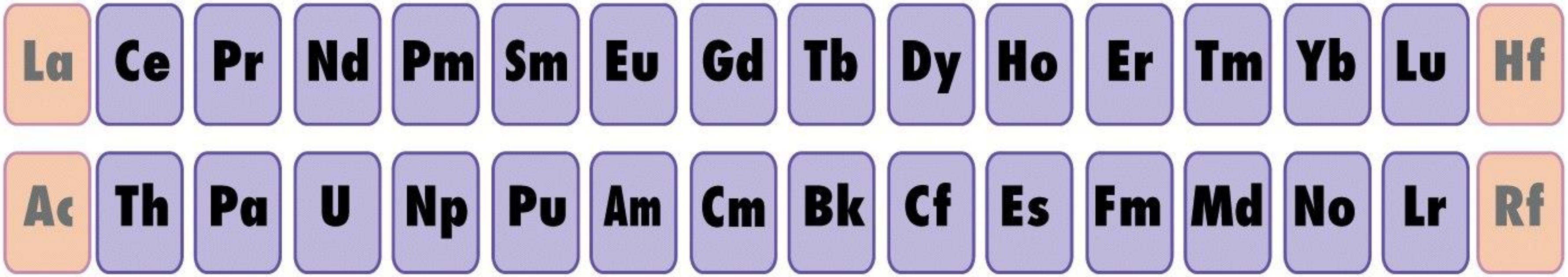
Elementi del blocco f

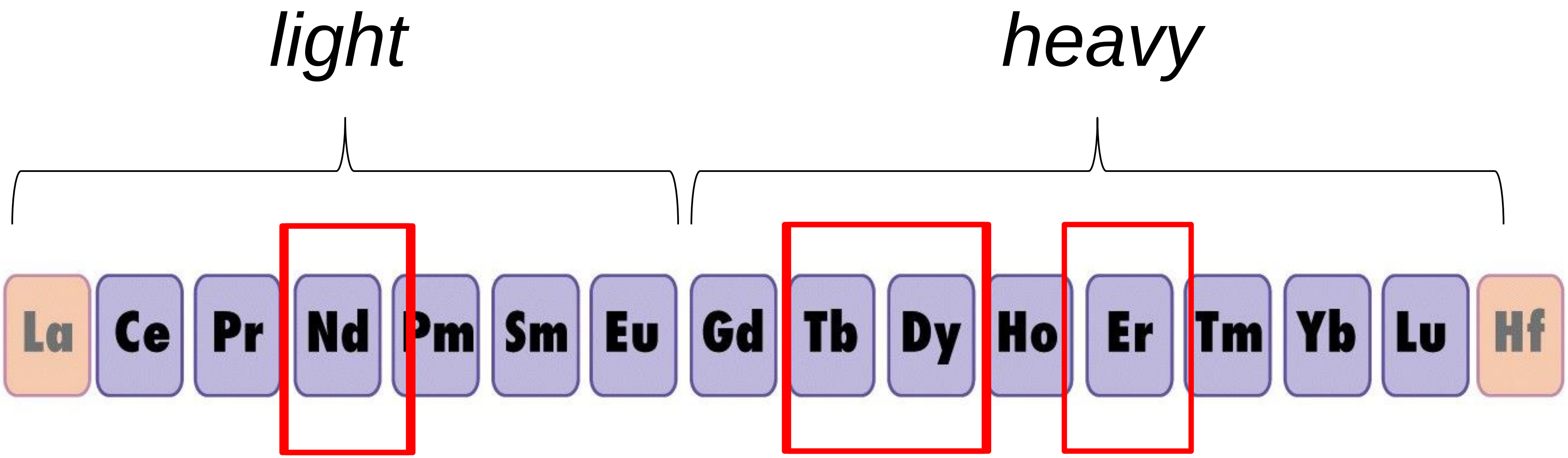


La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	Rf

Lantanide generico = Ln, $[Xe]4f^n6s^2$

Attinide generico = An, $[Rn]5f^n7s^2$

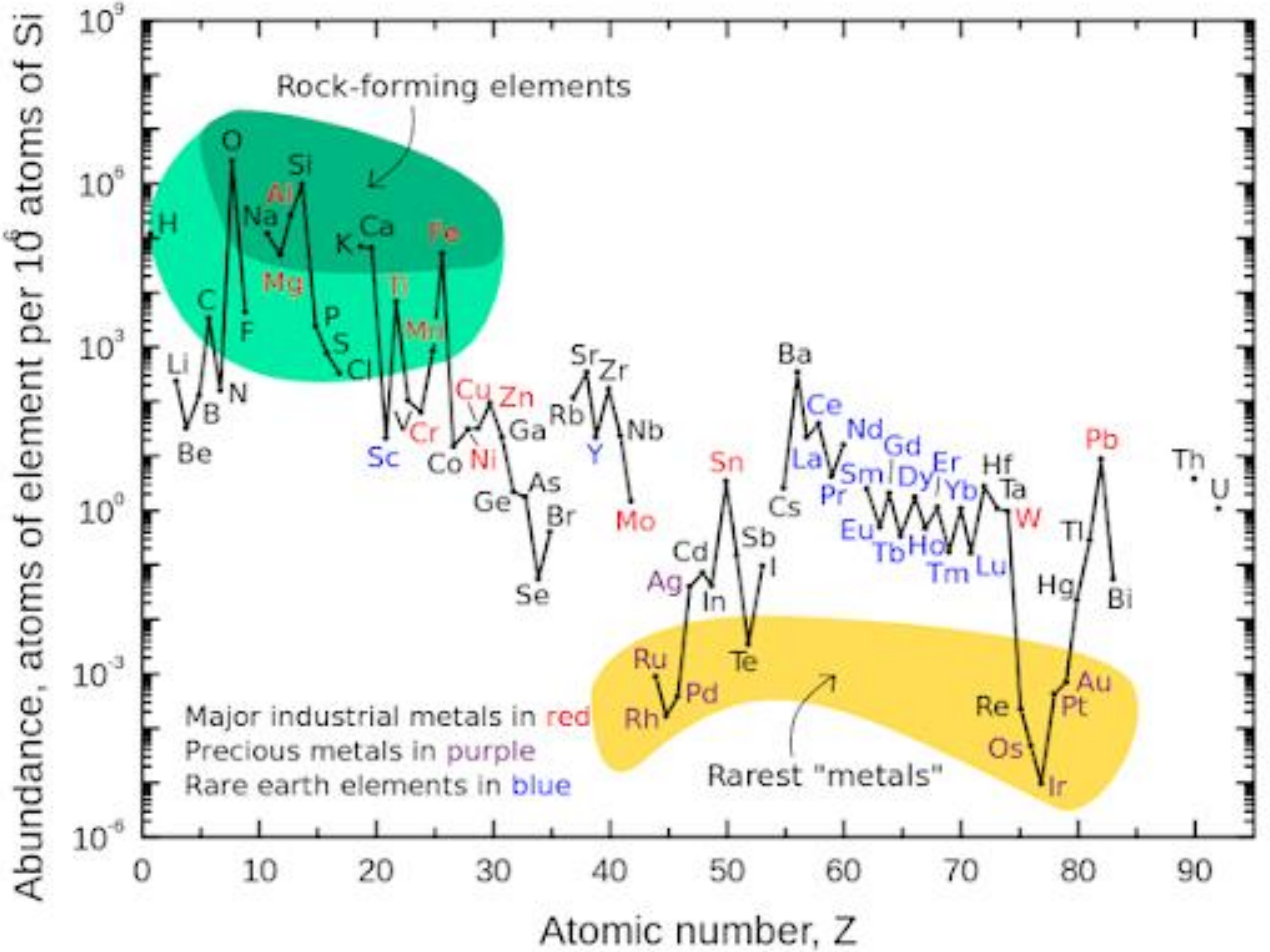
Lantanidi



Terre Rare (*rare earth metals*, REM o RE) = 15 elementi La – Lu (Z = 57–71) + Sc (Z = 21) + Y (Z = 39)

https://www.youtube.com/watch?v=ri7fFbrPPjw

Le Terre Rare non sono (tanto) rare



Rare Earth – Key Applications

Magnetics

🟩 Nd 🟦 Tb, Dy ▨ Pr

Computer Hard Drives
Disk Drive Motors
Anti-Lock Brakes
Automotive Parts
Frictionless Bearings
Magnetic Refrigeration
Microwave Power Tubes
Power Generation
Microphones & Speakers
Communication Systems
MRI

🟩 CREOs
🟦 HREOs
▨ LREOs

Phosphors

🟩 Nd, Eu, Tb, Y 🟦 Er, Gd ▨ Ce, Pr

Display phosphors - CRT, LPD, LCD
Fluorescent Lighting
Medical Imaging
Lasers
Fibre Optics

Metal Alloys

🟩 Nd, Y ▨ La, Ce, Pr

NimH Batteries
Fuel Cells
Steel
Super Alloys
Aluminium / Magnesium

Catalysts

🟩 Nd ▨ La, Ce, Pr

Petroleum Refining
Catalytic Converter
Fuel Additives
Chemical Processing
Air Pollution Controls

Ceramics

🟩 Nd, Y, Eu 🟦 Gd, Lu, Dy ▨ La, Ce, Pr

Capacitors
Sensors
Colorants
Scintillators
Refractories

Glass & Polishing

🟩 Nd 🟦 Gd, Er, Ho ▨ La, Ce, Pr

Polishing Compounds
Pigments & Coatings
UV Resistant Glass
Photo-Optical Glass
X-Ray Imaging

Defense

🟩 Nd, Eu, Tb, Dy, Y 🟦 Lu, Sm ▨ Pr, La

Satellite Communications
Guidance Systems
Aircraft Structures
Fly-by-Wire
Smart Missiles

A BREAKDOWN OF THE CRITICAL

METALS IN A SMARTPHONE

Some vital metals used to build these devices are considered at risk due to geological scarcity, geopolitical issues or trade policy.

This infographic details the critical metals that you carry in your pocket.

ALKALI METAL	ALKALINE EARTH	TRANSITION METAL	BASIC METAL	LANTHANOID

TOUCH SCREEN

It contains a thin layer of **indium** tin oxide, highly conductive and transparent, allowing the screen to function as a touch screen.

49 **In** Indium

MICROPHONE, SPEAKERS, VIBRATION UNIT

Nickel is used in the microphone diaphragm (that vibrates in response to sound waves). Alloys containing **neodymium, praseodymium and gadolinium** are used in the magnets contained in the speaker and microphone. **Neodymium, terbium and dysprosium** are used in the vibration unit.

Ni **Pr** **Nd**

Gd **Tb** **Dy**

DISPLAY

The display contains several **rare earth elements.** Small quantities are used to produce the colors on the liquid crystal display. Some give the screen its glow.

La **Pr** **Eu**

Gd **Tb** **Dy**

ELECTRONICS

Nickel is used in electrical connections. **Gallium** is used in semiconductors. **Tantalum** is the major component of micro capacitors, used for filtering and frequency tuning.

Ni **Ga** **Ta**

BATTERY

The majority of smartphones use **lithium**-ion batteries.

Li **Co** **Ni**

CASING

Nickel reduces electromagnetic interference. **Magnesium** alloys are superior at electromagnetic interference (EMI) shielding.

Mg **Ni**

Source: University of Birmingham

ELEMENTS

elements.visualcapitalist.com

The Earth's natural resources power our everyday lives. VC Elements breaks down the building blocks of the universe.

We live in a **material world.**

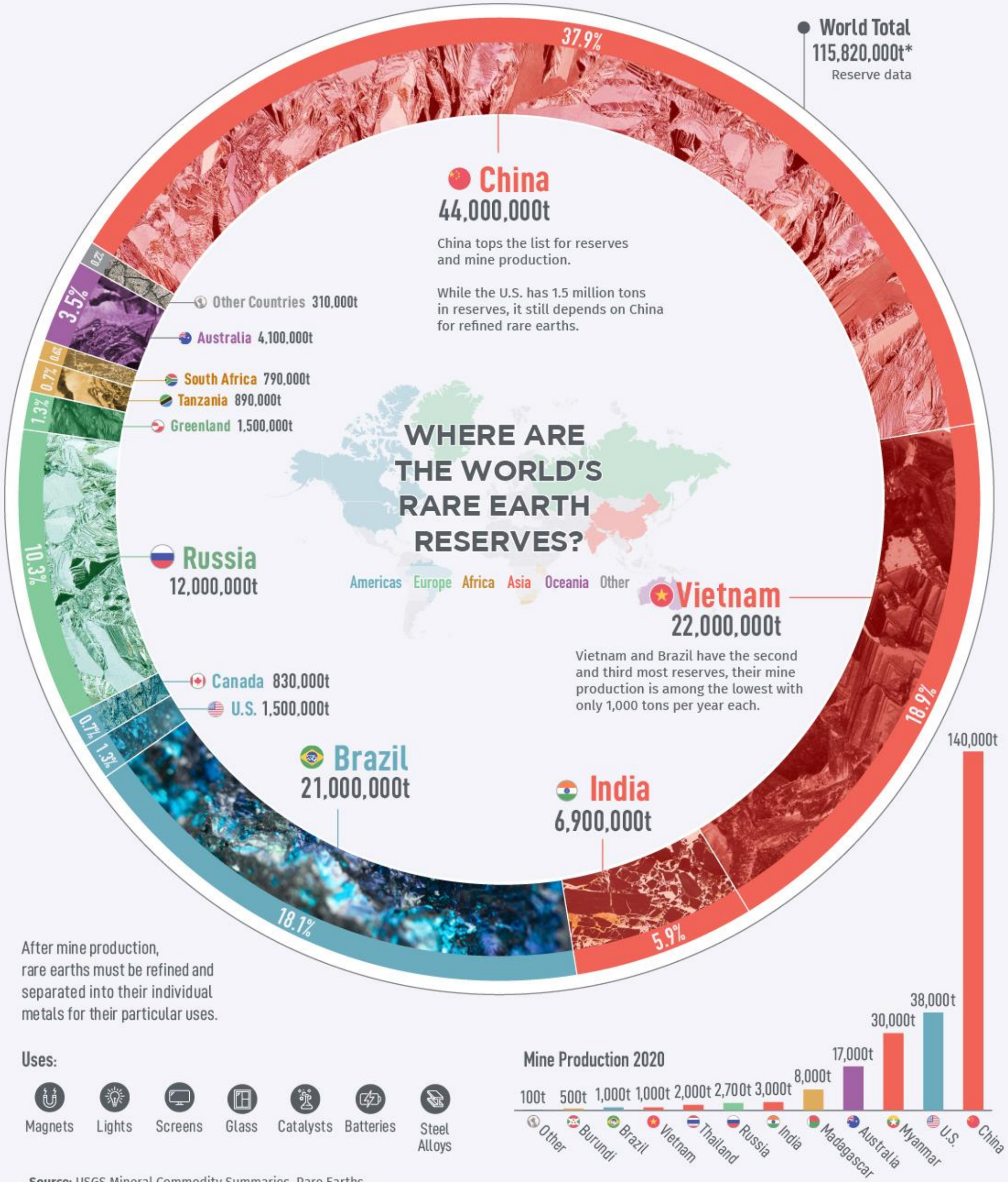
World Mine Production and Reserves: Reserves for Australia, Russia, the United States, and "Other countries" were revised based on information from Government and industry reports.

	Mine production		Reserves[8]
	2020	2021[e]	
United States	39,000	43,000	1,800,000
Australia	21,000	22,000	[9]4,000,000
Brazil	600	500	21,000,000
Burma	31,000	26,000	NA
Burundi	300	100	NA
Canada	—	—	830,000
China	[10]140,000	[10]168,000	44,000,000
Greenland	—	—	1,500,000
India	2,900	2,900	6,900,000
Madagascar	2,800	3,200	NA
Russia	2,700	2,700	21,000,000
South Africa	—	—	790,000
Tanzania	—	—	890,000
Thailand	3,600	8,000	NA
Vietnam	700	400	22,000,000
Other countries	100	300	280,000
World total (rounded)	240,000	280,000	120,000,000

World Resources:[8] Rare earths are relatively abundant in the Earth's crust, but minable concentrations are less common than for most other mineral commodities. In North America, measured and indicated resources of rare earths were estimated to include 2.4 million tons in the United States and more than 15 million tons in Canada.

Substitutes: Substitutes are available for many applications but generally are less effective.

WHERE ARE THE WORLD'S RARE EARTH RESERVES?



