was used as a tracer. The comparison was made between porous cation resin (home made) and Zerolit 225 cation resin, and the experimental results are given in Fig. 1. The results obtained show that the porous resin has better properties than Zerolit 225 resin in the separation of rare earth impurities from matrix yttrium.

The main spearation parameters are as follows: column length: 2 X 50 cm; resin size: ~200 mesh; concentration of the eluent (α-HIBA): 0.15 *M* (pH 5.4) for Y, 0.5 *M* (pH 5.4) for La, Ce, Pr, Nd, Sm, Eu.

Under these conditions the rare earth impurities (La–Eu) can be completly separated from matrix yttrium, the matrix residue amount is less than 100 μg for 1 g of Y_2O_3 on the column. Typical results are shown in Fig. 2.

Spectroscopic Determination. The solution dry-residue method with high absolute sensitivity was adopted to analyze the concentrate of rare earths. The detailed studies on carrier influence, matrix effect, and controlled atmosphere ratio (Ar: O_2) were made in this paper, and the adequate conclusions are given below:

(1) The addition of alkali elements increases the line intensities of rare earths, the increasing order is Cs > Rb > K > Na;

(2) The line intensities of La, Ce, Pr, Nd, Sm and Eu are rising with the concentration of CsCl, the optimal concentration range of CsCl in solution dry-residue method is from 5 to 20 mg/ml. If its concentration is higher than 20 mg/ml, the increase of the background and the decrease of the line intensities of rare earths will be observed (Fig. 3).

(3) The influence of matrix yttrium and third elements in concentrate should be considered. The experimental results show that the permissive maximum amounts of Y_2O_3 and CaO are 6 mg/ml and 5 mg/ml respectively.

(4) Controlled atmosphere ratio of 4:1 (Ar:O_2) was employed, and the gas-chamber used is shown in Fig. 4.

Sample Analysis. Analytical results for La, Ce, Pr, Nd, Sm and Eu in high-purity Y_2O_3 are listed in Table I.

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E33

Accumulation of Transplutonium Elements in Accelerators

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E34

Uranyl Doped Glasses for Solar Concentrators

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Solar concentrators containing uranyl are presented. Various types of glasses were investigated: silicate, borate and fluorinated glasses.

The electronic and fluorescence spectra were recorded, the life-time of the excited state and some quantum yields have been measured.

The variations of the quantum yield can be related with uranium–uranium interactions. Consequently the best concentration of the uranyl depending upon the nature of the glass was evaluated.

Thus it is possible to build solar concentrators with adaptated parameters.

E35

Cyclotron Production of Gamma-Emitting Actinides, as Tracers for Metabolic and Waste Disposal Studies

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The employ of short-lived radionuclides as tracers for metallobiochemical studies in laboratory animals is well known and widely investigated [1]. Furthermore high-specific-activity 'neutron-deficient' radionuclides produced by light charged particle activation in low energy cyclotrons, are suitable tracers for more general investigations in the following fields:

1. Nuclear medicine (as radiodiagnostics)
2. Inorganic and organic chemistry

3. Metallobiochemistry (for *in-vivo* studies)
4. Waste disposal of nuclear fuel
5. Others.

It is the purpose of this work to investigate the possibility of producing γ-emitting radiotracers of neptunium and plutonium with suitable half-lives for waste disposal studies of nuclear fuel, employing the cyclotrons which are running today in Italy.

In Table I is reported the status (1983) of the cyclotrons which are either running or near to be installed in Italy in the next future, with their technical parameters.

Finally, the superconducting cyclotron (CS) for heavy-ions (HI) beam acceleration at energies from 10 to 100 MeV/amu, which is building at the Cyclotron Laboratory of the Milan University, is not reported in Table I, being mainly devoted to high energy heavy-ions studies, ultra-heavy elements production and fundamental physics.

