Production of stable isotopes in RRC "Kurchatov Institute"

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Production of stable isotopes in RRC "Kurchatov Institute"

Electro-magnetic method
Physical Chemical (rectification, chemical exchange)
Gas centrifuges
Optical methods (AVLIS) (MLIS) Photochemistry
Plasma ICR method

H							He		
Li	Be	B	C	N	O	F	Ne		
Na	Mg	Al	Si	P	S	Cl	Ar		
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni
Cu	Zn	Ga	Ge	As	Se	Br	Kr		
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd
Ag	Cd	In	Sn	Sb	Te	I	Xe		
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt
Au	Hg	Tl	Pb	Bi	Po	At	Rn		
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	110
111	112	(113)	114	(115)	116	(117)	118		

La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Production of stable isotopes in RRC "Kurchatov Institute"

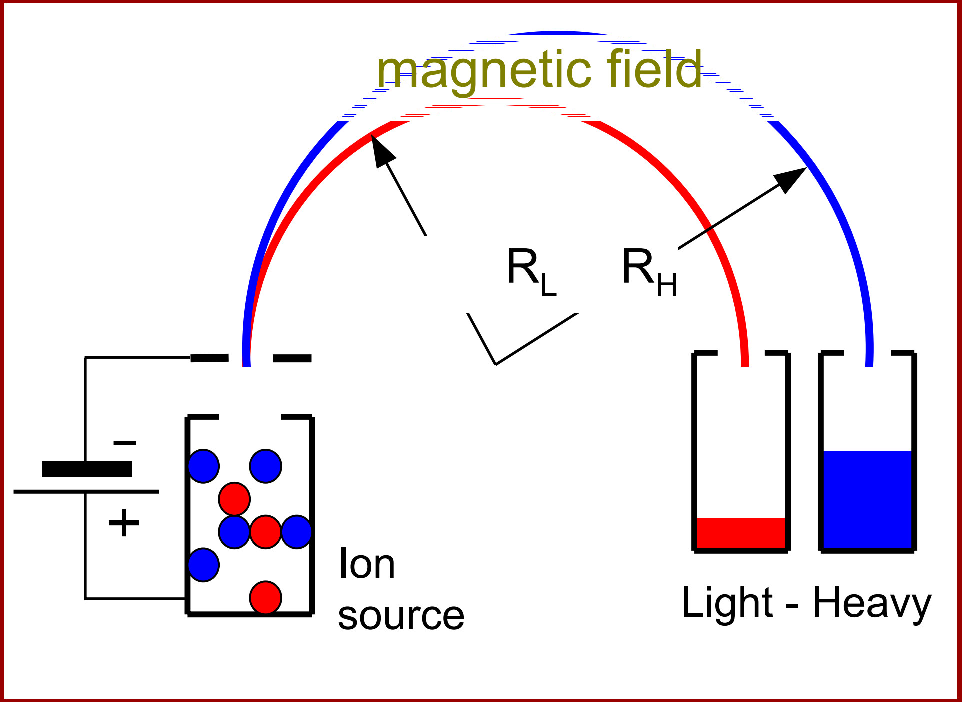
Location of main producers of stable isotopes in Russia

All technologies are presented in RRC “Kurchatov Institute”

