

VI. TASTE AND ODOR.

In their action upon the senses a few minerals possess *taste*, and others under some circumstances give off *odor*.

427. Taste belongs only to soluble minerals. The different kinds of taste adopted for reference are as follows:

1. *Astringent*: the taste of vitriol.
2. *Sweetish astringent*: taste of alum.
3. *Saline*: taste of common salt.
4. *Alkaline*: taste of soda.
5. *Cooling*: taste of saltpeter.
6. *Bitter*: taste of Epsom salts.
7. *Sour*: taste of sulphuric acid.

428. Odor.—Excepting a few gaseous and soluble species, minerals in the dry unchanged state do not give off odor. By friction, moistening with the breath, and the elimination of some volatile ingredient by heat or acids, odors are sometimes obtained which are thus designated:

1. *Alliaceous*: the odor of garlic. Friction of arsenical iron elicits this odor; it may also be obtained from arsenical compounds by means of heat.
2. *Horse-radish odor*: the odor of decaying horse-radish. This odor is strongly perceived when the ores of selenium are heated.
3. *Sulphurous*: friction elicits this odor from pyrite, and heat from many sulphides.
4. *Bituminous*: the odor of bitumen.
5. *Fetid*: the odor of sulphureted hydrogen or rotten eggs. It is elicited by friction from some varieties of quartz and limestone.
6. *Argillaceous*: the odor of moistened clay. It is obtained from serpentine and some allied minerals, after moistening them with the breath; others, as pyrrargillite, afford it when heated.

429. Feel.—The FEEL is a character which is occasionally of some importance; it is said to be *smooth* (sepiolite), *greasy* (talc), *harsh*, or *meager*, etc. Some minerals, in consequence of their hygroscopic character, *adhere to the tongue* when brought in contact with it.

PART III. CHEMICAL MINERALOGY.

GENERAL PRINCIPLES OF CHEMISTRY AS APPLIED TO MINERALS.

430. Minerals, as regards their chemical constitution, are either the uncombined elements in a native state, or definite compounds of these elements formed in accordance with chemical laws. It is the object of Chemical Mineralogy to determine the chemical composition of each species; to show the chemical relations of different species to each other where such exist; and also to explain the methods of distinguishing different minerals by chemical means. It thus embraces the most important part of Determinative Mineralogy.

In order to understand the chemical constitution of minerals, some knowledge of the fundamental principles of Chemical Philosophy is required; and these are here briefly recapitulated.

431. Chemical Elements.—Chemistry recognizes about seventy substances which cannot be decomposed, or divided into others, by any process of analysis at present known; these substances are called the chemical *elements*. A list of them is given in a later article (436); common examples are: Oxygen, nitrogen, hydrogen, chlorine, gold, silver, sodium, etc.

432. Atom. Molecule.—The study of the chemical properties of substances and of the laws governing their formation has led to the belief that there is for each element a definite, indivisible mass, which is the smallest particle which can play a part in chemical reactions; this indivisible unit is called the *atom*.

With some rare exceptions, the atom cannot exist alone, but unites by the action of what is called chemical force, or chemical affinity, with other atoms of the same or different kind to form the *molecule*. The molecule, in the chemical sense, may be defined as the smallest particle into which a given kind of substance can be subdivided without undergoing chemical decomposition. For example, two *atoms* of hydrogen unite to form a *molecule* of hydrogen gas. Again, one atom of hydrogen and one of chlorine form a molecule of hydrochloric acid gas; two atoms of hydrogen and one of sulphur form a molecule of the gas hydrogen sulphide.

433. Physical Molecules.—An important distinction must be made between the simple chemical molecules, regarded as made up of the smallest possible number of the atoms of each kind, united in the given proportion, and the actual *physical molecules* which together build up the structure of a particular

mass of matter. These physical molecules may be much more complex, each being made up of a number of chemical molecules but necessarily containing the respective atoms in the same proportion. In the case of a gas, it is always possible to determine the constitution of the molecule, as is explained later, but in the case of liquids and solids this is in general impossible.

