

## RADIOACTIVE MORGANITE

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Two strongly orangy pink morganites with residual radioactivity were studied. The dose rate of the samples, measured by a scintillation survey meter, ranged from 0.15 to 0.35  $\mu\text{Sv/h}$ . Although this radioactivity was likely not hazardous, it was above the recommended exposure limit set forth in 1990 by the International Commission on Radiological Protection. To identify the radionuclides, gamma rays from the samples were measured using a Ge(Li) semiconductor detector. The activation products  $^{134}\text{Cs}$ ,  $^{54}\text{Mn}$ , and  $^{65}\text{Zn}$  were detected, proving that the samples had been artificially irradiated with neutrons.

Some gem varieties (e.g., diamond, topaz, and quartz) are irradiated with gamma rays, electron beams, or neutrons to alter their original color (see, e.g., Ashbaugh, 1988). Disclosure of artificially colored gemstones is generally required at every level of the gem trade, and such material should only be sold as treated. These gems are typically not radioactive when they are commercially distributed. Exceptions include some radioactive green to black diamonds treated by compounds such as radium daughter-products and americium (Reinitz and Ashbaugh, 1993). In addition, radioactive cat's-eye chrysoberyl became a major issue in September 1997, and even drew mass media coverage. The chrysoberyl, originally from Orissa, India, had been irradiated with neutrons in an Asian country, and a portion of the activated material entered the gem market illegally (Johnson and Koivula, 1997). Several pieces of this material were identified in Japan, and one of the authors performed a detailed investigation



Figure 1. The morganite samples in this study weighed 49.18 ct (left, sample 1) and 39.40 ct (right, sample 2). Photo by H. Kitawaki.

that detected scandium-46 ( $^{46}\text{Sc}$ ) and iron-59 ( $^{59}\text{Fe}$ ), proving it had undergone artificial neutron irradiation (Kitawaki, 1998). Fortunately these radioactive cat's-eye chrysoberyls were not widely circulated in the gem trade.

Activated morganite appeared in the Japanese market in May 2010, and the Central Gem Laboratory has confirmed about 10 such specimens so far, including stones weighing >100 ct. The specimens typically show strongly orangy pink coloration (e.g., figure 1), and some are so orangy that they may fall outside the color range for morganite. Their radioactivity levels (measured with a NaI scintillation survey meter) ranged from 0.15 to 0.35 microsieverts per hour ( $\mu\text{Sv/h}$ ), or 5–10 times higher than the background radiation in Tokyo. While this is not believed to be a hazardous level, it is higher than the recommended exposure limit set by the International Commission on Radiological Protection in 1990 of 1 millisievert per year (or 0.114  $\mu\text{Sv/h}$ ; about 3.8 times higher than the background radiation in Tokyo), except for exposure to natural and medical radiation.

Regulations set by the Japan Jewellery Association and the Association of Gemmological Laboratories Japan state that gems showing any possibility of artificial irradiation should be checked by a Geiger counter, and

See end of article for About the Authors and Acknowledgments.

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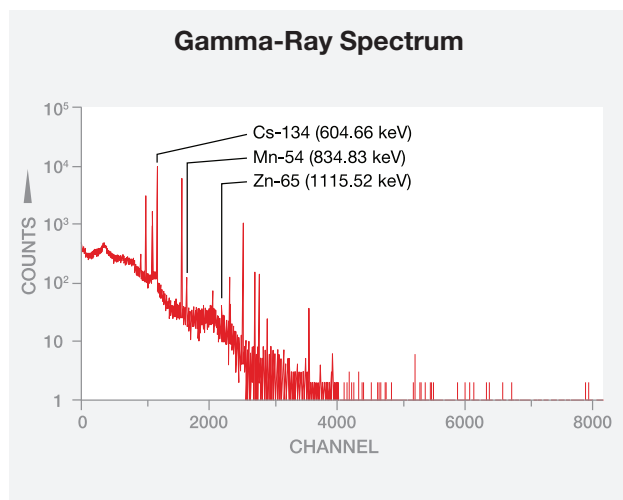


Figure 2. The gamma-ray spectrum of sample 1 shows peaks for <sup>134</sup>Cs, <sup>54</sup>Mn, and <sup>65</sup>Zn. The labeled peaks were used for quantification of the radioactivity in the samples.

those with residual radioactivity should not have gem identification reports issued. Yet there are natural gems containing radioactive impurities such as uranium (U) or thorium (Th) that emit very weak radioactivity. For this article, which was initiated in part by client demand, we identified the radionuclides in radioactive morganite to determine whether those stones had been artificially irradiated by a neutron source.

