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I.—*Application of Organic Acids to the Examination of Minerals.*

[Second Paper.]

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26. The behavior of minerals with organic acids has already formed the subject-matter of two papers read before the Academy in 1877 and 1878, and we now present the results of a continuation of our researches.

In our first paper* we described several new methods of attacking minerals, and their application to ninety-five specimens; in the following pages we extend the investigation to one hundred and six additional minerals. These methods of decomposition were as follows :—

- 1st. Treatment with a cold saturated solution of citric acid.
- 2d. Treatment with a boiling solution of the same.
- 3d. Heating with a saturated solution of citric acid to which sodium nitrate is added.
- 4th. Heating with a saturated solution of citric acid to which ammonium fluoride is added.

And in a second paper, under another title,† we added a fifth reaction :—

- 5th. Heating with a concentrated solution of citric acid to which potassium iodide is added.

* *Annals N. Y. Acad. Sci.*, Vol. I, p. 1.

† *Behavior of Natural Sulphides with Iodine and other Reagents. Annals N. Y. Acad. Sci.*, Vol. I, p. 153.

Similar reactions with oxalic, tartaric, acetic, and other organic acids, were described in the first paper, but preference is given to citric acid on account of its greater solvent power.

Minerals belonging to several groups were submitted to these processes, and gave phenomena which may be summarized as follows :

- 1st. More or less complete decomposition and solution of oxides, phosphates, etc., without formation of precipitates or liberation of gases.
- 2d. Complete solution of carbonates with evolution of carbonic anhydride.
- 3d. Decomposition of sulphides with evolution of sulphuretted hydrogen.
- 4th. Decomposition of sulphides with oxidation of the sulphur.
- 5th. More or less perfect decomposition of silicates with separation of either slimy or gelatinous silica.
- 6th. Decomposition of certain species by reagents forming characteristic precipitates.
- 7th. Wholly negative action.

These facts demonstrated that citric acid has a power of decomposing minerals little less than that possessed by hydrochloric acid, and that this very difference in degree gives the organic acid an advantage over the mineral acid in the determination of species.

27. This peculiar selective power of citric acid rendered desirable a further study of its action on a larger number of minerals ; the following list contains the names of the species which have since been submitted to the process named, together with their formulæ, condition, and locality.

Within the groups,—I, Sulphides, Arsenides, Tellurides, etc., —II, Oxides,—III, Silicates, and—IV, Sundries, the minerals are arranged in the order in which they are given in Dana's System of Mineralogy.

We desire to express our thanks to Prof. Thomas Egleston, of the School of Mines, Columbia College, who has again placed us under obligations by supplying many of the rarer minerals.

I. SULPHIDES, ARSENIDES, ETC.

MINERAL	FORMULA	DESCRIPTION	LOCALITY
Sulphur.....	S ₈	massive.....	Humboldt, Nev.
Realgar.....	As S	crystalline.....	Hungary.
Orpiment.....	As ₂ S ₃	crystals.....	Hungary.
Bismuthinite.....	Bi ₂ S ₃	in quartz.....	Clear Creek, Col.
Domeykite.....	Cu ₂ As ₂	massive.....	Chili, S. A.
Clausthalite.....	Pb Se	—.....	Tilkerode, Hartz.
Alabandite.....	Mn S	crystalline.....	Mexico.
Hessite.....	Ag Te	—.....	Boulder, Col.
Tiemannite.....	Hg Se	incrusting.....	Clausthal, Hartz.
Millerite.....	Ni S	crystalline.....	Lancaster Co., Pa.
Linnaeite.....	2 Co S + Co S ₂	crystals.....	Musen, Prussia.
Cobaltite.....	Co (S, As) ₂	grains.....	Tunaberg, Sweden.
Leucopyrite.....	Fe As ₂	massive.....	Breitenbrunn, Saxony.
Nagragite.....	2 (Pb, Au) + 3 (Te, Sb, S.)	foliated.....	Austria.
Covellite.....	Cu S ₂	massive.....	Germany.
Berthierite.....	Fe S + Sb ₂ S ₃	crystalline.....	Brannsdorff, Saxony.
Jamesonite.....	2 (Pb, Fe) S + Sb ₂ S ₃	fibrous.....	—
Pyrrargyrite.....	3 Ag S + Sb ₂ S ₃	massive.....	Chili.
Proustite.....	3 Ag S + As ₂ S ₃	massive.....	Chili.

