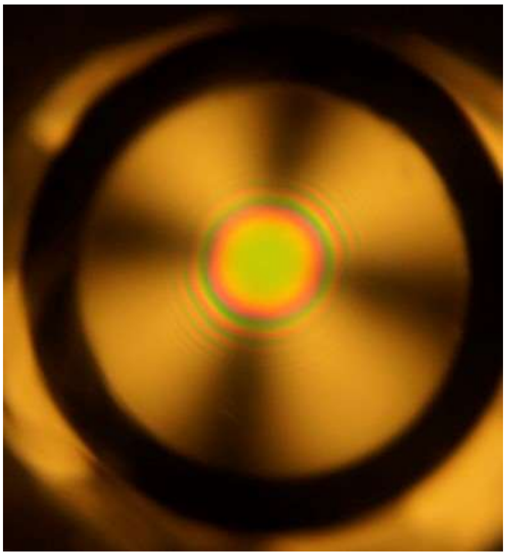
Practical Gemmology

How to Identify
Natural and Artificial
Gem-Stones



By

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Cover photograph is of the Quartz ‘Bull’s Eye’ as seen through the Conoscope. (See Chapter Three)

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Introduction

This book was really written for the novice gemmologist but does have material which ought to be of interest to the more advanced.

Focus is on the practical aspect of gemmology. Theory is kept to a minimum, except when dealing with areas not commonly found in the regular textbooks.

It is envisaged that the novice will, over a period of months, collect the basic equipment and selections of gem-stones for testing. The internet provides sites such as Ebay and Amazon where one can browse for equipment bargains. However be wary of far-eastern sites offering 'genuine', 'Natural' and 'earth-mined' stones as these are very often simulants, or at best synthetics.

All the photographs in this book were taken by myself using gem-stones in my personal possession. I did this to avoid the beautiful examples given in many text-books, of fabulous Museum pieces that the ordinary person will never be in a position to view, or handle, for themselves.

Any errors, typing or otherwise, are entirely my fault and will, hopefully be brought to my attention.

Hopefully you will enjoy the presentation.

Your's Sincerely

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Chapter One.

Rough Material 1.

Crystal structure and Hardness

290 carat Cubic Zirconia Rough

What is a gemstone? In general a gemstone is a mineral with a specific chemical formula which can be found as a crystal and has inherent beauty, durability and rarity. It becomes a jewel when faceted (has flat faces) or is cut into a cabochon (rounded shape).

Minerals are substances which were formed in the earth by natural inorganic (non-living) forces. They each have a uniform atomic structure with a specific chemical formula and a corresponding set of physical and optical properties which are the same throughout. Many thousand minerals exist, but only a few, about 80 in number, have the necessary conditions of **beauty, durability and rareness,** or have special optical effects, e.g. Opal (play of colour) Alexandrite (Colour change) and Chrysoberyl (Cats-eye), to be rated as gem-stones which may be used in jewellery.

Of these 80 or so minerals, some are elements, such as diamond (crystallised carbon), gold, silver, platinum, rhodium and iridium, but apart from the diamond these other elements are not considered to be gem-stones.

Minerals are found in the earth's crust in various degrees of purity, with the bulk of the crust consisting of different mixtures of minerals combined together as aggregates called rocks. The granite rock, for example, is a mixture of feldspar, mica and quartz, whereas a gemstone (with a very few exceptions), will be composed of a single material. This material was once in a molten state in the earth and on cooling formed crystals whose size depended on the rate of cooling and the space available to it.


Photo 1.1: 20.74ct Lab Alexandrite in artificial light and in day-light

Photo 1.2: A 27ct Serephinite (Angel Stone) with natural copper inclusions and hardness 2-4 (Mohs scale)

Photo 1.3: A polished piece of pink granite.

Photo 1.4: 19.1ct White Opal

Photo 1.5: Chrysoberyl Cat's Eye

Gemstones can be divided into three groups:

Group 1: The uncut, unpolished natural crystal or ornamental stone.

Photo 1.6: Selection of ornamental stones. Top row L to R: Labradorite, Lapis Lazuli, Fossil Coral. Bottom row L to R: Lazulite, Seraphinite, Larimar.

Photo 1.7: Free uncut amethyst

Photo 1.8: Emerald in its host rock

Group 2: The faceted cut crystal.

Photo 1.9: A selection of natural faceted cut crystal gemstones

Group 3: The non-faceted cabochon, rounded and polished crystal or ornamental stone, which generally comes with a flat underneath surface.

Photo 1.10: A selection of cabochons. *L to R : Apatite, Glass, Hackmanite, Malachite, Sunstone*.

Each of these three groupings may require tests which are unique to that grouping.

First Practical Session ….

Aims .. To select gems of the same colour from a variety of stones.

To get practice in the handling of gemstones using tweezers.

To observe different types of inclusions in gemstones.

Equipment Gemstone selection, Tweezers, Loupe or hand magnifying glass, Small sealable plastic bags, tray. (Bright day-light is best but otherwise a good white light source can be used.)

Below are photographs of various gem-stone tweezers and a selection of loupes and magnifiers

Photo 1.11: Gem-stone Tweezers

Photo1.12: Loupes and Magnifying glasses

Spread out your gemstones on a tray (white if you have it), not on a table. You may want to move the stones without disturbing their layout to a different place.

Now use a tweezers to match the stones for colour.

Do you have any stones with round tops and no flat surfaces (except perhaps the base)? These are known as cabochons. Put these aside for now.

Do you have any uncut stones? These are called roughs. Put these To one side for now.

From your selection of cut and polished stones………

Pick out one of each type of cut … round, oval, shield, square, rectangle etc. You might like to put these in a display box as your first exhibit.

Now examine some of the stones using a tweezer and a Loupe, (Photos 1.11 and 1.12), noting inclusions if any. An inclusion is any foreign body that is trapped inside another mineral while that mineral forms. It may be elemental, crystalline, liquid, gas bubbles or, simple fractures or those caused by internal radioactive material. Irregular colouring may also be considered as inclusion.

Note: Inclusions are to be found in most natural gem-stones. Any gems without any visible inclusions are generally man-made.

Photo 1.13: Quartz with golden rutile (Titanium Dioxide) needle Inclusions.

Photo 1.14: Quartz pyramid with black tourmaline needle Inclusions.

Make a note of the different ones you find. Use a tweezers, preferably one with a sliding lock to hold the stone. Take care not to send the stone flying by pinching it and keep the holding pressure light. Small stones tend to be difficult to see if they reach the floor.

Now place each of the matched stones in separate containers. (I find bank coin pouches useful here.)

You might be able to make a tentative identification from the colour. Note any such made.

We now move on to tests that can be used for the uncut rough stones. For now four are considered as follows…

1. Visual Examination
2. The hardness test
3. The magnetic test
4. The specific gravity test

Second Practical Session: Visual Examination.

In the first practical session a selection of gem material was sorted into roughs, faceted cut and cabochons. If you examine the roughs you may come across some with definite natural faces. These can help to narrow the number of possibilities for identification, as you may be able to determine to which crystal system the rough belongs. The photo below shows a selection of natural roughs showing definite planar faces.

Photo 1.15: Selection of crystals.

The crystals in Photo 1.15: are: L-R: Danburite, Chrome-Diopside, Tanzanite, Tourmaline, Quartz, Ruby. (Orthorhombic, Monoclinic, Orthorhombic, Trigonal, Trigonal, Trigonal (hexagonal cross-section))

The word crystal comes from the Greek word for ice, krystallos, and was once used only for those materials which had the clarity and transparency of ice. Over time it also came to be used for coloured or non-transparent materials.

Crystals have a definite shape with planar faces meeting at specific angles to each other. The overall shape is seen to be the same in all specimens of a particular mineral, irrespective of its size. Each crystal can be characterised by a number of imaginary lines (each called an axis of symmetry) around which the crystal may be turned to reveal a corresponding similar face.

The symmetry of crystals is defined by three elements: Axes, Planes and centres of symmetry.

An axis of symmetry is an imaginary line through the crystal such that when one rotates the crystal around it, the same position in space will be occupied two or more times during a single rotation. If this position occurs twice then the axis is deemed diagonal, if three times trigonal, four times tetragonal and six times hexagonal.

A plane of symmetry is an imaginary plane through the crystal, which, if the crystal is cut through it will lead the two sections to appear whole when placed with the cut plane against a mirror.

A centre of symmetry occurs when like faces and edges occupy corresponding positions on opposite sides of a central point.

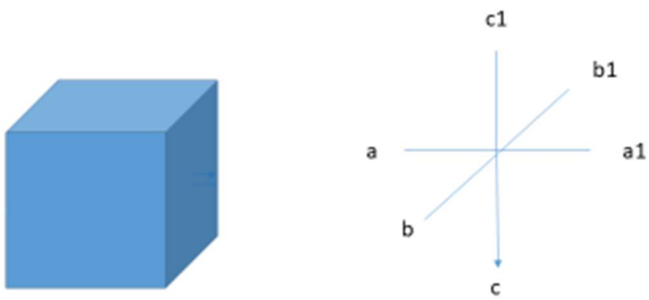
The credit for the establishment of the crystals' classification belongs to the French priest, Renè Just Haüy (1743 – 1822), who made such detailed studies of crystals that he is regarded as the father of modern crystallography. He was also involved in the establishment of the metric system during the French revolution.

Haüy divided crystals into seven systems which were further divided into 32 classes.

The Seven Crystal Systems

Cubic System

The Cubic System has three axes at right angles to each other. The horizontal axes are called the a and b axes while the perpendicular axis is the c axis)



Cubic crystal has three axes through the mid-points of opposing faces at 90^0 to each other with a-a1 = b–b1 = c–c1

Principal examples of gem-stones of the cubic crystal group are Diamonds, Fluorite, Garnet family and Spinel.

Photo 1.16:
0.1 ct Diamond crystal (Magnified)

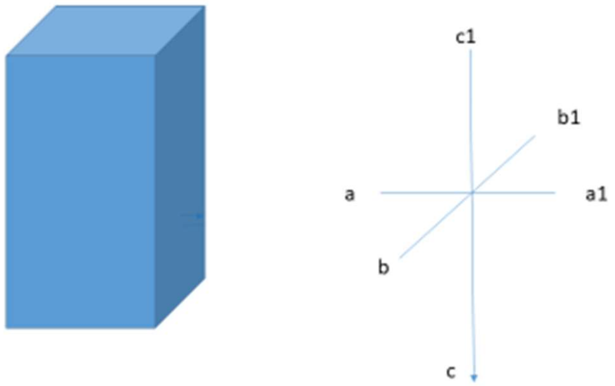
Photo 1.17:
3 octahedral Fluorite crystals

Photo 1.18: Three natural Garnet crystals showing a selection of different faces.

Typical shapes of the Cubic system are the cube, octahedron (8 triangular faces), rhombic dodecahedron (12 rhombic faces), pentagonal dodecahedron (12 pentagonal faces), icosi-tetrahedron (24 pentagon faces) and hexacisoctohedron (48 equal triangular faces). Members having the cubic crystal system may show different faces in the same sample.

Tetragonal system .. 3 crystal axes, the two lateral (a and b axes) being of equal length, the third (C axis) being longer or shorter. The angles between the axes being right angles.

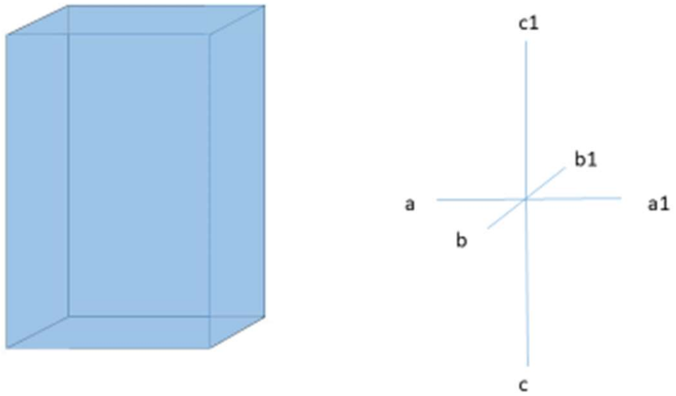
Typical shapes are four-sided prisms and pyramids, trapezohedrons (kite shaped faces of mirror prisms), eight-sided pyramids and double pyramids.



Tetragonal crystal has three axes through the mid points of opposing faces at 90^0 to each other with a-a1 = b–b1 but ≠ c–c1 (Elongated cube shape.)

Principal examples are Rutile, Scapolite and Zircon.

Orthorhombic system .. 3 crystal axes all at 90^0 to each other but of unequal lengths.



Orthorhombic Crystal. 3 unequal axes through mid-points of opposing faces. i.e a-a1 ≠ b-b1 ≠ c-c1. (Corn-flakes box shape)

Principal examples are Topaz, Peridot, Iolite, Chrysoberyl, Sinhalite, Tanzanite and Kornerupine.

Typical shapes are basal pinacoids, rhombic prism and pyramids and rhombic double pyramids.

Hexagonal system .. 4 crystal axes, the three lateral being at angles of 60^0 to each other and of equal length, the fourth at right angles to them and usually longer.

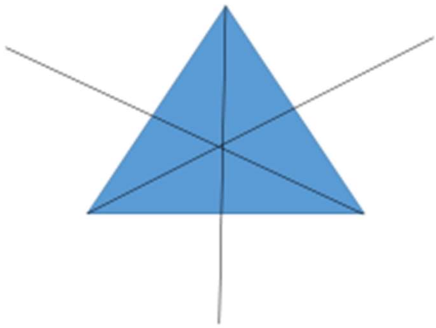
Horizontal cross section of hexagonal crystal. Three equal length axes from the centre points of the faces are at 60^0 to each other, the vertical axis is usually longer than these and at 90^0 to them and cuts their centre point. The six outer angles of the hexagon are 120^0 each.

Principal examples are Apatite, the Beryl family (including Emerald, Aquamarine and Precious Beryl), and Taaffeite.

Photo 1.19: Two natural part crystals of Emerald showing the 120^0 angle between faces.

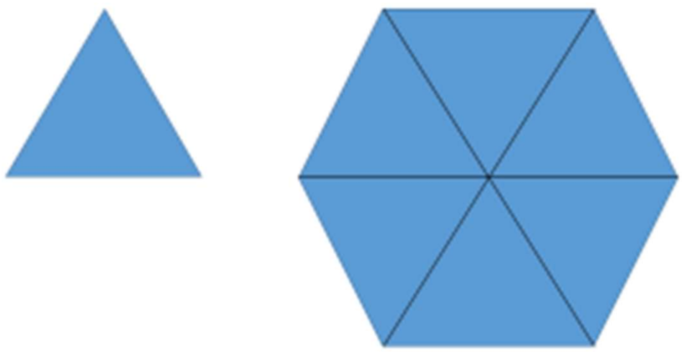
Typical shapes are hexagonal prisms and pyramids, also twelve-sided pyramids and double pyramids.

Trigonal system: (rhombohedral system) 4 crystal axes as with the Hexagonal but with symmetry lower than it. The prism base is an equilateral triangle (all three sides of equal length, and each of the three internal angles is 60^0).



Cross-section of the Trigonal crystal system is triangular with 3 axes from the points of the triangle to the opposing face centres intersecting. A fourth axis cut through this point at 90^0 to the three.

Many take this system to be a sub-set of the hexagonal crystal system especially in the United States. This can be seen in the following diagram where six of the trigonal bases can combine to form a perfect hexagon.



Left: a trigonal cross-section and right: six apices coming together at a point to form a hexagon.

The trigonal cross section also allows for a rhombohedral shape to form where four of the cross-sections can align 'head-to-toe' as shown in the following diagram.

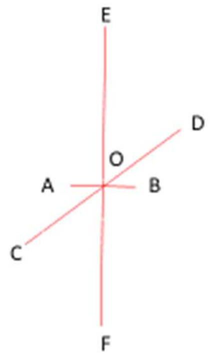
This structure can be separated from those of the Orthorhombic system by examination of the angles formed, which are 60^0 and 120^0.

Principal examples are Quartz, Calcite, Corundum (Ruby, Sapphire) and Tourmaline.

Photo 1.20: 45.85ct Calcite

Typical shapes are three-sided prisms and pyramids, rhombohedra and scalenohedra (A hemihedral crystal form, having half the faces for maximum symmetry, of 8 or 12 faces, each face being a scalene triangle (all three sides of different length).

Monoclinic system .. 3 crystal axes all of unequal lengths. Two of the axes intersect obliquely while the third is at right angles to their plane.



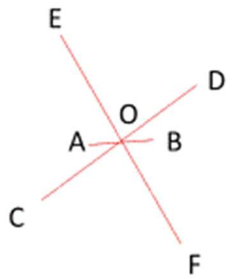
A Monoclinic crystal has three axes of unequal length
(AB ≠ CD ≠ EF).

The horizontal axes intersect at angles other than 90^0, while the vertical axis is at 90^0 to them. (AOC ≠ COB ≠ 90^0 and AOE = 90^0.

Principal examples are Diopside, Sphene, Ulexite and Orthoclase.

Typical shapes are basal pinacoids (two parallel faces which intersect only the c crystallographic axis) and prisms with inclined end faces.

Triclinic system .. 3 crystal axes of unequal lengths and inclined to each other at angles other than 90^0. Typical shapes are paired faces.



Triclinic crystals have three intersecting axes of unequal length (AB ≠ CD ≠ EF) and are inclined to each other at angles other than 90^0. (AOE ≠ AOC ≠ COB ≠ 90^0)

Principal examples are Amblygonite, Kyanite, Rhodonite, Turquoise, Labradorite and Oligoclase.

On occasion one may find crystals with pyramidal terminations. These are facets forming from the ends of the crystal body and coming to a point. A single termination is more common than the double since most crystals have grown outwards from a rock base.

