Dissolution and solvent extraction for the purification of Sr-89 from irradiated yttria target in Hot cells

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As a Radioisotope in medical applications for therapeutic treatment

- ^{89}Sr : pure β- emitter, t ½ = 50.5 days : Energy ~ 1.5 MeV
- Pain palliative medicine for bone metastases.
- Strontium biological analogue to calcium & high affinity for metabolically active bone.
- Normal dose 40 – 60 µCi / kg of body weight
- Biological t ½ = 14 days in normal bone: Exceeds 50 d in osteoblastic metastases.
- As IV injection 4 mCi /4 ml per injection as ($^{89}SrCl_2$ in 0.1 N HCl, pH: 6-7)
- US FDA approved ^{89}Sr, ^{32}P & ^{153}Sm as candidates: ^{32}P & ^{153}Sm found to result in mild to severe bone marrow suppression

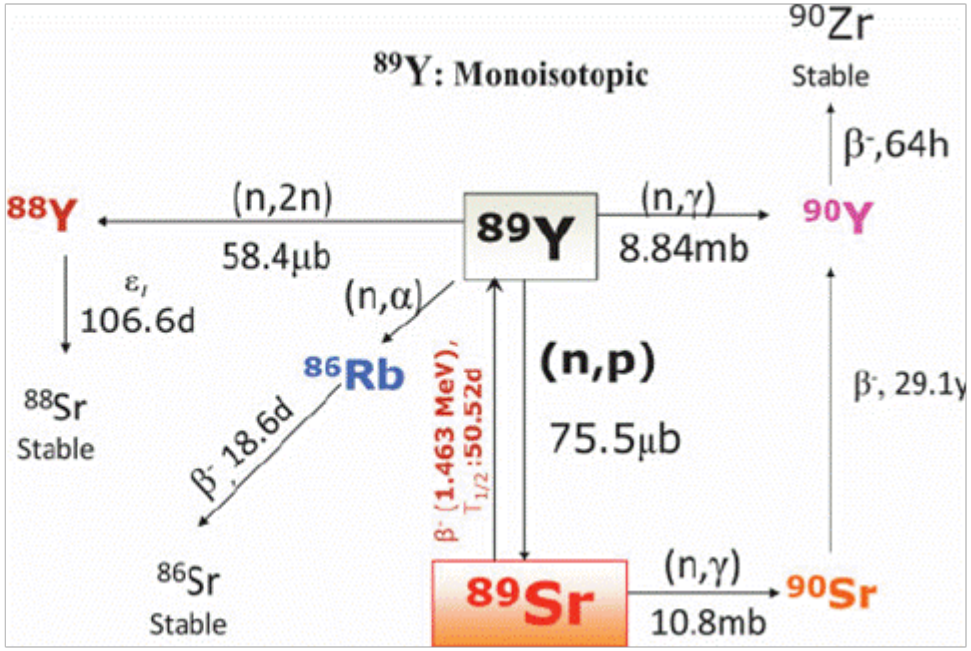
Production Principle

Fast Reactor route: $^{89}Y(n,p)^{89}Sr$

Advantage: Product with very high specific activity possible: 19 kCi ^{89}Sr/g of Sr
Sr produced is easily separated from Y target as product.

Present Study:
$^{89}Y(n,p)^{89}Sr$ in FBTR

Sr-89 Production Principle



Other products: Sr^{90} t ½ = 29 years and Yttrium 88 - t ½ 106 days

Yield (Ci/g of Y) for 30 days at flux : 2.4 x 10^{15}n $cm^{-2}s^{-1}$

^{89}Sr: 0.011 :: ^{88}Y: 0.005 :: ^{90}Sr: 1.98 x 10^{-19}(Based on computed cross section)

Experimental

Yttria target preparation: Sintered Yttria Y_2O_3: 1g/pellet prepared and characterized for bulk density and Na compatibility test.