Boulangerite.....	$3 \text{ Pb S} + \text{Sb}_2 \text{ S}_3$	massive.....
Tennantite.....	$4 (\text{Cu Fe}) \text{ S} + \text{As}_2 \text{ S}_3$	crystalline.....Cornwall, England.
Stephanite.....	$5 \text{ Ag S} + \text{Sb}_2 \text{ S}_3$	massive.....Mexico.
Polybasite.....	$9 (\text{Ag Cu}) \text{ S} + (\text{Sb, As})_2 \text{ S}_3$	massive.....
Enargite.....	$3 \text{ Cu S} + \text{As}_2 \text{ S}_3$	massive.....Gilpin Co., Colorado.
Kermesite.....	$2 \text{ Sb S}_2 + \text{Sb O}_2$	crystalline.....Braunsdorf, Saxony.

II. OXIDES.

MINERAL.	FORMULA.	DESCRIPTION.	LOCALITY.
Melaconite.....	Cu O	massive.....	Copper Harbor, L. S.
Corundum.....	$\text{Al}_2 \text{ O}_3$	white, massive.....	North Carolina.
Menacaunte.....	$(\text{Ti, Fe}) \text{ O}_2$	crystals.....	Ilmen Mts., Russia.
Washingtonite.....	$(\text{Ti, Fe}) \text{ O}_2$	crystals.....	Litchfield, Conn.
Spinel.....	Mg Al_2	crystals.....	Franklin, N. J.
Chrysoberyl.....	Be Al_2	crystals.....	Brazil
Cassiterite.....	Sn	crystals.....	Cornwall, England.
Rutile.....	Ti	crystals.....	York, Pa.
Braunite.....	$2 \text{ Mn, Mn} + \text{Mn Si}$	crystalline.....	Thuringia.
Goethite.....	Fe H	crystalline.....	Easton, Pa.
Gummite.....	$(\text{U Fe}) + \text{H}$	amorphous.....	North Carolina.

Quartz..... $\ddot{\text{Si}}$
 Hyalite..... $\ddot{\text{Si}} + \text{aq.}$
 crystals.....Conn.
 mammillary.....Wallach, Bohemia.

III. SILICATES.

MINERAL	FORMULA	DESCRIPTION	LOCALITY
Enstatite.....	Mg Si	massive.....	North Carolina.
Hypersthene.....	$(\text{Mg Fe}) \text{Si}$	massive.....	Labrador.
Petalite.....	$(\frac{1}{2}\text{R}_2 + \frac{1}{2}\ddot{\text{R}}) \text{Si}_2 + 3 \text{Si}$	massive.....	Sweden.
Pargasite.....	$(\text{R}_2, \ddot{\text{R}}) (\text{Si } \ddot{\text{Al}} \ddot{\text{F}})$	massive.....	Diana, N. Y.
Actinolite.....	$(\text{Ca Mg Fe}) \text{Si}$	crystals.....	Orbow, N. Y.
Asbestos.....	$(\text{R}_2, \ddot{\text{R}}) (\text{Si } \ddot{\text{Al}} \ddot{\text{F}})$	silky fibrous.....	-----
Beryl.....	$(\frac{1}{3}\text{Be}_2 + \ddot{\text{Al}} \frac{1}{2}) \text{Si}_2$	transp. crystals.....	Brazil.
Tephroite.....	$\text{Mn}_2 \text{Si}$	massive.....	Franklin, N. J.
Pyrope.....	$(\frac{1}{2}(\text{Mg, Ca, Fe, Mn})_2 + \frac{1}{2}\ddot{\text{Al}} \frac{1}{2}) \text{Si}_2$	crystals.....	Bohemia.
Colophonite.....	$(\frac{1}{2}\text{R}_2 + \frac{1}{2}\ddot{\text{R}}) \text{Si}_2$	crystals.....	Willaborough, N. Y.
Zircon.....	Zr Si	crystals.....	North Carolina.
Vesuvianite.....	$(\frac{1}{2}\text{R}_2 + \frac{1}{2}\ddot{\text{R}}) \text{Si}_2$	crystals.....	Moldavia.
Allanite.....	$\text{Si}_2, \ddot{\text{Al}}, \text{Fe, Mn, Ca, La, Dd, Y, H}$	partially decomposed.....	Virginia.
Zoisite.....	$(\frac{1}{2}\text{Ca}_2 + \frac{1}{2}\ddot{\text{Al}} \frac{1}{2}) \text{Si}_2$	massive.....	Conway, Mass.
Ilvaite.....	$(\frac{1}{2}\text{R}_2 + \frac{1}{2}\ddot{\text{R}}) \text{Si}_2$	massive.....	Hartz Mts.