For example, it is certain that a molecule of water vapor consists of two atoms of hydrogen and one atom of oxygen, but the molecules of water which unite to build up a snow crystal, though containing the atoms of the two elements hydrogen and oxygen in the same proportion, may be highly complex, as if made up of many gas molecules. Since it is in general impossible in the case of solids to fix the constitution of the actual molecule, it is usually better to regard it as a chemical molecule of the simplest possible form.

434. Atomic Weight.—The atomic weight of an element is the weight, or, better expressed, the mass of its atom compared with that of the element hydrogen taken as the unit. Thus the mass of an atom of oxygen is very nearly sixteen times that of the atom of hydrogen (exactly 15.96), and hence this number is called the atomic weight of oxygen. Of the methods by which the relation between the masses of the atoms is determined it is unnecessary here to speak; the results that have been obtained are given in the table on p. 241.

435. Symbol. Formula.—The symbol of an element is the initial letter, or letters, often of its Latin name, by which it is represented when expressing in chemical notation the constitution of substances into the composition of which it enters. Thus O is the symbol of oxygen, H of hydrogen, Cl of chlorine, Fe (from *ferrum*) of iron, Ag (from *argentum*) of silver, etc. Further, this symbol is always understood to indicate that definite amount of the given element expressed by its atomic weight; in other words, it represents one atom. If twice this quantity is involved, that is, two atoms, this is indicated by a small subscript number written immediately after the symbol. Thus, Sb_2S_3 means a compound consisting of two atoms of antimony and three of sulphur, or of 2×120 parts by weight of antimony and 3×32 of sulphur.

This expression, Sb_2S_3 , is called the *formula* of the given compound, since it expresses in briefest form its composition. Similarly the formula of the mineral albite is $NaAlSi_3O_8$.

Strictly speaking, such formulas are merely *empirical formulas*, since they express only the actual result of analysis, as giving the relative number of atoms of each element present, and make no attempt to represent the actual constitution. A formula developed with the latter object in view is called a rational, structural, or constitutional formula (see Art. 453).

436. Table of the Elements.—The following table gives a list of all the definitely established elements with their accepted symbols and also their atomic weights.*

Of the elements given in this list—about seventy in all—only a very small number, say twelve, play an important part in making up the crust of the earth and the water and air surrounding it. The common elements concerned in the composition of minerals are: Oxygen, sulphur, silicon, aluminium, iron, calcium, magnesium, sodium, potassium. Besides these, hydrogen is present in water, nitrogen in the air, and carbon in all animal and vegetable substances. Only a very few of the elements occur as such in nature, as native gold, native silver, native sulphur, etc.

* These correspond in value to those commonly accepted, and are given accurate to one decimal place. In strict chemical sense the atomic weight of oxygen is 15.96, etc.

Of the elements, oxygen, hydrogen, nitrogen, chlorine, and fluorine are gases; bromine is a volatile liquid; mercury is also a liquid, but the others are solids under ordinary conditions.