At the Milan Cyclotron Laboratory several studies have been carried out in the last ten years about the production of radionuclides mainly devoted to the following applications:

1. Nuclear medicine: under the financial support of the Istituto Nazionale di Fisica Nucleare (INFN) and the Consiglio Nazionale delle Ricerche (CNR), Progetto Finalizzato 'Biomedical Technology' [2–4].
2. Metallobiochemistry of heavy metal pollution: in collaboration with the Radiochemistry Division of the JRC Euratom, Ispra [5–7].

In order to start the production of short-lived technetium and actinide (Np, Pu) radiotracers for nuclear waste disposal studies, some preliminary irradiation have been carried out at the Milan Cyclotron Laboratory. The high-current proton, deuteron and helium (4-He, 3-He) beams of the Scanditronix MC 40 cyclotron of the JRC Euratom (see Table I), will enable production of large activities of these radionuclides.

Gamma-Emitting Actinides. In Table II are reported the calculated Q values (MeV) and Coulomb Barriers (MeV) of the main nuclear reactions for production of 'neutron-deficient' Pu and Np radionuclides by low-energy light ions irradiation.

Cyclotron Production of 235-Np. Among the 'neutron-deficient' neptunium radionuclides the only one which presents suitable characteristics for waste disposal studies is the 235-Np($t_{1/2}$ = 396d, X-rays), while the shorter-lived 234-Np($t_{1/2}$ = 4.4d, γ = 1528 keV, others) can be used as a tracer for metabolic patterns determination of neptunium in short term experiments.

At Milan Cyclotron Laboratory some preliminary irradiations have been carried out on metallic natural 238-U targets, 1 mm thick, which were cased in the internal water cooled probe of the cyclotron, with a beam current of 5 μA for 2 hours, at a 44.5 MeV incident proton energy, in order to induce the 238-U-(p, 4n) nuclear reaction. A strong activation of the target (several R/h) has been noticed, due to a lot of undesired secondary activation and U-fission products. The best results have been obtained, on the contrary, by irradiation on sheets of uranium/aluminium alloy (80:20 w/w), 1 mm thick, 89.84 enriched in 235-U, with a beam current of 2 μA for 5 hours, at a 25 MeV incident proton energy, in order to induce the 235-U(p,n) nuclear reaction. In this case the exposure by the irradiated target (some tenth mR/h) resulted to be very much lower than the first one. A very high radionuclidic purity mixture of 234, 235-Np was obtained after a suitable radiochemical separation from the uranium target. In conclusion this route seems to be promising for routine production of neptunium γ-emitting tracers.

Cyclotron Production of 237-Pu. Among the 'neutron-deficient' plutonium radionuclides the only one with suitable characteristics for metabolic [9–11] and waste disposal studies seems to be the 237-Pu ($t_{1/2}$ = 45.6 d, γ = 60 keV, X-rays). It can be produced via 235-U(α,2n), 237-Np(d,2n), 235-U(τ, n), 238-U(τ,4n), 238-U(α,5n), 234-U(α,n) and 237-Np(p,n) nuclear reactions (see Table II). Among these reactions the most investigated are the (α,2n) and d,2n) [8, 10, 11, 12]. A few data are available

TABLE I.

Cyclotron	Laboratory	Cp	E MeV	$I_{\mu A}^{ext}$	Main applications
AVF	University of Milan (1965–)	p	45	5	Nuclear and Appl. Phys.
Scanditronix MC 40	JRC Euratom, Ispra (1982–)	p	40	65	
		d	20	65	Radiation Damage
		α	40	30	Isotope Production
		τ	53	30	
CGR 320	CNR Pisa (end of 1983?)	p	15	50	Isotope Production for Nuclear Medicine
		d	8	50	
Scanditronix MC 40	CNR and Univ. Milan (1985?)	*idem*/JRC Ispra			Isotope Production for Nuclear Medicine

TABLE II.

