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GNEISS TIMES

Wickenburg Gem & Mineral Society, Inc.
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The purpose of this organization shall be to educate and to provide fellowship for people interested in rocks and minerals; to foster love and appreciation of minerals, rocks, gems, and the Earth. Membership shall be open to all interested people.

CAUSES OF COLOR IN MINERALS

Color is probably the first thing we notice when we see a mineral specimen. But what causes those colors and their variations? We often simply say that the presence of a particular element (either integral to the mineral's composition, or as in impurity) imparts a particular color. And basically that is true, however……...

In fact, Beryl, Quartz, and Tourmaline are examples of minerals that would be clear, if not for impurities.

But technically, color is caused by the absorption of wavelengths of visible light*****, so that the light reflected back to our eyes is deficient in the wavelength absorbed. There are five main categories under which this occurs: metal ions in the chemical formula or as impurity, intervalence charge transfer, radiation, band gaps, and physical effects (diffraction, dispersion, interference, scattering). Additionally, heat could be entered as another catalyst of color change -- in association with other processes. And of course, often it is a combination of these processes that determines the color and/or depth of color. Plus the light source is a factor, as it determines what wavelengths of light are available. I'm afraid nothing is ever simple!

A mineral's color is dependent on

- Interaction of light with atoms
- Wavelengths of light available
- Composition of the mineral
- Bonding strengths within the mineral
- Integrity of the crystal lattice

** Visible white light is composed of many wavelengths of light within the visible spectrum -- red, orange, yellow, green, blue, violet (ROYGBV). And each wavelength represents a different energy level.*

Color continued on page 3…..

Congratulations to Everett Solper

Recipient of the 2017 Wickenburg Scholarship Award

A graduate of Wickenburg High School, Everett is attending Estrella Community College, and will transfer to ASU in the future.

ELECTIONS COMING -- DUTIES OF CLUB OFFICERS

The club will be holding election of officers in December. The nominating committee will be preparing a ballot of nominees. Several of these positions are open. Anyone willing to fill an opening please contact Craig or Debbie. The vitality of our club is dependent on the participation of the members! The club was founded in the early 1970's and the current membership is 127. Please consider lending your talents.

This article is from the Wickenburg Gem and Mineral Society bylaws:

ARTICLE VII

DUTIES

Section 1: The President shall preside at all business meetings of the group.

Section 2: The Vice President shall assume the duties of the president when the president is absent.

Duties continued on page 2….

INSIDE THIS ISSUE

potluck: a communal meal to which people bring food to share

Merriam-Webster Dictionary

See you at 6:00 pm on November 10th to share a meal with your fellow members, before the meeting!

BREAK OUT THE HOLIDAY DUDS
and save the date

friday, december 1

6:00 pm

Potluck and White Elephant Gift Exchange

REMEMBER:

WGMS ROCK & MINERAL SHOW

Nov 25 & 26, 2017

Sat 9-5; Sun 9-4

Hassayampa Elementary School

This is our club's show, and it is important that we all participate as much as we can. **Please consider VOLUNTEERING!**

- Donate items for door prizes
- Donate items or the silent auction
- Help set up on Friday, and take down on Sunday
- Lend some time to the Kid's Table & Fluorescent Room
- Enter the Best Rock Contest
- Attend the show and support the vendors
- Buy a nugget raffle ticket (or a whole string of tickets!) See Karen Coulter at the next meeting or buy at the show.

Meeting Minutes — October 13, 2017

The meeting was called to order by Debbie Keiser with 31 people in attendance. The pledge of allegiance was said. After a pot-luck dinner Stan C presented a program on the August 21, 2017 Total Eclipse.

The minutes for the May meeting were not available. The treasurer report was approved as presented by Debbie. Guests and new members were introduced.

Unfinished Business: Everett Solper was the 2017 scholarship recipient. $3,000 was deposited into his student account at the Estrella Mountain Community College.

New Business: Craig has announced he will not be running for president of the club next year. The secretary position is also open, Judi Z will not be returning to AZ for the winter. With elections coming up in December Stan requested a description of responsibilities of each office be presented in the newsletter. Debbie will review the club by-laws and put together a summary of officers duties.

There is also a need for committee chairs. Karen C volunteered to greet people and hand out door prize tickets, along with Roxy and Don U who will be making the coffee and setting up the potluck dinners at each meeting.

Steve H will be inquiring about Helicopter rescue insurance for club outings.

Craig will be taking a group out for Thanksgiving Day in the desert. Details next month.

Club Show Saturday November 25th 9AM-5PM and Sunday the 26th 10AM-4PM: Signup sheets available for the 4 show cases, and to help with Kid's table, silent auction, best rock contest, raffle ticket sale, door prize ticket and UV light display. Thanks to Robbie and Ken for donating their nugget. We will have 2 gold nuggets for this year's raffle. Bill and Karen will be selling tickets. Also thanks to George and Margaret D for donating a beautiful silver pendent for the show raffle. Rocks will be needed for the Silent auction, along with prizes to give away in the hourly door prize drawings. Enter your best rock you ever found in the 4th annual Best Rock Contest.

Continued….

Show and tell prize was won by George S and the first door prize winner was Erma R.

Next meeting will be Nov. 10 with a potluck dinner starting at 6PM.

Respectively submitted,
Debbie Keiser

...Duties continued from page 1

Section 10: The Publicity Chair shall use all means available to publicize the Clubs activities and help promote the WOWW show.

Section 11: The Editor shall publish and distribute monthly newsletters for the meeting months and is also responsible for the housing and upkeep of the photocopy machine and computer.

Section 12: The Scholarship Chair shall coordinate necessary actions such as preparing, updating and distributing scholarship applications, evaluating applicants and presenting the committee's recommendations to the membership for approval.

Duties continued on page 4….

This is probably a Beech leaf (Fagus sp.). Sue & Stan collected it at the Fossil Bowl, in the mid-Miocene lake sediments, near Clarkia, ID. 15-15.5 million years ago, flows of the Columbia Plateau basalts dammed a river, forming a lake, up to 500 feet deep. In the cold, low-oxygen water delicate biota was superbly preserved.

Photos by Sue Celestian

….Color continued from page 1….