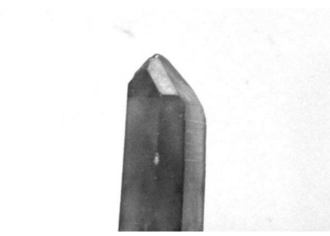



Photo 1.21: (Left) Terminated crystals of colourless and smokey Quartz
Photo 1.22: (Right) Close-up of termination of a Smokey Quartz.

Third Practical Session: The Hardness Test

In 1812 the *Mohs scale* of mineral hardness was devised by the German mineralogist Frederich *Mohs* (1773-1839), who selected the ten minerals, each of which can be scratched by those lower on the scale. The scale goes from 1 to 10, softest to hardest and is non-linear. 10 on the scale being 1500 times harder than 1 on the scale.

Hardness			Absolute Hardness
1	Talc		1
2	Gypsum		2
3	Calcite		9
4	Fluorite		21
5	Apatite		48
6	Feldspar		72
7	Quartz		100
8	Topaz		200
9	Corundum	(Ruby, Sapphire)	400
10	Diamond		1500

(Gemologists ignore the absolute hardness and only use Mohs 1 to 10 Scale. The absolute hardness is only given, here, to show the non-linearity of his scale.)

The price of a gemstone depends principally on three factors

1: Its beauty   2: Its durability   3: Its rarity

Durability depends largely on the hardness of the gemstone.

Most dust is simply small specks of quartz.
Sand is also quartz.
Quartz has a hardness of 7 on Mohs' scale so it will scratch any compound with a lower value.
For that reason gemstones for jewellery will generally have a hardness of 7 or above.

Once you have got a selection of known gemstones you can make up a set of small ones set aside for use as hardness testers, but a home hardness kit could be made of the following …

	Hardness
Fingernail	2.5
Copper Coin	3
Iron Nail	4.5
Knife Blade	5.5
Glass	6+
Hardened Steel File	7+

A piece of quartz, picked up on the beach or elsewhere, has a hardness of 7 and is commonly to be found.

Photo 1.23: 55gm Beach milky Quartz

If you have some small known gemstones of those of the Mohs scale, you could mount them on the slightly hollowed end of pencils using epoxy glue to have a permanent testing set. Industrial sets are available.

Test 1. If you collect a number of small stones from the beach or garden you can use these to be tested for hardness until you get some rough gem material.

Photo 1.24: A selection of polished ‘rough’ suitable for hardness testing. (Bought on EBay).

Photo 1.25: A box of named polished ‘rough’ (EBay).

Take some of the rock samples and use your hardness kit to estimate the various hardness of each by trying to scratch it with each of the testers, starting with the least hard.

Write down your results.

What conclusion did you arrive at?

Question? Should this type of test be performed on a faceted gemstone? Why?

Answer: No, because you will leave a mark on it once you reach a tester with a greater hardness. Only use this test on Rough material.

Chapter Two

Rough Material 2.

Magnetism. Specific Gravity.

Nine double terminated natural Tanzanian Ruby (83ct) crystals.

Barrel-shaped with 6 sided cross-sections

Fourth Practical Session …. Magnetic attraction

Equipment… Button magnets
Flat-topped nail
Side plate
Water
Top-pan digital scales, Pocket variety is fine.

Take a few of the button magnets and place on top of each other and use the flat head of a nail to hold them while you use your magnet spear… (you can vary the number of magnets to find the optimum attraction.)

Photo 2.1: Magnet spear, (Magnet wand)

Take out one of each of the matched stones and place them on the tray apart from each other. Bring the flat end of the spear close to a stone and see if you can move the stone without touching it. Note any that move.
Now see if any of the stones can be lifted by the magnet spear (Yes you can touch the stone with the magnet) Note any such stones.

Take a plate or other object and add water to a depth of about 1 cm. Place a stone on to a piece of bubble wrap or other light floatable material and place on to the surface. Now use your magnet spear to attempt to draw the floating stone around the plate. You will note (of course) that only those which were attracted earlier will do so now.

You can try to move some of the floating stones by raising the plate on "stilts" and moving the magnet spear underneath.

Photo 2.2: The magnet spear has lifted a red stone, (a garnet), from the selection shown earlier.

To finish this lesson put an empty plastic container (from yoghurt or some other food stuff) to rest upside down on your top balance.

First note the reading on the balance. Now take your magnet spear and hold just above the container. If the reading changes at all then you need a taller container.

Stick a small amount of blue-tac onto the container and make an indentation in it to hold a stone with the table facet upright. (Facets are the flat faces of the cut stone and the table facet is the flat area on the top of the stone.)

Place a stone onto the indentation, (here a 101.4ct brown sapphire).

Note the reading (Photo 2.3: 32.25 gm).

Now bring the magnet spear as close to the stone as you can without touching.

Note any change in reading. Here Photo 2.4: 32.19 gm, a drop of .06 grams.

Photo 2.3

Photo 2.4

Record your readings as follows…

No change (no attraction),

1 – 3 centigram change (slight attraction),

3 – 7 centigram change (Moderate attraction),

Greater than 7 centigram change (large attraction).

These values have been taken as a working model, you may feel that a different range is more suitable for your equipment.)

(Note this will be a regular test to be made on an unknown stone)

Note 1 … did you find that a dark red stone was the most attracted to the magnet spear? This stone is probably a garnet and so you have your first positive test for identification.

Note 2 … You can use this test on mounted stones, for example those in rings. Watch out that the magnetic effect is not due to the metal of the ring itself.

Some notes ….

The Magnet will attract, may even pick up small stones of the following:

Demantoid Garnet
Spessartine Garnet
Red Garnet
Rhodolite Garnet may be picked up.
Tsavorite Garnet may be picked up.
Peridot can be dragged. (Glass is inert).
Moissanite is strongly attracted by the magnet.
Sphene (yellow) weakly affected by the magnet.
Sapphire
Ruby (any magnetic effect indicates a natural stone.)
Alexandrite (Chrysoberyl) is weakly magnetic while the synthetic is not.
Spinel (natural is weakly magnetic while the synthetic is not.)
Turquoise (natural, green and blue) is moderately affected by the magnet while imitations are not.
Rhodocrosite is highly affected by the magnet.
Aquamarine is weakly to moderately attracted by the magnet.

Fifth Practical Session… Specific Gravity

Vocabulary …..

Raw material the gemstone in the rock.
Rough the gemstone extracted from the rock, usually a crystal.
A **fashioned stone** is one cut and polished either as a faceted stone or a cabochon

Specific Gravity is the ratio of the mass of an object divided by the mass of an equal volume of pure water @ 4°C and 1 atmosphere pressure.

The use of specific gravity can, on occasion, be used in the identification of cut stones but is an essential test for the identification of rough material. Although somewhat tedious to perform it is well worth while becoming competent in its use.

Table 1 in the appendix gives the specific gravity of the common gemstones.

Note: This method cannot be used for mounted stones, i.e. stones in jewellery.

The traditional method for finding the specific gravity of a stone is to measure the apparent loss of mass when the stone is immersed in pure water. (Pure water is rarely readily available, so ordinary tap-water can be used with a correction factor added, as described later on in this chapter.)

The stone is suspended from a balance and its mass is noted (M1) while it is free-hanging. A container of water is then placed so that the stone is completely covered and the new mass is noted (M2).

The Specific Gravity is given by the formula M1/(M1-M2)

It is quite tedious to set up the apparatus for this, and so I suggest an easier approach which uses the law of conservation of energy.

Photo 2.5: Apparatus for Specific Gravity test.

The necessary apparatus for this method is as follows, from the left in Photo 2.5 ….

Container of water

Stand, through which a knitting needle is fitted to hold the stone support.

Top-pan balance.

Stone support (here a shaped copper coin with four lengths of fine chain attached).

Stone to be tested (here a round cut clear quartz).

A specific gravity bottle. (pycnometer)

Note … (A hydrometer can be used instead of the pycnometer)

Method **Step 1**

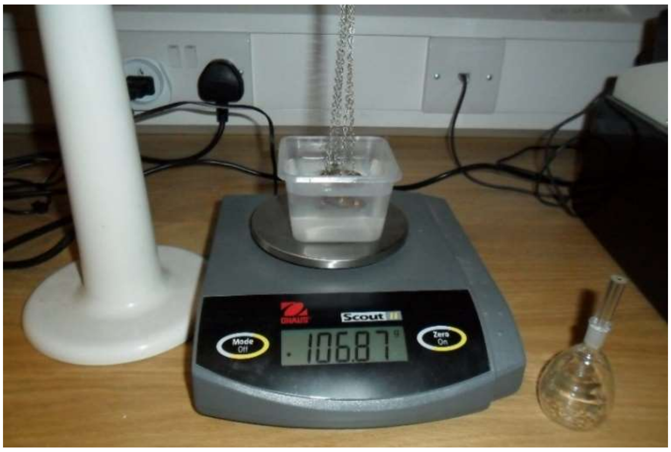


Photo 2.6: Specific Gravity Set-Up.

The container of water is placed on the balance and the stone support is freely immersed in the water. The mass is 106.87 gm.

Step 2

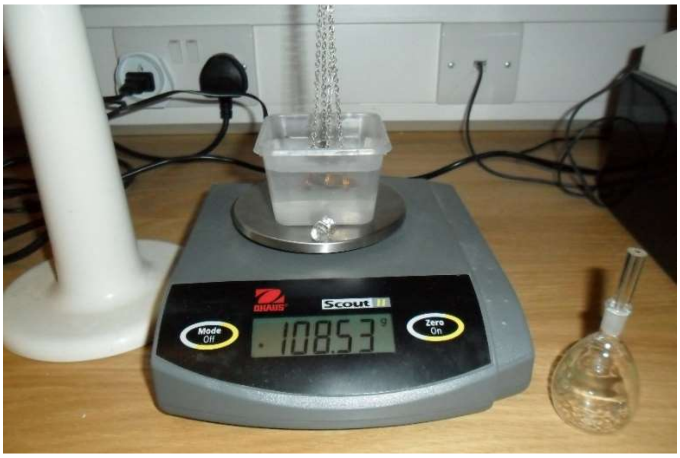


Photo 2.7: Weighing the test stone.

The stone is now also placed on the weighing pan giving a mass of 108.53 gm in total. (Photo 2.7). Thus the mass of the stone is 108.53 – 106.87 gm, i.e. 1.66 gm.

Step 3

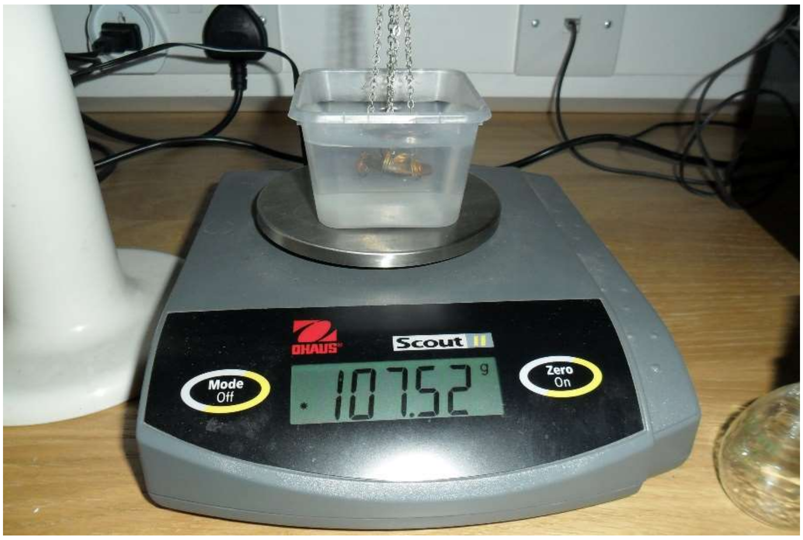


Photo 2.8: The stone is now placed on the stone support making sure it is wholly immersed. The total mass is now 107.52 gm which shows a gain of (107.52 – 106.87) gm, i.e. 0.65 gm.

This gain, by the principle of conservation of energy has to be equal to the loss of mass of the stone when immersed in the water.

Thus the specific gravity of the stone is the mass of the stone divided by the apparent loss in weight in water, here 1.66 / 0.65 which works out to be 2.56.

A correction needs to be made since tap water was used instead of pure distilled water.

The traditional method for finding this correction will be explained later in this chapter. I recommend, however, a different method based on the remarks of the celebrated Irishman Robert Boyle

(25/Jan/1627 – 31/Dec/1691) which is easier and less open to experimental error.

Robert Boyle suggested that rock crystal, due to its obvious purity and availability could be taken as the standard for comparison of specific gravity. Such a crystal, either in the rough, or cut, can be used to do away the need to have absolutely pure water when determining specific gravity.

[The following is given for interest only, and can be ignored. The mathematics are as follows… S.G. (Gem X) = (Mass (Gem X) / apparent loss of Mass (Gem X) in water) * S.G. of the water used.
S.G. (Rock Crystal) = (Mass (Rock Crystal)/apparent loss of Mass (Rock Crystal) in water) * S.G. of the water used.
Dividing the S.G. (Gem X) by the S.G. (Rock crystal) removes the S.G. of the water used leaving the following …
S.G. (Gem X) / S.G. (Rock crystal) = (Mass (Gem X) / apparent loss of mass of Gem X in water) / (Mass (Rock Crystal) / apparent loss of mass of Rock Crystal in water)
Having previously found the S.G. of the Rock Crystal by detailed experiment or, by the use of the standard value of 2.65, the specific gravity of our gem can now be found without the need to know the specific gravity of the water used.]

Recommended method:

1. **Find mass of gemstone in air - M1**
2. **Find apparent loss in water - M2**
3. **Find mass of a quartz stone in air - M3**
4. **Find apparent loss of mass of the stone in water -M4**
5. **The specific gravity of the gemstone is**
   ((M1/M2)/(M3/M4))* 2.65

Note: M3 and M4 only need to be worked out once for each fill of the container being used.

Note: It is worth while keeping a quartz stone apart as a reference stone for all your specific gravity procedures. I use the clear crystal of 29.55 carat mass shown in the photograph 2.9 below.

Photo 2.9: Quartz reference stone

Photo 2.10: Green stone from Photo 1.24

In the centre of the photo of a selection of ‘roughs’ (Photo 1.24) is a green one (Photo 2.10) with rectangular faces. It has the rhomboid shape of the Trigonal Crystal system. (See Photo 1.20)

Performing the specific gravity test on this stone produced the following results: M1 = 5.40g, M2 = 2.04g, M3 = 5.91g, M4 = 2.24g. Inserting these values into the recommended formula gave a value of 2.6587 for the stone’s specific gravity. On comparing this with the entries in Table 1 (Appendix), you will see that Aventurine fits the result and this is confirmed when Table 2 (Appendix), shows Aventurine to have the Trigonal crystal structure.

Traditional Specific Gravity of water method to find the correction factor.

The traditional method for correcting the specific gravity of the water used the following is given. If you are happy to use the quartz crystal method then ignore this section.

Step 1. A 25 ml specific gravity bottle is weighed, see Photo 2.11 below, 19.00 gm**.**

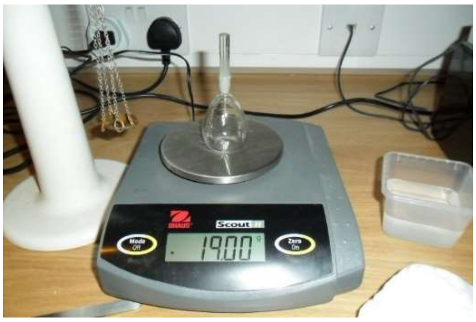


Photo 2.11: Empty S.G. Bottle

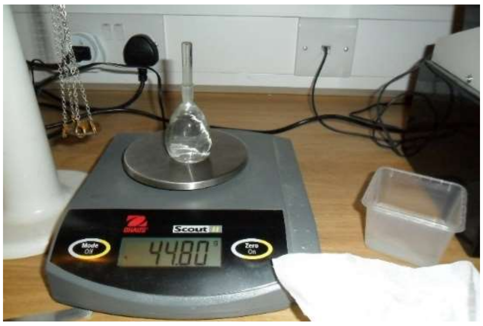


Photo 2.12: Filled S.G. Bottle

Step 2. The bottle is now filled with the water and re-weighed, see Photo 2.12, 44.80 gm.

Step 3. The specific gravity of the water is thus (44.80 – 19.00) / 25 which comes to 25.80 / 25, which is 1.03.

The correction …

This number, (1.03), now needs to multiply the 2.56 which was worked out earlier and so give the true specific gravity of the stone to be 2.64. The book figure for quartz is 2.65 so allowing for experimental error this is a remarkable result allowing for experimental error.

Having found the specific gravity of the stone being tested, compare the result with the figures in Table 1 (Appendix). If you find a match then you have a clear identification. If no exact match is your value fits for a number made or of the stones, you will, at least, be able to discount many stones leaving just a few for further consideration.

Important Note: The margin for error will increase with decreasing size of the sample. For very small stones it may not be worthwhile involving this test.

Chapter Three

The Faceted Gem-Stones 1

Polariscope, Dichroic Mirror, Conoscope.

A massive 1.455 carat faceted natural Ruby

This, and subsequent chapters, will demonstrate the steps involved in the identification of faceted and polished gemstones.

Photo 3.1: Tray of precious stones, Top to Bottom: Diamonds, Garnets, Rubies and Sapphires. (each container is 1 inch in diameter)

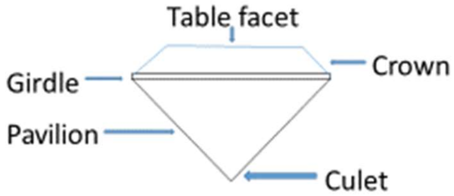
No single test will identify all the various gemstones, but each test will reduce the number of possibilities until a result is found.

The tests, detailed here, are aimed at loose stones but, in certain cases, may be used for stones that are mounted in rings, brooches etc.