Icolite	Si, Al, Fe, Mg	translucent.....Finland.
Phlogopite	($\frac{1}{2}$ R, + $\frac{1}{4}$ H; Si,	milky.....Moutville, N. J.
Lepidolite	Si, Al, Fe, Li, K, F	unicaceous.....Paris, Maine.
Nephelite	($\frac{1}{2}$ R, + $\frac{1}{4}$ H; Si, + $\frac{1}{4}$ Si	mixed with biotite....Vesuvius.
Lapis lazuli	Si, Al, Ca, Na, S.	massive.....Brazil.
Leucite	K Si + Al Si,	crystals.....Vesuvius.
Anorthite	($\frac{1}{2}$ R, + $\frac{1}{4}$ H; Si,	massive.....Tunaberg, Sweden.
Oligoclase	($\frac{1}{2}$ Na, Ca, + $\frac{1}{4}$ H; Si, + $\frac{3}{4}$ Si	massive.....Chester Co., Pa.
Andalusite.	Al Si	crystals.....Bavaria.
Fibrolite	Al Si	crystalline.....Wilmington, Del.
Topaz	Al Si	crystals.....Brazil.
Titanite	(Ca + Ti) Si	crystals.....Diana, N. Y.
Staurolite	($\frac{1}{2}$ R, + $\frac{1}{4}$ H; Si,	crystals....Franconia, N. H.
Laumontite	Si, Al, Ca, H	crystals.....Peter's Point, N. S.
Thomsonite	2 Si, Al ($\frac{1}{4}$ Ca + $\frac{1}{4}$ Na), 2H	crystalline.....Renfrewshire, Scotland.
Mesolite	3 Si, Al ($\frac{1}{4}$ Ca + $\frac{1}{4}$ Na) + 3 H	crystalline.....Peter's Point, N. S.
Herschelite	Si, Al, Ca, Na, K, H	——— Cyclops, Catania.
Heulandite	6 Si, Al, Ca, 5H	red, crystalline.....Fassathal, Tyrol
Bowenite	2 Mg Si + Mg H,	amorphous.....Smithfield, R. I.
Bastite	———	massive.....Germany.
Genthite	($\frac{1}{4}$ Ni, Mg) + $\frac{1}{4}$ H; Si + $\frac{1}{4}$ H	amorphous.....North Carolina.

Kaolin.....	$\frac{2}{3}\text{Si}, + 2\text{H}$	pulverulent.....Rossville, Staten Island
Gieseckite.....	$\text{Si}, \frac{1}{2}\text{H}, \frac{1}{2}\text{Fe}, \text{Mg}, \text{Ca}, \text{Na}, \text{H}$	massive.....St. Lawrence Co., N. Y.
Jefferiaite.....	$(\frac{1}{2}\text{R}_2 + \frac{1}{2}\text{H}) + \text{Si}_2 + 3\text{H}$	micaceous.....West Chester, Pa.
Prochlorite.....	$(\frac{1}{2}(\text{Mg Fe}) + \frac{1}{2}\text{H}) \text{Si} + \frac{1}{2}\text{H}$	crystalline.....New Bedford, Mass.
Masonite.....	$(\frac{1}{2}(\text{Fe Mg}) + \frac{1}{2}\text{H}) \text{Si}_2 + 3\text{H}$	massive.....Natic, B. I.

