Tucholsky Wagner Zola Scott Sydow Fonatne Freud Schlegel
Turgenev Wallace
Twain Walther von der Vogelweide Fouqué Friedrich II. von Preußen
Weber Freiligrath
Kant Ernst Frey
Fechner Fichte Weiße Rose von Fallersleben Richthofen Frommel
Hölderlin
Fehrs Engels Fielding Eichendorff Tacitus Dumas
Faber Flaubert
Eliasberg Ebner Eschenbach
Feuerbach Maximilian I. von Habsburg Fock Zweig
Ewald Eliot Vergil
Goethe London
Mendelssohn Balzac Shakespeare Elisabeth von Österreich
Lichtenberg Rathenau Dostojewski Ganghofer
Trackl Stevenson Doyle Gjellerup
Tolstoi Hambruch
Mommsen Thoma Lenz Hanrieder Droste-Hülshoff
von Arnim
Dach Verne Hägele Hauff Humboldt
Reuter
Karrillon Garschin Rousseau Hagen Hauptmann Gautier
Defoe Baudelaire
Damaschke Descartes Hebbel
Wolfram von Eschenbach Dickens Schopenhauer Hegel Kussmaul Herder
Bronner Darwin Melville Grimm Jerome Rilke George
Campe Horváth Aristoteles Bebel Proust
Bismarck Vigny Gengenbach Barlach Voltaire Federer Herodot
Heine
Storm Casanova Lessing Tersteegen Gilm Grillparzer Georgy
Chamberlain Langbein Gryphius
Brentano Lafontaine
Strachwitz Claudius Schiller Kralik Iffland Sokrates
Katharina II. von Rußland Bellamy Schilling
Gerstäcker Raabe Gibbon Tschechow
Löns Hesse Hoffmann Gogol Wilde Gleim Vulpius
Luther Heym Hofmannsthal Morgenstern
Roth Heyse Klopstock Klee Hölty Kleist Goedicke
Luxemburg Puschkin Homer Mörike
La Roche Horaz Musil
Machiavelli Kierkegaard Kraft Kraus
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Nietzsche Nansen Laotse Ipsen Liebknecht
Marx Ringelnatz
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The Chemistry, Properties and Tests of Precious Stones

John Mastin

Imprint

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PREFACE

Some little time ago certain London diamond merchants and wholesale dealers in precious stones made the suggestion to me to write a work on this section of mineralogy, as there did not appear to be any giving exactly the information most needed.

Finding there was a call for such a book I have written the present volume in order to meet this want, and I trust that this handbook will prove useful, not only to the expert and to those requiring certain technical information, but also to the general public, whose interest in this entrancing subject may be simply that of pleasure in the purchase, possession, or collection of precious stones, or even in the mere examination of them through the plate-glass of a jeweller's window.

JOHN MASTIN.

Totley Brook,
near Sheffield.

June 1911.

THE CHEMISTRY, PROPERTIES AND TESTS OF PRECIOUS STONES

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CHAPTER I.

INTRODUCTORY.

What constitutes a precious stone is the question which, at the onset, rises in the mind, and this question, simple as it seems, is one by no means easy to answer, since what may be considered precious at one time, may cease to be so at another.

There are, however, certain minerals which possess distinctive features in their qualities of hardness, colour, transparency, refractability or double refractability to light-beams, which qualities place them in an entirely different class to the minerals of a metallic nature. These particular and non-metallic minerals, therefore, because of their comparative rarity, rise pre-eminently above other minerals, and become actually "precious."

This is, at the same time, but a comparative term, for it will readily be understood that in the case of a sudden flooding of the market with one class of stone, even if it [Pg 2] should be one hitherto rare and precious, there would be an equally sudden drop in the intrinsic value of the jewel to such an extent as perhaps to wipe it out of the category of precious stones. For instance, rubies were discovered long before diamonds; then when diamonds were found these were considered much more valuable till their abundance made them common, and they became of little account. Rubies again asserted their position as chief of all precious stones in value, and in many biblical references rubies are quoted as being the symbol of the very acme of wealth, such as in Proverbs, chapter iii., verses 13 and 15, where there are the passages, "happy is the man that findeth wisdom ... she is more precious than rubies"—and this, notwithstanding the enormous quantity of them at that time obtained from the ruby mines of Ophir and Nubia, which were then the chief sources of wealth.