METAL IONS

One can visualize atoms as a nucleus, surrounded by roughly concentric energy shells or orbits, and sub-shells/orbits (Figure 1). (This is a very simplified conceptualization, as in actuality electrons move in spherical, dumbbell, and cloverleaf pathways around the nucleus). It is within these orbits that electrons will stay, unless they absorb discreet packages of energy. And the amount of energy it takes to dislodge an electron varies, depending on the bonding type and pull of the nucleus.)

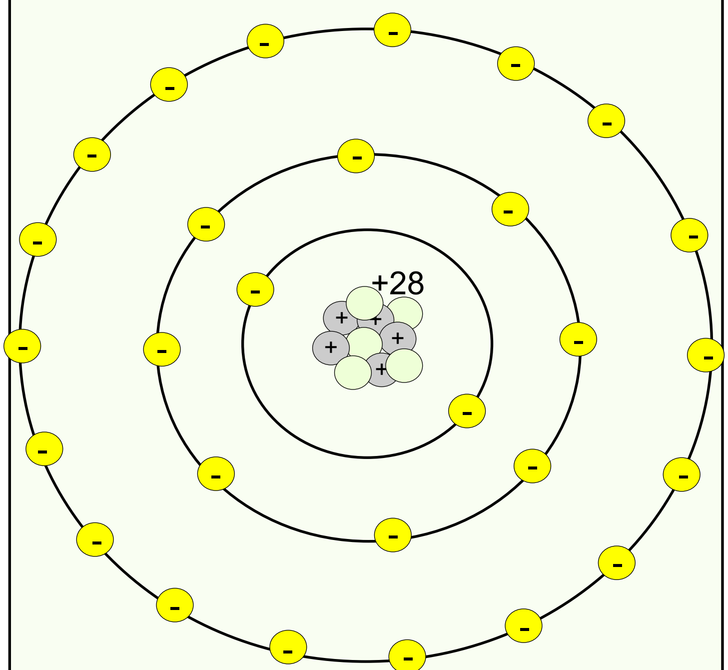


FIGURE 1 Idealized Schematic of an Atom The atom is composed of a positively-charged nucleus, surrounded by orbits of negatively-charged electrons. In this diagram, the green balls are neutrons (no charge), the blue balls are protons (positive charge), and the yellow balls are electrons (negative charge). Note that the negative and positive charges balance each other out, so that the atom has no net charge. *Diagram by Susan Celestian*

Color continued on page 5….

...Duties continued from page 2

Section 3: The Secretary shall keep a record of the business conducted at each meeting. These records shall be available for inspection by any member at any reasonable time. The Secretary shall also attend to all correspondence with the help of the President and keep the Bylaws up to date.

Section 4: The Treasurer shall receive all dues and funds and issue receipts for same, shall pay bills as authorized, give a financial report at each meeting and assist in development of the annual budget.

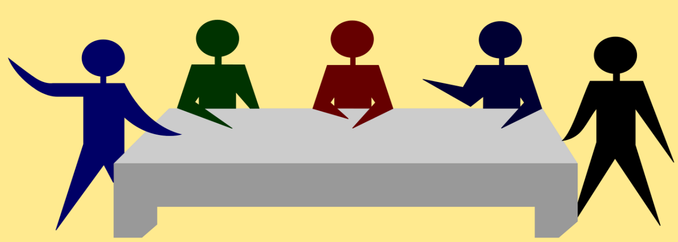
Section 5: The Program Chair shall conduct the program part of each meeting and shall arrange for speakers and educational programs as directed by members.

Section 6: The Field Trip Chair shall arrange and conduct tours for field material after ascertaining the members' choice of material and location.

Section 7: The Refreshment Chair shall have charge of refreshments served at meetings and shall purchase supplies as needed. All bills for same shall be turned over to the treasurer for payment on approval of members present.

Section 8: The Show Chair shall be responsible for the WOWW Wickenburg Gem and Arts Fair and with the assistance of the Co-Chairman shall make all the necessary arrangements regarding dealers, show cases, duty rosters, funds, set-up and dismantling and such other functions as required.

Section 9: The Membership Chair shall keep the membership list, encourage membership, greet and sign up persons attending each meeting, conduct the door prize drawing at each meeting, and contact or send cards to members who are ill and absent from meetings.



….Color continued from page 4

Metal Ions continued:

The positively-charged nucleus is composed of protons (+ charge) and neutrons (no charge). This is balanced by electrons (- charge). The ideal atom is neutral, with a balance of positive and negative charges. Electrons -- typically in pairs -- orbit the nucleus in these shells or orbits. Those in outer orbital, are far enough from the influence of the nucleus that they are vulnerable to interaction with visible light, and lone, unpaired electrons are wont to absorb energy, in search of a pairing. When light strikes some minerals, electrons in the outer orbits of metals (usually one of the transition metals -- Sc through Zn, in the first row of the periodic table, plus a few others such as uranium) may absorb some energy, and be kicked into higher energy levels. The wavelength that effected that change is subtracted from those of visible light, and the result is a particular color.

- For example, the presence of copper, intrinsic to the chemical compositions of azurite and malachite, results in the characteristic blue color of Azurite and the green of Malachite. Figure 2.
- Cavansite's color is due to VO^{2+} (vanadium oxide molecule). Figure 3.
- The atomic structure of minerals will help to determine what color is produced by a given ion, since the structure and bonding strengths will effect the energy needed to excite the electrons. Take Cr^{3+}, for example. It is the color-causing impurity in Ruby, Emerald, and Alexandrite. Wow! Those are 3 minerals with wildly different colors. However, the red of Ruby, green of Emerald, and purplish-red of Alexandrite are all the result of chromium ions as impurities, included in the mineral structure. Figure 4.

Color continued on page 6….

