RADIOISOTOPE PRODUCTION IN KAZAKHSTAN

A. Arzumanov, P. Chakrov, S. Lyssukhin, G. Sychikov, A. Zheltov

Institute of Nuclear Physics, Almaty, 480082, Kazakhstan.

Radioisotopes make important contributions to medicine, industry, ecology research and science throughout the world giving rise to essential economic and health benefits. At the time being Kazakhstan has two facilities suitable for production of radioisotopes: isochronous cyclotron U-150M and research reactor WWR-K. Both facilities are located at the Institute of Nuclear Physics (INP) in Alatau settlement nearby Almaty city, and isotope production is one of the priority and growing directions of the INP activities.

Cyclotron Isotope Production

The cyclotron in Almaty was designed and constructed by Efremov Institute in Leningrad as "classical" 20 MeV deuteron machine with fixed parameters and single beam line. In 1971-72 it was refurbished and converted to variable-energy isochronous mode of operation. Now it is a compact pole, 3 low spiral sector K=50 MeV machine with internal hooded Penning type positive ion source (Fig.1). The cyclotron generates beams of light ions: protons 6-30 MeV, deuterons 12.5-25 MeV, helium-3 ions 18.5-62 MeV, alpha particles 25-50 MeV. In the last years the cyclotron is regularly used for radioisotope production.

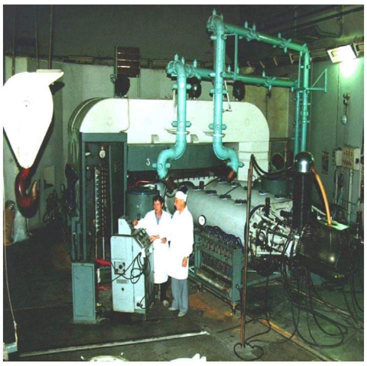


Fig.1. Isochronous cyclotron U-150M.

The radioisotope production program started in mid 1980-s and shares the cyclotron with basic research programs on nuclear physics and radiation physics of solids. Both external and internal ion beams are used for target irradiation. Irradiation of external target is typically being used during some years. The beam intensity on the external target is equal to 30 μA for protons and deuterons, 10 μA for helium-3 ions and 20 μA for alpha particles. Extracted beam intensity is limited by power dissipation in the electrostatic deflector at the level of 1-2 kW. For homogeneous target irradiation the circular beam scanning system is used. Transversal rotating magnetic field is generated by the stator of electro-motor and shifts the beam from the transport channel axis for up to 12 mm. Beam spot size and its shifting may be adjusted so that to get uniformity of power distribution better than 80% inside 20 mm circle. Beam power distribution for the extracted beam spot and for the circularly scanned beam are shown in Fig. 2.

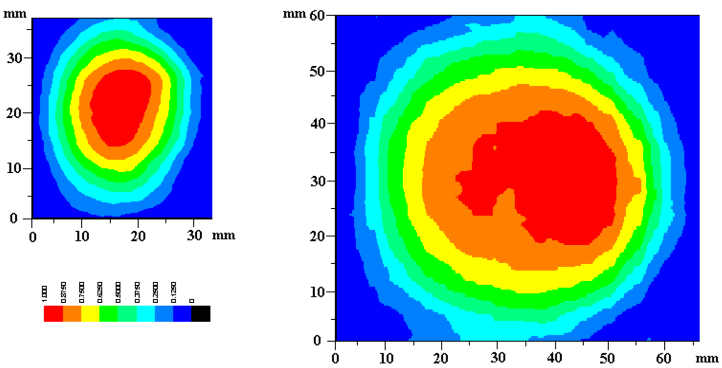


Fig.2. (a) External beam spot.
(b) Circularly swept beam spot.

High beam intensities, typically several hundred μA, are available on the internal target. In order to enlarge the beam spot on the target and so to reduce beam power density on the target it is declined with respect to the beam axis at the angle of 18°. The limiting ability of magnetic field axial focusing in the mode of proton acceleration to 30 MeV, results in increasing of axial dimension of beam spot two-three times. This feature is used to reduce beam power density on the target. The target irradiated area is 8-10 cm^2. The target reliably sustained cooling water pressure of 20 bar, providing use of internal proton beam with 30 MeV energy and beam intensity up to 500 μA. Elements of the internal target are shown in the Fig. 3.

