Irradiated Orange Sodalite

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Introduction

Sodalite, a captivating deep-blue mineral, was first discovered in Greenland in 1811 by Danish mineralogist Jens Esmark, and officially identified as a distinct mineral by British mineralogist Thomas Thomson in 1812. Sodalite is typically found in silica-poor igneous rocks such as nepheline syenites and pegmatites, forming through the interactions between sodium-rich fluids and other minerals under specific geological conditions. Significant sodalite deposits have been found in Greenland, Canada, Russia, Brazil, Namibia, and Afghanistan, each deposit contributing unique variations influenced by local geological characteristics. (https://www.minerals.net/mineral/sodalite.aspx).

Sodalite [$Na_8Al_6Si_6O_{24}Cl_2$] is a complex tectosilicate mineral belonging to the feldspathoid group. This mineral is valued both as a gemstone and ornamental items, such as beads and sculptures. Sodalite has a specific gravity ranging from 2.27 to 2.33 and a refractive index from 1.483 - 1.487. It can be found in various colors, including blue, yellow, orange, white, green, pink, and violet. In the gem market, several minerals related to sodalite are also available, which share some similar characteristics, including:

- Hauyne [$Na_3Ca(Si_3Al_3)O_{12}(SO_4)$] typically appears in blue and green color.
- Lazulite [$(Mg,Fe^{2+})Al_2(PO_4)_2(OH)_2$] is usually found in blue, green, and blue-green, similar to hauyne.
- Hackmanite [$Na_8Al_6Si_6O_{24}(Cl_2S)$] is notable for its tenebrescence, a phenomenon where it changes color under ultraviolet light, from light yellow or orange to intense purple. Tenebrescence is related to the presence of minor amounts of sulphur (S) substituting for chlorine (Cl) in the structure.

- Tugtupite [$Na_4AlBeSi_4O_{12}Cl$] is another tenebrescent mineral, often found in white, pink, crimson, and even blue and green. (https://geologyscience.com/minerals/sodalite/)

Material and methods

The Gem and Jewelry Testing Laboratory (GJTL) received for investigation 8 orange samples, 2 cut stones weighing 1.68-2.29 ct and 6 rough stones weighing 5.08-15.45 ct (Figure 1). The samples were provided by Mr. Ahmad Raza, the stones' owner and managing director of Khusrawy Gems & Minerals Co., Ltd., who informed us that these samples were Afghan sodalites that had been irradiated by gamma ray 2 Mrad.

The basic gemological properties were collected using standard gemological equipment. We examined color changes of the stones in a dark box by using standard long-wave and short-wave UV lamps for 1 hour then grading the color with the Munsell Book of Color under a Gretag Macbeth Judge II light box with D50 daylight.

The advanced analyses were carried out by PerkinElmer Lambda 1050 UV-VIS-NIR spectrophotometer, which operated in the range of 250-800 nm at room temperature with a sampling interval of 0.1 nm and a spectral bandwidth of 1.0 nm. The stone identity was confirmed using a Renishaw inVia Raman micro-spectroscopy using 532 nm laser excitation. The UV-Vis spectra were collected by a PerkinElmer Lambda 1050 spectrophotometer in the 250-800 nm range at room temperature and accumulated up to three scans to improve the signal-to-noise ratio. The stone chemical compositions were analyzed by using Horiba XGT-9000 micro-XRF analyzer (Micro-XRF).

Figure 1: Eight orange samples weigh 1.68-15.45 cts. used for this study.

Basic Gemological Properties

All samples are translucent, exhibit hues ranging from yellowish orange to pinkish orange color (2.5YR to 10R). The hydrostatic specific gravity values of approximately 2.27 and 2.29, and a single refractive index of 1.48, as measured from the two cut stones (see details in Table 1).

Table 1. Basic gemological properties of eight orange samples

Sample No.	Weight (cts)	Shape/ Cut	RI	SG	Color (Tone/Sat)	Color after SWUV exposure	Color after LWUV exposure	Tenebrescence	Name
Sam I1	1.68	Oval/ Fancy	1.48	2.28	Yellowish Orange 5YR (7/10)	Pinkish Orange 10R (6/10)	None	Weak	Sodalite
Sam I2	2.29	Oval/ Fancy	1.48	2.29	Yellowish Orange 2.5YR (7/12)	Pinkish Orange 10R (6/10)	None	Weak	Sodalite
Sam I3	5.08	Irregular	-	2.27	Yellowish Orange 2.5YR (6/6)	Pinkish Orange 10R (6/6)	None	Weak	Sodalite
Sam I4	5.25	Irregular	-	2.27	Yellowish Orange 2.5YR (7/6)	Orange-Pink 7.5R (7/6)	None	Weak	Sodalite
Sam I5	10.55	Irregular	-	2.28	Yellowish Orange 2.5YR (7/4)	Orange-Pink 7.5R (7/4)	None	Weak	Sodalite
Sam I6	10.35	Irregular	-	2.27	Yellowish Orange 2.5YR (6/10)	Pinkish Orange 10R (6/10)	None	Weak	Sodalite
Sam I7	15.45	Irregular	-	2.28	Yellowish Orange 2.5YR (7/8)	Pinkish Orange 10R (6/8)	None	Weak	Sodalite
Sam I8	14.90	Irregular	-	2.29	Pinkish Orange 10R (6/10)	Pinkish Orange 10R (7/8)	None	Weak	Sodalite

