SIMPLE FIELD TEST FOR DISTINGUISHING MINERALS BY ABRASION pH*

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Abstract

A simple field test is described for distinguishing minerals by estimating the pH of suspensions made by grinding them in water. The term abrasion pH is proposed to designate the pH values obtained by this grinding technique, which may differ from pH values obtained by shaking previously ground minerals in water. Soft minerals are scratched in one or two drops of water on a streak plate for about a minute to form a milky suspension and the resulting pH of the solution estimated with indicator papers. Hard minerals and those that absorb water are ground with a few drops of water in an agate mortar for about a minute. Abrasion pH values are given for about 280 mineral species, many of them confirmed repeatedly by determinations on specimens from different localities. Abrasion pH values of minerals range from 1 to 12. Many minerals whose compositions vary because of isomorphous replacements yield a range of values that reflect the varying content of alkali- or acid-forming materials, whereas minerals of fixed compositions show little variation in abrasion pH for each mineral species. Many minerals similar in appearance but differing in composition are easily distinguishable by the abrasion pH test, for example calcite from dolomite or magnesite, talc from pyrophyllite, and muscovite from phlogopite.

Introduction

Although frequently simple tests in the field may be sufficient to identify a mineral definitely, some specimens may require study of their optical properties and chemical composition in the laboratory before their identity or value can be established. Any additional property by which minerals can be definitely identified in the field, therefore, seems worthy of the attention of geologists and mineralogists.

The abrasion pH of a mineral is a property that can be estimated easily and quickly for field identification of a specimen. Although the precise determination of the pH of solutions requires considerable equipment, an estimate can be obtained by simple means. In the technique described below for the determination of abrasion pH the only equipment needed is a porcelain streak plate, small agate mortar and pestle, pH indicator papers, and distilled water or water of low salinity.

The alkaline reaction of some minerals has been noted in previous investigations. Kenngott[1] found that many silicates give alkaline reactions

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[1] Kenngott, A., Über einige Erscheinungen beobachtet an Natrolith: *Neues Jahrb.*, 77 **(1867)**.

to moistened test paper. Clarke[2] treated a number of powdered silicate minerals with water containing phenolphthalein, noting the intensity of color produced, and thus determined roughly the extent to which they were decomposed. Analyses by Steiger[3] showed a discrepancy between the intensity of the color and the quantity of alkali found in solution.

Atkins[4] discussed the application of pH to the study of geological problems and made several measurements on minerals. Stevens[5] made colorimetric and electrometric pH measurements on silicate minerals crushed in water. Umegaki[6] studied the pH values of water suspensions of plagioclase feldspars and carbonate minerals, which were first ground in air to pass a 200 mesh sieve and shaken with water for varying time intervals.

Comparison of Results by Different Methods of Attack. Definition of Abrasion pH.

The pH values presented in this paper and those previously reported by Stevens[5] on silicates of alkaline reaction are generally higher than the carefully determined values of Umegaki.[6] Probably this discrepancy is due to the different methods of attack of the minerals. Umegaki's results were obtained by placing the previously ground mineral in water and shaking for as long as 2½ hours, whereas the results here reported were determined by grinding the mineral in water. In grinding the mineral in water increased hydrolysis results from the continuous exposure of new surfaces to attack and perhaps from localized rise in temperature and pressure during the abrasion of the mineral grains.

Because of these discrepancies, apparently resulting from different methods of attacking the mineral, the term abrasion pH is adopted in the present study to designate the pH resulting from grinding the mineral under water.

Hydrolysis of Minerals

In an elementary treatment, salts may be considered the product of the reaction between an acid and an alkali. Thus, representing a hypo-

[2] Clarke, F. W., The alkaline reaction of some natural silicates: *U. S. Geol. Survey, Bull.* **167,** 156–158 (1900).

[3] Steiger, George, The solubility in water of certain natural silicates: *U. S. Geol. Survey, Bull.* **167,** 159–160 (1900).

[4] Atkins, W. R. G., Some geochemical applications of measurements of hydrogen-ion concentration: *Roy. Dublin Soc. Sci. Proc.*, **19,** 455–460 (1930).

[5] Stevens, R. E., Studies on the alkalinity of some silicate minerals: *U. S. Geol. Survey, Prof. Paper* **185A,** 1–13 (1934–1935).

[6] Umegaki, Yosiharu, Über die bei der Hydrolyse der Plagioklase und einiger Karbonatmineralien nachgewiesene Wasserstoffion-Konzentration: *Mem. Coll. Sci., Kyoto Imp. Univ.*, **14,** 141–154 (1938).

thetical acid by HA and a hypothetical alkali by BOH their reaction may be represented as follows:

$$HA+BOH=BA+H_2O.$$

The salt formed is a combination of elements in simple proportion, and, in the above reaction, the salt (BA) consists of an equal number of atoms of element B and of element A.

The hydrolysis of a salt may be represented as the reverse of the above reaction thus:

$$BA+HOH=HA+BOH.$$

As the acid (HA) and the alkali (BOH) are thus produced in equal molecular quantities the acidity or alkalinity of the resulting solution is dependent upon the extent to which the acid is ionized to yield hydrogen-ions and the alkali is ionized to yield hydroxyl-ions. Representing a strongly ionized acid by HA and a weakly ionized one by Ha, and a strong and a weak alkali by BOH and bOH respectively, the hypothetical salts BA, bA, Ba, and ba hydrolyze as follows:

$BA+HOH \rightleftarrows HA+BOH$ (solution essentially neutral)
$bA+HOH \rightleftarrows HA+bOH$ (solution acid)
$Ba+HOH \rightleftarrows Ha+BOH$ (solution alkaline)
$ba+HOH \rightleftarrows Ha+bOH$ (solution essentially neutral)

As examples of the above types of hydrolysis the following reactions of minerals with water may be cited:

KCl (sylvite)$+HOH \rightleftarrows HCl+KOH$ (solution essentially neutral, pH 6)
$Fe_2(SO_4)_3\cdot 9H_2O$ (coquimbite)$+HOH \rightleftarrows 3H_2SO_4+2Fe(OH)_3+4H_2O$ (solution acid, pH 1)
$Na_2B_4O_7\cdot 10H_2O$ (borax)$+HOH \rightleftarrows H_2B_4O_7+2NaOH+9H_2O$ (solution alkaline, pH 10)
$PbCO_3$ (cerussite)$+2HOH \rightleftarrows H_2CO_3+Pb(OH)_2$ (solution essentially neutral, pH 6)

In addition to the above types of materials, there are acid and basic salts whose pH in water is dependent not only upon the ionization of the acids and alkalies formed by hydrolysis but also upon the proportion of acid- or alkali-producing constituents, in the salt. Thus K_2SO_4 is essentially neutral, but $KHSO_4$ has a strong acid reaction. Weak acids and weak bases also occur as minerals, examples being H_3BO_3 (sassolite) and $Al(OH)_3$ (gibbsite), which give essentially neutral reactions in water.

This discussion of the elementary theoretical background of the test shows that the abrasion pH of a mineral may indicate its composition type and identity. Thus a mineral giving an abrasion pH of 2 is generally a salt of a weak alkali and a strong acid. However, other factors which may contribute to the result of the test are hardness and nonreactivity, cleavage in relation to the positions of atoms and impurities.

Many interesting differences in abrasion pH result from the substitution of one element for another in a mineral. Thus pyrophyllite, $Al_2Si_4O_{10}(OH)_2$, gives abrasion pH of 6, while its magnesium analogue talc, $Mg_3Si_4O_{10}(OH)_2$, gives pH 9. Increasing substitution of Li for Al in lepidolite raises the abrasion pH of that mineral.

Procedures for Making Mineral Suspensions for Abrasion pH Determinations.

With streak plate: For soft non-absorbent minerals scratch the mineral in a drop of water* on a streak plate for about a minute to form a milky suspension. Determine the abrasion pH with the appropriate indicator papers.

With mortar and pestle: For hard minerals and those that absorb water, grind fragments of the mineral for a minute with a few drops of water to make a heavy suspension and apply the indicator papers.

pH indicator papers: The abrasion pH may be determined in the laboratory either by the use of indicators in solution or by indicator papers. As indicator papers have obvious advantages for field work, they have been used in the present study.

Extensive lists of pH indicators are given by Clark,[7] Britton,[8] and in the Handbook of Chemistry and Physics[9] of the Chemical Rubber Co. Lange's Handbook of Chemistry[10] gives lists of indicators and an illustrative chart showing the pH ranges of various indicators. In most colorimetric pH work, in which buffer solutions are used for standards of comparison the entire range of color change is used for estimation of pH. In the present study the point at which an indicator changes from one color to another was found to be most useful as indicating a pH above or below a certain value. For example, pyrophyllite (pH 6) changes phenol red paper to yellow, indicating a pH below 6.8, whereas talc (pH 9) turns this indicator red. Other indicators with useful color changes are: thymol blue—red below pH 2.8, yellow above; methyl orange—red below pH 4.4, yellow above; brom thymol blue—yellow below pH 6.0, blue above; methyl red—red below pH 6.3, yellow above; phenol red—yellow be-

* Most of the tests here recorded were made with Washington, D. C., tap water, which is essentially neutral and gave abrasion pH values identical with distilled water. In the field natural waters may be used. Waters of high alkalinity, acidity, or salinity should not be used.

[7] Clark, W. Mansfield, The determination of hydrogen ions, 3rd ed., pp. 76–94, Baltimore, The Williams and Wilkins Company (1928).

[8] Britton, H. T. S., Hydrogen ions, 2nd ed., London, Chapman and Hall (1932).

[9] Handbook of Chemistry and Physics, 29th ed., 1363–1366, Cleveland, Ohio, Chemical Rubber Publishing Co. (1945).

[10] Lange's Handbook of Chemistry, p. 904, Sandusky, Ohio, Handbook Publishers, Inc. (1937).

low pH 6.8, red above; thymol blue—yellow below pH 8.0, blue above; phenolphthalein—colorless below pH 8.3, red above; alizarin yellow R—yellow below pH 10.1, orange above; Poirrier's blue—blue below pH 11.0, red above.

These indicators may be made up in solution as described by Clark, and strips of filter paper dipped therein and dried.

Prepared indicator papers may be purchased. Accutint papers, prepared by Anachemia, Ltd., Montreal, Canada, have been used extensively in this study. These papers are bound in small booklet form and a color chart for making the estimations is provided. Three wide-range Accutint papers are used for rough estimation and twenty short-range papers allow more precise measurements. pHydrion papers, distributed by Palo-Myers, Inc., New York City, are furnished in a convenient transparent plastic dispenser and consist of 2 wide-range papers covering all pH values, and 6 short-range papers. Nitrazine papers covering the pH range 4.5 to 7.5 are distributed by E. R. Squibb and Sons, New York. These are a few of the many brands of pH indicator papers available.

In using these papers for abrasion pH determinations they are dipped in the mineral suspension and removed to observe the color, mineral particles being retained on the under surface of the paper. Maximum deviation from neutrality is noted in making color comparisons with the chart. Suspensions of many minerals exhibit this maximum deviation on the paper only close to the mineral particles.

Determinations of Abrasion pH of Minerals.

Determinations of abrasion pH of a number of minerals are listed in table 1. In all, 280 minerals have been studied, many of the determinations repeatedly confirmed by results obtained on numerous specimens from different localities. In the table, the minerals giving various abrasion pH values are listed (alphabetically for each pH value), the number of specimens giving the specified values are noted, and abrasion pH values found for other specimens in the present study are given. At the end of the table is an index to the abrasion pH of the various mineral species.

The abrasion pH of minerals has been found to range from pH 1 to pH 12. Many of the mineral species do not vary in abrasion pH from specimen to specimen, whereas others may vary by as much as two or three units. For example, pyrophyllite which is essentially fixed in composition, $Al_2Si_4O_{10}(OH)_2$, gave consistently abrasion pH 6, whereas lepidolite, in which isomorphous substitution of Li for Al is known to occur, gave abrasion pH values of 8 to 9, the higher value representing samples highest in lithium. Biotite, a mineral in which Mg and Fe substitute for each other varied in abrasion pH between 8 and 9, and phlogopite, the magnesium end-member of the series, gave abrasion pH values of 10 and 11.

