Outotec

Physical characteristics of select minerals & materials

Mineral	Composition	Specific gravity	Magnetic response			Electrostatic response	
			F	P	NM	C	NC
Actinolite	$Ca_2(Mg,Fe)_5[Si_4O_{11}]_2(OH)_2$	3.0-3.2		X			X
Albite	$Na[AlSi_3O_8]$	2.6			X		X
Almandine	$Fe_3Al_2[SiO_4]_3$	4.3		X			X
Amphibole	$(Fe,Mg,Ca)_xSiO_3$	2.9-3.5		X			X
Anatase	TiO_2	3.9			X	X	
Andalusite	Al_2SiO_5	3.2					X
Andradite	$Ca_3Fe_2(SiO_4)_3$	3.8		X		(2) ←	X
Anhydrite	$CaSO_4$	3					X
Ankerite	$Ca_2MgFe(CO_3)_4$	2.9-3.1		X			X
Apatite	$Ca_5(PO_4)_3(F,Cl,OH)$	3.2			X		X
Aragonite	$CaCO_3$	3			X		X
Arsenopyrite	FeAsS	5.9-6.2		X →	(1)	X	
Asbestos	$Mg_3[Si_2O_5](OH)_4$	2.4-2.5			X		X
Augite	$(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al)_2O_6$	3.2-3.6		X		X →	(1)
Azurite	$Cu_3[CO_3]_2(OH)_2$	3.8			X		X
Baddeleyite	ZrO_2	5.5-5.6			X		X
Barite	$BaSO_4$	4.3-5.0			X		X
Bastnaesite	$(Ce,La,F)CO_3$	4.7-5.0		X			X
Bauxite	$Al_2O_3•_2H_2O$	2.6			X		X
Beryl	$Be_3Al_2[Si_6O_{18}]$	2.7-2.8			X		X
Biotite	$K(Mg,Fe)_3[Si_3AlO_{10}](OH,F)_2$	2.7-3.1		X			(4)
Bismuth	Bi	9.8			X	X	
Borax	$Na_2B_4O_7•10H_2O$	1.7			X		X
Bornite	Cu_5FeS_4	4.9-5.3		(1) ←	X	X	
Brannerite	$(UO,TiO,UO_2)TiO_3$	4.5-5.4		X		X	
Brookite	TiO_2	4.1			X	X	
Calcite	$CaCO_3$	2.7			X		X
Carnotite	$K_2(UO_2)_2(VO)_4•3H_2O$	4-5			X	(2) ←	X
Cassiterite	SnO_2	6.4-7.1			X	X	
Celestite	$SrSO_4$	4			X		X
Cerussite	$PbCO_3$	6.5			X	(2) ←	X
Chalcocite	Cu_2S	5.5-5.8			X	X	
Chalcopyrite	$CuFeS_2$	4.1-4.3		(1) ←	X	X	
Chlorite	$(Mg,Fe)_3(Si,Al)_4O_{10}(OH)_2•(Mg,Fe)_3(OH)_6$	2.6-3.3		X			X
Chromite	$(Fe,Mg)(Cr,Al)_2O_4$	4.6		X		X	
Chrysocolla	$(Cu,Al)_2H_2Si_2O_5(OH)_4•nH_2O$	1.9-2.4			X		X
Cinnabar	HgS	8.0-8.2			X		X
Cobaltite	(Co,Fe)AsS	6.0-6.3		X		X	
Colemanite	$Ca_2B_6O_{11}•5H_2O$	2.4			X		X
Collophanite	$Ca_3P_2O_8•H_2O$	2.6-2.9			X		(3)
Columbite	$(Fe,Mn)(Ta,Nb)_2O_6$	5.2-8.2		X		X	
Copper	Cu	8.9			X	X	
Corundum	Al_2O_3	3.9-4.1			X		X
Covellite	CuS	4.6-4.8			X	X	
Cryolite	Na_3AlF_6	3			X	(2) ←	X
Cuprite	Cu_2O	5.8-6.2			X		X
Diamond: (natural)	C	3.5			X		X
Diamond: (synthetic)	C	3.5		X			X
Diopside	$CaMgSi_2O_6$	3.2-3.5		X →	(1)		X
Dolomite	$CaMg(CO_3)_2$	2.8-2.9			X		X
Epidote	$Ca_2(Al,Fe)_3Si_3O_{12}(OH)$	3.3-3.5		X			X
Euxenite	$(Y,Ca,Ce,U,Th)(Nb,Ta,Ti)_2O_6$	4.7-5.0		X		X	
Feldspar Group	$(K,Na,Ca)_x(Al,Si)_3O_8$	2.5-2.9			X		X
Ferberite	$FeWO_4$	7.5	(1) ←	X		X	
Flint	SiO_2	2.6			X		X
Fluorite	CaF_2	3.2			X		X
Franklinite	$(Fe,Mn,Zn)O•(Fe,Mn)_2O_3$	5.1-5.2	X			X	
Gahnite	$ZnAl_2O_4$	4.0-4.6			X		X
Galena	PbS	7.4-7.6			X	X	
Garnet	Complex Ca,Mg,Fe,Mn Silicates	3.1-4.3		X →	(1)	(2) ←	X
Gibbsite	$Al(OH)_3$	2.3-2.4			X		X
Goethite	FeO(OH)	3.3 - 4.3		X		(2) ←	X
Gold	Au	15.6-19.3			X	X	
Graphite	C	2.1-2.2			X	X	
Grossularite	$Ca_3Al_2(SiO_4)_3$	3.5			X	(2) ←	X
Gypsum	$CaSO_4•2H_2O$	2.3			X		X
Halite	NaCl	2.1			X	(2) ←	X
Hematite	Fe_2O_3	4.9-5.3		X		X	
Hornblende	$Ca_2(Mg, Fe, Al)_5(Al, Si)_8O_{22}(OH)_2$	3.1-3.3		X		(2) ←	X
Huebnerite	$MnWO_4$	6.7-7.5		X →	(1)	X	
Hypersthene	$(Mg,Fe)SiO_3$	3.4-3.9		X			X
Ilmenite	$FeTiO_3$	4.7		X		X	
Ilmenorutile	$Fe_x(Nb,Ta)_{2x}•4Ti_{1-x}O_2$	5.1		X		X	
Ilvaite	$CaFe^{2+}2Fe^{3+}Si_2O_7O(OH)$	3.8-4.1		X		X →	(1)
Kaolinite	$Al_2Si_2O_5(OH)_4$	2.2-2.7			X		X
Kyanite	Al_2SiO_5	3.6-3.7			X		X
Lepidolite	$KLi_2Al(Al,Si)_3O_{10}(F,OH)_2$	2.8-2.9			X		X
Leucoxene	$FeTiO_3$ → TiO_2 (Alteration Product)	3.6-4.3		X →	(1)	X	
Limonite	$FeO(OH)•nH_2O$	3.6-4.0		X →	(1)	(2) ←	X
Magnesite	$MgCO_3$	3			X		X
Magnetite	Fe_3O_4	5.2	X			X	
Malachite	$Cu_2CO_3(OH)_2$	3.6-4			X		X
Manganite	MnO(OH)	4.3		X →	(1)	X	