At the present time only solid targets are used for isotope production at the internal and external beam of the INP isochronous cyclotron. Metallic targets prepared by cathodic electrodeposition of corresponding metal on a copper substrate of special design are used for production of Tl-201, Ga-67, Cd-109, Co-57. Choice of the method for electrolytic deposition depends on the type of metal to be deposited. Powder targets produced by pressing of RbCl, SrO and UO_2 into an aluminum holder at ~2500 N/cm^2 are used for production of Sr-85, Y-88 and Pu-237 radionuclides, correspondingly. In all cases the thickness of the pressed powder is equal to 1.5 mm.

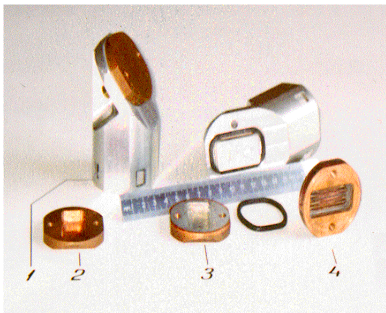


Fig.3. Elements of the internal target: 1 – the head of target, 2 – the backing of target, 3 – the backing covered with silver, 4 – finned backing.

To guarantee efficient and reliable operation of the targets, 25 keV electron beam with intensity up to 200 mA is used for target preliminary heat testing.

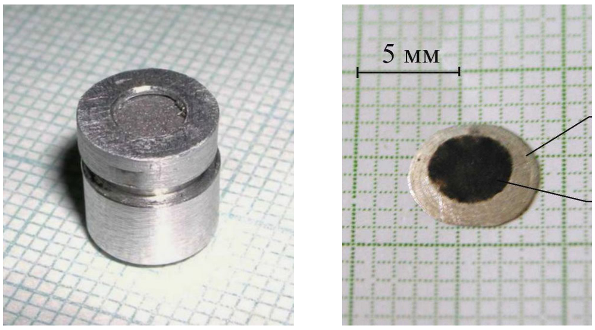
A list of radioisotope products produced currently at the Kazakhstan isochronous cyclotron is presented in the Table 1 below:

Table 1. Cyclotron radioisotopes produced at the INP-Almaty.

Product	Target materials	Target irradiation			Yield of activity (for nat.), mCi/(μA*h)
		E, MeV	I, μA	τ, h	
Radio pharmaceuticals					
Tl-201 chloride	Cu + Tl	28.5-22 (p)	100 – 150	9-9.5	≥ 0.2
Ga-67 citrate	Cu+{Ni}+Zn	30 (p)	100 – 150	8-8.5	≥ 1.3
Sealed sources					
Co-57	Cu+Ni	22 - 18 (p)	250 – 350	≥ 40	≥ 0.3
Cd-109	Cu+{Cu+Ag}+Ag	22 (p)	250 – 300	≥ 40	≥ 2.6e-3
Tracers					
Sr-85	RbCl	22 (p)	3	14	≥0.076
Y-88	SrO	22 (p)	3	14	≥ 0.103
Pu-237	UO_2	48(α)	1		≥ 1.7e-10

Tl-201 chloride radiopharmaceutical for heart diagnostics is routinely supplied to medical centres in Almaty. In the production of Ga-67 citrate for cancer diagnostics, the technology includes some novel elements: the processes of extraction, concentration and purification of Ga-67 are performed simultaneously by the method of extraction chromatography, which enables to produce this radiopharmaceutical both from enriched and natural abundance zinc. The pharmaceutical has successfully passed both pre-clinical and clinical trials, and licensing procedure is at final stage now.

Cobalt-57 sealed sources are applied in Moessbauer spectroscopy and for calibration of diagnostic medical equipment. Cadmium-109 sources (see Fig.4) are used in X-ray fluorescent elemental analysis (particularly, in mining and metallurgy industry). The activity of these sources ranges from 10 to 1000 mCi.



a **b**

Fig.4. Cd-109 sealed source:

(a) - General view;

(b) - Silver substrate (1) with deposited carrier-free Cd-109 (2).

Pu-237, Y-88 and Sr-85 radioisotopes are used as tracers in the radioanalytical laboratories for precise quantitative determination of Pu (239-240) and Sr-90 content in the environmental samples (soil, water, plants, air sediments), particularly from the former Semipalatinsk Nuclear Test Site.

Reactor Isotope Production

Development of radioisotope production at the research nuclear reactor WWR-K (Fig.5) has been started in 1998, when the reactor was re-commissioned after 10-year shutdown for safety upgrades. The primary goals were production of Technetium-99m and Iodine-131, as the most demanded isotopes for medicine.