It will also be remembered that Josephus relates how, at the fall of Jerusalem, the spoil of gold was so great that Syria was inundated with it, and the value of gold there quickly dropped to one-half; other historians, also, speaking of this time, record such a glut of gold, silver, and jewels in Syria, as made them of little value, which state continued for some considerable period, till the untold wealth became ruthlessly and wastefully scattered, when the normal values slowly reasserted themselves.

Amongst so many varieties of these precious minerals, it cannot be otherwise than that there should be important differences in their various characteristics, though for a stone to have the slightest claim to be classed as "precious" it must conform to several at least of the following requirements:—It [Pg 3] must withstand the action of light without deterioration of its beauty, lustre, or substance, and it must be of sufficient hardness to retain its form, purity and lustre under the actions of warmth, reasonable wear, and the dust which falls upon it during use; it must not be subject to chemical change, decomposition, disintegration, or other alteration of its substance under exposure to atmospheric air; otherwise it is useless for all practical purposes of adornment or ornamentation.

There are certain other characteristics of these curious minerals which may be classified briefly, thus:—Some stones owe their beauty to a wonderful play of colour or fire, due to the action of light, quite apart from the colour of the stone itself, and of this series the opal may be taken as a type. In others, this splendid play of colour is altogether absent, the colour being associated with the stone itself, in its substance, the charm lying entirely in the superb transparency, the ruby being taken as an example of this class of stone. Others, again, have not only colour, but transparency and lustre, as in the coloured diamonds, whilst the commoner well-known diamonds are extremely rich in transparency and lustre, the play of light alone showing a considerable amount of brilliancy and beauty of colour, though the stone itself is clear. Still others are opaque, or semi-opaque, or practically free from play of light and from lustre, owing their value and beauty entirely to their richness of colour.

In all cases the value of the stone cannot be appreciated fully till the gem is separated from its matrix and polished, and in some cases, such as in that of the diamond, cut in variously shaped facets, on and amongst [Pg 4] which the light rays have power to play; other stones, such as the opal, turquoise and the like, are cut or ground in flat, dome-shaped, or other form, and then merely polished. It frequently happens that only a small portion of even a large stone is of supreme value or purity, the cutter often retaining as his perquisite the smaller pieces and waste. These, if too small for setting, are ground into powder and used to cut and polish other stones.

Broadly speaking, the greatest claim which a stone can possess in order to be classed as precious is its rarity. To this may be added public opinion, which is led for better or worse by the fashion of the moment. For if the comparatively common amethyst should chance to be made extraordinarily conspicuous by some society leader, it would at once step from its humbler position as semi-precious, and rise to the nobler classification of a truly precious stone, by reason of the demand created for it, which would, in all probability, absorb the available stock to rarity; and this despite the more entrancing beauty of the now rarer stones.

The study of this section of mineralogy is one of intense interest, and by understanding the nature, environment, chemical composition and the properties of the stones, possibility of fraud is altogether precluded, and there is induced in the mind—even of those with whom the study of precious stones has no part commercially—an intelligent interest in the sight or association of what might otherwise excite no more than a mere glance of admiration or curiosity. There is scarcely any form of matter, be it liquid, solid, or gaseous, but has [Pg 5] yielded or is now yielding up its secrets with more or less freedom to the scientist. By his method of synthesis (which is the scientific name for putting substances together in order to form new compounds out of their union) or of analysis (the decomposing of bodies so as to divide or separate them into substances of less complexity), particularly the latter, he slowly and surely breaks down the substances undergoing examination into their various constituents, reducing these still further till no more reduction is possible, and he arrives at their elements. From their behaviour during the many and varied processes through which they have passed he finds out, with unerring accuracy, the exact proportions of their composition, and, in many cases, the cause of their origin.

It may be thought that, knowing all this, it is strange that man does not himself manufacture these rare gems, such as the diamond, but so far he has only succeeded in making a few of microscopic size, altogether useless except as scientific curiosities. The manner in which these minute gems and spurious stones are manufactured, and the methods by which they may readily be distinguished from real, will be dealt with in due course.