China tops the list for reserves and mine production.

While the U.S. has 1.5 million tons in reserves, it still depends on China for refined rare earths.

Vietnam and Brazil have the second and third most reserves, their mine production is among the lowest with only 1,000 tons per year each.

After mine production, rare earths must be refined and separated into their individual metals for their particular uses.

Uses:

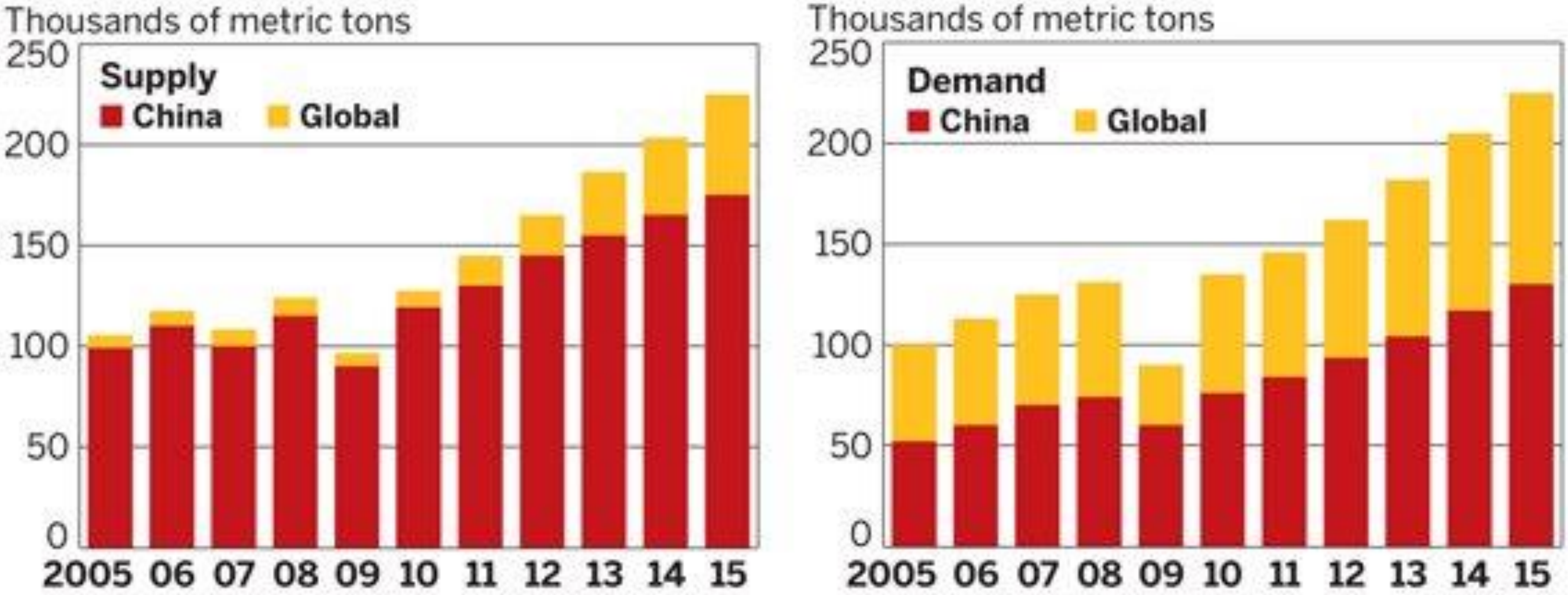
Magnets
Lights
Screens
Glass
Catalysts
Batteries
Steel Alloys

Mine Production 2020

Source: USGS Mineral Commodity Summaries, Rare Earths

RARE-EARTH SUPPLY AND DEMAND

China's increasing demand for its own rare-earth materials is predicted to drive production in other countries



SOURCE: Dudley Kingsnorth/Industrial Minerals Co. of Australia

Il Giappone ora è pronto a sfruttare il giacimento di "terre rare". E la Borsa vola

La scoperta nel 2012 vicino l'isola di Minami Torishima. Ma il deposito naturale finora era considerato troppo profondo per essere sfruttato. Ora la tecnica di estrazione è stata perfezionata. I materiali utili a costruire magneti per veicolo ibridi e laser

11 Aprile 2018

Minami Torishima

ROMA - Il Giappone avrebbe trovato il modo per portare in superfice, poco alla volta, un tesoro di oltre 16 milioni di tonnellate di terre rare. Sono materiali utili a costruire - ad esempio - magneti per veicoli ibridi e laser per diversi secoli. Il Giappone, dunque, sarebbe in grado di strappare alla Cina l'attuale dominio sul settore.

Le analisi fatte hanno rivelato che c'è abbastanza materia per coprire 730 anni di domanda globale di disprosio, un elemento usato nei magneti per veicoli ibridi, e l'equivalente di 780 anni di applicazioni per l'ittrio, utilizzato nei laser. Inoltre, c'è anche un volume equivalente a 620 anni di fornitura di europio e terbio 420, utilizzati nei composti fluorescenti e nelle celle a idrogeno.

La Repubblica 22 maggio 2019

Alla Cina sono bastate due parole perché gli Usa congelassero il bando a Huawei: terre rare

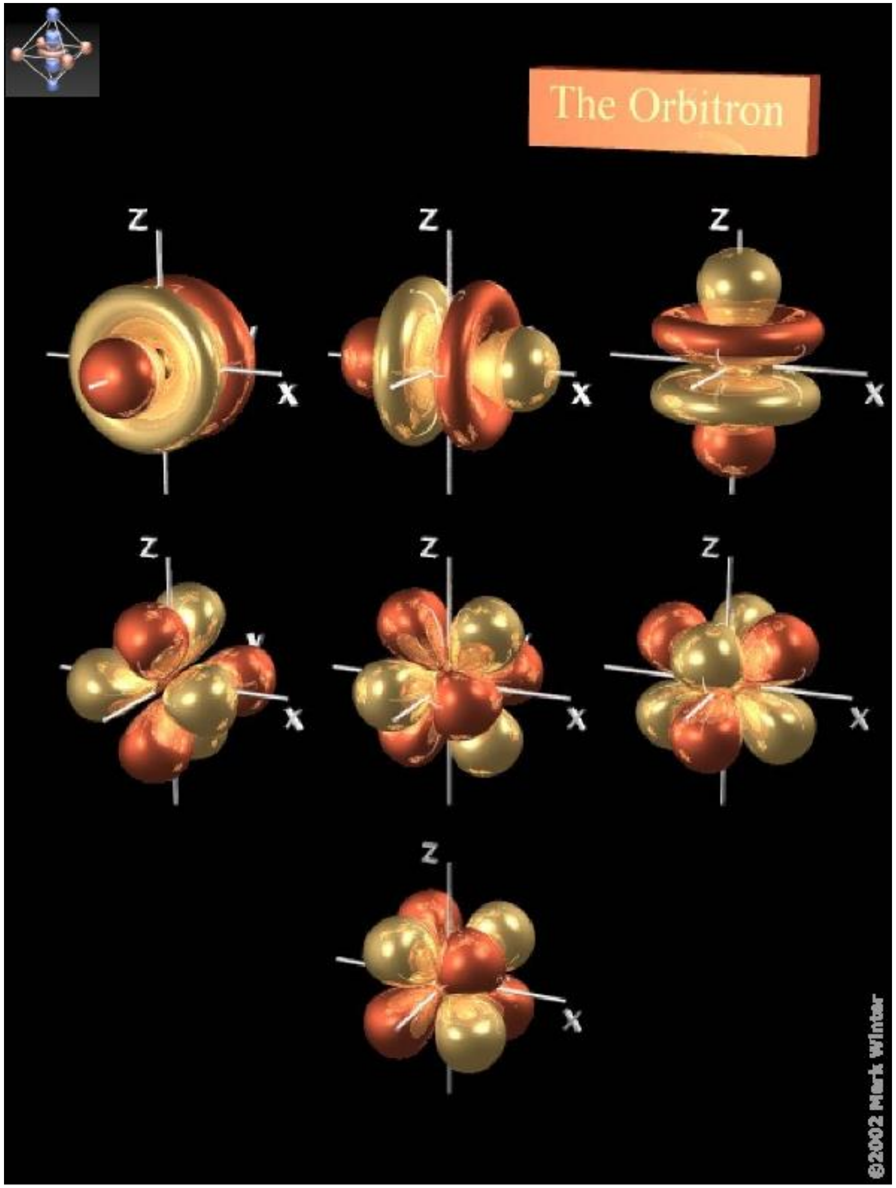
Terre rare: ecco la minaccia ‘fine di mondo’ della Cina che ha portato all’immediato congelamento del bando Usa a Huawei