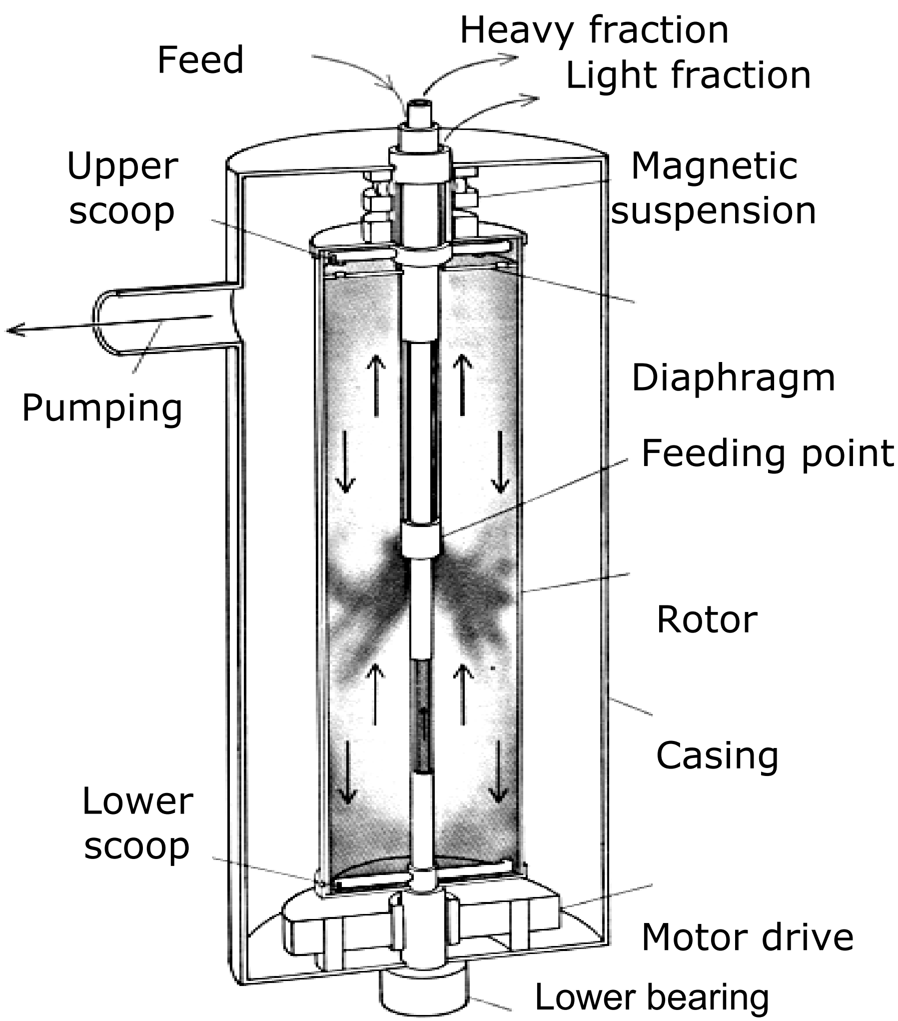
EM isotopes

EM separator is installed in
Institute of Nuclear Fusion

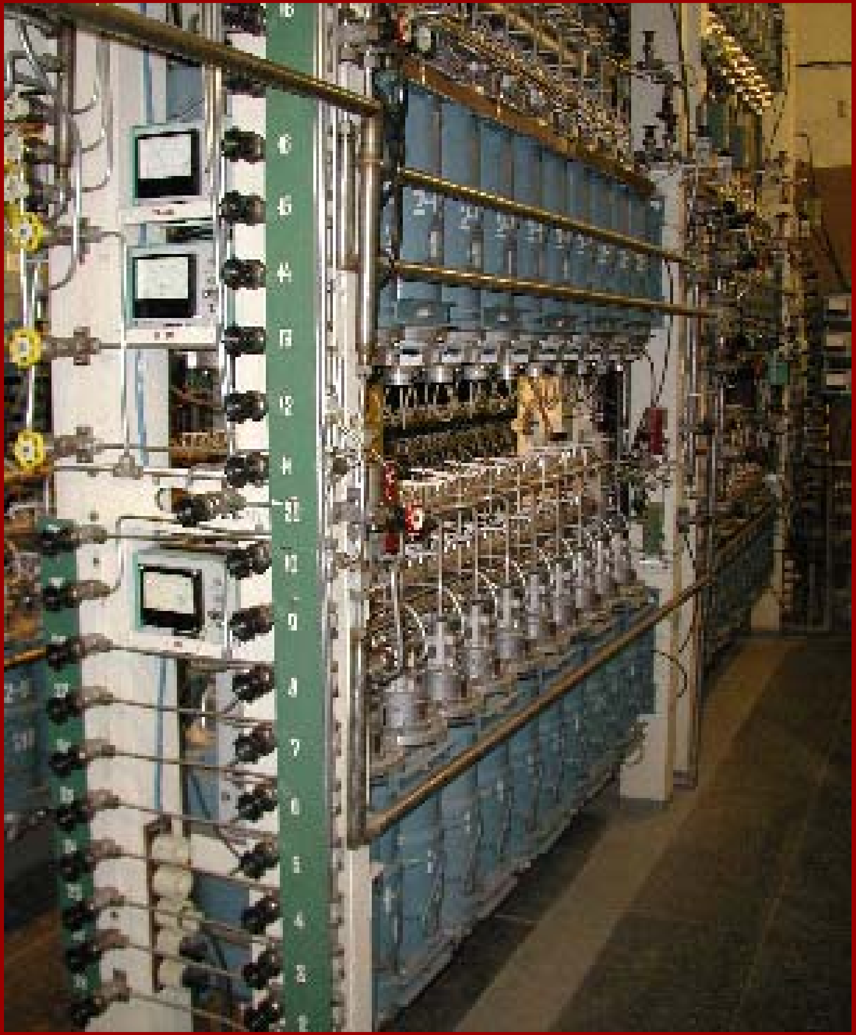
Main products: Tl-203, Zn-68, Pd-102, Yb-168



Centrifuge separation



Gas centrifuge diagram



Centrifuge cascade of IMP RRC KI

Volatile compounds for centrifuge separation

Fluorides, oxyfluorides, chlorides	Oxides, Carbonyls	Metal organics	Rare gases
SiF_4, SF_6, GeF_4, SeF_6, TeF_6, MoF_6, IrF_6, WF_6 CrO_2F_2, POF_3, $Ni(PF_3)_4$, $TiCl_4$ $SiCl_3H$, $GeCl_4$	OsO_4 $Fe(CO_3)_5$ CO_2	$Sn(CH_3)_4$ $Pb(CH_3)_4$ $Cd(CH_3)_2$ $Zn(CH_3)_2$ $Ga(CH_3)_3$	Xe, Kr