FIGURE 2 Azurite and Malachite
Both copper carbonates, azurite and malachite have copper ions to thank for their very characteristics colors. *Photos by Stan Celestian*

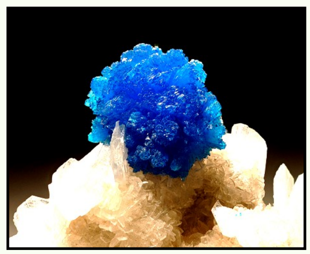
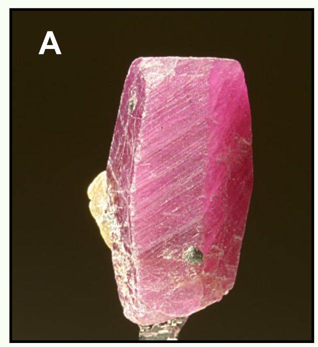
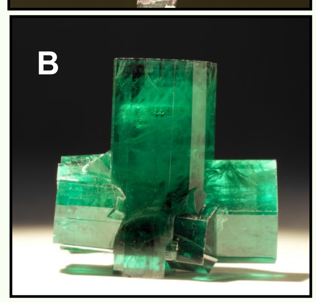


FIGURE 3 Cavansite
Wagholi Quarry, Wagholi, Pune District, Maharashtra, India *Photo by Stan Celestian*





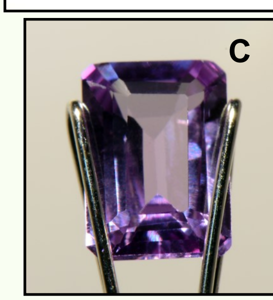


FIGURE 4 Ruby, Emerald and Alexandrite

Impurities of chromium ions (Cr^{3+}) are responsible for the red of Ruby (A), the green of Emerald (B), and the purplish-red of Alexandrite (C).

Different colors are caused by the same ion, because the atomic structures of the three minerals hold onto their electrons with varying strengths. Consequently, it takes different levels of energy to excite electrons in the outer orbits of the atoms.

Photos by Stan Celestian

….Color continued from page 5

Metal Ions continued:

- Other examples of a given ion producing different colors (Figure 5):

  Mn^{3+} red Beryl, green Andalusite, violet Tremolite, pink-red Tourmaline, Purpurite

  Mn^{2+} pink Rhodonite, red Rhodochrosite, yellow-green Willemite

  Fe^{2+} raspberry red Eudialyte, red Pyrope garnet, yellow-green Forsterite (olivine), bluish-green Phosphophyllite, blue Elbaite (tourmaline)

  Fe^{3+} pale purple Strengite & Coquimbite, yellow-green Andradite (garnet), yellow Plagioclase, bright orange Diopside

  Co^{2+} red Cobaltian Calcite, blue Spinel

  Cu^{2+} Paraiba Elbaite (tourmaline)

  Cr^{3+} & V^{3+} green Tourmaline

  Fe, Mn, Ti black Tourmaline

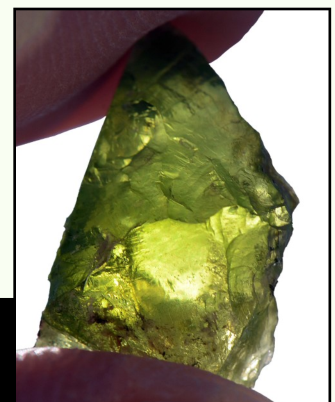
Purpurite Sandamap Farm, Kariib District, Erongo Massif, Namibia

Andradite (garnet), Stanley Butte, San Carlos Reservation, Graham Co., AZ

Elbaite, Pederneira Mine, Minas Gerais, Brazil

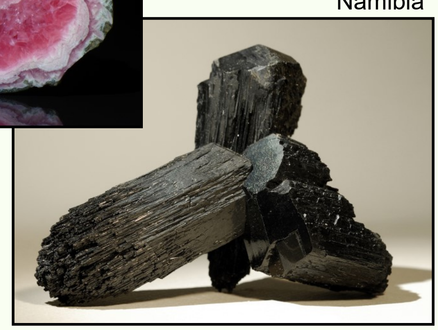
FIGURE 5 Minerals Determined by Metal Ions All the minerals on this page are colored by an impurity or integral atom of a transition metal ion. *Images by Stan Celestian*

Forsterite (olivine), San Carlos, Graham Co., AZ



Rhodochrosite, Capilitas Mine, Argentina

Schorl, Omaruru District, Erongo Massif, Namibia



Color continued on page 7….

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Metal Ions continued:

♦ Pleochroism is the property of some minerals to exhibit different colors. This can happen for a couple of reasons.

(A) One depends on in what direction one views the mineral. In other words, the atomic structure of these minerals exerts a strong influence on the absorption of light.

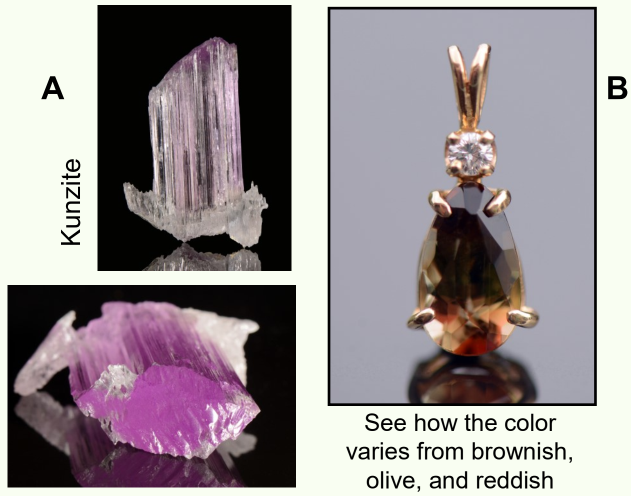
(B) The other depends on the wavelengths available from the light source. For example, the source is deficient in red, then blues will dominate; if it is deficient in blue, then reds will dominate. Typically it is sunlight, candlelight, and fluorescent lights that induce these variations.