Irradiation in FBTR:

Campaign No.	Position of irradiation	No.of days of irradiation (days)	Material of Pellet encapsulation tube	Solvent extraction route followed	Activity of Sr^{89} obtained (mCi/g)
I	Centre Core	72	SS	TBP	19
II	4th Ring	118	Quartz	CE	2
III	5th Ring	30	Quartz	TBP	0.9
IV	5th Ring	45	SS	CE	In process

Transportation of irradiated yttira

La-Calhene loaded in to lead cask

Unloading the lead cask

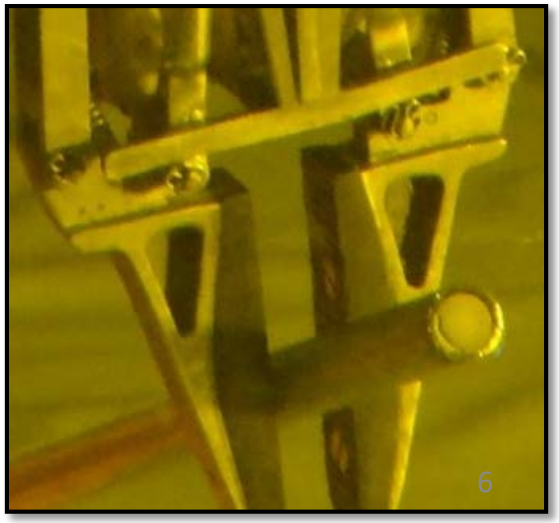
HP checking the dose level

Y_2O_3 pellets were posting in to Hot cell through EXTP.

Quartz tube cutting device

Developed in-house for cutting QT in Hot cell with MSM

In case of SS casing, the laser cutting carried out in Radio Metalurgical Laboratory of IGCAR and capped before transportation



Dissolution

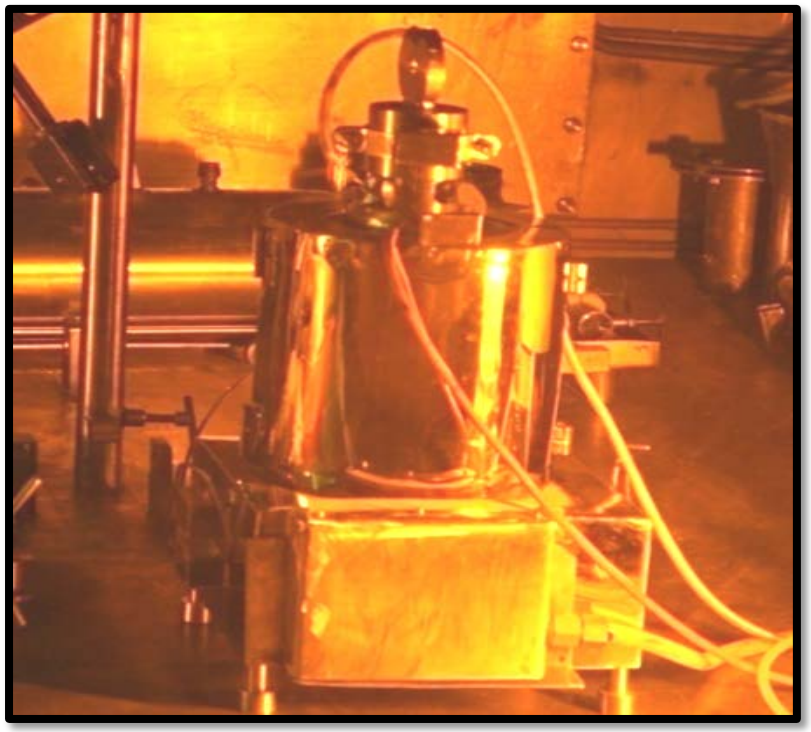
$$Y_2O_3 + 6HNO_3 \rightarrow 2Y(NO_3)_3 + 3H_2O$$

Dissolver: Titanium vessel of 350 ml inner volume.

25 nos of irradiated yttria pellets dissolved in 150 ml of 9 M /11 M HNO_3 under reflux condition for 24 hrs at 120^0 C

- **Vessel Dim: 70mm OD: 35mm ID & 300 mm height: Thickness 6 mm**

"O" rings used: EPDM or Viton



Base heater with cylindrical heat insulator and silicone insulated RTD outputs inside the cell.

