

4.5.3 Oxidation States of Lanthanoids

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

NEET/JEE
High Yield

d- and
f-Block
Elements



The Universal Standard: +3



Although La(II) and Ln(III) compounds predominate, the +3 oxidation state is the definitive, stable baseline for the entire series. All tripositive ions feature the general configuration [Xe] 4fⁿ (where n = 1 to 14).



The Golden Rule: No matter the anomaly, all lanthanoid ions possess a thermodynamic drive to ultimately revert to the +3 state.

The Engine of Exceptions

Irregularities in oxidation states arise exclusively from the extra thermodynamic stability of empty, half-filled, or completely filled f-subshells.



f-electron stability

Empty (f^0)

Noble gas configuration



f-electron stability

Half-filled (f^7)

High exchange energy



f-electron stability

Fully-filled (f^{14})

Complete subshell



The +4 Anomalies: The Oxidants



Certain elements lose a fourth electron to achieve f^0 or f^7 configurations. Because they actively seek an electron to return to +3, they act as strong oxidising agents.

Oxidation Ladder

+4 State

+3 Baseline



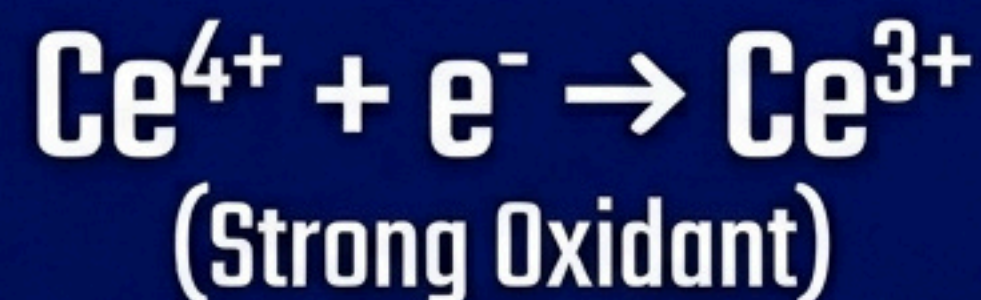
Ce⁴⁺

→ achieves f^0 (Noble gas core)

Tb⁴⁺

→ achieves f^7 (Half-filled core)

Note: Pr, Nd, Tb, and Dy also exhibit +4 states, but strictly in oxides (MO_2).





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$$E=mc^2$$



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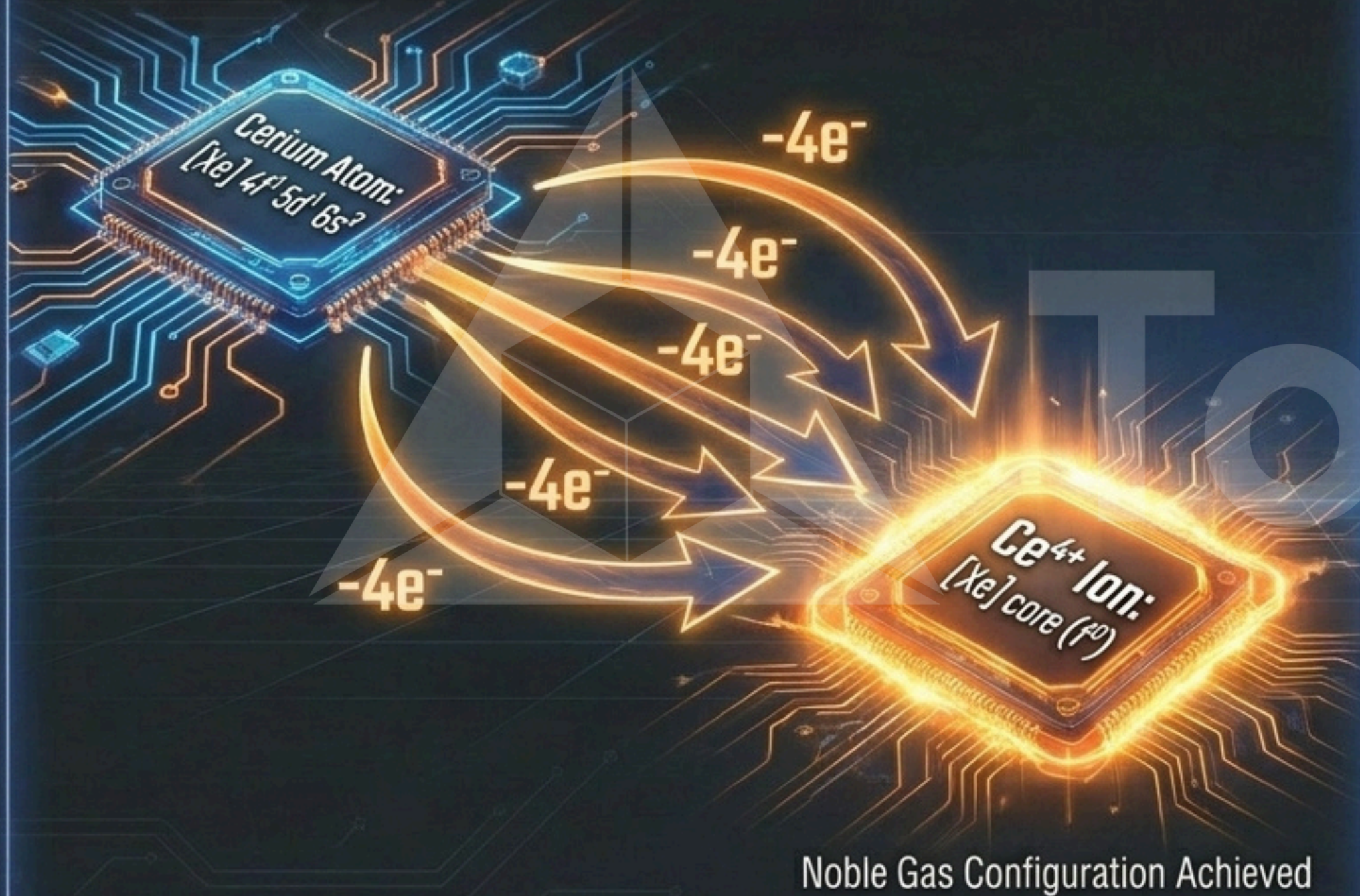
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Deep Dive: Cerium (Ce^{4+})