Some of the tests used for the rough materials can, and at times should also be used in the testing of faceted gem-stones.

The visual test here, is mainly one of colour as no crystal shape is to be found, but also, if the stone is mounted the type of mounting should be noted. E.g. is the backing of the stone enclosed or open, is the table facet above the ring grip?

The parts of the cut stone are given in the diagram below. Facets, the flat surfaces can be of different shapes, e.g. triangle, kite, rectangle and five or six sided.



The visual observations of inclusions will be left for later consideration.

Magnetic attraction (Chapter 2) ought to be undertaken as routine.

The hardness test (Chapter 1) should not be undertaken as it damages the stone and reduces its value.

The Specific Gravity test, detailed in Chapter 2, is ideal for loose stones but is of no use for mounted stones.

The first instrument we will examine is the Polariscope.

Using the Polariscope

The Polariscope will not immediately identify a gemstone but will limit the possibilities that it might be. It should be the first tool used in the identification of cut and polished gem-stones.

Note 1: Completely opaque stones, i.e. stones that do not allow light to pass through any part of them cannot be tested by the polariscope.

Note 2: Rings and brooches which have closed backs to the gemstone are also not testable by means of the polariscope.

The Polariscope is composed of two Polaroid circular plates, the lower one, (the polarizer), is fixed, while the upper, (the analyser), is rotatable. In between the two is a clear glass plate which can also be rotated (the stone-table). A light shines upwards from beneath the lower Polaroid plate and the apparatus is viewed through the top. The unit usually comes with a Conoscope converter, (a round glass ball), and a stone holder.

Each of the polaroid plates has its own vibrational plane. If these are set at right angles to each other, then the field in between them remains dark. This is the 'crossed position' and is used in the testing of the specimen gem.

Photo 3.2: Desk Polariscope with Conoscope converter in holder and stone holder (detached)

The operation involves four steps as follows…

Step 1. The upper Polaroid plate is turned so that minimum light is seen through the plates.

Step 2. The gemstone/mineral is placed on the clear glass plate, generally table facet down.

Step3. The clear glass plate is rotated slowly through 360^o.

Step 4. Any change in light transmission through the gemstone/mineral is noted.

Possible results….

1. No light is observed through the gemstone/mineral at all throughout the rotation. The gemstone/mineral is opaque and no conclusion can be gathered from the test.

2. The light through the gemstone/mineral remains dull throughout. This indicates that the gemstone/mineral is isotropic. To be sure place the gemstone/mineral on a different facet and repeat operation. If still no change then the test object is isotopic, i.e. belongs to the cubic system. Spinel, the members of the Garnet family, Diamond, Fluorite and the man-made YAG, CZ and GGG all belong to this system.

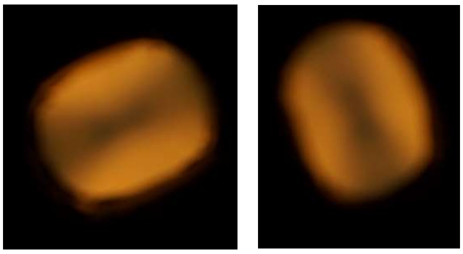
3. The light through the gemstone/mineral brightens and darkens four times each during the rotation. This indicates that the gemstone/mineral is anisotropic, i.e. belongs to one of the other six crystal systems.

4. The light through the gemstone/mineral remains bright throughout. This indicates a micro-crystalline substance. The various quartz materials fall into this category.

5. The light through the gemstone/mineral darkens and brightens irregularly on rotation of the clear glass plate. In this case rotate the clear glass plate until maximum brightness is seen through the gemstone/mineral. Now rotate the upper Polaroid plate (analyzer) through 90^0 and note whether or not the light brightens considerably through the gemstone/mineral. If it does then the test material displays ADR (anomalous double refraction) but belongs to the cubic system. If not then the test material is anisotropic, i.e. is not in the cubic crystal system – it belongs in one of the six other systems.

If the test material is anisotropic (see 3 and 5 above), then

1. Turn the stone table (glass plate) until the stone is darkest. Note orientation.
2. Rotate table until dark and again Note orientation.
3. If the new orientation is at right angles to original then the stone is uniaxial. (Tetragonal, Hexagonal or Trigonal Crystal Systems).
4. If new orientation is not at a right angle then the stone is biaxial. (Orthorhombic, Monoclinic or Triclinic Crystal Systems).



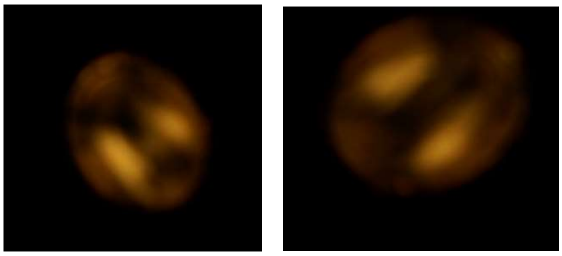


Photo 3.3: Uniaxial Sapphire 90^0. Photo 3.4: Biaxial Peridot other than 90^0

By now you have narrowed the possibilities for any stone you were able to test with the polariscope into one of three groups.
Note: the gemstones in red are the most likely.

Cubic	Uniaxial	Biaxial
CZ (Cubic Zirconia)	Apatite	Alexandrite
Diamond	Beryl Family	Amblygonite
Fluorite	Calcite	Andalusite
Garnet family	Kornerupine	Chrysoberyl
Spinel	Moissanite	Diopside
Sphalerite	Phenakite	Hiddenite
GGG	Quartz family	Iolite
YAG	Ruby (Corundum)	Kunzite
	Rutile	Kyanite
	Sapphire (Corundum)	Labradorite
	Scapolite	Moonstone
	Sinhalite	Oligoclase
	Taaffeite	Orthoclase
	Tourmaline Family	Peridot
	Zircon	Rhodonite
		Sphene
		Tanzanite
		Topaz
		Turquoise
		Ulexite

A portable hand polariscope is shown in Photos 3.5 and 3.6. This is laid out as in the table model above and the procedure is the same as above. The torch fits into the lower polaroid section and is clamped in place by the screw. (See Photo 3.6).

Photo 3.5: L-R Torch, Upper and lower polaroids, Stone-table

Photo 3.6: Gem placed on stone-table light coming through from the torch

The polariscope has another trick up its sleeve which may narrow the options for the gem-stone under examination.

Turn the stone-table so that the stone is in the lightest position
Note colour
Turn analyser through 90^0.
If a different colour or shade is now seen then the stone is pleochromic, i.e. has different colours when observed at different angles, especially when viewed through polarized light. Placing the stone on different facets may even show three colours.

Gemstones from the tetragonal, trigonal and hexagonal crystal systems (Uniaxial) can only display two colours and are called dichroic.

Those from the orthorhombic, monoclinic and triclinic crystal systems (Biaxial) can show three colours and are called trichroic.

The isometric gemstones can only exhibit one colour.

It should be noted that the effect can be very strong as in Andalusite, distinct as in Emerald and weak as in Orthoclase.

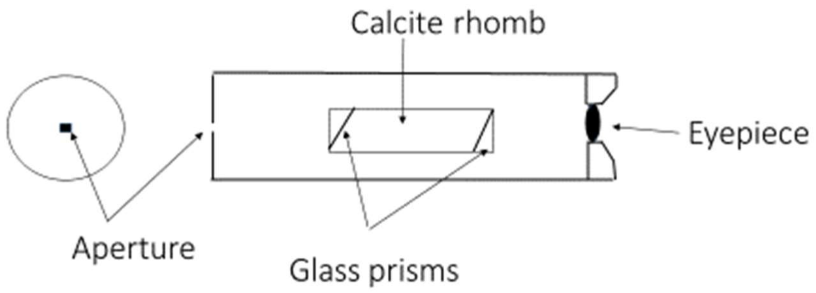
The Dichroic Mirror

Another pocket-sized instrument, the dichroic mirror, can be used instead of the polariscope for determining pleochroism more thoroughly.

Please note: this instrument is of no use in the identification of colourless gemstones of any crystal system or the coloured members of the cubic crystal system.

Photo 3.7: The aperture opening. Photo3.8: The Dichroic mirror.

On the following page is a schematic diagram of the Dichroic mirror.



How it works.

The calcite rhomb breaks the incoming light into two separate beams of polarised light which vibrate in different planes. To demonstrate this, place a crystal of Iceland Spar on lined paper. The line underneath appears doubled when viewed through the crystal. Looking at this through a polarised sheet, which is slowly rotated through 90^0, first one of the lines disappears and then reappears, while the other remains and then disappears.

The stone being examined must have a bright light shone through it. Then the aperture of the dichroic mirror is brought near to the stone. Looking through the eyepiece you will observe two rectangles side by side each of which may be of one or another colour.

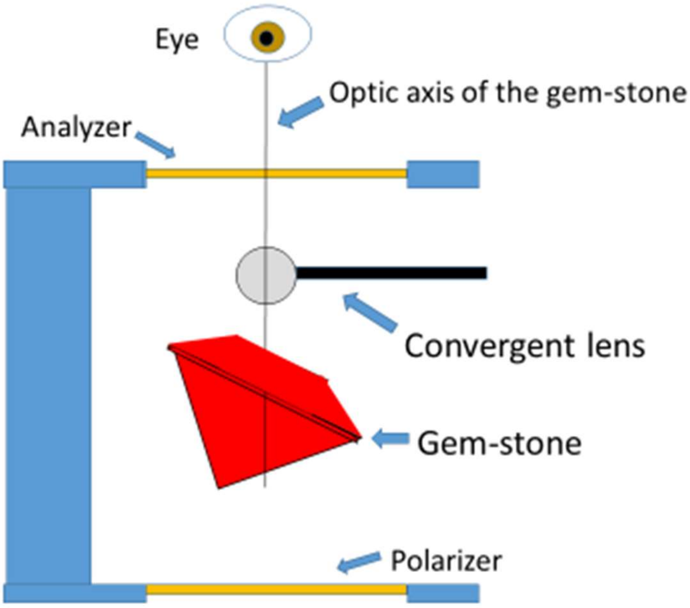
If only two colours can be seen, no matter how the stone is rotated, the gemstone is from the tetragonal, trigonal or hexagonal crystals. (Dichroic).
If three colours can be seen on rotation of the stone the gemstone is from the orthorhombic, monoclinic or triclinic crystal systems. (Trichroic).

Table 3 in the Appendix gives the pleochromatic colours for various gemstones.

The Conoscope.

To conclude this chapter let's look at the little used Conoscope which consists of the polariscope and the convergent lens accessory.

When viewing gem-stones, other than those of the Cubic system, an interference pattern may be seen by using the polariscope, a stone holder and a convergent lens. This lens is usually supplied with the polariscope and made of rounded stress-free glass.



Schematic drawing of the polariscope as conoscope

This is a finiky experiment to perform and is rarely used in practice because it only reveals whether the gem-stone belongs to the uniaxial or biaxial groups. However it does this in a spectacular fashion.

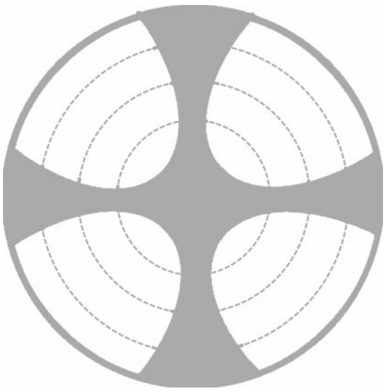
Procedure:

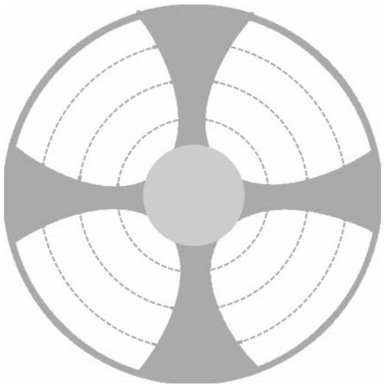
1. Ensure that the polarizer and analyzer are in the crossed position. (Little or no light passing through.)
2. Hold the gem-stone in between the crossed polarizers by means of the stone-holder of the polariscope.

3. Turn the gem-stone until bright interference colours are seen through some of the facets. You are now looking along an optic axis of the gem-stone. (This sounds simple but in practice takes time. If the gem-stone is of the cubic crystal variety no such colours will be found.)
4. Interference patterns can now be observed by placing the convergent lens above the gem-stone close to one of the coloured facets.

If the gem-stone is uniaxial, a set of concentric coloured rings through which a dark cross appears, is seen.

(Quartz, which is uniaxial, occassionally has a circular ‘bull’s eye’ where the centre is not dark but generaly of a pink or pale green colour.)





Left; Uniaxial Interference Quartz Bull’s eye

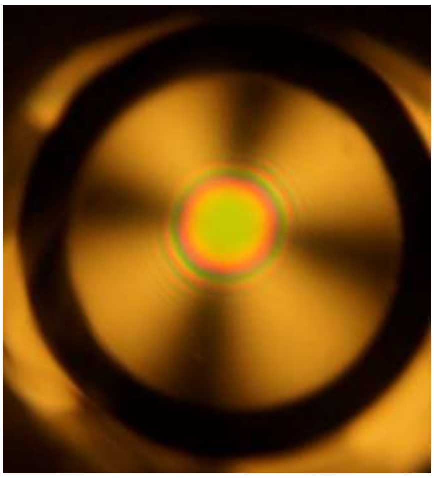


Photo 3.9: Photo of Quartz Bull’s Eye

If the gem-stone is biaxial the interference pattern may appear as a dark cross, the arms of which go through two sets of concentric coloured rings. The uprights of the cross may also be halfed, each moving to the centres of the concentric rings.

On occasion the pattern may be so large as to allow only a part of it to be seen.

Chapter Four

The Faceted Gem-Stones 2

The Refractometer

Two Polycrystalline (Massive) members of the Beryl Family

Left: A 4,250 carat faceted natural Emerald

Right: A 980 carat natural golden Beryl

Refraction

Have you ever noticed that a pond of water is considerably deeper than it appears to be? In fact it is one and a third times deeper. So a pond which appears to be a metre deep is in fact 1.333 metres deep. **The ratio between the actual depth and the apparent depth is known as the refractive index of the substance in question**. The phenomenon arises from the variation of the speed of light through the medium (substance) in question, compared to its speed through air.

Again have you noticed that a pencil, or other stick like object, when partially immersed in water appears to be bent at its junction with the surface of the water? This is shown in photo 4.1 below and is due to the different velocities of light passing through air and water.

If the pencil is standing upright no bending is noticed but the immersed portion appears to be shortened.

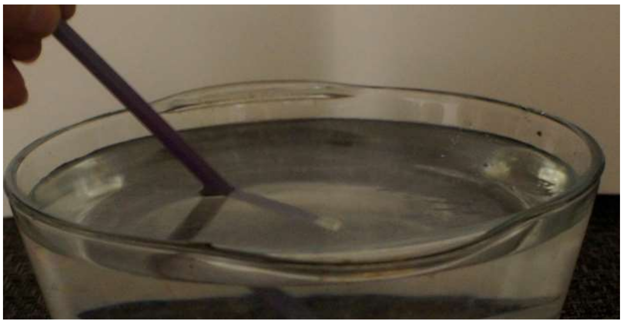


Photo 4.1 Refraction in water

The slower the velocity of light through a medium, the greater the refractive index of the medium, which is a measure of its optical density.

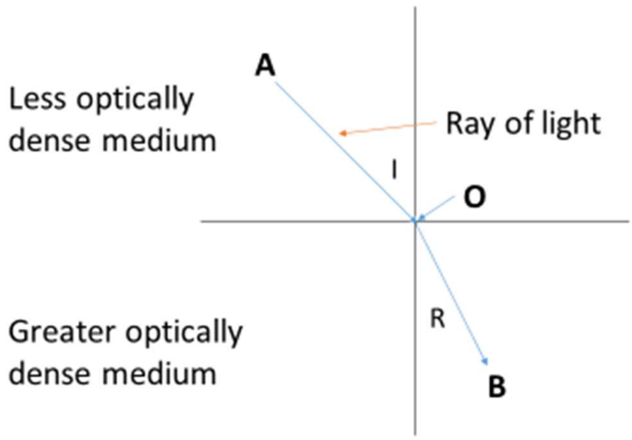


Diagram 4.1

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Diagram 4.1 above shows a ray of light (AB) passing through the origin (O) from a low optically dense medium, e.g. air, to a more optically dense medium, e.g. water. AO is called the incident ray while OB is called the refracted ray. The angle I is known as the angle of incidence while the angle R is the angle of refraction.

Willebroad Snellius (1580-1626) a Dutch astronomer formulated the equation (now called Snell's law) which states that the ratio of the sines of the angles formed by a ray of light with the perpendicular in different media is equal to the velocity of the ray in each medium and inversely equal to the refractive indices of each medium.

Thus in diagram 4.1 where V1 and V2 are the respective velocities of light in the less and greater optically dense media and N1 and N2 the respective refractive indices of the media the Snell's law is given by

$$\sin(I) / \sin(R) = V1 / V2 = N2 / N1$$

Note that if the ray was in the opposite direction the path shown would be the same but BO would now be the incident ray and OA the refracted ray. The angles' names would also be transposed.