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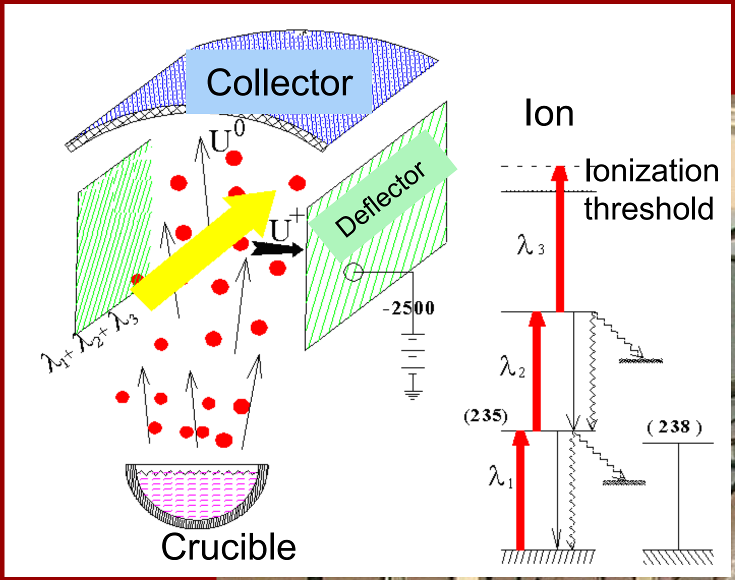
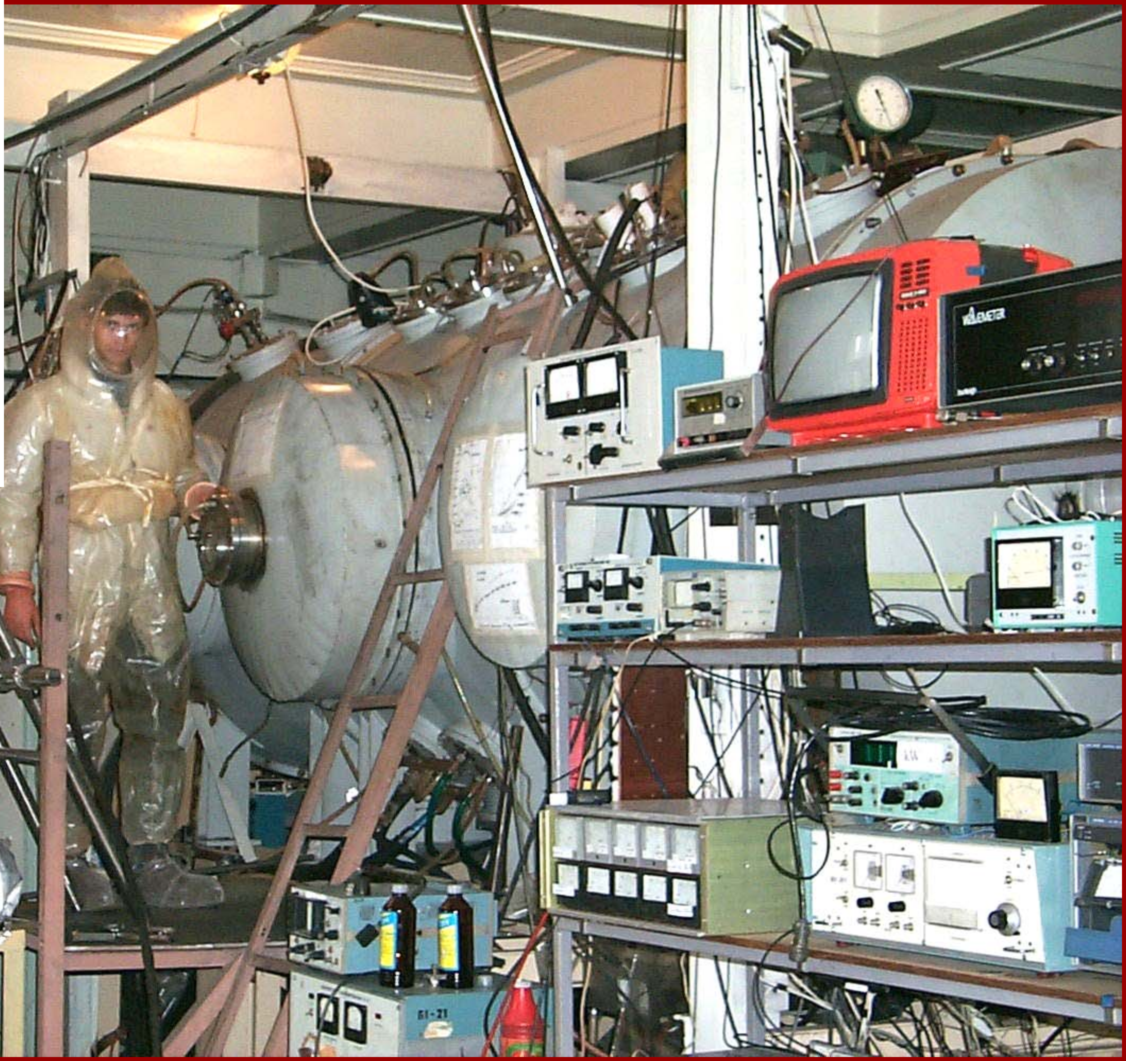
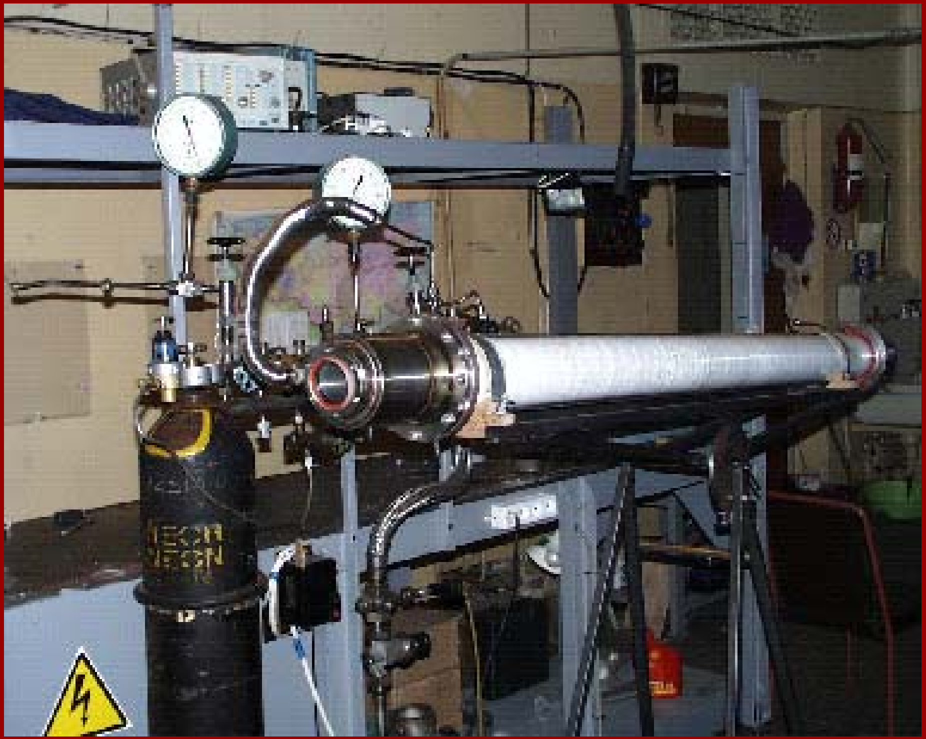




