CHAPTER - 3 **COLOUR IN GEMSTONE**

Gemstone's colour depends on the light. Without light, there is no colour. Gemstone colour is a result of absorption and reflection of visible light. When white visible light passes through a gemstone some of energy is reflected and some of the energy of the white light is absorbed in gemstone which caused colour in Gemstone.

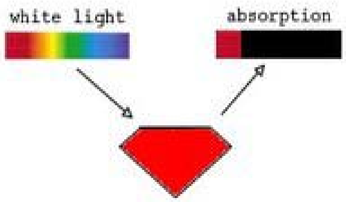


Fig. 3.1 Origin of colour in gemstone where some of the light absorb and some of the light reflect.

Gemstone colour is divided into three categories which are depended on the chemical composition of the gemstones, impurity available in the host and false colour. The colour of the gemstone is classified as Idiochromatic, Allochromatic and Pesudochromatic. The Idiochromatic colour means colours formed due to its original chemical composition. The Allochromatic colour means colour formed as a result of presence of impurity available in the gemstone. And the Pesudochromatic colour means colour originated from optical effect.

The causes of color can be divided into four theories:

1. The Crystal Field Theory
2. The Molecular Orbital Theory
3. The Band Theory
4. The Physical Properties Theory

THE CRYSTAL FIELD THEORY

According to Crystal field theory, colors of gemstone is originating from the excitation of electrons in transition elements and color centers.

When a transition metal ion has a partially filled d-shell, the electrons in the outer d-shell orbit the nucleus unpaired. The surrounding ions of the crystal lattice create a force which is known as a "crystal field" and it forms around such a transition element and the strength of those fields determine which energy levels are available for the unpaired electrons. Such a system of energy levels depends on the strength and nature of the bonding in the lattice as well as on the valence state of the transition element. These are different in every crystal.

As energy and energy levels are quantized, the electrons need a specific amount of energy to "jump" from its groundstate to a higher energy level. The complex calculations that determine which energy levels are available for the electron to excite also provide a few selection rules which exclude some levels for excitation.

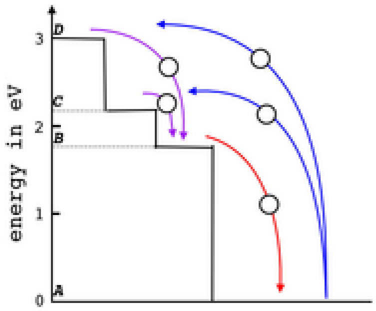


Fig. 3.2 Excitation state of the electron in ruby.

Absorption in ruby:

In ruby, Cr^{3+} substitutes some of the Al^{3+} ions in the Al_2O_3 lattice. As the chromium is not part of the ideal make-up, ruby is said to be allochromatic. The crystal field around the chromium impurity makes a few, quantized, energy levels available to the unpaired electrons. These are presented as levels B, C and D. However selection rules determine that level B is not available for excitation in this case. Levels C and D correspond with energies of respectively 2.23 eV and 3 eV. The energy needed to jump to level C (2.23 eV) corresponds with yellow-green light and level D (3 eV) corresponds with violet light.

This means that when white light enters a ruby, yellow-green and violet light will be absorbed by the unpaired electrons and these electrons now have sufficient energy to be excited to levels C or D. The residual colors that are not absorbed determine the red color of the ruby.

The same selection rules also forbid the excited electron to fall back to their ground states (A), but must instead first fall back to B. When the electrons in level B deexcite to their ground state, emmision of red light occurs (fluorescence) which gives an extra glow to the already red color caused by the absorption of the yellow-green and violet portions of white light.

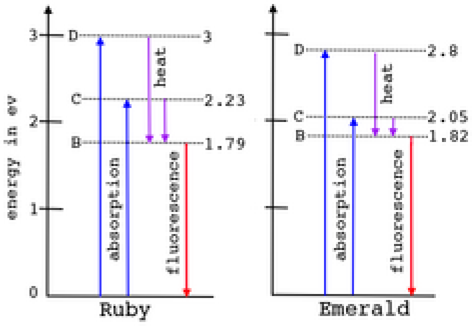


Fig. 3.3 Schematic overview of energy levels in ruby and emerald

For emerald in which allochromatic color is also caused by a Cr^{3+} impurity, the mechanism is similar as in case of the ruby but the crystal field from the surrounding elements has less strength and causes a shift in absorption bands. The D level is 2.8 eV which is lowered than the ruby level and the C level is 2.05 eV which is also lowered than the D level; of ruby. But, the B level is almost the same. The result is that emerald absorbs most violet and red portions of visible light and giving a dominant blue-green transmission with a red fluorescence.