The natural stones represent the slow chemical action of water, decay, and association with, or near, other chemical substances or elements, combined with the action of millions of years of time, and the unceasing enormous pressure during that time of thousands, perhaps millions, of tons of earth, rock, and the like, subjected, for a certain portion at least of that period, to extremes of heat or cold, all of which determine the [Pg 6] nature of the gem. So that only in the earth itself, under strictly natural conditions, can these rare substances be found at all in any workable size; therefore they must be sought after assiduously, with more or less speculative risk.

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CHAPTER II.

THE ORIGIN OF PRECIOUS STONES.

Though the origin, formation, composition, characteristics and tests of each stone will be examined in detail when dealing with the stones seriatim, it is necessary to enquire into those particulars of origin which are common to all, in order thoroughly to understand why they differ from other non-metallic and metallic minerals.

At the very commencement we are faced with a subject on which mineralogists and geologists are by no means in full agreement, and there seems just ground for considerable divergence of opinion, according to the line of argument taken. It is a most remarkable fact that, precious as are certain stones, they do not (with a few exceptions) contain any of the rarer metals, such as platinum, gold, etc., or any of their compounds, but are composed entirely of the common elements and their derivatives, especially of those elements contained in the upper crust of the earth, and this notwithstanding the fact that gems are often found deep down in the earth. This is very significant, and points to the conclusion that these stones were formed by the slow percolation of water from the surface through the deeper parts of the earth, carrying with it, in solution or suspension, the chemical constituents of the earth's upper crust; time and long-continued [Pg 8] pressure, combined with heat or cold, or perhaps both in turn, doing the rest, as already mentioned.

The moisture falling in dew and rain becomes acidulated with carbonic acid, CO_2 (carbon dioxide), from the combustion and decay of organic matter, vegetation, and other sources, and this moisture is capable of dissolving certain calcareous substances, which it takes deep into the earth, till the time comes when it enters perhaps a division-plane in some rock, or some such cavity, and is unable to get away. The hollow becomes filled with water, which is slowly more and more charged with the salts brought down, till saturated; then super-saturated, so that the salts become precipitated, or perhaps crystallised out, maybe by the presence of more or other salts, or by a change in temperature. These crystals then become packed hard by further supplies and pressure, till eventually, after the lapse of ages, a natural gem is found, *exactly filling* the cavity, and is a precious find in many cases.

If now we try to find its analogy in chemistry, and for a moment consider the curious behaviour of some well-known salts, under different conditions of temperature, what is taking place underground ceases to be mysterious and becomes readily intelligible.

Perhaps the best salt for the purpose, and one easy to obtain for experiment, is the sulphate of sodium—known also as Glauber's Salt.

It is in large, colourless prisms, which may soon be dissolved in about three parts of water, so long as the water does not exceed 60° F., and at this temperature a super-saturated solution may easily be made. But if the [Pg 9] water is heated the salt then becomes more and more insoluble as the temperature increases, till it is completely insoluble.

If a super-saturated solution of this Glauber's Salt is made in a glass, at ordinary atmospheric temperature, and into this cold solution, without heating, is dropped a small crystal of the same salt, there will be caused a rise in temperature, and the whole will then crystallise out quite suddenly; the water will be absorbed, and the whole will solidify into a mass which exactly fits the inner contour of the vessel.

We have now formed what *might* be a precious stone, and no doubt would be, if continuous pressure could be applied to it for perhaps a few thousand years; at any rate, the formation of a natural jewel is not greatly different, and after being subjected for a period, extending to ages, to the washings of moisture, the contact of its containing bed (its later matrix), the action of the changes in the temperature of the earth in its vicinity, it emerges by volcanic eruption, earthquake, landslip and the like, or is discovered as a rare and valuable specimen of some simple compound of earth-crust and water, as simple as Glauber's Salt, or as the pure crystallized carbon.

It is also curious to note that in some cases the stones have not been caused by aqueous deposit in an already existing hollow, but the aqueous infusion has acted on a portion of the rock on which it rested, absorbing the rock, and, as it were, replacing it by its own substance. This is evidenced in cases where gems have been found encrusted on their matrix, which latter was being slowly transformed to the character of the jewel encrusted, or "scabbed" on it. [Pg 10]

The character of the matrix is also in a great measure the cause of the variety of the stone, for it is obvious that the same salt-charged aqueous solution which undergoes change in and on ironstone would result in an entirely different product from that resting on or embedded in silica.