Multi –tasking table

Multi task work table

* Vice

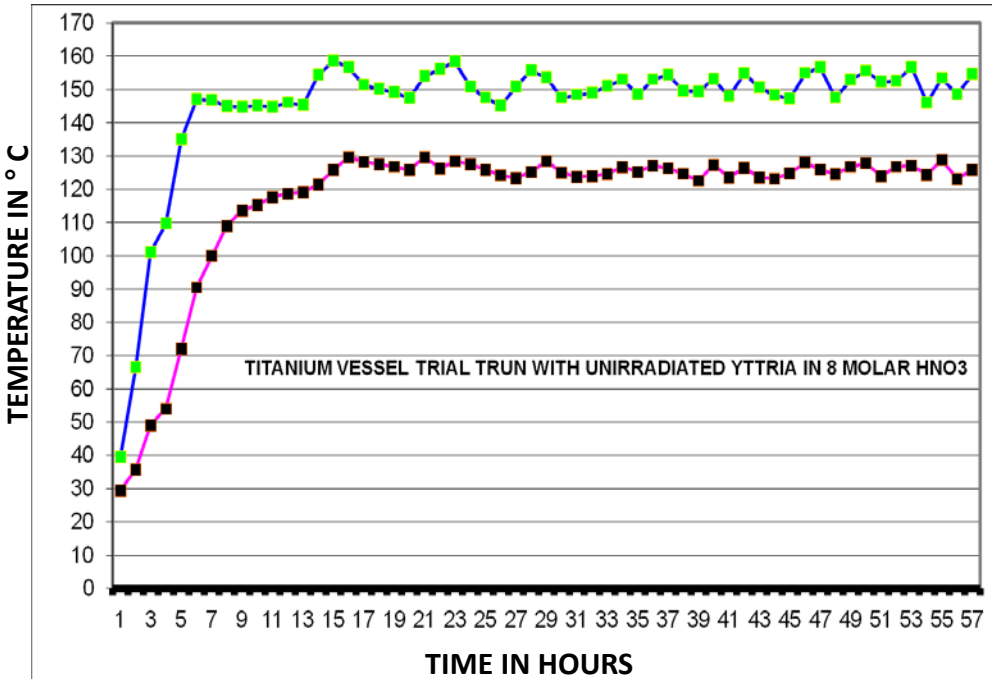
*Dissolver holder

*lid open cum closure arrangement

*Solution transfer system

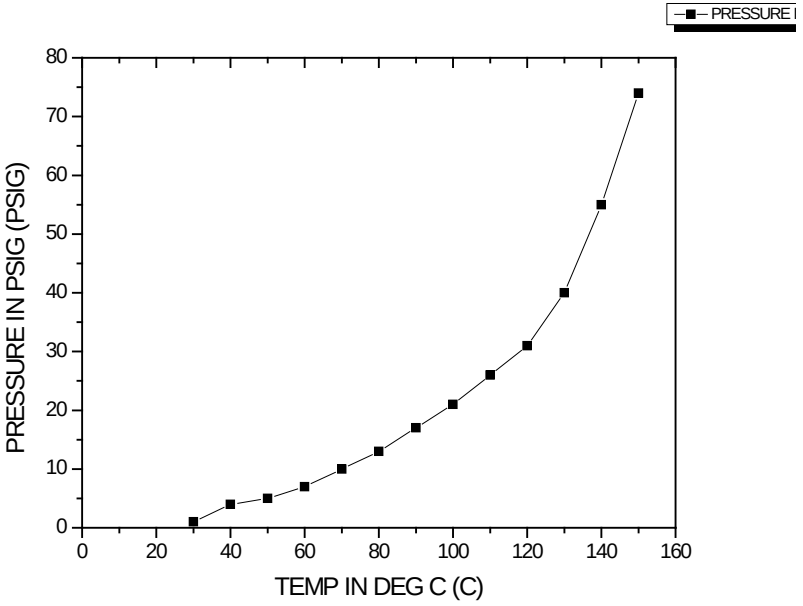
*Separation fixture

Temperature calibration of the vessel



Δ T (outer – inner) = 25°

For heating up to 150 ^{0}C pressure raised up to 5.203 kg/cm ^{2}



Solvent Extraction

Tri-Butyl Phosphate Route

$$Y(NO_3)_3 + 3\ TBP \rightarrow [Y(NO_3)_3 . 3\ TBP]$$

$$Y(NO_3)_3 + 3\ TBP \rightarrow [Y(TBP)_3 . HNO_3]$$

The bulk yttrium was separated by 100% TBP

Bulk Yttrium to organic phase and strontium in aqueous phase.

