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Development of Diffusion-Thermal Methods for Preparing ^{67}Cu and ^{124}I for Radionuclide Therapy and Positron Emission Tomography

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Abstract—Diffusion-thermal procedures for preparing ^{67}Cu and ^{124}I for radionuclide therapy and positron emission tomography are suggested. For these procedures, new cyclotron targets of metallic tantalum were developed, which, when exposed to high irradiation doses, ensure the absence of physicochemical interaction (diffusion, alloying) of materials being activated and final products with the support at high temperatures. The thermal, hydrodynamic, and strength characteristics of zinc and tellurium (elemental Te) cyclotron targets were evaluated. For commercial target assembly of the COSTIS system, the operation parameters of the process for preparing ^{124}I from elemental tellurium using the derived beams of IBA Cyclone 18/9 or MGTs-20 accelerators were determined.

Recent efforts of leading scientific laboratories and medical centers (Brookhaven National Laboratory, BNL; Los Alamos National Laboratory, LANL; Paul Scherrer Institute, PSI; Hammersmith Hospital, etc.) were focused on the development of procedures for preparing ^{67}Cu and ^{124}I [1–3]. This is due to the unique nuclear-physical properties of ^{67}Cu and ^{124}I, possibility of their production on compact cyclotrons, accelerators of high-energy charged particles, electron accelerators, and moderate-power reactors, and also to rich and well-studied chemistry of these elements.

^{67}Cu is a short-lived radionuclide ($T_{1/2}$ = 2.58 days) undergoing β-decay (100%) [4]. A short path of electrons with the energy from 181.5 to 575.0 keV in a living body allows elimination of tumors with a diameter of up to 5 mm [5]. The inherent γ-ray radiation of this radionuclide, whose energy spectrum and quantum yield (see below) are similar to those of ^{67}Ga widely used in single-photon emission tomography, is efficiently registered with a commercial scintillation γ-ray chamber providing reliable monitoring of the behavior of the labeled preparation in patient's body.

E_β, keV (%) [4]	E_γ, keV (%) [4]
390.4 (57.2)	184.6 (48.7)
481.7 (21.6)	93.3 (16.1)
575.0 (20.0)	91.3 (7.0)
181.5 (1.1)	

One more undeniable advantage of ^{67}Cu is formation of stable compounds with monoclonal antibodies, which provides target transport of radiopharmaceuticals (RPs) to the affected organ, high radiation doses within this organ, very low irradiation of intact tissues, and restricted capacity of tumor cells to regenerate the DNA structure after irradiation with electrons.

^{124}I is a positron emitter. Replacement of the key diagnostic radionuclide iodine-123 by ^{124}I in known RPs such as solution of sodium iodide, solution of sodium *o*-iodohippurate, *m*-iodobenzylguanidine, and Iodofen would substantially improve these preparations.

In this study we developed diffusion-thermal procedures for preparing these radionuclides.

PREPARATION OF ^{67}Cu

Accumulation of the Target Product

Accelerator irradiation with protons (energy up to 70 MeV). ^{67}Cu can be prepared by the reactions ^{68}Zn($p, 2p$), E_{thr} 10.1 MeV; ^{69}Ga($p, 3p$), E_{thr} 16.8 MeV; and ^{71}Ga($p, \alpha p + 4pn$), E_{thr} 5.41 MeV, occurring in zinc or gallium targets upon proton irradiation.