Il set cubico di orbitali *f*

3 piani nodali

4f = 0 nodi radiali

5f = 1 nodo radiale



f_{x^3} f_{y^3} f_{z^3}

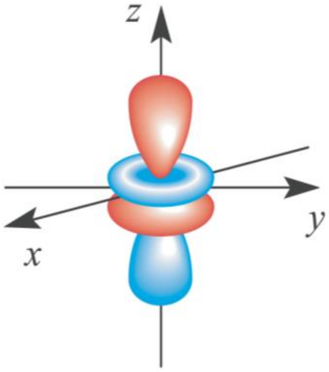
$f_{x(z^2-y^2)}$

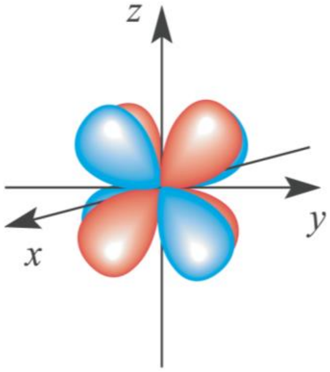
$f_{z(x^2-y^2)}$

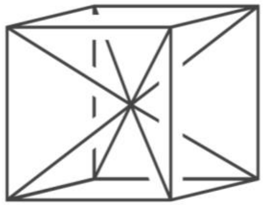
$f_{y(z^2-x^2)}$

f_{xyz}

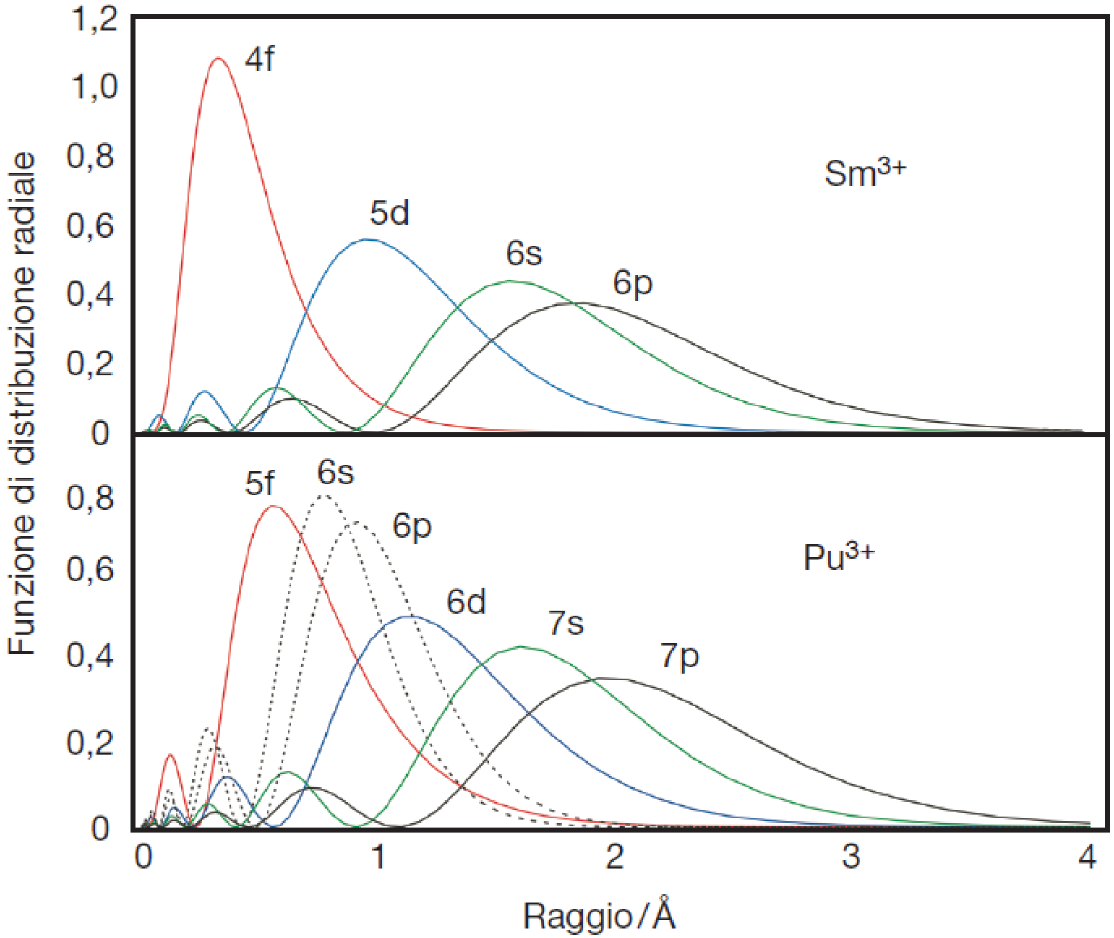
Il set cubico di orbitali *f*





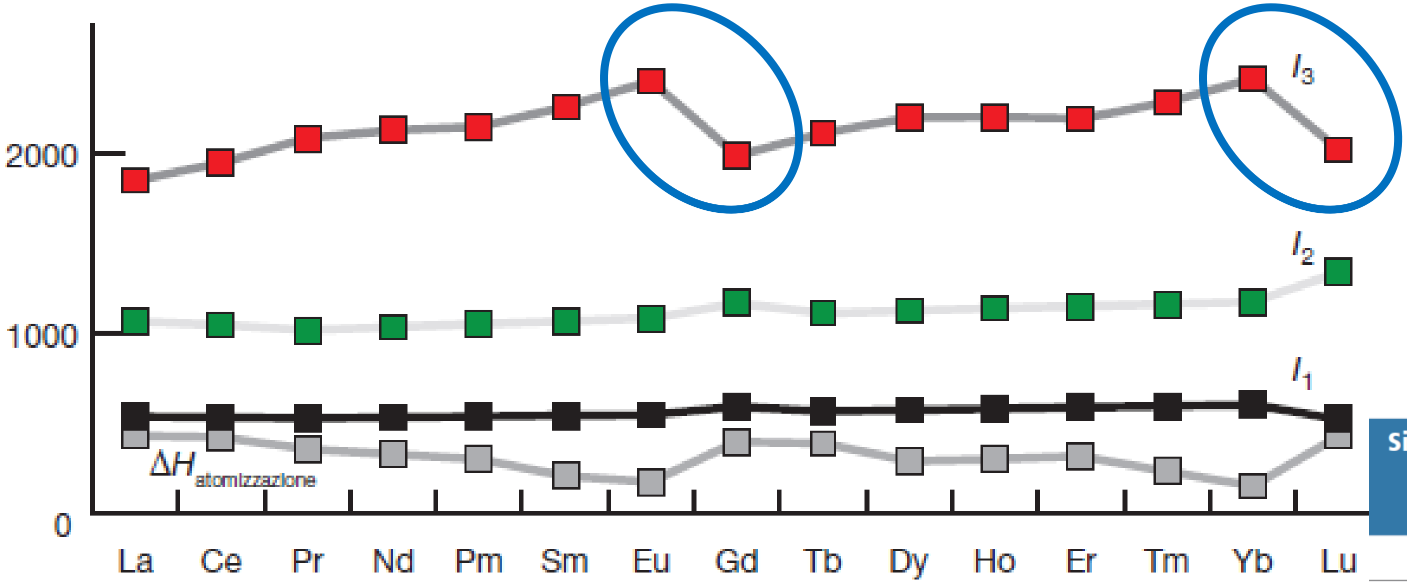


gli orbitali nf sono molto più contratti degli orbitali (n+1)d



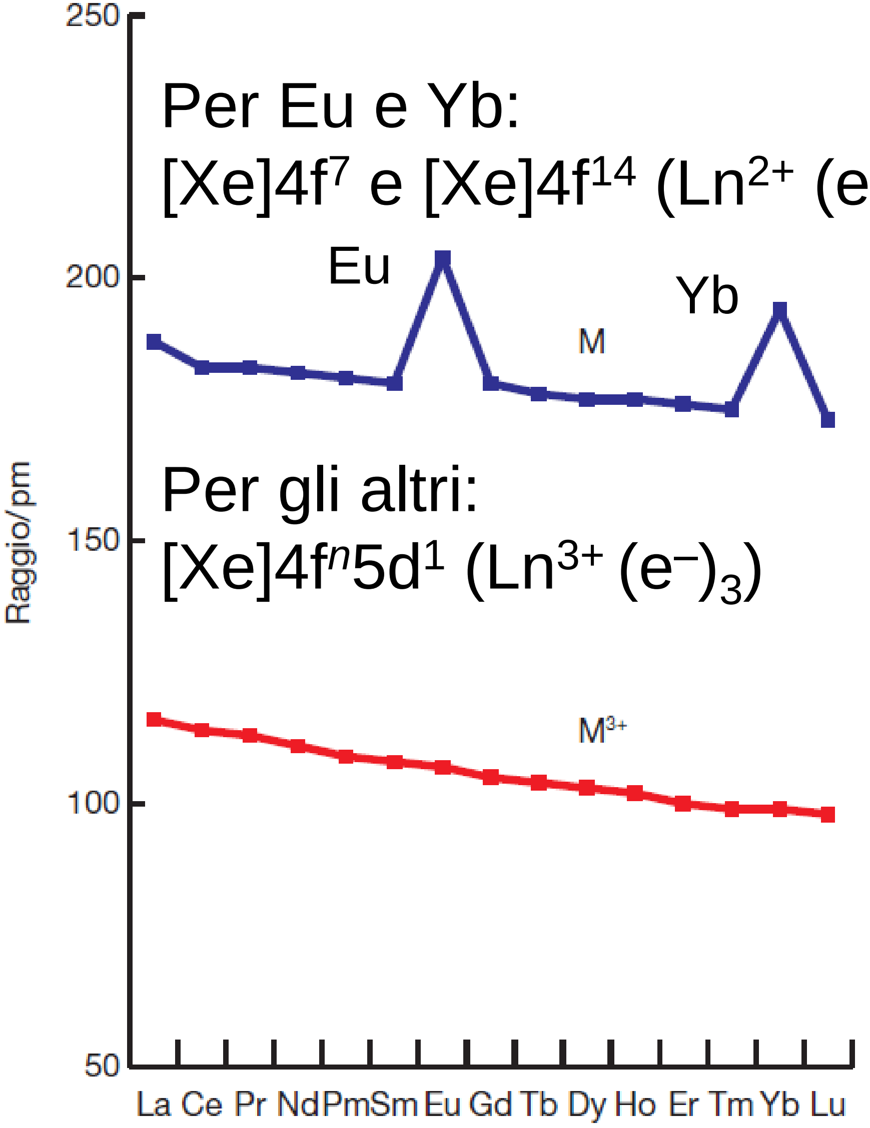
Gli orbitali f e d sono stati paragonati a petali di fiori: i lobi degli orbitali f sarebbero simili ai petali delle margherite mentre gli orbitali d sono come i petali del papavero gigante.

Energie di ionizzazione e configurazione elettronica



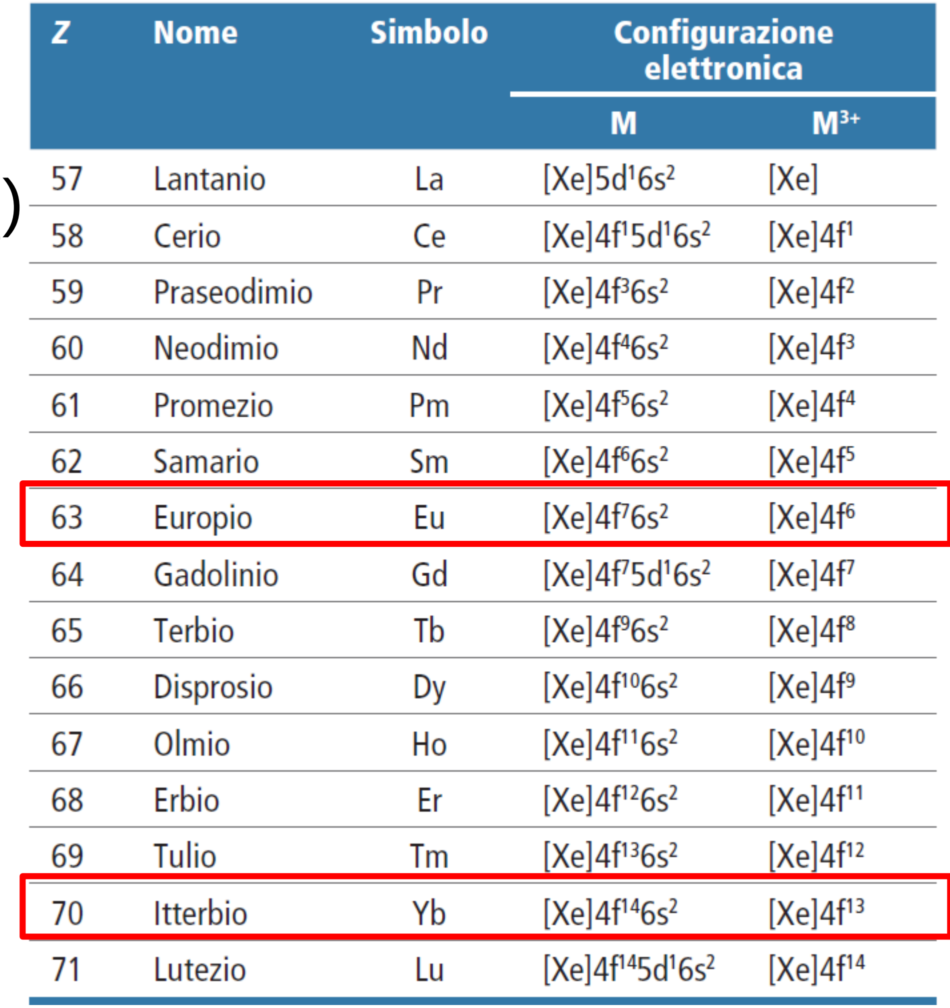
		Simbolo	Configurazione elettronica	
			M	M^{3+}
		La	$[Xe]5d^1 6s^2$	$[Xe]$
58	Cerio	Ce	$[Xe]4f^1 5d^1 6s^2$	$[Xe]4f^1$
59	Praseodimio	Pr	$[Xe]4f^3 6s^2$	$[Xe]4f^2$
60	Neodimio	Nd	$[Xe]4f^4 6s^2$	$[Xe]4f^3$
61	Promezio	Pm	$[Xe]4f^5 6s^2$	$[Xe]4f^4$
62	Samario	Sm	$[Xe]4f^6 6s^2$	$[Xe]4f^5$
63	Europio	Eu	$[Xe]4f^7 6s^2$	$[Xe]4f^6$
64	Gadolinio	Gd	$[Xe]4f^7 5d^1 6s^2$	$[Xe]4f^7$
65	Terbio	Tb	$[Xe]4f^9 6s^2$	$[Xe]4f^8$
66	Disprosio	Dy	$[Xe]4f^{10} 6s^2$	$[Xe]4f^9$
67	Olmio	Ho	$[Xe]4f^{11} 6s^2$	$[Xe]4f^{10}$
68	Erbio	Er	$[Xe]4f^{12} 6s^2$	$[Xe]4f^{11}$
69	Tulio	Tm	$[Xe]4f^{13} 6s^2$	$[Xe]4f^{12}$
70	Itterbio	Yb	$[Xe]4f^{14} 6s^2$	$[Xe]4f^{13}$
71	Lutezio	Lu	$[Xe]4f^{14} 5d^1 6s^2$	$[Xe]4f^{14}$

Raggi metallici dei lantanidi



Per Eu e Yb:
$[Xe]4f^7$ e $[Xe]4f^{14}$ ($Ln^{2+}(e^-)_2$)

Per gli altri:
$[Xe]4f^n5d^1$ ($Ln^{3+}(e^-)_3$)



Z	**Nome**	**Simbolo**	**Configurazione elettronica**	
			M	**M^{3+}**
57	Lantanio	La	$[Xe]5d^16s^2$	[Xe]
58	Cerio	Ce	$[Xe]4f^15d^16s^2$	$[Xe]4f^1$
59	Praseodimio	Pr	$[Xe]4f^36s^2$	$[Xe]4f^2$
60	Neodimio	Nd	$[Xe]4f^46s^2$	$[Xe]4f^3$
61	Promezio	Pm	$[Xe]4f^56s^2$	$[Xe]4f^4$
62	Samario	Sm	$[Xe]4f^66s^2$	$[Xe]4f^5$
63	Europio	Eu	$[Xe]4f^76s^2$	$[Xe]4f^6$
64	Gadolinio	Gd	$[Xe]4f^75d^16s^2$	$[Xe]4f^7$
65	Terbio	Tb	$[Xe]4f^96s^2$	$[Xe]4f^8$
66	Disprosio	Dy	$[Xe]4f^{10}6s^2$	$[Xe]4f^9$
67	Olmio	Ho	$[Xe]4f^{11}6s^2$	$[Xe]4f^{10}$
68	Erbio	Er	$[Xe]4f^{12}6s^2$	$[Xe]4f^{11}$
69	Tulio	Tm	$[Xe]4f^{13}6s^2$	$[Xe]4f^{12}$
70	Itterbio	Yb	$[Xe]4f^{14}6s^2$	$[Xe]4f^{13}$
71	Lutezio	Lu	$[Xe]4f^{14}5d^16s^2$	$[Xe]4f^{14}$

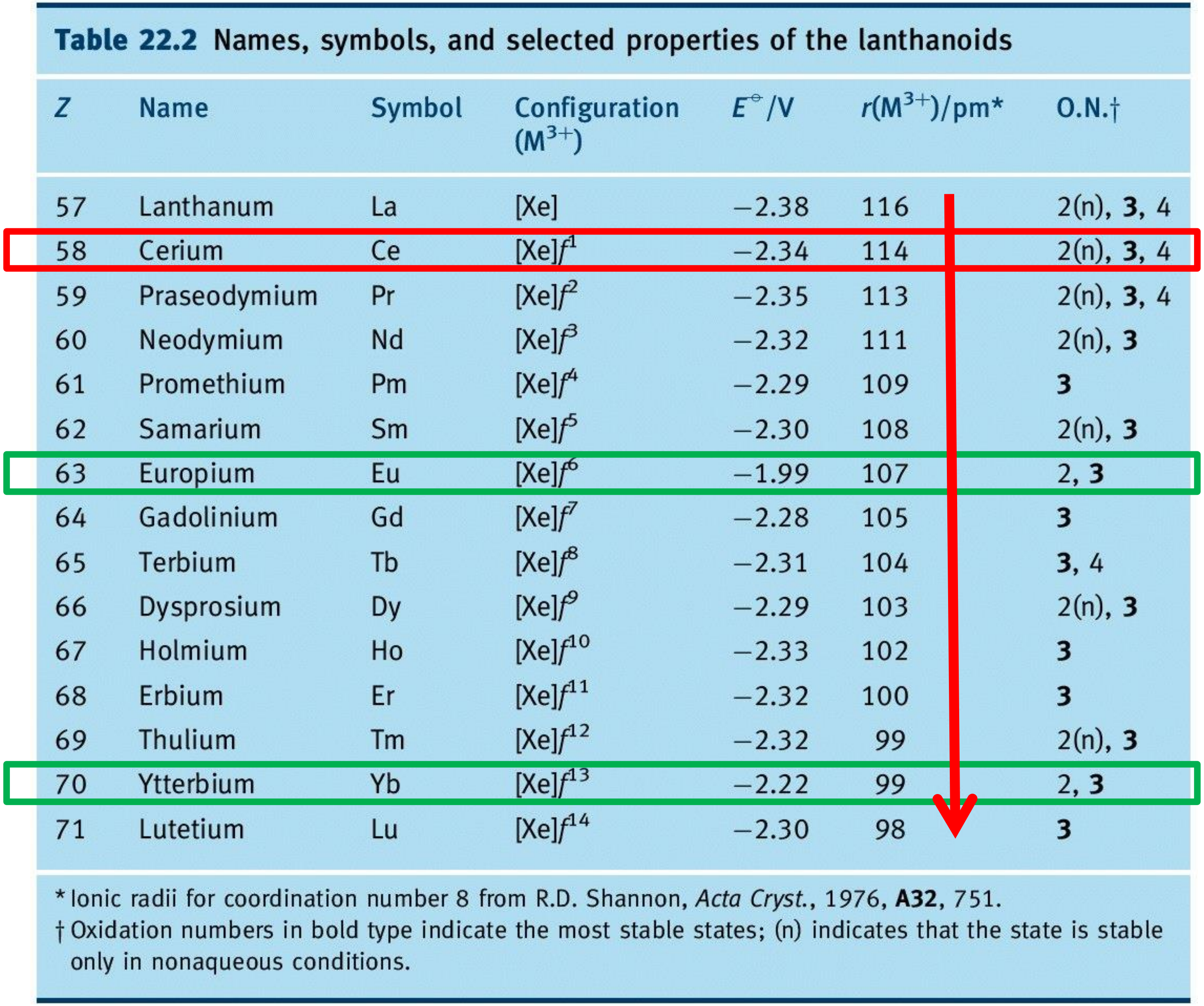


Table 22.2 Names, symbols, and selected properties of the lanthanoids

Z	Name	Symbol	Configuration (M^{3+})	$E^\ominus$/V	$r(M^{3+})$/pm*	O.N.†
57	Lanthanum	La	[Xe]	−2.38	116	2(n), **3**, 4
58	Cerium	Ce	[Xe]f^1	−2.34	114	2(n), **3**, 4
59	Praseodymium	Pr	[Xe]f^2	−2.35	113	2(n), **3**, 4
60	Neodymium	Nd	[Xe]f^3	−2.32	111	2(n), **3**
61	Promethium	Pm	[Xe]f^4	−2.29	109	**3**
62	Samarium	Sm	[Xe]f^5	−2.30	108	2(n), **3**
63	Europium	Eu	[Xe]f^6	−1.99	107	2, **3**
64	Gadolinium	Gd	[Xe]f^7	−2.28	105	**3**
65	Terbium	Tb	[Xe]f^8	−2.31	104	**3**, 4
66	Dysprosium	Dy	[Xe]f^9	−2.29	103	2(n), **3**
67	Holmium	Ho	[Xe]f^{10}	−2.33	102	**3**
68	Erbium	Er	[Xe]f^{11}	−2.32	100	**3**
69	Thulium	Tm	[Xe]f^{12}	−2.32	99	2(n), **3**
70	Ytterbium	Yb	[Xe]f^{13}	−2.22	99	2, **3**
71	Lutetium	Lu	[Xe]f^{14}	−2.30	98	**3**

* Ionic radii for coordination number 8 from R.D. Shannon, *Acta Cryst.*, 1976, **A32**, 751.

† Oxidation numbers in bold type indicate the most stable states; (n) indicates that the state is stable only in nonaqueous conditions.