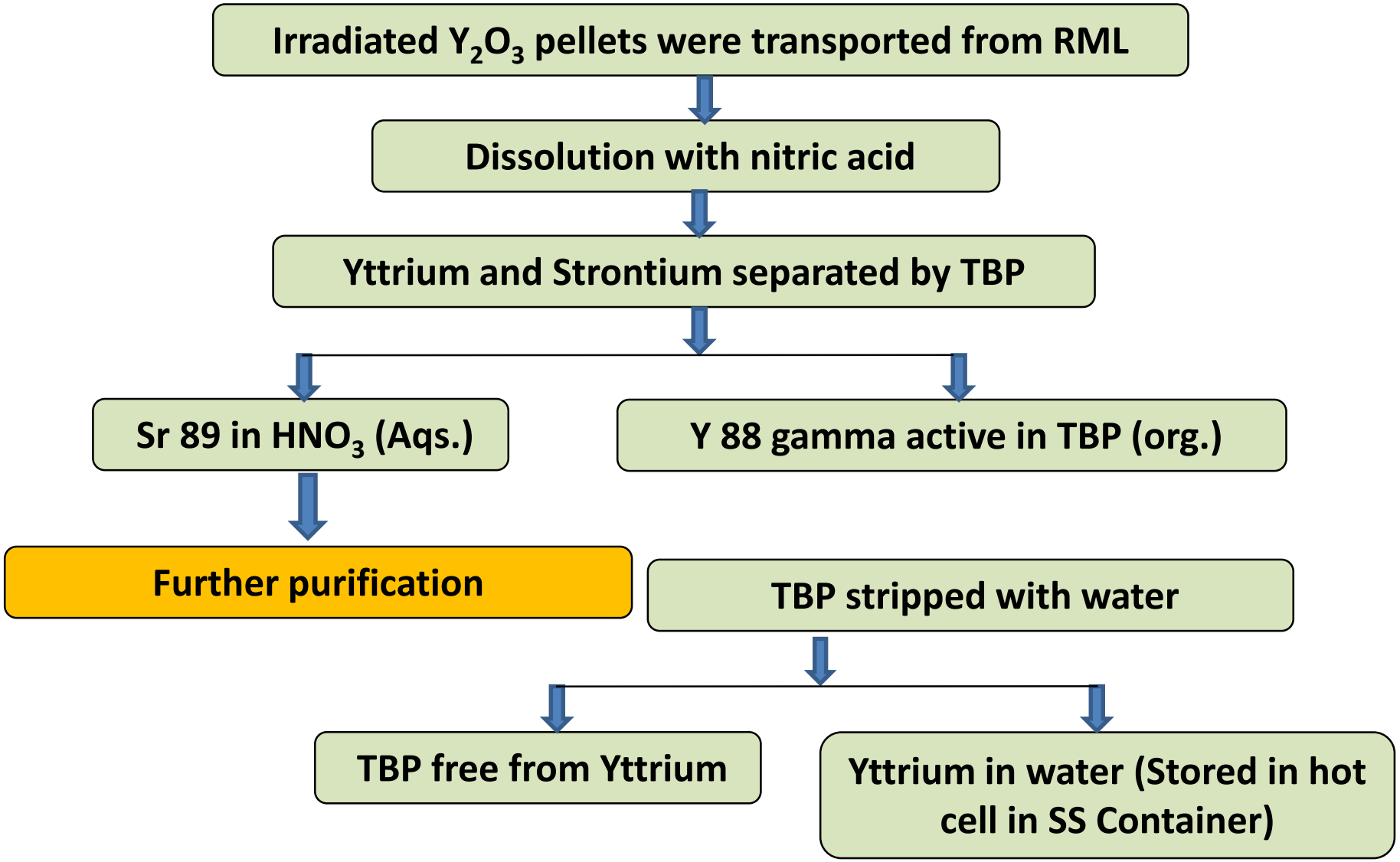
Crown Ether Route

$$Sr^{2+}(NO_3)_2 + C.E.(Dt.BuCh18C6) \rightarrow Sr(Dt.BuCh18C6)(NO_3)_2$$

