ADJECTIVAL ENDING OF CHEMICAL ELEMENTS USED AS MODIFIERS TO MINERAL NAMES*

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This paper is concerned with the question, can a uniform, clearly understandable scheme of nomenclature be adopted to express a minor and variable isomorphous replacement of an essential chemical element of a mineral by another analogous element?

Take, for example, celestite, strontium sulphate. Suppose we are describing a variety containing several per cent of barium isomorphously replacing a minor part of the strontium. How should such a variety be designated? By present usage any one of several expressions could be used—baric celestite, baricelestite, bariferous celestite, baro-celestite, barium celestite, barium-bearing celestite. Most of such expressions can be interpreted by the reader in more than one way. They may be taken to mean either a minor replacement of strontium by barium or a major, almost complete, replacement, yielding a compound that is essentially barium sulphate.

To cite another example, what does an author mean when he refers to a sodium orthoclase, a soda orthoclase, a sodic orthoclase, a sodiferous or a soda-bearing orthoclase? Does he mean a partial or complete replacement of potash, a chemical or a mineralogic isomorphism, a mechanical mixture of two mineral species (such as an intergrowth), or something still different?

Taking Dana's *System of Mineralogy*, 6th edition, as a comprehensive example of mineralogic literature, we find various methods used to indicate such minor and variable isomorphous replacement. Thus Dana lists the following terms:

1. Using the suffix *iferous*:
   Seleniferous sulphur (p. 10).
   Argentiferous gold (p. 15).
   Ferriferous sphalerite (p. 61).
   Zinciferous rhodochrosite (p. 278).
   Cupriferous smithsonite (p. 279).
   Chromiferous pyromorphite (p. 770).
2. Using the suffix *ian*:
   Magnesian magnetite (p. 225).
   Manganesian titanite (p. 714).

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3. Using the suffix *al*:
   Antimonial arsenic (p. 12).
   Arsenical silver (p. 43).
   Mercurial sphalerite (p. 61).
   A similar form is also used as a synonym for a mineral as antimonial silver for dyscrasite.
4. Using the suffix *eous*:
   Cupreous manganese (lampadite, var. psilomelane, p. 258).
5. Using the suffix *ic*:
   Bismuthic gold (probably not isomorphous, p. 15).
6. Running the adjective and mineral name together:
   Manganbrucite (p. 252).
   Baricalcite (p. 269).
   Ferrocalcite (p. 269).
   Zincocalcite (p. 269).
   Plumbocalcite (p. 269).
   Manganpectolite (p. 374).
   Manganapatite (p. 766).
   Cuprodescloizite (p. 788).
   Celestobarite (p. 902).
   Calciocelestite (p. 906).
   Similar compound names are used for mineral species, whose chemical composition is accurately expressed by the name, as manganotantalite, ferritungstite, natrojarosite.
   Similar forms that do not express such a relationship are also used as names of mineral species, as arsenopyrite (should have been named arsenomarcasite, being orthorhombic like marcasite and not isometric like pyrite), which is not a pyrite containing some arsenic; ferronatrite, which is not a natrite (synonym of natron) containing some iron; bismutosphaerite, which is not a sphaerite containing bismuth.
7. Using a hyphen:
   Palladium-gold (p. 15).
   Ferro-goslarite (p. 939).
8. Adding the chemical name:
   Chromium mica (fuchsite, var. of muscovite, p. 617).
   Barium mica (oellacherite, var. of muscovite, p. 617).

The name of the replacing element (for some the Latin form) with the proper suffix added seems the most desirable of the several forms listed. The use of a suffix is indicated above in 1, 2, 3, 4, and 5. There is thus formed a two-word phrase, short, accurate, and, if used consistently, readily conveying its meaning. Before considering the question whether or not a single suffix can be applied for all elements, the remaining usages (6, 7, and 8) may be briefly considered critically.

Joining the adjective and mineral name together (6) is too uncertain as to the meaning. The first example cited above, "manganbrucite," does not differentiate between (*a*) a brucite in which a minor and variable quantity of manganese replaces a small portion of the magnesium, and (*b*) a mineral analogous to brucite ($MgO \cdot H_2O$) with the formula $MnO \cdot H_2O$ (pyrochroite). The term "manganbrucite" may be interpreted by a reader as synonymous with pyrochroite. The same difficulty arises with the other examples and with any other term so formed. As a matter of fact, the running together of the names of a chemical element and of a mineral species has been used in the naming of individual species of an isomorphous group, as is well shown by the minerals analogous to jarosite—plumbojarosite, argentojarosite, natrojarosite, ammoniojarosite

The use of the hyphen (7) is very uncommon but is open to the same objection, perhaps even to a greater degree.

