Chapter (1)

1.1. Introduction

Gemstones are those stones which have beauty based on their color, transparency, brilliance (degree to which light is scattered) and crystalline perfection (no minerals or other inclusions).

The color of gemstone is very important in trade. Color of gem is one among other factors that evaluate the gem. Irradiation induced color change in some stones are one of the recent applications of the reactor facilities. The reason behind the color change is complex. However, one major reason involves a color center formation. A color center involves one electron missing from a normally occupied position leading to a hole color center(1).

Topaz is an aluminum fluorisilicate and is next in hardness to carborundum and diamonds (two of the hardest natural minerals).It contains atoms of aluminum, silicon, fluorine, and oxygen. Until the 1950s, topaz was generally known as a yellow or golden gemstone. Since then, routine radiation and heat treatment of pale-colored topaz to turn it to blue has changed the modern public's perception of this gem. Topaz usually is colorless, pale blue or yellow -- although pink stones can be produced by heating the golden brown topaz from Ouro Preto, Brazil. Topaz can obtain its color from natural radiation during its formation.

The structure of Topaz is controlled by a chain like structure of connected irregular octahedrons. These octahedrons have aluminium in the middle surrounded by four oxygens. Above and below the aluminium are the hydroxide or fluoride ions. The chains of octahedrons are held together by individual silicate tetrahedrons but it is the octahedron chains that give topaz its crystalline shape(2). Topaz is the hardest silicate mineral (8) and one of the hardest minerals in nature. However it has a perfect cleavage which is perpendicular to the chains and is caused by planes that break the weaker Al-O, Al-OH and Al-F bonds. None of the stronger Si-O bonds cross these planes. Topaz crystals can reach incredible size of several hundred pounds. Topaz can make very attractive mineral specimens due to their high luster, nice colors and well formed and multifaceted crystals.

Color centers may be produced by an excess electron (unattached to any single atom) trapped at some structural defect (mission ion, interstitial impurity) or a "hole"(the absence of an electron). The trapped electrons can occupy a number of energy states, and transitions between these states produce results similar to the crystal field transitions caused by transition elements. Electron transitions from higher to lower energy states can also cause optical fluorescence. Color centers can be produced by natural ionizing radiation(3). Most common minerals have had a long history of exposure to ionizing radiation from natural sources in rocks. A variety of minerals can also be colored by artificial irradiation. These enter the commercial market in the form of colored gemstones. Naturally occurring green diamonds are colored by natural radiation. An often proposed model is that the radiation dislodges a carbon atom from the diamond structure and an electron takes its place.

Brown topaz is often a product of natural radiation(4). The color is unstable and fades in light in a matter of hours or days(5).

Topaz is found in most continents of the earth. The color varieties are; transparent colorless, red, pink, orange, brown, yellow, blue and green, with the cherry-red imperial and pink topaz from Brazil being the most valuable. The blue topaz colored by radiation from natural radioactive materials in the ground during millions of years is also found. Its natural blue color, in deposits found so far, is a pale light blue that is

not given much attention. The most common topaz is the colorless topaz, which is found in abundance and for that reason is worth very little.
During the last two decades the technique of using radiation for coloring these colorless topaz into a more desirable and permanent blue color, has been refined and today the electron beam enhancement is used for mass production of large quantities of blue topaz. This technique has made the blue topaz the most common of the topaz used in jewelries.

Table(1) describes in general the different ways of irradiation for the production of blue topaz showing the possibility of residual radioactivity in the stones.

Table(1-1)Comparison of method by electron beam, neutron and γ-ray irradiation[6]

Radiation source	Radiation time	Total dose	Color	Induced radioactivity
Electron beam	2(days)	X 10^8 Gy	Sky blue	No
γ-ray	9(month)	X 10^9 Gy	Sky blue	No
Fast neutron	1(day)	X 10^{17} neutron/cm^2	Swiss blue	Very strong
Electron + γ-ray	5(month)	X 10^9 Gy	Sky blue	No