 | löllingite | $FeAs_2$ | moisture | oxidation | | to scorodite & symplesite | Howie 1992 |
| 3.9.12 | arsenopyrite | FeAsS | > 30C, high RH | oxidation | tarnish: dull brown or grey; occassional grey/black crystalline growths at fractures | to scorodite & hydrated iron sulfates | Howie 1992 |
| 3.9.NI | troilite | FeS | RT, ambient humidity | oxidation | tarnish | initially to sulfides, then sulfate | Terranova et al. 2018 |
| | | | Arsenic compounds, anoxia | alteration | | to pyrite & an FeAsS surface precipitate, potentially evolving into scorodite or orpiment | Bostick & Fendorf 2003 |
| 3.10.2 | linnaeite | $Co^{2+}Co^{3+}{}_2S_4$ | > 40-50% RH | oxidation | tarnish: red or violet | to hydrated cobalt sulfates | Howie 1992 |
| 3.10.10 | safflorite | $(Co,Ni,Fe)As_2$ | > 50% RH | oxidation | tarnish: darkens | to erythrite | Howie 1992 |
| 3.10.12 | skutterudite | $CoAs_3$ | high RH | oxidation | tarnish | to nickel & cobalt arsenates | Howie 1992 |
| | | | moisture | oxidation & hydration | | to erythrite | King 1985 |
| 3.10.13 | cobaltite | CoAsS | moisture | oxidation | tarnish: pink-blue | to cobalt sulfates, arsenates, and oxides | Howie 1992 |
| 3.10.17 | glaucodot | $(Co_{0.5}Fe_{0.5})AsS$ | moisture | oxidation | tarnish: brown | | Howie 1992 |
| 3.10.18 | carrollite | $Cu(Co,Ni)_2S_4$ | > 40-50% RH | oxidation | tarnish: red or violet | to hydrated cobalt sulfates | Howie 1992 |
| 3.11.3 | millerite | NiS | > 40-50% RH | oxidation | tarnish: iridescent grey | | Howie 1992 |
| | | | 22-24C, > 60% RH | surficial oxidation | | to theophrastite & nickel sulfate | Nesbitt & Reinke 1999 |
| | | | acids | | matted finish | | O'Donoghue 1983 |
| 3.11.4 | polydymite | $Ni^{2+}Ni^{3+}{}_2S_4$ | light | surficial photo-oxidation | colour change: red or violet | to erythrite & pitticite | Nassau 1992; King 1985 |
| | | | > 40-50% RH | oxidation | tarnish: red or violet | | Howie 1992 |
| 3.11.5 | vaesite | $NiS_2$ | > 40-50% RH | oxidation | tarnish | | Howie 1992 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 3.11.8 | violarite | $Fe^{2+}Ni^{3+}{}_2S_4$ | moisture | oxidation | tarnish: red | | Howie 1992 |
| 3.11.9 | pentlandite | $(Fe,Ni)_9S_8$ | moisture | oxidation | tarnish | | Howie 1992 |
| 3.11.10 | bravoite | $(Fe,Ni)S_2$ | > 40-50% RH | oxidation | tarnish: red | | Howie 1992 |
| 3.11.19 | penrosite | $(Ni,Co,Cu)Se_2$ | light | surficial photo-oxidation | tarnish: dull | | Nassau 1992 |
| | | | moisture | oxidation | tarnish: dull | | Howie 1992 |
| 3.11.22 | melonite | $NiTe_2$ | moisture | oxidation | tarnish: brown | | Howie 1992 |
| 3.11.26 | maucherite | $Ni_{11}As_8$ | moisture | tarnish | tarnish: darkens | | Parsons 1922 |
| 3.11.27 | nickeline | NiAs | > 30% RH | oxidation | tarnish: darkens, dull | to annabergite | Howie 1992 |
| | | | 22-24C, > 60% RH | surficial oxidation | | to theophrastite, annabergite, & nickel arsenite | Nesbitt & Reinke 1999 |
| 3.11.28 | rammelsbergite | $NiAs_2$ | > 30% RH | oxidation | green coating | to annabergite | Howie 1992 |
| 3.11.29 | pararammelsbergite | $NiAs_2$ | > 30% RH | oxidation | | to annabergite | Howie 1992 |
| 3.11.30 | nickelskutterudite | $(Ni,Co,Fe)As_3$ | high RH | oxidation | tarnish | to nickel arsenates & cobalt arsenates | Howie 1992 |
| 3.11.34 | gersdorffite | NiAsS | moisture | oxidation | tarnish: darkens, dull | | Howie 1992 |
| | | | moisture | oxidation | disintegrates; green mass | to annabergite | King 1983 |
| 3.11.36 | breithauptite | NiSb | moisture | oxidation | tarnish: violet | | Howie 1992 |
| 3.11.38 | ullmannite | NiSbS | | tarnish | colour change: iridescence | | Schumann 1992 |
| **4** | **Oxysulfides** | | | | | | |
| 4.2 | kermesite | $Sb_2S_2O$ | | dehydration | | | O'Donoghue 1983 |
| **5** | **Sulfosalts: Sulfarsenites & Sulfobismuthites** | | | | | | |
| 5.1.4 | chalcostibite | $CuSbS_2$ | light & moisture | photo-oxidation | tarnish: dull, pale blue | | Howie 1992 |
| 5.1.7 | emplectite | $CuBiS_2$ | | tarnish | colour change: yellow | | Schumann 1992 |
| 5.1.9 | wittichenite | $Cu_3BiS_3$ | moisture | oxidation | tarnish: pale lead-grey; surface alteration (yellow-brown, blue, red) | to bismutite & covelline | Howie 1992 |
| 5.1.10 | hodrušite | $Cu_8Bi_{12}S_{22}$ | light | photo-oxidation | tarnish: brown bronze | | Howie 1984 |
| 5.2.1 | smithite | $AgAsS_2$ | light | photochemical oxidation | red: orange | loss of form | Howie 1992; Nassau 1992; King 1985 |
| 5.2.2 | trechmannite | $AgAsS_2$ | light | surfical photo-oxidation | | | Nassau 1992 |
| 5.2.3 | proustite | $Ag_3AsS_3$ | light | photo-oxidation | colour change: darken & silvery; ultimately turns black | to silver & acanthite | Howie 1992; Nassau 1992; King 1983, 1985 |
| 5.2.4 | xanthoconite | $Ag_3AsS_3$ | light | surfical photo-oxidation | tarnish | | Nassau 1992 |
| 5.2.5 | pearceite | $[Ag_9CuS_4][(Ag,Cu)_6(As,Sb)_2S_7]$ | light | surfical photo-oxidation | tarnish | | Nassau 1992 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 5.2.8 | miargyrite | $AgSbS_2$ | light | surfical photo-oxidation | darkens | | Nassau 1992; O'Donoghue 1983 |
| 5.2.9 | pyrargyrite | $Ag_3SbS_3$ | light | photo-oxidation | tarnish: darkens, dull | to metallic silver, acanthite, & stibinite | Howie 1992; Nassau 1992; King 1985 |
| 5.2.10 | pyrostilpnite | $Ag_3SbS_3$ | light | surfical photo-oxidation | tarnish | | Nassau 1992 |
| 5.2.11 | stephanite | $Ag_5SbS_4$ | light | surfical photo-oxidation | tarnish: darkens | to silver & other silver sulfosalts | Nassau 1992; King 1985 |
| 5.2.12 | polybasite | $[(Ag,Cu)_6(Sb,As)_2S_7][Ag_9CuS_4]$ | light | surfical photo-oxidation | tarnish | to stephanite | Nassau 1992; King 1985 |
| 5.2.16 | aramayoite | $Ag_3Sb_2(Bi,Sb)S_6$ | high light levels | surficial photo-oxidation | tarnish | | Nassau 1992 |
| 5.2.17 | matildite | $AgBiS_2$ | light | surfical photo-oxidation | tarnish | | Nassau 1992 |
| 5.2.19 | pavonite | $AgBi_3S_5$ | light | photo-oxidation | tarnish | | Howie 1984 |
| 5.2.24 | volynskite | $AgBiTe_2$ | moisture | oxidation | | | Howie 1984 |
| 5.2.NI | fettelite | $[Ag_6As_2S_7][Ag_{10}HgAs_2S_8]$ | light | surficial photo-oxidation | tarnish | | Nassau 1992 |
| 5.5.1 | lorándite | $TlAsS_2$ | light | surfical photo-decomposition | translucent orange or yellow powdery coating | | Howie 1992 |
| 5.5.7 | hutchinsonite | $TlPbAs_5S_9$ | light | surfical photo-oxidation | tarnish | | Nassau 1992 |
| 5.5.10 | vrbaite | $Hg_3Tl_4As_8Sb_2S_{20}$ | light | surfical photo-oxidation | | | Nassau 1992 |
| 5.6.1 | sartorite | $PbAs_2S_4$ | light | surfical photo-oxidation | | | Nassau 1992 |
| 5.6.2 | dufrénoysite | $Pb_2As_2S_5$ | light | photo-oxidation | surficial colour change: brown | | Nassau 1992 |
| 5.6.4 | baumhauerite | $Pb_3As_4S_9$ | light | surficial photo-oxidation | tarnish: iridescent | | Howie 1992; Nassau 1992 |
| | | | moisture | oxidation | tarnish: iridescent | | Howie 1992 |
| 5.6.6 | jordanite | $Pb_{14}(As,Sb)_6S_{23}$ | moisture | oxidation | tarnish: iridescent | | Howie 1992; Schumann 1992 |
| 5.6.7 | fülöppite | $Pb_3Sb_8S_{15}$ | moisture | oxidation | tarnish: dull bronze | | Howie 1992 |
| 5.6.8 | zinkenite | $Pb_9Sb_{22}S_{42}$ | moisture | oxidation | tarnish: iridescent | | Howie 1992 |
| 5.6.13 | semseyite | $Pb_9Sb_8S_{21}$ | moisture | oxidation | tarnish: dull steel blue | | Howie 1992 |
| 5.6.15 | boulangerite | $Pb_5Sb_4S_{11}$ | low RH | oxidation | yellow spots | to bindheimite | Howie 1992 |
| 5.6.23 | galenobismutite | $PbBi_2S_4$ | moisture | oxidation | | to bismutite | Howie 1992 |
| 5.7.2 | bournonite | $PbCuSbS_3$ | light | alteration | darkens | | Howie 1992 |
| 5.7.9 | aikinite | $PbCuBiS_3$ | moisture | oxidation | tarnish: brown or copper-red; occassional yellow coating | to bismutite | Howie 1992 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 5.7.20 | marrite | $AgPbAsS_3$ | moisture | oxidation | tarnish: iridescent | | Howie 1992 |
| 5.7.22 | andorite | $AgPbSb_3S_6$ | light | photo-oxidation | tarnish: yellow, iridescent | | Howie 1992; Nassau 1992 |
| 5.7.23 | ramdohrite | $Pb_{5.9}Fe_{0.1}Mn_{0.1}In_{0.1}Cd_{0.2}Ag_{2.8}Sb_{10.8}S_{24}$ | light | surfical photo-oxidation | | | Nassau 1992 |
| 5.7.27 | fizélyite | $Ag_5Pb_{14}Sb_{21}S_{48}$ | light | surfical photo-oxidation | tarnish | | Nassau 1992 |
| 5.7.28 | owyheeite | $Ag_3Pb_{10}Sb_{11}S_{28}$ | moisture | oxidation | tarnish: yellow | | O'Donoghue 1983 |
| 5.7.29 | freieslebenite | $AgPbSbS_3$ | light | surfical photo-oxidation | tarnish | | Nassau 1992 |
| 5.7.30 | diaphorite | $Ag_3Pb_2Sb_3S_8$ | light | surfical photo-oxidation | tarnish | | Nassau 1992 |
| 5.7.39 | benjaminite | $Ag_3Bi_7S_{12}$ | moisture | oxidation | tarnish: dull yellow or red | to bismutite | Howie 1992 |
| 5.7.40 | lengenbachite | $Ag_4Cu_2Pb_{18}As_{12}S_{39}$ | light | surfical photo-oxidation | tarnish: iridescent | | Nassau 1992 |
| 5.7.47 | rathite | $Ag_2Pb_{12-x}Tl_{x/2}As_{18+x/2}S_{40}$ | light | surfical photo-oxidation | tarnish: iridescent | to arsenical sulfides | Nassau 1992; King 1985 |
| 5.8.1 | samsonite | $Ag_4MnSb_2S_6$ | light | surfical photo-oxidation | tarnish | | Nassau 1992 |
| 5.8.4 | berthierite | $FeSb_2S_4$ | moisture | oxidation | tarnish: iridescent or dark brown | | Howie 1992; O'Donoghue 1983 |
| 5.8.5 | jamesonite | $Pb_4FeSb_6S_{14}$ | moisture | oxidation | tarnish: iridescent | | Howie 1992; Schumann 1992 |
| **6** | **Sulfosalts** | | | | | | |
| 6.1.6 | stannite | $Cu_2FeSnS_4$ | moisture | oxidation | tarnish: blue | | Howie 1992 |
| 6.1.18 | franckeite | $Fe^{2+}(Pb,Sn^{2+})_6Sn^{4+}{}_2Sb_2S_{14}$ | moisture | oxidation | tarnish: iridescent | | Howie 1992 |
| 6.2.1 | germanite | $Cu_{13}Fe_2Ge_2S_{16}$ | | tarnish | colour change: dark violet, brown | | Schumann 1992 |
| 6.2.4 | argyrodite | $Ag_8GeS_6$ | light | surficial photo-oxidation | tarnish: violet | | Howie 1992; Nassau 1992 |
| 6.2.5 | canfieldite | $Ag_8SnS_6$ | light | surficial photo-oxidation | tarnish: blue or purple | | Howie 1992; Nassau 1992 |
| 6.3.1 | enargite | $Cu_3AsS_4$ | low temperatures, > 50% RH | oxidation | tarnish: dull | to tennanite | Howie 1992 |
| | | | sulfur compounds | oxidation | | develops black efflorescence | Howie 1992 |
| 6.4.1 | sulvanite | $Cu_3VS_4$ | moisture | oxidation | tarnish: dull | to cuprodescloizite | Howie 1992 |
| 6.5.1 | corderoite | $\alpha$-$Hg^{2+}{}_3S_2Cl_2$ | light | desulfidation | orange-pink / pink-brown: grey, black | to calomel, metalic mercury, & sulfur | Keune & Boon 2005; Da Pieve et al. 2013 |
| 6.5.NI | kenhsuite | $\gamma$-$Hg^{2+}{}_3S_2Cl_2$ | light | alteration | | to corderoite | Radepont et al. 2011 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| **7** | **Oxides & Hydroxides** | | | | | | |
| 7.3.1 | cuprite | $Cu_2O$ | light | photodecomposition | darkens | copper liberated | Nassau 1992 |
| | | | light | surficial photo-oxidation | tarnish | | Nassau 1992; O'Donoghue 1983; Howie 1984 |
| | | | chlorides | oxidation & hydrolysis | colour change: pale green encrustation | to copper trihydroxychloride species | Sharkey & Lewin 1971; Scott 1990, 2000 |
| 7.4.7 | periclase | MgO | moisture | tarnish | dull | | O'Donoghue 1983 |
| 7.5.12 | montroydite | HgO | light | surfical photo-oxidation | darkens | | Nassau 1992 |
| 7.6.1 | corundum | $Al_2O_3$ | high light levels | colour change | yellow: fades | | Nassau 1992 |
| 7.8.1 | quartz | $SiO_2$ | light, inc. sunlight | colour change (var. agate, amethyst, chrysoprase, citrine, morion, rose (crystalline), smokey) | fades | | Currier 1985; Kane 1985; King 1985; Nassau 1992 |
| 7.8.8 | opal | $SiO_2 \cdot nH_2O$ | moist air | hydration | | | Howie 1984 |
| | | | dry air &/or mild heating | dehydration | may show signs of shrinkage; cracks and loss of opalescence | | Schumann 1977; King 1985 |
| 7.9.2 | rutile | $TiO_2$ | light | colour change | darkens | | Nassau 1992 |
| 7.11.20 | massicot | β-PbO | high RH | carbonation | | to (hydro)cerussite | Aze et al. 2007 |
| | | | sulfuric acid | sulfidation | yellow: black | to galena | Smith & Clark 2002 |
| 7.11.21 | litharge | PbO | sulfuric acid | sulfidation | red: black | to galena | Smith & Clark 2002 |
| 7.11.22 | minium | $Pb_3O_4$ | sulfuric acid | sulfidation | red: black | to galena &/or other lead oxides | Smith & Clark 2002 |
| | | | sulfuric acid | sulfidation | | to platternerite & anglesite | Aze et al. 2007 |
| 7.11.23 | plattnerite | $PbO_2$ | acids | | | | O'Donoghue 1983 |
| 7.12.8 | navajoite | $(V^{5+},Fe^{3+})_{10}O_{24} \cdot 12H_2O$ | | dehydration | | to lower hydration states | Waller 1992 |
| 7.12.10 | bariandite | $Al_{0.6}(V^{5+},V^{4+})_8O_{20} \cdot 9H_2O$ | | dehydration | | to lower hydration states | Waller 1992 |
| 7.13.1 | arsenolite | $As_2O_3$ | acids | | | | O'Donoghue 1983 |
| 7.13.6 | stibiconite | $Sb^{3+}Sb^{5+}{}_2O_6(OH)$ | moisture | oxidation | white coating | stibiconite | O'Donoghue 1983 |
| | | | acids | | | | O'Donoghue 1983 |
| 7.16.1 | uraninite | $UO_2$ | radiogenic $Pb^{4+}$ | auto-oxidation | colour change: black | increases $U^{6+}$ content | Finch & Murakami 2000 |
| | | | oxygen & moisture | oxidation | corrosion crust | to uranyl oxyhydroxides | Finch & Murakami 2000 |
| 7.16.2 | schoepite | $(UO_2)_8O_2(OH)_{12} \cdot 12H_2O$ | RT, ambient humidity | dehydration | cracking along grain boundaries | to metaschoepite | Sowder et al. 1999 |
| | | | RT, ambient humidity, & mechanical stress | dehydration | structural instability | irreversibly to paulscherrerite | Sowder et al. 1999 |
| 7.16.3 | paraschoepite | $UO_3 \cdot 2H_2O$ | | dehydration | | to anhydrous phase | Waller 1992 |
| 7.16.4 | metaschoepite | $(UO_2)_8O_2(OH)_{12} \cdot 10H_2O$ | 22C, < 45% RH | dehydration | | irreversibly to paulscherrerite | Kirkegaard et al. 2019 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 7.16.7 | ianthinite | $U^{4+}(UO_2)_5O_7 \cdot 10H_2O$ | oxygen & moisture | oxidation | colour change (purple): lemon/sulfur yellow | to schoepite &/or metaschoepite | Finch & Murakami 2000; Singh et al. 2014 |
| 7.16.21 | davidite-(La) | $La(Y,U)Fe_2(Ti,Fe,Cr,V)_{18}(O,OH,F)_{38}$ | moisture | oxidation | tarnish | | O'Donoghue 1983 |
| 7.16.22 | davidite-(Ce) | $Ce(Y,U)Fe_2(Ti,Fe,Cr,V)_{18}(O,OH,F)_{38}$ | moisture | oxidation | tarnish | | O'Donoghue 1983 |
| 7.16.28 | vandendriesscheite | $PbU_7O_{22} \cdot 12H_2O$ | | dehydration | | to metavandendriesscheite | Waller 1992 |
| 7.17.2 | tellurite | $TeO_2$ | most acids | | | | O'Donoghue 1983 |
| 7.18.1 | manganosite | MnO | light | surficial reaction | colour change: blue | | Nassau 1992 |
| | | | light | surficial reaction | colour change: darkens | | O'Donoghue 1983 |
| 7.18.7 | manganite | $Mn^{3+}O(OH)$ | moisture | oxidation | tarnish: darkens | | O'Donoghue 1983 |
| 7.18.10 | pyrochroite | $Mn(OH)_2$ | light | surficial reaction | colour change: brown or darkens | | Nassau 1992 |
| 7.20.4 | hematite | $Fe_2O_3$ | 20C, > 90% RH | oxidation | | to goethite | Bedarida & Pedemont 1971 |
| | | | sulfuric acid | alteration | | to iron sulfides | Drosdoff & Truog 1935 |
| 7.20.5 | goethite | $\alpha\text{-}Fe^{3+}O(OH)$ | sulfuric acid | alteration | | to iron sulfides | Drosdoff & Truog 1935 |
| 7.20.6 | akaganeite | $(Fe^{3+},Ni^{2+})_8(OH,O)_{16}Cl_{1.25} \cdot nH_2O$ | | dehydrates | | loss of 5-10% wt $H_2O$ | Buchwald & Clarke 1989 |
| | | | moist air | chlorine depletion | | decomposes to maghemite & goethite | Buchwald & Clarke 1989 |
| **8** | **Halides** | | | | | | |
| 8.1.3 | halite | NaCl | 20C, > 75% RH | deliquescence | | | Waller 1992 |
| | | | light | photodecomposition (var. huantajayite & other silver-bearing specimens) | darkens | silver liberation | Parsons 1922; King 1985 |
| 8.1.4 | hydrohalite | $NaCl \cdot 2H_2O$ | < –0.1C | dehydration | to saturated solution of halite | | Waller 1992; Hazen & Ausubel 2016 |
| 8.1.5 | carobbiite | KF | 25C, > 30% RH | deliquescence | | | Waller 1992 |
| | | | | efflorescence | | | King 1985 |
| 8.1.6 | sylvite | KCl | 20C, > 85% RH | deliquescence | | | Waller 1992 |
| 8.1.7 | salammoniac | $NH_4Cl$ | 20C, > 79% RH | deliquescence | | | Waller 1992 |
| 8.2.1 | nantokite | CuCl | light | surficial photo-oxidation | green encrustation | to paratacamite | Nassau 1992; King 1985 |
| | | | | deliquescence | | | King 1985 |
| | | | moist air | hydration | | to eriochalcite | Scott 2000 |
| | | | 20C, > 70% RH | oxidation & hydrolysis | green encrustation | to copper trihydroxychloride species | Scott 1990, 2000 |
| | | | moisture & sulfur compounds | alteration | | to connellite &/or brochantite | Scott 2000 |
| 8.2.2 | tolbachite | $CuCl_2$ | moist air | hydration | | to eriochalcite | Waller 1992 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 8.2.3 | eriochalcite | $CuCl_2 \cdot 2H_2O$ | 20C, > 68% RH | deliquescence | | | Waller 1992 |
| | | | | dehydration | efflorescence | to lower hydration states | King 1985; Howie 1984 |
| 8.2.6 | botallackite | $Cu_2Cl(OH)_3$ | moist air | structural phase change | | to other copper trihydroxychloride species | Scott 2000 |
| 8.2.8 | calumetite | $CaCu_4(OH)_8Cl_2 \cdot 3.5H_2O$ | | dehydration | | to lower hydration states | Scott 2000 |
| 8.2.9 | anthonyite | $Cu(OH,Cl)_2 \cdot 3H_2O$ | | dehydration | | to lower hydration states | Waller 1992; Scott 2000 |
| 8.2.11 | marshite | CuI | light | surficial photo-oxidation | darkens: pale pink through brownish red | | Nassau 1992; O'Donoghue 1983 |
| 8.3.1 | chlorargyrite | AgCl | high light levels | photodecomposition | colour change: violet-brown, grey, black | to silver; silver liberation | Nassau 1992; King 1985 |
| 8.3.2 | bromargyrite | AgBr | high light levels | photodecomposition | darkens | to silver; silver liberation | Nassau 1992; King 1985 |
| 8.3.3 | bromian chlorargyrite | Ag(Cl, Br) | high light levels | photodecomposition | darkens | to silver; silver liberation | Nassau 1992; King 1985 |
| 8.3.4 | iodargyrite | AgI | light | photodecomposition | darkens | to silver; silver liberation | Nassau 1992; King 1985 |
| 8.3.5 | miersite | (Ag, Cu)I | high light levels | photodecomposition | darkens | silver liberation | Nassau 1992 |
| 8.4.3 | bischofite | $MgCl_2 \cdot 6H_2O$ | 20C, > 33% RH | deliquescence | | decomposes | Waller 1992 |
| | | | 25C, < 3% RH | dehydration | efflorescence | to lower hydration states | Waller 1992 |
| 8.4.5 | carnallite | $KMgCl_3 \cdot 6H_2O$ | | deliquescence | | | Waller 1992; King 1985 |
| | | | ambient conditions | | dull | | Schumann 1992 |
| | | | 32C, < 3% RH | dehydration | efflorescence | to lower hydration states | Waller 1992 |
| 8.4.6 | tachyhydrite | $CaMg_2Cl_6 \cdot 12H_2O$ | | deliquescence | | | Waller 1992; Hazen & Ausubel 2016 |
| 8.4.7 | fluorite | $CaF_2$ | light | colour change | pink: fades; green: purple; blue, purple: pink or colourless | | Nassau 1992; King 1985 |
| | | | acids | | | | King 1983 |
| 8.4.8 | sinjarite | $CaCl_2 \cdot 2H_2O$ | 25C, > 11% RH | hydration | | to higher hydration states, eventually to antarcticite | Waller 1992 |
| 8.4.9 | antarcticite | $CaCl_2 \cdot 6H_2O$ | > 29.9C | dehydration | | to saturated solution of sinjarite | Waller 1992 |
| | | | RT, > 33% RH | deliquescence | | | Waller 1992 |
| | | | RT, < 21% RH | dehydration | efflorescence | to sinjarite | Waller 1992 |
| 8.4.10 | chlorocalcite | $KCaCl_3$ | | deliquescence | | | O'Donoghue 1983; Hazen & Ausubel 2016 |
| 8.4.NI | chloromagnesite | $MgCl_2$ | | deliquescence | | | Howie 1984 |
| | | | | efflorescence | | | Howie 1984 |
| 8.5.2 | calomel | $[Hg_2]^{2+}Cl_2$ | light | disproportionation | | to metallic mercury & mercuric chloride | Neiman et al. 2015 |
| 8.5.3 | terlinguaite | $Hg_2OCl$ | light | surfical photo-oxidation | yellow: olive green | | Nassau 1992; King 1985 |
| 8.5.6 | eglestonite | $([Hg^{1+}]_2)_3OCl_3(OH)$ | light | surficial photo-oxidation | colour change: brown or darkens | mercury liberation | Nassau 1992; King 1985 |
| 8.6.2 | chloraluminite | $AlCl_3 \cdot 6H_2O$ | 25C, > ~40% RH | deliquescence | | | Waller 1992 |
| | | | | hydrolysis | | | King 1985; Howie 1984 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 8.6.3 | cadwaladerite | $AlCl(OH)_2 \cdot 4H_2O$ | | deliquescence | | | Waller 1992 |
| 8.7.1 | fluocerite-(Ce) | $(Ce,La)F_3$ | light | colour change | yellowish- or reddish-brown | | O'Donoghue 1983 |
| 8.8.17 | bideauxite | $Pb_2AgCl_3(F,OH)_2$ | high light levels | colour change | pale lavender | | Howie 1984 |
| 8.10.1 | scacchite | $MnCl_2$ | 25C, > ~56% RH | deliquescence | | | Waller 1992 |
| 8.10.3 | chloromanganokalite | $K_4MnCl_6$ | | deliquescence | | decomposes easily | Waller 1992; O'Donoghue 1983 |
| | | | | efflorescence | | | Howie 1984 |
| 8.11.1 | molysite | $FeCl_3$ | 25C, > ~5% RH | deliquescence | | | Waller 1992; Hazen & Ausubel 2016 |
| | | | | hydrolysis | | to hydrous iron oxide | King 1985 |
| 8.11.2 | hydromolysite | $FeCl_3 \cdot 6H_2O$ | 25C, > ~5% RH | deliquescence | | | Waller 1992 |
| 8.11.3 | rokühnite | $FeCl_2 \cdot 2H_2O$ | moist air | hydration | | to higher hydration states | Waller 1992 |
| 8.11.4 | douglasite | $K_2Fe^{2+}Cl_4 \cdot 2H_2O$ | | deliquescence | | | Waller 1992; King 1985 |
| | | | | efflorescence | | | Howie 1984 |
| 8.11.5 | erythrosiderite | $K_2Fe^{3+}Cl_5 \cdot H_2O$ | | deliquescence | | | Waller 1992; Hazen & Ausubel 2016 |
| | | | | efflorescence | | | Howie 1984 |
| 8.11.6 | rinneite | $K_3NaFe^{2+}Cl_6$ | | deliquescence | | | Waller 1992; King 1985 |
| 8.11.7 | kremersite | $(NH_4,K)_2Fe^{3+}Cl_5 \cdot H_2O$ | | deliquescence | | | Waller 1992; King 1985 |
| | | | | efflorescence | | | Howie 1984 |
| 8.11.9 | nickelbischofite | $NiCl_2 \cdot 6H_2O$ | 20C, > ~54% RH | deliquescence | | | Waller 1992 |
| | | | 20C, < 43% RH | dehydration | efflorescence | to lower hydration states | Waller 1992 |
| 8.11.10 | lawrencite | $(Fe^{2+},Ni)Cl_2$ | moisture | oxidation | | to ferric chloride | Bannister 1937 |
| | | | 25C, > 56% RH | deliquescence | | | Waller 1992 |
| **9** | **Borates** | | | | | | |
| 9.1.6 | kernite | $Na_2[B_4O_6(OH)_2] \cdot 3H_2O$ | RT, moist air | hydration | | to borax | Muessig & Allen 1957 |
| | | | | dehydration | efflorescence | to lower hydration states | King 1985; Howie 1984 |
| 9.1.8 | tincalconite | $Na_2(B_4O_7) \cdot 5H_2O$ | 20C, > 50% RH | hydration | | to borax | Waller 1992 |
| 9.1.9 | borax | $Na_2(B_4O_5)(OH)_4 \cdot 8H_2O$ | 20C, > 99% RH | deliquescence | | | Waller 1992 |
| | | | 20C, < 50% RH | dehydration | opaque white efflorescence | to tincalconite | Waller 1992 |
| 9.1.14 | larderellite | $(NH_4)B_5O_7(OH)_2 \cdot H_2O$ | | dehydration | efflorescence | | Howie 1984 |
| 9.2.17 | iquiqueite | $K_3Na_4Mg(CrO_4)B_{24}O_{39}(OH) \cdot 12H_2O$ | > 40C | dehydration | | loss of absorbed & fluid-inclusion water | Ericksen et al. 1986 |
| 9.3.12 | inyoite | $Ca(H_4B_3O_7)(OH) \cdot 4H_2O$ | | dehydration | efflorescence | to meyerhofferite | O'Donoghue 1983; King 1985 |
| 9.3.14 | colemanite | $Ca[B_3O_4(OH)_3] \cdot H_2O$ | < ~0C | structural phase change | | | Perloff & Block 1960 |
| 9.3.20 | probertite | $NaCaB_5O_7(OH)_4 \cdot 3H_2O$ | | dehydration | efflorescence | to lower hydration states | Waller 1992; King 1985 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| **10** | **Borates with other anions** | | | | | | |
| 10.1.2 | bandylite | $Cu[B(OH)_4]Cl$ | | deliquescence | | | Waller 1992 |
| 10.1.5 | boracite | $Mg_3(B_7O_{13})Cl$ | | efflorescence | | | Howie 1984; King 1985 |
| **11** | **Carbonates** | | | | | | |
| 11.1.2 | natrite | $Na_2CO_3$ | 32C | melts | | | Schumann 1992 |
| | | | 25C, > 22% RH | hydration | | to thermonatrite | Waller 1992 |
| 11.1.5 | thermonatrite | $Na_2CO_3 \cdot H_2O$ | | deliquescence | | | King 1985 |
| | | | 25C, > 66% RH | hydration | | to higher hydration states | Waller 1992 |
| | | | 25C, < 22% RH | dehydration | efflorescence | to natrite | Waller 1992 |
| 11.1.6 | trona | $Na_3H(CO_3)_2 \cdot 2H_2O$ | | deliquescence | | | Howie 1984 |
| | | | | dehydration | efflorescence | to lower hydration states | Waller 1992; King 1985 |
| 11.1.7 | natron | $Na_2CO_3 \cdot 10H_2O$ | > 32C | dehydration | | to saturated solution of thermonatrite | Waller 1992 |
| | | | 25C, > 87% RH | deliquescence | | | Waller 1992 |
| | | | 25C, < 76% RH | dehydration | efflorescence | to lower hydration states, eventually to thermonatrite | Waller 1992 |
| 11.1.10 | nyerereite | $Na_2Ca(CO_3)_2$ | | deliquescence | | | Waller 1992 |
| 11.1.13 | pirssonite | $Na_2Ca(CO_3)_2 \cdot 2H_2O$ | | dehydration | efflorescence | to nyerereite | Waller 1992; King 1985 |
| 11.1.14 | gaylussite | $Na_2Ca(CO_3)_2 \cdot 5H_2O$ | > 63C | dehydration | efflorescence | to nyerereite | Waller 1992; Johnson & Robb 1973 |
| 11.1.16 | fairchildite | $K_2Ca(CO_3)_2$ | | deliquescence | | | Waller 1992 |
| | | | moist air | hydration | | | King 1985 |
| 11.1.17 | bütschliite | $K_2Ca(CO_3)_2$ | moist air | deliquescence | | eventual decomposition | Waller 1992; King 1985; Pabst 1974 |
| 11.1.18 | teschemacherite | $(NH_4)HCO_3$ | | volatization | | | Parsons 1922 |
| | | | | deliquescence | | | Howie 1984 |
| 11.2.1 | malachite | $Cu_2(CO_3)(OH)_2$ | pH 4-6 | hydrolysis | | to paratacamite & atacamite | Sharkey & Lewin 1971 |
| | | | sulfuric acid | alteration | blackens | to covelite | Smith & Clark 2002 |
| | | | chlorides | alteration | | to paratacamite or atacamite | Sharkey & Lewin 1971 |
| 11.2.2 | azurite | $Cu_3(CO_3)_2(OH)_2$ | light | colour change | darkens | | King 1985 |
| | | | sulfuric acid | alteration | blackens | to covelite | Smith & Clark 2002 |
| 11.3.3 | nesquehonite | $MgCO_3 \cdot 3H_2O$ | | deliquescence | | | King 1985 |
| | | | RT, ambient humidity | dissociation | | loss of water & carbon dioxide | Robie & Hemingway 1972 |
| 11.3.4 | lansfordite | $MgCO_3 \cdot 5H_2O$ | < ~10C | dehydration | | to saturated solution of nesquehonite | Waller 1992 |
| | | | low RH | dehydration | dull & opaque; efflorescence | to nesquehonite | King 1985 |
| 11.3.7 | hydromagnesite | $Mg_5(CO_3)_4(OH)_2 \cdot 4H_2O$ | | dehydration | efflorescence | to lower hydration states | Waller 1992; King 1985 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 11.4.1 | calcite | $CaCO_3$ | light | colour change | fades | | Nassau 1992 |
| | | | light | surficial reaction | contains Fe/Co/Mn: darkens | | Nassau 1992 |
| | | | > ~10%RH | surficial hydration | | formation of a hydrated layer of strongly chemisorbed hydroxyl groups ($Ca(OH)(CO_3H)$) | Stipp et al. 1996; Al-Hosney & Grassian 2004, 2005; Usher et al. 2007 |
| | | | > 70%RH | hydration & surface reconstruction | | to vaterite | Baltrusaitis & Grassian 2009 |
| | | | carboxylic acids | alteration | efflorescence | to calcium acetate &/or calcium formate (depending on acid present) | Al-Hosney & Grassian 2004; Al-Hosney et al. 2005; Usher et al. 2007; Prince et al. 2008 |
| | | | nitric acid | alteration | | droplets or liquid film of calcium nitrate | Krueger 2003; Al-Hosney & Grassian 2004, 2005; Prince et al. 2008 |
| | | | sulfuric acid | alteration | efflorescence | to hannebachite & eventualliy gypsum | Al-Hosney & Grassian 2004, 2005; Rettger 1924 |
| 11.4.4 | monohydrocalcite | $CaCO_3 \cdot H_2O$ | | dehydration | | to calcite | Waller 1992 |
| 11.4.5 | ikaite | $CaCO_3 \cdot 6H_2O$ | | dehydration | white efflorescence | to vaterite &/or calcite | Baltrusaitis & Grassian 2009 |
| 11.7.2 | hydroscarbroite | $Al_{14}(CO_3)_3(OH)_{36} \cdot nH_2O$ | | dehydration | | to lower hydration states | Waller 1992; Hazen & Ausubel 2016 |
| 11.7.13 | hydrodresserite | $BaAl_2(CO_3)_2(OH)_4 \cdot 3H_2O$ | | dehydration | | to dresserite | Waller 1992; Hazen & Ausubel 2016 |
| 11.8.3 | lanthanite-(Ce) | $(Ce,La,Nd)_2(CO_3)_3 \cdot 8H_2O$ | | dehydration | efflorescence | to lower hydration states | King 1985 |
| 11.9.1 | cerussite | $PbCO_3$ | | deliquescence | | | Howie 1984 |
| | | | sulfuric acid | partial alteration | white: dark grey | to galena | Smith & Clark 2002 |
| 11.9.2 | hydrocerussite | $Pb_3(CO_3)_2(OH)_2$ | sulfuric acid | surficial alteration | white: black | to galena | Smith & Clark 2002 |
| 11.11.3 | swartzite | $MgCa(UO_2)(CO_3)_3 \cdot 12H_2O$ | | dehydration | yellowish-white | to lower hydration states | Waller 1992; O'Donoghue 1983 |
| 11.11.5 | bayleyite | $Mg_2(UO_2)(CO_3)_3 \cdot 18H_2O$ | | dehydration | pales | to lower hydration states | Waller 1992; O'Donoghue 1983 |
| 11.11.7 | zellerite | $Ca(UO_2)(CO_3)_2 \cdot 5H_2O$ | | dehydration | | to metazellerite | Waller 1992 |
| 11.11.8 | wyartite | $CaU^{5+}(UO_2)_2(CO_3)O_4(OH) \cdot 7H_2O$ | | oxidation | | to schoepite or metaschoepite | Gauthier et al. 1989 |
| 11.12.1 | rhodochrosite | $MnCO_3$ | light | surficial reaction | darkens | | Nassau 1992 |
| 11.13.1 | siderite | $FeCO_3$ | moisture | oxidation | darkens: blackish-brown; occassional iridescent tarnish | to goethite & hematite | Schaller & Vlisidis 1959; Palache et al. 1951 |
| 11.14.4 | hellyerite | $NiCO_3 \cdot 5.5H_2O$ | | dehydration | | to lower hydration states | Waller 1992 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| **12** | **Carbonates with other anions: with halides or sulfate** | | | | | | |
| 12.1.2 | barentsite | $Na_7Al(HCO_3)_2(CO_3)_2F_4$ | | deliquescence | | | Waller 1992 |
| 12.2.1 | burkeite | $Na_6(CO_3)(SO_4)_2$ | RT, > ~75% RH | deliquescence | | | Waller 1992 |
| 12.2.2 | hanksite | $Na_{22}K(SO_4)_9(CO_3)_2Cl$ | | deliquescence | | | Howie 1984 |
| | | | moist air | hydration | | to higher hydration states | King 1985 |
| | | | | efflorescence | | | Howie 1984; Bannister 1937 |
| **13** | **Nitrates** | | | | | | |
| 13.1 | nitratine | $NaNO_3$ | 20C, >74% RH | deliquescence | | | Waller 1992 |
| 13.2 | niter | $KNO_3$ | 25C, >92% RH | deliquescence | | | Waller 1992 |
| 13.3 | gerhardtite | $Cu_2(NO_3)(OH)_3$ | | deliquescence | | | King 1985 |
| 13.4 | nitromagnesite | $Mg(NO_3)_2 \cdot 6H_2O$ | 25C, >52% RH | deliquescence | | | Waller 1992 |
| | | | 25C, <2% RH | dehydration | efflorescence | | Waller 1992 |
| 13.5 | nitrocalcite | $Ca(NO_3)_2 \cdot 4H_2O$ | > 42.7C | dehydration | | to saturate solution of Ca(NO3)2 · 3H2O | Waller 1992 |
| | | | 19C, > 54% RH | deliquescence | | | Waller 1992 |
| | | | 20C, < 6% RH | dehydration | efflorescence | to lower hydration states | Waller 1992 |
| 13.6 | nitrobarite | $Ba(NO_3)_2$ | 20C, > 99% RH | deliquescence | | | Waller 1992 |
| 13.9 | darapskite | $Na_3(SO_4)(NO_3) \cdot H_2O$ | | deliquescence | | | Waller 1992; King 1985 |
| 13.12 | hydrombobomkulite | $(Ni,Cu)Al_4((NO_3)_2,SO_4)(OH)_{12} \cdot 13\text{-}14H_2O$ | | dehydration | | to mbobomkulite | Waller 1992 |
| 13.NI | gwihabaite | $(NH_4,K)NO_3$ | | deliquescence | | | Hazen & Ausubel 2016 |
| **14** | **Silicates not containing aluminum** | | | | | | |
| 14.2.5 | chrysocolla | $Cu_{2-x}Al_x(H_{2-x}Si_2O_5)(OH)_4 \cdot nH_2O$, $x < 1$ | | dehydration | may show signs of shrinkage | | Howie 1984; King 1985 |
| 14.3.1 | phenakite | $Be_2SiO_4$ | light | colour change | red: pale pink; yellow, orange, brown: colourless | | King 1985; Nassau 1992 |
| 14.4.11 | sepiolite | $Mg_4(Si_6O_{15})(OH)_2 \cdot 6H_2O$ | moist air | hydration | | to higher hydration states | Howie 1984 |
| | | | | dehydration | | to lower hydration states | Howie 1984 |
| 14.10.1 | zircon | $Zr(SiO_4)$ | light | colour change | flesh-colour: blue or grey | | King 1985; Nassau 1992 |
| 14.12.4 | pabstite | $Ba(Sn,Ti)(Si_3O_9)$ | light | colour change | pink: fades | | Nassau 1992 |
| 14.13.8 | barysilite | $Pb_8Mn^{2+}[Si_2O_7]_3$ | moisture | oxidation | tarnish | | O'Donoghue 1983 |
| 14.17.1 | rhodonite | $Mn^{2+}SiO_3$ | light | surficial reaction | darkens | | Nassau 1992 |
| 14.17.8 | bementite | $Mn_7Si_6O_{15}(OH)_8$ | moisture | oxidation | tarnish: darkens | | O'Donoghue 1983 |
| 14.18.21 | inesite | $Ca_2(Mn,Fe)_7Si_{10}O_{28}(OH)_2 \cdot 5H_2O$ | moisture | oxidation | tarnish: darkens, brown | | O'Donoghue 1983 |
| 14.19.1 | fayalite | $Fe^{2+}{}_2SiO_4$ | light | surficial reaction | green: brown | | Nassau 1992 |
| | | | light | colour change | green: blue | | King 1985; Nassau 1992 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 14.19.8 | hisingerite | $Fe^{3+}_2(Si_2O_5)(OH)_4 \cdot 2H_2O$ | light | colour change | red: brown | | King 1985; Nassau 1992 |
| | | | | deliquescence | | | King 1985 |
| **15** | **Silicates of aluminum** | | | | | | |
| 15.11 | allophane | $(Al_2O_3)(SiO_2)_{1.3\text{-}2} \cdot 2.5\text{-}3H_2O$ | moist air | hydration | | to higher hydration states | Howie 1984 |
| | | | > ~25C, ambient humidity | dehydration | | to lower hydration states | Kitagawa 1974; Howie 1984 |
| **16** | **Silicates containing aluminum & other metals** | | | | | | |
| 16.1.2 | spodumene | $LiAlSi_2O_6$ | light | colour change (var. kunzite, hiddenite) | fades rapidly | | Nassau 1992 |
| 16.2.2 | analcime | $Na(AlSi_2O_6) \cdot H_2O$ | moist air | hydration | | to higher hydration states | Howie 1984 |
| | | | | dehydration | | to lower hydration states | Howie 1984 |
| 16.2.5 | natrolite | $Na_2Al_2Si_3O_{10} \cdot 2H_2O$ | moist air | hydration | | to higher hydration states | Howie 1984 |
| | | | | dehydration | | to lower hydration states | Howie 1984 |
| 16.2.7 | paranatrolite | $Na_2Al_2Si_3O_{10} \cdot 3H_2O$ | | dehydration | | to natrolite | Waller 1992 |
| 16.4.1 | nepheline | $Na_3K(Al_4Si_4O_{16})$ | light | colour change | colourless: pale pink | | King 1985 |
| | | | light | colour change | pink: fades | | Nassau 1992 |
| | | | moist air | hydration | | to nepheline hydrate I | Edgar 1965 |
| 16.6.1 | beryl | $Be_3Al_2Si_6O_{18}$ | light | colour change | maxixe: fades or pink; morganite: (paler) pink | | Nassau 1992 |
| 16.7.9 | montmorillonite | $(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2 \cdot nH_2O$ | moist air | hydration | | to higher hydration states | Howie 1984 |
| | | | | dehydration | | to lower hydration states | Howie 1984 |
| 16.9.23 | laumontite | $CaAl_2Si_4O_{12} \cdot 4H_2O$ | moist air | hydration | | to higher hydration states | Howie 1984 |
| | | | | dehydration | efflorescence; dull, crumbly, opaque | to leonhardite | Waller 1992; King 1985 |
| | | | light | surficial reaction | opaque, powdery surface | | O'Donoghue 1983; Nassau 1992 |
| 16.11.NI | chabazite | $(Ca,K_2,Na_2)_2[Al_2Si_4O_{12}]_2 \cdot 12H_2O$ | moist air | hydration | | to higher hydration states | Howie 1984 |
| | | | | dehydration | | to lower hydration states | Howie 1984 |
| 16.18.1 | nontonite | $Na_{0.3}Fe_2((Si,Al)_4O_{10})(OH)_2 \cdot nH_2O$ | | dehydration | | to lower hydration states | Howie 1984 |
| 16.19.22 | vermiculite | $Mg_{0.7}(Mg,Fe,Al)_6(Si,Al)_8O_{20}(OH)_4 \cdot 8H_2O$ | moist air | hydration | | to higher hydration states | Howie 1984 |
| | | | | dehydration | | to lower hydration states | Howie 1984 |
| **17** | **Silicates containing other anions** | | | | | | |
| 17.2.1 | topaz | $Al_2SiO_4(F,OH)_2$ | high light levels | colour change | brown/orange/sherry: (pale) blue or colourless; sherry: pink; blue: colourless | | King 1985; Nassau 1992 |
| 17.2.NI | trilithionite | $K(Li,Al)_3(AlSi_3O_{10})(F,OH)_2$ | light | colour change | purple: grey | | Nassau 1992 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 17.3.3 | sodalite | $Na_4(Si_3Al_3)O_{12}Cl$ | light | colour change | colourless/pale blue: pink; hackmanite (red): green, blue, or fades; hackmanite (pink): colourless | | King 1985; Nassau 1992 |
| 17.4.2 | spurrite | $Ca_5(SiO_4)_2(CO_3)$ | | efflorescence | | | Howie 1984; Bannister 1937 |
| 17.10.4 | haüyne | $(Na,K)_3(Ca,Na)(Al_3Si_3O_{12})(SO_4,S,Cl)$ | light | colour change | blue: fades | | Nassau 1992 |
| **18** | **Niobates & Tantalates** | | | | | | |
| 18.1.4 | franconite | $Na(Nb_2O_5)(OH) \cdot 3H_2O$ | | dehydration | | to lower hydration states | Waller 1992 |
| 18.1.11 | microlite | $(Ca,Na)_2Ta_2(O,OH,F)_7$ | moist air | hydration | | to higher hydration states | King 1985 |
| 18.2.1 | fergusonite-(Y) | $YNbO_4$ | moist air | hydration | | to higher hydration states | King 1985 |
| 18.2.7 | formanite-(Y) | $YTaO_4$ | moist air | hydration | | to higher hydration states | King 1985 |
| 18.2.8 | pyrochlore | $A_2Nb_2(O,OH)_6Z$ | moist air | hydration | | to higher hydration states | King 1985 |
| 18.3.3 | betafite | $(Ca,Na,U)_2(Ti,Nb,Ta)_2O_6Z(OH)$ | moist air | hydration | | to higher hydration states | King 1985 |
| 18.4.1 | uranpyrochlore | $(Ca,U,Ce)_2(Nb,Ti,Ta)_2O_6(OH,F)$ | moist air | hydration | | to higher hydration states | King 1985 |
| 18.4.5 | euxenite | $(Y,Ca,Ce,U,Th)(Nb,Ta,Ti)_2O_6$ | moisture | oxidation | brown coating | | O'Donoghue 1983 |
| | | | moist air | hydration | | to higher hydration states | King 1985 |
| 18.4.8 | polycrase-(Y) | $Y(Ti,Nb)_2(O,OH)_6$ | moisture | oxidation | brown coating | | O'Donoghue 1983 |
| | | | moist air | hydration | | to higher hydration states | King 1985 |
| 18.4.12 | samarskite-(Y) | $YFe^{3+}Nb_2O_8$ | moisture | oxidation | coating | | O'Donoghue 1983 |
| | | | moist air | hydration | | to higher hydration states | King 1985 |
| **19** | **Phosphates** | | | | | | |
| 19.1.2 | olympite | $Na_5Li(PO_4)_2$ | moist air | hydration | | to higher hydration states | Waller 1992 |
| 19.1.3 | nahpoite | $Na_2HPO_4$ | 25C, > 28% RH | hydration | | to dorfanite | Waller 1992 |
| 19.1.4 | dorfmanite | $Na_2HPO_4 \cdot 2H_2O$ | 25C, > 61% RH | hydration | | to higher hydration states | Waller 1992 |
| | | | 25C, < 28% RH | dehydrate | | to nahpoite | Waller 1992 |
| 19.1.NI | schertelite | $(NH_4)_2MgH_2(PO_4)_2 \cdot 4H_2O$ | | deliquescence | | | Waller 1992 |
| 19.2.8 | turquoise | $CuAl_6(PO_4)_4(OH)_8 \cdot 4H_2O$ | light, inc. sunlight | colour change | fades | | Nassau 1992; King 1985 |
| | | | | dehydration | may show signs of shrinkage & colour loss | loss of capillary water | King 1985 |
| 19.3.18 | phosphorrösslerite | $Mg(HPO_4) \cdot 7H_2O$ | | dehydration | efflorescence | to newberyite | Waller 1992; King 1985 |
| 19.3.23 | struvite | $(NH_4)Mg(PO_4) \cdot 6H_2O$ | | dehydration | efflorescence; pale, dull | to dittmarite | Waller 1992; King 1985 |
| 19.4.1 | monetite | $Ca(HPO_4)$ | moist air | hydration | | to brushite | Waller 1992 |
| 19.4.3 | brushite | $Ca(HPO_4) \cdot 2H_2O$ | 20C, > 95% RH | deliquescence | | | Waller 1992 |
| | | | | dehydration | efflorescence | to monetite | Waller 1992; King 1985 |
| 19.5.6 | nabaphite | $NaBaPO_4 \cdot 9H_2O$ | | dehydration | | to lower hydration states | Waller 1992 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 19.5.8 | nastrophite | $Na(Sr,Ba)PO_4 \cdot 9H_2O$ | | dehydration | | to lower hydration states | Waller 1992 |
| 19.7.5 | variscite | $AlPO_4 \cdot 2H_2O$ | | dehydration | | to lower hydration states | Howie 1984 |
| 19.8.2 | brazilianite | $NaAl_3(PO_4)_2(OH)_4$ | light | colour change | green: fades | | Nassau 1992 |
| 19.10.10 | sincosite | $Ca(VO)_2(PO_4)_2 \cdot 5H_2O$ | | dehydration | | to lower hydration states | Waller 1992 |
| 19.11.10 | torbernite | $Cu(UO_2)_2(PO_4)_2 \cdot 12H_2O$ | | dehydration | | to metatorbernite | Waller 1992 |
| 19.11.14 | meta-autunite | $Ca(UO_2)_2(PO_4)_2 \cdot 6\text{-}8H_2O$ | 20C, >38% RH | hydration | | to autunite | Waller 1992 |
| | | | | dehydration | may show signs of shrinkage | to lower hydrates | Howie 1984; King 1985 |
| 19.11.15 | autunite | $Ca(UO_2)_2(PO_4)_2 \cdot 11H_2O$ | 25C, <40% RH | dehydration | | to meta-autunite | Waller 1992 |
| 19.11.22 | uranocircite | $Ba(UO_2)_2(PO_4)_2 \cdot 10H_2O$ | | dehydration | | to metauranocircite-I | Waller 1992 |
| 19.11.32 | uranospathite | $(Al,\square)(UO_2)_2(PO_4)_2F \cdot 20(H_2O,F)$ | | dehydration | | to sabugalite | Waller 1992 |
| 19.11.40 | lehnerite | $Mn^{2+}(UO_2)_2(PO_4)_2 \cdot 8H_2O$ | > 25C | dehydration | | | Vochten 1990 |
| 19.11.41 | bassetite | $Fe^{2+}(UO_2)_2(PO_4)_2 \cdot 10H_2O$ | > 25C, ambient humidity | dehydration | | to dihydrate | Vochten et al. 1984 |
| | | | oxygen | surficial oxidation | | iron oxidation | Vochten et al. 1984 |
| 19.12.10 | heterosite | $(Fe^{3+}, Mn^{3+})PO_4$ | moisture | oxidation | tarnish: darkens | | O'Donoghue 1983 |
| 19.12.11 | purpurite | $Mn^{3+}PO_4$ | light | surficial reaction | darkens | | Nassau 1992 |
| | | | moisture | oxidation | tarnish: darkens | | O'Donoghue 1983 |
| 19.12.16 | rockbridgeite | $Fe^{2+}Fe^{3+}{}_4(PO_4)_3(OH)_5$ | moisture | oxidation | colour change: brown | | O'Donoghue 1983 |
| 19.12.22 | hureaulite | $(Mn,Fe)_5(PO_4)_2(HPO_4)_2 \cdot 4H_2O$ | light | surficial photo-oxidation | | | Nassau 1992 |
| 19.12.35 | ludlamite | $Fe^{2+}{}_3(PO_4)_2 \cdot 4H_2O$ | oxygen | surficial oxidation | pale green: dark green or deep blue | extensive oxidation will eventually lead to structural collapse | Moore 1971 |
| 19.12.36 | graftonite | $Fe^{2+}Fe^{2+}{}_2(PO_4)_2$ | light | surficial photo-oxidation | darkens | | Nassau 1992 |
| 19.12.40 | messelite | $Ca_2Fe^{2+}(PO_4)_2 \cdot 2H_2O$ | light | surficial photo-oxidation | | | Nassau 1992 |
| 19.13.2 | strengite | $FePO_4 \cdot 2H_2O$ | light | surficial reaction | | | Nassau 1992 |
| 19.13.11 | vivianite | $Fe^{2+}{}_3(PO_4)_2 \cdot 8H_2O$ | oxygen | surficial oxidation & partial dehydration | colourless: pale green/blue to deep blue | extensive oxidation (& subsequent dehydration) will eventually lead to structural collapse & disintegration | Moore 1971; McCammon & Burns 1980; Marincea et al. 1997 |
| 19.13.19 | phosphoferrite | $Fe^{2+}{}_3(PO_4)_2 \cdot 3H_2O$ | oxygen | surficial oxidation | colourless/pale green: reddish-brown | to kryzhanovskite | Moore 1971 |
| 19.14.14 | anapaite | $Ca_2Fe^{2+}(PO_4)_2 \cdot 4H_2O$ | light | surficial photo-oxidation | | to mitridatite | Nassau 1992; King 1985 |
| 19.14.28 | koninckite | $Fe^{3+}PO_4 \cdot 3H_2O$ | light | surficial photo-oxidation | | | Nassau 1992 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 19.14.29 | lazulite | $MgAl_2(PO_4)_2(OH)_2$ | acids | | | | O'Donoghue 1983 |
| **20** | **Arsenates** | | | | | | |
| 20.2.3 | rösslerite | $Mg(HAsO_4) \cdot 7H_2O$ | | dehydration | efflorescence | to lower hydration states | King 1985 |
| 20.2.12 | ferrarisite | $Ca_5(AsO_4)_2(HAsO_4)_2 \cdot 9H_2O$ | | dehydration | | to lower hydration states | Waller 1992 |
| 20.2.14 | phaunouxite | $Ca_3(AsO_4)_2 \cdot 11H_2O$ | | dehydration | | to rauenthalite | Waller 1992 |
| 20.7.1 | trögerite | $(H_3O)(UO_2)(AsO_4) \cdot 3H_2O$ | 18-28C | structural phase change | | to low symmetry, pseudo-tetragonal form | de Benyacar & da Abeledo 1974 |
| 20.7.6 | metaováčekite | $Mg(UO_2)_2(AsO_4)_2 \cdot 8H_2O$ | moist air | hydration | | to nováčekite-II (10 $H_2O$) | Waller 1992 |
| 20.7.7 | nováčekite-I | $Mg(UO_2)_2(AsO_4)_2 \cdot 12H_2O$ | | dehydration | | to metanováčekite | Waller 1992 |
| 20.7.9 | metauranospinite | $Ca(UO_2)_2(AsO_4)_2 \cdot 8H_2O$ | high humidity | hydration | | to uranospinite | Mrose 1953; Frondel 1958 |
| 20.7.10 | uranospinite | $Ca(UO_2)(AsO_4)_2 \cdot 10H_2O$ | RT, ambient humidity | dehydration | | to metauranospinite | Mrose 1953; Frondel 1958 |
| 20.7.12 | heinrichite | $Ba(UO_2)_2(AsO_4)_2 \cdot 10H_2O$ | | dehydration | | to metaheinrichite | Waller 1992 |
| 20.7.14 | arsenuranospathite | $Al(UO_2)_2(AsO_4)_2F \cdot 20H_2O$ | | dehydration | | to lower hydration states | Waller 1992 |
| 20.9.6 | symplesite | $Fe^{2+}{}_3(AsO_4)_2 \cdot 8H_2O$ | light | surficial photo-oxidation | light green: indigo | loss of form | Nassau 1992; King 1985 |
| | | | | dehydration | efflorescence | | Howie 1984 |
| 20.10.1 | erythrite | $Co_3(AsO_4)_2 \cdot 8H_2O$ | high light levels | surficial photo-oxidation | | | Nassau 1992 |
| | | | | dehydration | efflorescence | | Howie 1984 |
| 20.10.9 | annabergite | $Ni_3(AsO_4)_2 \cdot 8H_2O$ | | dehydration | efflorescence | | Howie 1984 |
| **21** | **Vanadates** | | | | | | |
| 21.2.2 | rossite | $Ca(VO_3)_2 \cdot 4H_2O$ | | dehydration | efflorescence | to metarossite | Waller 1992; King 1985 |
| 21.2.3 | metahewettite | $CaV_6O_{16} \cdot 3H_2O$ | RT, ambient humidity | hydration | | to hewettite | Hillebrand et al. 1914 |
| 21.2.4 | hewettite | $CaV_6O_{16} \cdot 9H_2O$ | > 25C, dry air | dehydration | colour change: darkens | to metahewettite | Hillebrand et al. 1914 |
| 21.2.5 | pintadoite | $Ca_2(V_2O_7) \cdot 9H_2O$ | | dehydration | efflorescence | to lower hydration states | King 1985 |
| 21.2.8 | pascoite | $Ca_3(V_{10}O_{28}) \cdot 17H_2O$ | RT, ~0% RH | dehydration | | | Hillebrand et al. 1914 |
| 21.2.9 | sherwoodite | $Ca_{4.5}(AlV^{4+}{}_2V^{5+}{}_{12}O_{40}) \cdot 28H_2O$ | | alteration | colour change: yellow-green | | O'Donoghue 1983 |
| 21.2.10 | melanovanadite | $Ca(V^{5+},V^{4+})_4O_{10} \cdot 5H_2O$ | moist air | hydration | | to pascoite | King 1985 |
| 21.2.13 | metadelrioite | $CaSr(V_2O_6)(OH)_2$ | moist air | hydration | | to delriote | Waller 1992 |
| 21.2.14 | delrioite | $CaSr(V_2O_6)(OH)_2 \cdot 3H_2O$ | | dehydration | | to metadelrioite | Waller 1992 |
| 21.3.3 | metaschoderite | $Al_2(PO_4)(VO_4) \cdot 6H_2O$ | moist air | hydration | | to schoderite | Waller 1992 |
| 21.3.4 | schoderite | $Al_2(PO_4)(VO_4) \cdot 8H_2O$ | | dehydration | | to metaschoderite | Waller 1992 |
| 21.4.4 | carnotite | $K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$ | | dehydration | | to lower hydration states | Waller 1992 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 21.4.7 | metatyuyamunite | $Ca(UO_2)_2(VO_4)_2 \cdot 3\text{-}5H_2O$ | light | colour change | yellow: green | | Nassau 1992 |
| | | | 24C, > 55% RH | hydration | | to tyuyamunite | Waller 1992 |
| 21.4.8 | tyuyamunite | $Ca(UO_2)_2(VO_4)_2 \cdot 5\text{-}8H_2O$ | high light levels | colour change | bright yellow: dirty green-yellow | | King 1985 |
| | | | 24C, <55% RH | dehydration | efflorescence | to metatyuyamunite | Waller 1992 |
| 21.4.9 | rauvite | $Ca(UO_2)_2(V_{10}O_{28}) \cdot 16H_2O$ | | dehydration | | to lower hydration states | Waller 1992 |
| 21.4.11 | metavanuralite | $Al(UO_2)_2(VO_4)_2(OH) \cdot 8H_2O$ | 20C, > 47% RH | hydration | | to vanuralite | Waller 1992 |
| | | | | dehydration | efflorescence | to lower hydration states | King 1985; Howie 1984 |
| 21.4.12 | vanuralite | $Al(UO_2)_2(V_2O_8)(OH) \cdot 8.5\text{-}11H_2O$ | moist air | hydration | | to higher hydration states | Howie 1984 |
| | | | 20C, < 47% RH | dehydration | | to metavanuralite | Waller 1992 |
| **22** | **Phosphates, Arsenates, & Vanadates with other anions** | | | | | | |
| 22.1.23 | triplite | $Mn^{2+}{}_2(PO_4)F$ | moist air | hydration | | to higher hydration states | King 1985 |
| 22.2.14 | vanadinite | $Pb_5(VO_4)_3Cl$ | prolonged light exposure | colour change | bright yellow: dull brown; red: brown | | Nassau 1992; King 1985 |
| 22.2.NI | apatite | $Ca_5(PO_4)_3(Cl/F/OH)$ | light | colour change | fades | | Nassau 1992; King 1985 |
| 22.3.21 | sasaite | $(Al,Fe^{3+})_{14}(PO_4)_{11}(SO_4)(OH)_7 \cdot 83H_2O$ | | dehydration | | to lower hydration states | Waller 1992 |
| **25** | **Sulfates** | | | | | | |
| 25.1.1 | metathénardite | $Na_2SO_4$ | > 32.4C | deliquescence | | to saturated solution of metathénardite | Waller 1992 |
| | | | 25C, > 81% RH | hydration | | to mirabailite | Waller 1992 |
| 25.1.2 | matteuccite | $NaHSO_4 \cdot H_2O$ | 20C, > 52% RH | deliquescence | | | Waller 1992 |
| | | | 20C, < 16% RH | dehydration | | to thénardite | Waller 1992 |
| 25.1.3 | mirabilite | $Na_2SO_4 \cdot 10H_2O$ | RT, > 93% RH | deliquescence | | | Waller 1992 |
| | | | 25C, < 81% RH | dehydration | efflorescence | to lower hydration states, eventually to thénardite | Waller 1992 |
| 25.1.5 | mercallite | $KHSO_4$ | 20C, > 86% RH | deliquescence | | | Waller 1992 |
| 25.1.8 | mascagnite | $(NH_4)_2SO_4$ | 20C, > 81% RH | deliquescence | | | Waller 1992 |
| 25.2.1 | chalcocyanite | $CuSO_4$ | 25C, > 3% RH | hydration | | to bonattite | Waller 1992 |
| 25.2.2 | bonattite | $CuSO_4 \cdot 3H_2O$ | 15C, > ~27% RH; 20C, > 30% RH; 25C, > 33% RH | hydration | | to chalcanthite | Chou et al. 2002 |
| | | | 25C, < 22% RH | dehydration | efflorescence | to chalcocyanite | Chou et al. 2002 |
| 25.2.3 | chalcanthite | $CuSO_4 \cdot 5H_2O$ | 25C, > 97% RH | deliquescence | | | Chou et al. 2002 |
| | | | 15C, < ~27% RH; 20C, < 30% RH; 25C, < 33% RH | dehydration | efflorescence | to bonattite | Chou et al. 2002 |
| 25.2.4 | boothite | $CuSO_4 \cdot 7H_2O$ | | dehydration | efflorescence | to chalcanthite | Waller 1992; Hazen & Ausubel 2016 |
| 25.2.11 | kröhnkite | $Na_2Cu(SO_4)_2 \cdot 2H_2O$ | high RH | colour change | translucent sky blue: green or opaque | | King 1985 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 25.2.13 | piypite | $K_4Cu_4O_2(SO_4)_4 \cdot (Na,Cu)Cl$ | | deliquescence | | | Waller 1992 |
| 25.2.15 | cyanochroite | $K_2Cu(SO_4)_2 \cdot 6H_2O$ | | deliquescence | | | Howie 1984 |
| | | | 25C, < 36% RH | dehydration | efflorescence | to lower hydration states | Waller 1992 |
| 25.2.27 | poitevinite | $(Cu,Fe)SO_4 \cdot H_2O$ | 25C, > 22% RH | hydration | | to higher hydration states | Waller 1992 |
| | | | 25C, < 22% RH | dehydration | efflorescence | to anhydrous phase | Waller 1992 |
| 25.3.1 | kieserite | $MgSO_4 \cdot H_2O$ | 15C, > ~41% RH; 20C, > ~43%RH; 25C, > ~45% RH | hydration | | to hexahydrite | Chou & Seal 2003, 2007; Wang et al. 2009 |
| | | | 25C, < 4% RH | dehydration | efflorescence | to anhydrous phase | Waller 1992 |
| 25.3.2 | sanderite | $MgSO_4 \cdot 2H_2O$ | 31C, > 22% RH | hydration | | to higher hydration states | Waller 1992 |
| | | | 31C, < 8% RH | dehydration | efflorescence | to lower hydration states | Waller 1992 |
| 25.3.3 | starkeyite | $MgSO_4 \cdot 4H_2O$ | 15C, > 35% RH; 20C, > ~37% RH; 25C, > ~39% RH | hydration | | to hexahydrite | Chou & Seal 2003, 2007 |
| | | | 20C, < 19% RH | dehydration | efflorescence | to lower hydration states | Wang et al. 2009 |
| 25.3.4 | pentahydrite | $MgSO_4 \cdot 5H_2O$ | 25C, > 41% RH | hydration | | to higher hydration states | Waller 1992 |
| | | | 25C, < 37% RH | dehydration | efflorescence | to lower hydration states | Waller 1992 |
| 25.3.5 | hexahydrite | $MgSO_4 \cdot 6H_2O$ | 15C, > ~43% RH ; 20C, > ~48% RH; 25C, > ~53% RH | hydration | | to epsomite | Chou & Seal 2003, 2007 |
| | | | 15C, < ~41% RH; 20C, < ~43%RH; 25C, < ~45% RH | dehydration | | to kieserite | Chou & Seal 2003, 2007; Wang et al. 2009 |
| | | | 15C, < 35% RH; 20C, < ~37% RH; 25C, < ~39% RH | dehydration | efflorescence | to starkeyite | Chou & Seal 2003, 2007 |
| 25.3.6 | epsomite | $MgSO_4 \cdot 7H_2O$ | 15C, > ~94% RH; 20C, > ~93% RH; 25C, > ~91% RH | deliquescence | | to saturated solution of hexahydrite | Chou & Seal 2003, 2007 |
| | | | 15C, < ~43% RH ; 20C, < ~48% RH; 25C, < ~53% RH | dehydration | efflorescence | to hexahydrite | Chou & Seal 2003, 2007 |
| 25.3.10 | konyaite | $Na_2Mg(SO_4)_2 \cdot 5H_2O$ | | dehydration | | to blödite | Waller 1992 |
| 25.3.11 | löweite | $Na_{12}Mg_7(SO_4)_{13} \cdot 15H_2O$ | | deliquescence | | | Waller 1992 |
| | | | high RH | efflorescence | dull, white | | King 1982 |
| 25.3.13 | langbeinite | $K_2Mg_2(SO_4)_3$ | | deliquescence | | | Waller 1992; King 1985 |
| 25.3.14 | leonite | $K_2Mg(SO_4)_2 \cdot 4H_2O$ | moist air | hydration | | to picromerite | Waller 1992; King 1985 |
| 25.3.15 | picromerite | $K_2Mg(SO_4)_2 \cdot 6H_2O$ | | deliquescence | | | Howie 1984 |
| | | | | dehydration | efflorescence | to lower hydration states | King 1985; Howie 1984 |
| 25.3.17 | boussingaultite | $(NH_4)_2Mg(SO_4)_2 \cdot 6H_2O$ | 25C, > 96% RH | deliquescence | | | Waller 1992 |
| | | | 25C, < 20% RH | dehydration | efflorescence | to lower hydration states | Waller 1992 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 25.3.NI.1 | alpersite | $(Mg,Cu)(SO_4) \cdot 7H_2O$ | 21C, < 46% RH | dehydration | efflorescence | to copper-bearing pentahydrate | Peterson et al. 2006 |
| 25.3.NI.2 | meridianite | $MgSO_4 \cdot 11H_2O$ | > 2C | melts | | epsomite & water | Hazen & Ausubel 2016 |
| 25.4.1 | anhydrite | $CaSO_4$ | light | colour change | blue: white | | Nassau 1992; King 1985 |
| | | | 15C, > ~66% RH; 20C, > 70% RH; 25C, > 75% RH | hydration | | to gypsum | Chou & Seal 2007 |
| 25.4.3 | gypsum | $CaSO_4 \cdot 2H_2O$ | light | colour change | pink: fades | | Nassau 1992 |
| | | | 15C, < ~66% RH; 20C, < 70% RH; 25C, < 75% RH | dehydration | | to anhydrite | Chou & Seal 2007 |
| 25.4.13 | ettringite | $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26H_2O$ | | dehydration | efflorescence | to lower hydration states | Waller 1992; Howie 1984 |
| 25.4.15 | celestine | $SrSO_4$ | high light levels | colour change | blue: white | | Nassau 1992; King 1985 |
| 25.4.17 | baryte | $BaSO_4$ | high light levels | colour change | colourless, pale blue: chalky white or darker blue; blue: colourless; yellow/brown: green or blue | | Nassau 1992; King 1985 |
| 25.5.2 | goslarite | $ZnSO_4 \cdot 7H_2O$ | > 37.9C | deliquescence | | to saturated solution of zinkosite | Waller 1992 |
| | | | 15C, > 90% RH; 20C, > ~92% RH; 25C, > ~89% RH | deliquescence | | to aqueous solution | Chou & Seal 2005b |
| | | | 15C, < ~54% RH; 20C, < ~59% RH; 25C, < ~64% RH | dehydration | efflorescence | to bianchite | Chou & Seal 2005b |
| 25.5.6 | boyleite | $(Zn,Mg)SO_4 \cdot 4H_2O$ | | dehydration | | to lower hydration states | Waller 1992 |
| 25.5.11 | gunningite | $ZnSO_4 \cdot H_2O$ | 15C, > ~52% RH; 20C, > ~55% RH; 25C, > ~58% RH | hydration | | to bianchite | Chou & Seal 2005b |
| | | | 25C, < 4% RH | dehydration | efflorescence | to zinkosite | Waller 1992 |
| 25.5.13 | bianchite | $(Zn,Fe)SO_4 \cdot 6H_2O$ | > 48.8C | deliquescence | | to saturated solution of *chaidamuite* | Waller 1992 |
| | | | 15C, > ~54% RH; 20C, > ~59% RH; 25C, > ~64% RH | hydration | | to goslarite | Chou & Seal 2005b |
| | | | 15C, < ~52% RH; 20C, < ~55% RH; 25C, < ~58% RH | dehydration | efflorescence | to gunningite | Chou & Seal 2005b |
| 25.5.15 | zincmelanterite | $(Zn,Cu,Fe)SO_4 \cdot 7H_2O$ | 25C, > 89% RH | deliquescence | | | Waller 1992 |
| | | | 25C, < 65% RH | dehydration | efflorescence | to bianchite | Waller 1992 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| 25.6.3 | mendozite | $NaAl(SO_4)_2 \cdot 11H_2O$ | | dehydration | efflorescence | to tamarugite | Waller 1992; King 1985 |
| 25.6.5 | aluminite | $Al_2(SO_4)(OH)_4 \cdot 7H_2O$ | | dehydration | | to meta-aluminite | Waller 1992 |
| 25.6.7 | alunogen | $Al_2(SO_4)_3 \cdot 17H_2O$ | 20C, > 88% RH | deliquescence | | | Waller 1992 |
| | | | | dehydration | | to meta-alunogen | Waller 1992 |
| 25.6.8 | alunite | $KAl_3(SO_4)_2(OH)_6$ | | dehydration | may show signs of shrinkage | to lower hydration states | King 1985 |
| 25.6.10 | hydrobasaluminite | $Al_4(SO_4)(OH)_{10} \cdot 12\text{-}36H_2O$ | RT | dehydration | | to felsöbányaite | Waller 1992; Bigham & Nordstrom 2000 |
| 25.6.11 | zaherite | $Al_{12}(SO_4)_5(OH)_{26} \cdot 20H_2O$ | | dehydration | | to lower hydration states | Waller 1992; Hazen & Ausubel 2016 |
| 25.6.12 | tamarugite | $NaAl(SO_4)_2 \cdot 6H_2O$ | 20C, > 86% RH | hydration | | to alum-(Na) | Waller 1992 |
| 25.6.14 | alum-(Na) | $NaAl(SO_4)_2 \cdot 12H_2O$ | 20C, < 86% RH | dehydration | | to tamarugite | Waller 1992 |
| 25.6.17 | alum-(K) | $KAl(SO_4)_2 \cdot 12H_2O$ | 20C, < 9% RH | dehydration | | to kalinite | Waller 1992 |
| 25.6.20 | tschermigite | $(NH_4)Al(SO_4)_2 \cdot 12H_2O$ | 25C, < 7% RH | dehydration | efflorescence | to godovikovite | Waller 1992 |
| 25.7.3 | anglesite | $PbSO_4$ | light | colour change | yellow, brown: fades | | Nassau 1992; King 1985 |
| | | | water & carbon dioxide; carbonic acid | carbonation | | to cerussite & sulfuric acid | Swartzlow 1933 |
| 25.8.5 | minasragrite | $(V^{4+}O)(SO_4) \cdot 5H_2O$ | | deliquescence | | | King 1985 |
| | | | | dehydration | efflorescence | | King 1985 |
| 25.8.9 | uranopilite | $(UO_2)_6(SO_4)O_2(OH)_6 \cdot 12\text{-}14H_2O$ | | dehydration | | to meta-uranopilite | Waller 1992 |
| 25.9.1 | szmikite | $MnSO_4 \cdot H_2O$ | 25C, > 83% RH | hydration | | to higher hydration states | Waller 1992 |
| | | | 20C, < 17% RH | dehydration | efflorescence | to anhydrous state | Waller 1992 |
| 25.9.2 | jôkokuite | $MnSO_4 \cdot 5H_2O$ | 15C, > 84% RH | hydration | | to higher hydration states | Waller 1992 |
| | | | 20C, < 74% RH | dehydration | efflorescence | to lower hydration states | Waller 1992 |
| 25.9.3 | mallardite | $MnSO_4 \cdot 7H_2O$ | < 9C | dehydration | | to saturated solution of jôkokuite | Waller 1992 |
| 25.9.5 | chvaleticeite | $(Mn,Mg)SO_4 \cdot 6H_2O$ | | dehydration | | to lower hydration states | Hazen & Ausubel 2016 |
| 25.9.9 | ilesite | $(Mn,Zn,Fe)SO_4 \cdot 4H_2O$ | ambient conditions; <70% RH | dehydration | | to szmikite | Helda & Bohatý 2002; Anderson et al. 2012 |
| 25.10.1 | szomolnokite | $FeSO_4 \cdot H_2O$ | 20C, > 57% RH | hydration | | to rozenite | Waller 1992 |
| | | | 20C, < 11% RH | dehydration | efflorescence | to anhydrous state | Waller 1992 |
| 25.10.2 | rozenite | $FeSO_4 \cdot 4H_2O$ | RT, < 62% RH | oxidation | | to copiapite | Jerz & Rimstidt 2003 |
| | | | 15C, > ~54% RH; 20C, > ~57% RH; 25C, > ~62% RH | hydration | | to melanterite | Jambor et al. 2000; Chou et al. 2002 |
| | | | | dehydration | | to szomolnokite | Chou et al. 2002 |
| 25.10.3 | siderotil | $FeSO_4 \cdot 5H_2O$ | 22C, >35% RH | hydration | | to melanterite | Eckel 1933; Ehlers & Stiles 1965 |
| | | | 22C, <5% RH | dehydration | | to szomolnokite | Eckel 1933 |