Transition ion impurities :

Transition ion impurities is responsible for colour in gemstone otherwise gemstone look transparent .This is called crystal filled effect or alternately a legend filled effect. There is chemical bonding between the host crystal composition and guest impurities by donating electron on crystal to empty energy level on the metal impurities. In most of the cases, the Impurities are elements (e.g., Ti, V, Cr, Mn, Fe, Co, Ni, Cu...) those are not present in the pure compound. Impurities are elements that occur in low concentration in the gemstone. Transition ion have an incomplete set of 3*d* electrons in the transition metal ion to undergo an energy change. These electrons gain some necessary energy for excitation by absorbing a particular energy in the form of colour from white light which caused colour in gemstone.

The origin of the Green color of emeralds is similar to red color of rubies. However, the bulk of an emerald crystal is composed by the chromium beryllium aluminum silicate. In Emerald, the Green color is produced by chromium (III) ions, which replace some of the aluminum ions in the crystal. In emeralds, the Cr3+ is surrounded by six silicate ions, rather than the six oxide ions in ruby. These silicate ions also split the 3*d* orbital of Cr3+ into two sets. However, the magnitude of the energy difference between the sets is different from that produced by the oxide ions in ruby. Therefore, the color of emeralds is different from that of ruby.

Fig. 3.4 Photograph showing the Green colour in Emerald due to Cr^{3+}.

Chromium(III) also produces color in Alexandrite. The color of this gem is very unusual, because in bright sunlight it appears green to tale, but in incandescent light it appears blue violet or red. This unusual behavior is a result of the way human vision works. Our eyes are most sensitive to green light. Alexandrite reflects both green and red light. In bright sunlight, the proportion of green light is greater than it is in the light from an incandescent lamp. The light reflected by alexandrite in bright sunlight is rich in green light, to which our eyes are most sensitive, and perceive the gem as green. The light reflected by alexandrite in incandescent light is much richer in red, and we see the stone as red under these conditions.

Fig. 3.5 Photograph showing Alexandrite gemstone which show blue-violet colour in incandescent light and blue colour in day sun light.

Table-3.1 **Colored in gemstone due to Transition ion impurities**

Gems	Formula	Colour of Gemsotne	Impurities &/ Transition ion Sites
Aquamarine	Be3Al2(SiO3)6	Blue	Intervalence transition between Fe2+ and Fe3+ replacing Al3+ in adjacent octahedral sites
Alexandrite	Al2BeO4	Red/Green	Cr3+ replacing Al3+ in octahedral Site
Emerald	Be3Al2(SiO3)6	Green	Cr3+ replacing Al3+ in octahedral Site
Garnet	Mg3Al2(SiO4)3	Red	Fe2+ replacing Mg2+ in 8-coordinate site
Sapphire(Blue)	Al2O3	Blue	Fe2+ and Ti4+ replacing Al3+ in adjacent octahedral sites
Peridot	Mg2SiO4	Yellow-green	Fe2+ replacing Mg2+ in 6-coordinate site
Ruby	Al2O3	Red	Cr3+ replacing Al3+ in octahedral sites
Tourmaline	Na3Li3Al6(BO3)3(SiO3)6F4	Pink	Mn2+ replacing Li+ and Al3+ in octahedral site
Turquoise	Al6(PO4)4(OH)8A4H2O	Blue-green	Cu2+ coordinated to 4 OHG and 2 H2O

THE MOLECULAR ORBITAL THEORY

According to molecular orbital theory, electrons are traveling in paths when multiple atoms (two or more) tie chemically by sharing or exchanging an electron

There are two types of bonding:

1. Ionic bonding
2. Covalent bonding

Difference between ionic and covalent bonding is that in covalent bonding there is a *sharing* of electrons while in ionic bonding there is a *donation/receiving* of electrons. Both these bonds have different characteristics, mostly they play a role in the chemical bonding of gemstones as well as directly related to the *electronegativity* of the different elements that make up the chemical formula of a gemstone. Electrons are present only in the outer shells of atoms that play a role in both ionic or covalent bonding.