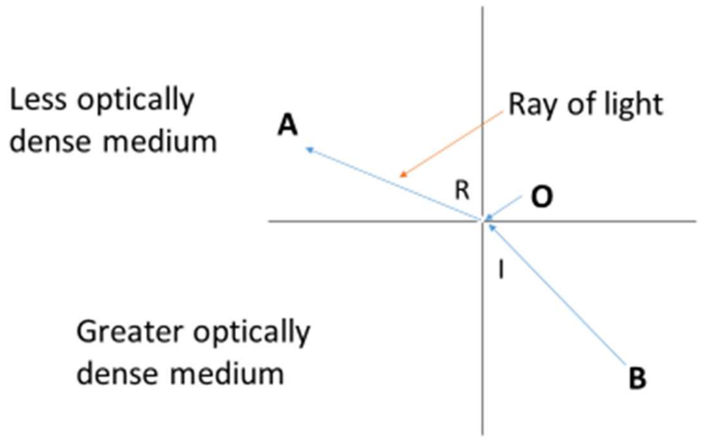


Diagram 4.2

Diagram 4.2 above shows the ray of light going from B through O to A. The angle I is now greater than in Diagram 4.1 with the corresponding angle R. A point will come as one increases I where the ray segment OA will lie on the horizontal axis with R now equal to 90^0. This angle I is dubbed the critical angle since any increase will cause the ray OA to be remain totally in the denser medium (Diagram 4.3) with no light passing out into the lower density medium. This phenomenon is known as total internal reflection.

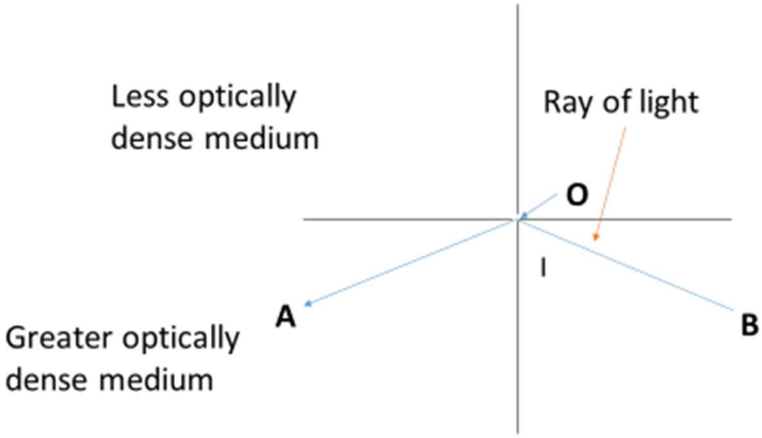


Diagram 4.3

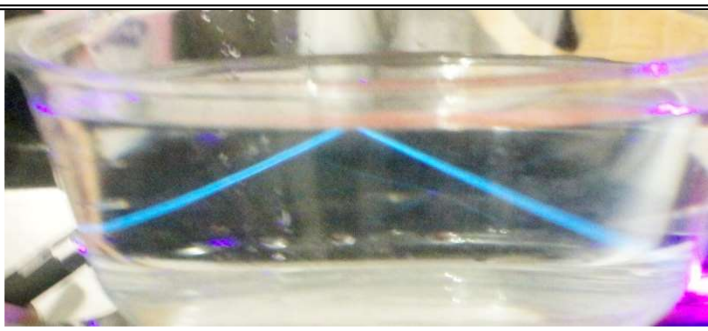


Photo 4.2: Total reflection of blue laser light from water to air.

In photo 4.2 blue light from a laser is passed upwards through a dish of tap-water (higher optical density) with the angle of incidence large enough to cause the ray to be totally reflected from the water-air junction. (Air has the lower optical density).

This is the basic principle of the refractometer, the instrument now being considered.

The Refractometer and its use.

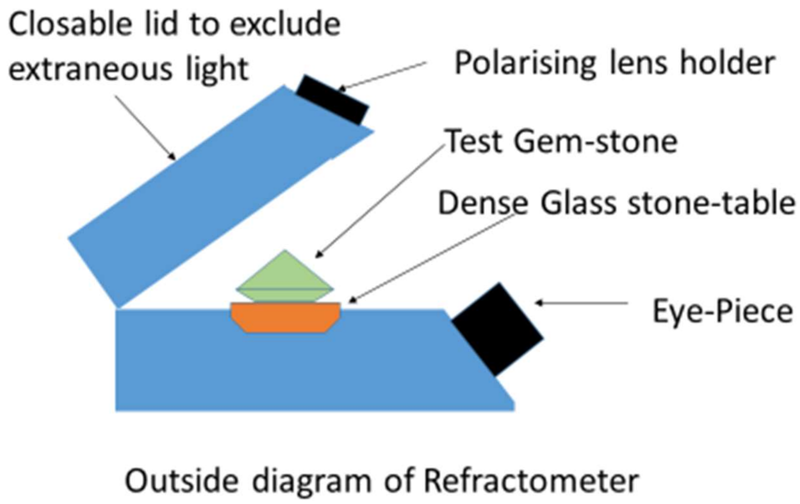


Diagram 4.4

The stone-table is made of dense lead-oxide glass with a refractive index of about 1.86. The refractive index of the contact liquid is usually between 1.78 and 1.81 depending on the supplier.

The diagram above is of an internally lit Refractometer as shown in Photos 4.3 and 4.4 below.

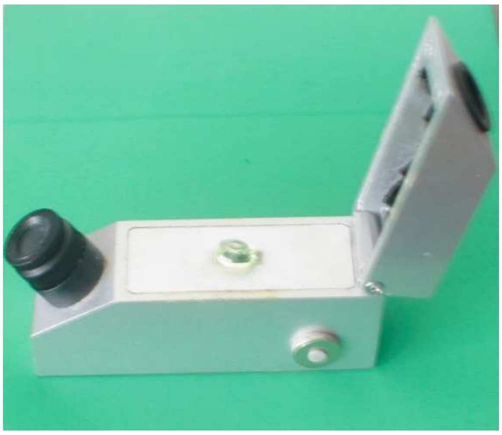


Photo 4.3: Cover Open

Photo 4.4: Cover Closed

The Refractometer open and closed showing on-off button at side.


1.35
1.40
1.45
1.50
1.55
1.60
1.65
1.70
1.75


1.55
1.60
1.65
1.70
1.75

Photo 4.5 Photo 4.6

When one looks through the lit-up eye-piece you can see a scale running from 1.30 to 1.81 (Part shown Photo 4.5 above). To read the scale the first two places of decimals are read from the scale markings with a third place of decimals estimated by the position of the shadow edge in the gap between the markings. From Photo 4.6 above the shadow line lies between the 1.72 and 1.73 scale markings and the third place is estimated to be about .003 giving a R.I. (Refractive index) of 1.723.

Method for operation …

A small drop of contact liquid (RI from 1.79 to 1.81) is placed on the line lit up on the stone table and the gem-stone to be tested is placed, table facet down over the lit-up line, or slid across it (carefully in both cases). The contact liquid is a saturated solution of sulphur in di-iodomethane (CH_2I_2). If allowed to dry out, the sulphur is left behind as a residue which needs to be cleaned off the stone table to avoid difficulties getting an image.

One Shadow Edge found.

One or two shadow edges will be seen through the eye-piece and the reading of each taken down. If only one shadow edge is found no matter how the gem-stone is positioned or rotated or table facet replaced by another facet the gem-stone is isometric of the cubic crystal system. Photo 4.6 earlier shows such a result and on checking the RI value (1.723) with the information in Table 5 below, it is seen that Spinel is the only candidate there.

If no shadow edge at all was found, and only a coloured edge, (or series of coloured edges arising from the contact liquid itself), is seen then the gem-stone has a negative value and its RI (Refractive Index) is above the refractometer's range.

Two Shadow Edges found. One fixed the other movable.

Where two shadow edges are found, either directly or by rotation of the Gem-stone, or changing the facet lying on the stone-table, the gem-stone is anisotropic and belongs to the Uniaxial or Biaxial crystal groups. If, when the stone is turned one shadow moves while the other is fixed the stone belongs to the Uniaxial crystal group.

The stone has double refraction which is given by subtracting the lowest R.I. of the shadow edges from the highest.

There are two possibilities here …

1. If the fixed shadow has the lower R.I., the stone's double refraction is deemed to be positive. The Optic sign is Positive .
2. If the fixed shadow is the higher of the R.I.s, the stone's double refraction is deemed to be negative. The Optic sign is negative.

Two Shadow Edges found. Both movable.

Where two shadow edges are found and when the stone is turned both shadows move, the stone is anisotropic and belongs to the Biaxial crystal group.

If the shadow edge indicating the lower RI value crosses the halfway point, the optic sign is negative. (Lower shadow has a greater range than the upper)

If the shadow edge indicating the higher RI value crosses the halfway point the optic sign is positive. (Upper shadow has a greater range than the lower.

The double refraction value and the optic sign, can be of great help in determining which gem-stone one has, when its RI is inside the ranges for multiple gemstone types.

Note: A gem-stone mounted in a ring may be tested using the refractometer as above, provided that the prongs, holding the gem-stone in place, do not extend beyond the table facet of the gem-stone itself.

The Distant Vision Method

Rounded gem-stones, such as cabochons, have no flat facets but still can be tested on the refractometer giving a reading to two decimal places and no double refraction reading.

The gem-stone under test, either with a drop of contact fluid placed on its rounded surface, or directly onto the stone-table, is then placed, rounded side down, on the stone-table as in Diagram 4.5

below. Looking through the eye-piece from a distance of at least 30 centimetres (one foot) and moving your head vertically up and down you can see a circle (or oval) appear over the scale going from clear to dark as the R.I. as indicated by the scale reduces. The refractive index (R.I.) is the point on the scale where the circle is half clear and half dark.

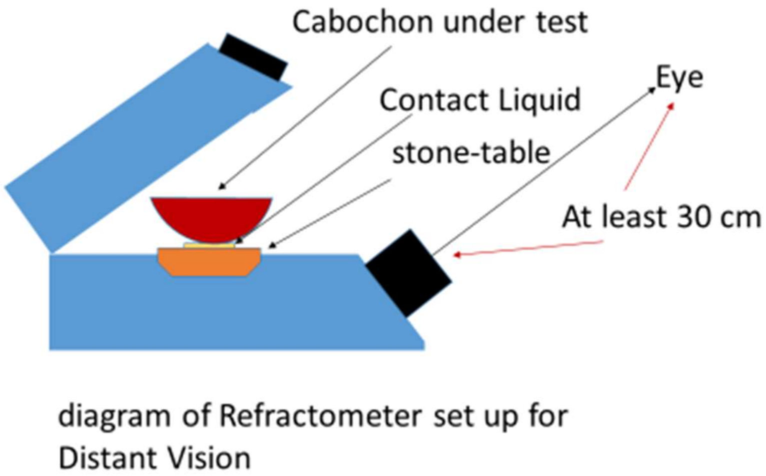


Diagram 4.5

The loss of accuracy is usually not sufficient to mis-identify the gem-stone. Note that this method does not indicate whether the stone is isotropic or anisotropic, nor yet whether it is uniaxial or biaxial or give its optic sign.

This method may also be of use for facetted gem-stones where the facets are not perfectly flat or have been damaged.

Electronic RI Meter

Electronic Refractive index meters but give approximate values only and no double refraction values or optic signs.

Photo 4.7: Electronic Meter light off

Photo 4.8: Meter with test stone value shown

All that is required is to switch on the instrument, place a facet of the gem-stone you are testing directly over the small opening (Photo 4.8) and press the Test button (Blue in the photographs.) Note that the same problems exist for a mounted stone as with the optical Refractometer when the prongs holding the stone are above the facet being tested. Also the Distant Vision method is not available.

To compare the instrument with the Refractometer detailed earlier seven colourless stones were taken and their readings noted from the electronic instrument, their RI book value and some reading on the optical refractometer.

(Note: Readings for the bottom three stones give negative values on the optical refractometer which is a distinct bonus for using the electronic instrument in conjunction with such stones. Table 6 in the Appendix gives values for stones whose RI values show negative values on the optical refractometer.)

==

	Electronic RI	Book RI	Refractometer RI
Beryl (Goshenite)	1.590	1.562-1.602	1.568-1.571

Spinel	1.710	1.712-1.762	1.720
Topaz	1.635	1.609-1.643	1.608-1.618
Sapphire	1.746	1.762-1.778	
Cubic Zirconia	2.161	2.15-2.18	
Moissanite	2.553	2.65-2.69	
Diamond	2.349	2.417-2.419	

==

I leave it with you to judge for yourself as to the efficacy of the electronic instrument.

Chapter Five

Conning the Public

Simulants, Synthetics, Composites, Gem Treatments

Photo of natural, simulant, synthetic, enhanced and artificial gem-stones.

Can you tell which is which?

Answer at end of the Chapter.

Simulants

Over the centuries people tried to mislead others as to the material of a 'gem-stone'. These 'fake' gem-stones imitating the genuine gem-stone are called simulants. The most common method was the use of a coloured glass matching the colour of the genuine gemstone. Photo 5.1 shows a range of faceted glass 'stones' which might be used to fool an un-wary buyer. These glass 'gem-stones' are known as 'paste'.

Photo 5.1: Glass simulants which could be used to imitate natural gem-stones. Top row: Garnets, Row 2 : Aventurine, Citrine, Lemon Quartz, Row 3: Topaz, Aquamarine, Bottom row: Ruby and three sapphires.

Simulants are common and might usefully be classified in three groups ….

1. Paste, glass simulants masquerading as natural gem-stones.
2. Quartz of various colours, which can be natural, masquerading as more precious gem-stones.
3. Natural gem-stones of one kind masquerading as more valuable gem-stones.

In the case of group 1 the refractometer will quickly reveal the true identity of glass. Glass's refractive index varies with the make-up of the glass ranging from 1.41 to 1.9 and showing no double refraction. It should be noted that any single refractive stone having a refractive index between 1.500 and 1.700 is glass.

Anomalous double refraction, (ADR), occurs in many glass 'gem-stones' and care needs to be taken when examining these under the polariscope.

Glass has a hardness on the Mohs scale of 5.5 to 7 and damage to the edges will be likely to be found on examination with a loupe.

The group 2 stones are also easily determined with the refractometer as the refractive index reading will be 1.544 with positive sign.

The group 3 stones are not as common as the other 2, but still occur. In former times any clear un-coloured stone was called a diamond and was sold as such. The first book on gemstones in English appeared in 1652 and was written by Thomas Nicols of Cambridge, England where he says "*Fair ones without colour are diamonds.*" (Fair here means clear.)

Colourless Beryl, Spinel, Topaz and sapphire are natural gem-stones which were used for many centuries as diamonds and even today the man-made Cubic Zirconia and Moissanite are still often labelled diamond and it is only in the very-small print that admission to the actual material is made in many web-sites selling jewellery.

Photo 5.2: Find the Diamond!

Photo 5.2 shows a selection of colourless gem-stones of which one is a Diamond. Did you identify it?

The stones are, from L to R: 5.65ct Goshenite Beryl, 0.05ct Spinel, 0.95ct Diamond, 4.6ct Topaz and 2.85ct Sapphire.

Photo 5.3: Five stones which were sold as Genuine gem-stones

L to R: : 5.8ct blue Glass sold as Spinel: 10ct Glass sold as Topaz: 4.5ct Quartz sold as Lemon Topaz 14.9ct Quartz sold as Tourmaline: 161.72ct glass sold as Aquamarine.

The Refractometer and Polariscope will quickly show up the diamond masquerades as they all have double refraction (except for Spinel) and also have a readable refractive index on the refractometer, (Diamonds having a negative reading.) A problem arises with the man-made simulants - both CZ and Moissanite have negative readings on the refractometer. However Moissanite, thankfully, does display double refraction.

The stones in Photo 5.3 can be differentiated from the supposed gem-stone by their readings on the refractometer.

There is an instrument which indicates a diamond by the rate of heat transmitted through a probe touching a facet of the diamond. (Picture 5.4 upper). Unfortunately this instrument also reads positive for Moissanite. A variation of the instrument is shown in Photo 5.4 Lower which reads each separately.

Photo 5.4: Upper Diamond selector. Lower Moissanite and Diamond differentiator.

An electronic refractive index instrument will, although not absolutely accurate, easily differentiate between the Diamond and its Cubic Zirconia and Moissanite simulants. (See Chapter Four.)

If the stones are not mounted then finding the specific gravity as detailed in Chapter Two will also differentiate between the stones.

S.G. Diamond 3.50-3.55: CZ 5.5-6.0 and Moissanite 3.2.

Synthetics

The next group of gem-stones to be considered are the synthetics, man-made copies of natural gemstones. These stones are essentially the same as the natural with similar physical and chemical properties. Distinguishing between the natural and the synthetic is perhaps the most difficult part of gem-stone identification. The most common synthetic gemstones are the Corundums (Ruby and Sapphire), Emerald, Spinel, Diamond, the various Quartz stones, Opal, Chrysoberyl and Alexandrite.

Photo 5.5, shows six Synthetic gem-stones. The Green Spinel is also a simulant having been sold as a Peridot.

Photo 5.5: Top: Cat's Eye Chrysoberyl; Bottom L to R: Alexandrite, Ruby, Spinel, Pink Ruby, Red Beryl

Common methods for the production of the synthetic gem-stones …

The Verneuil process, (**flame-fusion process)**

This, the oldest of the synthetic processes, was used initially for the production of Ruby (Al_2O_3) but now produces any of the oxide gem-stones such as sapphires (Al_2O_3), Spinel ($MgAl_2O_4$), Alexandrite ($BeAl_2O_4$) and the less common Rutile (TiO_2) and Strontium Titanite ($SrTiO_2$).

Photo 5.6 Three Boules of Verneuil process Spinels.

For Ruby finely divided Aluminium Oxide (Al_2O_3), together with a suitable colouring agent (for Ruby a Chromic salt, Cr^{3+}), is dropped into a oxy-hydrogen torch, the molten matter falling on to a rotating plate which is slowly retracted down from the flame causing a boule to be formed. A ceramic muffle surrounds the plate and flame.

Photo 5.7 A Verneuil Ruby Boule

For the Sapphire which has the same basic composition (Al_2O_3), different combinations of salts cause the various colours found. An absence of any salt yields the colourless variety.   Some of the colourants are as follows

Red and Pink: Chromic Oxide (Cr_2O_3)
Blue: Mixture of Iron and Titanium oxides (FeO and TiO_2)
Purple and Violet: Mixture of Cr^{3+}, Fe^{2+} and Ti^{4+}
Yellow: Nickel Oxide (NiO)
Orange: Mixture Ni^{3+} and Fe^{3+}
Green: Mixture of Cobalt, Vanadium and Nickel salts.