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|---|---|---|---|---|---|---|---|
| 25.10.4 | ferrohexahydrate | $FeSO_4 \cdot 6H_2O$ | | dehydration | | to lower hydration states | Jambor et al. 2000; Hyde et al. 2011 (Fig. 1) |
| | | | 25C, > 61% RH | hydration | | to higher hydration states | Waller 1992 |
| 25.10.5 | melanterite | $FeSO_4 \cdot 7H_2O$ | RT, 63-89% RH | oxidation | | to fibroferrite (via copiapite at 63-80% RH) | Jerz & Rimstidt 2003 |
| | | | 15-25C, > 95% RH | deliquescence | | | Chou et al. 2002; Jerz & Rimstidt 2003 |
| | | | 15C, < ~54% RH; 20C, < ~57% RH; 25C, < ~62% RH | dehydration | efflorescence | to rozenite, when Cu < 1.2% | Chou et al. 2002 |
| | | | 20C, < 65% RH | dehydration | efflorescence | to siderotil, when Cu > 1.2% | Jambor et al. 2000 |
| 25.10.6 | rhomboclase | $(H_5O_2)Fe^{3+}(SO_4)_2 \cdot 2H_2O$ | 25C, > 58-60% RH | deliquescence | | to solution $Fe_2(SO)_3$ | Xu et al. 2009 |
| | | | 22-25C, 33-53% RH | alteration | | to kornelite & paracoquimbite | Xu et al. 2009 |
| | | | | dehydration | efflorescence | to lower hydration states | Waller 1992; King 1985 |
| 25.10.8 | kornelite | $Fe^{3+}_2(SO_4)_3 \cdot 7H_2O$ | 22-25C, > 43% RH | hydration | | to paracoquimbite | Xu et al. 2009 |
| 25.10.9 | coquimbite | $AlFe^{3+}_3(SO_4)_6(H_2O)_{12} \cdot 6H_2O$ | 20C, >73% RH | deliquescence | | | Waller 1992 |
| | | | moist air | hydration | | to higher hydration states | Howie 1984 |
| | | | | dehydration | efflorescence | to lower hydration states | Waller 1992; King 1985 |
| 25.10.10 | paracoquimbite | $Fe^{3+}_4(SO_4)_6(H_2O)_{12} \cdot 6H_2O$ | 22-25C, < 43% RH | dehydration | | to kornelite | Xu et al. 2009 |
| 25.10.11 | quenstedtite | $Fe^{3+}_2(SO_4)_3 \cdot 11H_2O$ | | dehydration | efflorescence | to paracoquimbite | Waller 1992; King 1985 |
| 25.10.12 | ferricopiapite | $Fe^{3+}_{0.67}Fe^{3+}_4(SO_4)_6(OH)_2 \cdot 20H_2O$ | 22-25C, > 68% RH | deliquescence | | to solution $Fe_2(SO)_3$ | Xu et al. 2009 |
| | | | 22-25C, 33-53% RH | alteration | | to kornelite & paracoquimbite | Xu et al. 2009 |
| 25.10.14 | hohmannite | $Fe^{3+}_2(SO_4)_2O \cdot 8H_2O$ | | dehydration | | to metahohmannite | Hazen & Ausubel 2016 |
| 25.10.18 | fibroferrite | $Fe^{3+}(SO_4)(OH) \cdot 5H_2O$ | RT, > 88% RH | deliquescence | | | Jerz & Rimstidt 2003 |
| 25.10.22 | copiapite | $Fe^{2+}Fe^{3+}_4(SO_4)_6(OH)_2 \cdot 20H_2O$ | RT, ~63-78% RH | oxidation | | to fibroferrite | Jerz & Rimstidt 2003 |
| | | | RT, > 80% RH | deliquescence | | | Jerz & Rimstidt 2003 |
| 25.11.2 | sideronatrite | $Na_2Fe(SO_4)_2(OH) \cdot 3H_2O$ | light | photo-sensitive | | gradual decomposition | Hazen & Ausubel 2016 |
| | | | >~35C | dehydration | | to metasideronatrite | Ventruti et al. 2010; Ventruti et al. 2013 |
| 25.11.3 | metasideronatrite | $Na_2Fe(SO_4)_2(OH) \cdot H_2O$ | light | photo-sensitive | | gradual decomposition | Hazen & Ausubel 2016 |
| | | | <40C, >60%RH | hydration | | to sideronatrite | Ventruti et al. 2010 |
| 25.11.4 | ferrinatrite | $Na_3Fe(SO_4)_3 \cdot 3H_2O$ | | deliquescence | | | Waller 1992 |
| | | | moist air | hydration | | | King 1985 |
| 25.11.10 | voltaite | $K_2Fe^{2+}_5Fe^{3+}_3Al(SO_4)_{12} \cdot 18H_2O$ | moist air | hydration | | | King 1985 |
| | | | | dehydration | efflorescence | to lower hydration states | Waller 1992; King 1985 |
| 25.11.17 | lonecreekite | $(NH_4)Fe^{3+}(SO_4)_2 \cdot 12H_2O$ | | dehydration | | to sabieite | Hazen & Ausubel 2016 |
| 25.11.26 | halotrichite | $Fe^{2+}\ Al_2(SO_4)_4 \cdot 22H_2O$ | RT, > 90% RH | deliquescence | | | Jerz & Rimstidt 2003 |
| | | | | dehydration | efflorescence | to lower hydration states | Waller 1992; King 1985 |
| 25.11.NI | mikasaite | $Fe^{3+}_2(SO_4)_3$ | | deliquescence | | | Hazen & Ausubel 2016 |