The abrasion pH of the carbonate minerals of calcium and magnesium should be a useful test for differentiating these minerals in the field. Calcite gives consistently an abrasion pH of around 8, dolomite 9 to 10, and magnesite 10 to 11, thus enabling calcite to be quickly differentiated from these magnesium-containing carbonates. Several indicators are useful for this purpose, the best being phenolphthalein paper. With this indicator paper the abrasion test of calcite gives a colorless reaction (pH below 8.3), whereas dolomite and magnesite give an intense red color. Differentiation between dolomite and magnesite is not as definite, differences in abrasion pH being not as great and the available indicators in that range not as satisfactory.

It was hoped that sufficient differences in abrasion pH would be found to identify the different minerals of the plagioclase feldspar series. However, the calcium end-member, anorthite, $CaAl_2Si_2O_8$, gives an abrasion pH of 8 and the sodium end-member, albite, $NaAlSi_3O_8$, gives values ranging between 9 and 10. The spread in abrasion pH between the two end-members is not wide enough for differentiation of the intermediate plagioclase feldspars.

The differences in abrasion pH are further shown in Fig. 1, illustrating values found for representative minerals. This chart is similar to those published elsewhere to show pH ranges of indicators. The close interdependence of composition to abrasion pH can be readily seen.

The distribution in abrasion pH for the 280 different mineral species tested is illustrated in Fig. 2. Most minerals are nearly neutral or alkaline in reaction.

It is interesting to note that many of the pH groups contain minerals closely associated geologically. Thus minerals giving abrasion pH 1, 2 and 3 are the sulfates commonly formed when the acid solutions from oxidation of pyrite decompose aluminous rocks. Minerals of abrasion pH 10 include numerous borates and a number of minerals found in contact limestones (albite, amphibole, chondrodite, diopside, dolomite, hornblende, idocrase, monticellite, olivine, pectolite, phlogopite, picrolite, prehnite, pyroxene, serpentine, tremolite, and xonotlite). Those of abrasion pH 11 include several rare minerals usually found together, such as hillebrandite, merwinite, thaumasite, spurrite, etc. Soda lime carbonates, which occur together in nature, give abrasion pH 12. In a recent study of the biotite-phlogopite series of micas Heinrich[11] shows that high-

[11] Heinrich, E. Wm., Studies in the mica group; the biotite-phlogopite series: *Am. Jour. Sci.*, **244**, 836–848 (1946).

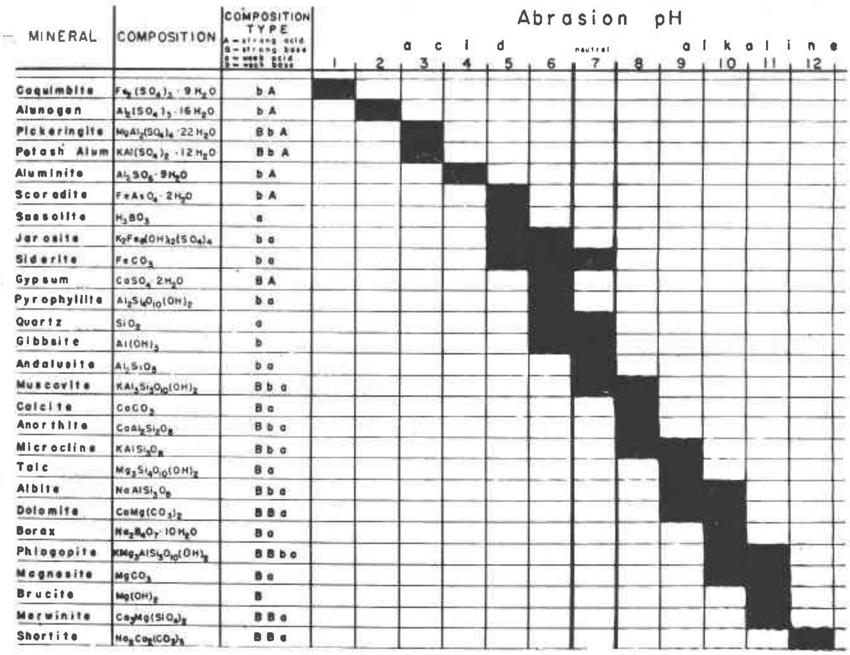

FIG. 1. Abrasion pH values of representative minerals.

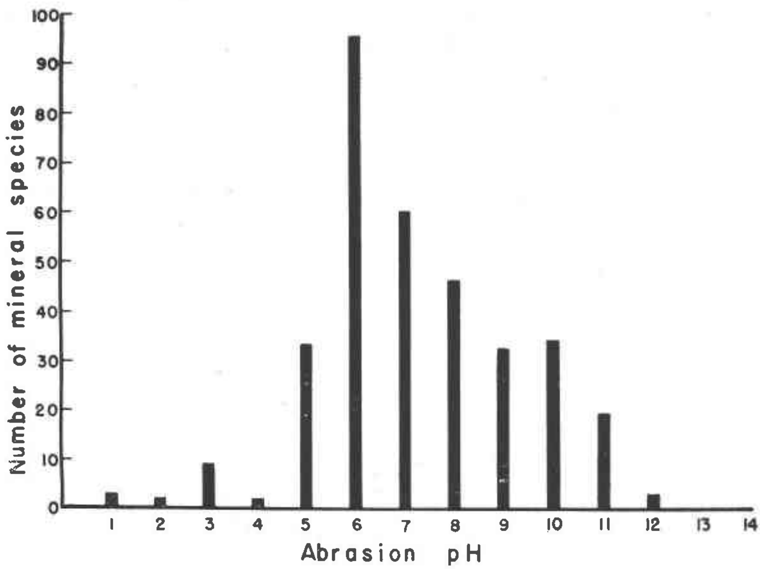

FIG. 2. Abrasion pH distribution of mineral species tested.

iron biotites are associated with the less basic rocks, such as granitic pegmatites, granites, etc., while phlogopites are found in more basic rocks, such as gabbro, peridotite and other ultramafics, and metamorphosed limestones. This occurrence together of minerals of equal abrasion pH is probably not as common for minerals of igneous origin as for those formed in hydrous environments.

