Distribution of radionuclide impurities in irradiated topaz

Temur Enik (JINR)

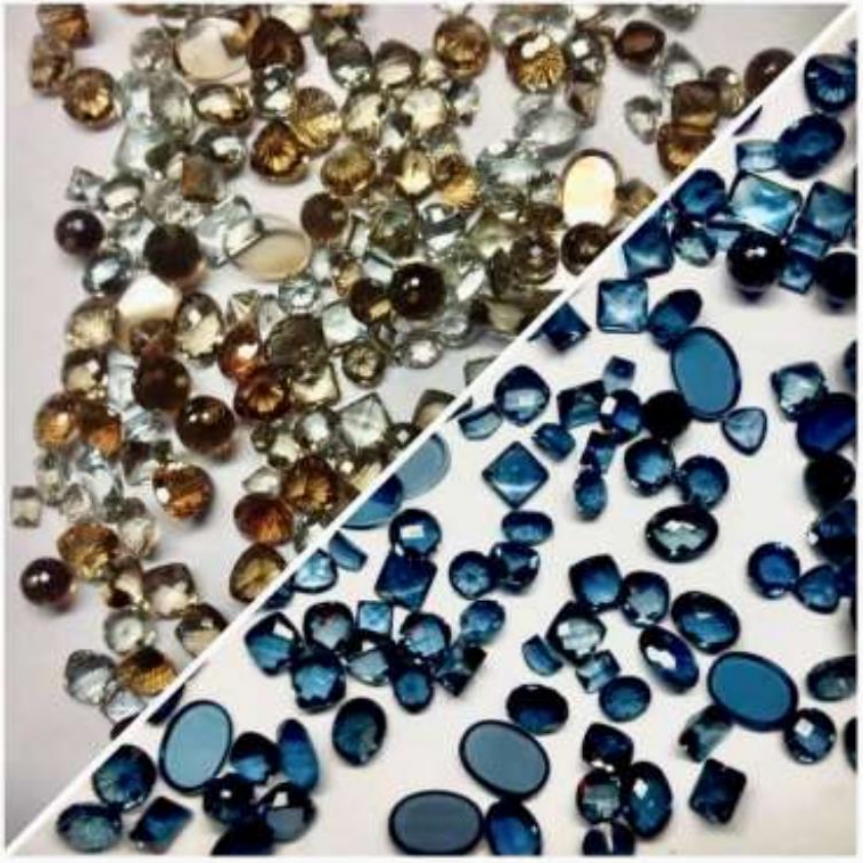
ISINN-30

April 14 – 18, 2024

Sharm El-Sheikh, Egypt

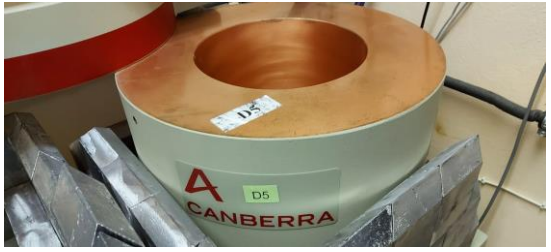
Topaz color enhancement

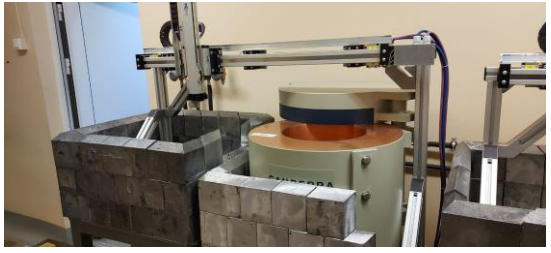
- Irradiation with neutrons is one of the most efficient ways for gemstone color enchantment
- After irradiation the color of topaz turns into deep blue resulting in so-called London blue topaz.
- However, neutron irradiation induces radionuclides of different half-life time and thus causes radioactivity of the gemstones.



Irradiation and activation measurements

- Irradiation by fast neutrons at the reactor IBR-2 (JINR) up to fluence 10^{18} cm^{-2} (operation cycle of 264 hours.)
- Spectroscopic measurements are performed with High purity Germanium detector Canberra
- 15 min/sample for ~400 samples