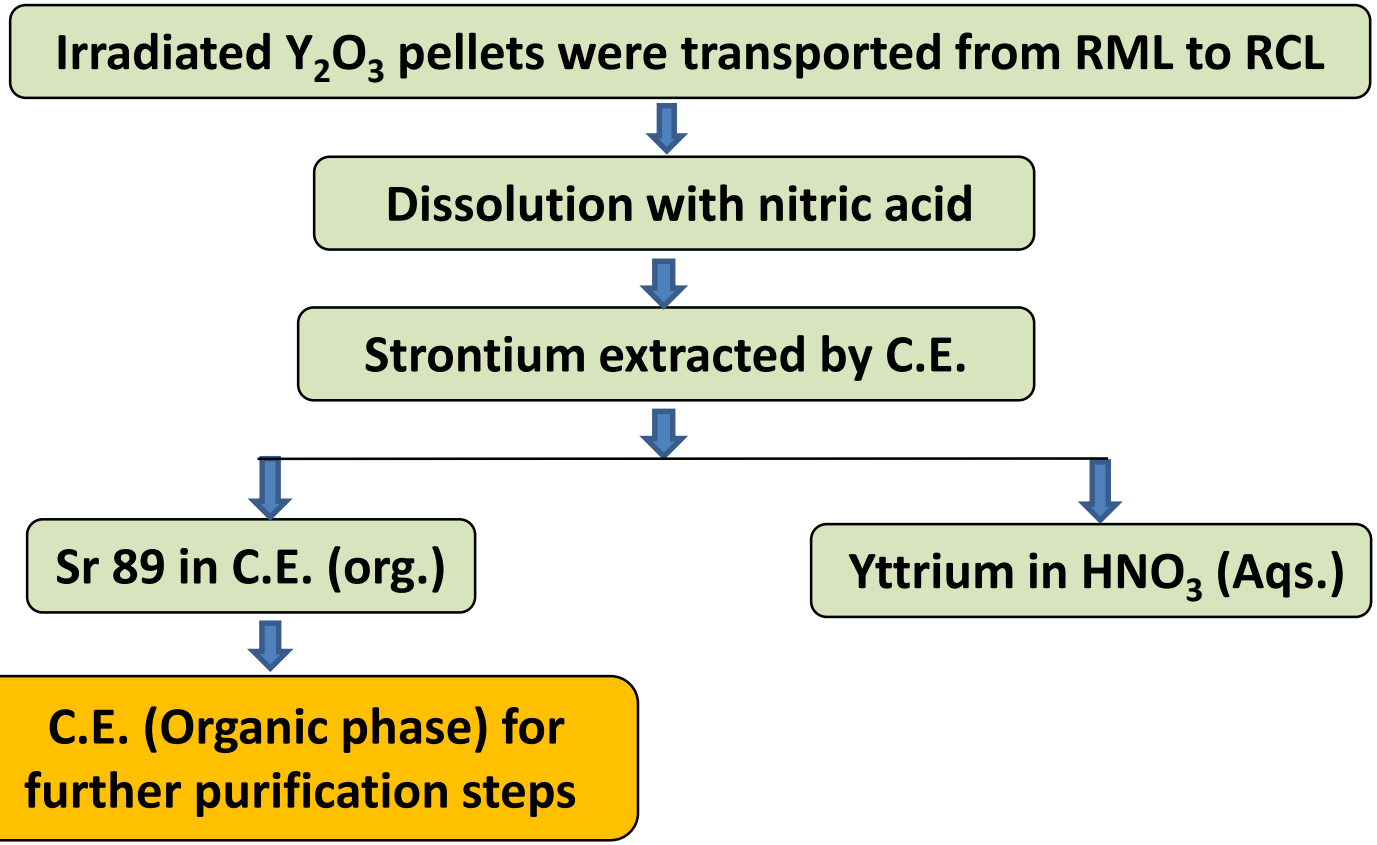
The bulk yttrium was separated by 0.2M CE in octonal

Strontium to organic phase and Yttrium in aqueous phase.