Covalent bonding plays a large role in the formation of color as the energy required to exchange the electrons causes absorption. *Charge transfer* is a common term to describe the continues exchange of electrons in covalent bonding when energy is applied to the molecule.

Charge Transfer

Charge transfer is intervalence interaction between two adjacent metal ions by transfer of electron. In charge transfer, the color is caused not by energy changes in a single transition metal ion, but by the exchange of electrons between two adjacent transition metal ions of differing oxidation states. The energy needed to transfer an electron from one ion to another corresponds to the energy of visible light. When the energy required for that transition is equivalent to energy in the visible range (or near that) of light, it will result in color.

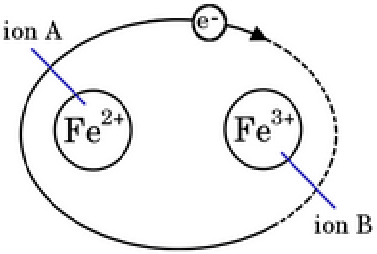


Fig. 3.6 An intervalence transition is also responsible for the blue color of aquamarine. In aquamarine, adjacent Al3+ ions in beryl are replaced by an Fe2+ ion and an Fe3+ ion

Fig. 3.7 Photograph showing colour change due to charge transfer in Aquamarine.

In the case of Iolite darker bule color is caused by the charge transfer between Fe^{2+} and Fe^{3+} ions. The Fe^{2+} ion has one more electron in its outer shell than the Fe^{3+} ion. That electron is attracted to the Fe^{3+} ion and when the electron orbits the Fe^{3+} ion, that ion will become an Fe^{2+} ion. The original Fe^{2+} ion will then become an Fe^{3+} ion and the process repeats & hance viasible blue colou is appear

Fig. 3.8 Photograph showing colour due to charge transfer in Iolite.

The usual notation for such a transfer is: $Fe^{2+} + Fe^{3+} \rightarrow Fe^{3+} + Fe^{2+}$

Interaction between ion of a deffrent metallic elements:

In case of blue sapphire is alumina (Al^{3+})ions are replaced by an Fe^{2+} ion and a Ti^{4+}. When light of the appropriate energy strikes the crystal, energy is absorbed, and an electron moves from the Fe^{2+} to the Ti^{4+}. Such a movement is called an intervalence transition between ion of different metallic elements.

Fig. 3.9 Photograph showing colour change due to charge transfer in Blue-Saphire.

Here, in the case of Blue sapphire, the Al^{3+} ion is replaced by Fe^{++} and the $Ti4+$ and it shows the blue colour by charge transfer.

Colour center

In some gemstones, colour is produced by presence of foreign atoms with different number of valance electron than once they replace. This foreign atoms are called colour center or Colour center is created when atoms are oxidized or removed Simultaneously an electron will occupy same hole center. In practice, this is done by radiation In both cases a "color center" is created and the unpaired electron can be raised to higher energy levels through the absorption of incident light as with unpaired electrons of the transition metal ions. In the first case (an electron substituting a misplaced ion), the color center is an "electron hole center". The term "hole color center" refers to the missing electron, leaving behind a hole and the term "electron color center" refers to the fact that there is a "free" electron where it normally wouldn't be. Such Gemstone colour can be removes or become fade under effect of heating or exposed in strong light.

Electron color centers

Electronic colour center in fluorite is due to natural irradiation and interaction of fluorite with rare earth element . The purple color of fluorite is caused by the absence of a fluorine (F^-) ion and an electron is trapped in the vacancy it leaves behind.

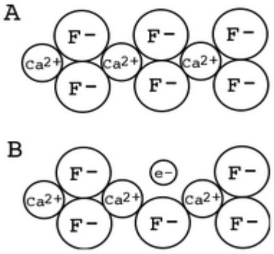


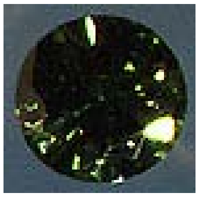
Fig. 3.10 Electron color center in fluorite.