Zinc targets are preferable owing to the (1) simple procedures of their preparation; a typical target is a fine layer of the material being activated (130 – 1000 μm depending on the incidence angle of the charged particles on the enriched ^{68}Zn target) de-

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Table 1. Yields of desired ^{67}Cu (bold face) and main impurity radionuclides from the zinc and gallium targets after irradiation with <70-MeV proton beams [7]

Target	Radionuclide ($T_{1/2}$, days)	Reaction, E_{thr}, MeV	Yield of radionuclides, MBq μA^{-1} h^{-1}, at indicated proton energy, MeV		
			20	30	60–70
^{68}Zn	**^{67}Cu (2.58)**	$(p,2p)$, 10.1	**0.043**	**0.223**	**3.15**
	^{67}Ga (3.26)	$(p,2n)$, 12.2	11.7	49.3	87.9
	^{65}Zn (244.3)	$(p,p3n+4n)$, 28.7	–	–	0.82
^{69}Ga	^{64}Cu (0.53)	$(p,\alpha pn)$, 14.6	0.24	3.04	>198
	^{67}Cu (2.58)	$(p,3p)$, 16.8	**0.011**	**0.296**	**0.37**
	^{65}Zn (244.3)	$(p,\alpha n)$, 6.7	0.104	0.425	1.3
	^{68}Ge (270.8)	$(p,2n)$, 11.6	0.572	1.41	>2.21
	^{69}Ge (1.63)	(p,n), 3.06	101	116	>157
^{71}Ga	^{64}Cu (0.53)	$(p,\alpha p3n)$, 31.8	–	–	>20
	^{67}Cu (2.58)	$(p,\alpha p+4pn)$, 5.41	**0.011**	**0.292**	**2.25**
	^{65}Zn (244.3)	$(p,\alpha 3n)$, 23.9	–	–	0.48
	^{67}Ga (3.26)	$(p,p4n)$, 36.0	–	–	26.7
	^{68}Ge (270.8)	$(p,4n)$, 28.8	–	–	>0.66
	^{69}Ge (1.63)	$(p,3n)$, 20.2	–	56	>271

posited by one or another method (most often electroplating) on a thick (several mm) silver or copper support, cooled with water from the back side; (2) more efficient removal of excess heat generated in the target during irradiation with a beam of particles of high energy and intensity (tens of μA): the thermal conductivity of zinc and gallium at 293 K is 112.7 and 29.3 W m^{-1} K^{-1}, respectively [6]; (3) higher yield and higher radiochemical purity of the final product at similar energies of the charged particles, and absence of the main impurity radionuclide ^{64}Cu (Table 1).

Reactor irradiation. Preparation of ^{67}Cu by the (n,p) reaction is not very promising because to low capture cross sections of thermal neutrons (0.64–0.82 mb) [8–10] and high content of the impurity ^{64}Cu: in the case of "natural" zinc, the ^{67}Cu : ^{64}Cu ratio is 1 : 700 and at irradiation of enriched ^{67}Zn (93.7% enrichment) the activity of ^{67}Cu reaches only 25–28% of the total activity of the target [11].

Irradiation with electron accelerators. Preparation of ^{67}Cu using the bremsstrahlung beams from electron accelerators seems the most promising. In one of the pioneering studies [12], ^{67}Cu was prepared on a 25-MeV electron accelerator (beam current 8–10 μA). In irradiation, the target [a stack of 2-mm discs 12 mm in diameter] was placed at a distance of 2 cm from the converter; the irradiation time was varied from 2 to 10 h.

It was found that the activity of ^{67}Cu decreases exponentially in the bremsstrahlung beam direction (Fig. 1). The threshold of the ^{68}Zn(γ,p) reaction is 9.99 MeV, and the capture cross section is maximal at 19 MeV.

As seen from the γ-ray spectrometric data, along with the desired product the targets contain ^{64}Cu, which is probably formed by the ^{66}Zn(γ,np) reaction (E_{thr} 19 MeV).

At a beam current of 10 μA and irradiation time of 10 h, the yield of ^{67}Cu from the 25-g target [a stack of "natural" zinc discs (12 mm in diameter), total thickness 30 mm] was 9.25 MBq.

In the case of enriched ^{68}Zn, the yield of ^{67}Cu can be increased to 0.5 MBq μA^{-1} h^{-1}; simultaneously, the procedure of radiochemical treatment of the zinc targets becomes simpler.