Adding the chemical name before the mineral name (8) leads to the same confusion as joining the adjective and mineral name together. Does "chromium mica" mean a mica in which a little chromium replaces a minor part of the aluminum or a mica in which chromium is one of the essential constituents? The term "chromium-bearing mica" would be much better than "chromium mica."

If a single suffix can be found that will apply to the names of all chemical elements and if it is used consistently, then a two-word phrase, in which the first word denotes the replacing element and the second word is the name of the mineral in which isomorphous replacement of a minor and variable extent has occurred, will partake of a definite meaning readily interpretable by all.

After considering the suffixes in use, as listed above, and also others, the writer has concluded that the ending *ian*, or *oan* if it is desired to indicate a lower valency, is the most satisfactory, and its consistent use is here advocated. A chromium muscovite, or a chromium-bearing muscovite, given the variety name fuchsite, would then be called chromian muscovite. Similarly the variety of brucite called manganbrucite would be called manganoan brucite. If the chemical element has only one valency or the author does not wish to bring up the question of valency, *ian* should be used. There is no chemical element whose name ends in *an*, *ian*, or *oan*.

The objections to the use of other suffixes are noted below. The various suffixes have been tried out on all the names of chemical elements, but most of such endings yield a few unsatisfactory names. The sound of the spoken form must be considered, though the written form would deserve the greatest consideration. Any scheme proposed must be adaptable to the names of all the chemical elements, to allow for any possible mineral combination that may be found in the future.

The main objection to *ic* lies in the possible "confusion which would result, owing to the use of this ending by chemists in a definite technical sense."[1] Chemists use it technically to express high states of oxidation. Thus ferric, manganic, and others are well understood chemical terms, used by way of contrast to ferrous, manganous, etc. The ending *ic* is also so generally used in such terms as geologic, electric, and topographic, that it could not be confined to a definite meaning. It is also the termination of the names of most acids, as carbonic, sulphuric, and phosphoric. The form for cesium would become cesic (seasick!), clearly understood when written but perhaps confusing when spoken. Changing *ic* to *itic* might be clearer, but the terms would be cumbersome and some at least not very euphonious.

A similar objection applies to *ous*, a recognized chemical ending denoting a lower state of oxidation. Thus ferrous, manganous and sulphurous are common chemical terms. Neither *ic* nor *ous* allows any latitude to express different valencies.

The ending *al* is one of the best and has few objections. Some of the words with this ending would not be euphonious.

The ending *iferous* is commonly used in mineralogic literature. It was recommended in Topic 6, D (last page) by the Committee on Nomenclature and Classification of the Mineralogical Society of America for 1923. As clearly defined by Wherry,[2] "Varieties based on isomorphism are also described by adjectives, constructed by adding the suffix *iferous* to the names of the elements present in the lesser amounts.*** In minerals in which one element is clearly essential and others replace it isomorphously, in widely varying but never significant amounts, the plan adopted in the preceding paper is followed: the name of the replacing element, with the suffix *iferous*, is used as an adjective." Although most

[1] Wherry, E. T., personal communication.

[2] Wherry, E. T., The nomenclature and classification of sulfide minerals: *Washington Acad. Sci. Jour.*, vol. **10**, p. 487, 1920.

commonly used by Dana and other writers, *iferous* is open to two objections. It is long, giving such cumbersome words as magnesiferous, aluminiferous, and it may be misleading. Thus, some students would interpret the ending as relating to iron on account of the *ferous*. Wherry[3] now feels the weight of these objections and recommends the use of the ending *ian*.

The names of all the chemical elements would be placed in seven groups. In each of the first six groups all the names would have the same ending; the seventh group would include names with various endings. The adjectival ending of the names of all the chemical elements is formed according to the rules given under each group. Ordinary usage is followed in applying the suffix to the names. Latin names are used for copper, (cuprum), gold (aurum), iron (ferrum), lead (plumbum), silver (argentum), and tin (stannum). Stibium is optional for antimony, natrium for sodium, and wolfram for tungsten, but hydrargyrum is not used for mercury and kalium is not ordinarily used for potassium. If lower valency is to be expressed, use *oan* instead of *ian*, as in ferroan and ferrian.