Ce^{4+}, f^0

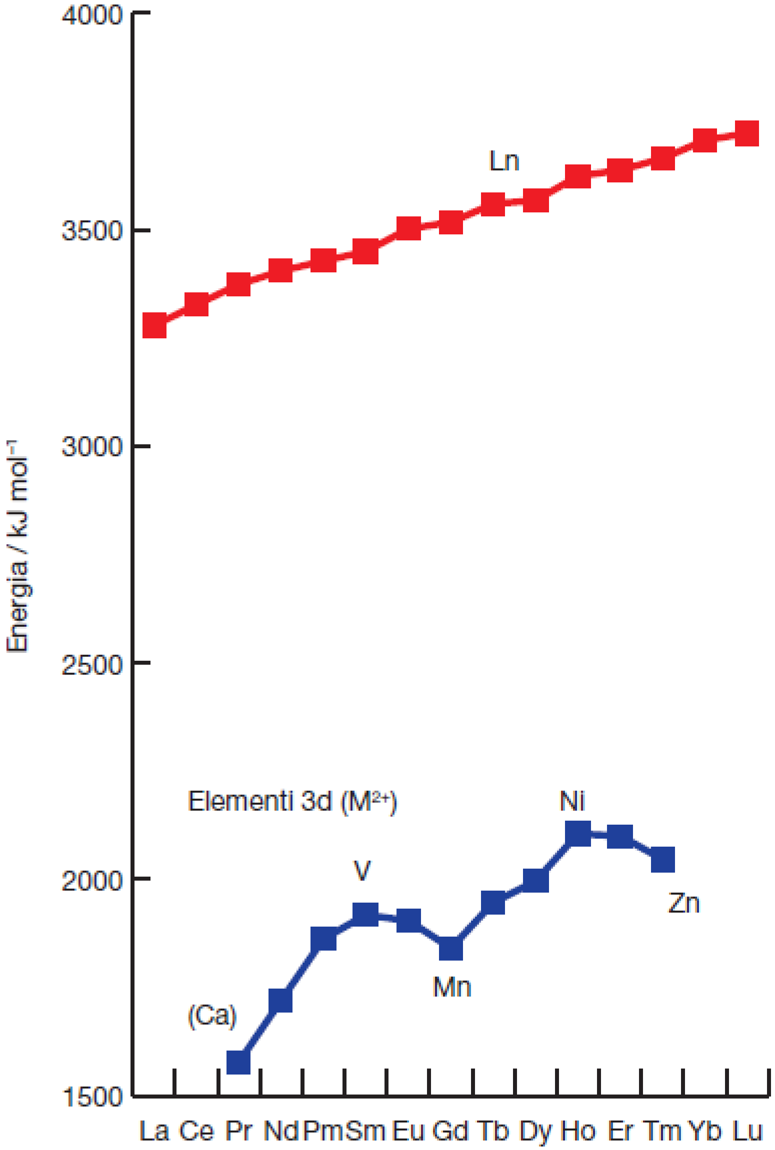
Eu^{2+}, f^7

Contrazione Lantanidica

Metal	$\Delta_a H^o$(Ln) / kJ mol^{-1}	$IE_1 + IE_2 + IE_3$ / kJ mol^{-1}	$\Delta_{hyd} H^o$(Ln^{3+}, g) / kJ mol^{-1}	$E^o_{Ln^{3+}/Ln}$ / V	$E^o_{Ln^{2+}/Ln}$ / V
La	431	3455	−3278	−2.38	
Ce	423	3530	−3326	−2.34	
Pr	356	3631	−3373	−2.35	−2.0
Nd	328	3698	−3403	−2.32	−2.1
Pm	348	3741	−3427	−2.30	−2.2
Sm	207	3873	−3449	−2.30	−2.68
Eu	177	4036	−3501	−1.99	−2.81
Gd	398	3750	−3517	−2.28	
Tb	389	3792	−3559	−2.28	
Dy	290	3899	−3567	−2.30	−2.2
Ho	301	3924	−3613	−2.33	−2.1
Er	317	3934	−3637	−2.33	−2.0
Tm	232	4045	−3664	−2.32	−2.4
Yb	152	4195	−3724	−2.19	−2.76
Lu	428	3886	−3722	−2.28	

[†] Values of $\Delta_{hyd} H^\circ$(M^{3+}, g) are taken from: L.R. Morss (1976) *Chem. Rev.*, vol. 76, p. 827.

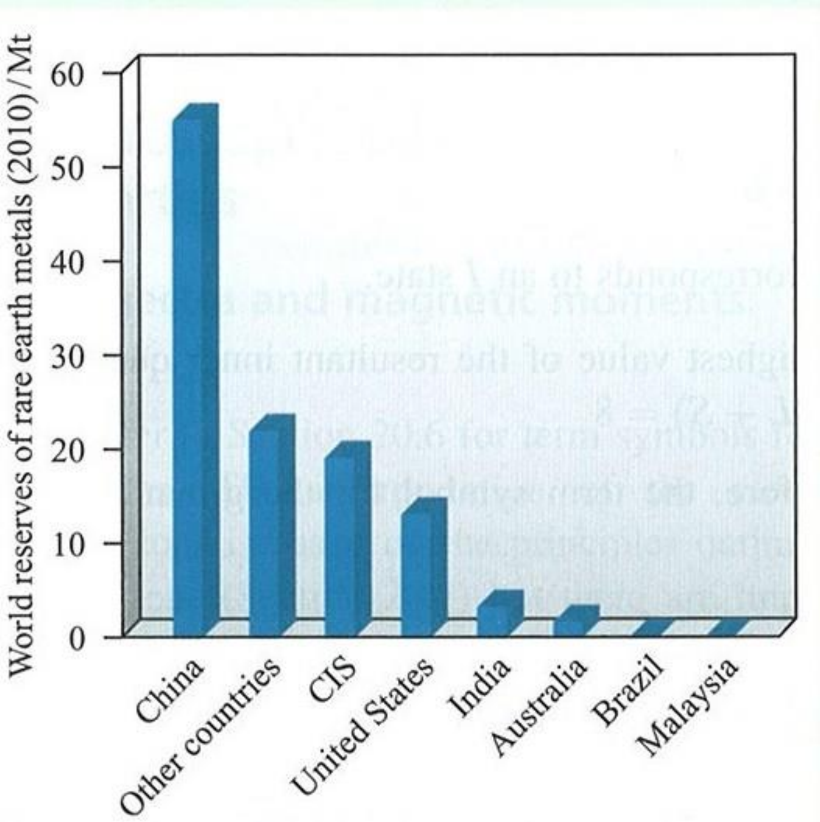
Energie di idratazione a confronto: LFSE trascurabile nei Ln^{3+}



Temperatura di transizione fra isolante e conduttore (T_{IM}) in Perovskiti dei lantanidi $LnNiO_3$

	$PrNiO_3$	**$NdNiO_3$**	**$EuNiO_3$**
$r(Ln^{3+})$/pm	113	111	107
T_{IM}/K	135	200	480

Risorse mondiali e produzione



Nel 2010: 114.000 tonnellate di REM

Ce, La, Nd, Y > 10.000 t/anno

Pr, Dy > 1000 t/anno

Gd, Sm, Eu, Tb > 100 t/anno

Miniera di Bayan Obo
(4.1% di REO, *Rare Earth Oxide*)

Miniera di Mountain Pass

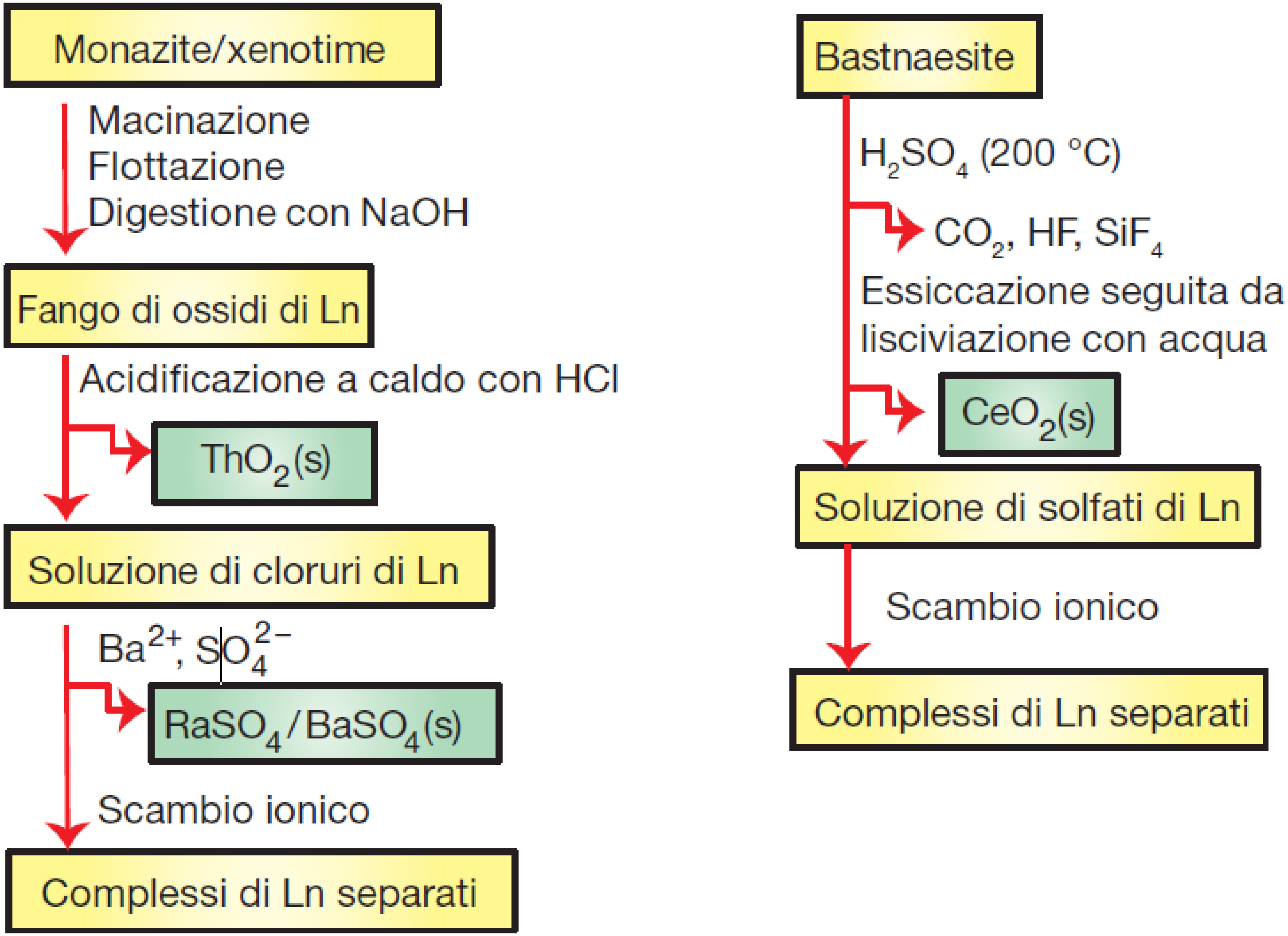
(7.7% di REO)


289

- **bastnäsite** $[Ce,La,Nd](CO_3)F$
- **monazite** $[Ce,La,Nd,Th](PO_4)$
- **xenotime** $[Y, Ln,Th](PO_4)$

Ln leggeri

Ln pesanti



Monazite/xenotime

Macinazione
Flottazione
Digestione con NaOH

Fango di ossidi di Ln

Acidificazione a caldo con HCl

$ThO_2(s)$

Soluzione di cloruri di Ln

Ba^{2+}, SO_4^{2-}

$RaSO_4/BaSO_4(s)$

Scambio ionico

Complessi di Ln separati

Bastnaesite

H_2SO_4 (200 °C)

CO_2, HF, SiF_4

Essiccazione seguita da
lisciviazione con acqua

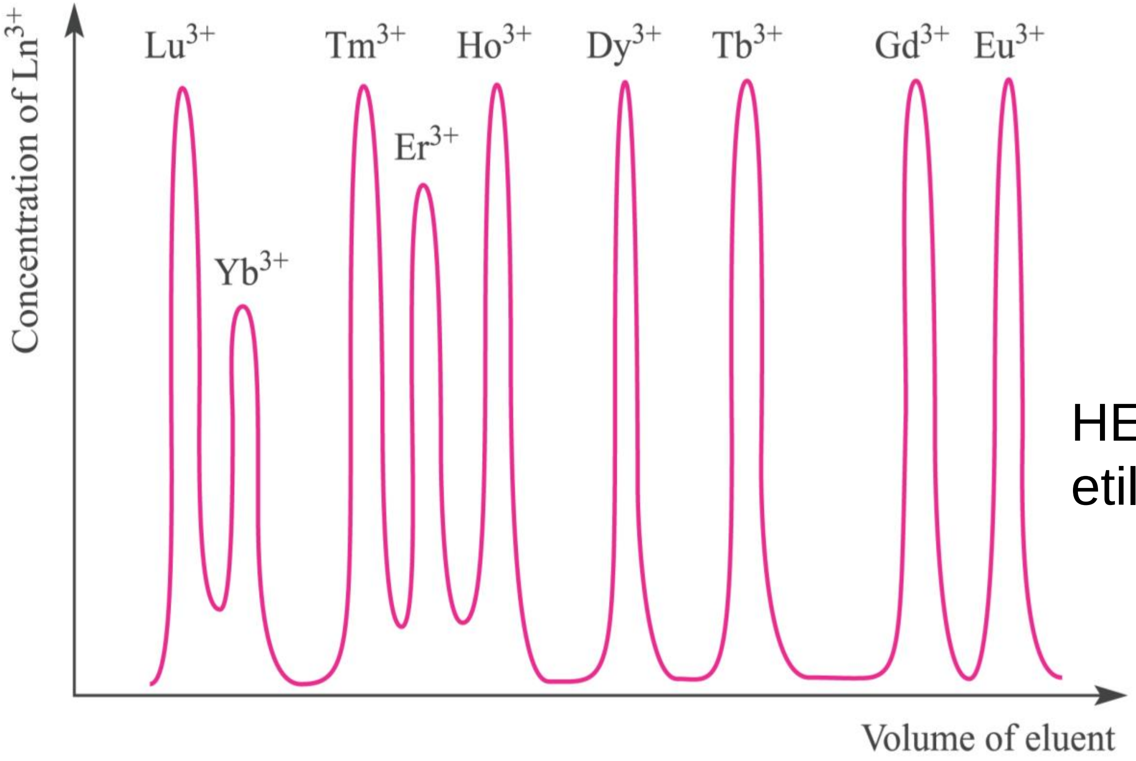
$CeO_2(s)$

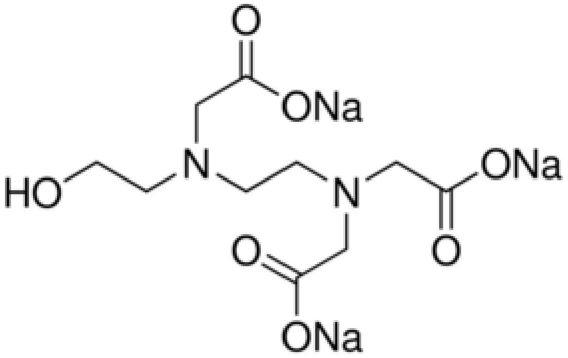
Soluzione di solfati di Ln

Scambio ionico

Complessi di Ln separati

Sequenza di eluizione da una colonna a scambio cationico (fase stazionaria non selettiva, e.g. Dowex) dei complessi dei lantanidi più pesanti eluendo con una soluzione di EDTA^{4-}

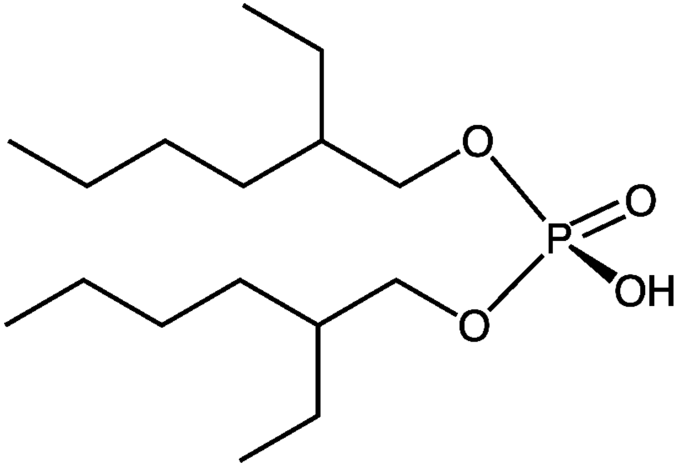




HEDTA = acido N-idrossietil-etilendiaminotriacetico

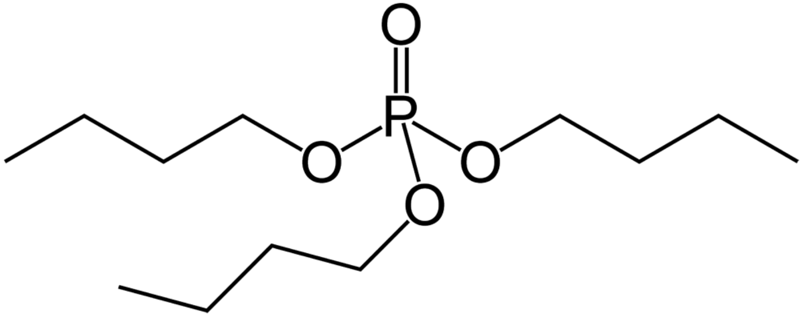
SX, *Solvent eXtraction*

fattore di separazione $\alpha_B^A = \frac{D_A}{D_B}$



acido di-2-etil-esilfosforico (**HDEHP** o DEHPA) per RE come cloruri o solfati

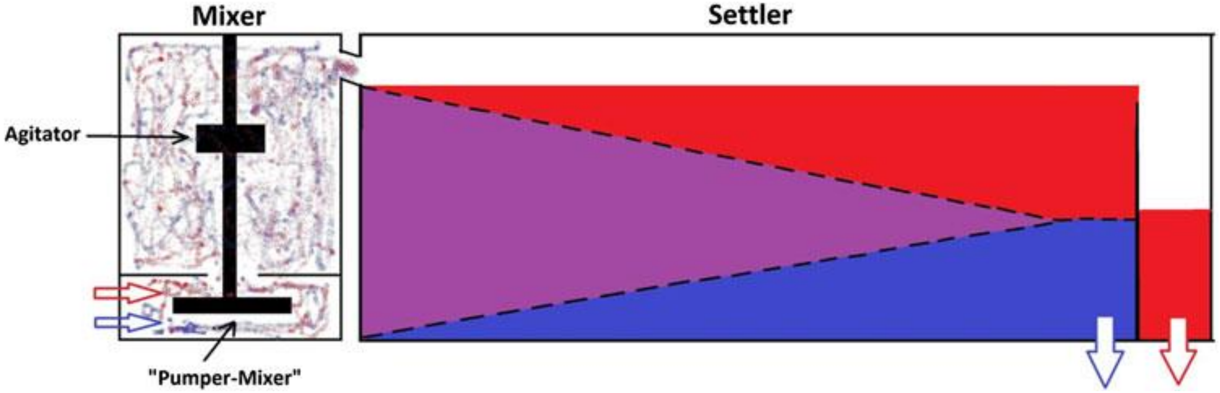
$[RE^{3+}]aq + [6(HA)]org \rightarrow [RE(A)_3(HA)_3]org + 3[H^+]aq$