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Abrasion pH of Minerals

	Mineral	*Composition*	*Number of specimens*	*Other abrasion pH values*
pH 1	Coquimbite	$Fe_2(SO_4)_3 \cdot 9H_2O$	1	
	Kornelite	$Fe_2(SO_4)_3 \cdot 7\frac{1}{2}H_2O$	1	
	Rhomboclase	$FeH(SO_4)_2 \cdot 4H_2O$	1	
pH 2	Alunogen	$Al_2(SO_4)_3 \cdot 16H_2O$	1	
	Melanterite	$FeSO_4 \cdot 7H_2O$	1	3
pH 3	Alum	$KAl(SO_4)_2 \cdot 12H_2O$	2	
	Botryogen	$Mg_2Fe_2(SO_4)_4(OH)_2 \cdot 14H_2O$	1	
	Copiapite	$Fe_4(OH)_2(SO_4)_5 \cdot 18H_2O$	1	
	Halotrichite	$FeAl_2(SO_4)_4 \cdot 22H_2O$	1	
	Melanterite	$FeSO_4 \cdot 7H_2O$	1	2
	Pickeringite	$MgAl_2(SO_4)_4 \cdot 22H_2O$	9	
	Redingtonite	$(Fe, Mg)(Al, Cr)_2(SO_4)_4 \cdot 22H_2O$	2	
	Tschermigite	$NH_4Al(SO_4)_2 \cdot 12H_2O$	2	
	Vanoxite	$2V_2O_4 \cdot V_2O_5 \cdot 8H_2O$	1	
pH 4	Aluminite	$Al_2SO_6 \cdot 9H_2O$	1	
	Turquois	$H_5(CuOH)[Al(OH)_2]_6(PO_4)_4$	1	6
pH 5	Anglesite	$PbSO_4$	2	
	Blomstrandite	Titanocolumbate of U, Th, Y, Er, Ce, etc.	1	
	Carnallite	$KMgCl_3 \cdot 6H_2O$	1	
	Celestite	$SrSO_4$	2	6
	Cotunnite (art.)	$PbCl_2$	1	
	Cyrtolite	Altered $ZrSiO_4$	2	6, 7
	Diadochite	Basic iron sulfate-phosphate	2	
	Evansite	$2AlPO_4 \cdot 4Al(OH)_3 \cdot 12H_2O$	1	
	Glauconite	$K_2(Mg, Fe)_2Al_6(Si_4O_{10})_3(OH)_2$	1	
	Jarosite	$K_2Fe_6(OH)_{12}(SO_4)_4$	4	6
	Kaolinite	$Al_2Si_2O_5(OH)_4$	1	6, 7
	Minervite	Hydrous phosphate of K and Al	1	

	Mineral	Composition	Number of specimens	Other abrasions pH value
	Monazite	Essentially (Ce, La, Pr, Nd)PO_4	2	6
	Nontronite	$FeSi_2O_5(OH) \cdot nH_2O$	2	6
	Paligorskite	Hydrous Mg Al silicate	1	7
	Plumbojarosite	$PbFe_6(OH)_{12}(SO_4)_4$	1	
	Polyhalite	$2CaSO_4 \cdot MgSO_4 \cdot K_2SO_4 \cdot 2H_2O$	2	6
	Pseudoboléite	$5PbCl_2 \cdot 4CuO \cdot 6H_2O$	1	
	Pseudowavellite	$CaAl_3(PO_4)_2(OH)_5 \cdot H_2O$	1	
	Rectorite	Appx. $NaAl_5Si_7O_{20}(OH)_4 \cdot 4H_2O$	1	
	Rhagite	$2BiAsO_4 \cdot 3Bi(OH)_3$	1	
	Sassolite	H_3BO_3	3	
	Scorodite	$FeAsO_4 \cdot 2H_2O$	2	
	Siderite	$FeCO_3$	1	6, 7
	Spencerite	$Zn(PO_4)_2 \cdot Zn(OH)_2 \cdot 3H_2O$	1	
	Sphalerite	ZnS	1	6
	Staurolite	$FeAl_4Si_2O_{10}(OH)_2$	1	6, 7
	Stibiotantalite	$Sb_2(Ta, Cb)_2O_8$	1	
	Uraninite (pitchblende)	UO_2	1	6
	Vanadinite	$3Pb_3V_2O_8 \cdot PbCl_2$	2	6
	Variscite	$AlPO_4 \cdot 2H_2O$	1	6
	Vivianite	$Fe_3P_2O_8 \cdot 8H_2O$	2	
	Wavellite	$4AlPO_4 \cdot 2Al(OH)_3 \cdot 9H_2O$	1	
pH 6	Alunite	$KAl_6(OH)_{12}(SO_4)_4$	5	
	Anhydrite	$CaSO_4$	4	
	Arseniosiderite	$Ca_3Fe(AsO_4)_3 \cdot 3Fe(OH)_3$	1	
	Barite	$BaSO_4$	1	
	Bastnaesite	(Ce, La, Pr, Nd)FCO_3	1	
	Beaverite	$CuO \cdot PbO \cdot Fe_2O_3 \cdot 2SO_3 \cdot 4H_2O$	1	
	Beryl	$Be_3Al_2Si_6O_{18}$	6	7
	Betafite	Titanocolumbate of U, etc.	6	
	Bismutite	$Bi_2CO_5 \cdot H_2O$	1	
	Bloedite	$MgSO_4 \cdot Na_2SO_4 \cdot 4H_2O$	1	
	Boehmite	$AlO(OH)$	1	7
	Boléite	$9PbCl_2 \cdot 8CuO \cdot 3AgCl \cdot 9H_2O$	1	
	Brookite	TiO_2	1	
	Cassiterite	SnO_2	2	
	Celestite	$SrSO_4$	2	5
	Cerussite	$PbCO_3$	1	
	Chrysoberyl	$BeAl_2O_4$	1	7
	Chrysocolla	$CuSiO_3 \cdot 2H_2O$	1	
	Columbite	(Fe, Mn)(Cb, Ta)$_2O_6$	1	
	Cryolite	Na_3AlF_6	1	7
	Cuprotungstite	$Cu_2WO_5 \cdot H_2O$	1	
	Cyrtolite	Altered $ZrSiO_4$	1	5, 7
	Descloisite	$PbZnVO_4(OH)$	1	
	Diaspore	$HAlO_2$	3	7
	Dickite	$Al_2Si_2O_5(OH)_4$	7	