Situation A in the image shows the ideal configuration of fluorite, while situation B shows the electron that is trapped in the vacancy left behind by the displaced fluorine ion. There are various reasons why the fluorine ion is missing from a particular site in the crystal lattice. Among those are an excess of calcium and radiation. either during or after growth of the crystal. This creates a so called "F-center" or "Farbe center" where Farbe is the German word used for color. This F-centre and a free electron from the pool of unpaired electrons in the crystal is trapped in the vacancy. This unpaired electron can then be raised to, the now available, higher energy levels by the absorption of energy in photons and similar crystal field rules of absorption and fluorescence, as described above, are in effect.

The fluorine ion is usually displaced and creates an interstitual in the lattice is so called "Frenkel defect", meaning that there is an ion at a particular site in the lattice where it normally would not be. This displaced fluorine ion does not play a role in the development of color (only the vacancy it leaves behind does).

Hole color centers

Hole color centers are responsible for colour in Amethyst and smokey quartz. The colour of both smokey quartz and amathyst are more stable in white light but it can remove on being heated and colour o gemstone can be restored by on other irradiation.



smokey quatz **Al+++ <=> Si4+**

Fig. 3.11 Hole color center in smokey quartz.

In quartz (SiO_2), oxygen atoms to be weakened and radiation (X-ray, gamma rays etc.) can remove one of the weaker bonded electrons of the oxygen atoms. This leaves a hole (one electron is missing) and different energy levels become available to the now unpaired electron on the oxygen ion. In quartz, remaining unpaired oxygen electron and the resulting color is a smokey brown to which smokey quartz owes its name. The displaced electron will be trapped at other sites in the crystal lattice and it doesn't contribute to the color making scheme.

In Amethyst, ferric iron (Fe^{3+}) produces the typical purple color.Here Fe^{3+} replacing Al^{3+} and producing violet colour in Amethyst. Following equation shows $[FeO4]^{-5}$

Hole center that provide colour.

$$[FeO4]^{-5} \rightarrow [FeO4]^{-4} + e^{--}$$

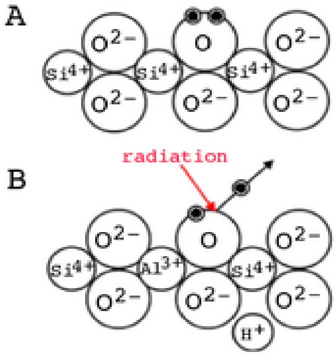


Fig. 3.12 Schematic diagram showing Formulation of ametyst crystal Fe^{3+} prlacing Al^{3+} and producing violet colour

If the crystal of smokey Quartz is heated around 400° C and Amethyst at 450° C, the displaced electron is freed from it's trap and returns to its original site, traveling as paired electrons again. The color of the crystal will then return to its original color.

THE BAND THEORY

This theory was developed to explain electrical conductivity in metals. Later this theory was further developed with quantum mechanics and also used to explain colors in the Gemstone

Depending on the energy required for an electron to overcome from gap, the materials have divided into three catergories:

1. Insulators (large gap with no electrical conductivity)
2. Conductors (small to no gap to overlapping energy levels with a good electrical conductivity)
3. Semiconductors (intermediate between insulators and conductors)

In insulators, the gap is so large that under normal conditions i.e. at room temperature there is not enough energy for an electron to bridge the large gap between the valence and the conduction band. As a consequence material with a large gap, it will be react as an electrical insulators as well as it looks like colorless. The colorless look is logical because the solid material can not absorb energy from visible light. Glass is an example of a good insulator.

In conductors, there is a very small band gap or no band gap i.e. usually the band and conduction gaps overlap. Therefore, electrons can easily be in the conduction band. As little energy is required for an electron to go from the valence band to the conduction band, these materials will be opaque because all of the energy from visible light will be absorbed. The ideal situation would result in an opaque black material, but other forces may turn it into a colored opaque material (such as yellow for gold).