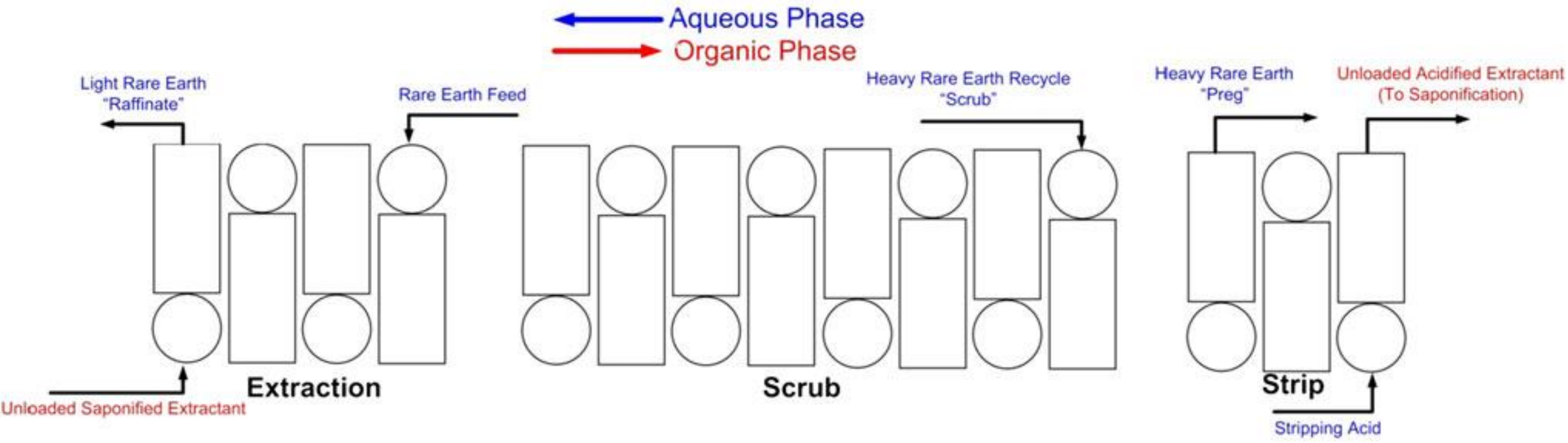
tri-*n*-butil fosfato (**TBP**) per RE come nitrati

$[RE(NO_3)_3 \cdot 3H_2O]aq + 3[TBP]org \rightarrow [RE(NO_3)_3 \cdot TBP_3]org + 3H_2O$

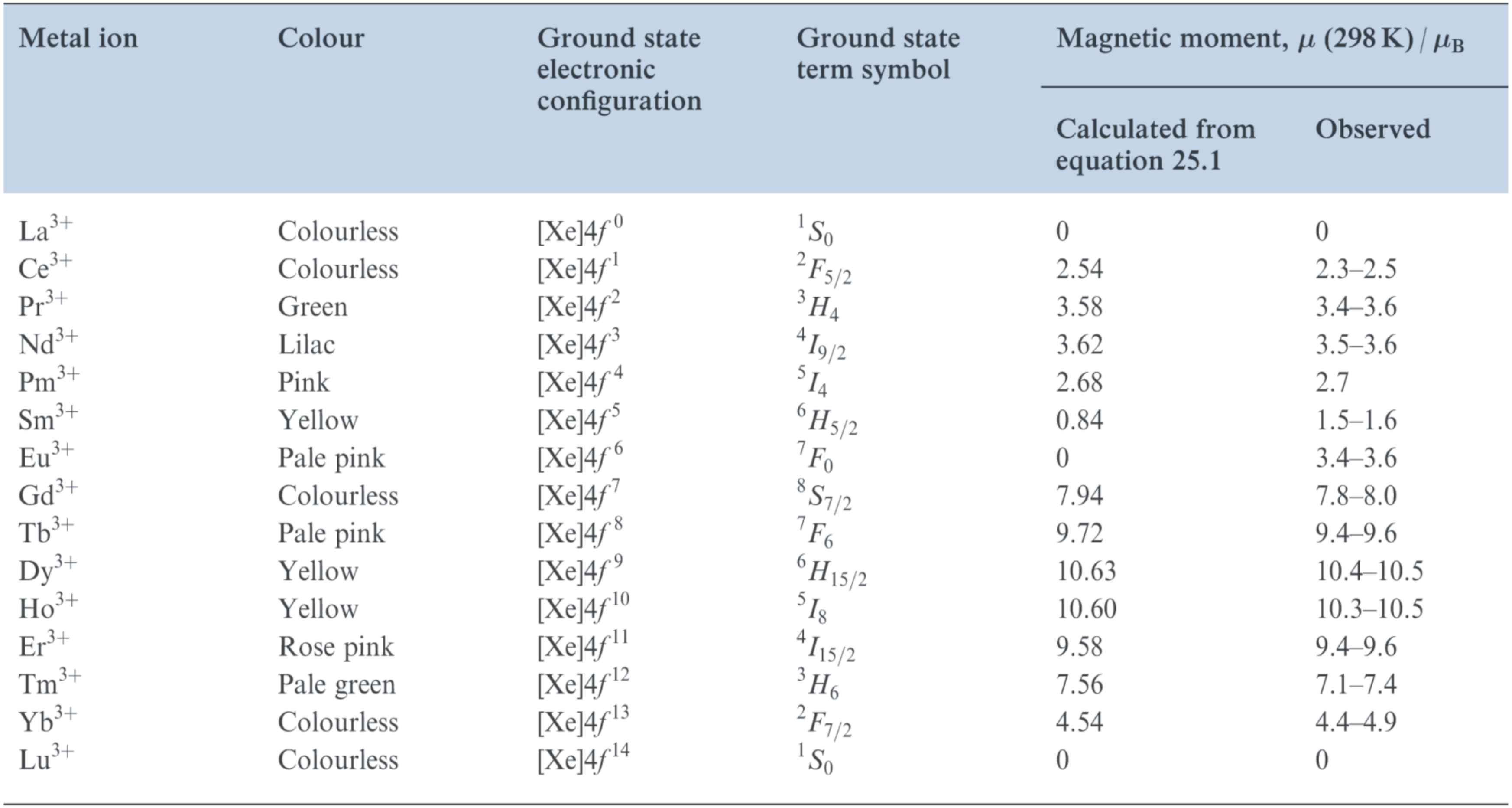
Unità *mixer-settler*



Schema di impianto SX



Proprietà ottiche degli ioni dei lantanidi

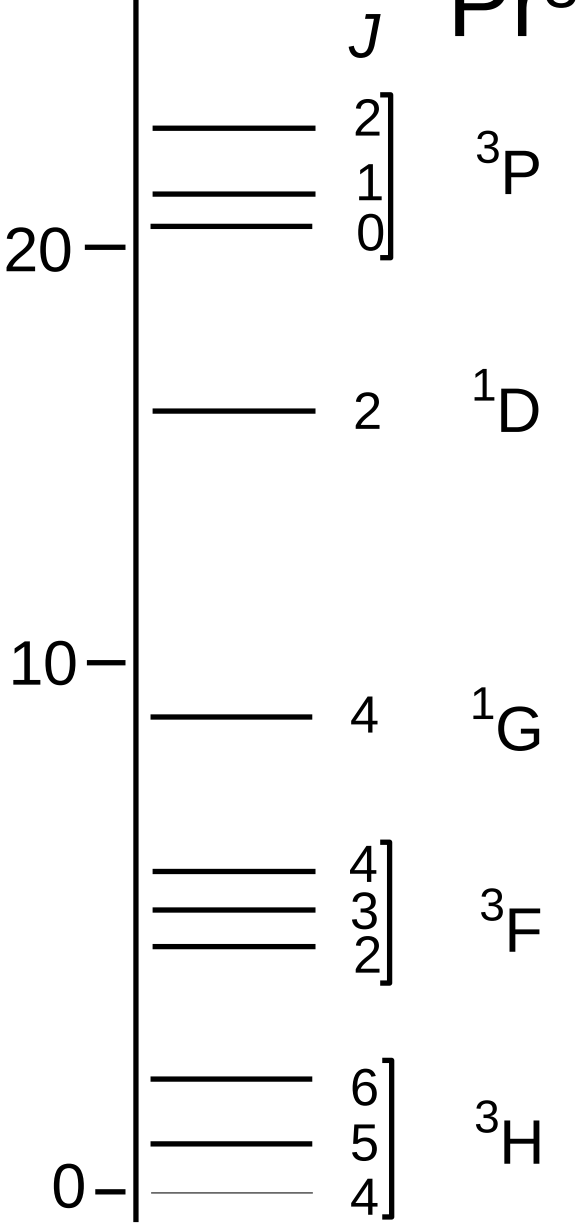


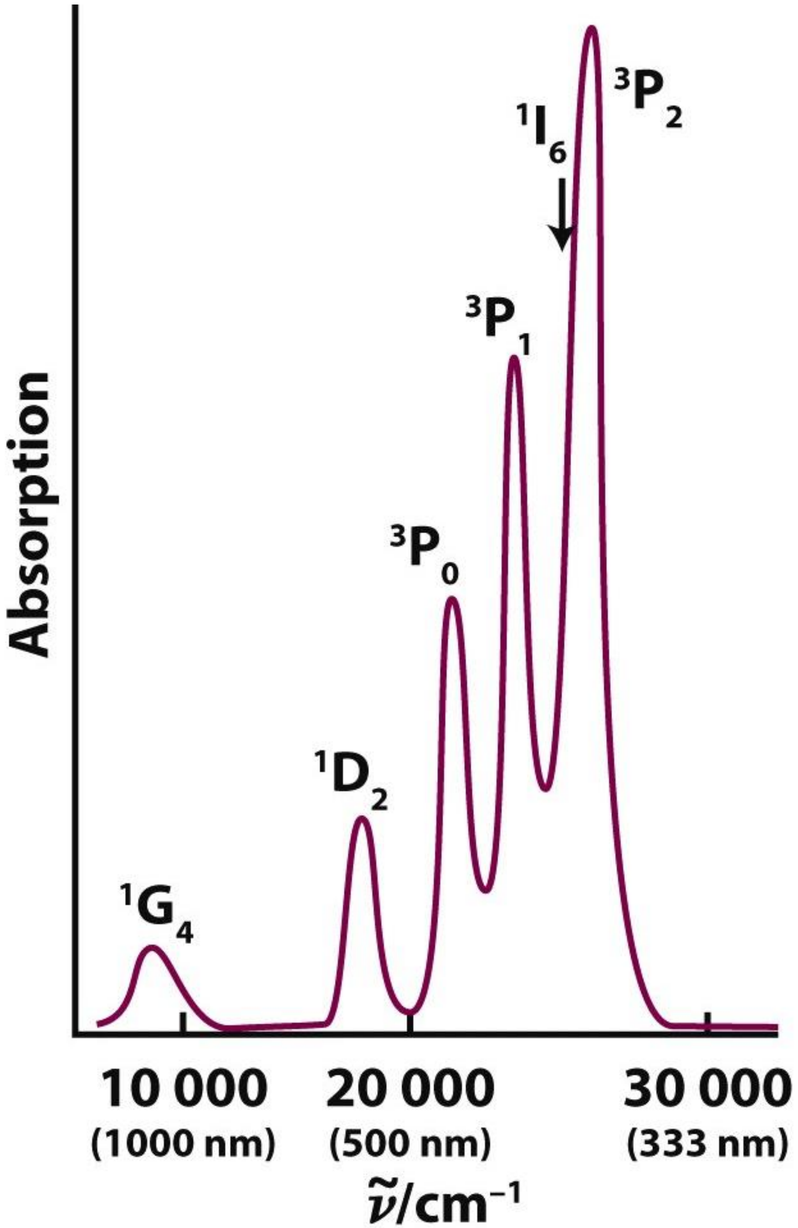
Metal ion	Colour	Ground state electronic configuration	Ground state term symbol	Magnetic moment, μ (298 K) / μ_B	
				Calculated from equation 25.1	Observed
La^{3+}	Colourless	$[Xe]4f^0$	$^1S_0$	0	0
Ce^{3+}	Colourless	$[Xe]4f^1$	$^2F_{5/2}$	2.54	2.3–2.5
Pr^{3+}	Green	$[Xe]4f^2$	$^3H_4$	3.58	3.4–3.6
Nd^{3+}	Lilac	$[Xe]4f^3$	$^4I_{9/2}$	3.62	3.5–3.6
Pm^{3+}	Pink	$[Xe]4f^4$	$^5I_4$	2.68	2.7
Sm^{3+}	Yellow	$[Xe]4f^5$	$^6H_{5/2}$	0.84	1.5–1.6
Eu^{3+}	Pale pink	$[Xe]4f^6$	$^7F_0$	0	3.4–3.6
Gd^{3+}	Colourless	$[Xe]4f^7$	$^8S_{7/2}$	7.94	7.8–8.0
Tb^{3+}	Pale pink	$[Xe]4f^8$	$^7F_6$	9.72	9.4–9.6
Dy^{3+}	Yellow	$[Xe]4f^9$	$^6H_{15/2}$	10.63	10.4–10.5
Ho^{3+}	Yellow	$[Xe]4f^{10}$	$^5I_8$	10.60	10.3–10.5
Er^{3+}	Rose pink	$[Xe]4f^{11}$	$^4I_{15/2}$	9.58	9.4–9.6
Tm^{3+}	Pale green	$[Xe]4f^{12}$	$^3H_6$	7.56	7.1–7.4
Yb^{3+}	Colourless	$[Xe]4f^{13}$	$^2F_{7/2}$	4.54	4.4–4.9
Lu^{3+}	Colourless	$[Xe]4f^{14}$	$^1S_0$	0	0