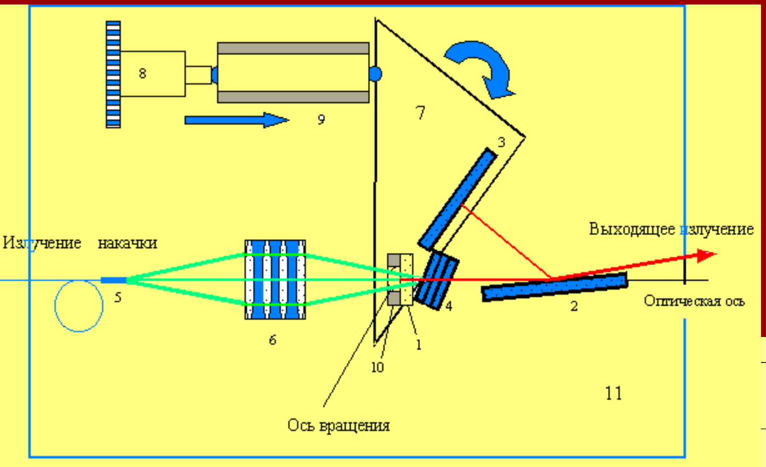
AVLIS - atom vapor laser isotope separation

AVLIS

CVL – copper vapor lasers

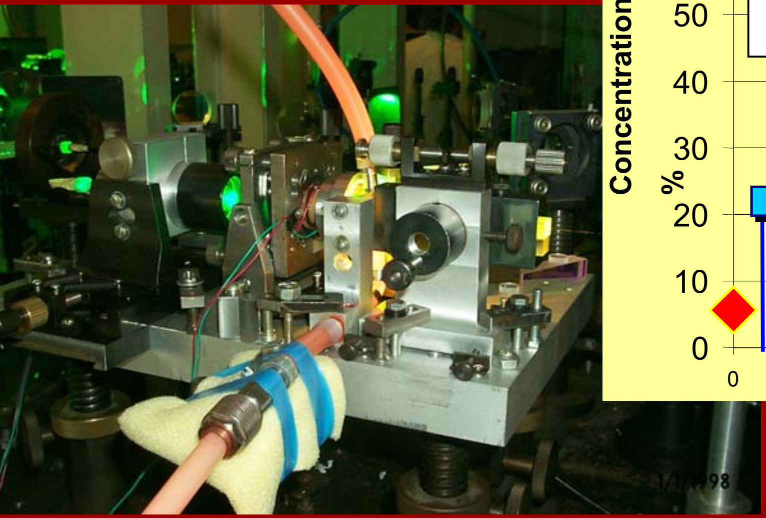


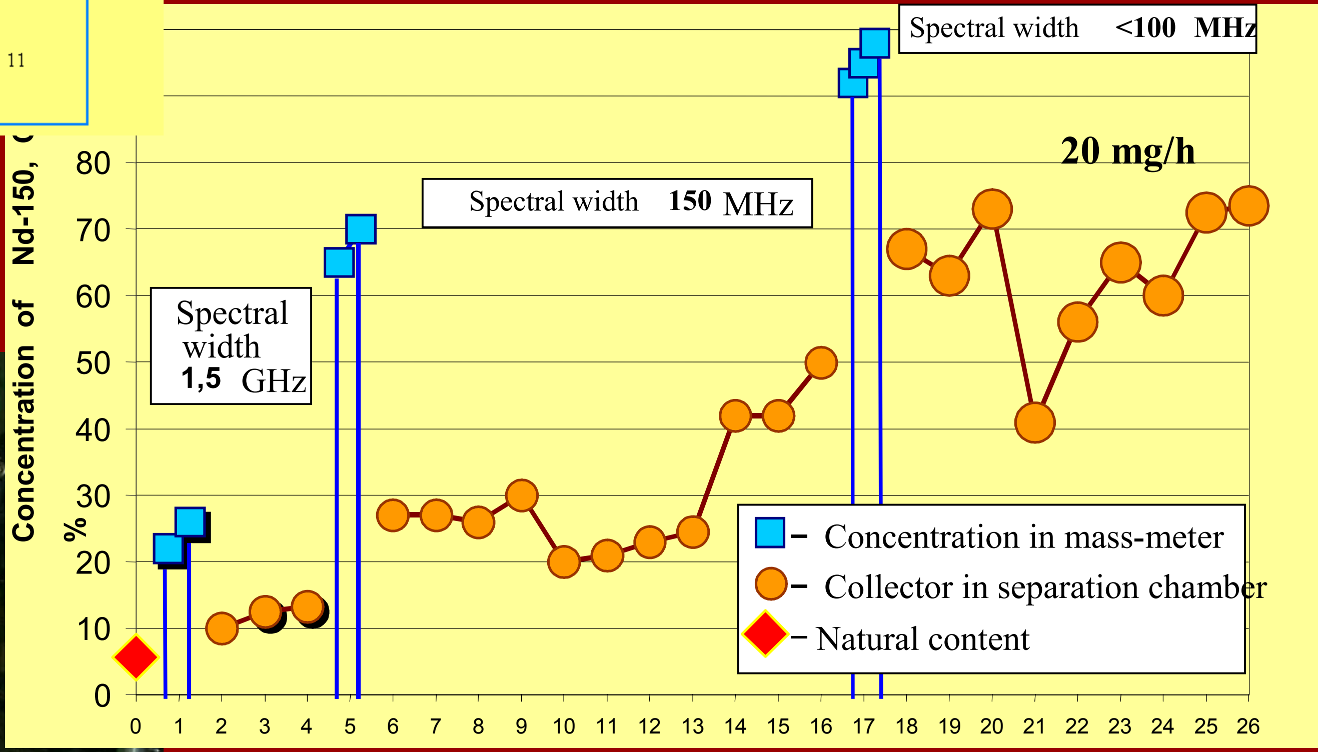
AVLIS