Taking into account rather limited number of high-energy accelerators [LANL; BNL; PSI; National Accelerator Centre, NAC; Faure (Republic of South

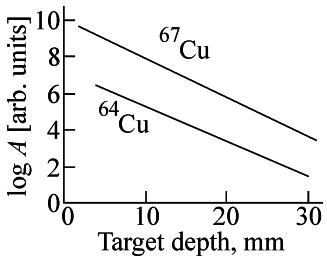

Fig. 1. Accumulation of ^{67}Cu and ^{64}Cu in the course of irradiation of the zinc targets with the bremsstrahlung beam from an electron accelerator [12]; (*A*) activity.

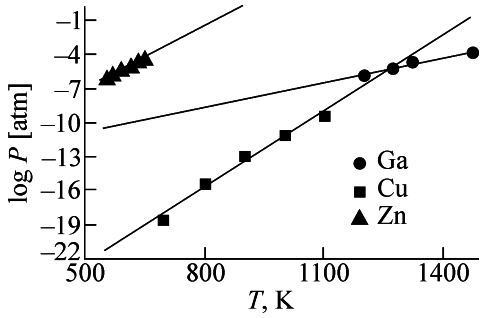

Fig. 2. Temperature dependence of the vapor pressure of Cu, Zn, and Ga.

Africa), TRIUMF (Vancouver, Canada), Institute of Nuclear Research (Troitsk, Moscow oblast, Russia); Institute of Theoretical and Experimental Physics (Moscow, Russia); and St. Petersburg Institute of Nuclear Physics (Gatchina, Leningrad oblast, Russia)], the above procedure of ^{67}Cu production seems the most promising.

Isolation of ^{67}Cu from Irradiated Zinc Targets

Irrespective of the procedure of radionuclide accumulation, ^{67}Cu can be isolated by vacuum distillation separation of the irradiated zinc targets performed at temperature and pressure providing their complete removal and excluding evaporation of the desired product. This procedure is based on the difference of the evaporation rates and partial vapor pressures of the elements being separated over the solid phase [13].

This method requires changes in the common design of the cyclotron targets (copper or silver supports with deposited isotope material; their modification should exclude physicochemical interaction (diffusion, alloying) of the material being activated and final radionuclides with the support material at elevated temperatures. One of possible solutions is preparation of the targets from inert high-melting materials.

Special cyclotron supports were developed for irradiation of zinc targets in derived beams of domestic reactors (e.g., U-120 reactor of the St. Petersburg University). In this target, the material to be activated is deposited on a thin (750 μm) tantalum support (24 mm in diameter); the "loss" in the thermal conductivity of tantalum as compared to silver and zinc is compensated by optimal combination of the strength and mechanical properties. Zinc metal is deposited by fusion in an inert atmosphere in a special cavity (14 mm in diameter) in the support center. In the course of irradiation, the excess heat is removed from the back side of the tantalum support with water, and the face side and the inlet titanium foil (50 μm thick) separating the irradiated target and accelerator volume are additionally cooled with a helium flow. Below we analyze the feasibility of this approach in the development of new cyclotron targets (e.g., for more complex case such as accumulation of ^{124}I from elemental tellurium, whose thermal conductivity is smaller than that of zinc by nearly 2 orders of magnitude).

Copper-67 can be isolated in a metallic vacuum chamber providing the residual pressure in the working volume as low as 10^{-6} mm Hg. The pilot model was presented previously in [14]; now in collaboration with the Institute of Analytical Instrument-Making we developed a new commercial installation. The chamber is equipped with special fittings for connecting a vacuum pump (turbomolecular pump is preferable), irradiated cyclotron target, replaceable condenser for the evaporated staring isotope and impurity gallium radionuclides, water supply unit, valves for inert gas supply, heater, and thermocouples. The condenser is hermetically connected to a water supply unit, which is connected through a pipe with a water cooling system used in the course of distillation to maintain the required temperature. A furnace (equipped with a holder for irradiated target) is arranged over the condenser using a movable rod; the required temperature is controlled with thermocouples.