Group 1. If the name ends in *um*, drop the *um*, and add *ian* (or *oan* if a lower valency is to be expressed).

Aluminum—aluminian.

Ferrum—ferroan and ferrian.

Group 2. If the name ends in *ium*, drop the *um*, and add *an*.

Barium—barian.

Group 3. If the name ends in *ine*, drop the *ne*, and add *an*.

Bromine—bromian.

Group. 4. If the name ends in *on*, add *ian*, except for boron and silicon.

Carbon—carbonian.

For boron and silicon, drop the *on* and add *ian*.

Boron—borian.

Silicon—silician.

The abbreviated forms for boron and silicon follow the generally adopted usage, as the shorter forms boric acid and silicic acid are more commonly used in mineralogic literature than boracic acid and siliconic acid. For iron, the Latin name ferrum is used (Group 1).

Group 5. If the name ends in *gen* (three gases), add *ian*.

Hydrogen—hydrogenian.

[3] Personal communication.

GROUP 6. If the name ends in *y*, drop the *y*, and add *ian* (or *oan*).

Antimony—antimonian

Mercury—mercuroan and mercurian.

GROUP 7. For the following names, use the form shown.

Arsenic—arsenoan and arsenian.

Bismuth—bismuthian.

Cobalt—cobaltian.

Manganese—manganoan and manganian.

Nickel—nickelian.

Phosphorus—phosphorian.

Sulphur—sulphurian.

Zinc—zincian.

Tungsten—tungstenian or wolframian.

The adjectival endings thus formed for the names of all the chemical elements are given below.

Aluminum—aluminian
Antimony—antimonian
Argon—argonian
Arsenic—arsenoan, arsenian
Barium—barian
Beryllium—beryllian
Bismuth—bismuthian
Boron—borian
Bromine—bromian
Cadmium—cadmian
Calcium—calcian
Carbon—carbonian
Cerium—cerian
Cesium—cesian
Chlorine—chlorian
Chromium—chromian
Cobalt—cobaltian
Columbiun—columbian
Copper—cuproan, cuprian
Dysprosium—dysprosian
Erbium—erbian
Europium—europian
Fluorine—fluorian
Gadolinium—gadolinian
Gallium—gallian
Germanium—germanian
Gold—aurian
Hafnium—hafnian
Helium—helian
Holmium—holmian
Hydrogen—hydrogenian
Indium—indian
Iodine—iodian
Iridium—iridian
Iron—ferroan, ferrian
Krypton—kryptonian
Lanthanum—lanthanian
Lead—plumbian
Lithium—lithian
Lutecium—lutecian
Magnesium—magnesian
Manganese—manganoan, manganian
Mercury—mercuroan, mercurian
Molybdenum—molybdenian
Neodymium—neodymian
Neon—neonian
Nickel—nickelian
Nitrogen—nitrogenian
Osmium—osmian
Oxygen—oxygenian
Palladium—palladian
Phosphorus—phosphorian
Platinum—platinian
Potassium—potassian
Praseodymium—praseodymian

Radium—radian
Radon—radonian
Rhenium—rhenian
Rhodium—rhodian
Rubidium—rubidian
Ruthenium—ruthenian
Samarium—samarian
Scandium—scandian
Selenium—selenian
Silicon—silician
Silver—argentian
Sodium—sodian
Strontium—strontian
Sulphur—sulphurian
Tantalum—tantalian
Tellurium—tellurian
Terbium—terbian
Thallium—thallian
Thorium—thorian
Thulium—thulian
Tin—stannian
Titanium—titanian
Tungsten—tungstenian
Uranium—uranoan, uranian
Vanadium—vanadian
Xenon—xenonian
Ytterbium—ytterbian
Yttrium—yttrian
Zinc—zincian
Zirconium—zirconian

Where an element shows more than two valencies, the proper form can easily be made. Thus, for vanadium:

For vanadous vanadium, valency of 3, use vanadoan.
For vanadyl vanadium, valency of 4, use vanadylian.
For vanadic vanadium, valency of 5, use vanadian.