Mineral	Composition	Specific gravity	Magnetic response			Electrostatic response	
			F	P	NM	C	NC
Marcasite	FeS_2	4.8-4.9		(1) ←	X	X	
Martite	(See Hematite)	-					
Microline	$KAlSi_3O_8$	2.6			X		X
Microlite	$Ca_2Ta_2O_7$ (See Pyrochlore)	5.5			X		X
Millerite	NiS	5.2-5.6		X		X	
Molybdenite	MoS_2	4.7-5.0			X	X	
Monazite	$(Ce,La,Y,Th)PO_4$	4.9-5.3		X			X
Mullite	$Al_4Si_2O_{13}$	3.2			X		X
Muscovite	$KAl_2(AlSi_3O_{10})(F,OH)_2$	2.8-3.0			X		(4)
Nahcolite	$NaHCO_3$	2.2			X		X
Nepheline Syenite	$(Na,K)(AlSi)_2O_4$	2.6			X		X
Niccolite	NiAs	7.6-7.8		X		X	
Olivine	$(Mg,Fe)_2SiO_4$	3.3-3.5		X			X
Orpiment	As_2S_3	3.4-3.5			X	X	
Orthoclase	$KAlSi_3O_8$	2.5-2.6			X		X
Periclase	MgO	3.6–3.9			X		X
Perovskite	$CaTiO_3$	4			X		X
Petalite	$LiAl(Si_2O_5)_2$	2.4			X		X
Phosphate (pebble)	(See Collaphanite)	-					
Platinum	Pt	14.0-21.5		(1) ←	X	X	
Pyrite	FeS_2	5		(1) ←	X	X	
Pyrochlore	$(Na,Ca)_2(Nb,Ti)_2O_6(OH,F)$	4.2-4.4			X	X	
Pyrolusite	MnO_2	4.7-5.0		(1) ←	X		X
Pyrope	$Mg_3Al_2(SiO_4)_3$	3.5			X	(2) ←	X
Pyroxene	$(Ca,Mg,Fe,Al)_2Si_2O_6$	3.2-3.6		X →	(1)	(2) ←	X
Pyrrhotite	$Fe_{x-1}S_x$	4.6-4.7	X			X	
Quartz	SiO_2	2.7			X		(3)
Realgar	AsS	3.6			X	X	
Rhodochrosite	$MnCO_3$	3.4-3.7			X	(2) ←	X
Rhodonite	$MnSiO_3$	3.6-3.7			X	(2) ←	X
Rutile	TiO_2	4.2-4.3			X	(2)	
Samarskite	$(Y,Ce,U,Fe)_3(Nb,Ta,Ti)_5O_{16}$	4.3 - 5.87	(1) ←	X		X	
Scheelite	$CaWO_4$	5.9-6.1			X		X
Serpentine	$Mg_6[Si_4O_{10}](OH)_8$	2.2-2.7		X			X
Siderite	$FeCO_3$	3.8		X		(2) ←	X
Sillimanite	$Al_2O[SiO_4]$	3.2			X		X
Silver	Ag	10.1-11.1			X	X	
Smithsonite	$ZnCO_3$	4.3-4.5			X		X
Sodalite	$Na_8[Al_6Si_6O_{24}]C_{l2}$	2.1-2.3			X		X
Spessartine	$Mn_3Al_2(SiO_4)_3$	4.2			X		X
Sphalerite	(Zn,Fe)S	3.9-4.1		X →	(1)	X →	(1)
Sphene (Titanite)	$CaTiSiO_5$	3.4-3.6			X	(2) ←	X
Spinel	$MgAl_2O_4$	3.6		(1) ←	X	X	(1)
Spodumene	$LiA(SiO_3)_2$	3.1-3.2			X		X
Stannite	Cu_2FeSnS_4	4.3-4.5			X	X	
Staurolite	$Fe^{+2}Al_4[Si_4O_{11}]_2O_2(OH)_2$	3.6-3.8		X		(2) ←	X
Stibnite (Antimonite)	Sb_2S_3	4.6			X	X	
Struverite	$(Ta_2O_5,Nb_2O_5)_xTiO_2$	5.1		X		X	
Sulphur	S	2.1			X		X
Sylvite	KCl	2			X		X
Talc	$Mg_3Si_4O_{10}(OH)_2$	2.5-2.8			X		X
Tantalite	$(Fe,Mn)(Ta,Nb)_2O_6$	7.3-7.8		X		X	
Tapiolite	$Fe,Mn\ (Ta,Nb)_2O_6$	4.6-5.2		X		X	
Tetrahedrite	$(Cu,Fe,Zn)_{12}Sb_4S_{13}$	5		X		X	
Thorianite	ThO_2	9.7			X		X
Thorite	$ThSiO_4$	4.5-5.4			X		X
Topaz	$Al_2SiO_4(F,OH)_2$	3.4-3.6			X		X
Tourmaline	$(Na,Ca)(Mg,Fe^{+2},Fe^{+3},Al,Li)_3\ Al_6(BO_3)_3Si_6O_{18}(OH)_4$	2.9-3.2		X →	(1)	(1,2) ←	X
Uraninite	UO_2	9-9.7		X			X
Vermiculite	$(K,Fe)Mg_3[Al,Si_3O_{10}](OH)_2 \bullet nH_2O$	2.4-2.7		→	X		X
Wolframite	$(Fe,Mn)WO_4$	6.7-7.5		X		X	
Wollastonite	$CaSiO_3$	2.8-2.9			X		X
Wulfenite	$PbMoO_4$	6.5-7.0			X	X	
Xenotime	YPO_4	4.4-5.1		X			X
Zeolite	Hydrous Alumino-Silicate usually of Ca and Na	2.0-2.5			X		X
Zincite	ZnO	5.7			X	(1) ←	X
Zircon	$ZrSiO_4$	4.7			X		X