91 microstati

Pr^{3+}, f^2

$$\frac{[2(2l+1)]!}{x! \times [2(2l+1)-x]!}$$

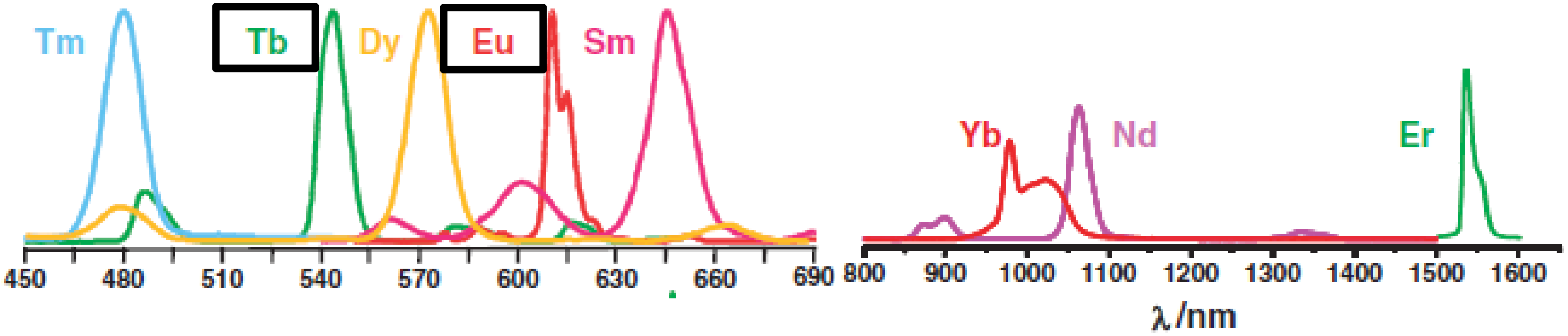




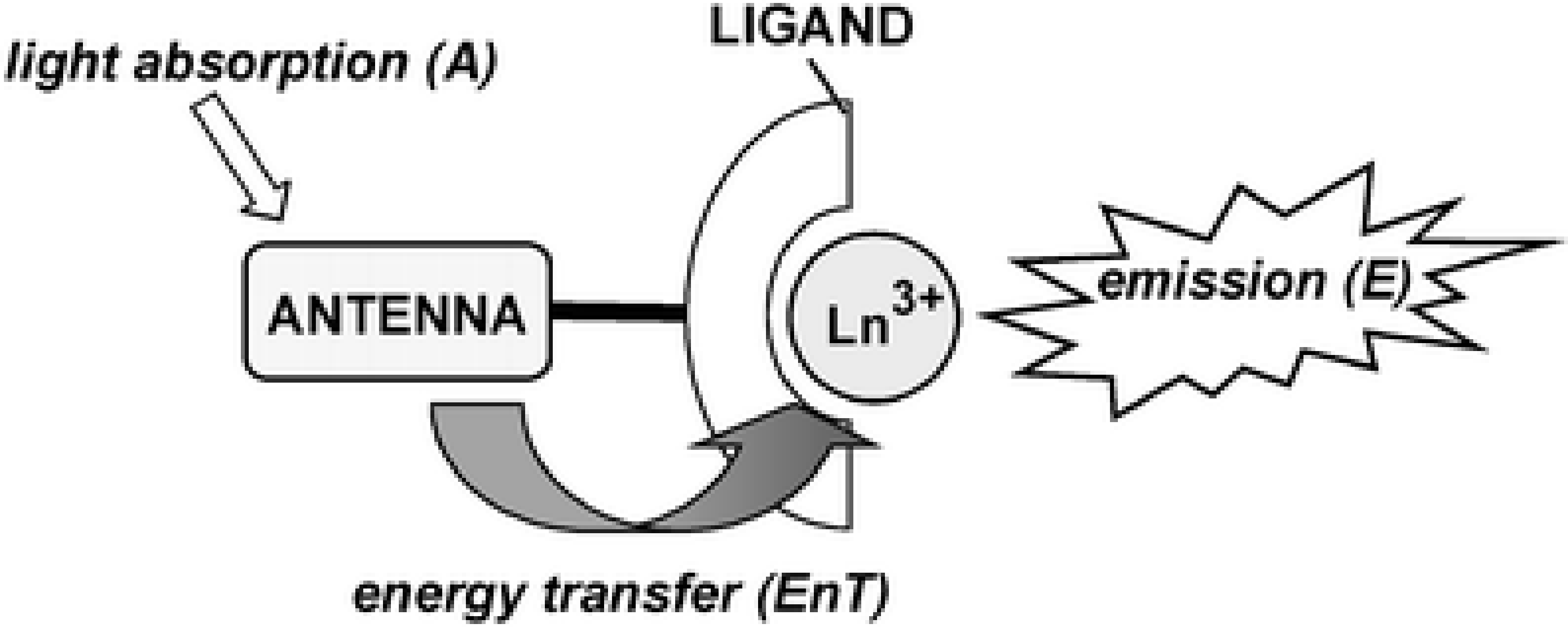
Spettri di assorbimento elettronico degli ioni Ln^{3+}

- Numero elevato di assorbimenti a causa del gran numero di microstati.
- Assorbimenti deboli a causa della mancanza di mescolamento fra gli orbitali (transizioni proibite secondo Laporte). I coefficienti di assorbanza molare (ε) valgono tipicamente 1 – 10 $dm^3\ mol^{-1}\ cm^{-1}$; in confronto, quelli dei metalli d sono prossimi a 100 $dm^3\ mol^{-1}\ cm^{-1}$.
- Bande affilate a causa delle deboli interazioni degli orbitali f con le vibrazioni dei leganti.
- Spettri in larga parte indipendenti dalla natura dei leganti e dal numero di coordinazione.

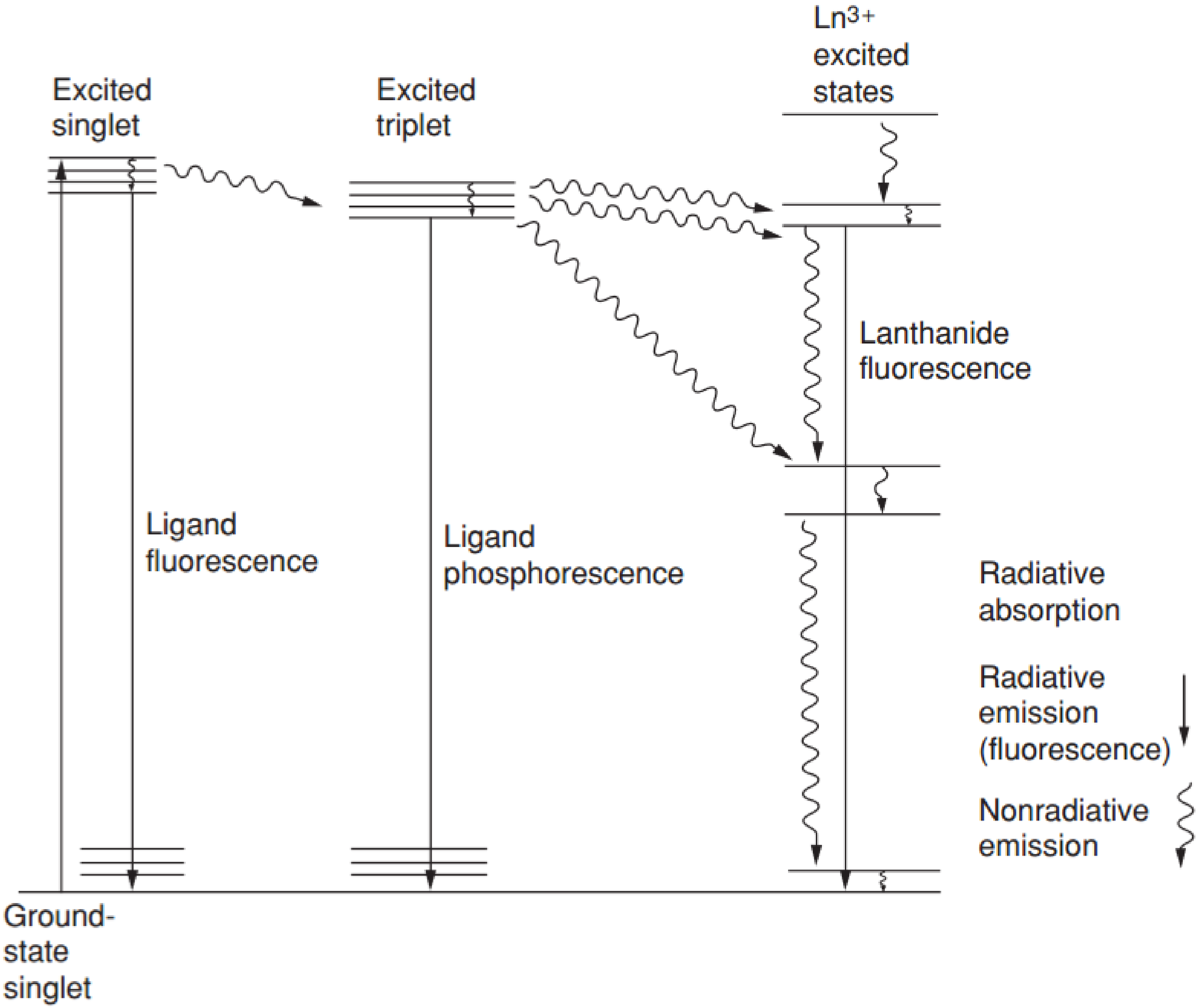
Spettri di emissione degli ioni Ln^{3+}



Sensibilizzazione (*antenna excitation*)



Sensibilizzazione (*antenna excitation*)



Lanthanide-doped LED (*fosfori*)

White-emitting LED = core LED blu (GaN, λ_{em} = 450 – 470 nm) ricoperto da uno strato di resina epossidica contenente un *fosforo al lantanide* che emette nel giallo (e.g. *yttrium aluminium garnet, YAG,* drogato con cerio (YAG:Ce)).

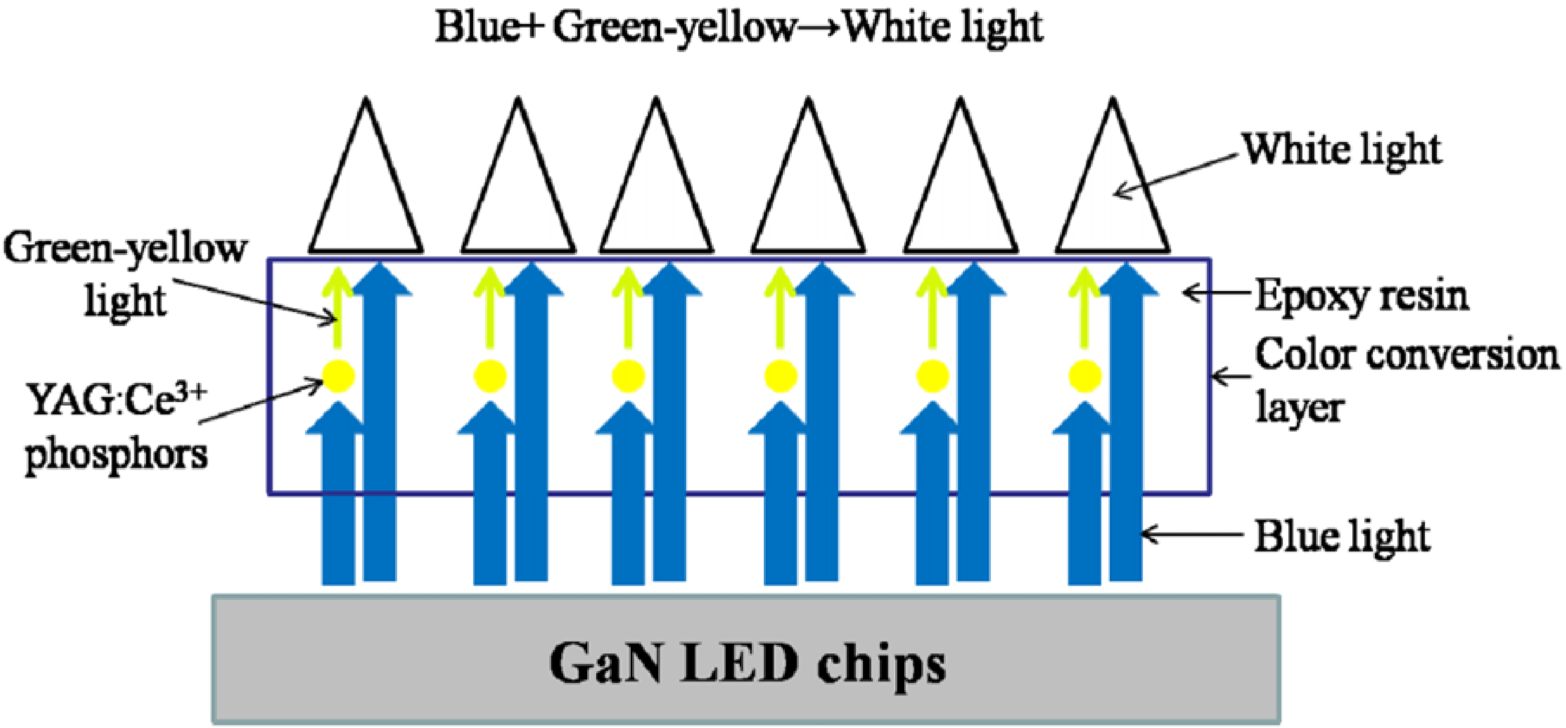
Blu + giallo = bianco

Granato (*garnet*) = $M_3M'_2(XO_4)_3$, (M/M' = $2^+/3^+$, X = Si, Al, Ga, Ge)

Granato di ittrio e alluminio (YAG) = $Y_3Al_5O_{12}$

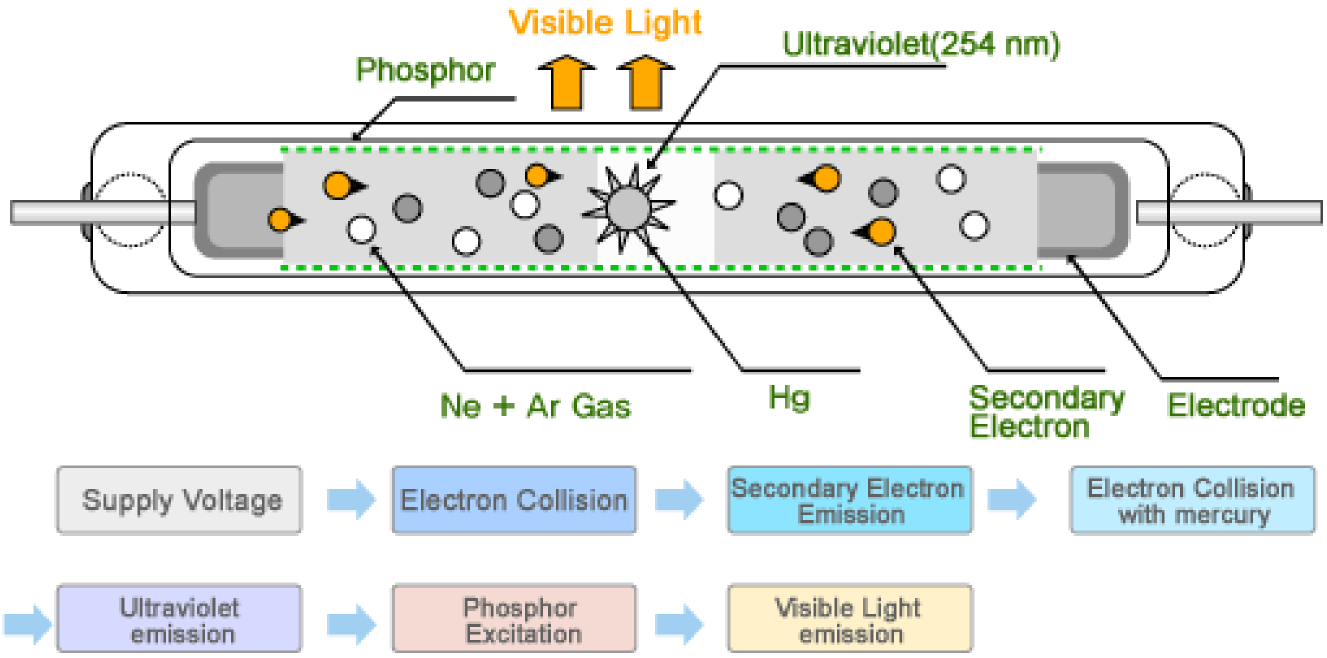
La struttura del granato definisce dei siti ottacoordinati che possono venire occupati da ioni dei lantanidi (e.g. al posto di Y^{3+})

Lanthanide-doped LED



Fosfori a base di lantanidi per lampade fluorescenti (*Cold Cathode Fluorescent Lamp*, CCFL)

Cold Cathode Fluorescent Lamp (CCFL)

