American Mineralogist, Volume 94, pages 935–941, 2009

Determination of the potential for extrinsic color development in natural colorless quartz

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Abstract

Colorless natural quartz can develop many extrinsic colors after exposure to ionizing radiation and heat due to trace elements such as aluminum, iron, hydrogen, lithium, and sodium. The infrared spectrum of colorless natural quartz is correlated to the development of these colors, because the bands between 3200 and 3600 cm^{-1} are related to the presence of trace elements. The colors produced by γ-ray or electron beam irradiation are caused by displacements of electrons in the quartz lattice and can be bleached by ultraviolet irradiation. Colors produced by irradiation and additional heating, however, are resistant to ultraviolet rays, probably due to Li^{+} diffusion. The infrared spectra of colorless natural quartz crystals can be used to identify the crystals' potential for color development by irradiation and heating. At room temperature, all natural colorless samples of alpha quartz show bands at 2499, 2600, 2677, 2771, 2935, and 3063 cm^{-1}. The samples that do not develop color after irradiation also show bands at 3202 and 3304 cm^{-1}. The samples that become grayish to black after irradiation show three additional bands at 3381, 3433, and 3483 cm^{-1}. This last band is related to the development of the colors greenish yellow, yellow, or brown (citrine) after irradiation and heating. The samples that become grayish olive green after irradiation and olive green after additional heating show a pair of bands at 3404 and 3510 cm^{-1} in addition to the former bands noted. The samples that become violet (amethyst) or green (prasiolite) after irradiation, or sky blue after irradiation plus heating show a broad band at ~3441 cm^{-1} and a band at 3585 cm^{-1}.

Keywords: Infrared spectrometry, quartz, color, irradiation, heating