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|---|---|---|---|---|---|---|---|
| 25.12.1 | bieberite | $CoSO_4 \cdot 7H_2O$ | 15-25C, > ~95% RH | deliquescence | | to aqueous solution | Chou & Seal 2005a |
| | | | 15C, < 60% RH; 20C, < ~65% RH; 25C, < 70% RH | dehydration | efflorescence | to moorhouseite | Chou & Seal 2005a |
| 25.12.3 | aplowite | $(Co,Mn,Ni)SO_4 \cdot 4H_2O$ | | dehydration | | to lower hydration states | Hazen & Ausubel 2016 |
| 25.12.4 | moorhouseite | $(Co,Ni,Mn)SO_4 \cdot 6H_2O$ | 15C, > 60% RH; 20C, > ~65% RH; 25C, > 70% RH | hydration | | to bieberite | Chou & Seal 2005a |
| 25.12.5 | retgersite | $NiSO_4 \cdot 6H_2O$ | 15C, > ~79% RH; 20C, > ~82%RH; 25C, > 87% RH | hydration | | to morenosite | Wang et al. 2017 |
| 25.12.6 | morenosite | $NiSO_4 \cdot 7H_2O$ | 15-25C, > ~95% RH | deliquescence | | | Wang et al. 2017 |
| | | | 15C, < ~79% RH; 20C, < ~82%RH; 25C, < 87% RH | dehydration | efflorescence | to retgersite | Wang et al. 2017 |
| 25.12.13 | nicklehexahydrite | $(Ni,Mg,Fe)SO_4 \cdot 6H_2O$ | moist air | hydration | | to higher hydration states | Howie 1984 |
| | | | | dehydration | efflorescence | | Howie 1984 |
| **26** | **Sulfates with halide** | | | | | | |
| 26.14 | kainite | $KMg(SO_4)Cl \cdot 3H_2O$ | | deliquescence | | | Waller 1992; King 1985 |
| | | | 32C, < 3% RH | dehydration | | to anhydrokainite | Waller 1992 |
| 26.15 | mosesite | $(Hg_2N)(Cl, SO_4, MO_4) \cdot H_2O$ | light | colour change | yellow: green | | Nassau 1992 |
| 26.16 | kleinite | $(Hg_2N)(Cl, SO_4) \cdot nH_2O$ | high light levels | colour change | yellow: orange | | Nassau 1992; King 1985 |
| | | | light | surficial photo-oxidation | darkens | | Nassau 1992 |
| **27** | **Sulfites, Chromates, Molybdates, & Tungstates** | | | | | | |
| 27.2.1 | tarapacáite | $K_2(CrO_4)$ | 20C, > 88% RH | deliquescence | | | Waller 1992 |
| 27.2.5 | crocoite | $PbCrO_4$ | light | surficial photo-oxidation | darkens | | Nassau 1992 |
| 27.2.6 | phoenicochroite | $Pb_2(CrO_4)O$ | light | surficial reaction | | | Nassau 1992 |
| 27.2.NI | edoylerite | $Hg^{2+}{}_3(CrO_4)S_2$ | light | photo-sensitive | colour change: olive-green | gradual decomposition | Hazen & Ausubel 2016 |
| 27.3.14 | ferrimolybdite | $Fe^{3+}{}_2(Mo^{6+}O_4)_3 \cdot 7H_2O$ | warm, dry air | dehydration | colour variation | prolonged dehydration leads to structural collapse | Golding et al. 1960 |
| **28** | **Selenites, Selenates, Tellurites, & Tellurates** | | | | | | |
| 28.1.8 | marthozite | $Cu^{2+}(UO_2)_3(SeO_3)_2O_2 \cdot 8H_2O$ | | dehydration | | to lower hydration states | Waller 1992; Hazen & Ausubel 2016 |
| **29** | **Iodates** | | | | | | |
| 29.5 | dietzeite | $Ca_2(IO_3)_2(CrO_4) \cdot H_2O$ | light | surficial photo-oxidation | | | Nassau 1992 |