IV. SUNDRY MINERALS.

MINERAL.	FORMULA.	DESCRIPTION.	LOCALITY.
Atacamite.....	$3\text{Cu H} + \text{Cu Cl H}$	granular.....Chili.	
Columbite.....	$(\text{Fe Mn}) (\text{Co Ti})$	crystalline.....Haddam, Conn.	
Mimetite.....	$3\text{Pb As} + \text{Pb Cl}$	crystals.....Bohemia.	
Triphylite.....	$(\text{Fe Mn Li})_2 \text{P}$	massive.....Grafton, N. H.	
Triphlite.....	$\text{R}_2 \text{P} + \text{R Fl}$	massive.....Limoges, France.	
Libethenite.....	$\text{Cu}_2 \text{P} + \text{H}$	crystalline.....Cornwall, England.	
Olivine.....	$\text{Cu}_2 (\text{As P}) + \text{Cu H}$	crystalline.....Cornwall, England.	
Pseudomalachite.....	$\text{Cu}_2 \text{P} + 3\text{H}$	massive granular.....Copperopolis, Utah.	
Wavellite.....	$\frac{1}{2}\text{H P}, \text{H}$	crystalline.....Montgomery Co., Ark.	
Pharmacosiderite.....	$3\frac{1}{2}\text{Fe As} + \frac{1}{2}\text{Fe H}_2 + 12\text{H}$	crystalline.....Cornwall, England.	

Torbernite.....	$\ddot{\text{U}}, \ddot{\text{P}} + \text{Cu} \ddot{\text{H}} + 7 \ddot{\text{H}}$	crystals.....	.. Cornwall, England.
Actinite.....	$\ddot{\text{U}}, \ddot{\text{P}} + \text{Cu} \ddot{\text{H}} + 7 \ddot{\text{H}}$	crystals.....	Autun, France.
Ulexite.....	$\ddot{\text{Si}}, \ddot{\text{B}}, \text{Ca}, \text{Na}, \text{K}, \text{H}$	nodular fibrous.....	Nevada.
Cryptomorphite.....	$\ddot{\text{B}}, \text{Ca}, \text{Na}, \text{H}$	chalky.....	Oregon.
Wolframite.....	$(\text{Fe Mn}) \ddot{\text{W}}$	massive.....	Zinnwald, Bohemia.
Hübnerite.....	$\text{Mn} \ddot{\text{W}}$	massive.....	Nye Co., Nev.
Scheelite.....	$\text{Ca} \ddot{\text{W}}$	crystals.....	Zinnwald, Bohemia.
Wulfenite.....	Pb Mo	crystals.....	Mica, Carinthia.
Barite.....	Ba S	massive.....	Pillar Point, N. Y.
Celestite.....	Sr S	crystals.....	Strontian Is., L. Erie.
Anhydrite.....	Ca S	crystals.....	Durtemberg.
Crocoite.....	Pb Cr	crystalline.....	Hungary.
Brochantite.....	$\text{Cu S} + 2\frac{1}{2} \text{Cu H}$	crystalline.....	Chili.
Mercury.....	Hg	liquid.....	—
Arsenic.....	As	massive.....	Germany.
Graphite.....	C	foliated.....	Ticonderoga, N. Y.
Aragonite.....	Ca O	crystalline.....	N. Y.

One hundred and six species.

28. The minerals of the foregoing list were submitted to the action of the following reagents successively: (1) A solution of citric acid saturated at the temperature of the laboratory, say 65° to 70° Fahrenheit; this we call simply "citric acid." (2) The same solution to which solid sodium (or potassium) nitrate is added, which for convenience we shall call the "nitro-citric mixture." (3) The same solution to which solid potassium iodide is added at the time of testing, and which for simplicity we shall designate as the "iodo-citric mixture."