All the stones showed no noticeable color change after LWUV exposure. However, some slight changes in intensity and hue were observed from yellowish orange to pinkish orange after exposure to SWUV for 1 hour. Comparison color between before and after SWUV exposure including color codes are presented in Figure 2 and Table 1. All the samples were left in a dark room about 2 weeks, the color was then faded to its initial hue. These color change effects can be called a kind of tenebrescence phenomenon (see Kondo & Beaton 2009).

Figure 2: Comparison colors before (left) and after exposure to SWUV for 1hour (right).

Microscopic observations

The internal characteristics of all samples showed multi-phase inclusions and numerous transparent crystals that were unable to identify by the Raman micro-spectroscopy (Figure 3).

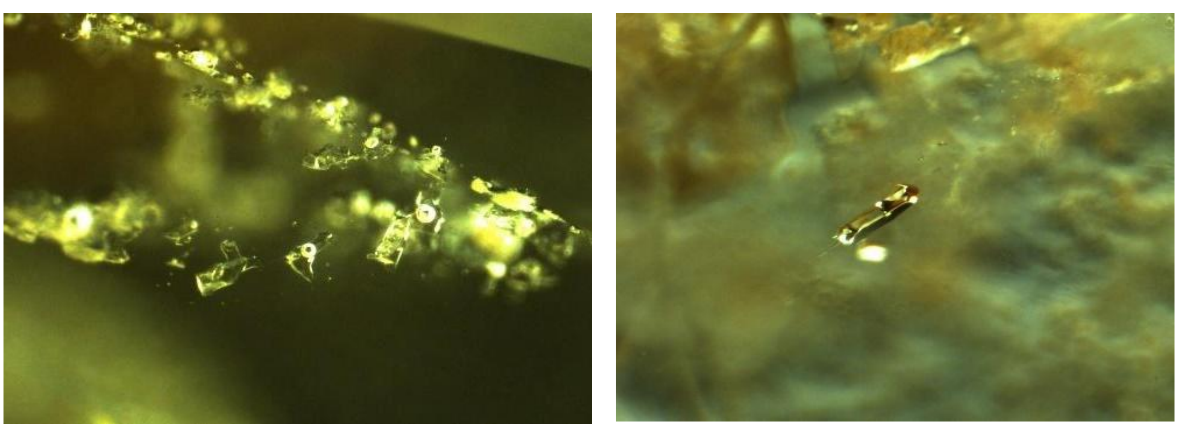

Figure 3: Showing 2-phase inclusions (left) and transparent crystals (right) as common internal features in Sam I1

Advanced Instruments analyses

Chemical Analysis

The semi-quantitative chemical analyses by Micro-XRF revealed Sodium (Na), Aluminum (Al), and Silicon (Si) as the major components with trace elements such as Sulfur (S), Chlorine (Cl), Potassium (K), Calcium (Ca), and Iron (Fe) that are in agreement with the chemical formula (Table 2).

Table 2: The chemical analyses of the irradiated orange sodalite by Micro-XRF. (in wt. % Oxides)

Sample No.	Na_2O	Al_2O3	SiO_2	SO_3	Cl	K_2O	CaO	Fe_2O_3
Sam_I1	8.25	30.62	52.27	0.14	8.21	0.33	0.12	0.02
Sam_I2	9.29	30.74	51.44	0.35	7.63	0.27	0.22	0.02
Sam_I3	5.74	26.43	44.58	11.43	6.95	0.24	4.26	0.32
Sam_I4	8.37	28.71	47.60	5.15	7.08	0.21	2.80	0.05
Sam_I5	9.36	30.43	52.23	0.13	7.42	0.21	0.17	0.02
Sam_I6	6.81	29.85	53.26	0.14	9.44	0.25	0.20	0.03
Sam_I7	8.41	31.12	52.43	0.16	7.49	0.24	0.11	0.02
Sam_I8	6.76	29.60	53.06	0.21	9.74	0.35	0.22	0.03

Raman Spectroscope

The Raman spectra of all 8 samples in the range of 200 – 1200 cm^{-1} displayed the peaks at 265, 295, 465, 987, and 1067 cm^{-1} that matched well with that of the RRUFF online database (R060345; Sodalite from Afghanistan). However, we also observed an additional peak at 970 cm-1 in the SAM_I1 to SAM_I3 but not in the SAM_I4 to SAM_I8 (Figure 4).