Using the pilot vacuum chamber, we isolated the products of nuclear reactions from natural metal zinc irradiated with deuterons (13.6/6.0 MeV). Zinc was virtually quantitatively removed from the irradiated target: after thermal treatment, no photopeaks at 0.4386 [^{69m}Zn, ^{68}Zn(d,p)] and 1.116 MeV [^{65}Zn, ^{64}Zn(d,p)] were recorded. The yields of ^{66}Ga [^{66}Zn$(d,2n)$], ^{67}Ga [^{66}Zn(d,n) and ^{67}Zn$(d,2n)$], and ^{64}Cu [^{66}Zn(d,α) and ^{67}Zn$(d,\alpha n)$] were about 98%, whereas the content of impurity zinc radionuclides was less than 0.02%.

A significant difference in the vapor pressures of all the elements to be separated (Zn, Cu, Ga) in a wide temperature range (Fig. 2) should allow preparation of ^{67}Cu with a radionuclide purity of about 99%.

PRODUCTION OF ^{124}I USING TELLURIUM CYCLOTRON TARGETS

Optimal Energy of Protons and Yield of the Final Product

The most efficient way to prepare ^{124}I is the reaction ^{124}Te(p,n), which can be performed on compact

accelerators. In the course of irradiation of the enriched ^{124}Te target with protons with the initial energy of 15–18 MeV (e.g., close to the energies of the derived beams of IBA Cyclone 18/9 or MGTs-20 accelerator), the following reactions can proceed: ^{124}Te$(p,n)^{124}$I, E_{thr} 3.98 MeV, $T_{1/2}$ 4.18 days; ^{124}Te$(p,2n)^{123}$I, E_{thr} 11.63 MeV, $T_{1/2}$ 13.19 h; ^{124}Te$(p,d)^{123m}$Te, E_{thr} 7.24 MeV, $T_{1/2}$ 119.7 days; ^{124}Te$(p,{}^3\mathrm{He})^{122}$Sb, E_{thr} 9.90 MeV, $T_{1/2}$ 2.7 days; ^{124}Te$(p,\alpha n)^{120m}$Sb, E_{thr} 5.33 MeV, $T_{1/2}$ 5.76 days.

The highest yields of transmutation radionuclides will be observed for reactions (p,n) and $(p,2n)$, i.e., the main radionuclide impurity in the final product will be ^{123}I. The energy dependences of the yields of ^{123}I and ^{124}I [7] are given below.

Energy, MeV	Yield of ^{123}I, MBq μA^{-1} h^{-1}	Yield of ^{124}I, MBq μA^{-1} h^{-1}
8/0	–	0.0056
9/0	–	0.0464
10/0	–	0.184
11/0	–	0.407
12/0	0.0121	0.666
13/0	0.184	0.851
14/0	0.854	1.15
15/0	2.58	1.39
16/0	5.55	1.57
18/0	17.0	1.78

The optimal radionuclide purity of the target product for medical purposes should be no less than 99.5%, i.e., the content of ^{123}I should be no more than 0.5%. In this case, the initial proton energy should not exceed 11.6 MeV. Under these conditions, the $(p,2n)$ reaction is completely prevented; the maximal yield of ^{124}I is 0.5568 MBq μA^{-1} h^{-1} at the proton energy of 11.6/8.0 MeV [7].

To decrease the amount of expensive initial starting material (^{124}Te), the energy of the charged particles should be lower (11.6/8.6 MeV); in this case the loss of ^{124}I would be no more than 3.4%. The data on the yields of the final product as influenced by the energy of charged particles and intensity of the proton beams are given below.