Mineral	*Composition*	*Number of specimens*	*Other abrasion pH values*
Dumortierite	$Al_8BSi_3O_{19}(OH)$	4	7
Eosphorite	$AlPO_4 \cdot Mn(OH)_2 \cdot H_2O$	1	
Euxenite	Columbate and titanothorate of Y, Er, Ce, U	1	
Fayalite	Fe_2SiO_4	1	
Flajolotite	$4FeSbO_4 \cdot 3H_2O$	1	
Francolite	$3Ca_3P_2O_8 \cdot Ca[F_2, (OH)_2, CO_3]$	1	7
Fremontite	$(Na, Li)Al(OH, F)PO_4$	1	
Gibbsite	$Al(OH)_3$	1	7
Glauberite	$Na_2SO_4 \cdot CaSO_4$	2	
Greenalite	Hydrous ferrous silicate	1	
Gypsum	$CaSO_4 \cdot 2H_2O$	12	
Halite	NaCl	9	
Halloysite	$Al_2Si_2O_5(OH)_4+H_2O$	4	
Hematite	Fe_2O_3	1	
Hemimorphite	$Zn_2SiO_3(OH)_2$	2	7
Herderite	$CaBe(F, OH)PO_4$	1	
Hinsdalite	$2PbO \cdot 3Al_2O_3 \cdot P_2O_5 \cdot 2SO_3 \cdot 6H_2O$	1	
Huebnerite	$MnWO_4$	3	
Hureaulite	$H_2Mn_5(PO_4)_4 \cdot 4H_2O$	1	
Ilmenite	$FeTiO_3$	2	
Ilmenorutile	$TiO_2 \cdot nFe(Cb, Ta)_2O_6$	1	
Jarosite	$K_2Fe_6(OH)_{12}(SO_4)_4$	1	5
Kaolinite	$Al_2Si_2O_5(OH)_4$	1	5, 7
Kieserite	$MgSO_4 \cdot H_2O$	1	
Kyanite	Al_2SiO_5	4	
Langbeinite	$K_2Mg_2(SO_4)_3$	1	
Lanthanite	$(La, Pr, Nd, Ce)_2(CO_3)_3 \cdot 8H_2O$	1	
Lepidocrocite	$FeO(OH)$	1	
Manganotantalite	$(Fe, Mn)(Cb, Ta)_2O_6$	1	
Mirabilite	$Na_2SO_4 \cdot 10H_2O$	1	
Monazite	$(Ce, La, Pr, Nd)PO_4$	1	5
Montmorillonite	$(Al_2, Mg_3)Si_4O_{10}(OH)_2 \cdot nH_2O$	2	7
Montmorillonite (Bentonite)	Ditto	2	
Mottramite	$PbCuVO_4(OH)$	2	
Nitre	KNO_3	2	
Nitrocalcite	$Ca(NO_3)_2 \cdot 4H_2O$	1	
Nontronite	$FeSi_2O_5(OH) \cdot nH_2O$	3	5
Olivenite	$Cu_3As_2O_8 \cdot Cu(OH)_2$	1	
Opal	$SiO_2 \cdot nH_2O$	1	7
Pinite	Near muscovite	1	
Planchéite	$3CuSiO_3 \cdot H_2O$	1	
Polyhalite	$2CaSO_4 \cdot MgSO_4 \cdot K_2SO_4 \cdot 2H_2O$	1	5
Pyrophyllite	$Al_2Si_4O_{10}(OH)_2$	9	
Quartz	SiO_2	1	7
Quartz (amethyst)	SiO_2	1	7