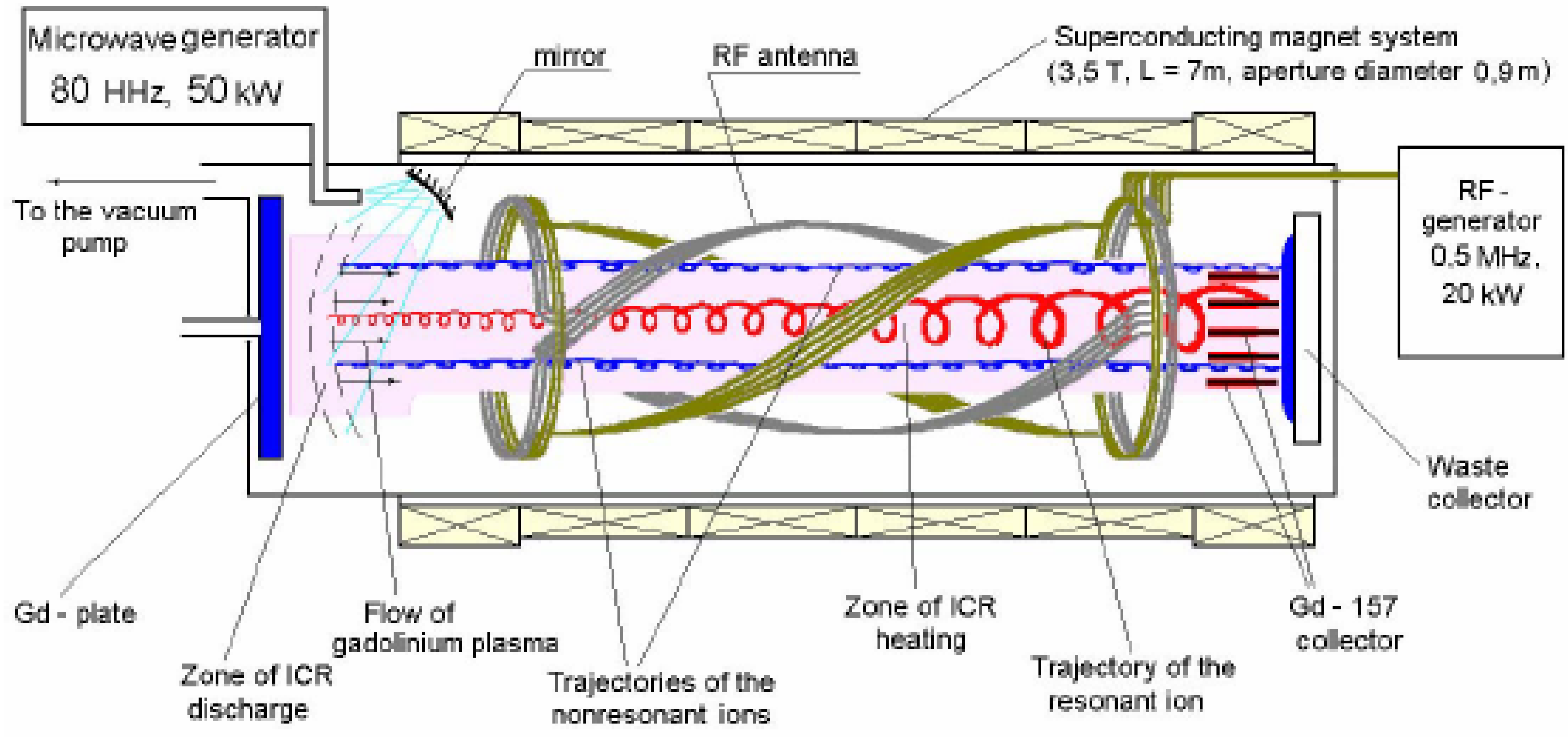
Single mode dye laser

Nd-150 extraction





MCIRI isotope separation system



$Q \approx 10$ kg/day

$I_{eq} \leq 100$A

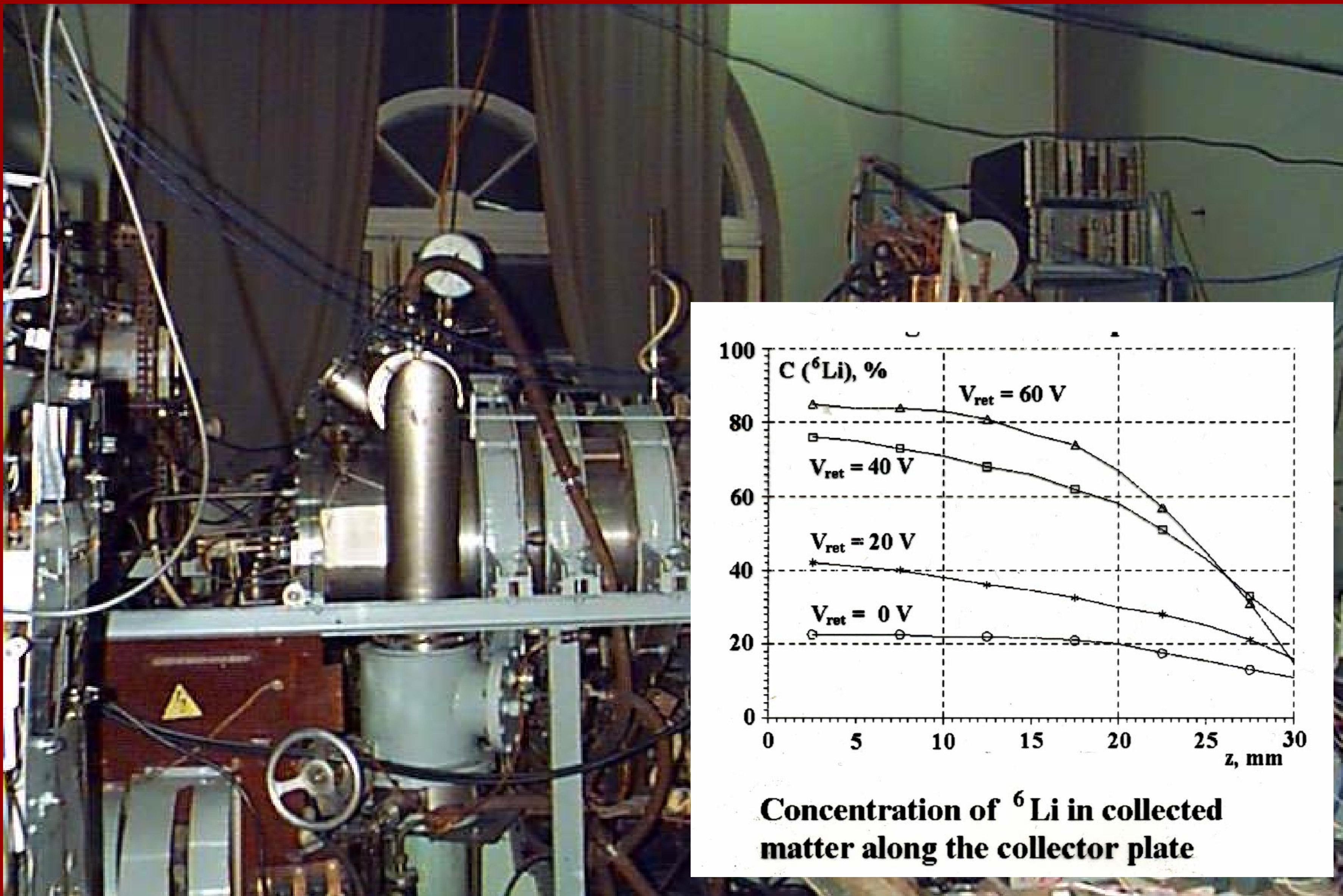
Zone of homogeneous field