Some practical examples would then be:

Aluminian chromite for a chromite with a minor quantity of aluminum replacing part of the chromium.

Antimonian tennantite if the mineral contains a little antimony.
Barian celestite
Cadmian sphalerite
Calcian siderite
Cerian xenotime
Ferrian variscite
Manganoan siderite (manganous manganese)
Manganian spodumene (manganic manganese)
Rubidian lepidolite
Uranoan zircon (uranous uranium)
Uranian fergusonite (uranic uranium)
Tungstenian or wolframian powellite
Zincian tetrahedrite

The various forms given by Dana and listed in the earlier part of this paper, except for those of group 2 which remain unchanged, would then be changed as follows:

Seleniferous sulphur becomes selenian sulphur
Argentiferous gold becomes argentian gold
Ferriferous sphalerite becomes ferroan sphalerite
Zinciferous rhodochrosite becomes zincian rhodochrosite

Cupriferous smithsonite becomes cuprian smithsonite
Chromiferous pyromorphite becomes chromian pyromorphite
Antimonial arsenic becomes antimonian (or stibian) arsenic
Arsenical silver becomes arsenian silver
Mercurial sphalerite becomes mercurian sphalerite
Cupreous manganese becomes cuprian manganese (psilomelane)
Bismuthic gold becomes bismuthian gold
Manganbrucite becomes manganoan brucite
Baricalcite becomes barian calcite
Ferrocalcite becomes ferroan calcite
Zincocalcite becomes zincian calcite
Plumbocalcite becomes plumbian calcite
Manganpectolite becomes manganian pectolite
Manganapatite becomes manganian apatite
Cuprodescloizite becomes cuprian descloizite
Celestobarite becomes strontian barite
Calciocelestite becomes calcian celestite
Palladium-gold becomes palladian gold
Ferro-goslarite becomes ferroan goslarite
Chromium mica becomes chromian mica
Barium mica becomes barian mica

Some names of varieties of minerals would be abandoned, the two-word phrases being used instead, thus doing away with the uncertainty of determining whether a nondescriptive mineral name represents a species or only a variety of some species whose name bears no relation to the name of the variety. Thus

Marmatite becomes ferroan sphalerite
Przibramite becomes cadmian sphalerite
Tarnowitzite becomes plumbian aragonite
Tawnawite becomes chromian epidote
Danaite[4] becomes cobaltian arsenopyrite
Freibergite becomes argentian tetrahedrite
Schwatzite becomes mercurian tetrahedrite
Malinowskite becomes plumbian tetrahedrite
Sandbergite becomes zincian tennantite
Worobieffite becomes cesian beryl
Actinolite becomes ferroan tremolite (as long as the molecular ratio of MgO is greater than that of FeO)
Cuprogoslarite becomes cuprian goslarite
Pisanite becomes cuprian melanterite or ferroan boothite, depending on whether iron or copper is in excess (molecularly)
Nicholsonite becomes zincian aragonite
Molybdosodalite becomes molybdenian sodalite
Ferroprehnite becomes ferrian prehnite

[4] This term is liable to be confused with danalite.

The two-word phrase would then be interpreted as referring to a minor and variable isomorphous replacement of an essential constituent. It would also mean that a *variety* of the mineral is being named.

Obviously, the scheme above set forth would apply only to single isomorphous replacement. If the essential element of the mineral is replaced by more than one element, then the name of the element whose replacing effect is the largest, or is for some reason to be emphasized, would be used. Thus if a brucite contains 5 per cent of MnO (molecular ratio 0.07), 2 per cent of ZnO (molecular ratio 0.02), and 1 per cent of FeO (molecular ratio 0.01), it would still be called manganoan brucite. The determination as to which element has the largest replacing effect should be based on molecular ratios and not on chemical percentages. If more than one essential chemical element in a mineral is partly replaced by other elements, then the element showing the greatest replacement should be chosen for the adjectival name.

For many minerals (such as tourmaline) the question of isomorphous replacement is so complex that the problem of determining what scheme should be used for naming the varieties can well be left to the future. The number of varieties to which the plan herein suggested is applicable is sufficiently large to warrant its consideration. Perhaps the plan, if acceptable, will suffice as a beginning upon which decisions as to the more complex questions can be based.