	Mineral	*Composition*	*Number of specimens*	*Other abrasion pH values*
	Reddingite	$Mn_3P_2O_8 \cdot 3H_2O$	1	
	Rhodochrosite	$MnCO_3$	1	7
	Rutile	TiO_2	1	7
	Salammoniac	NH_4Cl	1	
	Samarskite	(Y, Er, Ce, U, Ca, Fe, Pb, Th) (Cb, Ta, Ti, Sn)$_2O_6$	4	
	Scheelite	$CaWO_4$	3	7
	Siderite	$FeCO_3$	2	5, 7
	Soda nitre	$NaNO_3$	1	
	Sphalerite	ZnS	1	5
	Staurolite	$FeAl_4Si_2O_{10}(OH)_2$	2	5, 7
	Sulfur	S	1	
	Sylvite	KCl	2	
	Tantalite	(Fe, Mn)(Cb, Ta)$_2O_6$	1	
	Thorotungstite	W and Th oxides	1	
	Topaz	$Al_2SiO_4(F, OH)_2$	1	7
	Torbernite	$Cu(UO_2)_2P_2O_8 \cdot 8H_2O$	1	
	Triplite	(Fe, Mn, Mg)PO_4F	1	
	Tungstite	$WO_3 \cdot H_2O$	1	
	Turquois	$H_5(CuOH)[Al(OH)_2]_6(PO_4)_4$	2	4
	Uraninite (pitchblende)	UO_2	2	5
	Vanadinite	$3Pb_3V_2O_8 \cdot PbCl_2$	1	5
	Vanthoffite	$3Na_2SO_4 \cdot MgSO_4$	1	
	Variscite (lucinite)	$AlPO_4 \cdot 2H_2O$	1	5
	Wolframite	(Fe, Mn)WO_4	1	
	Wulfenite	$PbMoO_4$	1	
	Zircon	$ZrSiO_4$	2	
pH 7	Allanite	(Ca, Ce, La, Na)$_2$(Al, Fe, Mn, Be, Mg)$_3(SiO_4)_3OH$	2	8
	Andalusite	Al_2SiO_5	4	
	Annabergite	$Ni_3As_2O_8 \cdot 8H_2O$	1	
	Aurichalcite	2(Zn, Cu)$CO_3 \cdot$3(Zn, Cu)$(OH)_2$	1	
	Azurite	$2CuCO_3 \cdot Cu(OH)_2$	1	
	Beidellite	Similar to montmorillonite	1	
	Beryl	$Be_3Al_2Si_6O_{18}$	6	6
	Boehmite	AlO(OH)	1	6
	Brushite (art.)	$HCaPO_4 \cdot 2H_2O$	1	
	Carnotite	$K_2(UO_2)_2(VO_4)_2 \cdot 8H_2O$	1	
	Cerite	(Ce, Y, Pr, Nd)$_2Si_2O_7 \cdot H_2O$	1	
	Chlorite	(Mg, Fe)$_5Al_2Si_3O_{10}(OH)_8$ (var.)	2	8
	Chloritoid	(Fe, Mg)$_2Al_4Si_2O_{10}(OH)_4$ (var.)	1	
	Chrysoberyl	$BeAl_2O_4$	1	6
	Collophanite	$3Ca_3P_2O_8 \cdot Ca[F_2, (OH)_2, CO_3]$	1	
	Corundum	Al_2O_3	1	
	Cryolite	Na_3AlF_6	1	6
	Cyrtolite	Altered $ZrSiO_4$	1	5, 6

Mineral	*Composition*	*Number of specimens*	*Other abrasion pH values*
Danalite	$(Fe, Mn, Zn)_4Be_3Si_3O_{12}S$	2	
Diaspore	$HAlO_2$	1	6
Dickinsonite	$H_2Na(Mn, Fe)_{14}(PO_4)_{12} \cdot H_2O$	1	
Dumortierite	$Al_8BSi_3O_{19}(OH)$	3	6
Fairfieldite	$Ca_2MnP_2O_8 \cdot 2H_2O$	2	
Fillowite	$3(Mn, Fe, Na_2)_3P_2O_8 \cdot H_2O$	1	
Fluorite	CaF_2	5	
Francolite	$3Ca_3P_2O_8 \cdot Ca[F_2, (OH)_2, CO_3]$	1	6
Fuchsite	$K(Al, Cr)_2AlSi_3O_{10}(OH)_2$	2	
Gahnite	$ZnAl_2O_4$	1	
Garnet	$(Mg, Fe^{++}, Mn^{++}, Ca)_3(Al, Fe^{+++}, Cr, Ti, Mn^{+++})_2(SiO_4)_3$	3	
Gearksutite	$CaF_2 \cdot Al(F, OH)_3 \cdot H_2O$	1	
Gibbsite	$Al(OH)_3$	1	6
Grunerite	$(Mn, Fe, Mg)Si_8O_{22}(OH)_2$	1	
Hambergite	$Be_2(OH)BO_3$	1	
Helvite	$(Mn, Fe, Zn)_4Be_3Si_3O_{12}S$	1	
Hemimorphite	$Zn_2SiO_3(OH)_2$	4	6
Hulsite	$Fe_4^{++}Fe_2^{+++}B_2O_{10}$ with Mg and Sn	1	
Kaolinite	$Al_2Si_2O_5(OH)_4$	1	5, 6
Malachite	$CuCO_3 \cdot Cu(OH)_2$	1	
Montmorillonite	$(Al_2, Mg_3)Si_4O_{10}(OH)_2 \cdot nH_2O$	3	6
Muscovite (sericite)	$KAl_3Si_3O_{10}(OH)_2$	1	8
Opal	$SiO_2 \cdot nH_2O$	1	6
Paligorskite	Hydrous MgAl silicate	1	5
Parsettensite	$Mn_4Si_4O_{10}(OH)_4 \cdot 3H_2O$	1	
Petalite	$LiAlSi_4O_{10}$	2	8
Pyroxmangite	$(Mn, Fe)SiO_3$	1	
Quartz	SiO_2	1	6
Quartz (amethyst)	SiO_2	1	6
Rhodochrosite	$MnCO_3$	1	6
Rutile	TiO_2	1	6
Scapolite	$(Na, Ca)_8Al_6(Al, Si)_6Si_{12}O_{48}(Cl_2, CO_3)$	1	8
Scheelite	$CaWO_4$	1	6
Siderite	$FeCO_3$	2	5, 6
Sillimanite	Al_2SiO_5	3	
Smithsonite	$ZnCO_3$	1	
Spinel	$MgAl_2O_4$	1	
Staurolite	$FeAl_4Si_2O_{10}(OH)_2$	1	5, 6
Stilbite	$(Ca, Na, K)_3Al_5(Al, Si)Si_{14}O_{40} \cdot 15H_2O$	1	8
Strontianite	$SrCO_3$	1	8
Thenardite	Na_2SO_4	1	
Thorianite	$(Th, U)O_2$	1	
Topaz	$Al_2SiO_4(F, OH)_2$	2	6
Tourmaline	$(Na, Ca)(Mg, Fe^{++}, Fe^{+++})_3 B_3Al_3(Al_3Si_6O_{27})(O, OH)_4$	5	8
Triploidite	$(Fe, Mn)OH \cdot (Fe, Mn)PO_4$	1	