| Hey Number | Mineral Name | Chemical Formula | Conditions | Response | Appearance | Alterations | References |
|---|---|---|---|---|---|---|---|
| **30** | **Thiocyanates** | | | | | | |
| 30.2 | kafehydrocyanite | $K_4[Fe(CN)_6] \cdot H_2O$ | 20C, < 42% RH | dehydration | | to lower hydration states | Waller 1992 |
| **32** | **Crystalline Organics** | | | | | | |
| 32.11 | acetamide | $CH_3CONH_2$ | air & sunlight | volatizes | | | Hazen & Ausubel 2016 |
| | | | | deliquescence | | | Waller 1992 |
| 32.13 | urea | $CO(NH_2)_2$ | 25C, > 77% RH | deliquescence | | | Waller 1992 |
| **O** | **'Precious' Non-minerals** | | | | | | |
| O.1 | amber | | | dehydration | may show signs of shrinkage | | King 1985; Howie 1984 |
| | | | acids, biocides, & cleaning agents (see reference for full list) | absorbtion then desorption | may show signs of swelling/ shrinkage; possible darkening, softening, or efflorescence, depending on compound | volumetric change | Waddington & Fenn 1988 |
| O.2 | pearl | $CaCO_3$ | | dehydration | | | O'Donoghue 1983 |
| O.3 | obsidian | | | hydration | black: white; may show signs of expansion | to perlite; extensive hydration can lead to the formation of clay &/or zeolite minerals | Jezek & Noble 1978 |
| O.4 | coral | $CaCO_3$ | light | colour change | red: fade | | Schumann 1974 |