11.6/8.0 MeV		11.6/8.6 MeV	
Intensity of the proton beam, μA	Yield of ^{124}I, MBq	Intensity of the proton beam, μA	Yield of ^{124}I, MBq
5	2.784	5	2.690
10	5.568	10	5.379
15	8.352	15	8.069
20	11.136	20	10.758

The optimal energy of protons and the yields of the final product and impurity ^{123}I were evaluated using the reference data [7]. However, the data on the industrial production of ^{124}I at the Hammersmith Hospital (London, the United Kingdom) [3] showed that the absolute yields of ^{124}I given in this handbook are underestimated by a factor of almost 3.5. For example, the yield of ^{124}I at irradiation of the enriched tellurium target with 12.5-MeV protons is 2.5 MBq μA^{-1} h^{-1}, and not 0.76 MBq μA^{-1} h^{-1}, as given above. At the same time, the ratios of ^{124}I and ^{123}I are similar: only 2% of ^{123}I is remains in the target after irradiation of the enriched tellurium (99.8%) target.

Evaluation of the Effective Thickness and Weight of Tellurium Target; Criteria for Selection of the Support for Cyclotron Target Based on Elemental Tellurium

The paths of protons with various initial energies in elemental tellurium (1 mg cm^{-2} = 1.6 μm) [15] are given below.

Energy, MeV	Path, mg cm^{-2}
7	159.1
8	197.3
9	239.0
10	284.1
11	332.5
12	384.1

As a rule, the diameter of the proton beam in irradiation of the targets on the industrial IBA Cyclone 18/9 cyclotron and domestic MGTs-20 accelerator is 12 mm, i.e., the target area is 1.13 cm^2.

When ^{124}I is prepared using 11.6/8.0-MeV protons, their path in elemental tellurium is 265.9 μm. The weight of the cyclotron target is 188 mg, and the heat release in the target is 3.6 W μA^{-1}.

When ^{124}I is prepared using 11.6/8.6-MeV protons, their path in elemental tellurium is 225.8 μm. The weight of the cyclotron target is 159 mg, and the heat release in the target is 3.0 W μA^{-1}.

It is advisable to use as a support for elemental tellurium high-melting monoisotopic metals (V, Nb, Ta) to decrease the total radiation load after the irradiation, the number of possible nuclear reactions (8/0- or 8.6/0-MeV protons are adsorbed by the support), and to eliminate possible loss of ^{124}I in the support material in the course of isolation of the final product.

Table 2. Main parameters of thermal processes in irradiation of tellurium target (proton beam current 15 μA)

Part	Material	Layer thickness, μm	Energy loss, MeV	Proton energy, MeV	Heat release in irradiation, W	Thermal-power volume density, W m^{-3}
Inlet window	Ti (foil VT-1-0)	50	0.75	12.3/11.55	11.2	1.98×10^9
Target	Te	250	3.38	11.55/8.17	50.7	1.8×10^9
Support	Ta, electron-beam melting	143	8.17	8.17/0	122.5	7.6×10^9

Design of the Cyclotron Target Based on Elemental Tellurium

Criteria for selection of the support material. Comparative analysis of thermal and mechanical properties of these metals (V, Nb, Ta) [6] and typical products of nuclear reactions showed that metallic tantalum is the best support material for elemental tellurium. As compared to commonly used materials (Ag, Cu, Al, Pt), the loss in the thermal conductivity can be compensated by a decrease in the target thickness owing to higher strength properties of tantalum.

The main aim of this part of the study was to determine the process parameters of preparing ^{124}I under the conditions of operation of the industrial target assembly of the COSTIS system (COmpact Solid Target Irradiation System) for the derived beam of the IBA Cyclone 18/9 accelerator.

Main parameters of thermal processes in the course of irradiation of tellurium target on tantalum support are given in Table 2.

All further calculations were carried out taking into account the data on the operation conditions and geometric size of the target assembly of the COSTIS system (Fig. 3).