Some examples of pleochroism due to atomic structure control are:

- Andalusite: green brown/dark red/purple (Figure 6)
- Beryl (Emerald): green/blue-green
- Corundum: purple/orange; yellow-brown/orange; yellow/pale yellow
- Hypersthene: purple/orange
- Spodumene (Kunzite): purple/clear/pink
- Tourmaline: pale purple/purple; light blue/dark blue; blue-green/brown-green/yellow-green; pale yellow/dark yellow; light red/dark red

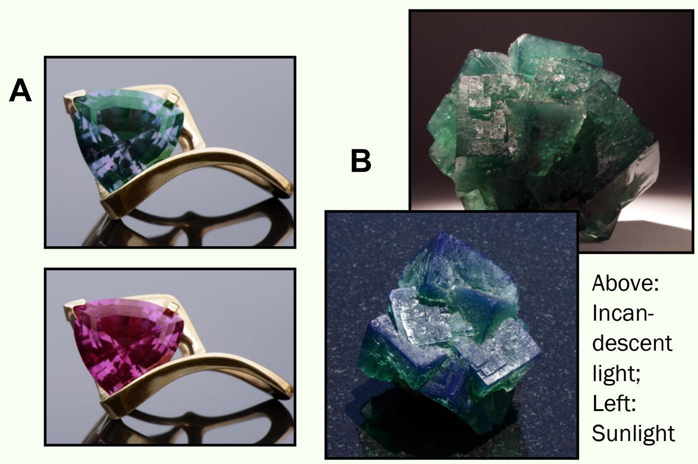
Some examples of pleochroism -- often called 'color change' to distinguish it from the structure-controlled displays listed above -- due to light source variation are:

- Chrysoberyl (Alexandrite): dark red/orange/green (Figure 7)
- Zoisite (Tanzanite): blue/purple/red
- Some Garnets: most exhibit some variation of green to some variation of red
- Diaspore (Zultanite): khaki green/sage green/pink to raspberry/champagne/canary yellow//ginger
- A rare Sapphire: blue/purple or green/pink or reddish-violet
- Fluorite, especially that from the Rogerly Mine, in England (Figure 7)



See how the color varies from brownish, olive, and reddish

FIGURE 6 Pleochroism Due to Atomic Structure Control When viewed along different directions within the atomic structure, both Kunzite (A) and Andalusite (B) appear in different colors, or intensities of color.
Photos by Stan Celestian



Above: Incandescent light; Left: Sunlight

FIGURE 7 Pleochroism Due to Light Source Variation ***A*** Alexandrite appears green in daylight, because in the presence of the full light spectrum, the human eye is most sensitive to green; while in incandescent light (which is deficient in green and blue) it appears reddish/purplish. **B** Fluorite from the Rogerley Mine in England, actually fluoresces in Sunlight.
Photos by Stan Celestian

Color continued on page 8….

….Color continued from page 7

INTERVALENCE CHARGE TRANSFER

Ions are atoms with a charge. In other words, there are either more protons than electrons (and the atom is positively-charged), or more electrons than protons (and it is negatively-charged). For example, common ions of iron are Fe^{2+} and Fe^{3+}. Another common element ion pair is titanium -- Ti^{3+} and Ti^{4+} Of course, there are many other ions that participate in this transfer.

Intervalence charge transfer (IVCT) occurs when an electron transfers between adjacent metal ions with different charges, or as described below -- between metal and non-metal ions. In the case of Fe^{2+} and Fe^{3+}, when an electron transfer occurs the Fe^{2+} becomes Fe^{3+}, and the Fe^{3+} becomes Fe^{2+} (Figure 8). This usually results from the absorption of red wavelengths of light, so the mineral is typically blue or green.

- In both Kyanite and blue Sapphire, Fe^{2+}-Fe^{3+} and Fe^{2+}- Ti^{4+} IVCT come into play, to create the blue colors. (Figure 9)
- In the case of Lazurite, it is IVCT between a triad of sulfur ions that cause its bright blue color. (Figure 9)
- Some of the many colors of tourmaline can be accounted for by IVCT Interactions (sometimes activated by radiation, and often in combination with metal ions as impurities):

Fe^{2+}- Fe^{3+}	Black
Fe^{2+}-Ti^{4+}	Amber to orange-brown, green
Mn^{2+}-Ti^{4+}	Yellow to yellow-brown

Fe^{2+} (position A) - Fe^{3+} (position B) **Absorption of Red Wavelengths** → **Fe^{3+} (position A) - Fe^{2+} (position B)**

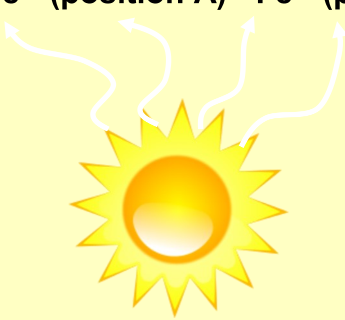


FIGURE 8 Fe^{+2}- Fe^{+3} Intervalence Charge Transfer The absorption of energy, from the red portion of the light spectrum, causes an electron to jump from Fe^{3+} to Fe^{2+}. As the original Fe^{2+} loses an electron, it is altered to Fe^{3+}, and as the original Fe^{3+} gains an electron it becomes Fe^{2+}. (Positions A and B do not denote any particular site, they are just hypothetical sites, where the respective ions reside in the atomic lattice, of a given mineral.) That absorption of red light, causes the mineral to show in the blue part of the spectrum.
Diagram by Susan Celestian

- An example of Fe^{2+}- Fe^{3+} IVCT can be found in Vivianite. It is naturally pale green, turning blue as IVCT occurs. (Figure 9)
- With Beryl, the result is aquamarine. (Figure 9)
- In Jade, the Fe^{2+}- Fe^{3+} IVCT may account for lavender color.

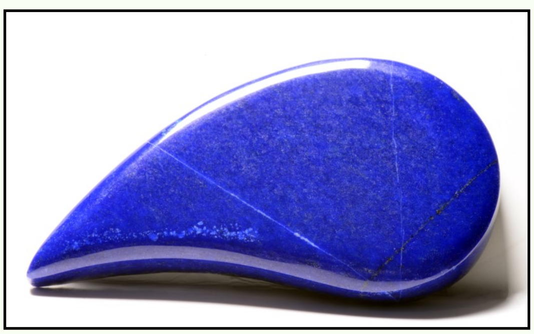
See Figure 9 for images of minerals whose color depends in Intervalence Charge Transfer.

Color continued on page 9….

….Color continued from page 8

FIGURE 9 Minerals Whose Color is the Result of Intervalance Charge Transfer All the pictures on this page have been colored as a result of IVCT.
Photos by Stan Celestian

Kyanite, Barra do Salinas, Minas Gerais, Brazil



Lazurite $(Na,Ca)_8[S,Cl,SO_4,OH)_2]$ is a vibrant blue.