The action of these reagents was studied in the simple manner detailed in our first paper. The mineral to be examined was carefully freed from its associated gangue and finely pulverized in an agate mortar; a portion was placed in a test-tube, the solution of the acid was added, and the resulting phenomena, in the cold, and on boiling, carefully noted. In many instances the partial decomposition of the mineral was ascertained by filtering from the residue, and testing the solution with an appropriate reagent; or by examining the disengaged gas with a suitable test-paper.

SULPHIDES, ARSENIDES, ETC.

29. Minerals of this group treated with citric acid alone, yielded results as follows:

- (a) Clausthalite and leucopyrite dissolve in the cold without liberation of gas.
- (b) Alabandite is very strongly attacked in the cold, with evolution of sulphuretted hydrogen. On applying heat it is wholly soluble. In this respect alabandite appears to be the most easily decomposed of all the sulphides yet examined, 37 in number.
- (c) Boulangerite, jamesonite, and kermesite are more or less attacked by boiling citric acid, yielding sulphuretted hydrogen. The remaining minerals of this group resist the action of cold or hot citric acid. Sulphur is absolutely unattacked even when the citric acid solution is heated to the melting point of the element.

The powerful solvent action of a mixture of citric acid and sodium nitrate was discussed in our first paper (19), here we

need only add that the intensity of action claimed for it is fully maintained by later researches.

- (d) All the minerals of the first group, 25 in number, with three exceptions, dissolve in the nitro-citric mixture rapidly and completely, several of them yielding solutions of characteristic color. Even sulphur itself is decidedly attacked, with formation of sulphuric acid. The exceptions are realgar, orpiment, and proustite.
- (e) Two of these, realgar and orpiment, are partially decomposed by boiling with the iodo-citric mixture. Proustite and sulphur resist even on prolonged heating. All the remaining minerals of this group are quite readily dissolved, the decomposition of the sulphides being accompanied by liberation of sulphuretted hydrogen.

The differentiating power of these solvents is again exhibited by these reactions. In our first paper we showed, that while bornite and pyrrhotite are decomposed by citric acid, their kindred compounds, chalcopyrite and pyrite, are not (13). We now find that proustite resists completely the decomposing solutions named, while pyrargyrite is decidedly attacked by the nitro-citric mixture as well as by the iodo-citric mixture, even in the cold.

This difference in behavior of the two closely allied minerals was established by numerous determinations.

OXIDES.

30. The oxides examined include such stable minerals as corundum, spinel, chrysoberyl, cassiterite, rutile, hyalite, and quartz, which naturally resist these methods of attack.

Gummite is attacked by cold citric acid, and melaconite and goethite are soluble to a certain extent on heating. Menaccanite and washingtonite are feebly attacked by the nitro-citric mixture and strongly by the iodo-citric solution. This latter also strongly attacks braunite and goethite.

SILICATES.

31. Silicates are very unequally attacked by citric acid as well as by mineral acids.

(a) Nephelite, lapis lazuli, laumontite, herschelite, thomsonite, mesolite, and prochlorite, are decomposed by citric acid in the cold, a portion of them with formation of a jelly.

Tephroite, ilvaite, gieseckite, jefferisite, heulandite, and genthite, are strongly attacked on boiling with the citric acid alone. Pargasite, pyrope, almandite, colophonite, phlogopite, bastite, maeonite, and allanite (?), are feebly attacked. Some doubt obtains, however, as to the last named, because the specimens examined were partially decomposed on the surface.

(b) The addition of sodium nitrate to the solution of citric acid does not notably increase its solvent power as respects silicates, but the addition of potassium iodide aids decidedly in effecting their decomposition. The iodo-citric mixture strongly attacks the garnets named, as well as enstatite, hypersthene, pargasite, epidote, and those named in paragraph 32.