	Mineral	Composition	Number of specimens	Other abrasion pH values
pH 8	Allanite	$(Ca, Ce, La, Na)_2(Al, Fe, Mn, Be, Mg)_3(SiO_4)_3OH$	1	7
	Amblygonite	$LiAl(F, OH)PO_4$	1	
	Anorthite	$CaAl_2Si_2O_8$	1	
	Anthophyllite	$(Mg, Fe)_7Si_8O_{22}(OH)_2$	5	9
	Apatite	$Ca_3P_2O_8 \cdot Ca[F_2, Cl_2, (OH)_2, O, CO_3, SO_4]$	6	
	Aragonite	$CaCO_3$	3	
	Bementite	$Mn_5Si_4O_{10}(OH)_6$	1	9
	Benitoite	$BaTiSi_3O_9$	1	
	Biotite	$K(Mg, Fe)_3AlSi_3O_{10}(OH)_2$	3	9
	Calcite	$CaCO_3$	16	
	Chlorite	$(Mg, Fe)_5Al_2Si_3O_{10}(OH)_8$ (var.)	2	7
	Chondrodite	$Mg_5(SiO_4)_2(F, OH)_2$	1	10
	Cryophyllite	$K_2Fe_2^{++}Li_3Al_3Si_7O_{20}(OH, F)_4$	1	
	Epidote	$Ca_2(Al, Fe)_3Si_3O_{12}(OH)$	5	
	Gillespite	$BaFeSi_4O_{10}$	1	
	Hectorite	Li, Mg end-member montmorillonite	1	
	Heulandite	$(Ca, Na, K)_6Al_{10}(Al, Si)Si_{29}O_{80} \cdot 25H_2O$	1	
	Hypersthene	$(Fe, Mg)SiO_3$	1	
	Labradorite	$Ab_{50-30}An_{50-70}$	2	9
	Larderellite	$(NH_4)_2B_{10}O_{16} \cdot 5H_2O$	1	
	Lawsonite	$CaAl_2Si_2O_7(OH)_2 \cdot H_2O$	1	
	Lepidolite	Lithium mica	5	9
	Lithiophyllite	$Li(Mn, Fe)PO_4$	2	
	Ludwigite	$Mg_4Fe_2B_2O_{10}$	1	
	Margarite	$CaAl_4Si_2O_{10}(OH)_2$	3	9
	Microcline	$KAlSi_3O_8$	4	9
	Muscovite	$KAl_3Si_3O_{10}(OH)_2$	7	7
	Nahcolite	$NaHCO_3$	1	
	Orthoclase	$KAlSi_3O_8$	6	
	Petalite	$LiAlSi_4O_{10}$	1	7
	Phillipsite	$(Ca, Ba, K, Na)_3Al_4(Al, Si)Si_5O_{20} \cdot 10H_2O$	1	
	Pollucite	$(Cs, Na, K)_4(Si, Al)_{13}O_{26} \cdot H_2O$	6	
	Rhodonite	$MnSiO_3$	3	
	Roscoelite	$KV_2AlSi_3O_{10}(OH)_2$ (var.)	1	
	Scapolite	$(Na, Ca)_8Al_6(Al, Si)_6Si_{12}O_{48}(Cl_2, CO_3)$	3	7
	Scolecite	$CaAl_2Si_3O_{10} \cdot 3H_2O$	1	
	Sepiolite	$Mg_2Si_3O_6(OH)_4$	1	
	Serpentine (ferruginous)	$(Mg, Fe)_3Si_2O_5(OH)_4$	1	10
	Spodumene	$LiAlSi_2O_6$	2	
	Stilbite	$(Ca, Na, K)_3Al_5(Al, Si)Si_{14}O_{40} \cdot 15H_2O$	2	7
	Strontianite	$SrCO_3$	1	7
	Tourmaline	$(Na, Ca)(Mg, Fe^{++}, Fe^{+++})_3B_3Al_3(Al_3Si_6O_{27})(O, OH)_4$	1	7
	Vermiculite	$(Mg, Fe)_3(Al, Fe)AlSi_3O_{10}(OH)_4 \cdot 4H_2O$	1	9
	Witherite	$BaCO_3$	1	

	Mineral	Composition	Number of specimens	Other abrasion pH values
	Zincite	ZnO	1	
	Zinnwaldite	$KLiMgAl_2Si_3O_{10}(OH, F)_2$	3	
pH 9	Aegirite	$(Ca, Na)(Mg, Fe, Al)Si_2O_6$	3	
	Albite	$NaAlSi_3O_8$	1	10
	Albite (peristerite)	Ditto	1	
	Alleghenyite	$Mn_5(SiO_4)_2(OH, F)_2$	1	
	Anthophyllite	$(Mg, Fe)_7Si_8O_{22}(OH)_2$	4	8
	Bavenite	$Ca_4BeAl_2Si_9O_{25}(OH)_2$	1	
	Bementite	$Mn_5Si_4O_{10}(OH)_6$	3	8
	Biotite	$K(Mg, Fe)_3AlSi_3O_{10}(OH)_2$	1	8
	Chabazite	$(Ca, Na, K)_7Al_{12}(Al, Si)_2Si_{26}O_{80} \cdot 40H_2O$	1	
	Chlorite (sheridanite)	$Mg_5Al_2Si_3O_{10}(OH)_8$	1	
	Clinochlore	$(Mg, Fe)_5Al_2Si_3O_{10}(OH)_8$	2	
	Colemanite	$Ca_2B_6O_{11} \cdot 5H_2O$	1	10
	Danburite	$CaB_2Si_2O_8$	1	
	Deweylite	$4MgO \cdot 3SiO_2 \cdot 6H_2O$	1	
	Dolomite	$CaMg(CO_3)_2$	1	10
	Idocrase	$Ca_{10}Al_4(Mg, Fe)_2Si_9O_{34}(OH)_4$	3	10
	Imerinite	Sodium amphibole	1	
	Inyoite	$2CaO \cdot 3B_2O_3 \cdot 13H_2O$	1	
	Kotschubeite	$(Mg, Fe)_5Al_2Si_3O_{10}(OH)_8$	1	
	Labradorite	$Ab_{50-30}An_{50-70}$	2	8
	Lepidolite	Lithium mica	3	8
	Margarite	$CaAl_4Si_2O_{10}(OH)_2$	1	8
	Microcline	$KAlSi_3O_8$	4	8
	Oligoclase	$Ab_{90-70}An_{10-30}$	3	
	Polylithionite	$KLi_2AlSi_4O_{10}F_2$	1	
	Serendibite	$CaMg_2Al_3BSi_2O_{13}$	1	
	Sphene	$CaTiSiO_5$	3	
	Talc	$Mg_3Si_4O_{10}(OH)_2$	5	
	Ulexite	$NaCaB_5O_9 \cdot 8H_2O$	2	10
	Vermiculite	$(Mg, Fe)_3(Al, Fe)AlSi_3O_{10}(OH)_4 \cdot 4H_2O$	1	8
	Xanthophyllite (walueite)	$CaMg_2Al_4SiO_{10}(OH)_2$	1	
	Zoisite	$Ca_2Al_3Si_3O_{12}(OH)$	8	
pH 10	Albite	$NaAlSi_3O_8$	2	9
	Amphibole	$(Mg, Fe, Ca, Al)_7(Si, Al)_8O_{22}(OH, F)_2$	1	
	Augite	$Ca(Mg, Fe, Al)(Al, Si)_2O_6$	3	
	Borax	$Na_2B_4O_7 \cdot 10H_2O$	1	
	Chondrodite	$Mg_5(SiO_4)_2(F, OH)_2$	1	8
	Colemanite	$Ca_2B_6O_{11} \cdot 5H_2O$	3	9
	Datolite	$CaBSiO_4(OH)$	3	11
	Diopside	$CaMgSi_2O_6$	6	11
	Diopside (violane)	Ditto	1	
	Dolomite	$CaMg(CO_3)_2$	2	9