	Symbol.	At. Weight.		Symbol.	At. Weight.
Aluminium, Aluminum	Al	27	Manganese	Mn	54.8
Antimony (<i>Stibium</i>)	Sb	120	Mercury (<i>Hydrargyrum</i>)	Hg	199.8
Argon	A	39.9	Molybdenum	Mo	96
Arsenic	As	74.9	Nickel	Ni	58.6
Barium	Ba	137	Niobium	Nb	93.7
Beryllium	Be (or Gl)	9.1	Nitrogen	N	14
Bismuth	Bi	207.5	Osmium	Os	191
Boron	B	10.9	Oxygen	O	16
Bromine	Br	79.8	Palladium	Pd	106.2
Cadmium	Cd	111.7	Phosphorus	P	31
Cæsium	Cs	58.7	Platinum	Pt	194.3
Calcium	Ca	39.9	Potassium (<i>Kalium</i>)	K	39
Carbon	C	12	Rhodium	Rh	104.1
Cerium	Ce	141	Rubidium	Rb	85.2
Chlorine	Cl	35.4	Ruthenium	Ru	103.5
Chromium	Cr	52.5	Scandium	Sc	44
Cobalt	Co	58.7	Selenium	Se	78.9
Columbium, see <i>Niobium</i> .			Silicon	Si	28
Copper (<i>Cuprum</i>)	Cu	63.2	Silver (<i>Argentum</i>)	Ag	107.7
Didymium	Di	142	Sodium (<i>Natrium</i>)	Na	23
Erbium	Er	166	Strontium	Sr	87.3
Fluorine	F	19.1	Sulphur	S	32
Gallium	Ga	69.9	Tantalum	Ta	182
Germanium	Ge	73.3	Tellurium	Te	125
Glucinum, see <i>Beryllium</i> .			Thallium	Tl	203.7
Gold (<i>Aurum</i>)	Au	196.7	Thorium	Th	232
Helium	He	4.4	Tin (<i>Stannum</i>)	Sn	117.4
Hydrogen	H	1	Titanium	Ti	48
Iidium	Ii	113.4	Tungsten (<i>Wolframium</i>)	W	183.6
Iodine	I	126.5	Uranium	U	240
Iridium	Ir	192.5	Vanadium	V	51.1
Iron (<i>Ferrum</i>)	Fe	55.9	Ytterbium	Yt	172.6
Lanthanum	La	138	Yttrium	Y	89
Lead (<i>Plumbum</i>)	Pb	206.4	Zinc	Zn	65.1
Lithium	Li	7	Zirconium	Zr	90.4
Magnesium	Mg	24			

437. Metals and Non-metals.—The elements may be divided into two more or less distinct classes, the metals and the non-metals. Between the two lie a number of elements sometimes called the semi-metals. The *metals*, as gold, silver, iron, sodium, are those elements which, *physically* described, possess to a more or less perfect degree the fundamental characters of the ideal metal, viz.: malleability, metallic luster (and opacity to light), conductivity for heat and electricity; moreover, *chemically* described, they commonly play the part of the positive or basic element in a simple compound, as later defined (Arts. 446–449). The *non-metals*, as sulphur, carbon, silicon, etc., also the gases, as oxygen, chlorine, etc., have none of the physical characters alluded to: they are, if solids, brittle, often transparent to light-radiation, are poor conductors for heat and electricity. Chemically expressed, they usually play the negative or acid part in a simple compound.

The so-called *semi-metals*, or metalloids, include certain elements, as tellurium, arsenic, antimony, bismuth, which have the physical characters of a metal to a less perfect degree (*e.g.*, they are more or less brittle); and, more important than this, they often play the part of the acidic element in the compound into which they enter. These points are illustrated later.

It is to be understood that the distinctions between the classes of the elements named cannot be very sharply applied. Thus the typical metallic characters mentioned are possessed to a very unequal degree by the different substances classed as metals; for example, by silver and tin. Corresponding to this a number of the true metals, as tin and manganese, play the part of an acid in numerous salts. Further, the mineral magnetite, FeFe_2O_4 , is often described as an *iron ferrate*; so that in this compound the same element would play the part of both acid and base.

438. Positive and Negative Elements.—It is common to make a distinction between the *electro-positive* and *electro-negative* element in a compound. The passage of a sufficiently strong electrical current through a chemical compound in many cases results in its decomposition (or electrolysis) into its elements or parts. In such cases it is found that for each compound the atoms of one element collect at the negative pole (the cathode) and those of the other at the positive pole (the anode). The former is called the electro-positive element and the latter the electro-negative element. Thus in the electrolysis of water (H_2O) the hydrogen collects at the cathode and is hence called positive, and the oxygen at the anode and is called negative. Similarly, in hydrochloric acid (HCl) the hydrogen is thus shown to be positive, the chlorine negative. This distinction is also carried to complex compounds, as copper sulphate (CuSO_4), which by electrolysis is broken into Cu, which is found to be electro-positive, and SO_4 (the last separates into SO_2 , forming H_2SO_4 and free oxygen).