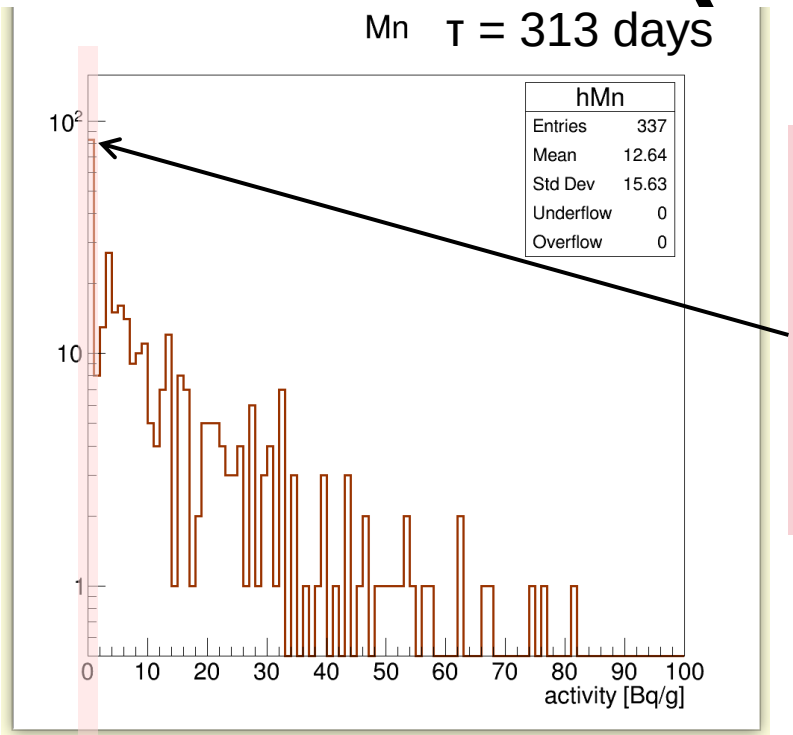


Spectrometric measurements of irradiated samples

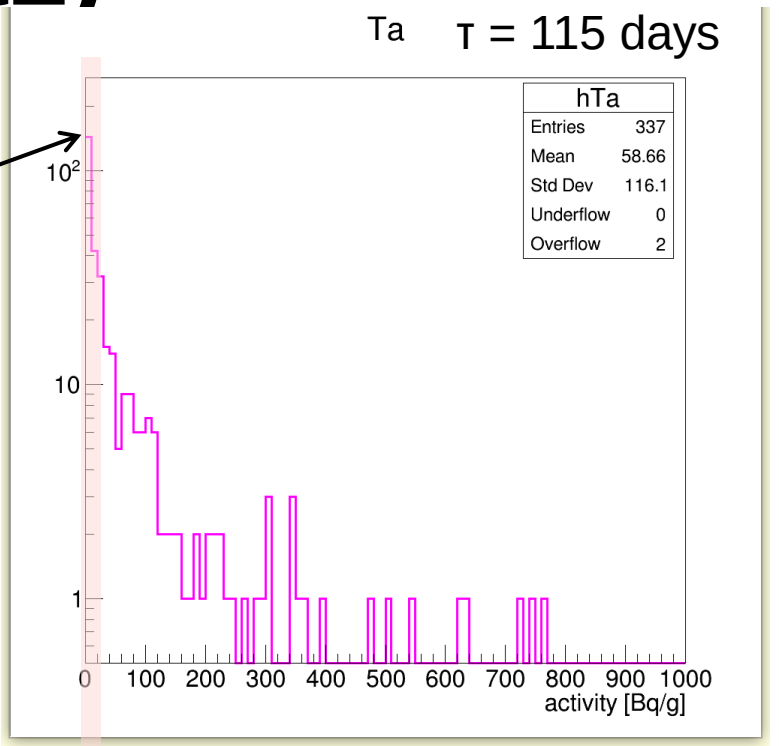
Detected isotope	Half-life time
^{46}Sc	84 days
^{54}Mn	313 days
^{60}Co	5.3 years
^{65}Zn	244 days
^{182}Ta	115 days

- The measurements are performed in ~12 months after the irradiation. 202 samples were checked for ^{54}Mn and ^{182}Ta presence (set1) and 135 samples were investigated more thorough detecting ^{46}Sc, ^{54}Mn, ^{60}Co, ^{65}Zn, ^{182}Ta (set2)

Mn and Ta activity distributions (set1+set2)