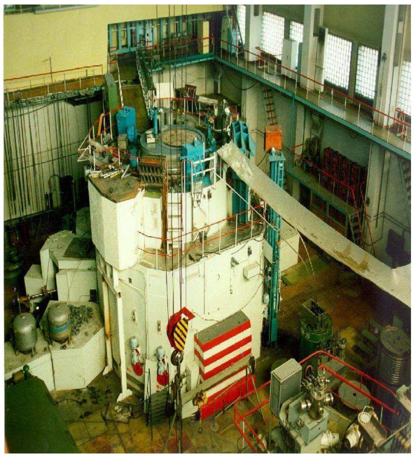
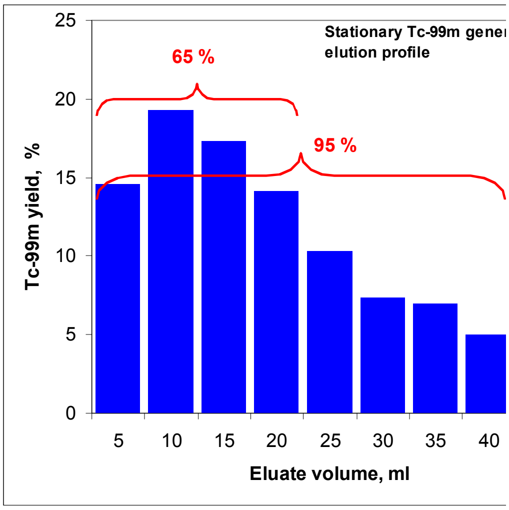


Fig.5. Nuclear reactor WWR-K:
- Light water research reactor.
- Thermal power: 6 MW.
- Max. thermal neutron flux: $1.4{\cdot}10^{14}$n/(cm^{2}s).

After preliminary experiments, so called gel-method has been chosen for production of Tc-99m pertechnetate solution, which is most commonly used for labelling of reagent kits for diagnostics of various human internals (kidney, liver, heart, brain, bones, blood pools, etc.). The initial target is naturally abundant molybdenum in the form of MoO_3 powder sealed into quartz ampoule. Neutron irradiation converts natural Mo-98 into Mo-99, parent isotope for Tc-99m. Chemical processing of neutron irradiated target results in granular zirconium-polymolybdate gel poured into the column of large stationary technetium generator (Fig.6) which operates as usual chromatographic generator, with daily elution of pertechnetate solution by isotonic saline. Routine supply of Tc-99m pharmaceutical to Almaty medical centres has been started in 2002, after pre-clinical and clinical trials completed in 2001.

Stationary Tc generator in the hot cell



Remotely operated solution dispensing unit

Fig.6. Technetium-99m production at stationary gel-type generator. Typical radioactive concentration of the eluate on the first day of generator elution is 2.5 GBq/ml (~70 mCi/ml) in the first 20-ml portion, and 1.2 GBq/ml (32 mCi/ml) in the second 20-ml portion.

Well known dry distillation technique has been applied to produce I-131 for diagnostics and treatment of thyroid disease. The target is (natural tellurium) TeO_2 powder in quartz ampoule. Distillation of iodine from the irradiated target is carried out in the hot cell equipped with additional carbon filters built into ventilation system. Free iodine is trapped in alkaline solution thus forming bulk solution of $Na^{131}I$, which is forwarded to pharmaceutical production laboratory for further conditioning and dispensing.

Fig.7. Ready-to-use radiopharmaceutical solution.

For radioecological research, Cs-134 tracer is produced at the reactor by neutron irradiation of natural Cs-133.

More recent activity at WWR-K reactor is a development of production of Iridium-192 and Cobalt-60 sealed radioactive sources for industry. Available irradiation positions in the reactor allow commercially feasible production of Ir-192 with a specific activity up to 500 Ci/g, which is enough for almost any applications, and Co-60 with ~20 Ci/g specific activity, which is suitable to produce medium-activity cobalt sources. The radioactive material is sealed into single or double wall stainless steel capsule by remotely operated TIG welding in the hot cell (Fig.8,9), with subsequent certification tests.

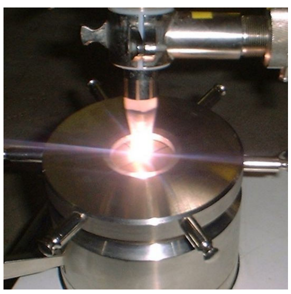


Fig.8. Remote TIG welding.

Fig.9. Ir-192 sealed sources.

Growing demand for radioisotope products, mostly for national oil and gas, mining and metallurgy industry, as well as for medical applications, provides a good prospect for further development of isotope production in Kazakhstan.