$B = 3{,}5$ T, $\frac{\Delta B}{B} \leq 3 \cdot 10^{-4}$

$l = 5$ m, diameter 0,5 m.

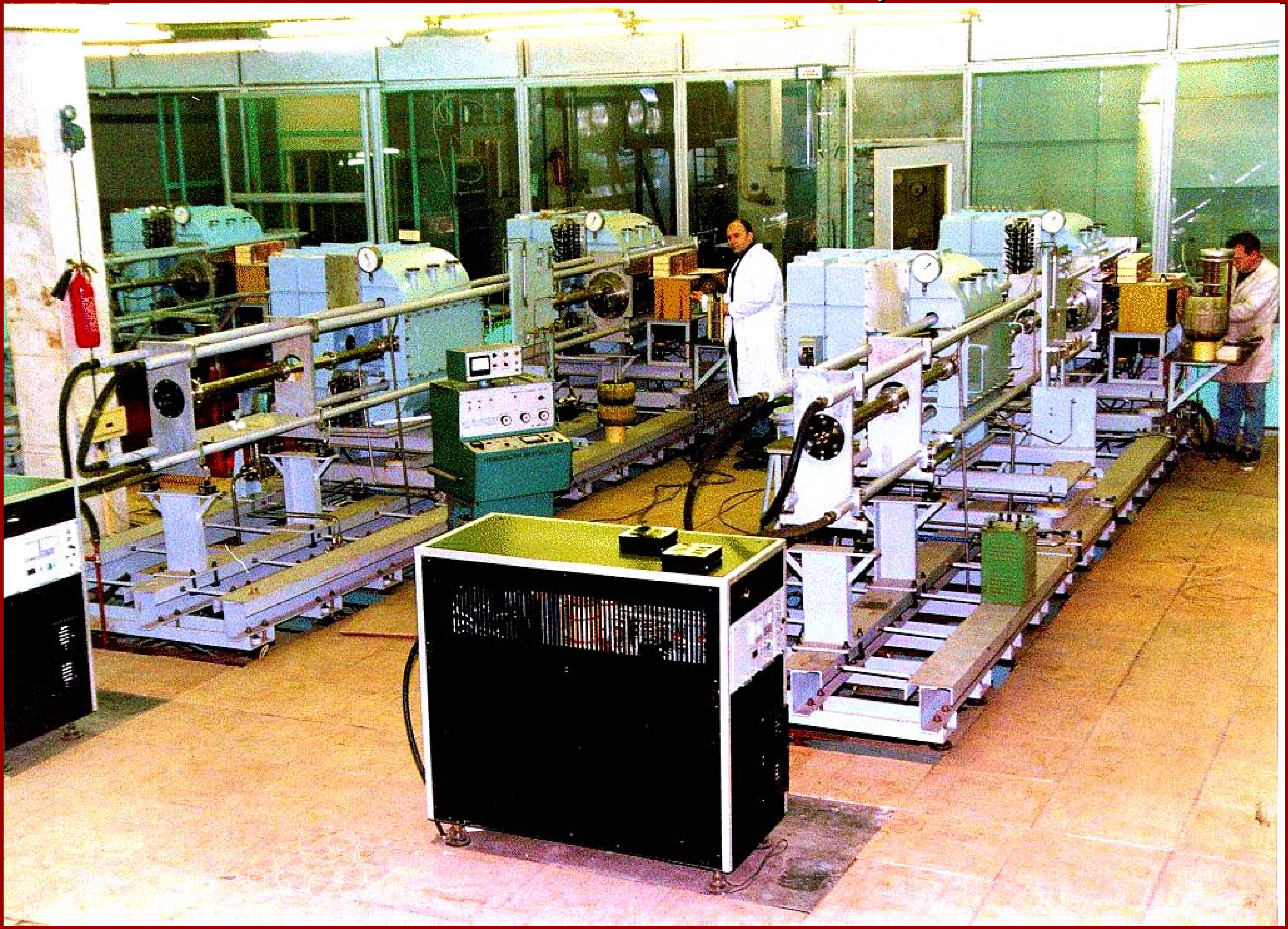
^{157}Gd (80%)	250 g/day
^{102}Pd (40%)	10 g/day
^{150}Nd (80%)	200 g/day
^{48}Ca (20%)	10 g/day