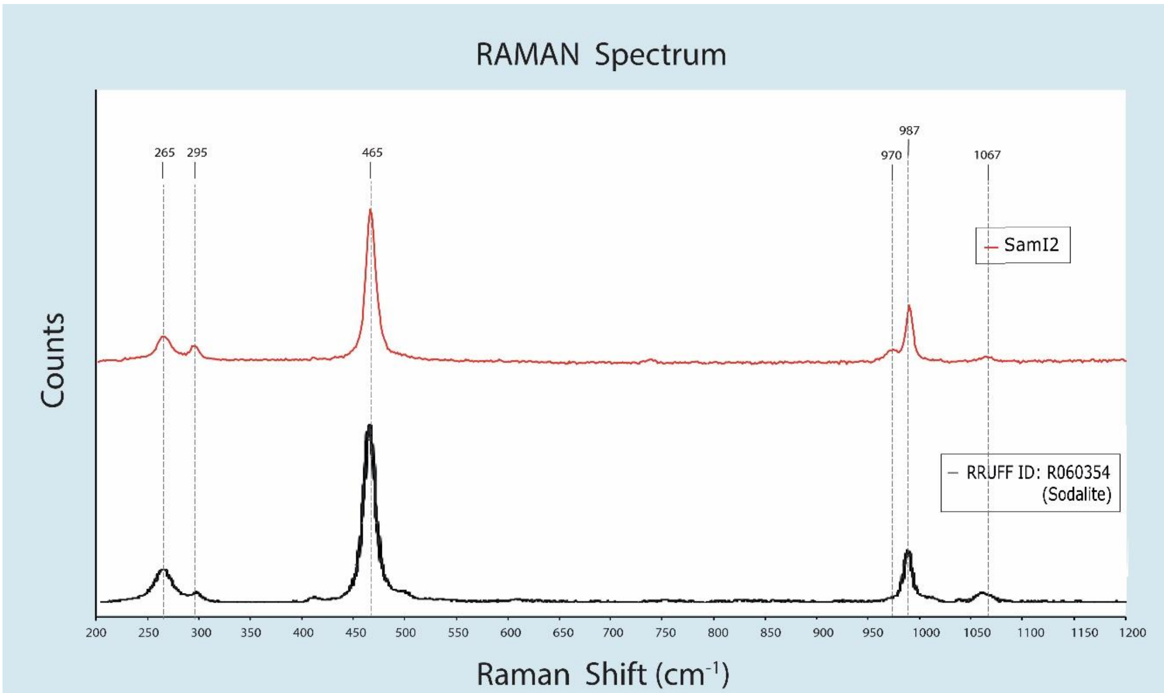

Figure 4: The Raman spectra of a representative sample (red line) show peaks at 265, 295, 465, 987, and 1067 cm^{-1} closely match that of the sodalite reference (black line) from the RRUFF database (R060345).

UV-Vis Spectra

The non-polarized UV-Vis spectra of the two cut samples before exposure to SWUV exhibited a strong absorption band at about 313 nm and a very broad band peaked at approximately 450 nm (Figure 5). The absorption spectra of the cut samples showed a slight shift of the 457 nm broad band to 483 and 507 nm after exposure to LWUV and SWUV, respectively (see Figures 6). This spectral shift is consistent with the noticeable intensity and color change from yellowish orange to pinkish range after exposure to SWUV in particular (see Figure 2).