Blue Sapphire
(a variety of Corundum)

Vivianite, Bolivia This specimen was a translucent bluish green 25 years ago, when Stan & Sue first bought it. Exposure to light has caused it to darken over the years.

Beryl variety Aquamarine, Kala, Darrah Pech, Kunar Province, Afghanistan

Color continued on page 10….

….Color continued from page 9

IONIZING RADIATION

Natural or artificial radiation can effect changes to minerals, that influence the color. The results vary -- color centers, intervalence charge transfers, molecular aggregates, and unknown (or in combination with some atomic substitutions).

Unknown: amber Calcite, blue Calcite, golden Beryl, lemon yellow quartz, pink quartz (not rose quartz)

Color Centers or F-Centers: Radiation (usually gamma rays) may damage the crystal lattice, and electrons may be dislodged from their normal positions. These unattached electrons may wander a bit and then settle into a space (trap) within the crystal lattice. And these electrons may absorb various wavelengths of light, changing the color of the mineral.

Heat or ultraviolet radiation may introduce enough energy to free the electrons from their traps, and the color will fade or return to its pre-radiation color.

- *Examples*: purple Fluorite, blue Fluorite, smoky Quartz, some amethyst quartz, green Kunzite, some brown topaz, laboratory-irradiated blue topaz (most blue topaz on the market), pink tourmaline Figures 10-14.
- Natural or laboratory-irradiated diamond (green) actually have color centers that are not occupied by an electron. The radiation has dislodged Carbon atoms from their original positions. These "holes" tend to absorb light in the red-orange range of the color spectrum.

***FIGURE 10 Green* Kunzite** *Photo by Stan Celestian*

FIGURE 11 Fluorite and Color Centers
The two blue specimens are from the Blanchard Mine, Socorro Co., NM, and the purple one is from Rosiclare, IL
Photos by Stan Celestian

FIGURE 12 Quartz Made Smoky by Irradiation
Radioactive minerals within alpine granites produced the energy to disrupt the atomic structure of these quartz crystals, and cause color center-induced darkening.
Photo by Stan Celestian

FIGURE 13 Topaz This sherry-colored topaz from Topaz Mt., UT has been exposed to natural radiation. Exposure to the Sun causes the damaged atomic lattice to "heal", and the color fades to clear, as seen in the topaz sand grain from a wash on the mountain. *Photos by Stan Celestian*

FIGURE 14 Blue Topaz For over 3 decades, nearly all commercial blue topaz has been irradiated to either enhance the blue color, or to change colorless topaz to blue.
Photo by Stan Celestian

Color continued on page 11….

….Color continued from page 9

Ionizing Radiation continued:

***Intervalence Charge Transfer* (IVCT):** radiation (usually gamma rays) may supply the energy necessary to initiate an IVCT.

- This occurs when Fe^{4+} is created from Fe^{3+}, to produce Amethyst Quartz. In this case, ultraviolet (UV) light from sunlight supplies enough energy to reverse this process, and the purple color fades.
- Irradiation creates Fe^{3+} to produce golden Beryl. Heating golden Beryl will reduce Fe^{3+} to Fe^{2+}, and the result is blue Beryl. Figure 15.

FIGURE 15 Golden Beryl aka Heliodor Natural radiation induces the IVCT creation of Fe^{3+}, causing a golden yellow color. *Photo by Stan Celestian and used courtesy of the Natural History Museum of Los Angeles*

NHMLA 24210

Molecular Aggregate (this is a bit of a permutation on Color Centers): Example: In the case of blue Halite, color centers produced by radiation turn the salt to an amber color. Given time, the electrons trapped in color centers may migrate and join with sodium ions (Na^+), to produce metallic sodium (Na). Those metal atoms will migrate and aggregate into colloidal-sized (very very small - .000000001 to .0000001 meter) particles --- and these cause the blue color. Figure 16.

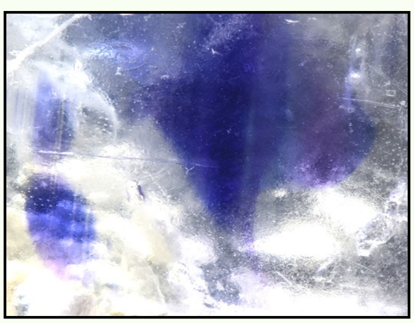


FIGURE 16 Blue Halite This blotch of inky coloration is stable -- does not seem to fade. *Photo by Stan Celestian*

http://minerals.gps.caltech.du/color_causes/Radiate/index.html

HEAT

Heat, either natural or laboratory facilitated, can contribute to color in some minerals. In fact, heat treatment (and irradiation, for that matter) are so common, that it is the norm in the realm of faceted gemstones.

The physics that causes color change is generally related to a) releasing color center electrons from their traps, or to re-arrangement of the atomic structure, thus removing "holes" in the atomic lattice; b) facilitating Intervalence Charge Transfers; c) the rise in temperature facilitating the mobility of atoms, and the subsequent "healing" of lattice defects (such as those created by irradiation). Some examples follow:

- Smoky Quartz can be lightened or turned clear. This probably is accomplished by releasing color center electrons from their traps.
- Amethyst Quartz can be lightened, or turned to Citrine (yellow, orange, orange-brown). In fact, Ametrine (part amethyst and part citrine) is created by heat treatment. This may be related to and IVCT interaction that converts Fe^{3+} to Fe^{2+}. Heating some amethyst to about 500° C, turns it green (a variety called Prasiolite) Figures 26 and 17.

FIGURE 17 Prasiolite Created by Heating Amethyst. *Photo by Stan Celestian*

- Spodumene (Kunzite) is often treated to cause the color to darken or become more intense.
- Beryl (Morganite) is heated to change the color from orange-ish to pink-ish.
- Beryl (Aquamarine) is heated to remove green hues, and create a more

Color continued on page 11….

….Color continued from page 11

Heat continued:

- Corundum's (Ruby) red color deepens, and inclusions and cracks are 'healed'.
- Corundum (Sapphire) is very commonly heated to improve the intensity and uniformity of the color.
- Zoisite (Tanzanite) is often a not-so-attractive purplish-gray or reddish-brown. heat treatment brings out the more desirable vivid violet-blue.
- Green and blue varieties of Tourmaline are color-enhanced by heating.
- Coupled with irradiation, heat can produce blue or pink colors in Topaz.
- Black Diamonds are rare, so most on the market are low quality diamonds that have been heated.