Following out the explanation of the aqueous solution, in which the earth-crust constituents are secreted, we find that the rarer and more precious metals do not generally enter into the composition of precious stones—which fact may advisedly be repeated. It is, of course, to be expected that beryllium will be found in the emerald, since it is under the species beryl, and zirconium in zircon; but such instances are the exception, and we may well wonder at the actions of the infinite powers of nature, when we reflect that the rarest, costliest and most beautiful of all precious stones are the simplest in their constituents.

Thus we find the diamond standing unique amongst all gems in being composed of one element only—carbon—being pure crystallised carbon; a different form from graphite, it is true, but, nevertheless, pure carbon and nothing else. Therefore, from its chemical, as well as from its commercial aspect, the diamond stands alone as the most important of gems.

The next in simplicity, whilst being the most costly of all, is the ruby, and with this may be classed the blue sapphire, seeing that their chemical constituents are exactly the same, the difference being one of colour only. These have two elements, oxygen and aluminium, which important constituents appear also in other stones, but [Pg 11] this example is sufficient to prove their simplicity of origin.

Another unique stone is the turquoise, in that it is the only rare gem essentially containing a great proportion of water, which renders it easily liable to destruction, as we shall see later. It is a combination of alumina, water, and phosphoric acid, and is also unique in being the only known valuable stone containing a phosphate.

Turning to the silica series, we again find a number of gems with two elements only, silica—an important constituent of the earth's crust—and oxygen—an important constituent of atmospheric air. In this group may be mentioned the opal, amethyst, agate, rock-crystal, and the like, as the best known examples, whilst oxygen appears also mostly in the form of oxides, in chrysoberyl, spinel, and the like. This silica group is extremely interesting, for in it, with the exception of the tourmaline and a few others, the composition of the gems is very simple, and we find in this group such stones as the chrysolite, several varieties of topaz, the garnet, emerald, etc., etc.

Malachite and similar stones are more ornamental than precious, though they come in the category of precious stones. These are the carbonate series, containing much carbonic acid, and, as may be expected, a considerable proportion of water in their composition, which water can, of course, be dispelled by the application of heat, but to the destruction of the stone.

From all this will be seen how strong is the theory of aqueous percolation, for, given time and pressure, water charged with earth-crust constituents appears to be the [Pg 12] origin of the formation of all precious stones; and all the precious stones known have, when analysed, been found to be almost exclusively composed of upper-earth-crust constituents; the other compounds which certain stones contain may, in all cases, be traced to their matrix, or to their geo-logical or mineralogical situation.

In contradistinction to this, the essentially underground liquids, with time and pressure, form metallic minerals and mineralise the rocks, instead of forming gems.

Thus we see that in a different class of minerals—compounds of metals with the sulphates, such as sulphuric acid and compounds; also those containing the metallic sulphides; in cases where the metalliferous ores or the metallic elements enter into composition with the halogens—bromine, chlorine, fluorine, and iodine—in all these, precious stones are comparatively common, but the stones of these groups are invariably those used for decorative or ornamental purposes, and true "gems" are entirely absent.

It would therefore appear that though metallic minerals, as already mentioned, are formed by the action of essentially *underground* chemically-charged water—combined with ages of time and long-continued pressure, rocks and earth being transformed into metalliferous ores by the same means—precious stones (or that portion of them ranking as jewels or gems) must on the contrary be wholly, or almost wholly, composed of *upper*-earth-crust materials, carried deep down by water, and subjected to the action of the same time and pressure; the simpler the compound, the more perfect and important the result, as seen in the diamond, the ruby, and the like.

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CHAPTER III.

PHYSICAL PROPERTIES.

A—Crystalline Structure.

Before proceeding to the study of precious stones as individual gems, certain physical properties common to all must be discussed, in order to bring the gems into separate classes, not only because of some chemical uniformity, but also because of the unity which exists between their physical formation and properties.

The first consideration, therefore, may advisedly be that of their crystals, since their crystalline structure forms a ready means for the classification of stones, and indeed for that of a multitudinous variety of substances.

It is one of the many marvellous phenomena of nature that mineral, as well as many vegetable and animal substances, on entering into a state of solidity, take upon themselves a definite form called a crystal. These crystals build themselves round an axis or axes with wonderful regularity, and it has been found, speaking broadly, that the same substance gives the same crystal, no matter how its character may be altered by colour or other means. Even when mixed with other crystallisable substances, the resulting crystals may partake of the two varieties and become a sort of composite, yet to the physicist they are read like an open book, and when [Pg 14] separated by analysis they at once revert to their original form. On this property the analyst depends largely for his results, for in such matters as food adulteration, etc., the microscope unerringly reveals impurities by means of the crystals alone, apart from other evidences.