The feldspars resist these reagents, yet orthoclase and labradorite give up iron to them: Petalite, actinolite, asbestos, beryl, zircon, vesuvianite, zoisite, iolite, lepidolite, leucite, andalusite, fibrolite, topaz, titanite, staurolite, and kaolin, either wholly resist or give to the attacking solution only a trace of iron.

The variety of serpentine known as bowenite resists citric acid, while serpentine itself, of a normal character, is decomposed.

On the whole, citric acid attacks the silicates with a power nearly approaching that of hydrochloric acid.

REVISION OF THE SILICATES.

32. While carrying on these researches we were continually compelled to combat the firmly grounded impression that the organic acids are weak as respects mineral species. In conse-

quence of this pre-conceived notion, we overlooked in our first paper the fact, that the decomposition of many silicates takes place at ordinary temperatures, having in fact applied heat at once when conducting the examination.

A closer investigation, however, shows that a saturated solution of citric acid is able to decompose many silicates in the cold, even to the formation of gelatinous silica. This necessitated a revision of the silicates named in our first paper (16), with the following results:—

- (a) Willemite, pectolite, calamine, natrolite, wollastonite, chrysolite, chondrodite, chrysocolla, apophyllite, rhodonite, analcite, chabazite, stilbite, and dowsylite, are more or less strongly attacked by cold citric acid,—the first four yielding a jelly.

Datolite, prehnite, serpentine, chrysotile, and retinalite, are attacked on boiling the solution.

- (b) The use of the iodo-citric solution as a solvent having been discovered subsequent to the examination of the silicates named in our first paper, a further revision of this group became necessary. The results are briefly as follows:—

Olivine, augite, almandite, and epidote, heated with the iodo-citric mixture, are strongly attacked. Orthoclase, labradorite, hornblende, and spodumene, are very feebly attacked, or yield only iron to the solution.

Wernerite, albite, diopside, kyanite, talc, muscovite, biotite, ripidolite, and tourmaline, are not attacked.

These changes do not invalidate the accuracy of our published results, and are introduced simply to explain the change in position of these minerals in the Tables at the close of this paper.

SUNDRY MINERALS.

33. Under this head are grouped phosphates, arseniates, tungstates, sulphates, etc., as stated in the list given in (27).

A large number, chiefly phosphates, dissolve easily in a cold solution of citric acid; these embrace the following:—

Mimetite, triphylite, triplite, libethenite, olivenite, ataca-

mite, pseudomalachite, wavellite, pharmacosiderite, torbernite, autunite, uloxite, cryptomorphite, and brochantite. Wulfenite and crocoite are strongly attacked on boiling, the latter yielding a green solution, owing to the reducing action of the organic acid on the chromic acid.

Columbite and wolframite are attacked by the iodo-citric mixture, at least so far as partially to dissolve the iron which forms one of their constituents.

Hübnerite is attacked by the nitro-citric mixture; while scheelite, barite, celestite, anhydrite, and graphite, resist completely these methods of attack.

Native Elements.—In our first paper we called attention to the solvent-power of the nitro-citric mixture, as shown by the fact that it dissolves metallic copper, silver, lead, tin, bismuth, and antimony, besides iron, zinc, and magnesium, (20); to this list we now add arsenicum and mercury.

TABULATION OF RESULTS.

34. In paragraph (22) we gave a table showing the behavior of ninety minerals with citric acid and other reagents, arranged under eleven heads, viz. :—

- A. Minerals which dissolve in cold citric acid without evolution of gas.
- B. Minerals which dissolve in cold citric acid with liberation of carbonic anhydride.
- C. Minerals which are decomposed by cold citric acid with evolution of sulphuretted hydrogen.
- D. Minerals which dissolve in hot citric acid without evolution of gas.
- E. Minerals which dissolve in hot citric acid with liberation of carbonic anhydride.
- F. Minerals which are decomposed by hot citric acid with evolution of sulphuretted hydrogen.
- G. Minerals which are decomposed by hot citric acid with formation of gelatinous silica.
- H. Minerals which are decomposed by hot citric acid with separation of slimy silica.