Nuclear reaction	Q-value (MeV)	Threshold (MeV)	Coulomb Barrier (MeV)
235-U(p,n)235-Np	−0.91	0.91	12.9
235-U(p,2n)234-Np	−8.98	9.02	12.9
235-U(p,3n)233-Np	−13.90	13.96	( )
234-U(p,n)234-Np	−2.60	2.61	12.9
234-U(p,2n)233-Np	−8.63	8.67	12.9
238-U(p,n)238-Np	−0.90	0.90	12.9
238-U(p,2n)237-Np	−6.33	6.35	12.9
238-U(p,3n)236-Np	−13.06	13.12	( )
238-U(p,4n)235-Np	−18.74	18.82	( )
238-U(p,5n)234-Np	−25.70	25.81	( )
283-U(p,6n)233-Np	−31.73	31.86	( )
235-U(d,n)236-Np	2.54	0.00	12.5
235-U(d,2n)235-Np	−3.13	3.16	12.5
235-U(d,3n)234-Np	−10.09	10.18	12.5
235-U(d,4n)233-Np	−16.12	16.26	( )
234-U(d,n)235-Np	2.14	0.00	12.5
234-U(d,2n)234-Np	−4.82	4.87	12.5
234-U(d,3n)233-Np	−10.86	10.95	12.5
237-Np(p,n)237-Pu	−1.01	1.01	13.0
237-Np(p,2n)236-Pu	−7.00	7.03	13.0
237-Np(p,3n)235-Pu	−14.32	14.38	( )
237-Np(d,n)238-Pu	3.71	0.00	12.6
237-Np(d,2n)237-Pu	−3.23	3.26	12.6
237-Np(d,3n)236-Pu	−9.23	9.31	12.6
237-Np(d,4n)235-Pu	−16.55	16.69	( )
235-U(α,n)238-Pu	−10.83	11.02	24.1
235-U(α,2n)237-Pu	−17.77	18.08	24.1
235-U(α,3n)236-Pu	−23.77	24.18	( )
235-U(α,4n)235-Pu	−31.09	31.62	( )
234-U(α,n)237-Pu	−12.51	12.72	24.1
234-U(α,2n)236-Pu	−18.50	18.82	24.1
234-U(α,3n)235-Pu	−25.82	26.26	( )
238-U(α,n)241-Pu	−11.18	11.37	25.4
238-U(α,2n)240-Pu	−16.59	16.87	25.4
238-U(α,3n)239-Pu	−23.05	23.43	25.4
238-U(α,4n)238-Pu	−28.66	29.14	( )
238-U(α,5n)237-Pu	−35.60	36.20	( )
238-U(α,6n)236-Pu	−41.60	42.30	( )
235-U(τ,n)237-Pu	2.78	0.00	24.5
235-U(τ,2n)236-Pu	−3.22	3.26	24.5
235-U(τ,3n)235-Pu	−10.54	10.67	24.5
235-U(τ,4n)234-Pu	−16.80	17.01	24.5
238-U(τ,n)240-Pu	3.96	0.00	24.3
238-U(τ,2n)239-Pu	−2.49	2.53	24.3
238-U(τ,3n)238-Pu	−8.11	8.21	24.3
238-U(τ,4n)237-Pu	−15.05	15.24	24.3
238-U(τ,5n)236-Pu	−21.05	21.32	24.3

about the (τ,4n) reaction [12]. At the Milan Cyclotron Laboratory the employ of the 237-Np(p,n) reaction has been considered. In principle, if the proton energy is lower than the threshold of the (p, 2n) reaction which leads to the α-emitting 236-Pu, the (p,n) reaction seems to lead to a 237-Pu with a high radionuclidic purity, higher than that obtained via (d,2n) and (α,2n) reactions. Only preliminary irradiations on a 'thin' layer of 237-Np deposited and sealed between Al foils led to a very complicated mixture of γ-emitting products, which made impossible to perform conventional γ measurements without a suitable radiochemical separation.

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E36

Comparative Study of Self-Diffusion of the Trivalent Ions Eu^{3+}(4f) and Am^{3+}(5f) in Aqueous Solutions

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The self diffusion coefficients of the $^{152}Eu^{3+}$ ion aqueous nitrate solution and the $^{241}Am^{3+}$ ion in neodymium perchlorate solution are determined by the open end capillary method (OCM). The aim of this work is as follows: Verification of the Onsager