	Mineral	*Composition*	*Number of specimens*	*Other abrasion pH values*
	Hornblende	$Ca_2Na(Mg, Fe^{++})_4(Al, Fe^{+++}, Ti)_3 Si_6O_{22}(O, OH)_2$	1	
	Howlite	$Ca_2SiB_5O_9(OH)_5$	3	
	Idocrase	$Ca_{10}Al_4(Mg, Fe)_2Si_9O_{34}(OH)_4$	4	9
	Inesite	$Mn_7Ca_2Si_{10}O_{28}(OH)_2 \cdot 5H_2O$	1	
	Jeffersonite	$Ca(Mg, Mn, Fe, Zn)Si_2O_6$	1	
	Kernite	$Na_2B_4O_7 \cdot 4H_2O$	1	
	Leucite	$(Ca, Na, K)(Al, Si)_2O_6$	1	
	Magnesite	$MgCO_3$	1	11
	Monticellite	$CaMgSiO_4$	1	
	Natrolite	$Na_2Al_2Si_3O_{10} \cdot 2H_2O$	3	
	Nesquehonite	$MgCO_3 \cdot 3H_2O$	1	
	Olivine (chrysolite)	$(Mg, Fe)_2SiO_4$	1	11
	Pectolite	$Ca_2NaSi_3O_8(OH)$	1	11
	Phlogopite	$KMg_3AlSi_3O_{10}(OH)_2$	5	11
	Prehnite	$Ca_2Al_2Si_3O_{10}(OH)_2$	2	
	Pyroxene	$(Ca, Mg, Fe, Mn, Zn)SiO_3$	1	
	Roweite	$H_2(Mn, Mg, Zn)Ca(BO_3)_2$	1	
	Searlesite	$NaB(SiO_3)_2 \cdot H_2O$	1	
	Serpentine	$Mg_3Si_2O_5(OH)_4$	2	8
	Serpentine (picrolite)	Ditto	1	
	Sodalite	$Na_4Al_3Si_3O_{12}Cl$	3	
	Szaibelyite	$Mg_2B_2O_5 \cdot H_2O$	2	
	Tremolite	$Ca_2Mg_5(OH)_2(Si_4O_{11})_2$	1	11
	Trona	$Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$	1	
	Ulexite	$NaCaB_5O_9 \cdot 8H_2O$	2	9
	Xonotlite	$Ca_3Si_3O_8(OH)_2$	1	11
	Zeophyllite	$Ca_8Si_6O_{15}(OH, F)_{10}$	1	
pH 11	Actinolite	$Ca_2(Mg, Fe)_5Si_8O_{22}(OH)_2$	4	
	Apophyllite	$KCa_4Si_4O_{10}F_2 \cdot 8H_2O$	3	
	Bakerite	$Ca_8B_{10}Si_6O_{35} \cdot 6H_2O$	1	
	Brucite	$Mg(OH)_2$	3	
	Datolite	$CaBSiO_4(OH)$	1	10
	Diopside	$CaMgSi_2O_6$	1	10
	Hanksite	$9Na_2SO_4 \cdot 2Na_2CO_3 \cdot KCl$	1	
	Hillebrandite	$Ca_2SiO_3(OH)_2$	1	
	Magnesite	$MgCO_3$	3	10
	Merwinite	$Ca_3Mg(SiO_4)_2$	1	
	Olivine	$(Mg, Fe)_2SiO_4$	5	10
	Pectolite	$Ca_2NaSi_3O_8(OH)$	2	10
	Phlogopite	$KMg_3AlSi_3O_{10}(OH)_2$	2	10
	Roeblingite	$2PbSO_4 \cdot Ca_7Si_6O_{14}(OH)_{10}$	1	
	Spurrite	$2Ca_2SiO_4 \cdot CaCO_3$	1	
	Thaumasite	$CaSiO_3 \cdot CaCO_3 \cdot CaSO_4 \cdot 15H_2O$	3	
	Tremolite	$Ca_2Mg_5(OH)_2(Si_4O_{11})_2$	5	10

	Mineral	Composition	Number of specimens	Other abrasion pH values
	Wollastonite	$CaSiO_3$	5	
	Xonotlite	$Ca_3Si_3O_8(OH)_2$	1	10
pH 12	Gaylussite	$CaCO_3 \cdot Na_2CO_3 \cdot 5H_2O$	1	
	Pirssonite	$CaCO_3 \cdot Na_2CO_3 \cdot 2H_2O$	1	
	Shortite	$Na_2Ca_2(CO_3)_2$	1	

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