Semiconductors are intermediate between the two states i.e. insulators and conductors mentioned above and it divides semiconductors into two categories:

1. Intrinsic semiconductors
2. Extrinsic semiconductors

1. Intrinsic semiconductors: These semiconductors with a large band gap usually behave as insulators such as diamond. Every carbon atom in the diamond structure has 4 valence atoms and they try to combine with 4 other carbon atoms to form a tetrahedral molecular structure. This means that in a pure diamond structure the valance band is fully occupied and the conduction band is empty. Yet if we could find a means to make room in the valence band and/or to occupy the conduction band, then the diamond could be an electrical conductor. Thus, Intrinsic semiconductors are made up of pure elements. For this we would need an impurity to substitute for a carbon atom in the "ideal" diamond structure.

2. Extrinsic semiconductors: These semiconductors are also known as doped elements. Doping means that there are impurities with a different valence state in the crystal lattice, like in allochromatic gemstones.

Doped semiconductors are further divided into two types:

a. N- Type semiconductor
b. P- Type semiconductor

a). N- Type semiconductor: If we would replace a carbon (C) atom from Diamond with a nitrogen (N) atom, which has 5 valency electrons instead of 4, then the Diamond would have one electron more than the pure Diamond. This excess electron would create an extra energy level inside the band gap below the conduction band. Some electrons in this extra electron energy level can now be excited into the conduction band. This type of a *doped semiconductor* is named an N-type semiconductor. Here, the initial N is used for negative charge from the extra electrons. The good example of this type is Yellow type IIa diamond.

b) P- Type semiconductor: If, we introduce boron (B) in the lattice of the Diamond, which has 3 valence electrons, the diamond would have a positive charge and it would create a hole in the energy gap. An electron from the valence band is excited to fill the hole and that creates a hole in the valence band. A neighbouring electron in the valence band will fill that hole and the hole seems to be moving through the valence band, which creates conductivity. This type is named a P-type semiconductor where the initial P comes after the positive charge created by the hole. Blue type IIb diamond is an example of this. Irradiated blue diamond does not conduct, so a distinction can be made between them.

THE PHYSICAL PROPERTIES THEORY

Optical phenomena of gemstone depending on interaction of light with certain inclusions or structural features within the gemstones.

Major Optical Phenomena in Gemstones:

- Iridescence:
    - Orient
    - Labradorescence
    - Play of color
- Adularescence
- Aventurescence
- Chatoyancy:
    - Simple chatoyancy

  - Cat'seye effect
  - Asterism
- Color change

Iridescence:

It is caused by *diffraction*. As white light passes through very small openings such as pores or slits, or through thin layers, Cleavage, fracture or Parting plan of Gemstone which differ in refractive index, a prism effect causes it to separate into spectral colors. These may then be seen on the surface, or in some cases in the interior, of the Gemstone.

When combined with *interference,* where the slightly out of phase color waves bouncing off different layers overlap as they reflect, a loss of some colors and a reinforcement of others can take place giving rise to dramatic color blocks, which may shift with viewing angle.

Iridescence is the most widespread of the optical phenomena, we see its effects in: the "orient" of pearls, the displays of fire agate, "rainbow calcite", certain obsidians, and iris agate. It also creates the rainbow display of fractures, the beautiful colors of Labradorite, and, probably most well known, the "color play" of precious opal.

Pearls: The "orient" of pearls, is a delicate, shifting, iridescent color layer that is distinct from the basic body color of the pearl or from its luster.

Fig. 3.13 Photograph showing the displays of orient: baroque freshwater cultured pearl and cultured Tahitian black pearl.

Fire Agate: The aggregate quartz gem known as fire agate, gets its iridescence from thin coatings of iron oxide (limonite) layered over its botryoidal chalcedony surface. The best specimens of this material can be very striking, and will command some of the highest prices of any aggregate form of quartz.

Fig. 3.14 Photograph showing Fire agate cabochon in a pendant and, a close up view of some fire agate colors.

Fractures/Cleavages: As we know that an internal cleavage can give evidence of its presence by a "cleavage rainbow". The picture below, showing impressive iridescence, is a magnified view of a very thin conchoical fracture in a gem.

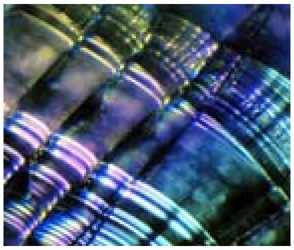


Fig. 3.15 Photograph showing conchoidal fracture in aquamarine.

There are other cases, where the presence of microscopic fractures or cleavages is responsible for the beauty of a particular gem. Two examples which are given below are known as "rainbow calcite" and "iris quartz".