For reasons which will be explained later, the positive element is said to play the basic part, the negative the acidic. The metals, as already stated, in most cases belong to the former class, the non-metals to the latter, while the semi-metals may play both parts.

It is common in writing the formula to put the positive or basic element first, thus H_2O , H_2S , HCl, H_2SO_4 , Sb_2S_3 , As_2O_3 , AsH_3 , NiSb, FeAs_2 . Here it will be noted that antimony (Sb) and arsenic (As) are positive in some of the compounds named but negative in the others.

439. Periodic Law.—In order to understand the relations of the chief classes of chemical compounds represented among minerals, as still more their further subdivision, down finally to the many *isomorphous groups*—groups of species having analogous composition and closely similar form, as explained in Art. 456—the fundamental relations and grouping of the elements must be understood, especially as developed of recent years and shown in the so-called Periodic Law.*

Although the subject can be only briefly touched upon, it will be useful to give here the general distribution of the elements into Groups and Series, as presented in the Principles of Chemistry (Engl. Ed., 1891) of D. Mendeléeff, to whom is due more than any one else the development of the Periodic Law. A few remarks are added on the grouping of the elements as illustrated by mineral compounds; artificial compounds show these relations still more fully and clearly. For the thorough explanation of this subject, more particularly as regards the periodic or progressive relation between the atomic weights and various properties of the elements, the reader is referred to the work above mentioned or to one of the many other excellent modern text-books of chemistry.

The relations of some of the elements of the first group are exhibited by the isomorphism (see Art. 456, also the description of the various groups and species here referred to, which are given in Part IV of this work) of NaCl, KCl, AgCl; or again of LiMnPO_4 and NaMnPO_4 , etc. In the second group,

* The relations here brought out are important, even if the validity of the Periodic Law is less general than has been supposed.

Groups . . .	I	II	III	IV	V	VI	VII	VIII
Series 1 . . .	H	—	—	RH ₄	RH ₃	RH ₂	RH	Hydrogen Compounds.
" 2 . . .	Li	Be	B	C	N	O	F	
" 3 . . .	Na	Mg	Al	Si	P	S	Cl	
" 4 . . .	K	Ca	Se	Ti	V	Cr	Mn	Fe Co Ni Cu
" 5 . . .	(Cu)	Zn	Ga	Ge	As	Se	Br	
" 6 . . .	Rb	Sr	Y	Zr	Nb	Mo	—	Ru Rh Pb Ag
" 7 . . .	Ag	Cd	In	Gn	Sb	Te	I	
" 8 . . .	Cs	Ba	La	Ce	Di?	—	—	
" 9 . . .	—	—	—	—	—	—	—	
" 10 . . .	—	—	Yb	—	Ta	W	—	Os Ir Pt Ag
" 11 . . .	Au	Hg	Tl	Pb	Bi	—	—	
" 12 . . .	—	—	—	—	—	U	—	
	R ₂ O	R ₂ O ₂	R ₂ O ₂	R ₂ O ₄	R ₂ O ₅	R ₂ O ₆	R ₂ O ₇	Higher Oxides RO ₄

reference may be made to the isomorphism of the carbonates and sulphates (p. 250) of calcium, barium, and strontium; while among the sulphides, ZnS, CaS, and HgS are doubly related. In the third group, we find boron and aluminium often replacing one another among silicates. In the fourth group, the relations of silicon and titanium are shown in the titano-silicates, while the compounds TiO_2 , SnO_2 , PbO_2 (and MnO_2), also ZrSiO_4 and ThSiO_4 , have closely similar form. In the fifth group, many compounds of arsenic, antimony, and bismuth are isomorphous among metallic compounds; while the relations of phosphorus, vanadium, arsenic, also antimony, are shown among the phosphates, vanadates, arsenates, and antimonates; again the mutual relations of the niobates and tantalates are to be noted.

