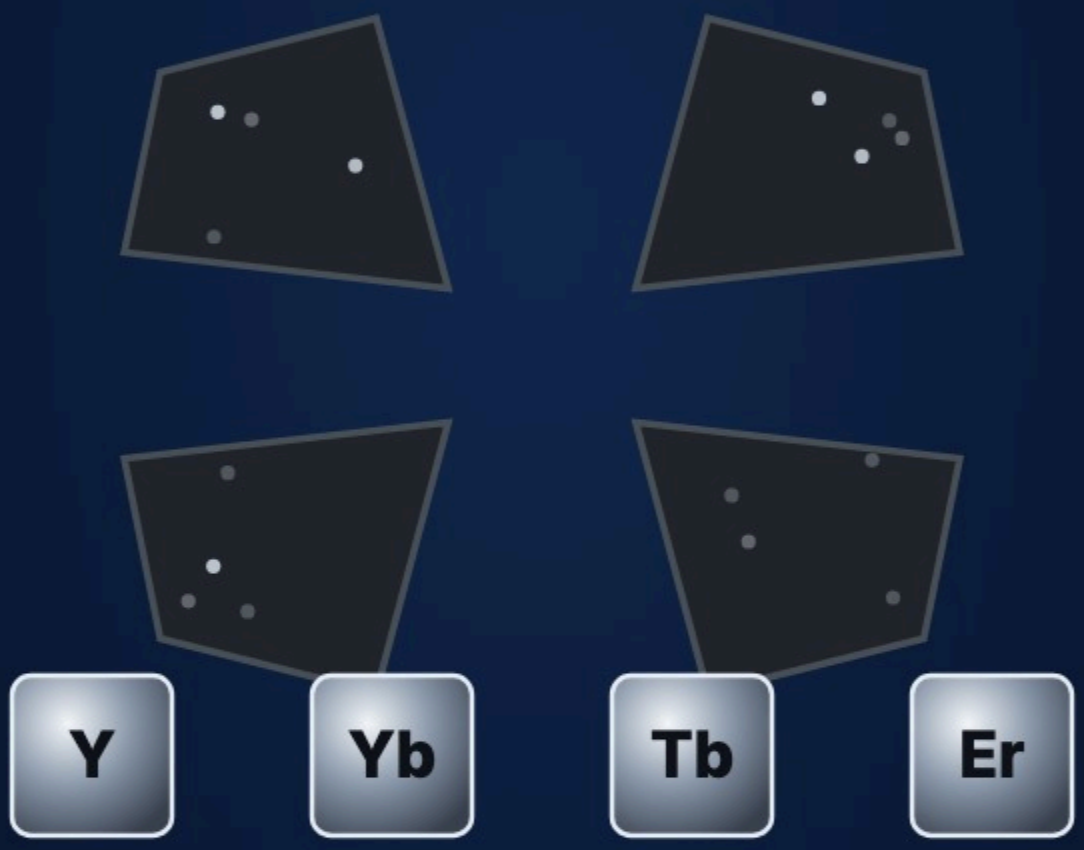
Elements almost exactly alike



1787, Ytterby (Sweden): one black mineral held **many look-alike elements**.

Telling them apart took chemists **over a century**.

The lanthanoids

La	Ce	Pr	Nd	Pm	Sm	Eu	Gd
Tb	Dy	Ho	Er	Tm	Yb	Lu	

Lanthanum and the **14 elements after it** (Ce → Lu).

Kept in a **separate row** below the periodic table.

Same face, change inside



outer $6s^2$ the same; 4f fills inside

Each new electron goes **deep into 4f**, shielded by $5s^2 5p^6$.

The outside ($6s^2$) stays the same, so the chemistry is **very similar**.

General configuration

$$[Xe]\ 4f^{1\text{-}14}\ 5d^{0\text{-}1}\ 6s^{2}$$

Ce $[Xe]\ 4f^{1}\ 5d^{1}\ 6s^{2}$

Gd $[Xe]\ 4f^{7}\ 5d^{1}\ 6s^{2}$ (half-filled 4f)

Lu $[Xe]\ 4f^{14}\ 5d^{1}\ 6s^{2}$

Ce, Gd and Lu keep one 5d electron.

Gd keeps a **half-filled $4f^{7}$** (extra stable).

Home: +3



lose $6s^2$ + one more electron

Losing two 6s + one more electron gives Ln^{3+}.

La^{3+} $4f^0$ … Lu^{3+} $4f^{14}$: +3 is the common state.

+2 and +4: special 4f counts



Ce^{4+} Eu^{2+} Yb^{2+}

Seen when 4f becomes empty ($4f^0$), half-filled ($4f^7$) or full ($4f^{14}$).

Also Tb^{4+} ($4f^7$); Pr, Nd, Dy in some oxides (MO_2).

They return to +3

$$Ce^{4+} + e^- \rightarrow Ce^{3+}$$

strong oxidant ($E^\circ \approx +1.74$ V)

$$Eu^{2+} \rightarrow Eu^{3+} + e^-$$

strong reductant

Ce^{4+} is a **strong oxidant**; Eu^{2+} is a **strong reductant**.

Both want to get back to **+3**.

Remember



Gd^{3+} Eu^{2+}

Electrons fill the deep 4f; the home is **+3**; +2 / +4 only at $4f^0$, $4f^7$, $4f^{14}$.

Your turn: how many 4f electrons in Gd^{3+} and in Eu^{2+}?