Due to the rotation of the boule while forming, circular growth lines are a sure tell-tale sign of a man-made boule, (growth lines in natural gem-stones are straight). Very clear stones are also a giveaway: if a stone of any size is perfectly clear to the eye one can take it that it is man-made.

Note: The Verneuil Ruby has a round cross-section but the Cross-section of the Verneuil Spinel is square with rounded edges in keeping with its Cubic Crystal System. Photo 5.8 below shows the flattened square faces of two Verneuil Spinels.

Photo 5.8 Two Boules of Synthetic Spinel from which Sapphire simulants are cut..

Czochralski Process (Pulling Method)

Here the nutrients are first melted in a platinum or iridium crucible. A suspended small crystal of the required gem-stone is lowered to touch the surface of the molten liquid and rotated while it is slowly raised as crystallisation begins.

Chrysoberyl, Alexandrite, Corundum and the rare earth Garnets (YAG, GGG etc.) are commonly formed by this method.

Small pieces of the crucible and nutrients are commonly found as inclusions. Circular growth lines may be observed.

Flux Method

This method is expensive. In a way it like the method used in school laboratories to make crystals. The basic ingredients for emerald, (oxides of beryllium and aluminium with chromic oxide as the colourant), mixed with a flux are melted in a platinum crucible and seed crystals are inserted. When sufficient over-growth of the seeds has occurred the crystals are removed and cooled. Emeralds are commonly formed using this method but Corundum (Ruby and Sapphire), Spinel and Alexandrite have also been made. Flux and Crucible particles may be found as inclusions.

The Hydrothermal Method

This is the preferred method for the manufacture of Quartz, both clear and coloured varieties. The method involves the super-heating (400^0C) of nutrient rich water in a silver lined autoclave (essentially a pressure cooker) which is then allowed to cool, whereupon crystallisation of the Quartz begins onto suspended seed plates. It is fundamentally the same as the natural formation of this gem-stone.

Man-made Emerald and Ruby have also been made using this method.

Skull Melt Process

Cubic Zirconia is the resulting gem-stone of this method. It is somewhat similar to the Flux Method but the temperature is considerably higher, more than 2000^0C. In order to contain the liquid, the outside of the containing vessel is kept cool and the liquid touching this solidifies and forms the “Skull cap” that contains the super-hot liquid. As the liquid is allowed to cool perfect crystals of Cubic Zirconia are formed.

Diamond Formation

Diamonds are formed in one of two ways, either by Chemical Vapour Deposition (CVD) or by High Pressure High Temperature (HPHT).

In CVD, heated Hydrogen and Methane form a high-temperature plasma, releasing carbon atoms that are allowed to fall, in a vacuum, onto a base where the diamond grows on seed plates.

In HPHT, Graphite is subjected to more than 60,000 times atmospheric pressure and heated to up to 3300^{0}C in molten metal. (Iron, Nickel, Manganese or Cobalt)

Composite Gemstones

Composite Gemstones are formed from two or three sections of the same or different gem-stones cemented together. Opal, which is found in both doublet and triplet form, is not regarded as a composite, as the Opal vein is invariably very thin, and needs to be supported and protected from scratching, due to its low (5.5 – 6.0) hardness on the Mohs scale.

The sections can be

of the same material, e.g. Diamond, in order to have a bigger stone than either of the pieces would make, or

of different materials, e.g. a Soudé Emerald where a thin layer of Emerald has a top and bottom of clear Quartz.

Photo 5.9 Left: Spinel-Amethyst-Spinel Triplet: Right: Spinel-Sapphire-Spinel Triplet. Enlargements of both stones are shown later-on in Chapter Seven.

Examination of the stone from the side will usually show the junction between the two materials used. Immersing the stone in water may help to make this junction clearer.

Viewing through the loupe, or microscope, may well show bubbles in the cement used when attaching the various sections.

If the stone is large enough, refractometer readings of the table and pavilion facets will confirm the different materials used in the composite.

The point of such stones is to deceive the buyer into thinking they have a much more valuable item.

Treatments of Gemstones

In times gone by coloured foil or paper was often put on the back of glass giving a simulant of the real gem-stone. This was then mounted in a closed setting so as not to be seen. A variant was to mirror the pavilion of the stone in order to lighten the colour of the stone. Again a closed setting would be used. Any stone in a closed setting should be taken as suspect. Poor quality gem-stones are still subject to these treatments.

Refractive Indices will, of course, show up glass simulants and examination with a loupe or microscope will show that a backing is being used.

Photo 5.10: Six Silver foiled Glass Gem-stones simulating Citrine.

A dyed oil is used on occasion to heighten the colour of a gem-stone and can be seen in non-crystalline Ruby, Lapis Lazuli and Turquoise.

Such oiling is easily shown by rubbing a Cotton Bud dipped in acetone or alcohol across the stone. Some of the dye will appear on the Q-tip.

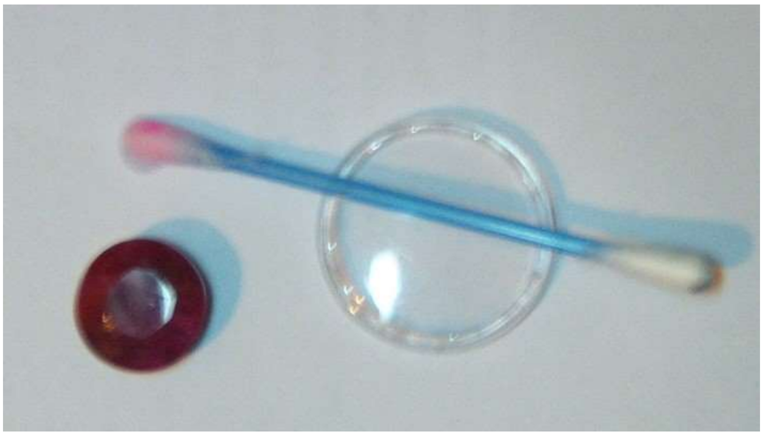


Photo 5.11: Oiled 2.15ct Red Beryl and Cotton Bud after dipping in Ethanol and rubbing across the crown facets.

Microcrystalline or poly-crystalline stones have a somewhat porous surface which means that a dye can penetrate the outer regions of the stone to colour a colourless stone or else imitate a different gem-stone. The Agates are especially prone to being coloured as a matter of course so you should assume any you encounter have been coloured in this way.

Refractive Indices will show the nature of the basic stone involved and since only the outer layers of the stones are dyed, a clear stone, when examined with the loupe or microscope from the side, should clearly show the dyed layers or patches of the colouring material.

Heating gem-stones to improve or change their colour has been going on for centuries and is prevalent in the clear quartz varieties, Tourmalines, Topaz, Zircon, Rubies and the different coloured Sapphires.

Unfortunately determining heat treatment is beyond the capabilities of the amateur and the only advice that can be given is to look for two-phase or three-phase inclusions (See chapter 7 on inclusions) in the stone using the loupe or microscope to determine the natural nature of the Gem-Stone in question. In general, you should assume the stone has been heated unless a certificate can be produced to the contrary.

Pits and cracks reaching the surface in valuable gem-stones are often heated with glass which fills and bonds with the gem material. If suspected then look for flattened gas bubbles, where the glass and gem material meet, using the loupe or microscope. Any glass reaching the surface is liable to scratching and if ultra-sonic cleaned, may split and ruin the stone.

To close this Chapter we will look at how two varieties of Gem-Stones can be coloured.

Mystic Topaz and Mystic Quartz.

There is one treatment that does not set out to deceive the buyer. Very good specimens of colourless Topaz or Quartz have an ultra-thin reflective metallic coating, which is similar to the protective coatings on lenses for spectacles etc., applied to the pavilion of the Gem-Stone causing rainbow colours to appear on the surface of the stone. The Gemstone is now called a Mystic Topaz or Mystic Quartz depending on the original Gem-Stone that underwent the treatment. The crown facets are unaffected so that Reflective Indices will show the values for Topaz or Quartz for the Gem-Stone being used and are also resistant to scratching. The basic value of the Gem-Stones is increased by the treatment and there is no natural Gem-Stone with the same appearances of the Mystic varieties.

Answer to Chapter heading Photo question. "Can you tell which is which?"

Top 5 : Natural Emerald; Lab Sapphire; Artificial Moissanite; Lab Ruby; Lab Beryl.

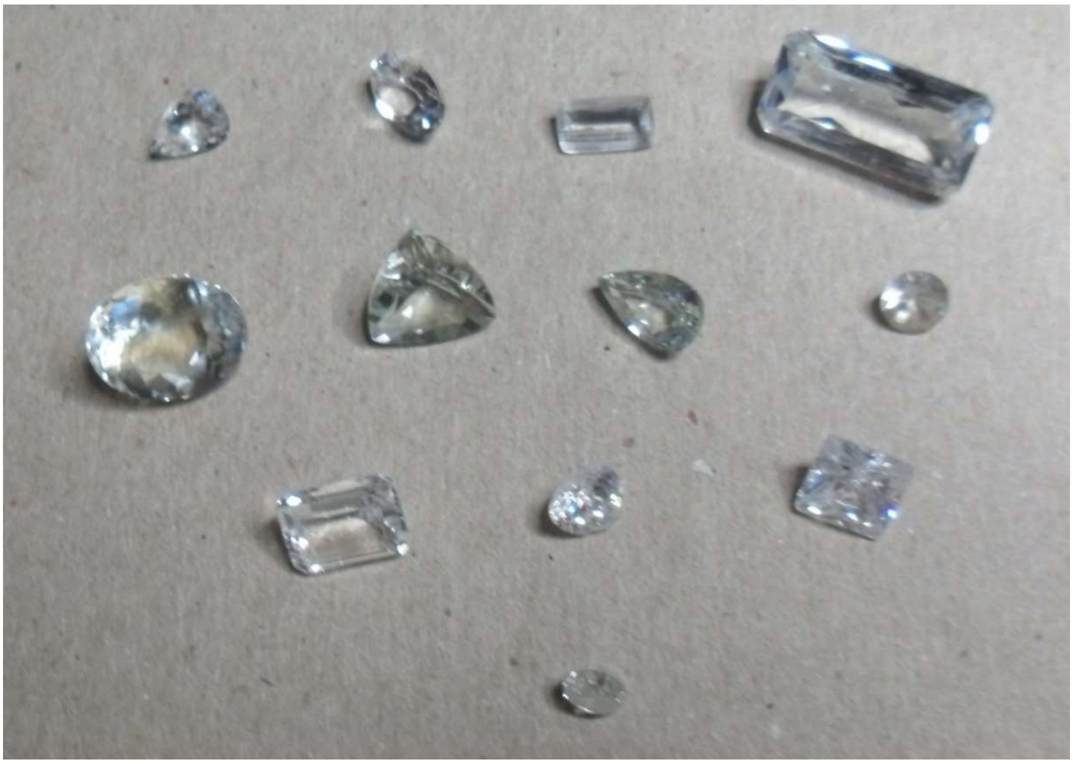
Mid 3: Garnet Doublet; Lab Spinel; Lab Goshenite.

Bottom 5: Lab Ruby; Spinel Dyed; Artificial Moissanite; Lab Aquamarine; Natural Ruby (Glass filled).

Chapter Six

Other Tools

Microscopes , Filters, Ultra-Violet light, Spectroscope



The 'Diamond' group .. (Natural stones which could be taken as Diamonds.)
Top Row: Goshenite 0.5ct; Danburite 1.3ct; Hambergite 0.5ct; Kunzite 9ct.
Upper Middle: Orthoclase 4.9ct; Quartz 2.8ct; Sapphire 2.85ct; Spinel 0.5ct.
Lower Middle: Topaz 2.4ct; Tourmaline 1.25ct; Zircon 2.85ct.
Bottom: Diamond 0.5ct.

Microscopes

A magnifying glass can be taken as a microscope in its simplest form, however much greater magnification is got by a combination of lenses acting together. Loupes usually have a number of lenses working together and will easily show the bigger inclusions in a gem-stone, but many inclusions will only show through the more powerful microscopes.

Some microscopes, such as the binocular one shown below allow for one of the eye-pieces to be by-passed by a camera, (shown at the top of the binocular microscope) which is linked to a computer and so allows for the image to be caught and saved.

The monocular microscope shown has a built-in scale which allows the measurements of small gemstones to be accurately ascertained.

The electronic microscope has its own screen for viewing rather than an eye-piece. The screen image can be captured for later use. The model shown also allows for connection to a computer for down-loading the saved images or for live viewing on the computer's bigger screen.

Photo 6.1.1

Photo 6.1.2

Photo 6.1.3

Photo 6.1.1: Binocular Microscope with camera linked to computer.

Photo 6.1.2: Monocular Microscope with built in scale for measuring gems.

Photo 6.1.3: Electronic Microscope with built-in screen viewing.

Photo 6.2.1 Photo 6.2.2

Screen shots taken through the camera on the binocular microscope.
Photo 6.2.1: Colombian Trapiche Emerald shown in Photo 8.7.
Photo 6.2.2: Spanish Sphalerite Doublet showing the clear red internal crystal.

The binocular microscope can be used to find the refractive index of stones which give negative readings on the refractometer. Note that opaque stones cannot utilise this method.

If one has a Vernier travelling microscope, the heights at which clear focus is found can be read directly from its Vernier scale, otherwise one has to adapt an ordinary microscope using a ruler and a level section of the moving portion of the microscope as shown in Photo 6.3.
This is a very finicky procedure and is only recommended as a last resort.

Photo 6.3: Adapted binocular microscope.

The microscope is focused on its stage and the reading on the ruler at the side noted. (R1)
The microscope is now raised to allow the test stone to be placed on the stage, culet down, supported by some blue-tac.
The microscope is now focused on the culet through the stone and the reading noted. (R2)
The microscope is now focused on the table facet and the reading again noted. (R3)
The Refractive Index is now got from the actual depth of the stone divided by its apparent depth. RI = (R3-R1)/ (R3-R2)

Mounted stones may be tested if one can directly measure the depth of the stone by a Vernier Caliper and finding the apparent depth by use of the microscope.

The bigger the test stone the more accurate the RI value obtained will be.

Filters

Chelsea (also known as Jadeite) filter

Originally this filter was designed to separate genuine Emeralds from a mix of similarly coloured stones. Under strong electric light, on a black background, it only transmits yellow-green and deep red light. Emeralds which absorb the yellow-green light usually appear distinctly red or pinkish depending on the depth of colour of the stone. Most imitations, such as green Glass, Tourmaline, Peridot etc., retain a green appearance through the filter.

Synthetic Emerald will usually also show red through the filter but usually much brighter than the natural.

The filter is also of use in distinguishing Aquamarine and blue Topaz from their blue synthetic-Spinel simulants as the blue synthetic Spinel containing Cobalt allows the red colour to be displayed whereas the natural stones do not.

Photo 6.4 Left: Glass Ruby Filter and Right: Chelsea Filter

Two types of **Ruby** filter are available and used to differentiate between Rubies and other red stones such as Red Beryl, various red Garnets, red Glass, red Spinel and red Tourmaline, when viewed on a black background under strong electric light through the filter.

In the usual Ruby glass filter Ruby, synthetic Ruby and Red Spinel appear bright red, other red stones appear grey or black.

In the Hanneman Ruby filter (a green plastic filter)

Ruby appears bright blue;
Pink Sapphire appears light blue;
Red Beryl, Almandine Garnet and Rhodolite Garnet all appear grey;
Pyrope Garnet appears brownish;
Red Spinel appears gray-blue;
Pink Spinel appears light blue;
Red Tourmaline appears grey-purple.

Ultra-Violet light

When invisible ultra-violet is allowed to impinge on certain gemstones, energy is absorbed by impurities within the gemstone and this energy is then released as lower energy visible light, the gemstone being said to fluoresce. The gemmological UV box (Photo 6.5) allows for either short wave UV light or long wave UV light to be used to illuminate the test stone. Background light should be dimmed or avoided entirely while viewing through the aperture of the UV box.

Photo 6.5 : Ultra-violet light box

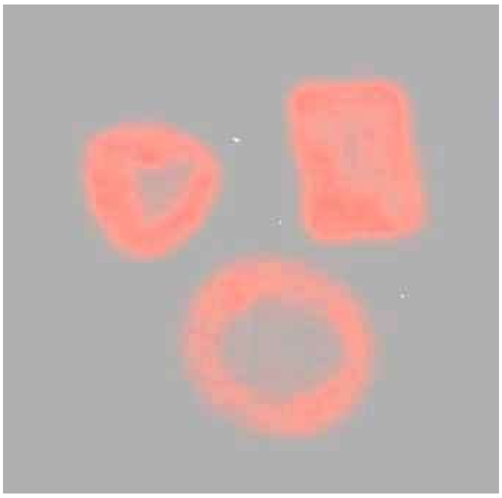


Photo 6.6 3 lab-rubies under short-wave UV light

Gemstone	Short wave UV	Long wave UV
Spinel		
Natural Red	Medium to Strong Red	Strong Red
Natural Mauve	Yellow	Yellow-green
Synthetic (bar Red)	None	None
Emerald		
Natural	None or Reddish	Same
Synthetic	Usually Weak Red	Usually Strong Red
Ruby		
Natural	Strong Red	Very Strong Red
Synthetic	Strong Red	Stronger Red
Sapphire		
Natural Blue	Usually None	None
Ceylon Blue		
(Light Blue)	Weak Orange, Reddish	Mustard to Strong Red to
Yellow/Orange		
Ceylon Yellow	Orange-Yellow	Strong Orange
Blue (Heat treated)	Milky Bluish-White	None
Blue Synthetic	Usually Deep Green	Usually None
Orange Synthetic	Red	Red
Pink Natural	Strong Red	Strong Red
Quartz		
Amethyst	Usually None, but may be	
	Deep Blue	Same
Synthetic	None	None
Citrine	None	None

Some authors advise that a set of Natural and Synthetic stones be kept as reference and used in the UV Box with the test stone to determine the nature of the test stone.