In the sixth group, the strongly acidic elements, sulphur, selenium, tellurium, are all closely related, as seen in many sulphides, selenides, tellurides; further, the relations of sulphur and chromium, and similarly of both of these to molybdenum and tungsten, are shown among many artificial sulphates, chromates, molybdates, and tungstates.

In the seventh group the relations of the halogens are too well understood to need special remark. In the eighth group, we have Fe, Co, Ni alloyed in meteoric iron, and their phosphates and sulphates are in several cases closely isomorphous; further, the relation of the iron series to that of the platinum series is exhibited in the isomorphism of FeS_2 , FeAsS , FeAs_2 , etc., with PtAs_2 , and probably RuS_2 .

440. Combining Weight.—Chemical investigation proves that the mass of a given element entering into a compound is always proportional either to its atomic weight or to some simple multiple of this; the atomic weight is hence also called the *combining weight*. Thus in rock salt, sodium chloride, the masses involved of sodium and chlorine present are found by analysis to be equal to 39.4 and 60.6 in 100 parts, and these numbers are in proportion to 33 : 35.4, the atomic weights of sodium and chlorine; hence it is concluded

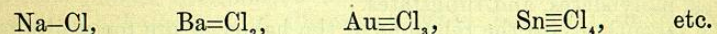
that one atom of each is present in the compound. The formula is, therefore, NaCl. In calcium chloride, by the same method the masses present are found to be proportional to 39.9 : 70.8, that is, to $39.9 = 2 \times 35.4$; hence the formula is CaCl_2 .

Still again, a series of compounds of nitrogen with oxygen is known in which the ratios of the masses of the two elements are as follows: (1) 28 : 16, (2) 14 : 16, (3) 28 : 48, (4) 14 : 32, (5) 28 : 80. It is seen at once that these must have the formulas (1) N_2O , (2) NO , (3) N_2O_3 , (4) NO_2 , (5) N_2O_5 . On the contrary, atmospheric air which contains these elements in about the ratio of 76.8 to 23.2 cannot be a chemical compound of these elements, since (aside from other considerations) these numbers are not in the ratio of $n \times 14 : m \times 16$ where n and m are simple whole numbers.

441. Molecular Weight.—The molecular weight is the weight of the molecule of the given substance, expressed in terms of the mass of the hydrogen atom as unit. The molecular weight of hydrogen is 2 because the molecule can be shown to consist of two atoms. The molecular weight of hydrochloric acid (HCl) is 36.4, of water vapor (H_2O) it is 18, of hydrogen sulphide (H_2S) it is 34.

Since, according to the law of Avogadro, like volumes of different gases under like conditions as to temperature and pressure contain the same number of molecules, it is obvious that the molecular weight of substances in the form of gas can be derived directly from the relative density or specific gravity. If the density is referred to hydrogen, whose molecular weight is 2, it will be always true that the molecular weight is twice the density in the state of a gas and *vice versa*. Thus the observed density of carbon dioxide (CO_2) is 22, hence its molecular weight must be 44. It is this principle that makes it possible in the case of a gas to fix the constitution of the molecule when the ratio in number of the atoms entering into it has been determined by analysis. In the case of solids, where the constitution of the molecule in general cannot be fixed, it is best, as already stated, to write the molecular formula in its simplest form, as $\text{NaAlSi}_3\text{O}_8$ for albite. The sum of the weights of the atoms present is then taken as the molecular weight.

442. Valence.—The valence of an element is given by the number of its atoms which are required to unite with one unit atom, as of hydrogen or chlorine. Thus, using the examples of Art. 440, in NaCl , since one atom of sodium unites with one of chlorine, its valence is one; or in other words, it is said to be *univalent*, and is called a monad. Further, calcium (as in CaCl_2), also barium, etc., are bivalent; gold is (usually) trivalent; tin is tetravalent, etc. The valence may be expressed by the number of bonds by which one element in a compound is united to another, thus:



The valences of the common elements, expressed by their symbols, are as follows:

Univalent: H, Cl, Br, I, F; Li, Na, K, Rb, Cs, Ag.