Flowchart for separation of strontium (TBP Route)

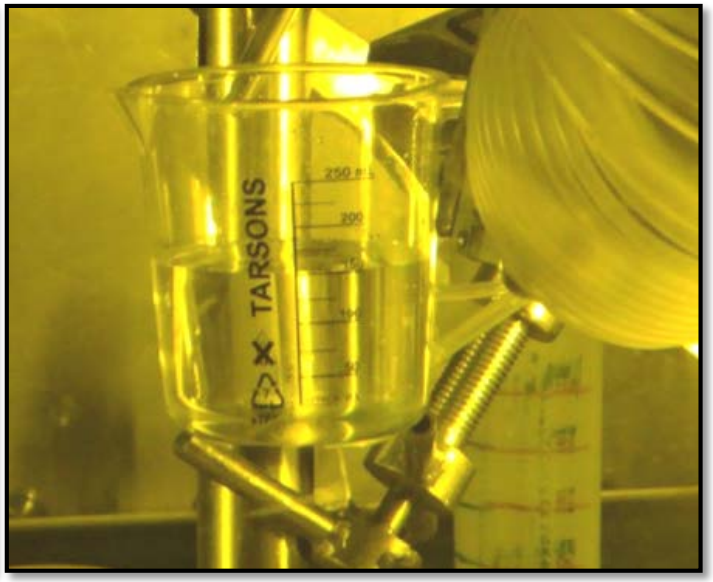


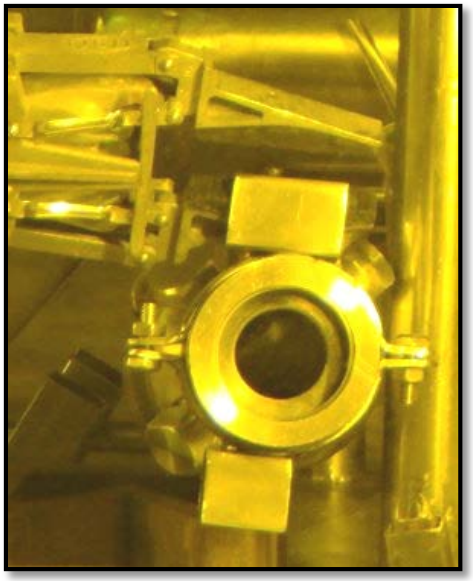
Flowchart for separation of strontium (CE Route)



Transfer of Dissolver Solution

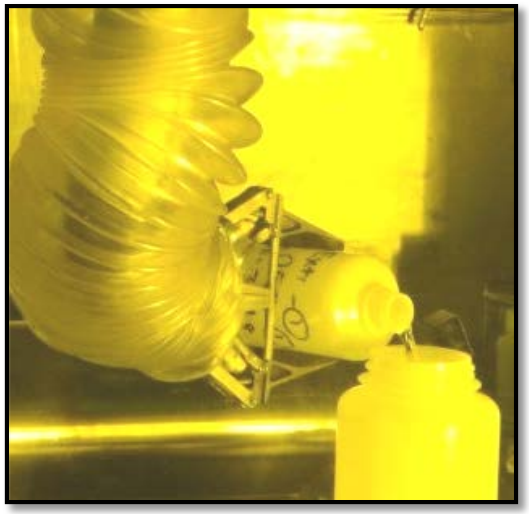
- Dissolver solution transferred to a beaker & volume measured.
- No evaporation loss
- No residue inside the dissolver vessel.