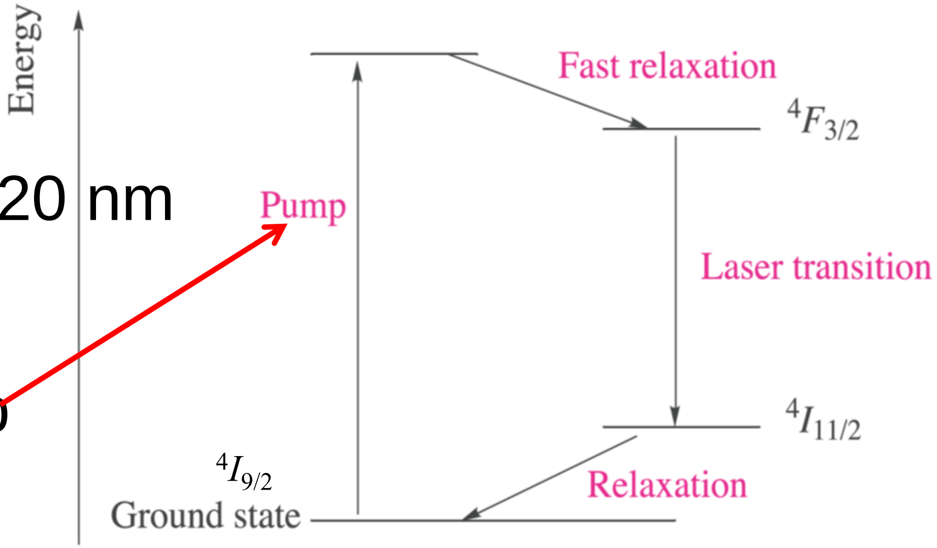


fosfori a base di Y, La, Ce, Eu, Gd, Tb

Light Amplification by Stimulated Emission of Radiation

Laser Nd:YAG (*yttrium aluminum garnet,* $Y_3Al_5O_{12}$)

inversione di popolazione



730–760 e 790–820 nm

Kripton flash lamp

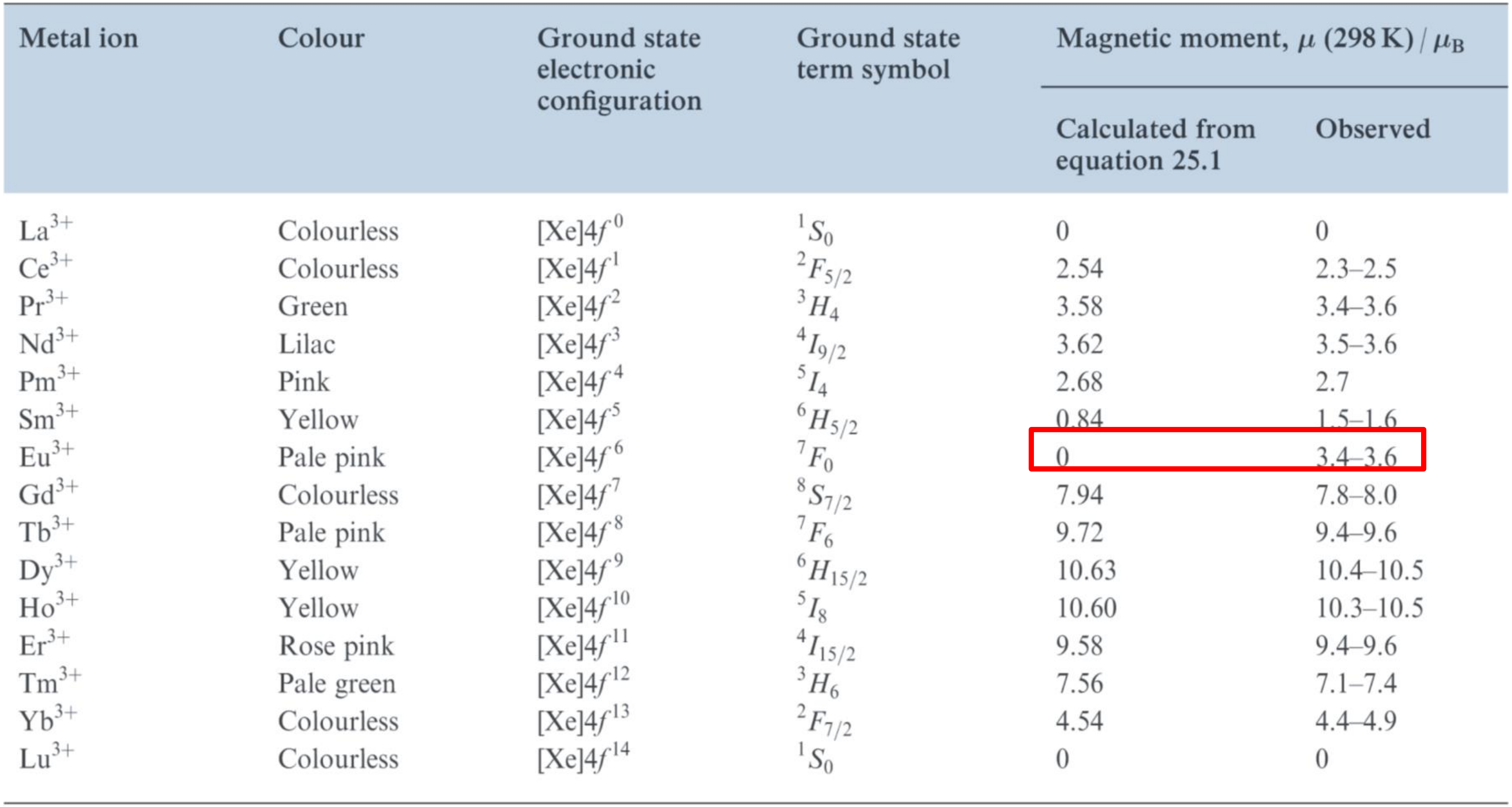
1064 nm

532 nm
355 nm
266 nm

LASER a 4 livelli

$$\mu = g_J\{J(J+1)\}^{1/2}\,\mu_B \qquad g_J = 1 + \frac{S(S+1) - L(L+1) + J(J+1)}{2J(J+1)}$$

g = fattore di Landè



Metal ion	Colour	Ground state electronic configuration	Ground state term symbol	Magnetic moment, μ (298 K) / μ_B	
				Calculated from equation 25.1	Observed
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Gd^{3+}	Colourless	$[Xe]4f^7$	$^8S_{7/2}$	7.94	7.8–8.0
Tb^{3+}	Pale pink	$[Xe]4f^8$	$^7F_6$	9.72	9.4–9.6
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Lu^{3+}	Colourless	$[Xe]4f^{14}$	$^1S_0$	0	0