Bivalent: O, S, Se, Te; Be, Mg, Ca, Sr, Ba, Pb, Hg, Cu, Zn, Co, Ni.

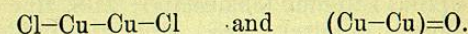
Trivalent: B, Au; probably also Al, Fe, Mn, Cr.

Tetravalent: C, Si, Ti, Zr, Sn.

Pentavalent: N, P, As, Sb, V, Bi, Nb, Ta.

The above list, though convenient for reference, is not to be taken as complete or final. A considerable number of the elements show a different valence in different compounds. Thus both Sb_2O_3 and Sb_2O_5 are known; also FeS , Fe_2O_3 , and FeS_2 ; Cu_2Cl_2 , CuCl_2 , and similarly Cu_2S (Cu_2O) and CuS (CuO),

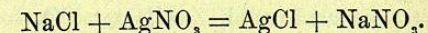
etc. In certain cases the composition of two compounds of the same elements may be made consistent with each other, by an assumption as to the possible grouping of the atoms. Thus in cupric chloride, CuCl_2 , or cupric oxide, CuO , copper is bivalent as usual. But the cuprous compounds, Cu_2Cl_2 and Cu_2O , also occur, and for them the formulas may be written



Again, the elements Al, Fe, Mn, Cr, which form the compounds AlCl_3 , Al_2O_3 , etc., are sometimes called tetravalent and the formula of the oxide written, for example, $(\text{Al}=\text{Al})\equiv\text{O}_2$.

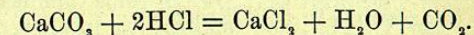
443. Chemical Reactions.—When solutions of two chemical substances are brought together, in many cases they react upon each other with the result of forming new compounds out of the elements present; this phenomenon is called a *chemical reaction*. One of the original substances may be a gas, and in many cases similar results are obtained from a liquid and a solid, or less often from two solids.

For example, solutions of sodium chloride (NaCl) and silver nitrate (AgNO_3) react on each other and yield silver chloride (AgCl) and sodium nitrate (NaNO_3). This is expressed in chemical language as follows:



This is a chemical equation, the sign of equality meaning that equal weights are involved both before and after the reaction.

Again, hydrochloric acid (HCl) and calcium carbonate (CaCO_3) yield calcium chloride (CaCl_2) and carbonic acid (H_2CO_3); which last breaks up into water (H_2O) and carbon dioxide (CO_2), the last going off as a gas with effervescence. Hence



444. Radicals.—A compound of two or more elements according to their relative valence in which all their bonds are satisfied is said to be *saturated*. This is true of H_2O , or, as it may be written, $\text{H}-\text{O}-\text{H}$. If, however, one or more bonds is left unsatisfied, the resulting combination of elements is called a *radical*. Thus $-\text{O}-\text{H}$, called briefly hydroxyl, is a common radical, having a valence of one, or, in other words, univalent; NH_2 is again a univalent radical; so, too, (CaF) , (MgF) or (AlO) . Radicals often enter into a compound like a simple element; for example, in ammonium chloride, NH_4Cl , the univalent radical NH_4 plays the same part as the univalent element Na in NaCl . In the chemical composition of mineral species, the commonest radical is hydroxyl ($-\text{O}-\text{H}$) already defined. Other examples are (CaF) in apatite (see Art. 456), (MgF) in wagnerite, (AlO) in many basic silicates, etc.

445. Chemical Compound.—A chemical compound is a combination of two or more elements united by the force of chemical attraction. It is always true of it, as before stated (Art. 440), that the elements present are combined in the proportion of their atomic weights or some simple multiples of these. A substance which does not satisfy this condition is not a compound, but only a mechanical mixture.

Examples of the simpler class of compounds are afforded by the *oxides*, or compounds of oxygen with another element. Thus, among minerals we have Cu_2O , cuprous oxide (cuprite); ZnO , zinc oxide (zincite); Al_2O_3 , alumina