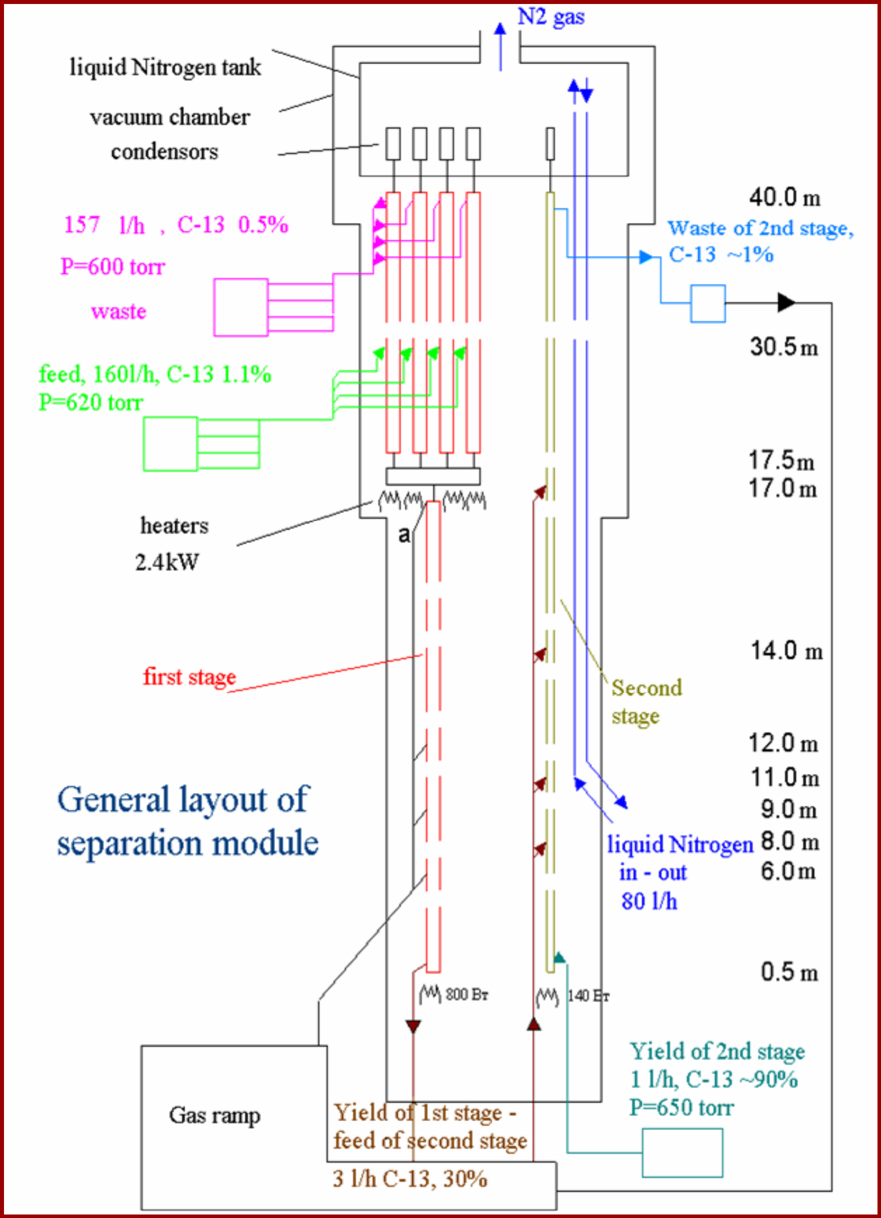
Plasma ICR installation "Sirena" for Lithium isotopes separation