Supermagneti

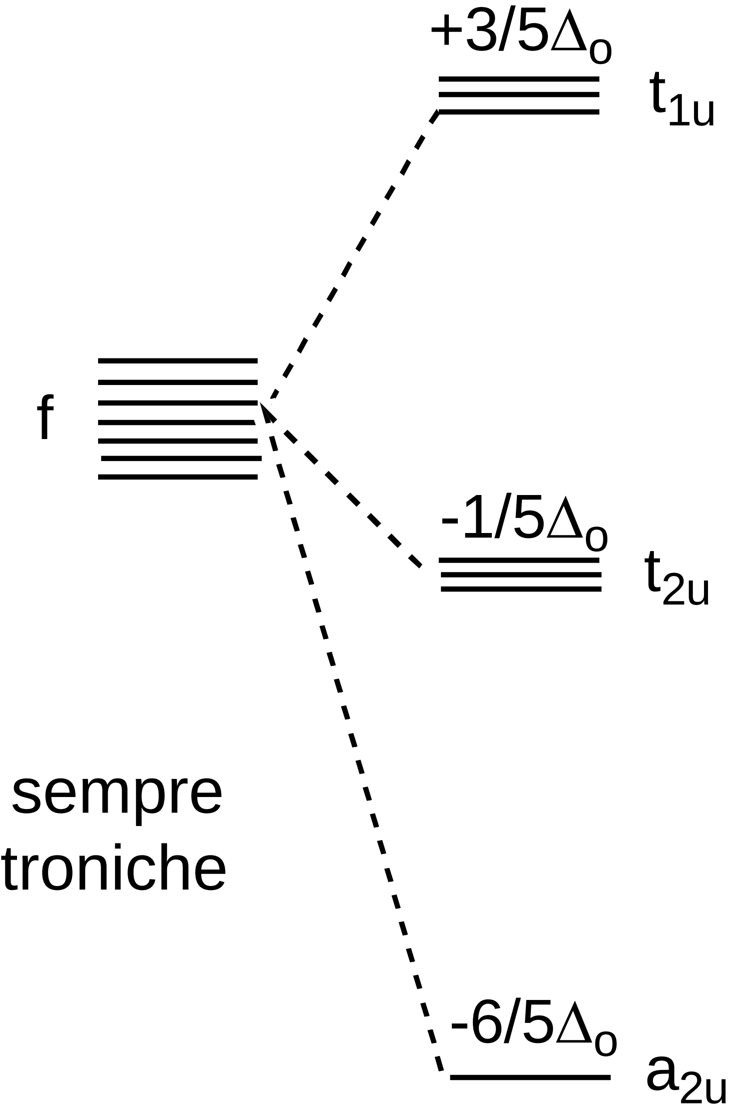
Leghe samario-cobalto

$SmCo_5$ o Sm_2Co_{17}

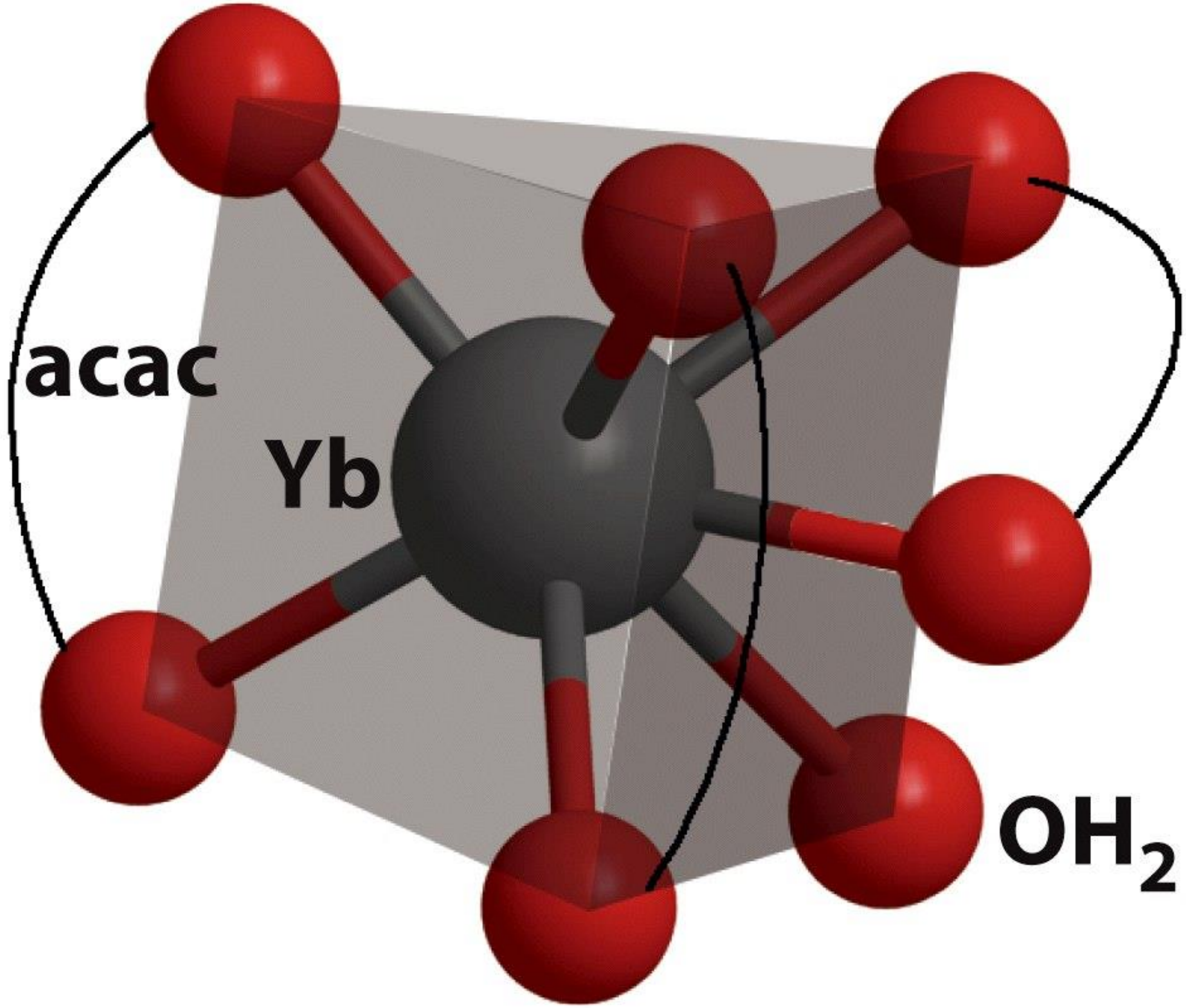
$Nd_2Fe_{14}B$

Boruro di neodimio e ferro

Splitting in campo ottaedrico

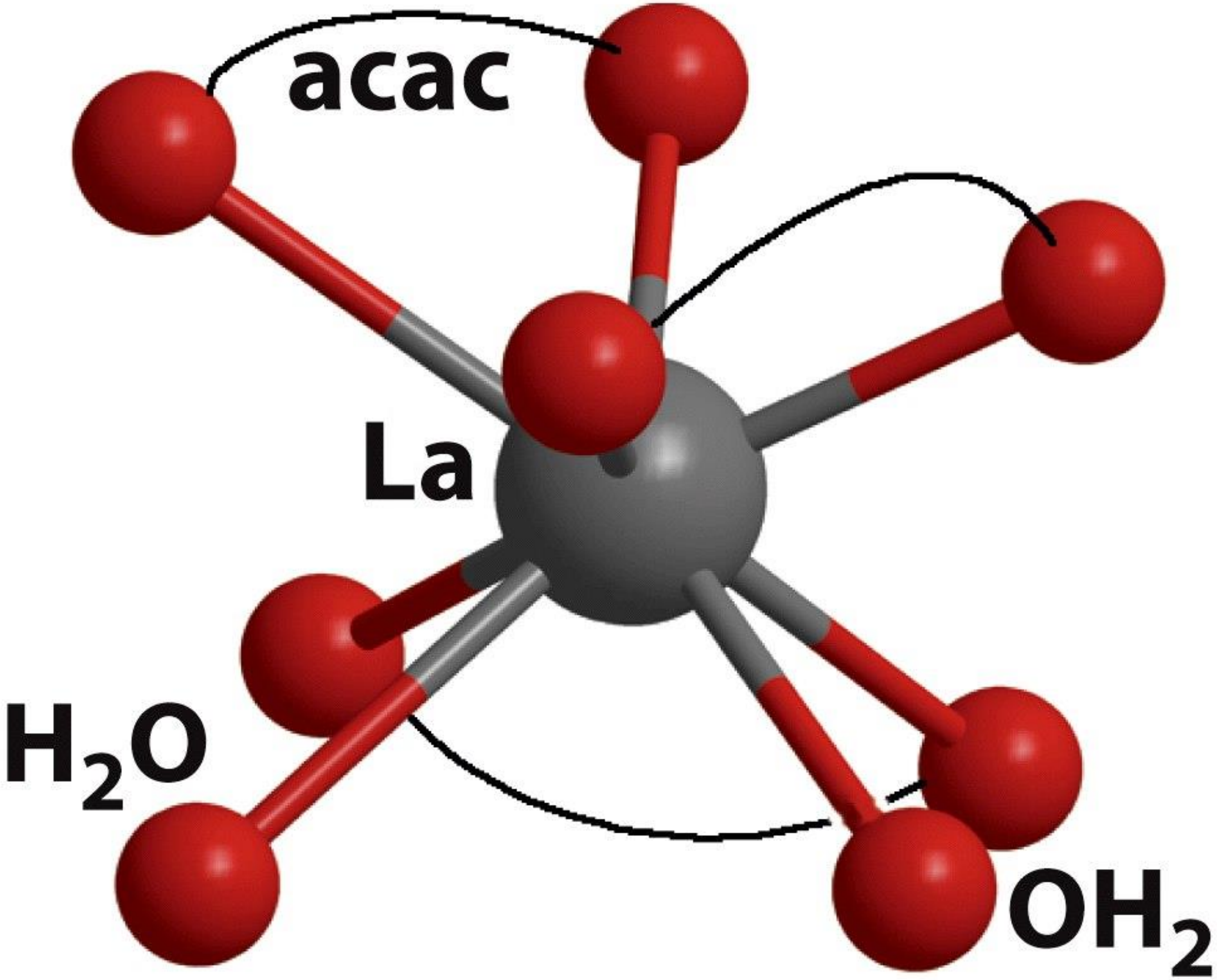


Splitting modesto, sempre
configurazioni elettroniche
ad alto spin



$[Yb(acac)_3(OH_2)]$

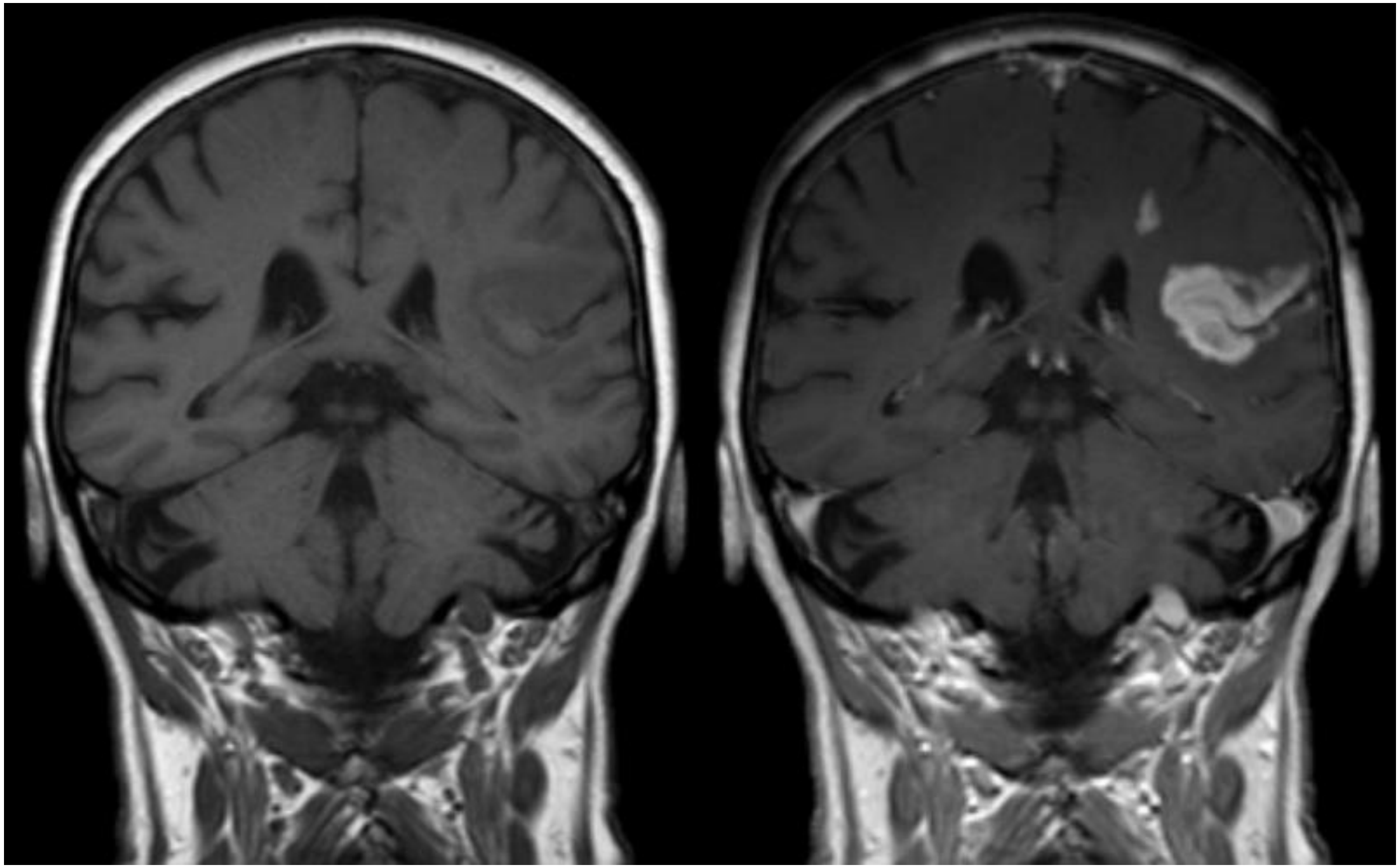
Prisma trigonale cappato



$[La(acac)_3(OH_2)_2]$

Antiprisma quadrato

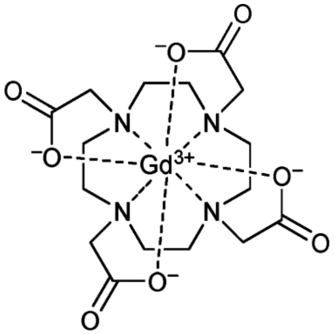
Magnetic Resonance Imaging (MRI)



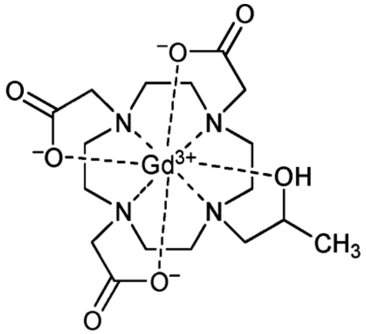
Defect of the blood-brain barrier after stroke shown in MRI. T1-weighted images: left image = without; right image = with contrast medium administration

Some commercial T_1 contrast agents

(extracellular fluid CAs)

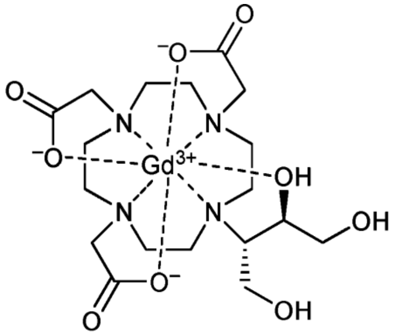


Gd-DOTA
Dotarem®
(Guerbet)

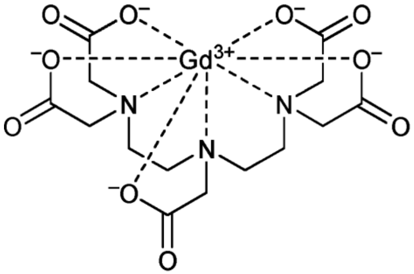


Gd-HP-DO3A
ProHance®
(Bracco)

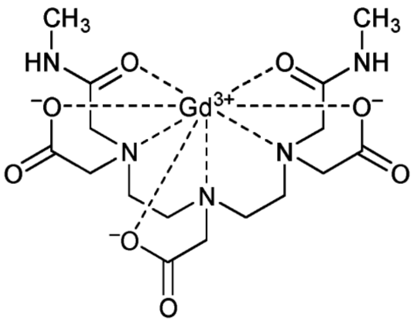
Typical dose =
0.1 – 0.3 mmoles/kg



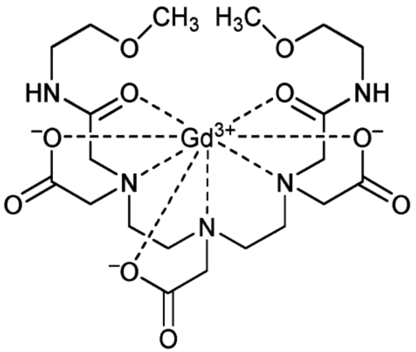
Gd-BT-DO3A
Gadovist®
(Schering)



Gd-DTPA
Magnevist®
(Schering)



Gd-DTPA-BMA
Omniscan®
(Amersham)



Gd-DTPA-BMEA
OptiMARK®
(Mallinckrodt)

Attinidi

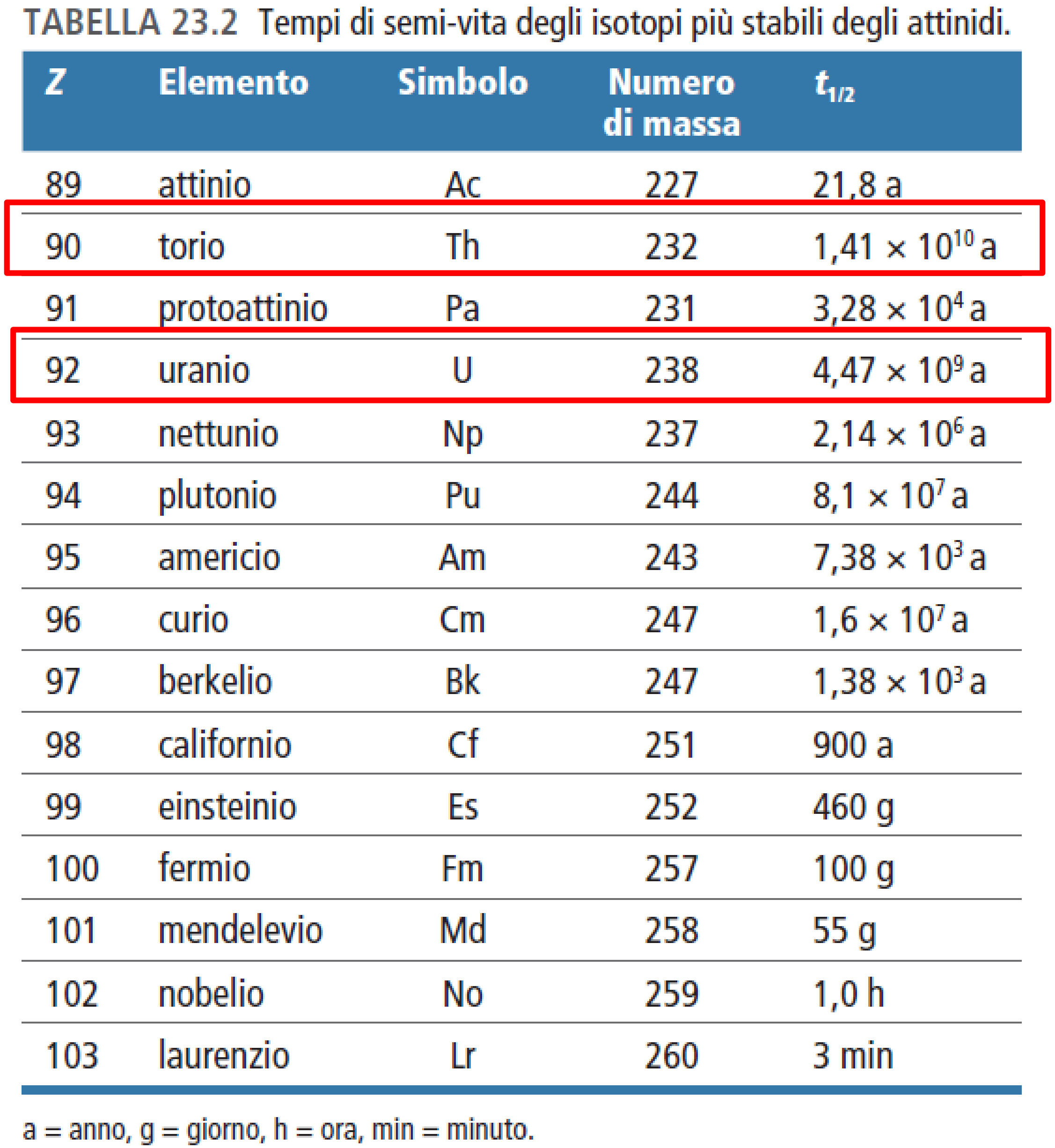
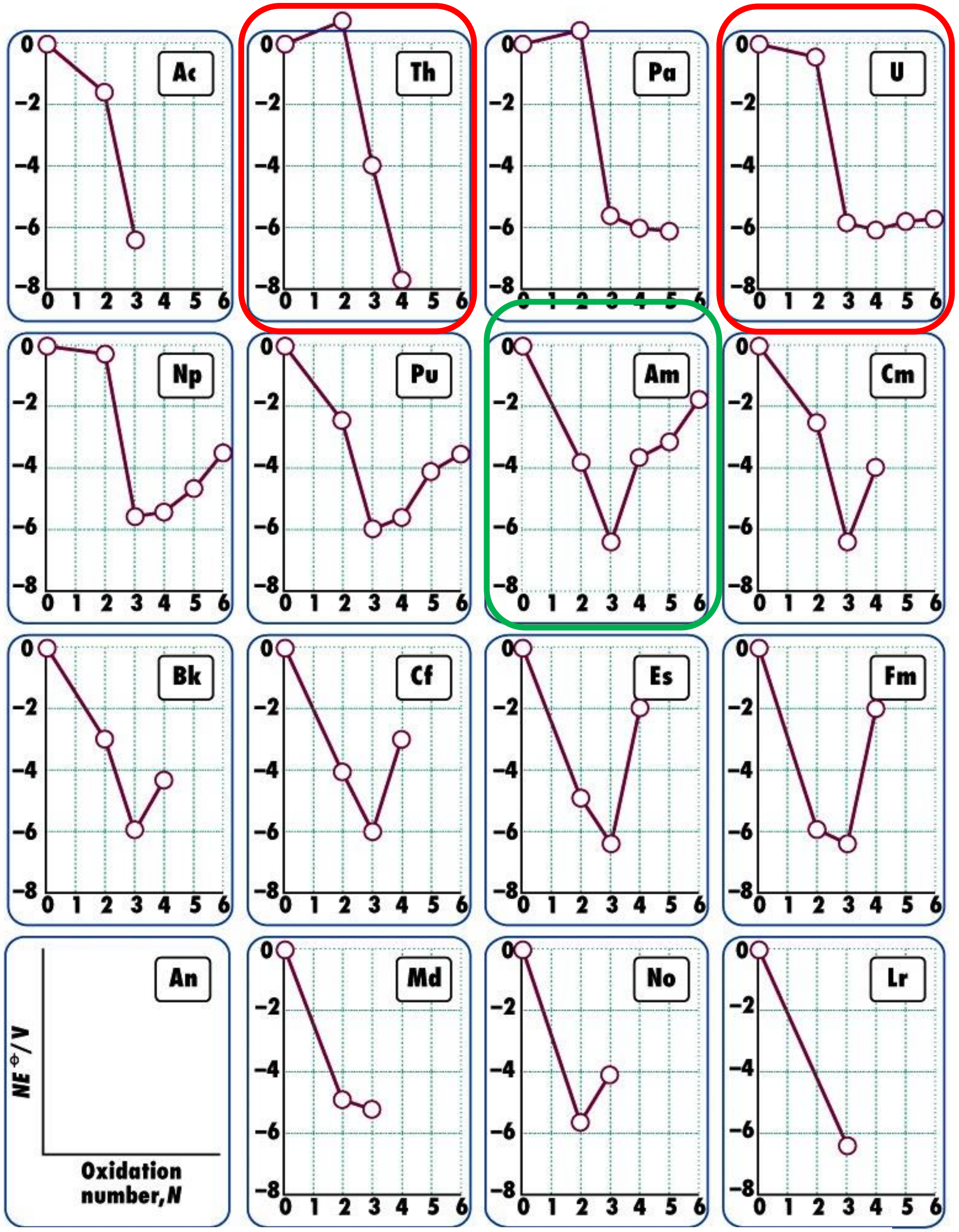


TABELLA 23.2 Tempi di semi-vita degli isotopi più stabili degli attinidi.

Z	Elemento	Simbolo	Numero di massa	$t_{1/2}$
89	attinio	Ac	227	21,8 a
90	torio	Th	232	1,41 × 10^{10} a
91	protoattinio	Pa	231	3,28 × 10^{4} a
92	uranio	U	238	4,47 × 10^{9} a
93	nettunio	Np	237	2,14 × 10^{6} a
94	plutonio	Pu	244	8,1 × 10^{7} a
95	americio	Am	243	7,38 × 10^{3} a
96	curio	Cm	247	1,6 × 10^{7} a
97	berkelio	Bk	247	1,38 × 10^{3} a
98	californio	Cf	251	900 a
99	einsteinio	Es	252	460 g
100	fermio	Fm	257	100 g
101	mendelevio	Md	258	55 g
102	nobelio	No	259	1,0 h
103	laurenzio	Lr	260	3 min

a = anno, g = giorno, h = ora, min = minuto.


Ac
Th
Pa
U
Np
Pu
Am
Cm
Bk
Cf
Es
Fm
An
Md
No
Lr
0
−2
−4
−6
−8
0 1 2 3 4 5 6
NE$^{\ominus}$/V
Oxidation number, N

Vetri all’uranio emettono fluorescenza verde se irraggiati con luce UV