- I. Minerals decomposed by boiling with citric acid and sodium nitrate.
- K. Minerals decomposed by heating with citric acid and ammonium fluoride.
- L. Minerals which are not attacked by any of these methods.

To this we added, in a subsequent paper, a twelfth group, viz. :—

- M. Minerals decomposed by heating with citric acid and potassium iodide.

In the Tables accompanying this paper we have combined, on a similar plan, the results obtained in the present and previous communications, thus giving a comprehensive view of the behavior of two hundred minerals with citric acid. The arrangement differs somewhat from the foregoing; we have re-adjusted the silicates to accord with facts stated in (32), and we have omitted the reaction with ammonium fluoride as of no importance in determining species.

To ascertain the exact position for each mineral has been no trivial task; and should errors be discovered, we crave indulgence, and beg our friends to remember the French saying: "*Ceux qui ne se trompent jamais sont ceux qui ne font rien.*"

SUMMARY.

35. The number of minerals examined, though considerable, if we regard the labor involved, is but small compared with those which remain to be treated by these methods, and any attempt at generalization must be correspondingly weak.

It may, however, be admissible to study the Tables with a view to determining whether there is any relation, peculiar to the organic acid, between its solvent power and the chemical constitution of the minerals. This question may be considered from two standpoints, corresponding to two methods of classifying minerals, viz., with reference to their acidic and to their basic constituents.

(a.) The first method of grouping the minerals is the same as that of the list given (27); the question applied to them may be answered thus :—

All carbonates and phosphates are decomposed by citric acid.

The sulphides are very unequally attacked ;—two resist the solvents, three yield only to the iodo-citric mixture, twenty-two only to the nitro-citric mixture, and ten are attacked by the acid alone. The oxides and anhydrous silicates are very unequally attacked.

The hydrous silicates are (with one or two exceptions) decomposed by citric acid alone.

(b.) An examination of the influence of the basic constituents on the solubility discloses the following points.

All the copper minerals are soluble in one or more of the solvents.

All the manganese minerals are decomposed,—the sulphide and the silicates with great facility.

All the lead minerals are decomposed by citric acid alone.

In some cases the presence of lead would seem to render a mineral easily broken up ; this is marked in the case of the sulphides, which, as we have seen, are very unequally attacked ;—thus selenide of lead is attacked and selenide of mercury is not ; sulphide of lead is attacked, while sulphide of silver is not. The minerals jamesonite, bournonite, and boulangerite (containing lead) are attacked, while the closely allied species stephanite, tennantite, polybasite, proustite, berthierite, etc. (devoid of lead) are not decomposed.

These facts may possibly point to a connection between chemical constitution and solubility, peculiar to the reagent employed ; but we offer the suggestion with diffidence, owing to the limited number of facts on which to base generalizations. Moreover we find that the results obtained by the *prolonged* action of citric acid on minerals (10 to 30 days), differ greatly from those here recorded. To this we shall return at a subsequent period.

In conclusion, we beg leave to remind our readers that the immediate object in view, as was stated at length in our first paper, is the practical application of these methods to the examination of minerals in the field.

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Tables showing the Behavior of certain Minerals with Citric Acid, alone and with Reagents.

I.

DECOMPOSED (IN FINE POWDER) BY A SATURATED SOLUTION OF CITRIC ACID.

1.—IN THE COLD.

A. <i>Without evolution of Gas.</i>	B. <i>With liberation of CO₂.</i>	C. <i>With " liberation of H₂S.</i>	D. <i>With separation of SiO₂.</i>
Clausthalite, Leucopyrite, Atacamite, Brucite, Gummite, Pyromorphite,* Mimetite, Triphylite, Triphite, Vivianite, † Libethenite, † Olivenite, † Pseudomalachite, Wavellite, Pharmacosiderite † Torbernite, Autunite, Ulexite, † Cryptomorphite, † Anglesite, Brochantite. †	Calcite, † Dolomite,* Gurhofite, † Ankerite,* Rhodochrosite,* Smithsonite,* Aragonite, † Witherite, † Strontianite, † Barytocalcite, † Cerussite, † Malachite, † Azurite.*	Stibnite, Galenite, Alabandite, Sphalerite, Pyrrhotite.	Wollastonite, Rhodonite, † Chrysolite, Willemite, †‡ Nephelite, Lapis lazuli, Chondrodite, Pectolite, †‡ Laumontite, †‡ Chrysocolla, † Calamine, †‡ Apophyllite, Thomsonite, † Natrolite, †‡ Mesolite, † Analcite, Chabazite, Herschelinite, ‡ Stilbite, Deweyllite, Prochlorite.