| Hey Number | Mineral Name | Chemical Formula | Water | Acids | Alterations | References |
|---|---|---|---|---|---|---|
| **1** | **Elements & Alloys** | | | | | |
| 1.1 | copper | Cu | | easily soluble in nitric acid | | O'Donoghue 1983; Schumann 1992 |
| 1.2 | silver | Ag | | soluble in nitric acid, hot sulfuric acid, & aqua regia | | O'Donoghue 1983 |
| 1.48 | dyscrasite | $Ag_3Sb$ | | soluble in nitric acid | | O'Donoghue 1983; Schumann 1992 |
| 1.49 | bismuth | Bi | | soluble in nitric acid | | Schumann 1992 |
| 1.54 | tellurium | Te | | soluble in concentrated sulfuric acid | | Schumann 1992 |
| 1.57 | iron | Fe | | soluble in acids, especially nitric | | O'Donoghue 1983 |
| **3** | **Sulfides, Selenides, Tellurides, Arsenides and Bismuthides** | | | | | |
| 3.1.1 | chalcocite | $Cu_2S$ | | soluble in nitric acid | | Schumann 1992 |
| 3.1.8 | covellite | CuS | | soluble in nitric acid | | Schumann 1992 |
| 3.1.23 | bornite | $Cu_5FeS_4$ | | soluble in nitric acid | | Schumann 1992 |
| 3.1.25 | chalcopyrite | $CuFeS_2$ | | soluble in nitric acid | | Schumann 1992 |
| 3.2.1 | acanthite | $Ag_2S$ | | soluble in acid | | Schumann 1992 |
| 3.3.9 | sylvanite | $(Au,Ag)_2Te_4$ | | soluble in nitric acid & aqua regia | | O'Donoghue 1983; Schumann 1992 |
| 3.4.4 | sphalerite | ZnS | | decomposes in acids | to hydrated sulphates | Howie 1992 |
| 3.4.5 | wurtzite | (Zn,Fe)S | | redily souble in mineral acids | | King 1983 |
| 3.4.7 | greenockite | CdS | soluble | | | King 1992 |
| 3.6.5 | galena | PbS | | soluble in nitric acid | | Schumann 1992 |
| 3.7.8 | orpiment | $As_2S_3$ | slightly soluble in hot water | | | King 1992 |
| | | | | soluble in most acids, inc. nitric acid & aqua regia | | O'Donoghue 1983; Schumann 1992 |
| 3.7.14 | stibnite | $Sb_2S_3$ | | soluble in weak acids | | King 1983 |
| 3.8.6 | molybdenite | $MoS_2$ | | soluble in nitric acid & aqua regia | | Schumann 1992 |
| 3.9.3 | pyrite | $FeS_2$ | | soluble in nitric acid | | Schumann 1992 |
| 3.9.11 | löllingite | $FeAs_2$ | | soluble in nitric acid | | Schumann 1992 |
| 3.9.12 | arsenopyrite | FeAsS | | soluble in nitric acid | | Schumann 1992 |