In our calculations we used the following data: size of the support disc (24 mm in diameter, 2 mm thick), diameter of the effective irradiation area (12 mm), size of the inlet titanium foil (12 mm in diameter, 0.05 mm thick); temperature of the target assembly (15–30°C), helium flow rate (25 l min^{-1}), water flow rate (16 l min^{-1}), and water pressure (0.5 MPa).

Since the tellurium target is cooled from the opposite sides with water and helium, maximal temperatures are observed in the material bulk and not on the target surface. The coefficient of heat transfer at the tellurium–helium boundary can be calculated only when the helium pressure is known (or set); it can be calculated taking into account the size of titanium window and the requirements of PNAE G-7-002–86 (Rules and Regulations in Nuclear Power Engineering, hereinafter PNAE) [16].

Calculations of the main characteristics of the helium heat exchanger. Helium heat exchanger is a diffuser–confuser. Arrangement of the tellurium and titanium surfaces in the area of this unit strongly intensifies the heat exchange; the diffuser divergence (or confuser convergence) angles in the direction of titanium increase the coefficient of heat transfer at the helium–titanium boundary, providing more efficient cooling.

At a proton beam current of 15 μA, the foil receives 11.2 W and can be cooled by helium convection (at a helium pressure P_{He} 30 mm Hg) if its mechanical contact with the stainless-steel frame of the heat exchanger is efficient.

With a decrease in the working pressure from 30 to 20 mm Hg, the temperature of the titanium foil decreases from 136 to 112 °C, and the conditional coefficient of the pressure reserve increases by a factor of almost 2. However, operation under such conditions is impossible because of the extremely high helium flow velocity (1306 m s^{-1} at P_{He} < 25 mm Hg) exceeding the speed of sound (~1060 m s^{-1}).

Our calculations of the helium pressures in accordance with the requirements of PNAE G-7-002–86 [16] showed that the titanium foil can operate at a helium pressure of 30 mm Hg. The maximal working stresses are smaller than 100 MPa at a maximal temperature of the titanium window of 138°C. With an increase in the helium pressure, the mechanical stresses linearly increase; the breaking stress decreases because of increasing temperature of the foil.

Evaluation of the principal dimensions of the tantalum support and its strength; determination of the working temperatures of the support and tellurium target. The choice of the dimensions of the tantalum support reduces to evaluation of the thickness (S_{Te}) of the hollow bottom where tellurium is placed. In turn, S_{Te} determines some main characteristics of the target: voltage level, maximal flexure,