BAND GAPS

Very simply put, in minerals that are conductors (metals), semi-conductors (sulfides -- such as galena and pyrite, oxides, sulfosalts), and semi-conductors with impurities, the electrons in the outer shells (or bands) are shared by the whole mineral, rather than being bound to individual atoms or molecules -- they can be very mobile (hence the ability to conduct electricity, deform rather than break when impacted, and conduct heat). Inputs of various levels of energy can cause electrons to jump from their normal (or valence) band, into a higher energy band (conductive band), where they are quite mobile and able to move fairly freely. The energy difference between these two bands is the "band gap", and that gap determines the amount of energy necessary (light frequencies absorbed) to effect the jump of electrons to the higher state. Figure 18, page 14.

- For example, if the frequency absorbed is in the blue range of the color spectrum, the mineral will appear red to yellow, as in realgar, orpiment, cinnabar, sulfur, cuprite, and sphalerite. Figure 19, page 14.
- Metals have characteristic opaque gold, silver, copper metallic lusters because these band gap electrons absorb light energy, but then re-emit some of it, as they fall back to lower energy bands. How much is re-emitted determines the color of the metal. When the amount of energy re-emitted equals the amount absorbed, the color is silver; when the amount re-emitted is less than that absorbed, other colors are created. Figure 20.

FIGURE 20 Native Copper & Native Silver
Copper and Silver owe their distinctive colors to the energy band-hopping of freely moving electrons. This is a "half-breed" specimen from Michigan.

- And in diamonds (which are semi-conductors), a Nitrogen impurity produces a yellow color, while boron produces blue.

PHYSICAL OPTICS

Interference Iridescence in hematite, bornite, and chalcopyrite is caused by light passing through layers of oxidation, that are different thicknesses -- but all very, very thin. As light reflects off the oxidation layers, and the surface between the mineral and the tarnish, it is reflected back at different speeds, depending on the thicknesses of the layers. As the various reflected light rays interact with each other, they may be "in phase" with each other and reinforce the wavelength, or they may be "out of phase" and cancel each other out -- thereby causing a rainbow of colors to be displayed. This is also what causes an oil slick to display varying bands of color. See Figures 21-22.

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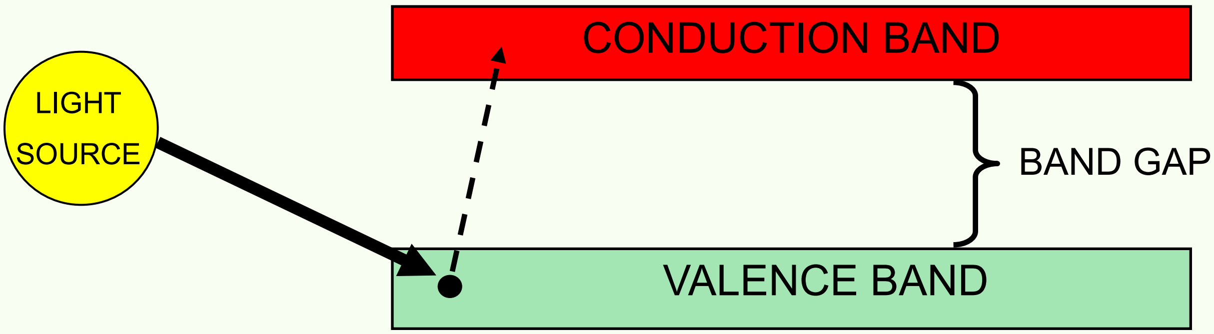

FIGURE 18 Band Gap In semi-conducting metals (and metals), there is a partially-occupied band of electrons that are not tied to any specific atoms. This is the Conduction Band. With the absorption of light energy, electrons, in outer shells of atoms in the Valence Band, may jump into the conduction band. The energy necessary for that jump is called the Band Gap. And a mineral's color will be depleted in the wavelengths absorbed. *Diagram by Susan Celestian*

FIGURE 19 Minerals Colored by Band Gaps

These five minerals all owe their red to yellow colors to absorption of wavelengths in the blue end of the color spectrum. A - Realgar (red) and Orpiment (yellow), Getchell Mine, Humboldt Co., NV; B - Sulfur crystals at a fumerole in Bumpas Hell, Lassen NP, CA; C - Sphalerite, Silver Bell Mine, Pima Co., AZ; D - Cinnabar, Wanshan Mine, Guizhou Province, China; E - Cuprite (var. chalcotrichite), Ray Mine, Pinal Co., AZ.

Photos B-E by Stan Celestian, photo A with permission of Tom Loomis, Dakota Matrix Minerals dakotamatrix.com

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Physical Optics continued:

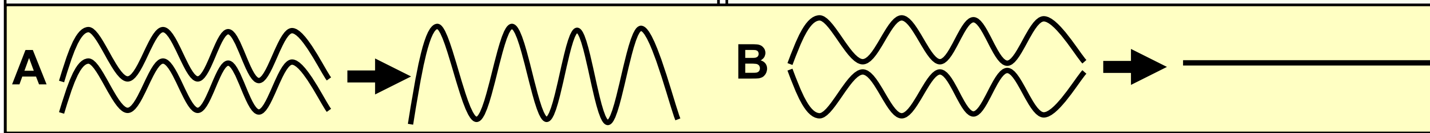

FIGURE 21 Interference of Light Waves In "A" above, two light waves are "in phase" with each other and effect constructive interference, reinforcing the wavelength in question. In "B" the two light waves are "out of phase" and effect destructive interference, cancelling out the energy. The amount that waves are "out of phase" determines what wavelengths will be cancelled by interference.

FIGURE 22 Iridescence of Films & Tarnishes A thin, but irregular, film of Turgite (maybe a combo of Goethite and Hematite) on Hematite (upper photo) is colorful, because as light travels through layers of varying thicknesses, it is slowed at different rates, and bent, and as the rays emerge, they interfere constructively -- destructively, creating a rainbow of colors. The same process occurs with the tarnish on chalcopyrite (lower photo).