| Hey Number | Mineral Name | Chemical Formula | Water | Acids | Alterations | References |
|---|---|---|---|---|---|---|
| 3.10.2 | linnaeite | $Co^{2+}Co^{3+}{}_2S_4$ | | soluble in nitric acid | | Schumann 1992 |
| 3.10.12 | skutterudite | $CoAs_3$ | | soluble in nitric acid | | Schumann 1992 |
| 3.11.3 | millerite | NiS | decomposes in hot water | | | King 1992 |
| | | | | soluble in nitric acid & aqua regia | | Schumann 1992 |
| 3.11.8 | violarite | $Fe^{2+}Ni^{3+}{}_2S_4$ | decomposes in hot water | | | King 1982 |
| 3.11.9 | pentlandite | $(Fe,Ni)_9S_8$ | | soluble in nitric acid | | Schumann 1992 |
| 3.11.26 | maucherite | $Ni_{11}As_8$ | | soluble in concentrated nitric acid | | Schumann 1992 |
| 3.11.27 | nickeline | NiAs | | soluble in nitric acid | with green colour | Schumann 1992 |
| 3.11.30 | nickelskutterudite | $(Ni,Co,Fe)As_3$ | | soluble in nitric acid | | Schumann 1992 |
| 3.11.34 | gersdorffite | NiAsS | | soluble in nitric acid | | O'Donoghue 1983; Schumann 1992 |
| 3.11.36 | breithauptite | NiSb | | soluble in nitric acid & aqua regia | | Schumann 1992 |
| **5** | **Sulfosalts: Sulfarsenites & Sulfobismuthites** | | | | | |
| 5.1.7 | emplectite | $CuBiS_2$ | | soluble in acid | | Schumann 1992 |
| 5.2.3 | proustite | $Ag_3AsS_3$ | | soluble in nitric acid | | Schumann 1992 |
| 5.2.9 | pyrargyrite | $Ag_3SbS_3$ | | soluble in nitric acid | | Schumann 1992 |
| 5.2.11 | stephanite | $Ag_5SbS_4$ | | soluble in nitric acid | | Schumann 1992 |
| 5.3.1 | nagyágite | $[Pb_3(Pb,Sb)_3S_6](Au,Te)_3$ | | soluble in nitric acid & aqua regia | | Schumann 1992 |
| 5.6.15 | boulangerite | $Pb_5Sb_4S_{11}$ | | soluble in warm nitric acid | | Schumann 1992 |
| 5.7.2 | bournonite | $PbCuSbS_3$ | | soluble in nitric acid | | Schumann 1992 |
| 5.7.3 | meneghinite | $Pb_{13}CuSb_7S_{24}$ | | soluble in nitric acid | | Schumann 1992 |
| **6** | **Sulfosalts** | | | | | |
| 6.1.6 | stannite | $Cu_2FeSnS_4$ | | soluble in nitric acid | | Schumann 1992 |
| 6.2.1 | germanite | $Cu_{13}Fe_2Ge_2S_{16}$ | | soluble in nitric acid | | Schumann 1992 |
| 6.3.1 | enargite | $Cu_3AsS_4$ | | soluble in nitric acid & aqua regia | | Schumann 1992 |

| Hey Number | Mineral Name | Chemical Formula | Water | Acids | Alterations | References |
|---|---|---|---|---|---|---|
| **7** | **Oxides & Hydroxides** | | | | | |
| 7.3.2 | tenorite | $CuO$ | | easily soluble in acids | | Schumann 1992 |
| 7.4.7 | periclase | $MgO$ | | soluble in acid (powder: easily; crystal: difficult) | | Schumann 1992 |
| 7.4.8 | brucite | $Mg(OH)_2$ | | easily soluble in acids | | Schumann 1992 |
| 7.5.1 | zincite | $ZnO$ | | soluble in acids | | Schumann 1992 |
| 7.8.1 | quartz | $SiO_2$ | 6ppm (@ 25C, 1 atm) | | | Fournier & Rowe 1962 |
| 7.8.5 | cristobalite | $SiO_2$ | 27ppm (@ 25C, 1 atm) | | solution of silica | Fournier & Rowe 1962 |
| 7.10.10 | thorianite | $ThO_2$ | | soluble in nitric acid | | Schumann 1992 |
| 7.13.1 | arsenolite | $As_2O_3$ | soluble in hot/warm water | | | King 1992; Schumann 1992 |
| 7.13.4 | valentinite | $Sb_2O_3$ | | easily soluble in acids | | Schumann 1992 |
| 7.16.1 | uraninite | $UO_2$ | | easily soluble in sulfuric acid & warm nitric acid | | Schumann 1992 |
| **8** | **Halides** | | | | | |
| 8.1.2 | villiaumite | $NaF$ | highly soluble | | | King 1992 |
| 8.1.3 | halite | $NaCl$ | highly soluble | | | O'Donoghue 1983; King 1992; Schumann 1992 |
| 8.1.6 | sylvite | $KCl$ | highly soluble | readily soluble in acids | | O'Donoghue 1983; King 1992; Schumann 1992 |
| 8.1.7 | salammoniac | $NH_4Cl$ | highly soluble | | | King 1992; Schumann 1992 |
| 8.2.4 | atacamite | $Cu_2(OH)_3Cl$ | | readily soluble in ammonia | | Schumann 1992 |
| 8.2.12 | mitscherlichite | $K_2CuCl_4 \cdot 2H_2O$ | highly soluble | | | King 1992 |
| 8.3.1 | chlorargyrite | $AgCl$ | | soluble in ammonia | | Schumann 1992 |
| 8.4.3 | bischofite | $MgCl_2 \cdot 6H_2O$ | highly soluble | | | King 1992 |
| 8.4.5 | carnallite | $KMgCl_3 \cdot 6H_2O$ | highly soluble | | with crackling sound | King 1992; Schumann 1992 |
| 8.4.6 | tachyhydrite | $CaMg_2Cl_6 \cdot 12H_2O$ | highly soluble | | | King 1992 |
| 8.6.5 | cryolite | $Na_2NaAlF_6$ | slightly soluble | | | King 1992 |
| | | | | easily soluble in sulfuric acid | | Schumann 1992 |