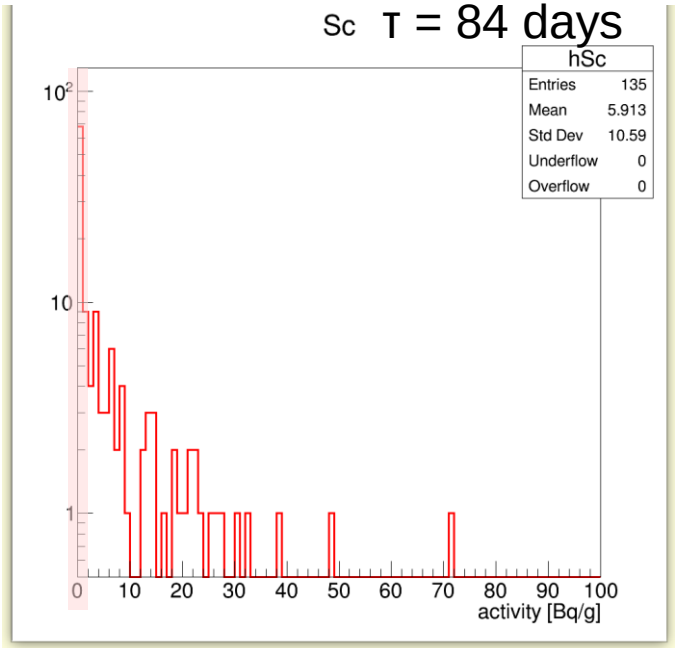


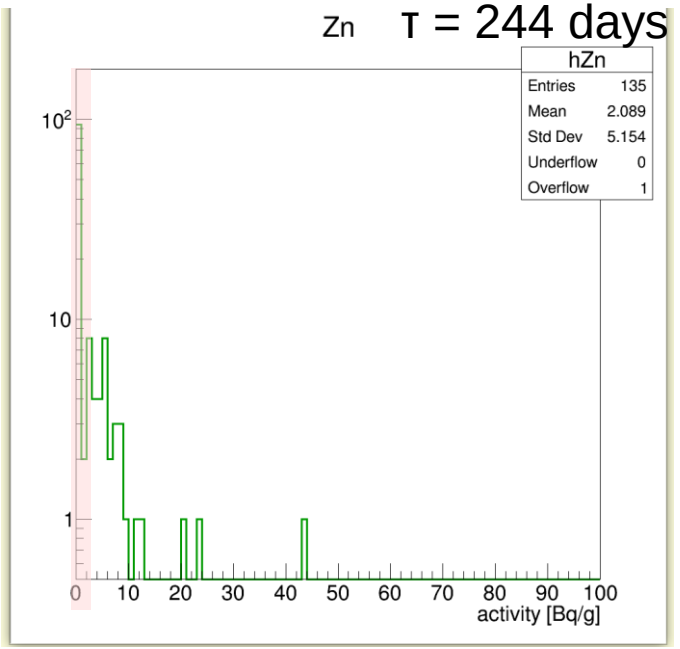
Samples with negligible (below the sensitivity limit) presence of the isotopes

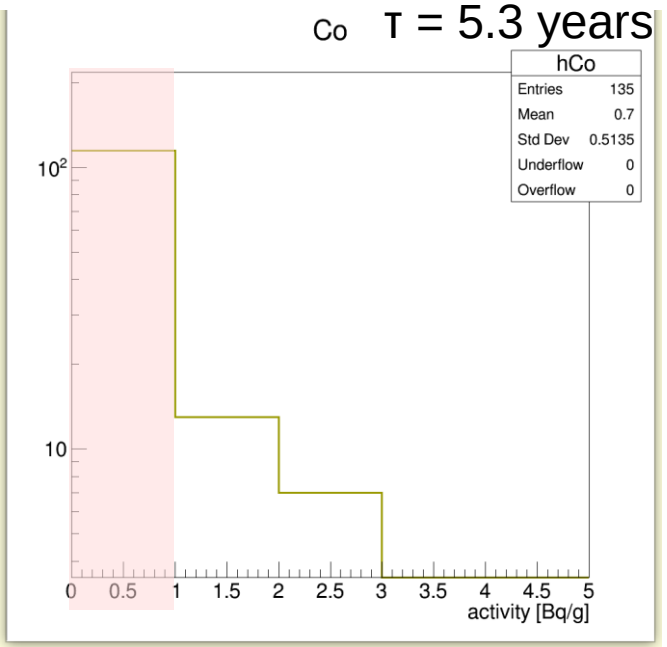


Huge variation of the activation has been observed among the samples

Isotope distribution (set2)







Exemption levels

Comparative Study of EC and IAEA Guidance on Exemption and Clearance Levels

RADIATION PROTECTION NO 157

Directorate-General for Energy
Directorate D — Nuclear Energy
Unit D4 — Radiation Protection
2010

Table 4.1: Numerical comparison of the sets of values contained in RS-G-1.7, RP 122 part I, RP 89, RP 113 and of the exemption values (all values in Bq/g; explanation see text)

Nuclide	$T_{½}$ [d]	RP122/I end	RP122/I scen	RP122/I raw	RP 89	RP 113	RS-G-1.7	SR 44 real.	SR 44 low pr.	SR 44 water	Ex. val.
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
Sc-46	8.0E+01	0.1	1.5E-01	0.1	1	0.1	0.1	2.5E-01	1.5E+00		10
Mn-54	3.0E+02	0.1	3.8E-01	1	1	0.1	0.1	1.5E-01	1.5E+00	1000	10
Co-60	2.0E+03	0.1	9.9E-02	0.1	1	0.1	0.1	3.1E-02	3.2E-01	100	10
Zn-65	2.0E+02	1	5.2E-01	1	1	1	0.1	2.6E-01	2.6E+00	1	10
Ta-182	1.0E+02	0.1	2.5E-01	0.1	1	0.1	0.1	2.6E-01	2.5E+00		10

mass specific exem
[EUR 96]

[EUR 96] COUNCIL OF THE EUROPEAN UNION

Council Directive 96/29/Euratom laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation
Official Journal of the European Communities, ISSN 0378-6978, L 159, Vol. 39, 29.06.96

Summary and Further steps

- Large variation of the residual activity is observed for the irradiated topaz samples
- Due to the large half-life times the quarantine time for some of irradiated samples may be up to several years
- Post-irradiation selection of the highly active samples is problematic due to the high activation level of the whole set
- Pre-irradiation with a low flux may be useful to identify and to remove the samples with large concentration of impurities to avoid the high activation level after the complete irradiation procedure. This may reduce the quarantine time for the common set of the topaz samples