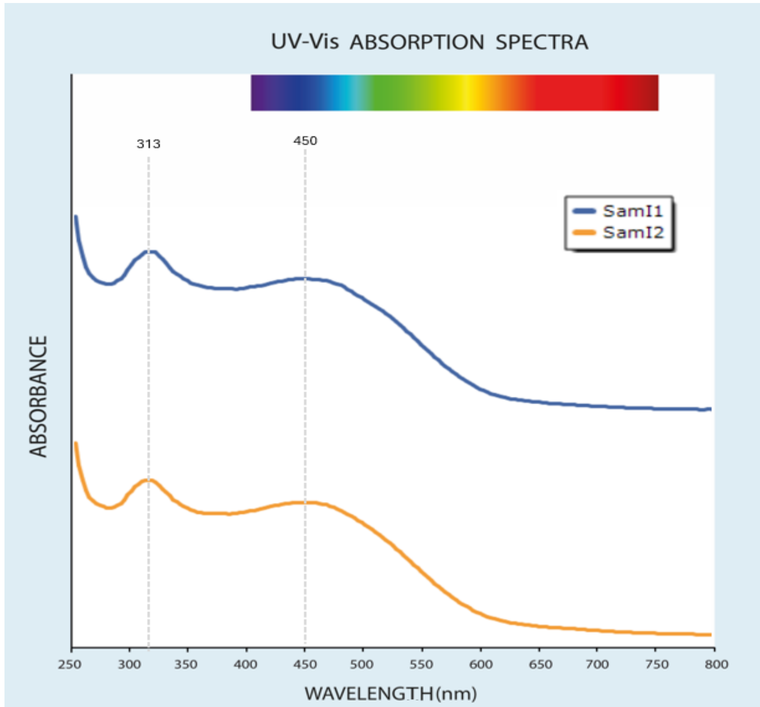

Figure 5: non-polarized UV-Vis spectra of two cut samples. The spectra have been vertically offset for clarity.

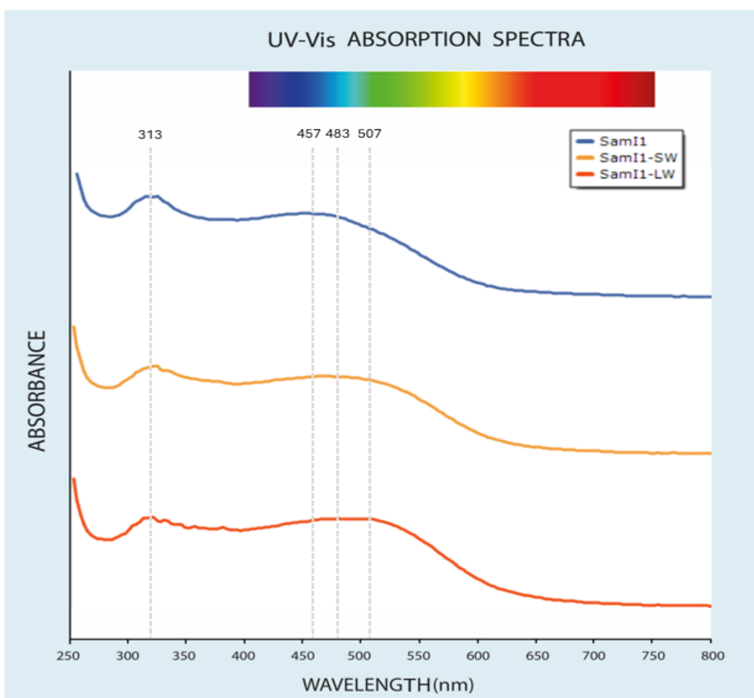

Figure 6: Comparison non-polarized UV-Vis spectra of Sam_I1 before (green line), after exposure to LWUV (red line) and SWUV (blue line).

Discussion and conclusions

Our standard gemological testing indicated that these samples exhibited a single refractive index of 1.48 and a specific gravity ranging from 2.27 to 2.29. The advanced analyses confirmed these specimens were sodalite. After exposure to short-wave ultraviolet light (SWUV) for one hour, all eight samples showed a weak tenebrescence effect, shifting in color from yellowish orange to pinkish orange. Furthermore, the colors of the samples were gradually returned to their original hues after they were left for two weeks in a dark room. Based on our data, we conclude that these samples should still be called "orange sodalite" because the tenebrescence effect is rather weak (see also Kondo & Beaton 2009). However, we were unable to confirm, based on the testing and instruments available in our lab, whether these stones had been irradiated as informed by the stones' owner. Further study is necessary to definitively determine the irradiation of these stones.

References

Gaines, R. V., Skinner, H.C.W., Foord, E.E., Mason, B., Rosenzweig, A.,1997. Dana's New Mineralogy: The System of Mineralogy of James Dwight Dana and Edward Salisbury Dana, 8th Edition.

Hackmanite. *Available*: https://www.mindat.org/min-1789.html. April 2, 2024.

Hackmanite Na8Al6Si6O24Cl2 An illustration of tenebrescence. *Available*: https://www.gemologyonline.com/hackmanite.html. April 2, 2024.

Kondo, D. & Beaton, D. 2009. Hackmanite/sodalite from Myanmar and Afghanistan. *Gems &* Gemology, 45(1), 38–43.

K. Nassau, The Physics and Chemistry of Color: The Fifteen Causes of Color, Wiley, New York, 2^{nd} Edition, 2001.

Sodalite R060354. *Available*: https://rruff.info/hackmanite/R060354. April 2, 2024.

Acknowledgments

The authors would like to express our thanks to Mr. Ahmad Raza, the managing director of Mr. Ahmad Raza, managing director of Khusrawy Gems & Minerals Co., Ltd., for kindly providing the samples of hackmanite for data collection in this article.