Fig. 3.16 Photograph showing Iridescence due to internal micro-cleavages: "rainbow calcite" and "iris quartz":

Labradorescence: This phenomenon is a type of iridescence caused by repeated, microscopically thin layer (lamellar) twinning in Labradorite feldspar. One of its most notable characteristics is that the twinning is quite specifically oriented within the crystal, making the iridescent display highly directional. At some angles the light encounters no thin layers and no effect is seen, in other directions of view we see a bright blue, gold, green or multicolored surface. Looking at the sample of Labradorite rough pieces below you can see that only some of the "faces" are showing color at the angle at which they were photographed.

The finest pieces have strong displays which skilled cutters take care to orient to best advantage for the face-up view. The lovely cabochon pair and brooch below show how bright and attractive the display can be, but if they were turned to a different angle, that beauty would temporarily be lost, only to return again as the pieces were moved in another direction.

Fig. 3.17 Photograph showing Labradorite feldspar rough, Labradorite cabochons and Labradorite brooch.

Play of color: Play of color is seen as shifting patches of spectral colors on the gem's surface and/or in its the interior. This phenomenon is caused by the unique ultrastructure of the opal. The graphic below represents an interior view of opal at 25,000X via the electron microscope. Opal is made of spheres of cristobalite silica, SiO_2(a polymorph of quartz). These are arrayed in closely stacked layers and have air, or more rarely, liquid, in between them. The openings act as diffraction gratings which split the light into colors, and the layered structure creates interference. As the light is reflected from the various layers the, now slightly out of sync waves overlap, decreasing or removing certain spectral colors, and reinforcing others. Thus, we get a shifting group of colors which flicker on and off, and move as we twist and turn the gem altering the light path and viewing angle. Which colors are seen is a function of the size and regularity of the spheres *(with smaller spheres more blue is seen, with larger ones more red)* and of our angle of view.

Fig. 3.18 Photograph showing the different Precious opals which show play of colours.

In a common opal, the openings between the spheres are so large that light doesn't have to bend when traveling through them, so that no diffraction takes place. Rather, the scattering and bouncing of light off the inner particles creates a sort of hazy effect commonly known as "opalescence".

Fig. 3.19 Photograph showing Yellow common opal which show typical opalescent haze.

Adularescence:

Actually, opalescence is an example of another phenomenon called adularescence. When a gem displays a billowy floating light which appears to come from below the surface it is showing adularescence. The name comes from the most prominent gem displaying the phenomenon: moonstone, known historically as "adularia". The term "shiller" or "schiller" is sometimes used to describe the light.

In moonstone, adularescence is due to a layer effect, where thin inner strata of two types of feldspar intermix, *(exsolution regions of sodium feldspar in potassium feldspar)*. These layers scatter light either equally in all spectral regions producing a white shiller, or as in the most valuable specimens, preferentially in the blue or the blue and orange. As in so many cases of optical phenomena the size or distance from layer to layer influences the colors we see.

Fig. 3.20 Photograph showing different Adularescence in moonstone which shows white, blue and rainbow colours in moonstones.

In other gems, the scattering shows up in a less dramatic form due to minute inclusions that scatter multiple wavelengths of light. In certain quartzes and opals, golden shifting light can be seen in the interior, which is sometimes called the "girasol" effect.

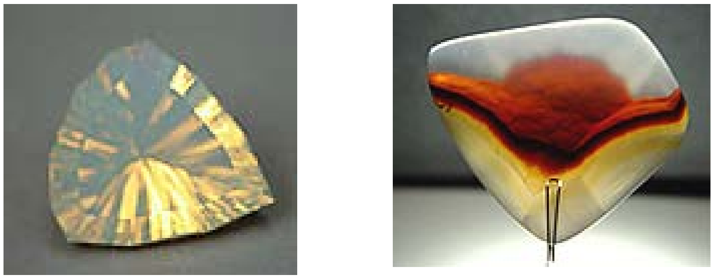


Fig. 3.21 Photograph showing Girasol effect in opal and agate.