Concentration of ^{6}Li in collected matter along the collector plate

Laser installation for C-13 production

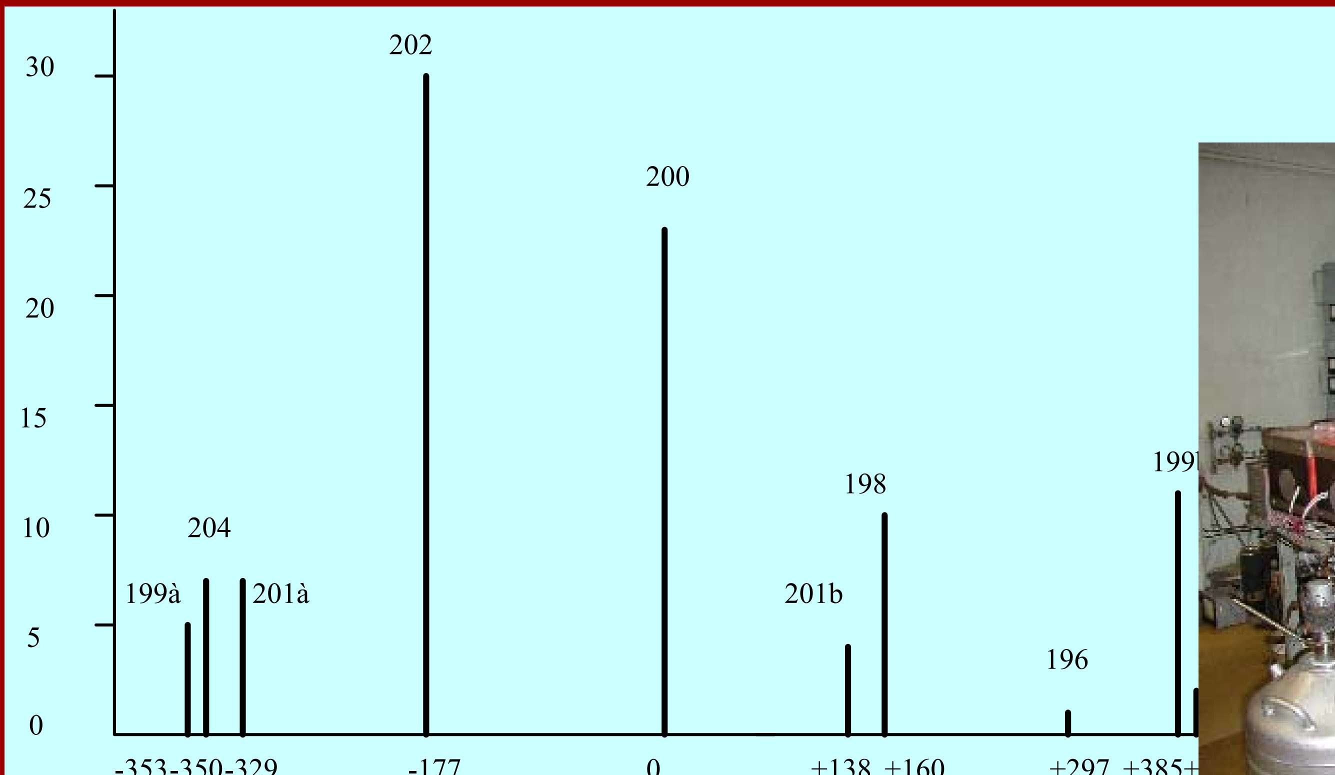




Production of carbon isotopes by means of cryogenic rectification

Photo-chemical separation of Mercury isotopes

Hg+hv(253.7nm) → Hg* + O_2 → HgO_2* + C_4H_6 →HgO + hydrocarbons oxides



For today even isotopes
Hg-196, Hg-198, Hg-200, Hg-200
have been produced.
Hg-199, Hg-201, Hg-204
are under investigating.

Application of stable isotopes

Nuclear energy
^{10}B, ^{157}Gd, ^{64}Zn (depleted), ^{15}N

Nuclear Physics
^{136}Xe, ^{150}Nd, ^{76}Ge, ^{116}Cd, ^{50}Cr …
^{48}Ca

Medicine, biology, ecology
Diagnostics (^{13}C, ^{18}O, ^{17}O, ^{129}Xe), isotope labels
Targets for r/a isotopes production

Semiconductor electronics, solid state physics
Si, Ge, Ga

Separation technology for specific isotopes

Isotope	Method
^{50}Cr	Centrifuge
^{76}Ge	Centrifuge
^{82}Se	Centrifuge
^{100}Mo	Centrifuge
^{116}Cd	Centrifuge
^{130}Te	Centrifuge
^{136}Xe	Centrifuge
^{96}Zr	AVLIS, ICR
^{150}Nd	AVLIS, ICR

The problem of raw material for isotope production

World production of natural Xenon ~ 30,000 kg

World production (including refinery) of natural Germanium ~ 30,000 kg

$Cd(CH_3)_2$ is expensive compound

Salient Statistics—United States:	**1999**	**2000**	**2001**	**2002**	**2003[e]**
Production, refinery[e]	20,000	23,000	20,000	15,000	12,000
Total imports[1]	12,400	8,220	8,240	13,100	12,000
Exports	NA	NA	NA	NA	NA
Consumption[e]	28,000	28,000	28,000	28,000	24,000
Price, producer, yearend, dollars per kilogram:					
Zone refined	1,400	1,250	890	620	470
Dioxide, electronic grade	900	800	575	400	300
Stocks, producer, yearend	NA	NA	NA	NA	NA
Employment, plant,[2] number[e]	85	90	90	85	65
Net import reliance[3] as a percentage of estimated consumption	NA	NA	NA	NA	NA

Recycling: Worldwide, about 30% of the total germanium consumed is produced from recycled materials. During the manufacture of most electronic and optical devices, more than half of the germanium metal used is routinely recycled as new scrap. Little domestic germanium returns as old scrap because there is a low unit use of germanium in most electronic and infrared devices.

Import Sources (1999-2002):[4] China, 33%; Belgium, 25%; Taiwan, 19%; Russia, 9%; and other, 14%.

As of March 31, 2003, the NDS inventory of germanium metal was 41,460 kg
— all of which has been authorized for sale.

Total world stockpile ~ 60,000 kg

The major end uses for germanium

polymerization catalysts	35%
infrared optics	25%
fiber-optic systems	20%
electronics/solar electrical applications	12%
other (phosphors, metallurgy, and chemotherapy)	8%

45% of consumption in chemical form of $GeCl_4$

Volatile compounds for centrifuge separation

Fluorides, oxyfluorides, chlorides	Oxides, Carbonyls	Metal organics	Rare gases
SiF_4, SF_6, GeF_4, SeF_6, TeF_6, MoF_6, IrF_6, WF_6 CrO_2F_2, POF_3, $Ni(PF_3)_4$, $TiCl_4$ $SiCl_3H$, $GeCl_4$	OsO_4 $Fe(CO_3)_5$ CO_2	$Sn(CH_3)_4$ $Pb(CH_3)_4$ $Cd(CH_3)_2$ $Zn(CH_3)_2$ $Ga(CH_3)_3$	Xe, Kr

$GeCl_4$ can be used as working material for ^{76}Ge extraction !!!

Mass distribution in $GeCl_4$

M	210	212	213	214	215	216	217	218	219	220	221	222	224
C (%)	6,68	**17,58**	2,53	**27,66**	**3,27**	**24,46**	**1,59**	**12,05**	**0,34**	**3,31**	0,03	**0,47**	0,03
Ge-70	1	0,492	0	0,152	0	0,037	0	0,006	0	0	0	0	0
Ge-72	0	0,508	0	0,418	0	0,23	0	0,101	0	0,03	0	0	0
Ge-73	0	0	1	0	1	0	1	0	1	0	1	0	0
Ge-74	0	0	0	0,43	0	0,63	0	0,622	0	0,489	0	0,276	0
Ge-76	0	0	0	0	0	0,103	0	0,272	0	0,481	0	0,724	1
% (76)						2,519		3,253		1,592		0,340	0,03

Mass distribution in GeF_4

M	146	148	149	150	152
C (%)	20.51	27.43	7.76	36.54	7.76

GeF_4

There is no material on the market. Additional step – synthesis of GeF4, which increases cost of raw material.

After separation work material must be converted back to the oxide or metal and must be purified.

Good extraction efficiency.

Lower separation work.

$GeCl_4$

Main material in Germanium technology.

Low extraction efficiency.

No problem with waste material.

One important thing – in case of fluoride additional concentration of heavy impurities (UF_6) can take place.

Production of 500-1000 gram of Ge-76 based on $GeCl_4$ can answer on main question “How most cost effective to produce necessary big amount of Ge-76?”

Thank you for your attention