Spectroscope

The spectroscope is a device that examines absorption and emission wavelengths in a visible white light spectrum. The colours of the visible spectrum, from left to right, are Violet, Indigo, Blue, Green, Yellow, Orange and Red. (Two mnemonics by which to remember these are VIBGYOR for Right to Left, and **R**ichard **O**f **Y**ork **G**ave **B**attle **I**n **V**ain from Left to Right.)

The wavelengths of the visible spectrum go from 775 to 375 nm. (A nm, nanometre is 10^{-9} metre.) Moving below the Violet brings one into the non-visible Ultra-Violet range and going above the Red brings one into the non-visible Infra-Red range.

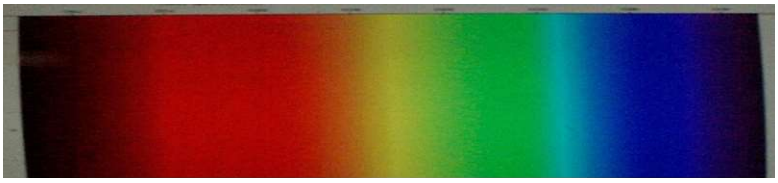


Photo 6.7: The visible spectrum range, wavelengths from 775 to 375 nm left to right.

Two types of spectroscope are in general use: prism and diffraction-grating units. The diffraction grating type is of simpler construction, cheaper to buy, and is often pocket sized.

Photo 6.8: shows the OPL teaching diffraction grating spectroscope set up for use. The flexible light (Left) is focused on the test-stone which is placed table facet down on the platform that holds the spectroscope (Right).

Photo 6.9 and 6.10 show views through the eye-piece of the spectrum produced from the test-stone in Photo 6.8 using the diffraction grating and prism spectroscopes respectively.

Note that in a Diffraction Grating Spectroscope spectrum the red end is widened while the blue is shortened, while in the Prism Spectroscope spectrum, the opposite is true.

Note also that Book spectra will show equal distance spacing throughout. Also Book spectra will show the red to the left and the blue to the right whereas the view through the spectroscope will vary as the spectroscope is turned.

In the spectra shown in Photos 6.9 and 6.10 one can see three dark bands in the Blue and Green respectively.

Photo 6.8: The OPL Diffraction Grating teaching spectroscope

Photo 6.9: View through eye-piece of the diffraction grating Spectroscope

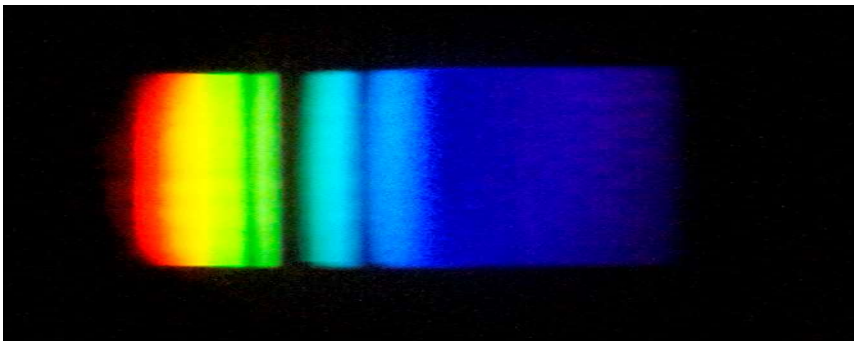


Photo 6.10: View through eyepiece of the prism Spectroscope

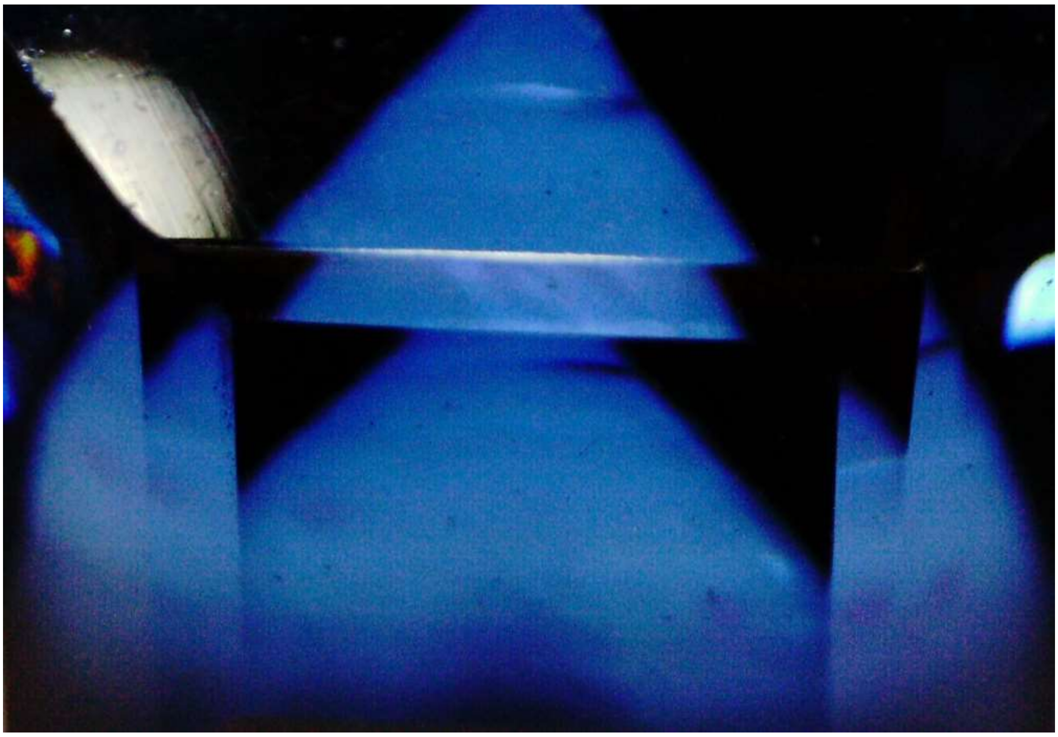
Photo 6.11: A pocket spectroscope on the left alongside the OPL teaching spectroscope, both diffraction-grating models.

Any lines showing up in the spectrum should be compared with those on charts given in various Internet sites. A match will indicate a specific stone. If a match is not found for a stone testing positive for a specific gem through the earlier tests, then the stone is not natural – it is synthetic.

Note: This can be a very difficult test to do. Do not be dis-heartened if at first one does not succeed. The old adage 'Practice makes perfect' applies here.

Chapter Seven

Inclusions



An 8.27ct Tanzanite 'Forest' (Magnified internal reflections from facets)

Any material, solid, liquid or gas that gets trapped inside another material as it forms, is termed an inclusion. The material could be a crystal, either of the encompassing material itself or another, colouring variations, liquid or gas bubbles, internal fractures filled with a liquid or gas and so on.

Natural coloured gemstones are expected to have inclusions and these, for the most part, do not devalue the stone in question. Synthetic gem-stones tend to be much cleaner, so much so that lack of inclusions is generally an indication that a particular stone is synthetic.

All the photographs in this chapter were taken on the electronic microscope shown in Chapter Six.

Coloured gem-stones may be divided into three Types as follows …

Type 1: Natural stones with few or no inclusions, such as Topaz, Aquamarine and Zircon.

Photo 7.1: A virtually flawless 2 carat natural Zircon photographed through the pavilion.

Type 2: Natural stones with some inclusions, such as the Corundums, Spinel and Garnet.

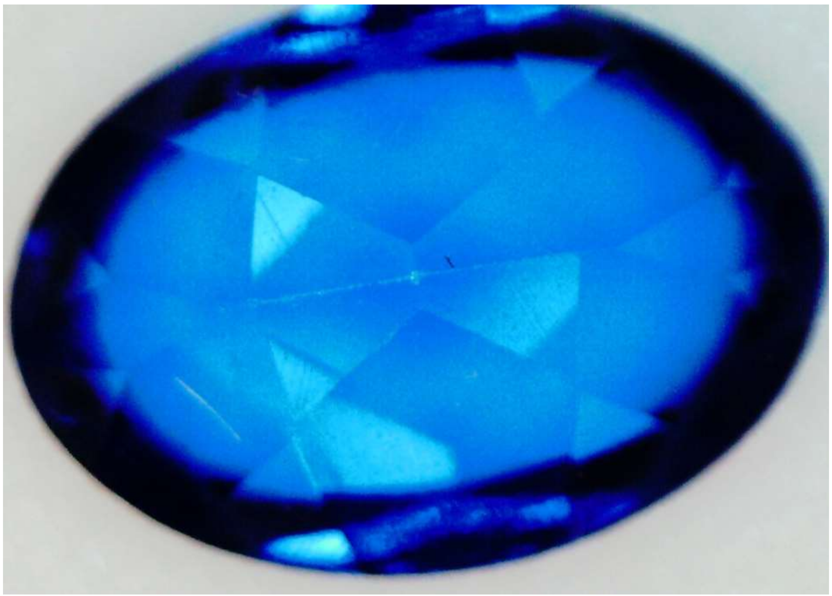


Photo 7.2: A Lab-Spinel 9.85ct, with virtually no inclusions.

Type 3: Natural stones, which in general have many inclusions, such as the Tourmalines and Emerald.

Photo 7.3: Inclusions in a Natural Emerald. The colouration is not uniform - a Synthetic will show a more even colouration.

In general the synthetic gem-stones will be virtually free of inclusions and certainly any gemstone larger than one or two carats which is virtually clear of inclusions must be treated with the utmost distrust.

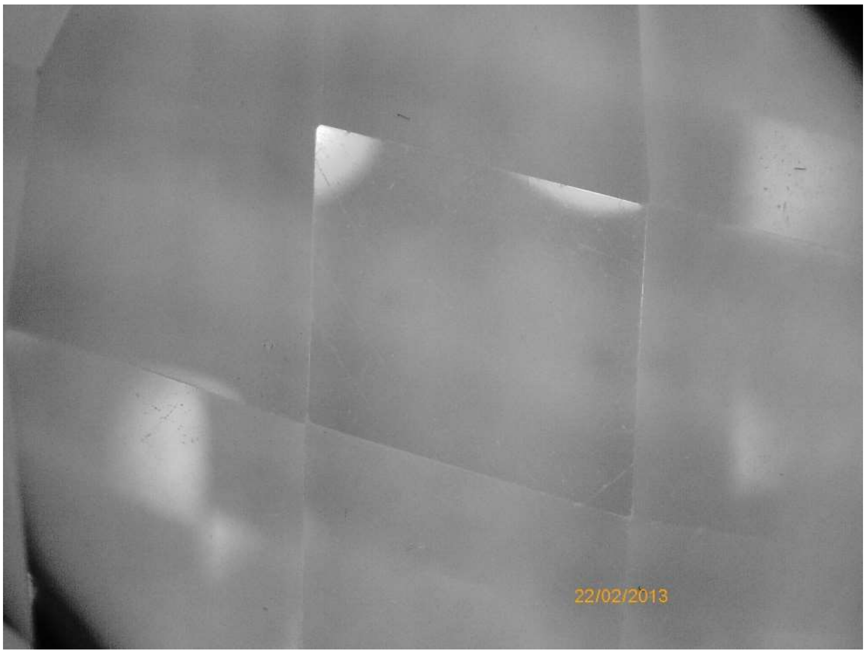


Photo 7.4: A totally clear GGG 11.6ct (Gadolinium Gallium Garnet)

The man created gemstone GGG in Photo 7.4 displays no inclusion whatsoever even as enlarged as it is.

Some inclusions are shown in other Chapters:

Photo 1.2: Serephinite with Copper inclusions.
Photo 1.13: Quartz with rutile needle inclusions.
Photo 1.14: Quartz with Tourmaline needle crystal inclusions.
Photo 6.2.2: Sphalerite Crystal in Doublet.
Photo 8.8: Natural included Emeralds
Photo 8.10 & 8.11: Natural Sapphire growth lines.

A variety of photographs of natural and synthetic gemstones now follow showing a variety of inclusions. Do remember that none of the tests shown in this book will identify the nature of the included material.

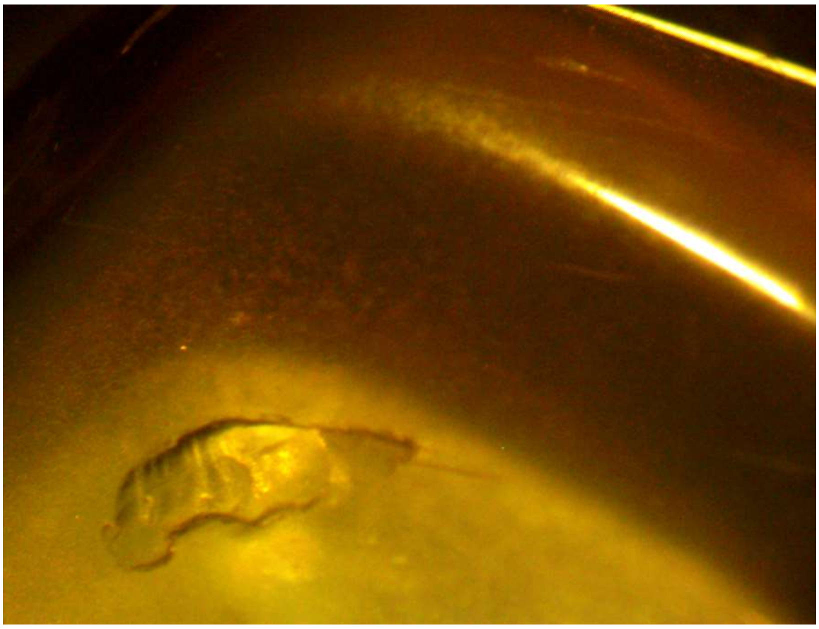


Photo 7.5: Crystal inclusion in a natural 21.5 carat specimen of Golden Scapolite.

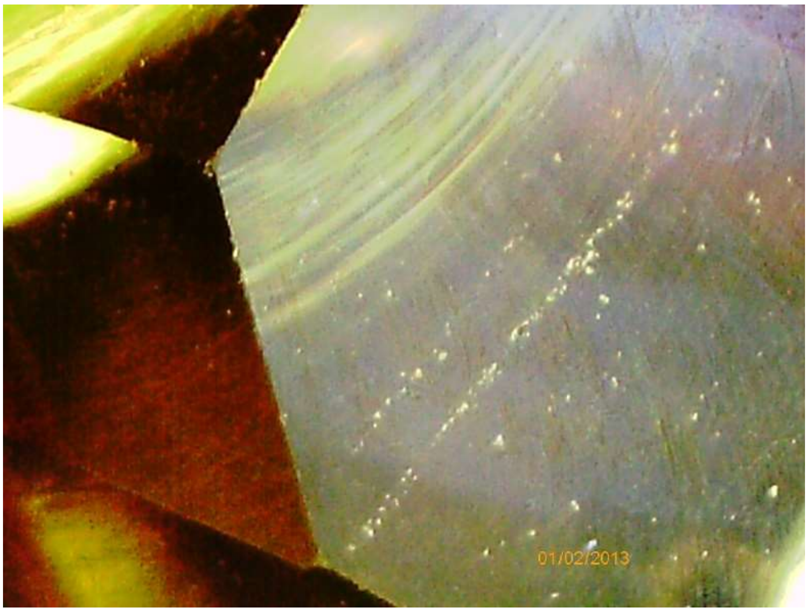


Photo 7.6: Lines of gas bubbles commonly seen in glass.

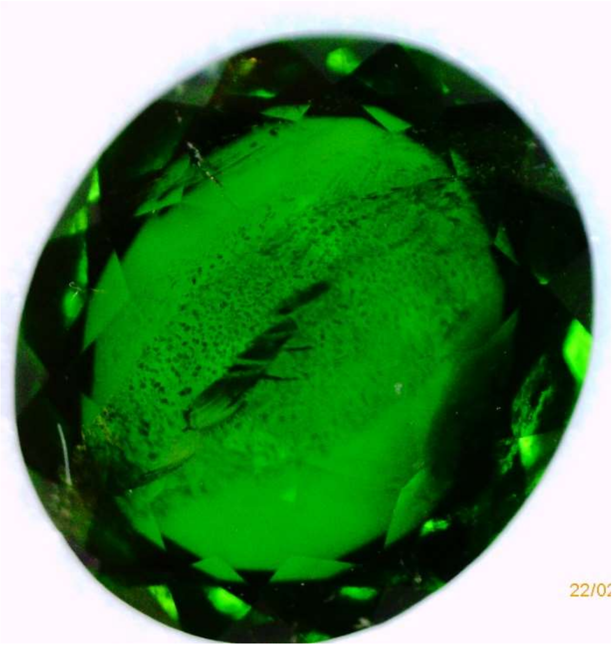


Photo 7.7: Natural Chrome-Diopside 2.09ct

A ‘mist’ of inclusions is shown in the Chrome-Diopside gem-stone above.