**Materials and Methods.** Radionuclide determination was performed on two morganites, weighing 49.18 and 39.40 ct (again, see figure 1). The samples were imported from Germany, according to our client, but when and where they may have been irradiated was unknown. Standard gemological properties were collected, and energy-dispersive X-ray fluorescence (EDXRF) analysis was performed with a JEOL JSX-3200 instrument. Gamma rays from the two samples were measured using a Princeton Gamma-Tec Ge(Li) semiconductor detector (see, e.g., Ashbaugh, 1992). The device, located in the Radioisotope Center at the University of Tokyo, has a relative efficiency of 34.4% at 1332 keV, and FWHM of 1.78 keV on the 1332 keV <sup>60</sup>Co γ-line and 743 eV on the 122 keV <sup>57</sup>Co γ-line. The measurement period had a live time of 7,200 seconds and a dead time of ~0.35%. The gamma-ray libraries used for nuclide identification were Spectrum Navigator (Seiko EG&G Co. Ltd.) and a nuclide library generation program (NucLib version 1.12), together with the IAEA Handbook of Nuclear Data for Safeguards. A nuclide was identified by two or more clear and independent peaks in the gamma-ray spectra that were more than 3σ above

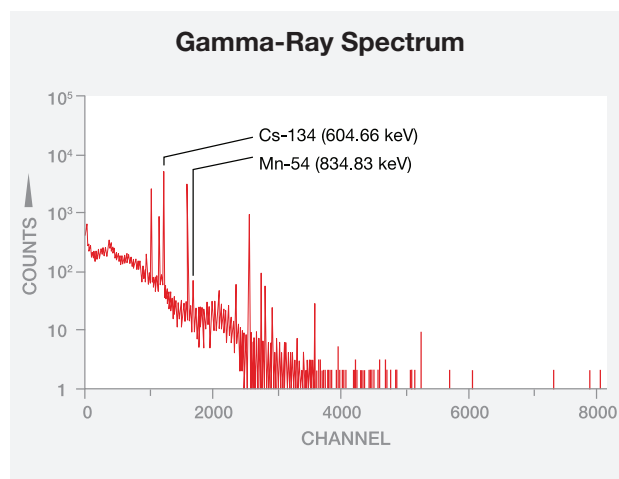
the baseline. The energy efficiency of the gamma rays was also corrected for, and an attenuation (decay) correction was set at the initiation of measurement.

**Results and Discussion.** Both morganites displayed a strong orangy pink color. Their RI measurements were 1.582–1.590 (birefringence 0.008), and their other gemological properties were consistent with morganite. EDXRF spectroscopy of both samples detected about 3.8 wt.% Cs<sub>2</sub>O and traces of K<sub>2</sub>O, FeO, and Rb<sub>2</sub>O, as well as the major Al and Si expected for beryl.

Gamma-ray spectra obtained from the two samples are shown in figures 2 and 3. From the gamma-ray spectrum of sample 1, cesium-134 (<sup>134</sup>Cs), manganese-54 (<sup>54</sup>Mn), and zinc-65 (<sup>65</sup>Zn) were detected; only <sup>134</sup>Cs and <sup>54</sup>Mn were identified in sample 2. All the detected radionuclides were activation products, clearly demonstrating that both samples had been neutron irradiated. The activities of each radionuclide are listed in table 1.

Both morganites contained more than 2,000 becquerels (Bq) of <sup>134</sup>Cs, suggesting that a high thermal neutron flux, such as a nuclear reactor or accelerator, was used for irradiation. Morganite generally contains a small amount of naturally occurring cesium (<sup>133</sup>Cs), which becomes radioactive when irradiated with a neutron beam. The detected radionuclide with the shortest half-life was <sup>65</sup>Zn (244 days). Since the amount of time since the samples were irradiated is unknown, it is highly possible that some additional radionuclides had already decayed to below the detection limits when the samples were measured.

Figure 3. The gamma-ray spectrum of sample 2 shows peaks for <sup>134</sup>Cs and <sup>54</sup>Mn.



**TABLE 1.** Detected radionuclides and their estimated radioactivity.

Sample no.	Radionuclide	Half-life (days)	Radioactivity (Bq)	Error (Bq)	Detection limit
1	<sup>134</sup> Cs	752.6	2612.4	±11.1	13.4
	<sup>54</sup> Mn	312.2	36.7	±3.4	7.88
	<sup>65</sup> Zn	244.0	22.1	±4.1	17.8
2	<sup>134</sup> Cs	752.6	2019.0	±11.9	14.7
	<sup>54</sup> Mn	312.2	32.5	±3.2	10.0

**Conclusion.** Two samples of morganite that registered significant dose rates using a scintillation survey meter were measured for gamma-ray emission to determine the radionuclides present. Radioactive isotopes including <sup>134</sup>Cs were detected in both samples, proving they had been artificially irradiated with neutrons. <sup>134</sup>Cs has a half-life of about two years, so the radioactivity of such morganites should decay to a safe level after a period of several years from when they were irradiated.

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Additional radioactive morganites entering the Japanese market since 2010 also appear to have been artificially irradiated with neutrons. Although it is common to use gamma rays to deepen the hue of morganite, it is unknown why these samples were irradiated with neutrons. Proper identification of such radioactive stones by gemological laboratories, and full disclosure by exporting countries, are strongly urged.

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