| Hey Number | Mineral Name | Chemical Formula | Water | Acids | Alterations | References |
|---|---|---|---|---|---|---|
| 8.6.10 | koenenite | $Na_4Mg_9Al_4Cl_{12}(OH)_{22}$ | decomposes in water | | to scaly precipitate | King 1992 |
| 8.8.4 | cotunnite | $PbCl_2$ | highly soluble | | | King 1992 |
| 8.8.18 | boleite | $KPb_{26}Ag_9Cu_{24}(OH)_{48}Cl_{62}$ | | soluble in nitric acid & ammonia | | Schumann 1992 |
| 8.10.3 | chloromanganokalite | $K_4MnCl_6$ | readily soluble | | | Antony et al. 1997 |
| 8.11.4 | douglasite | $K_2Fe^{2+}Cl_4 \cdot 2H_2O$ | slightly soluble | | | King 1992 |
| 8.11.5 | erythrosiderite | $K_2Fe^{3+}Cl_5 \cdot H_2O$ | highly soluble | | | King 1992 |
| 8.11.6 | rinneite | $K_3NaFe^{2+}Cl_6$ | highly soluble | | | King 1992 |
| 8.11.7 | kremersite | $(NH_4,K)_2Fe^{3+}Cl_5 \cdot H_2O$ | highly soluble | | | King 1992 |
| 8.11.9 | nickelbischofite | $NiCl_2 \cdot 6H_2O$ | soluble | | | King 1992 |
| 8.12.4 | hieratite | $K_2SiF_6$ | highly soluble | | | King 1992 |
| **9** | **Borates** | | | | | |
| 9.1.1 | sassolite | $H_3BO_3$ | soluble in warm water | | | King 1992; Schumann 1992 |
| 9.1.6 | kernite | $Na_2[B_4O_6(OH)_2] \cdot 3H_2O$ | moderately soluble | | | King 1992 |
| 9.1.8 | tincalconite | $Na_2(B_4O_7) \cdot 5H_2O$ | highly soluble | | | King 1992 |
| 9.1.9 | borax | $Na_2(B_4O_5)(OH)_4 \cdot 8H_2O$ | highly soluble | | | King 1992; Schumann 1992 |
| 9.2.16 | kaliborite | $KMg_2H[B_6O_8(OH)_5]_2(H_2O)_4$ | slightly soluble | | | King 1992 |
| 9.2.17 | iquiqueite | $K_3Na_4Mg(CrO_4)B_{24}O_{39}(OH) \cdot 12H_2O$ | somewhat soluble in cold water | | | Ericksen et al. 1986 |
| 9.3.12 | inyoite | $Ca(H_4B_3O_7)(OH) \cdot 4H_2O$ | highly soluble in hot water | | | King 1992 |
| 9.3.14 | colemanite | $Ca[B_3O_4(OH)_3] \cdot H_2O$ | slightly soluble | | | King 1992 |
| 9.3.21 | ulexite | $NaCa[B_5O_6(OH)_6] \cdot 5H_2O$ | moderately soluble | | | King 1992; Schumann 1992 |
| **10** | **Borates with othe anions** | | | | | |
| 10.1.12 | hydrochlorborite | $Ca_4B_8O_{15}Cl_2 \cdot 21H_2O$ | soluble | | saturated salt solution | Hurlbut et al. 1977 |
| 10.3.1 | sulfoborite | $Mg_3[B(OH)_4]_2(SO_4)(OH,F)_2$ | decomposes in water | | | King 1992 |

| Hey Number | Mineral Name | Chemical Formula | Water | Acids | Alterations | References |
|---|---|---|---|---|---|---|
| **11** | **Carbonates** | | | | | |
| 11.1.2 | natrite | $Na_2CO_3$ | highly soluble | | | Schumann 1992 |
| 11.1.3 | nahcolite | $NaHCO_3$ | highly soluble | | | King 1992 |
| 11.1.5 | thermonatrite | $Na_2CO_3 \cdot H_2O$ | highly soluble | | | King 1992 |
| 11.1.6 | trona | $Na_3H(CO_3)_2 \cdot 2H_2O$ | highly soluble | | | King 1992 |
| 11.1.7 | natron | $Na_2CO_3 \cdot 10H_2O$ | highly soluble | | | King 1992 |
| 11.1.14 | gaylussite | $Na_2Ca(CO_3)_2 \cdot 5H_2O$ | soluble | | | King 1992; Schumann 1992 |
| 11.1.18 | teschemacherite | $(NH_4)HCO_3$ | highly soluble | | | King 1992 |
| 11.1.NI | gregoryite | $(Na_2,K_2,Ca)CO_3$ | soluble | | | Hazen & Ausubel 2016 |
| 11.2.1 | malachite | $Cu_2(CO_3)(OH)_2$ | decomposes in hot water | | | King 1992 |
| 11.2.2 | azurite | $Cu_3(CO_3)_2(OH)_2$ | decomposes in hot water | | | King 1992 |
| | | | | soluble in nitric acid & ammonia | nitric acid: effervescence | Schumann 1992 |
| 11.3.1 | magnesite | $MgCO_3$ | | readily soluble in warm dilute acids | | King 1983 |
| | | | 4.2ppm (@ 25C & 1atm) | | | Morey 1962 |
| 11.4.1 | calcite | $CaCO_3$ | 20ppm (@ 25C & 1atm) | | | Morey 1962 |
| 11.4.2 | aragonite | $CaCO_3$ | highly soluble | | | King 1983 |
| 11.4.6 | dolomite | $CaMg(CO_3)_2$ | 3-4ppm (@ 25C & 1atm) | | | Morey 1962 |
| 11.6.1 | smithsonite | $ZnCO_3$ | | easily soluble in warm acids | | Schumann 1992 |
| 11.6.5 | aurichalcite | $(Zn,Cu)_5(CO_3)_2(OH)_6$ | | soluble in acid & ammonia | | Schumann 1992 |
| 11.8.3 | lanthanite-(Ce) | $(Ce,La,Nd)_2(CO_3)_3 \cdot 8H_2O$ | decomposes in hot water | | | King 1992 |
| 11.9.1 | cerussite | $PbCO_3$ | decomposes in hot water | | | King 1992 |
| | | | | readily soluble in dilute acids | | King 1983 |
| | | | | soluble in niric acid | effervescence | Schumann 1992 |
| 11.9.3 | dundasite | $PbAl_2(CO_3)_2(OH)_4 \cdot H_2O$ | | soluble in acid | disintegration | King 1983 |
| 11.11.4 | grimselite | $K_3Na(UO_2)(CO_3)_3 \cdot H_2O$ | soluble | | | Hazen & Ausubel 2016 |
| 11.11.5 | bayleyite | $Mg_2(UO_2)(CO_3)_3 \cdot 18H_2O$ | soluble | | | Hazen & Ausubel 2016 |

| Hey Number | Mineral Name | Chemical Formula | Water | Acids | Alterations | References |
|---|---|---|---|---|---|---|
| 11.12.1 | rhodochrosite | $MnCO_3$ | | readily soluble in warm, dilute mineral acids | | King 1983 |
| **12** | **Carbonates with other anions: with halides or sulfate** | | | | | |
| 12.2.1 | burkeite | $Na_6(CO_3)(SO_4)_2$ | highly soluble | | | King 1992 |
| 12.1.23 | phosgenite | $Pb_2CO_3Cl_2$ | | soluble in dilute nitric acid | | Schumann 1992 |
| 12.2.2 | hanksite | $Na_{22}K(SO_4)_9(CO_3)_2Cl$ | highly soluble | | | King 1992 |
| 12.2.11 | leadhillite | $Pb_4(CO_3)_2(SO_4)(OH)_2$ | | soluble in dilute nitric acid | | Schumann 1992 |
| 12.2.18 | schröckingerite | $NaCa_3(UO_2)(CO_3)_3(SO_4)F \cdot 10H_2O$ | highly soluble | | | King 1992 |
| **13** | **Nitrates** | | | | | |
| 13.1 | nitratine | $NaNO_3$ | highly soluble | | | King 1992; Schumann 1992 |
| 13.2 | niter | $KNO_3$ | highly soluble | | | King 1992 |
| 13.4 | nitromagnesite | $Mg(NO_3)_2 \cdot 6H_2O$ | highly soluble | | | King 1992 |
| 13.5 | nitrocalcite | $Ca(NO_3)_2 \cdot 4H_2O$ | highly soluble | | | King 1992 |
| 13.6 | nitrobarite | $Ba(NO_3)_2$ | highly soluble | | | King 1992 |
| 13.9 | darapskite | $Na_3(SO_4)(NO_3) \cdot H_2O$ | highly soluble | | | King 1992 |
| **14** | **Silicates not containing aluminum** | | | | | |
| 14.2.1 | dioptase | $CuSiO_3 \cdot H_2O$ | | soluble in nitric acid & ammonia | | Schumann 1992 |
| 14.4.11 | sepiolite | $Mg_4(Si_6O_{15})(OH)_2 \cdot 6H_2O$ | | soluble in acid | | Schumann 1992 |
| 14.5.1 | wollastonite | $CaSiO_3$ | | soluble in acid | | Schumann 1992 |
| 14.5.6 | larnite | $Ca_2SiO_4$ | moderately soluble | | | King 1992 |
| 14.9.6 | titanite | $CaTi(SiO_4)O$ | | soluble in sulfuric acid | | Schumann 1992 |
| 14.16.10 | uranophane | $Ca(UO_2)_2(SiO_3OH)_2 \cdot 5H_2O$ | | soluble in acid | | Schumann 1992 |
| **16** | **Silicates containing aluminum & other metals** | | | | | |
| 16.8.6 | phlogopite | $KMg_3(AlSi_3O_{10})(OH)_2$ | | soluble in sulfuric acid | | Schumann 1992 |
| 16.9.2 | anorthite | $Ca(Al_2Si_2O_8)$ | | soluble in acid (inc. var. bytownite & labradorite) | | Schumann 1992 |
| 16.16.5 | carpholite | $Mn^{2+}Al_2(Si_2O_6)(OH)_4$ | | easily soluble in acid | | Schumann 1992 |

| Hey Number | Mineral Name | Chemical Formula | Water | Acids | Alterations | References |
|---|---|---|---|---|---|---|
| 16.23.3 | vesuvianite | $Ca_{19}Fe^{3+}Al_4(Al_6Mg_2)(□_4)□[Si_2O_7]_4[(SiO_4)_{10}]O(OH)_9$ | | partially soluble in acid | | Schumann 1992 |
| **17** | **Silicates containing other anions** | | | | | |
| 17.2.9 | zinnwaldite | $KFe2^{2+}Al(Al_2Si_2O_{10})(OH)_2$ – $KLi_2Al(Si_4O_{10})(F,OH)_2$ | | soluble in acid | | Schumann 1992 |
| 17.3.3 | sodalite | $Na_4(Si_3Al_3)O_{12}Cl$ | | soluble in nitric acid | | Schumann 1992 |
| **18** | **Niobates & Tantalates** | | | | | |
| 18.3.3 | betafite | $(Ca,Na,U)_2(Ti,Nb,Ta)_2O_6Z(OH)$ | | soluble in acid | | Schumann 1992 |
| 18.4.5 | euxenite | $(Y,Ca,Ce,U,Th)(Nb,Ta,Ti)_2O_6$ | | powder soluble in sulfuric acid | | Schumann 1992 |
| **19** | **Phospahtes** | | | | | |
| 19.2.8 | turquoise | $CuAl_6(PO_4)_4(OH)_8 \cdot 4H_2O$ | | soluble in acids | | Schumann 1992 |
| 19.8.2 | brazilianite | $NaAl_3(PO_4)_2(OH)_4$ | | soluble in acids | | Schumann 1992 |
| 19.9.3-5 | monazite | $REE(PO_4)$ | | easily soluble in sulfuric acid | | Schumann 1992 |
| 19.11.10 | torbernite | $Cu(UO_2)_2(PO_4)_2 \cdot 12H_2O$ | | soluble in nitric acid | | Schumann 1992 |
| 19.11.14 | meta-autunite | $Ca(UO_2)_2(PO_4)_2 \cdot 6\text{-}8H_2O$ | highly soluble | | | King 1992 |
| 19.11.15 | autunite | $Ca(UO_2)_2(PO_4)_2 \cdot 11H_2O$ | highly soluble | | | King 1992 |
| 19.12.35 | ludlamite | $Fe^{2+}{}_3(PO_4)_2 \cdot 4H_2O$ | | soluble in acids | | Schumann 1992 |
| 19.13.11 | vivianite | $Fe^{2+}{}_3(PO_4)_2 \cdot 8H_2O$ | | readily soluble in weak acids | | King 1983 |
| **20** | **Arsenates** | | | | | |
| 20.1.2 | olivenite | $Cu_2(AsO_4)(OH)$ | | soluble in acid & ammonia | | Schumann 1992 |
| 20.1.8 | euchroite | $Cu_2(AsO_4)(OH) \cdot 3H_2O$ | | soluble in nitric acid | | Schumann 1992 |
| 20.1.13 | liroconite | $Cu_2Al(AsO_4)(OH)_4 \cdot 4H_2O$ | | soluble in acids | | Schumann 1992 |
| 20.7.10 | uranospinite | $Ca(UO_2)(AsO_4)_2 \cdot 10H_2O$ | | easily soluble in acids | | Frondel 1958 |
| 20.9.2 | scorodite | $Fe^{3+}AsO_4 \cdot 2H_2O$ | soluble | | to iron hydroxides & aqueous arsenate | Dove & Rimstidt 1985 |
| 20.10.9 | annabergite | $Ni_3(AsO_4)_2 \cdot 8H_2O$ | | soluble in acids | | Schumann 1992 |