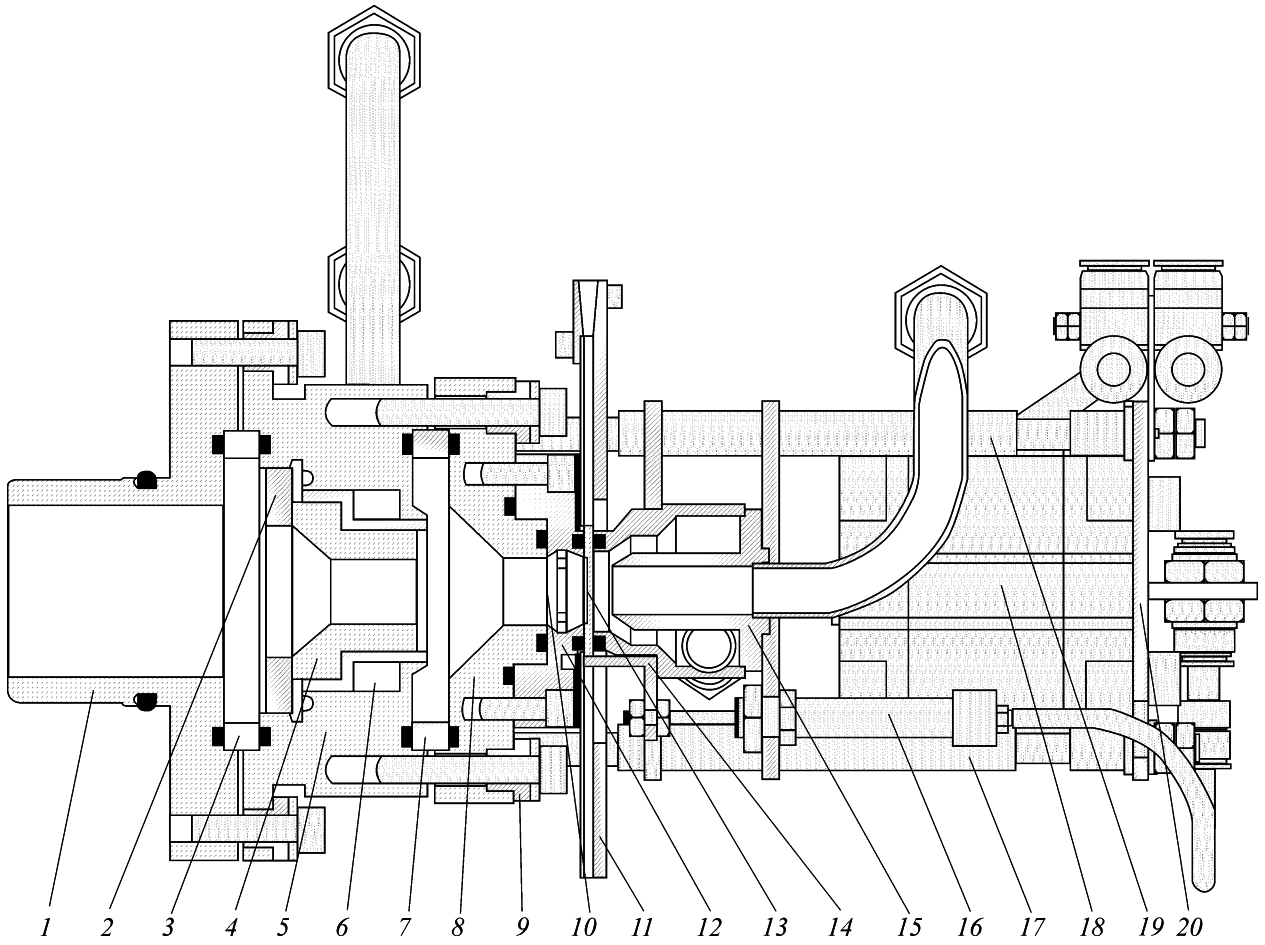

Fig. 3. Longitudinal section of the target assembly of the COSTIS system: (*1*) fitting for connecting the target assembly to the derived beam of the IBA Cyclone 18/9 accelerator, (*2*) graphite insert in the collimator, (*3*) part insulating the collimator from the grounded fitting, (*4*) ring graphite collimator with an aperture 12 mm in diameter, (*5*) water cooler of the collimator with an insert of oxygen-free copper, (*6*) channel for water supply, (*7*) part insulating the target from the collimator, (*8*) core fixing the support at the collimator, (*9*) insulator for assembling bolts, (*10*) titanium window (50-μm foil), (*11*) support for fixing the target, (*12*) helium cooling of the titanium foil and cyclotron target, (*13*) support with the starting material, (*14*) lock, (*15*) water cooling of the back side of the support, (*16, 17*) pneumocylinders releasing the target, (*18, 19*) pneumocylinders controlling the water jet, and (*20*) board of the target assembly.

which is especially important in operation with brittle targets and with materials poorly compatible with the support or intermediate layer (small depth of diffusion interaction $<10^{-7}$ m, low mutual solubility, significant difference in the linear coefficients of thermal expansion LCTE, etc.), temperature drop between maximal T of the heat-conducting layer and water temperature, temperature drop in the layers with internal heat sources, and radial temperature drop in the support and its change along the profile of the heat-conducting layer.

