Same Face, Different Inside: The Lanthanoids

The lanthanoids (lanthanum and the fourteen elements after it) have the general configuration [Xe] $4f^{1\text{-}14}$ $5d^{0\text{-}1}$ $6s^2$. Each new electron goes into the deep 4f subshell, shielded by $5s^25p^6$, while the outer $6s^2$ stays the same, so the elements are very alike (the Ytterby minerals took chemists over a century to sort out). Losing $6s^2$ and one more electron gives the characteristic +3 state (La^{3+} $4f^0$ … Lu^{3+} $4f^{14}$). +4 and +2 appear near empty, half-filled or full 4f (Ce^{4+} $4f^0$, Tb^{4+} $4f^7$, Eu^{2+} $4f^7$, Yb^{2+} $4f^{14}$), but Ce^{4+} is a strong oxidant and Eu^{2+} a strong reductant: both return to +3.

Name: Date: Score: ____ / 24

A. Fill in the blanks

1. The lanthanoids are lanthanum and the ____ elements that follow it.

2. In lanthanoids, the new electrons enter the ____ subshell.

3. The characteristic oxidation state of lanthanoids is ____.

4. Ce^{4+} has the 4f configuration ____.

5. Gadolinium has the configuration [Xe] $4f^7$ $5d^1$ ____.

B. True or False

6. The 4f electrons are shielded by the 5s and 5p electrons. True / False

7. Eu^{2+} is a strong oxidising agent. True / False

8. Lanthanoids are placed in a separate row of the periodic table. True / False

9. La^{3+} has a $4f^1$ configuration. True / False

10. Yb^{2+} has a completely filled 4f subshell. True / False

C. Assertion and reason

11. Assertion (A): +3 is the most common oxidation state of lanthanoids.
Reason (R): The energy to remove $6s^2$ and one more electron is repaid by hydration/lattice energy of Ln^{3+}.

(a) Both A and R are true, and R explains A
(b) Both A and R are true, but R does not explain A
(c) A is true, R is false
(d) A is false, R is true

Answer: _____

12. Assertion (A): Eu^{2+} is a strong reducing agent.
Reason (R): Eu^{2+} readily loses an electron to reach the common +3 state.

(a) Both A and R are true, and R explains A
(b) Both A and R are true, but R does not explain A
(c) A is true, R is false
(d) A is false, R is true

Answer: _____

D. Choose the correct option

13. The general configuration of the lanthanoids is:

(a) $[Xe]4f^{1-14}5d^{0-1}6s^2$ (b) $[Ar]3d^{1-10}4s^2$

(c) $[Rn]5f^{1-14}6d^{0-1}7s^2$ (d) $[Kr]4d^{1-10}5s^2$

Answer: _____

14. Which ion is a strong oxidising agent?

(a) Ce^{4+} (b) Eu^{2+}

(c) Yb^{2+} (d) Lu^{3+}

Answer: _____

15. The number of 4f electrons in Gd^{3+} is:

(a) 6 (b) 7

(c) 8 (d) 0

Answer: _____

16. Which shows +4 because it reaches $4f^0$?

(a) Ce (b) Eu

(c) Yb (d) Gd

Answer: _____

17. The 4f configuration of Lu^{3+} is:

(a) $4f^0$ (b) $4f^7$

(c) $4f^{13}$ (d) $4f^{14}$

Answer: _____

18. Lanthanoids have very similar chemistry because:

(a) their 4f electrons are deep inside and outer configuration is the same (b) they are all gases

(c) they have no electrons (d) they are radioactive

Answer: _____

E. Numerical problems

19. Write the 4f configuration of Pr^{3+} ($Pr = [Xe]4f^36s^2$).

20. Write the 4f configuration of Tb^{4+} ($Tb = [Xe]4f^{9}6s^{2}$).

F. Short answer questions

21. Give the general electronic configuration of the lanthanoids with two examples.

22. Why do Ce^{4+} and Eu^{2+} exist, and why do they revert to +3?

23. Why are lanthanoids difficult to separate from one another?

G. Match the columns

24. Match each item in Column A with the correct item in Column B.

Column A	Column B	Your answer
1. Ce^{4+}	(a) $4f^{7}$, strong reductant	1 → ____
2. Eu^{2+}	(b) $4f^{0}$, strong oxidant	2 → ____

Detailed solutions

1. fourteen

2. 4f

3. +3

4. $4f^0$

5. $6s^2$

6. True. They lie deep inside.

7. False. It is a strong reducing agent.

8. True. Below the main table.

9. False. La^{3+} is $4f^0$.

10. True. $4f^{14}$.

11. (a) For all members.

12. (a) Eu^{3+} is $4f^6$.

13. (a) $[Xe]4f^{1\text{-}14}5d^{0\text{-}1}6s^2$. NCERT 4.5.

14. (a) Ce^{4+}. Reverts to Ce^{3+}.

15. (b) 7. Half-filled.

16. (a) Ce. Ce^{4+}.

17. (d) $4f^{14}$. Completely filled.

18. (a) their 4f electrons are deep inside and outer configuration is the same. Shielded 4f.

19. lose $6s^2$ and one 4f electron. **Answer: $4f^2$**

20. lose $6s^2$ and two 4f electrons. **Answer: $4f^7$**

21. $[Xe]\ 4f^{1\text{-}14}\ 5d^{0\text{-}1}\ 6s^2$. Ce: $[Xe]4f^1 5d^1 6s^2$; Gd: $[Xe]4f^7 5d^1 6s^2$ (half-filled 4f retained).

22. They reach special configurations (Ce^{4+} $4f^0$, Eu^{2+} $4f^7$), but +3 is energetically preferred; Ce^{4+} is therefore a strong oxidant and Eu^{2+} a strong reductant.

23. Successive electrons enter the inner 4f subshell (shielded by $5s^2 5p^6$); the outer configuration and ionic sizes are almost the same, so their chemistry is nearly identical.

24. 1 → (b), 2 → (a).