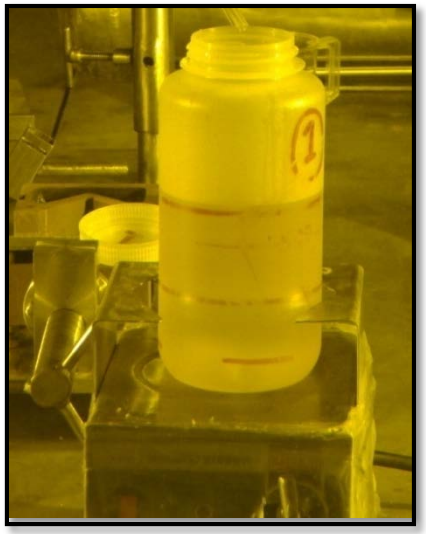


100% Dissolution without residue

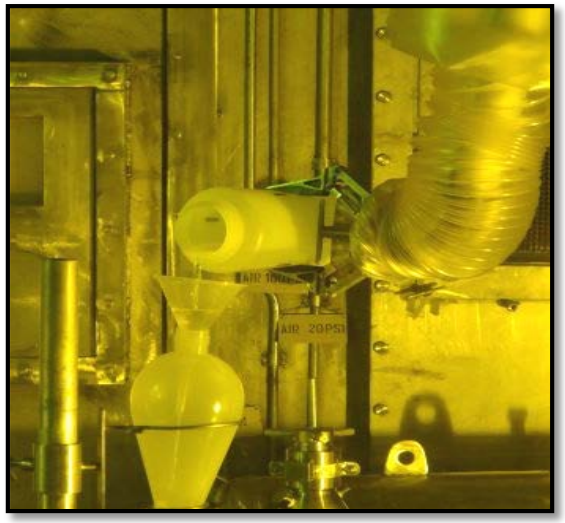
Solvent Extraction Steps



Organic transferred in to the bottle



Stirring unit



Solution transferred in to separating funnel

Phase separation

Interface position

Collection of Aqueous and Organic

Strontium phase

Further Purification Steps

List of radioactive impurities formed during irradiation

Isotope	Route	Source
Y-88	89Y(n,2n)88Y	Target material
Rb-86	89Y(n,α)86Rb	
Tb-160	159Tb(n,γ)160Tb	Rare Earth impurities in the target material
Ce-139	138Ce(n,γ)139Ce	
Ce-141	140Ce(n,γ)141Ce	
Eu-154	153Eu(n,γ)154Eu	
Zn-65	64Zn(n,γ)65Zn	Binder used in pellet preparation
Co-58	58Ni(n, p)58Co	Activation products of S.S
Mn-54	54Fe(n, p)54Mn	

Further Purification Steps (NRCS)

Impurities in Strontium after SE separation (TBP Route)

Aq. Soln. after TBP extraction with impurities in 0.1M HNO_3

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Loaded on to Cation Exchange Column : DOWEX 50W X 8 resin (100-200 Mesh size) Conditioned to 0.1M HNO_3 (FR: 0.3 ml/min)

↓

Elution with 1 M HNO_3 for selective removal of Sr

↓

Elution with 3 M HNO_3 for removal of Y from the column

CE Route:

CE being highly selective to Sr, the purification steps involved are less.

Calcination :

$$Sr^{2+}(NO_3)_2 \xrightarrow[800\ ^{o}C]{\Delta} SrO \xrightarrow{HCl} SrCl_2$$

Qualification for medical application

Specifications for $^{89}SrCl_2$ for use as bone pain palliation

Property	Value
Appearance	Trasnparent colourless solution
pH	4.0 – 7.0
Radionuclides purity (% ^{89}Sr)	> 99.6
Total beta impurities (%^{89}Sr)	< 0.2
Gamma emitting radionuclides (%^{89}Sr)	< 0.4
^{90}Sr activity relative to ^{89}Sr activity (%^{89}Sr)	< 2.3 x 10^{-4}
Specific activity (MBq/mg Sr)	3.5 – 3.6
Radioactive concentration (MBq/mL)	37.5
Chemical Purity, overall (%)	≥ 99.8%
Al	< 2.0
Fe	< 5.0
Pb	< 5.0
Assay of strontium chloride (mg/mL)	10.8 – 19.4
Sterility	Sterile

$^{89}SrCl_2$ Solution obtained using the above procedure has qualified the requirements


Thank you!