Our approximate strength calculations in accordance with PNAE G-7-002–86 [16] showed that the tantalum bottom should be 279 μm thick. Because of importance of deformation characteristics, we decided to equalize deflections along the axis of the COSTIS target and the suggested unit; as a result, S_{Te} was taken as 750 μm. This decreases the heat transfer in a support in the radial directions by 30% in comparison with a platinum support of the same thickness. However, this decrease is not decisive.

Our calculations of the stresses and deflections of the tantalum target as influenced by the pressure of cooling water and heat load (i.e., current of the charged particle beam) of the cyclotron target showed that the whole target cross section operates under the conditions of small compression stresses (from –14 to –45 MPa), which is the best regime providing stable operation of the metal for more than 100 h at beam currents of up to 20 μA.

Using the procedure for longitudinal flow along an impermeable plate [17, 18], we determined the coefficients of heat transfer of tantalum in water of 98000–67200 $W\,m^{-2}\,K^{-1}$, decreasing in the direction from the center. Taking into account these coefficients, we found that the maximal temperature in the irradiated layer of elemental tellurium is lower than 545.6 K (272.6°C).

Thus, our calculations showed the principal suitability of the target of elemental tellurium deposited on a tantalum support; the most dangerous cross section of the support operates under the compression conditions, which allows the beam current to be increased to 20 μA. To decrease the deflection of the tantalum support (i.e., to eliminate the possibility of exfoliation of elemental tellurium), its thickness can be increased to 1–1.5 mm.

Preparation of the Target Based on Elemental Tellurium

Because of weak interaction between the elements, formation of a strong tellurium coating directly on tantalum is impossible. Thus, it is necessary to make a thin intermediate layer providing sufficient diffusion junction of the composite without affecting the heat transfer.

The material of this layer should be characterized by the intermediate (between Ta and Te) coefficients of linear thermal expansion, fairly high thermal conductivity (to provide satisfactory heat removal during irradiation), ability to form strong coatings on the tantalum surface, high adhesion to tellurium to prepare strong coatings withstanding repeated cycles of irradiation and thermal treatment of the targets, and absence of the volatile products of nuclear reactions proceeding in the course of proton irradiation.

Metallic Ni is the most appropriate for this purpose: LCTEs of Ta, Ni, and Te (K^{-1}) are 6.79×10^{-6} (373–673 K), 13.2×10^{-6} (143–693 K), and 17.0×10^{-6} K^{-1} (273–373 K), respectively [6]; the heat conductivities of Ta, Ni, and Te ($W\,m^{-1}\,K^{-1}$), 45.3–53.6 (273–673 K), 67.0–71.4 (293–500 K), and 1.8–1.34 (350–700 K), respectively [6]. High mutual solubility of Ta and Ni and Ni and Te [19] should provide the required diffusion junction of the elements and stability of the final three-layer composite in the repeated cycles of irradiation and thermal treatment. Irradiation of nickel with protons yields radionuclides of cobalt and copper, whose vapor pressure at 700 K is less than 1×10^{-16} atm [6].

The optimal procedure to prepare the intermediate nickel layer of 3–5 μm thickness is electroplating, which is widely used in mechanical engineering. Then, the layer of elemental tellurium can be deposited by fusion in an inert atmosphere.

Design of the Sublimation Installation for Isolating ^{124}I

The radionuclide ^{124}I can be isolated using a sublimation installation with horizontal loading of the cyclotron target, equipped with an optical quartz separator and two furnaces.

The quartz separator is a two-cell device.

In the horizontal chamber (40 mm internal diameter and 150 mm length) ^{124}I is separated from irradiated elemental tellurium in the course of its melting. Under these conditions, the vapor pressure of Te is about 0.4 mm Hg, which is close to that of TeO_2 at radiochemical treatment of the commonly used targets [20]. Then the desired product is transported with a flow of heated inert carrier gas through a horizontal-vertical chamber (internal diameters of the horizontal and vertical sections of the chambers are 16 and 10 mm, respectively) to a trap with 0.01–0.02 M NaOH.

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