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Explanation of Table:

The magnetic and electrostatic separation characteristics listed in this table are based on separation tests made in Outotec's laboratory.

Magnetic Response is classified as (a) ferromagnetic: attraction to a conventional permanent magnetic separator at a metric flux density of less than 0.2 Tesla (2,000 gauss), (b) paramagnetic: attraction to the magnetic zone of a high intensity magnetic separator operating at greater than 0.2 to 2.0 Tesla (2,000-20,000 gauss), and (c) non-magnetic or diamagnetic: not-affected or repelled respectively from the magnetic force described in (b).

Electrostatic response is classified as conductive or non-conductive based on the surface resistivity of a mineral Generally, minerals with a surface resistivity of less than 1011 ohms will report as "conductors" using standardized settings on an electrostatic separator. Minerals with a surface resistivity above 1012 ohms will report as "non-conductors" under similar equipment settings.

Notes: (1) Variations in response to magnetic and electrostatic separation will occur based on the actual composition of the mineral from varying locations and the presence of inclusions, (2) The response of some minerals can be varied by treatment at elevated temperature, i.e. rutile becomes more conductive at temperatures greater than 200 C, (3) Triboelectric (contact) charging can be used to selectively charge certain minerals; and they, in turn, can be attracted to an electrode of the opposite polarity, i.e. quartz from collophanite (pebble phosphate), (4) The separation of particles with a pronounced shape factor (mica) can also be accomplished by the use of a non-uniform electric field (dielectrophoresis).