Atomic Schematic



Technical Specifications Dashboard



Standard Electrode Potential (E°)



High Potential: E° for $\text{Ce}^{4+} / \text{Ce}^{3+}$ is +1.74 V.



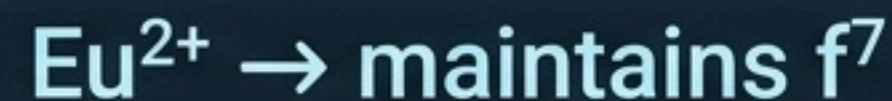
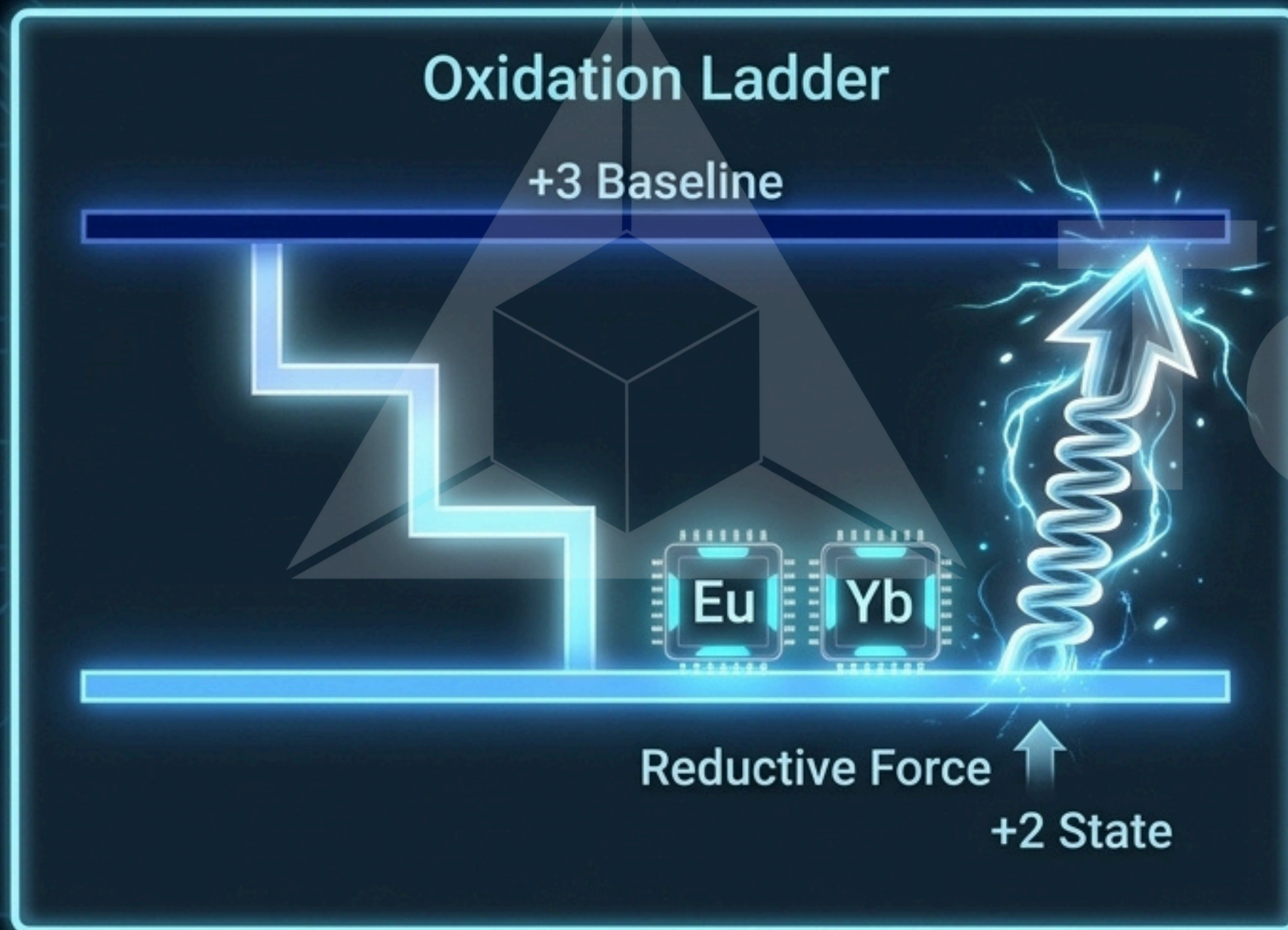
Water Oxidation: Thermodynamically capable of oxidising water.