3.—ON BOILING.

E.	F.	G.	H.
<i>Without evolution of Gas.</i>	<i>With liberation of CO₂.</i>	<i>With liberation of H₂S.</i>	<i>With separation of SiO₂.</i>
Cuprite, † Zincite. Melanconite, Goethite, * Limonite, * Allanite, (?) Apatite, * Wolframite, * Wulfenite, Crocoite, Gypsum.	Hausmannite, † Pyrolusite, †† Manganite, † Psilomelane, †† Wad, †† Magnesite, † Siderite, †	Bornite, Jamesonite, * Bournonite, Boulangerite, Kermesite.	Tephrolite, † Ilvaite, Phlogopite, * Datolite, †† Prehnite, * Heulandite, Serpentine, Chrysotile, Retinalite, Bastite, Genthite, Giesckeite, * Jeffersite, Masonite, *
<i>and those in A.</i>	<i>and those in B.</i>	<i>and those in C.</i>	<i>and those in D.</i>

II.

DECOMPOSED BY A BOILING SOLUTION OF CITRIC ACID, MIXED

I.—WITH SODIUM NITRATE.		K.—WITH POTASSIUM IODIDE.	
Silver, Mercury, Copper, Arsenic, Antimony, Bismuth, Sulphur, * Bismuthinite, Domeykite, † Argentite. Hessite, Chalcocite, † Tiemannite, † Millerite, † Nicolite, † Pyrite, † Chalcopyrite, † Linnacite, Smaltite, †	Cobaltite, † Ullmannite, † Marcasite, † Arsenopyrite, † Nagyagite, Covellite, † Berthierite, † Pyrrargyrite, Tetrahedrite, † Tennantite, † Stephanite, Polybasite, † Enargite, † Uraninite, † Hübnerite. <i>and those in C and G.</i>	Realgar, * Orpiment, * Cinnabar, † Hematite, * Menaccanite, * Washingtonite, * Magnetite, * Franklinite, Braunite, Estatite, Hypersthene, Augite, Spodumene, * Hornblende, * Actinolite, * Pargasite, * Olivine, <i>and most of those in A, B, C, D, E, F, G, H, and I.</i>	Almandite, Pyrope, Colophonite, Epidote.

III.

MINERALS NOT DECOMPOSED BY THE ABOVE REAGENTS.

Graphite, Molybdenite, Proustite, Fluorite, Cryolite, Corundum, Diopside, Petalite, Asbestos, Beryl, Zircon, Vesuvianite, Zoisite,	Iolite, Biotite, Muscovite, Lepidolite, Wernerite, Leucite, Andalusite, Fibrolite, Kyanite, Topaz, Titanite, Staurolite, Bowenite,	Talc, Kaolin, Ripidolite, Columbite, Samarskite, Spinel, Chromite, Chrysoberyl, Cassiterite, Rutile, Quartz, Hyalite, Anorthite,	Labradorite, Oligoclase, Albite, Orthoclase, Tourmaline, Scheelite, Barite, Celestite, Anhydrite. (Two hundred species.)
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N. B.—The gases evolved are examined with acetate of lead test-paper the solutions with appropriate reagents.

The kind and degree of action are indicated in the above Tables by the following signs :—

! Completely decomposed or dissolved.

• Feebly attacked.

† The CO₂ evolved is derived from the Citric Acid.

‡ Gelatinizes.