| Hey Number | Mineral Name | Chemical Formula | Water | Acids | Alterations | References |
|---|---|---|---|---|---|---|
| **21** | **Vanadates** | | | | | |
| 21.2.1 | metarossite | $Ca(V_2O_6) \cdot 2H_2O$ | moderately soluble | | | King 1992 |
| 21.2.2 | rossite | $Ca(VO_3)_2 \cdot 4H_2O$ | slightly soluble | | | King 1992 |
| 21.2.3 | metahewettite | $CaV_6O_{16} \cdot 3H_2O$ | slightly soluble | | | Hillebrand et al. 1914; King 1992 |
| 21.2.4 | hewettite | $CaV_6O_{16} \cdot 9H_2O$ | slightly soluble | | | Hillebrand et al. 1914; King 1992 |
| 21.2.5 | pintadoite | $Ca_2(V_2O_7) \cdot 9H_2O$ | moderately soluble | | | King 1992 |
| 21.2.7 | fernandinite | $(Ca,K)(V^{5+},V^{4+},Fe^{2+})_8O_{20} \cdot 10H_2O$ | moderately soluble | | | King 1992 |
| 21.2.8 | pascoite | $Ca_3(V_{10}O_{28}) \cdot 17H_2O$ | easily soluble | | | Hillebrand et al. 1914 |
| 21.3.10 | descloizite | $PbZn(VO_4)(OH)$ | | soluble in acids | | Schumann 1992 |
| **22** | **Phosphates, Arsenates, & Vanadates with other anions** | | | | | |
| 22.1.1 | amblygonite | $LiAl(PO_4)F$ | | soluble in sulfuric acid | | Schumann 1992 |
| 22.2.9 | pyromorphite | $Pb_5(PO_4)_3Cl$ | | soluble in nitric acid | | Schumann 1992 |
| 22.2.10 | mimetite | $Pb_5(AsO_4)_3Cl$ | | soluble in nitric acid | | Schumann 1992 |
| 22.2.14 | vanadinite | $Pb_5(VO_4)_3Cl$ | | readily soluble in nitric acid | | Schumann 1992 |
| 22.2.NI | apatite | $Ca_5(PO_4)_3(Cl/F/OH)$ | | easily soluble in acid | | Schumann 1992 |
| 22.3.6 | chalcophyllite | $Cu_{18}Al_2(AsO_4)_4(SO_4)_3(OH)_{24} \cdot 36H_2O$ | | easily soluble in acid & ammonia | | Schumann 1992 |
| 22.4.5 | tyrolite | $Ca_2Cu_9(AsO_4)_4(CO_3)(OH)_8 \cdot 11H_2O$ | | easily soluble in acid & ammonia | | Schumann 1992 |
| **25** | **Sulfates** | | | | | |
| 25.1.1 | metathénardite | $Na_2SO_4$ | soluble | | | King 1992; Schumann 1992 |
| 25.1.3 | mirabilite | $Na_2SO_4 \cdot 10H_2O$ | highly soluble | | | King 1992 |
| 25.1.4 | arcanite | $K_2SO_4$ | highly soluble | | | |
| 25.1.6 | misenite | $K_8H_6(SO_4)_7$ | highly soluble | | | King 1992 |
| 25.1.7 | aphthitalite | $(K,Na)_3Na(SO_4)_2$ | highly soluble | | | King 1992 |
| 25.1.8 | mascagnite | $(NH_4)_2SO_4$ | highly soluble | | | King 1992 |

| Hey Number | Mineral Name | Chemical Formula | Water | Acids | Alterations | References |
|---|---|---|---|---|---|---|
| 25.1.NI | lecontite | $(NH_4,K)NaSO_4 \cdot 2H_2O$ | highly soluble | | | King 1992; Hazen & Ausubel 2016 |
| 25.2.1 | chalcocyanite | $CuSO_4$ | highly soluble | | | King 1992 |
| 25.2.3 | chalcanthite | $CuSO_4 \cdot 5H_2O$ | highly soluble | | | King 1992; Schumann 1992 |
| 25.2.5 | dolerophanite | $Cu_2(SO_4)O$ | highly soluble | | | King 1992 |
| 25.2.7 | brochantite | $Cu_4(SO_4)(OH)_6$ | | soluble in dilute acid | | Schumann 1992 |
| 25.2.11 | kröhnkite | $Na_2Cu(SO_4)_2 \cdot 2H_2O$ | highly soluble | | | King 1992 |
| 25.2.12 | natrochalcite | $NaCu_2(SO_4)_2(OH) \cdot 2H_2O$ | moderately soluble | | | King 1992 |
| 25.2.14 | fedotovite | $K_2Cu_3(SO_4)_3O$ | soluble | | | Hazen & Ausubel 2016 |
| 25.2.15 | cyanochroite | $K_2Cu(SO_4)_2 \cdot 6H_2O$ | highly soluble | | | King 1992 |
| 25.2.20 | cyanotrichite | $Cu_4Al_2(SO_4)(OH)_{12} \cdot 2H_2O$ | | soluble in acid | | Schumann 1992 |
| 25.2.24 | ransomite | $CuFe_2(SO_4)_4 \cdot 6H_2O$ | soluble | | | Hazen & Ausubel 2016 |
| 25.3.1 | kieserite | $MgSO_4 \cdot H_2O$ | moderately soluble | | | King 1992 |
| 25.3.5 | hexahydrite | $MgSO_4 \cdot 6H_2O$ | highly soluble | | | King 1992 |
| 25.3.6 | epsomite | $MgSO_4 \cdot 7H_2O$ | highly soluble | | | King 1992; Schumann 1992 |
| 25.3.8 | vanthoffite | $Na_6Mg(SO_4)_4$ | moderately soluble | | | King 1992 |
| 25.3.9 | blödite | $Na_2Mg(SO_4)_2 \cdot 4H_2O$ | highly soluble | | | King 1992 |
| 25.3.11 | löweite | $Na_{12}Mg_7(SO_4)_{13} \cdot 15H_2O$ | highly soluble | | | King 1992 |
| 25.3.13 | langbeinite | $K_2Mg_2(SO_4)_3$ | slightly soluble | | | King 1992 |
| 25.3.14 | leonite | $K_2Mg(SO_4)_2 \cdot 4H_2O$ | highly soluble | | | King 1992 |
| 25.3.15 | picromerite | $K_2Mg(SO_4)_2 \cdot 6H_2O$ | highly soluble | | | King 1992 |
| 25.3.17 | boussingaultite | $(NH_4)_2Mg(SO_4)_2 \cdot 6H_2O$ | highly soluble | | | King 1992 |
| 25.3.18 | pickeringite | $MgAl_2(SO_4)_4 \cdot 22H_2O$ | highly soluble | | | King 1992 |
| 25.4.3 | gypsum | $CaSO_4 \cdot 2H_2O$ | slightly soluble | | | King 1983; King 1992 |
| 25.4.4 | glauberite | $Na_2Ca(SO_4)_2$ | moderately soluble | | | King 1992; Schumann 1992 |
| 25.4.8 | syngenite | $K_2Ca(SO_4)_2 \cdot H_2O$ | slightly soluble | | separation of gypsum | King 1992 |
| 25.4.10 | polyhalite | $K_2Ca_2Mg(SO_4)_4 \cdot 2H_2O$ | decomposes in water | | separation of gypsum | King 1992 |
| 25.4.11 | koktaite | $(NH_4)_2Ca(SO_4)_2 \cdot H_2O$ | soluble | | | Hazen & Ausubel 2016 |
| 25.4.12 | ye'elimite | $Ca_4Al_6(SO_4)O_{12}$ | soluble | | | Hazen & Ausubel 2016 |
| 25.4.13 | ettringite | $Ca_6Al_2(SO_4)_3(OH)_{12} \cdot 26H_2O$ | moderately soluble | | | King 1992 |

| Hey Number | Mineral Name | Chemical Formula | Water | Acids | Alterations | References |
|---|---|---|---|---|---|---|
| 25.4.17 | baryte | $BaSO_4$ | | slowly soluble in concentrated sulfuric acid | | Schumann 1992 |
| 25.5.2 | goslarite | $ZnSO_4 \cdot 7H_2O$ | highly soluble | | | King 1992 |
| | | | readily soluble in cold water | | | King 1983 |
| 25.5.7 | serpierite | $Ca(Cu,Zn)_4(SO_4)_2(OH)_6 \cdot 3H_2O$ | | souble in acid | | Schumann 1992 |
| 25.5.13 | bianchite | $(Zn,Fe)SO_4 \cdot 6H_2O$ | highly soluble | | | King 1992 |
| 25.5.15 | zincmelanterite | $(Zn,Cu,Fe)SO_4 \cdot 7H_2O$ | highly soluble | | | Waller 1992 |
| 25.6.3 | mendozite | $NaAl(SO_4)_2 \cdot 11H_2O$ | highly soluble | | | King 1992 |
| 25.6.5 | aluminite | $Al_2(SO_4)(OH)_4 \cdot 7H_2O$ | | souble in acid | | Schumann 1992 |
| 25.6.7 | alunogen | $Al_2(SO_4)_3 \cdot 17H_2O$ | highly soluble | | | King 1992 |
| 25.6.8 | alunite | $KAl_3(SO_4)_2(OH)_6$ | | soluble in hot sulfuric acid | | Schumann 1992 |
| 25.6.14 | alum-(Na) | $NaAl(SO_4)_2 \cdot 12H_2O$ | highly soluble | | | Waller 1992 |
| 25.6.16 | kalinite | $KAl(SO_4)_2 \cdot 11H_2O$ | highly soluble | | | King 1992 |
| 25.6.17 | alum-(K) | $KAl(SO_4)_2 \cdot 12H_2O$ | highly soluble | | | King 1992 |
| 25.6.20 | tschermigite | $(NH_4)Al(SO_4)_2 \cdot 12H_2O$ | highly soluble | | | King 1992 |
| 25.7.3 | anglesite | $PbSO_4$ | | soluble in warm sulfuric acid | | Schumann 1992 |
| 25.7.6 | linarite | $PbCu(SO_4)(OH)_2$ | | soluble in dilute nitric acid | | Schumann 1992 |
| 25.8.5 | minasragrite | $(V^{4+}O)(SO_4) \cdot 5H_2O$ | highly soluble | | | King 1992; Hazen & Ausubel 2016 |
| 25.8.7 | redingtonite | $(Fe^{2+},Mg,Ni)(Cr,Al)_2(SO_4)_4 \cdot 22H_2O$ | soluble | | | Hazen & Ausubel 2016 |
| 25.9.3 | mallardite | $MnSO_4 \cdot 7H_2O$ | highly soluble | | | King 1992 |
| 25.9.7 | apjohnite | $Mn^{2+}Al_2(SO_4)_4 \cdot 22H_2O$ | highly soluble | | | King 1992 |
| 25.9.9 | ilesite | $(Mn,Zn,Fe)SO_4 \cdot 4H_2O$ | highly soluble | | | King 1992 |
| 25.9.13 | dietrichite | $(Zn,Fe^{2+},Mn^{2+})Al_2(SO_4)_4 \cdot 22H_2O$ | highly soluble | | | King 1992 |
| 25.10.1 | szomolnokite | $FeSO_4 \cdot H_2O$ | moderately soluble | | oxidises to Fe3+ | King 1992 |
| 25.10.3 | siderotil | $FeSO_4 \cdot 5H_2O$ | highly soluble | | | King 1992 |
| 25.10.5 | melanterite | $FeSO_4 \cdot 7H_2O$ | highly soluble | | | King 1992 |
| 25.10.6 | rhomboclase | $(H_5O_2)Fe^{3+}(SO_4)_2 \cdot 2H_2O$ | highly soluble | | | Tosca et al. 2007 |

| Hey Number | Mineral Name | Chemical Formula | Water | Acids | Alterations | References |
|---|---|---|---|---|---|---|
| 25.10.8 | kornelite | $Fe_2(SO_4)_3 \cdot 7H_2O$ | highly soluble | | | King 1992 |
| 25.10.9 | coquimbite | $AlFe^{3+}{}_3(SO_4)_6(H_2O)_{12} \cdot 6H_2O$ | highly soluble | | | King 1992 |
| 25.10.17 | amarantite | $Fe^{3+}{}_2(SO_4)_2O \cdot 7H_2O$ | decomposes in water | | | King 1992 |
| 25.10.20 | römerite | $Fe^{2+}Fe^{3+}{}_2(SO_4)_4 \cdot 14H_2O$ | highly soluble | | | King 1992 |
| 25.10.21 | bílinite | $Fe^{2+}Fe^{3+}{}_2(SO_4)_4 \cdot 22H_2O$ | highly soluble | | | King 1992 |
| 25.10.22 | copiapite | $Fe^{2+}Fe^{3+}{}_4(SO_4)_6(OH)_2 \cdot 20H_2O$ | highly soluble | | | King 1992 |
| 25.11.2 | sideronatrite | $Na_2Fe(SO_4)_2(OH) \cdot 3H_2O$ | decomposes in hot water | | | King 1992 |
| 25.11.4 | ferrinatrite | $Na_3Fe(SO_4)_3 \cdot 3H_2O$ | slightly soluble | | | King 1992 |
| 25.11.7 | krausite | $KFe(SO_4)_2 \cdot H_2O$ | decomposes in water | | | King 1992 |
| 25.11.9 | jarosite | $KFe^{3+}{}_3(SO_4)_2(OH)_6$ | | soluble in acid | | Schumann 1992 |
| 25.11.10 | voltaite | $K_2Fe^{2+}{}_5Fe^{3+}{}_3Al(SO_4)_{12} \cdot 18H_2O$ | decomposes in water | | yellow precipitate | King 1992 |
| 25.11.12 | metavoltine | $Na_6K_2Fe^{2+}Fe^{3+}{}_6(SO_4)_{12}O_2 \cdot 18H_2O$ | slightly soluble | | | King 1992 |
| 25.11.18 | godovikovite | $(NH_4)Al(SO_4)_2$ | slowly soluble | | | Jambor & Grew 1990; King 1992; Antony et al. 2003 |
| 25.11.19 | botryogen | $MgFe^{3+}(SO_4)_2(OH) \cdot 7H_2O$ | slightly soluble in hot water | | | King 1992 |
| 25.11.26 | halotrichite | $Fe^{2+}Al_2(SO_4)_4 \cdot 22H_2O$ | highly soluble | | | King 1992; Schuman 1992 |
| 25.12.6 | morenosite | $NiSO_4 \cdot 7H_2O$ | highly soluble | | | King 1992 |
| 25.12.NI | wupatkiite | $(Co,Mg,Ni)Al_2(SO_4)_4 \cdot 22H_2O$ | soluble | | | Hazen & Ausubel 2016 |
| **26** | **Sulfates with Halide** | | | | | |
| 26.2 | sulphohalite | $Na_6(SO_4)_2FCl$ | slightly soluble | | | King 1992 |
| 26.3 | schairerite | $Na_{21}(SO_4)_7ClF_6$ | moderately soluble | | | King 1992 |
| 26.9 | aubertite | $CuAl(SO_4)_2Cl \cdot 14H_2O$ | soluble | | | Hazen & Ausubel 2016 |
| 26.14 | kainite | $KMg(SO_4)Cl \cdot 3H_2O$ | decomposes in water | | to epsomite & sylvite | King 1992 |
| 26.23 | pseudograndreefite | $Pb_6(SO_4)F_{10}$ | soluble | | | Hazen & Ausubel 2016 |
| 26.25 | caracolite | $Na_3Pb_2(SO_4)_3Cl$ | soluble | | | Hazen & Ausubel 2016 |

| Hey Number | Mineral Name | Chemical Formula | Water | Acids | Alterations | References |
|---|---|---|---|---|---|---|
| **27** | **Sulfites, Chromates, Molybdates, & Tungstates** | | | | | |
| 27.2.5 | crocoite | $PbCrO_4$ | | disintegrates in acids | | King 1983 |
| 27.3.3 | wulfenite | $Pb(MoO_4)$ | | decomposes in acids | | King 1983 |
| 27.4.15 | wolframite | $(Fe^{2+})WO_4 – (Mn^{2+})WO_4$ | | powder turns blue in concentrated sulfuric acid | | Schumann 1992 |
| **29** | **Iodates** | | | | | |
| 29.3 | lautarite | $Ca(IO_3)_2$ | slightly soluble | | | King 1992 |
| 29.5 | dietzeite | $Ca_2(IO_3)_2(CrO_4) \cdot H_2O$ | moderately soluble | | | King 1992 |
| **31** | **Oxalates, Citrates, Mellitates, & Acetates** | | | | | |
| 31.1.1 | oxammite | $(NH_4)_2(C_2O_4) \cdot H_2O$ | highly soluble | | | King 1992 |
| 31.1.3 | wheatleyite | $Na_2Cu(C_2O_4)_2 \cdot 2H_2O$ | soluble | | | Hazen & Ausubel 2016 |
| 31.1.5 | whewellite | $Ca(C_2O_4) \cdot H_2O$ | | easily soluble in acids | | Schumann 1992 |
| 31.1.NI | natroxalate | $Na_2(C_2O_4)$ | soluble | | | Hazen & Ausubel 2016 |
| 31.3.1 | mellite | $Al_2[C_6(COO)_6] \cdot 16H_2O$ | | soluble in nitric acid & potassium hydroxide | | Schumann 1992 |
| **O** | **'Precious' Non-minerals** | | | | | |
| O.4 | coral | $CaCO_3$ | | soluble in acid | effervescence | Schumann 1992 |
| | | | soluble in hot water | | | Schumann 1974 |

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