Photos by Stan Celestian and Turgite used by courtesy of the Natural History Museum of Los Angeles NHMLA 40827

Diffraction & Interference Diffraction occurs when light encounters an obstacle or opening. The light wave bends around the obstacle, or bends and emerges from the opening at a different angle, than it entered the opening. In the case of minerals, this phenomenon is often also influenced by interference.

- **Opal**: Opal is composed of tiny spheres of silica. When these spheres are uniform in size and regularly arranged, light is diffracted as it passes through, light waves interfere with each other, and the characteristic "fire" flashes before our eyes. See Figure 20. The color of the "fire" is determined by the size of the spheres, and of the spaces between them. Small spheres (< 150 nanometers) typically produce blue and violet; while larger spheres (150-350 nanometers) produce red and orange. Figures 23-24.

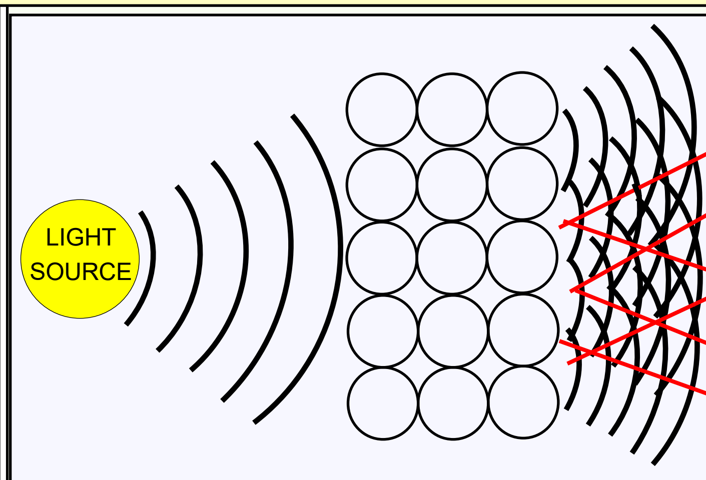

FIGURE 23 Diffraction in Opal Opal's stack of spheres acts as a diffraction grating. As white light bends around the spheres making up opal, it exits the opal headed in different directions. As the exiting light waves overlap each other, both constructive and destructive interference occurs, resulting in the "fire" characteristic of Fire Opal. As one rotates an opal specimen in the light, and one observes light interacting with the spheres from different angles, the colors change.

The red lines represent areas of interference (they do NOT represent the color red). *Diagram by Susan Celestian*

FIGURE 24 Fire Opal From Australia Opal's gauntlet of spheres, causes diffraction of light. Interference of light waves creates "fire". The colors change like the Aurora, as a specimen is rotated,and exposes a different angle of the stack of spheres.
Photo by Stan Celestian

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Physical Optics continued:

- **Labradorite**:Labradorite $(Ca,Na)(Al,Si)_4)O_8$, is an intermediate member of the plagioclase series, within the feldspar group. When conditions are just right, the mineral is formed by often parallel lamellae (thin layers) of calcium-rich and sodium-rich varieties of plagioclase. Separations between the lamellae act as a diffraction grating, thus causing the play-of-colors, or *labradorescence*, so desired by lapidarists. Figure 25.

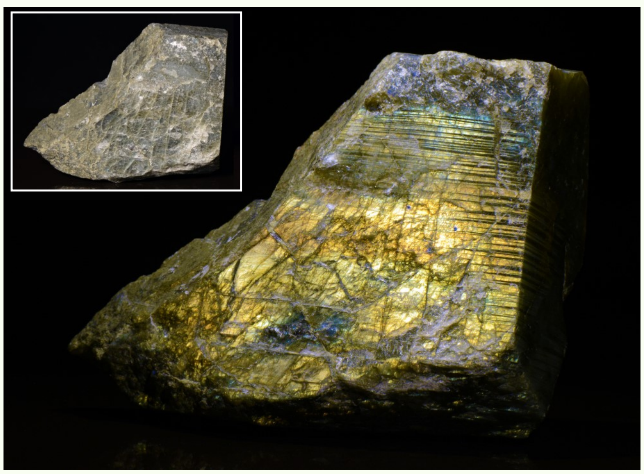

FIGURE 25 Labrodorite Some Labradorite (and some Bytownite $(Ca,Na)[Al(Al,Si)Si_2O_8]$) display a play-of-colors, caused by diffraction off of internal lamellae. In this image, you can see the parallel striations, caused by polysynthetic twinning, characteristic of the plagioclase feldspars. Inset: specimen at a different angle. *Photo by Stan Celestian*

Dispersion Dispersion is the process whereby white light is split up into its component wavelengths, i.e. colors. (This is the process by which rainbows are generated.) As light approaches a different medium, at an angle, the light wave bends, or is refracted. For example, as a light wave encroaches upon a prism, the part of the wave that first encounters the prism, slows down. The rest of the wave proceeds at original speed. However, as each portion of the wave encounters the prism, refraction proceeds. The component wavelengths, are refracted at different angles; and thus the colors separate out. The waves refract again as they leave the prism and re-enter the air (See Figure 26).

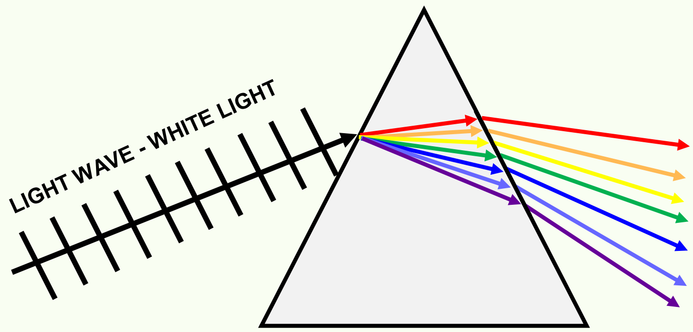

FIGURE 26 Refraction and Dispersion of Light in a Prism As light waves slow upon entering a denser or less dense medium, the light wave bends or refracts. Each component wavelength (color) refracts at a different angle, thereby splitting out into a rainbow of colors. *Diagram by Susan Celestian*

- The faceting of gemstones results in the refraction and reflection of light, giving the stones their sparkle or 'fire'. (Facets cause light waves to be reflected back and forth inside the stone, to enhance the color separation). This is especially attractive in Diamonds. Figure 27.