It is most curious, too, to note that no matter how large a crystal may be, when reduced even to small size it will be found that the crystals are still of the same shape. If this process is taken still further, and the substance is ground to the finest impalpable powder, as fine as floating dust, when placed under the microscope each speck, though perhaps invisible to the naked eye, will be seen a perfect crystal, of the identical shape as that from which it came, one so large maybe that its planes and angles might have been measured and defined by rule and compass. This shows how impossible it is to alter the shape of a crystal. We may dissolve it, pour the solution into any shaped vessel or mould we desire, recrystallise it and obtain a solid sphere, triangle, square, or any other form; it is also possible, in many cases, to squeeze the crystal by pressure into a tablet, or any form we choose, but in each case we have merely altered the *arrangement* of the crystals, so as to produce a differently shaped *mass*, the crystals themselves remaining individually as before. Such can be said to be one of the laws of crystals, and as it is found that every substance has its own form of crystal, a science, or branch of mineralogy, has arisen, called "crystallography," and out of the conglomeration of confused forms there have been evolved certain rules of comparison by which all known crystals may be classed in certain groups. [Pg 15]

This is not so laborious a matter as would appear, for if we take a substance which crystallises in a cube we find it is possible to draw nine symmetrical planes, these being called "planes of symmetry," the intersections of one or more of which planes being called "axes of symmetry." So that in the nine planes of symmetry of the cube we get three axes, each running through to the opposite side of the cube. One will be through the centre of a face to the opposite face; a second will be through the centre of one edge diagonally; the third will be found in a line running diagonally from one point to its opposite. On turning the cube on these three axes—as, for example, a long needle running through a cube of soap—we shall find that four of the six identical faces of the cube are exposed to view during each revolution of the cube on the needle or axis.

These faces are not necessarily, or always, planes, or flat, strictly speaking, but are often more or less curved, according to the shape of the crystal, taking certain characteristic forms, such as the square, various forms of triangles, the rectangle, etc., and though the crystals may be a combination of several forms, all the faces of any particular form are similar.

All the crystals at present known exhibit differences in their planes, axes and lines of symmetry, and on careful comparison many of them are found to have some features in common; so that when they are sorted out it is seen that they are capable of being classified into thirty-three groups. Many of these groups are analogous, so that on analysing them still further we find that all the known crystals may be classed in six separate systems [Pg 16] according to their planes of symmetry, and all stones of the same class, no matter what their variety or complexity may be, show forms of the same group. Beginning with the highest, we have—(1) the cubic system, with nine planes of symmetry; (2) the hexagonal, with seven planes; (3) the tetragonal, with five planes; (4) the rhombic, with three planes; (5) the monoclinic, with one plane; (6) the triclinic, with no plane of symmetry at all.

In the first, the cubic—called also the isometric, monometric, or regular—there are, as we have seen, three axes, all at right angles, all of them being equal.

The second, the hexagonal system—called also the rhombohedral—is different from the others in having four axes, three of them equal and in one plane and all at 120° to each other; the fourth axis is not always equal to these three. It may be, and often is, longer or shorter. It passes through the intersecting point of the three others, and is perpendicular or at right angles to them.

The third of the six systems enumerated above, the tetragonal—or the quadratic, square prismatic, dimetric, or pyramidal—system has three axes like the cubic, but, in this case, though they are all at right angles, two only of them are equal, the third, consequently, unequal. The vertical or principal axis is often much longer or shorter in this group, but the other two are always equal and lie in the horizontal plane, at right angles to each other, and at right angles to the vertical axis.

The fourth system, the rhombic—or orthorhombic, or prismatic, or trimetric—has, like the tetragonal, three axes; but in this case, none of them are equal, though the two lateral axes are at right angles to each other, and [Pg 17] to the vertical axis, which may vary in length, more so even than the other two.

The fifth, the monoclinic—or clinorhombic, monosymmetric, or oblique—system, has also three axes, all of them unequal. The two lateral axes are at right angles to each other, but the principal or vertical axis, which passes through the point of intersection of the two lateral axes, is only at right angles to one of them.