Reaction Kinetics: The reaction rate is extremely slow. Therefore, Ce(IV) is a highly reliable analytical reagent.

The +2 Anomalies: The Reductants

Elements like Europium and Ytterbium stay at +2 to preserve their stable f-configurations. Because they actively want to lose an electron to reach +3, they act as strong reducing agents.



Note: Samarium (Sm) behaves similarly, exhibiting both +2 and +3 states.





Oxidation Anomalies Comparison

Feature	The +4 State	The +2 State
Key Ions	Ce ⁴⁺ , Tb ⁴⁺	Eu ²⁺ , Yb ²⁺
Driving Force	Achieve f ⁰ , f ⁷	Preserve f ⁷ , f ¹⁴
Chemical Nature	Strong Oxidants (accept e ⁻)	Strong Reductants (lose e ⁻)
Ultimate Fate	Reverts to +3	Reverts to +3

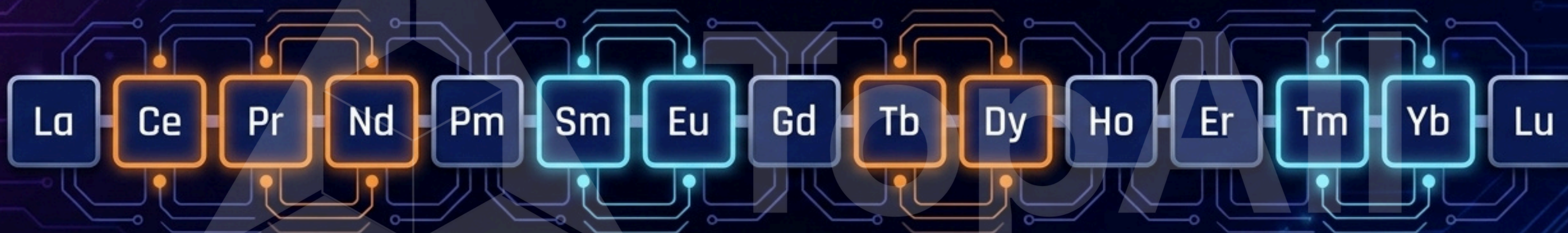
Takeaway Chip

The 'Why' is always orbital stability.
The 'Destination' is always +3.

Oxidation Variability Heatmap



Anomalies are not random; they cluster around the elements immediately preceding or following the f^0 , f^7 , and f^{14} milestones.



Exclusively +3



Exhibits +4



Exhibits +2

NEET/JEE Exam Logic

Do not memorize isolated facts. Use the +3 baseline to instantly determine redox behavior in multiple-choice questions.

Ion is +4

**Has too few
electrons**

**Wants 1 e^-
to reach +3**

**It is an
OXIDANT.**

Ion is +2

**Has too many
electrons**

**Wants to
lose 1 e^- to
reach +3**

**It is a
REDUCTANT.**

4.5.3 Quick Revision

1. The Anchor



+3 is the dominant, most stable oxidation state for all lanthanoids (La^{3+} to Lu^{3+}).

2. The Catalyst



Exceptions only exist to reach empty (f^0), half-filled (f^7), or fully-filled (f^{14}) subshells.

3. The Oxidants



Ce^{4+} (f^0) and Tb^{4+} (f^7). They force oxidation to return to +3. Ce(IV) is a key analytical reagent.

4. The Reductants



Eu^{2+} (f^7) and Yb^{2+} (f^{14}). They force reduction (giving up an electron) to return to +3.



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