Photo 7.8: Peridot 1.65ct Colour Change with a large solid inclusion

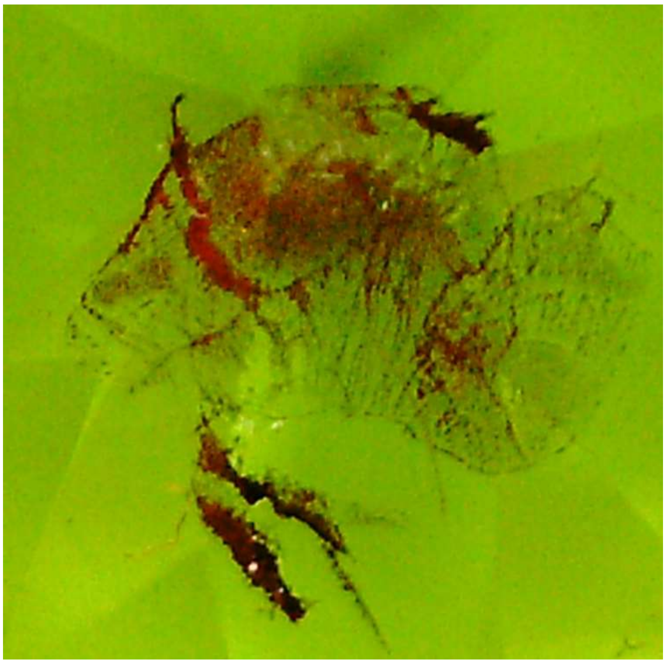


Photo 7.9: A typical Peridot 3.3ct 'Lily-pad' inclusion is shown above, with two phase inclusions underneath.

Photo 7.10: Amethyst-Spinel Triplet 5.35ct

The two Triplets shown above and below may also be regarded as included as they display bands of colouring material.

Photo 7.11: Sapphire-Spinel 12.25ct Triplet Side view.

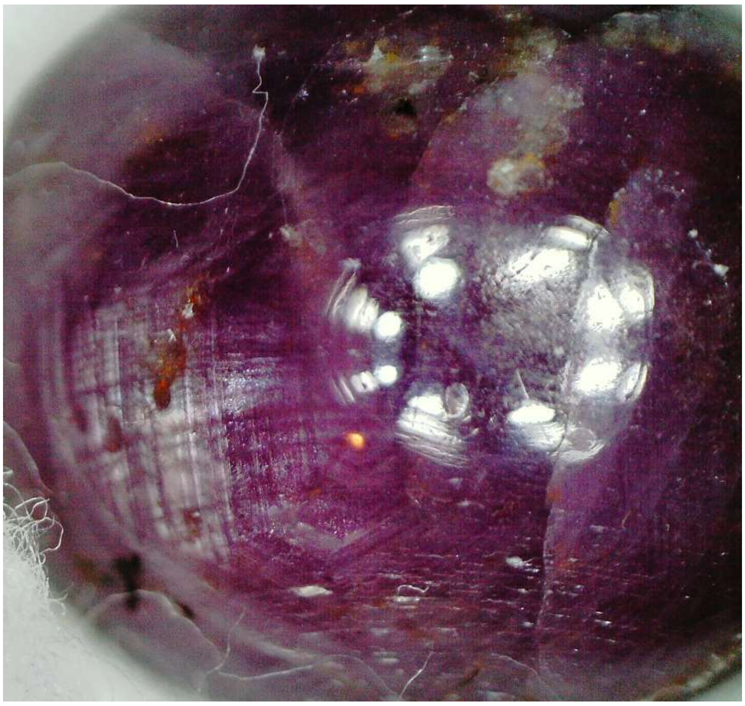


Photo 7.12: Curved growth lines in a 14.3 Star Ruby indicating that it is laboratory formed.

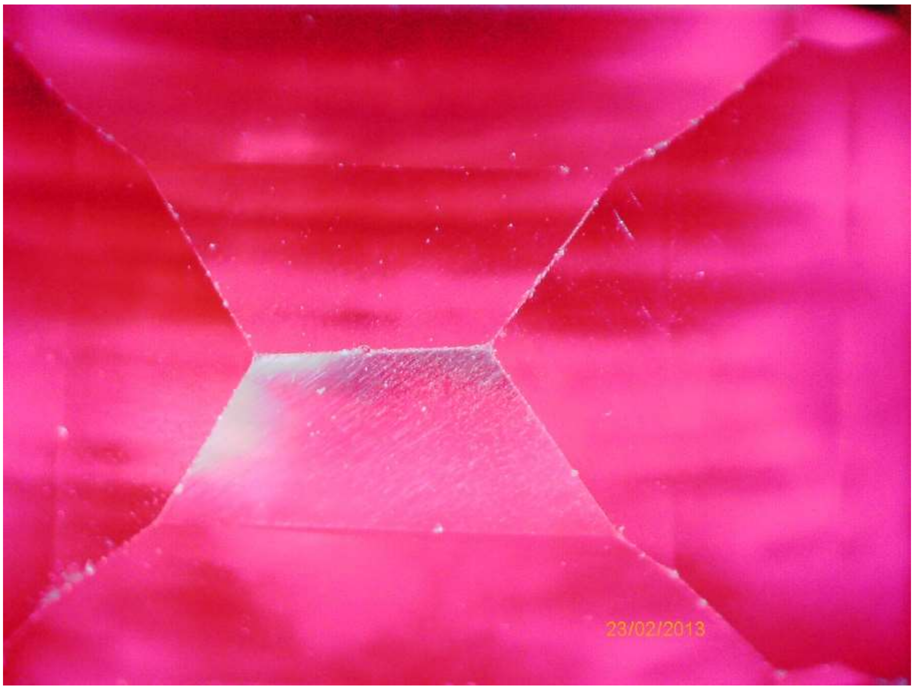


Photo 7.13: Straight colour banding in a heated 23ct Ruby.

Photo 7.14: Many black carbon inclusions in a natural 0.5 carat Diamond

Photo 7.15: Straight inclusion lines in a highly magnified 7.28 carat natural Aquamarine.

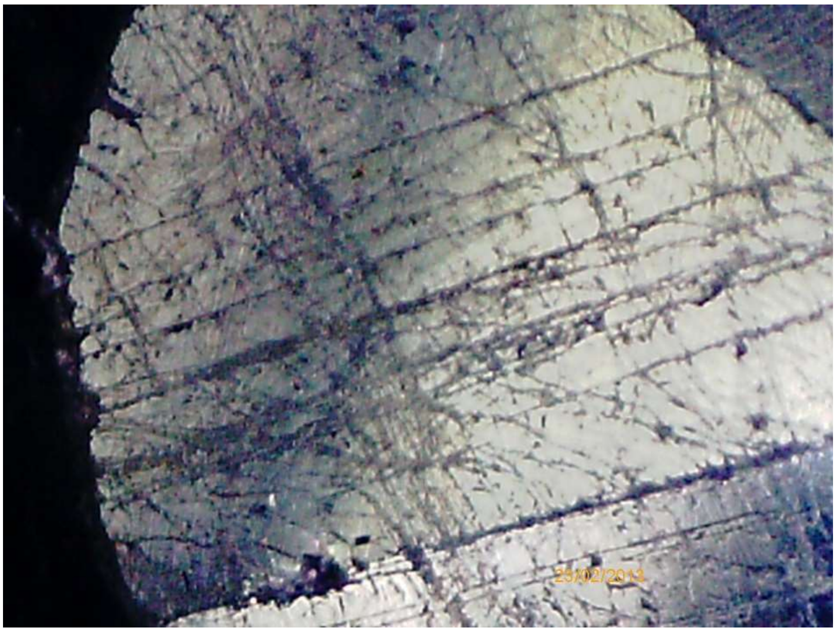


Photo 7.16: Straight growth lines in a 13.95 natural blue Sapphire.

Photo 7.17: Straight colouring lines in a Sri Lankan 8 carat yellow natural Sapphire.

Photo 7.18: Engulfed cubic crystal in a natural green Grossular Garnet Crystal

Photo 7.19: Blue-black and red Garnet crystals engulfed in a natural green Grossular Garnet crystal.

Chapter Eight

Testing for common synthetics.

Butterfly in Amber (Resin)

(Man-made)

Although nearly all the varieties of Gem-Stone have been synthesised, only four of the Gem-Stone groups are commonly encountered in practice. These are the Spinel, Quartz, Corundum (Ruby and Sapphire) and Emerald (others of the Beryl group are much less common). Synthetic Diamond, Opal and Alexandrite are only occasionally encountered.

In this Chapter these four common groups are examined in order to determine the natural from the synthetic.

Natural Gem-Stone	Specific Gravity	Refractive Index	Double Refraction & Optic Sign
Quartz	2.65	1.544-1.553	+0.009
Emerald	2.67-2.78	1.562-1.602	-0.006
Spinel Group	3.58-3.61	1.712-1.736	None
(Magnesium Spinel		1.719 Red 1.74)	
Ruby	3.97-4.05	1.762-1.788	-0.008
Sapphire	3.95-4.03	1.762-1.788	-0.008

Note: In general there is a positive correlation between the Specific Gravity of a Gem-Stone and it's Refractive Index.

The following results from testing will often give definitive results for Synthetic Gem-Stones…

1. Specific Gravity of the test-stone being lower/higher than that of the natural.
2. The Refractive Index of the test-stone being outside the range of that of the natural.
3. Total, or near total, clarity of the test-stone is an indication of a Synthetic stone, the Natural Stone will virtually always have inclusions.
4. Curved growth lines, or curved colour streaks, in a test-stone will indicate a Synthetic stone.
5. Clear bubble inclusions in the test-stone will indicate a Synthetic stone.

In the light of processes covered in earlier chapters examination of the Groups mentioned earlier is now undertaken.

The hardness test is not carried out on faceted gem-stones and is to be ignored.

The determination of Specific Gravity was detailed in Chapter Two, The use of the Polariscope, Dichroic Mirror and Conoscope in Chapter Three and Refractive Index in Chapter four. The methodology will not be repeated here in this Chapter.

Spinel

Natural Spinel, (chemical formula $MgAl_2O_4$) comes in various shades, the most common of which are colourless, pink, rose, blue, green, yellow, brown and black and has Specific Gravity values between 3.58 and 3.61, with refractive Index of 1.719, no double refraction. (The red spinel has a higher R.I, of 1.74.)

In Photo 8.1 a selection of Spinel is shown. The small colourless stone on the bottom left and the black on the top right are natural whilst the others are synthetic and could be used as simulants for Aquamarine, Sapphire, Morganite, Emerald and Topaz respectively.

Photo 8.1: Selection of natural and synthetic Spinel

Spinel is allochromic, its colours being given by small amounts of substitution of its metal atoms by transition element atoms where

Red and pink are due to Cr^{3+} substitution of Aluminium atoms,
Blue and violet are due to Magnesium substitution by Fe^{2+}
Dark blue to magnesium substitution by Fe^{2+} and Co^{2+} (high levels of the Fe^{2+} and Co^{2+} will give an opaque black colour.)
Green by Fe^{3+} substitution of the Spinel's aluminium.

The man-made Verneuil Spinel has a higher R.I. (from 1.728 to 1.74), than the natural (R.I. 1.719) and exhibits anomalous double refraction due to the presence of unchanged Al_2O_3. Initially this Spinel was formed from 1 to 1 ratio of MgO and Al_2O_3, but this led to poor quality stones and an adjustment of 1 to 2 of MgO to Al_2O_3 was employed.

The five views below (Photos 8.2 to 8.6) show the appearance of a lab 9.45ct Colourless Spinel as it was rotated under the polariscope. A double refractive stone would show very clear succession of dark and brightness.

Photo 8.2 Photo 8.3 Photo 8.4 Photo 8.5 Photo 8.6

Spinels formed by the Verneuil method have Specific Gravities between 3.58 and 3.80 which will be higher than those of the natural stone.

The man-made Flux-Melt Spinels tend to have lower R.I. but similar specific gravity to the natural stone. They also tend to have residual flux inclusions. Flux growth stones can take a year to prepare so are much more costly than the Verneuil process which can produce an eighty millimetre boule in about four hours, and so are less likely to be encountered.

With the exception of the red, all natural spinel is inert, which means they don't react to short wave or long wave ultra violet light and so any Spinel with an R.I. above the 1.719, apart from the red, showing a reaction to the ultra violet light is man-made.

The Verneuil red spinel may exhibit curved growth lines and/or small gas bubbles when viewed with a loupe or microscope.

Spinel, natural or man-made, which belongs to the cubic crystal system, does not exhibit pleochromism.

Natural Spinel is weakly susceptible to magnetism (the black is strongly susceptible due to iron content) whereas the man-made Spinel is inert.

By the use of the various tests detailed above one should have been able to determine whether a particular Spinel stone is natural or synthetic.

The natural Spinel is relatively rare and so most Spinel appearing in jewellery is synthetic. Man-made Spinel is very often used as a simulant for other gem-stones the R.I. value being a dead giveaway.

The Chelsea filter can be used to distinguish natural Aquamarine and blue Topaz from their blue synthetic-Spinel simulants as the blue synthetic Spinel containing Cobalt allows the red colour to be displayed whereas the natural stones do not.

Emerald

Formula $Al_2Be_3Si_6O_{18.}$ The molecule is made up from 3 molecules of Beryllium Oxide (BeO), 2 molecules of Aluminium Oxide (Al_2O_3), and six molecules of Silicon Dioxide (SiO_2). The crystal system of Emerald is Hexagonal. Photo 8.7 shows a rare Colombian Trapiche Emerald which shows the hexagonal layout beautifully. The central hexagonal core formed first after which a mix, principally albite, quartz and carbon entered the surrounding mixture and formed at the junctions of the emerging crystals of emerald giving the six spoked trapiche.

Photo 8.7: The six-spoked 185.4ct Colombian Emerald Trapiche.

Most natural emeralds are heavily included so any perfectly clear emerald has to be taken with extreme caution and is most likely to be Synthetic. Photos 8.8 and 8.9 show two natural emeralds with a great deal of inclusions. The Emerald on the right has large Crystals of Red Beryl included within it.

Photo 8.8 Photo 8.9

Two Natural included Emeralds

Use of the polariscope will show the stone has double refraction and is Uniaxial. It will also show that the natural stone is pleochromic and use of the dichroic mirror will show green and blue-green colours.

When heated Emerald can change colour becoming yellowish, brownish and even resemble Citrine, but whereas Citrine exhibits dichroism, the heated Emerald has lost its dichroism.

The composition of Emerald means it is not suitable as a candidate for the Vermeuil process and the synthetic stone is formed either by the Flux method, which can take up to eight months to produce facetable material, or by the Hydro method. This makes such stones costly and less likely to appear in mixed gemstone lots.

The Refractometer reading will qu1ckly indicate whether the stone is natural, formed by the flux method or by the hydro process. Readings for each of the production methods are as follows …

Natural Emerald R.I. 1.577 to 1.583 with DR of -0.006

Hydro formed Emerald R.I. 1.568 to 1.573 and

Flux formed Emerald R.I. 1.561 – 1.564.

Specific Gravity of the natural Emerald can vary from 2.67 to 2.78 with an average value of 2.76. The synthetics tend to be about 2.65.

Natural Emerald reacts weakly to magnetism whereas the synthetic tend not to react at all.

Chelsea/Jadeite filter

This filter was designed to separate genuine Emeralds from a mix of similarly coloured stones. Under strong electric light it only transmits yellow-green and deep red light. Emeralds, which absorb the yellow-green light, usually appear distinctly red or pinkish depending on the depth of colour of the stone. Most imitations, such as green Glass, Tourmaline, Peridot, retain a green appearance through the filter.

Synthetic Emerald will usually also show red through the filter but usually much brighter than the natural.

Under UV light none or a reddish reaction is got for both Short and long wave for the natural emerald, whereas the synthetic usually shows a weak red for short wave, and a strong red for long wave.

Sapphire

Sapphire has the same basic composition as Ruby, the difference being in the substitution of some of the basic atoms by other atoms leading to different coloured stones. Aluminium Oxide (Al_2O_3), the basic ingredient of the Corundum stones, will form a colourless crystal if unmixed while the crystal is forming. The colouring agents for Sapphire were discussed in Chapter Five.

Natural sapphire will exhibit weak magnetic attraction while the synthetic is inert.

Photo 8.10: Natural Sapphire under magnification.

Photos 8.10 and 8.11 show straight growth lines in magnified images of two Sapphires crossing at angles of 120^0 , indicating that the stones in question are natural. Curved growth lines will suggest a Verneuil process stone.

Photo 8.11: Natural Sapphire under magnification.

Another indicator of a natural Sapphire is shown by those stones which are particoloured (i.e. have more than one colour in the stone). Synthetics of these have not been produced.

The natural Sapphire will invariably have inclusions which are easily seen, so any stone which is perfectly clean should be taken as suspect.

Round bubbles as inclusions also indicate the synthetic stone.

Diffusion colouring of Sapphire very often only has a shallow penetration and should be readily shown-up on viewing from the side.

Ruby

Glass simulants of Ruby are clearly shown up by use of the polariscope and refractometer. With the polariscope glass will never show double refraction, but may occasionally show anomalous double refraction. The Refractive Index of Ruby at over 1.7 is considerably higher than any glass simulant.

Using the usual glass Ruby filter it is possible to differentiate between Rubies and other red stones (such as Red Beryl, various red Garnets, red Glass, red Spinel and red Tourmaline), when viewed under strong electric light through the filter. The Ruby, synthetic Ruby and synthetic Red Spinel will all appear bright red due to their Chromium colouring agents, while other stones will appear grey or black. To differentiate between natural and synthetic ruby, use may be made of the Ultra-Violet Light Box.

Under Ultra-Violet light Natural ruby exhibits strong, and very Strong red fluorescence under short and long wave U.V. respectively, while the synthetics show stronger effects under the same circumstances. Remember that the use of known natural and synthetic rubies are recommended as comparison stones.

Under the microscope the synthetic Flame Fusion (Verneuil) Ruby may give itself away by having curved growth lines or curved colour zoning. Growth lines in the natural Ruby will be straight and if they meet at angles of 120^0 you can be sure the stone is natural. Again gas bubbles are not found in the natural stone. Tadpole-like inclusions, (undigested grains of the feed powder used), may be seen in the synthetic stone. If the stone is very clean you may find it difficult to see inclusions. However since most rubies will show inclusions, a very clean stone, especially of any size, can be taken as being synthetic.

There is a Verneuil 'Alexandrite coloured' Corundum found in some jewellery posing as natural Alexandrite, which can be a problem for the buyer. Similarly, a synthetic Spinel may also be found.