FIGURE 27 Gemstones Sparkle This faceted Citrine and Peridot sparkle with an array of colors as light rays penetrate faceted surfaces, refract, and break up into the colors of the rainbow. *Photos by Stan Celestian*

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Scattering Scattering is the deflection of light from a straight path. This deflection occurs when the light wave encounters obstacles. If all wavelengths are scattered equally, the mineral appears white. Often the shorter wavelengths are selectively scattered, and a bluish tint will display.

- **Moonstone** - an intermediate variety of feldspar, called Adularia, that is composed of a mixture of Albite and Orthoclase. These 2 minerals are intergrown as alternating layers. As light encounters the interfaces between the different layers, it is bent and scattered in many directions. The effect is to produce a diffuse, glowing appearance called *adularescence*. It is often white or bluish. Figure 28.

FIGURE 28
Moonstone
Scattering of light waves gives Moonstone (either Adularia, an orthoclase feldspar; or Oligoclase, a plagioclase feldspar) its cloudy white to blue sheen. *Photo by Stan Celestian*

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SCENES of SUMMER 2017

Angular Unconformity in Salina Canyon, near Salina, Sevier Co., UT The vertical red beds are the Mid-Jurassic Twist Gulch Formation; and the horizontal white rocks are the mid-Paleocene Flagstaff Formation. At that contact, about 100 million years of rock record are missing. Continuing up the slope are the Colton and Green River Formations (Upper Paleocene-Eocene). *Photo by Susan Celestian*

Mormon Cricket (Anabrus simplex) This creature visited us before the Great American Eclipse. *Photo by Susan Celestian*

UPCOMING AZ MINERAL SHOWS

November 3-5 - Black Canyon City, AZ High Desert Helpers Rock-a-Rama Gem and Mineral Show; High Desert Park, 19001 E Jacie Ln; Fri 9-4, Sat 9-5, Sun 9-4; Admission: free.

November 18-19 - Payson, AZ Payson Rimstones Rock Club, Inc.; Payson H.S./Longhorn Gym, west of Longhorn Rd., east of McLane; Sat 9-5, Sun 10-4; Admission: $2, children 12 and under free.

November 25-26 - Wickenburg, AZ Wickenburg Gem and Mineral Club; Wrangler Event Center, 251 S. Tegner St.; Sat 9-5, Sun 10-4; Admission: free.

January 5-7 - Mesa, AZ Flagg Mineral Foundation -- Flagg Gem & Mineral Show; Mesa Community College; 1833 W Southern Av; Fri-Sun 9-5; Admission: free.

January 12-14 - Globe, AZ Gila County Gem & Mineral Society; Gila County Fairgrounds; Hwy 60, 3 miles north of Globe; Fri-Sat 9-5, Sun 9-4; Admission: $3 indiv, $5 couple, students/children free.

January 19-February 11- Tucson, AZ There will be many separate shows throughout Tucson during this period. For a general schedule, go to: http://www.tucsongemshows.net/coming.html

February 8-11 - Tucson, AZ Tucson Gem and Mineral Society; Tucson Convention Center; 260 S Church Av; Thur-Sat 10-6, Sun 10-5; Admission: $13, children 14 and under free.

February 8-11 - Mesa, AZ Apache Jct Rock and Gem Club; Skyline High School, 845 S Crimson Rd.; Sat 9-5, Sun 10-4; Admission: $3 adults, $1 students, children 12 and under free.

March 24-25 - Anthem, AZ Daisy Mountain Rock and Mineral Club; Boulder Creek High School Gym, 40404 N Gavilan Peak Pkwy; Sat 9-5, Sun 10-4; Admission: $3 adults, $2 seniors and children, children 12 and under free.

If you are travelling, a good source of shows AND clubs is http://www.the-vug.com/vug/vugshows.html or http://www.rockngem.com/ShowDatesFiles/ShowDatesDisplayAll.php?ShowState=AZ For out-of-the-country shows: http://www.mindat.org/shows.php?current=1

UPCOMING WGMS FIELD TRIPS

WHEN: Monday, October 30, 2017
WHERE: Harquahala Ghost Mine & Mining District
WHAT: History, dioptase
MEET: Goodwill parking lot in Wickenburg at 8 am
BRING: water, lunch, shade, chair, hammer
ANY CAR CAN MAKE THIS TRIP

If you all have some place that you would like to go, let Craig J. 208-681-4770 or Mel C. 502-641-3118 know. This is your club. Let's go out and have some fun.

Officers and Chairperson

President: Craig Jones...................208-523-9355
Vice President: Mel Canter 502-641-3118
Secretary: Judy Zimmerlee.............. 517-652-1355
Treasurer: Debra Keiser................. 928-684-1013
Program Director: Dale Keiser........ 928-684-1013
Publicity: currently open position
Membership: Roma Hagan 602-469-7662
Editor: Susan Celestian 602-361-0739
Field Trip: Craig J, Bob B, Mel C
Show Chair: Beth Myerson.................480-540-2318
Scholarship Chair: Steve Hill......... 928-533-3825
Historian: Jeanine Brown................ 928-684-0489

Meetings are held the **2nd Friday most months** at **Coffinger Park banquet room.** Potluck dessert at 6:30 pm. Business meeting at 7:00 pm. **Exceptions: February and December** meetings are held on the **first Friday of the month.** We do not meet in the summer — **no meetings in June, July or August**.

Membership Dues: $15.00 Adults per Person
$ 5.00 Juniors and Students

Meeting Dates for 2017

Wickenburg: Jan 13, Feb 3, Mar 10, Apr 14, May 12, Sept 8, Oct 13, Nov 10, Dec 1

Stanton meets Thursday after the Wickenburg meetings. Jan 19, Feb 9, Mar 16, Apr 20, May 18, Sept 14, Oct 19,

http://www.wickenburggms.org/

If you ever have photos from a club field trip, send a couple to Dale, for posting on the website.

NOTES FROM THE EDITOR

Have a geological interest? Been somewhere interesting? Have pictures from a club trip? Collected some great material? Write a short story (pictures would be great). I'd like topic suggestions also.

I would love to have some pictures from field trips! Snap a couple and send them to me.

Deadline for the newsletter is the 27th of the month.

Mail or Email submissions to:
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