This general scattering of light, often is not distinctive, but rather shows up as subtle haziness, as in the case of the opalescence of common opal. Frequently we see the term "milky" used to describe individual specimens of a usually non-hazy species which show this type of adularescence. An exception is rose quartz which is virtually always hazy, so it doesn't need a special adjective, like milky, to distinguish it.

Fig. 3.22 Photograph showing Opalescent haze in common opal, milky quartz with pyrite inclusion, milky aqua and rose quartz.

Aventurescence: Unlike the other phenomena discussed so far which owe their beauty and distinctiveness to structural features which diffract or scatter light, aventurescence is a consequence of reflection. When disk or plate-like inclusions of another mineral are present, and are of a highly reflective nature such that they act as tiny mirrors, the gem sparkles and glitters. This glitter is called aventurescence. The term shiller, is also sometimes used to describe this spangly glow. The most common reflectors are copper, hematite and mica.

The name is derived from the Italian word for "chance" or accident, and *has no "d" in it!* The most commonly encountered species showing this effect are certain feldspars and one variety of quartz.

Fig. 3.23 Photograph showing Shiller effect in Sunstone (copper platelets in feldspar) and in aventurine quartz (mica platelets).

Chatoyancy: This phenomenon is also due to reflection, but in this case, rather than involving plate-like inclusions scattered randomly, it is due to parallel thread-like reflective inclusions such as needles or tubes. When the inclusions are either *not* highly organized, or the gem is *not* cut in such a way as to concentrate or focus the light from them, we see a silky glow called simple chatoyance.

Tiger's eye is the most common gemstone that shows simple chatoyance phenomenon. Most pieces are a yellow to light brown color, but enhancements can create reds or other colors, and a naturally occurring variant called "hawk's eye" has a grey-blue to greenish color.

Less familiar to many, but greatly admired for their displays of chatoyance are the purple Charoites and the silvery grey serefinites.

Corundum often contains rutile needles but frequently they are not abundant or organized enough to produce a star gemstone, and instead show up as a general silky glow, as seen in the ruby and sapphire carvings below.

Fig. 3.24 Photographs showing gemstone showing simple chatoyancy in tiger's eye, Charoite, serefinite, ruby in zoisite and sapphire.

The cat's eye effect: When the reflective fibers that create chatoyancy are aligned within a single crystal axis, *and* when the gem is properly oriented and cut as a domed cabochon, the reflections concentrate into a single band of light on the dome known as an "eye".

Viewing this phenomenon is easiest with a single overhead source of light like sunlight, or a spotlight or penlight, and less successful with multiple light sources, or in dimly lit surroundings.

Fig. 3.25 Photograph showing a close up of the parallel growth tubes in a rubellite tourmaline and the effect seen in that gem when it is viewed with proper lighting.

Cat'seye gems have been popular throughout history, especially in the Orient. Cat'seye chrysoberyl is the most valued of all, and it has traditionally been given the honor of simply being called "cat'seye", whereas all other types called with their host mineral like cat'seye tourmaline, cat'seye moonstone, etc.

Fig. 3.26 Photograph showing Cat’s eye effect in Cat’seye tourmaline and cat’seye moonstone.

Asterism: This phenomenon is essentially a special case of the cat'seye effect, where the inclusions responsible for reflections are oriented parallel to more than one axis in the crystal. As with cat'seyes, the stone must be both properly oriented, and cut in a high dome to display the star.

Fig. 3.27Photograph showing Asterism effect in Star stones like ruby, sapphire, white sapphire, rose quartz, (6 rayed), oonstone (4 rayed)]

Depending on the nature of the inclusions and the crystal system of the host, a four or six rayed star will generally be displayed. By far, the most common star stone species is corundum, with quartz a distant second. Star effects are relatively rare in other species.

Fig. 3.28 Photograph showing Colour change effect in Alexandrite: incandescent (blue-violet), daylight (teal).

Color change: A color change gem is one whose color is substantially different when viewed with an incandescent light source as compared to its color as seen under daylight or a daylight equivalent fluorescent source. Due to this phenomenon's strong association with the Alexandrite variety of chrysoberyl, it is sometimes termed the "Alexandrite effect", regardless of which species is displaying it. Simulant color change stones have been made which create the effect very strongly. In addition to Alexandrite chrysoberyl, other species which are occasionally found in color change forms are: sapphire, spinel, garnet, tourmaline and diaspore.