However if we list the Refractive Index and Specific Gravity of the three natural stones we get the following…

Stone	R.I.	S.G.
Alexandrite	1.746-1.763 DR +0.007 to +0.011	3.70 to 3.78
Corundum	1.762-1.778 DR -0.008	3.97 to 4.05
Spinel	1.712-1.762 No DR	3.54 to 3.63

If the stone in question is loose then the Polariscope, Refractometer and Specific Gravity will provide the evidence for a simulated Alexandrite, noting particularly that the Spinel is Isometric and that the Polar sign for Ruby is negative while that of the natural Alexandrite is positive.

If, however, the stone is mounted and does not permit the use of the three tests one must look elsewhere to determine the nature of the stone.

Test for magnetism, pleochromism, and use the microscope to look for curved growth lines or curved colour banding. Examine the facet cut quality, and clarity and inclusions.

The natural Alexandrite is weakly affected by magnetism whereas the synthetic, Lab. Corundum and Spinel, are not affected.

Use of the dichroic mirror shows that natural Alexandrite is trichroic, Spinel does not react and Corundum is dichroic.

Quartz

Quartz (formula SiO_2) in all the various colours should, in general, be taken as synthetic.

Photo 8.12: Tray of various coloured Quartz

Colourless (rock crystal), Purple (Amethyst) and the yellow/gold (Citrine) Quartz gem-stones can be found as natural stones but only the Amethyst is of any real value. Natural Amethyst usually has patches or stripes of colour.

Natural Citrine usually will display subtle colour zoning, best seen under the microscope, while the synthetic will be more uniform in colouring.

In larger synthetic Citrines, when viewed under the microscope, colourless seed-crystals (or part thereof), may be seen which show that the stone in question is synthetic.

Photo 8.13

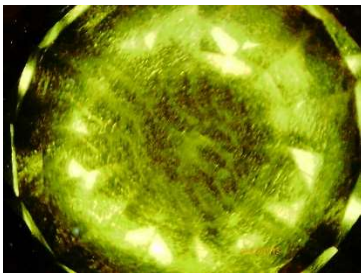


Photo 8.14

Photo 8.15

Photo 8.13 and 8.15 show clear crystal inclusions in two synthetic Citrines (one of 18.65ct, the other of 10.04ct) while Photo 8.14 shows colour zoning in a natural Citrine.

Photo 8.16: Citrine rough on white quartz

Apart from the natural Amethyst, the various natural and synthetic quartz stones do not fluorescence under U.V. light. The Natural Amethyst will occasionally have a deep blue fluorescence under both the short and long waves.

Any large clear coloured Quartz stones are most likely to be synthetic, and as they tend to be very cheap to buy, can be generally ignored. Photo 8.16 shows a typical natural Citrine on a bed of white quartz. Finding suitable such Citrine for cutting into gem-stones is fairly rare.

The use of the Refractometer, Specific Gravity and Polariscope will confirm that a test stone is quartz, but none of the tests shown in this book are really of any use in determining the nature of any such stone. Equipment which would do so is far beyond the pocket of the amateur gemologist and has not been discussed here.

Sometimes one will have to admit defeat and move on to a different stone.

Chapter Nine

Test Procedure Sheets

A selection of decorative stone and Quartz crystal elephants.

It is said that an elephant never forgets. Perhaps this is true, but it is a certainty that we humans do. So when doing a detailed testing program on a gem-stone it is important to keep a written record of the results of the various tests undertaken.

The fronts-piece for this chapter shows a selection of carved Quartz based Elephants. They are as follows…

Back Row L to R: Aventurine 247ct; Amethyst 128ct; Rose Quartz 231ct; Dalmation Jasper 263ct.

Front row L to R: Green Jasper 359ct; Tiger's Eye 525ct; Hematite/Red Jasper 354ct.

All except for the Amethyst and Rose Quartz are Cryptocrystalline.

To help in the remembering process the following pages give a suggested order to follow when testing an unknown gem-stone. You can, of course, test in any order provided you record the outcome of each test performed. This is essential when testing a number of stones at the same time.

Copies of the pages ought to be printed out, one for each stone being tested.

At various stages, results obtained should be checked against known values, listed in the appendices, or against gem data given in various internet sites.

If a specific stone is indicated, it should be noted in the appropriate section of the sheets as you go along.

Finally an overall result should take in the evidence from all the testing, noting specifically the variety of gem-stone found and whether it is natural or other stone. (Simulant, Synthetic or Treated.)

Stone Identity (Client)

Test Result Sheet **Section 1.** Visual

Mounted Loose

Rough Cabochon Faceted

Clear Translucent Opaque

Colour

Inclusions

Cut Are the facets in a tier uniformly cut? Yes No

Composite Yes No

Section 2. Magnetic Effect None Weak Moderate Strong

Section 3. Specific Gravity Available Not Available

If Available Result

Indicated Stone from tables

Section 4. Polariscope, Dichroic Mirror

Stone Opaque --- Move to Section 5.

Isotropic Anisotropic Microcrystalline

ADR (Anomolous Double Refraction)

If Isotropic move to Section 5.

If Anisotropic Uniaxial Biaxial

Pleochromic Yes No

If Pleochromic then Dichroic Mirror colours

Section 5. Refractometer

Cabochon Distant Vision Reading result

Indicated Stone from tables

Faceted One Shadow Edge Reading

Two Shadow Edges

Fixed Lower Higher Moving: Readings

DR + Optic sign

Fixed Higher Lower Moving: Readings

DR + Optic sign

Two Shadow Edges (Both Moving)

DR + Optic sign

Result: Indicated Stone from tables

If Negative Value then Electronic RI reading

Result: Indicated Stone from tables

Section 6. Microscope and other tools.

Inclusions (Detail)

Reaction to UV Long Wave

Short Wave

Result: Indicated Stone from tables

Reaction to filter

Filter used Chelsea Jadeite Ruby

Result: Indicated Stone from tables

Spectroscope Spectrum

Result: Indicated Stone from tables

Other Tests

Overall Result:

Appendix

Display of Natural Month-Stones

In the photograph fronting the Appendix section the three left-hand columns are the principal stones for the month, beginning left-Top with January and third on bottom row being for December. The two right-hand Columns are alternative stones for the stated months.

Principal Month –Stones (Columns One to Three)

Column 1 (Left)		Column 2	
January	Garnet	February	Amethyst
April	Diamond	May	Emerald
July	Ruby	August	Peridot
October	Opal	November	Citrine

Column 3 (from left)

March	Aquamarine
June	Moonstone
September	Sapphire
December	Blue Topaz

Some supplementary Month-Stones (Columns Four to Five)

Column 4 (from Left)		Column 5	
March	Bloodstone	June	Alexandrite
June	Pearl	October	Tourmaline
November	Topaz	December	Turquoise
December	Zircon	December	Lapis Lazuli

Table 1 Mohs Hardness, Specific Gravity and Chemical Formulae for the more common natural Gem-Stones.

	Mohs	S.G.	Formula
Aquamarine	7.5 – 8	2.68–2.74	$Al_2Be_3Si_6O_{18}$
Alexandrite	8.5	3.70–3.78	$BeAl_2O_4$
Aventurine	7	2.64-2.69	SiO_2
Beryl (Group)	7.5 – 8	2.68–2.74	$Al_2Be_3Si_6O_{18}$
CZ	8 – 8.5	5.6-6	ZrO_2
Chrysoberyl	8.5	3.7–3.78	$BeAl_2O_4$
Diamond	10	3.5–3.53	C
Emerald	7.5 – 8	2.67–2.78	$Al_2Be_3Si_6O_{18}$
Fluorite	4	3–3.25	CaF_2
Garnet (Group)	6.5 – 7.5	3.57–4.30	$A_3B_2(SiO_4)_3$
Iolite	7 – 7.5	2.35	$Be_2BO_3(OH)$
Jade	6.5 – 7	3.30–3.38	$NaAlSi_2O_6$
Moissanite	9.5	3.218-3.22	SiC
Moonstone	6 – 6.5	2.56–2.59	$KAlSi_3O_8$
Opal	5.5 – 6.5	1.98–2.50	SiO2 $*nH_2O$
Peridot	6.5 – 7	3.28–3.48	(Mg, $Fe^{2+)}$2SiO_4
Quartz (Group)	7	2.65	SiO_2
Ruby	9	3.97–4.05	Al_2O_3
Sphene	5 – 5.5	3.52–3.54	$CaTiSiO_5$
Sphalerite	3.5 – 4	3.90–4.10	(Zn,Fe)S
Sapphire	9	3.95–4.03	Al_2O_3
Spinel	8	3.54–3.63	$MgAl_2O_4$
Tanzanite	6.5 – 7	3.35	$Ca_2Al_2(SiO_4)_3(OH)$
Topaz	8	3.49–3.57	$Al_2SiO_4(F,OH)_2$
Tourmaline (Group)	7 – 7.5	2.82–3.32	(Complicated)
Turquoise	5 – 6	2.31–2.84	$CuAl_6(PO_4)_4(OH)_8.4H_2O$
Zircon (natural)	6.5 – 7.5	3.93–4.73	$ZrSiO_4$

Table 2 Crystal System of selected Gem-Stones

Gem-Stone	Crystal System
Aquamarine	Hexagonal prisms
Alexandrite	Orthorhombic
Andalusite	Orthorhombic
Aventurine	Trigonal
Apatite	Hexagonal
Benitoite	Hexagonal
Beryl (Group)	Hexagonal prisms
Calcite	Trigonal
CZ	Cubic
Chrysoberyl	Orthorhombic
Danburite	Orthorhombic
Diamond	Cubic, cubes but mainly octahedrons.
Emerald	Hexagonal prisms
Fluorite	Cubic
Garnet (Group)	Cubic , mainly dodecahedrons and icositetrahedrons.
Hiddenite	Monoclinic
Iolite	Orthorhombic, short prisms.
Jade	Monoclinic
Kunzite	Monoclinic
Moissanite	Hexagonal
Moonstone	Monoclinic
Opal	Amorphous
Orthoclase	Triclinic
Peridot	Orthorhombic, short compact prisms, striated. vertically
Phenakite	Trigonal
Quartz (Group)	Trigonal

Ruby	Trigonal, hexagonal prisms.
Sphene	Monoclinic, platy
Sphalerite	Cubic, tetrahedral
Sapphire	Trigonal, barrel-shaped, hexagonal pyramids.
Spinel	Cubic, octahedron
Tanzanite	Orthorhombic
Topaz	Orthorhombic
Tourmaline (Group)	Trigonal, striations parallel to main axis.
Turquoise	Triclinic, seldom, grape-shaped aggregates.
Zircon (natural)	Tetragonal

Table 3 Pleochroic Gemstones

Colour	Stone	Strength	Colours
Purple & Violet	Andalusite	Strong	Green-brown / dark brown / purple
Green	Andalusite	Strong	Brown-green / Dark red
Red & Pink	Andalusite	Strong	Dark red / Brown red
Blue	Apatite	Stroong	Blue-yellow / blue-colourless
Blue	Benitoite	Strong	Colourless / Dark blue
Purple & Violet	Beryl	Medium	Purple / Colourless
Blue	Aquamarine	Medium	Clear / Light blue or light blue / Dark blue
Green	Emerald	Strong	Green / Blue-green
Red & Pink	Morganite	Medium	Light-red / Red-Violet
Blue	Alexandrite	Strong	Dark red-purple / Orange / Green
Green	Alexandrite	Strong	Dark red / Orange / Green
Yellow	Alexandrite	V. Weak	Red-yellow / Yellow-green / Green
Red & Pink	Alexandrite	Strong	Dark red / Orange / Green
Blue	Iolite	V. Strong	Pale yellow / Violet/ Pale blue
Purple & Violet	Sapphire	High	Purple / Orange
Blue	Sapphire	Strong	Dark violet-blue / Light blue-green
Green	Sapphire	Strong	Green / Yellow-green
Yellow	Sapphire	Weak	Yellow / Pale yellow
Brown & Orange	Sapphire	Strong	Yellow-brown / Orange
Red & Pink	Ruby	Strong	Violet-red / Orange-red
Yellow	Danburite	Weak	Very pale yellow / Pale yellow
Yellow	Orthoclase	Weak	Different shades of pale yellow
Yellow	Hornblende	Strong	Light-green / Dark green / Yellow / Brown
Purple & Violet	Hyperstene	Strong	Purple / Orange
Green	Kornerupine	Strong	Green / Pale yellowish brown/ Reddish-brown
Green	Peridot	Weak	yellow-green / Green / Colourless
Yellow	Phenacite	Medium	Colourless / Yellow-orange
Purple & Violet	Amethyst	V. Weak	Different shades of purple
Yellow	Citrine	V. Weak	Different shades of pale yellow

Green	Titanite	Medium	Brown-green / Blue-green
Purple & Violet	Kunzite	Strong	Purple / Clear / Pink
Green	Hiddenite	Strong	Blue-green / Emerald-green / Yellow-green
Yellow	Kunzite	Medium	Different shades of pale yellow
Blue	Topaz	V. Weak	Colourless / Pale Blue / Pink
Yellow	Topaz	Medium	Tan / Yellow / Yellow-orange
Brown & Orange	Topaz	Medium	Brown-yellow / Dull brown-yellow
Purple & Violet	Tourmaline	Strong	Pale Purple / Purple
Blue	Tourmaline	Strong	Dark Blue / Light Blue
Green	Tourmaline	Strong	Blue-green / Brown-green / Yellow-green
Yellow	Tourmaline	Medium	Pale yellow / dark yellow
Brown & Orange	Tourmaline	V. Weak	Dark brown / Light brown
Red & Pink	Tourmaline	Strong	Dark red / Light red
Blue	Zircon	Strong	Blue / Clear / Gray
Green	Zircon	Weak	Greenish-brown / Green
Yellow	Zircon	Weak	Tan / Yellow / Yellow-orange
Brown & Orange	Zircon	V. Weak	Brown-red / Brown-yellow
Red & Pink	Zircon	Medium	Purple / Red-brown
Blue	Tanzanite	Strong	Blue / Red-purple / Yellow-green

Table 4…… Pleochromic Gemstones and their Crystal Systems

Colour	Stone	Crystal System
Purple & Violet	Andalusite	Orthorhombic
Green	Andalusite	Orthorhombic
Red & Pink	Andalusite	Orthorhombic
Blue	Apatite	Hexagonal
Blue	Benitoite	Hexagonal
Purple & Violet	Beryl	Hexagonal
Blue	Aquamarine	Hexagonal
Green	Emerald	Hexagonal
Red & Pink	Morganite	Hexagonal
Blue	Alexandrite	Orthorhombic
Green	Alexandrite	Orthorhombic
Yellow	Alexandrite	Orthorhombic
Red & Pink	Alexandrite	Orthorhombic
Blue	Iolite	Orthorhombic
Purple & Violet	Sapphire	Trigonal
Blue	Sapphire	Trigonal
Green	Sapphire	Trigonal
Yellow	Sapphire	Trigonal
Brown & Orange	Sapphire	Trigonal
Red & Pink	Ruby	Trigonal
Yellow	Danburite	Orthorhombic
Yellow	Orthoclase	Triclinic
Yellow	Hornblende	Monoclinic
Purple & Violet	Hyperstene	Orthorhombic
Green	Kornerupine	Orthorhombic
Green	Peridot	Orthorhombic
Yellow	Phenacite	Trigonal
Purple & Violet	Amethyst	Trigonal
Yellow	Citrine	Trigonal
Green	Titanite	Monoclinic
Purple & Violet	Kunzite	Monoclinic
Green	Hiddenite	Monoclinic

Yellow	Kunzite	Monoclinic
Blue	Topaz	Orthorhombic
Yellow	Topaz	Orthorhombic
Brown & Orange	Topaz	Orthorhombic
Purple & Violet	Tourmaline	Trigonal
Blue	Tourmaline	Trigonal
Green	Tourmaline	Trigonal
Yellow	Tourmaline	Trigonal
Brown & Orange	Tourmaline	Trigonal
Red & Pink	Tourmaline	Trigonal
Blue	Zircon	Tetragonal
Green	Zircon	Tetragonal
Yellow	Zircon	Tetragonal
Brown & Orange	Zircon	Tetragonal
Red & Pink	Zircon	Tetragonal
Blue	Tanzanite	Orthorhombic

Table 5 The common gemstones within the range of the refractometer.

Stone	RI Range	Double Refraction & Optic Sign
Aquamarine	1.564 to 1.596	-0.004 to -0.005
Beryl	1.562 to 1.602	-0.004 to -0.010
Emerald	1.562 to 1.602	-0.006
Iolite	1.542 to 1.578	-0.008 to -0.012
Peridot	1.650 to 1.703	+0.036 to +0.038
Quartz	1.544 to 1.553	+0.009
Amethyst Citrine and Smokey Quartz are the same as Quartz		
Ruby	1.762 to 1.788	-0.008
Sapphire	1.762 to 1.788	-0.008

Spinel	1.712 to 1.762	None
Tanzanite	1.691 to 1.700	+0.009
Topaz	1.609 to 1.643	+0.008 to +0.016
Tourmaline	1.614 to 1.666	-0.014 to -0.032

Table 6 Refractive Indices for some 'Negative Value' Gem-Stones (Using an Electronic RI Meter.)

Stone	R.I.	D.R.
Almandine (Garnet)	1.770 – 1.820	No
Andradite (Garnet)	1.88 – 1.94	No
CZ (Cubic Zirconia)	2.150 – 2.180	No
Diamond	2.417 – 2.419	No
GGG (Gadolinium Gallium Garnet)	1.979 – 2.020	No
Moissanite	2.65 – 2.69	Yes
Rutile	2.616 – 2.903	Yes
YAG (Yttrium Aluminium Garnet)	1.833 – 1.835	No
Zircon	1.810 – 2.024	Yes