# I.15 General Chemistry of f-Block Elements

Civil Services 2016–2026: **26** parts, **235** marks · IFoS 2016–2025: **20** parts, **172** marks

**Syllabus.** Lanthanides and actinides; separation, oxidation states, magnetic and spectral properties; lanthanide contraction.

| Marks | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CSE | 20 | 20 | 25 | 10 | 20 | 20 | 20 | 20 | 30 | 25 | 25 |
| IFoS | 25 | 10 | 15 | 18 | 23 | 18 | 15 | 15 | 18 | 15 | |

**How to use this chapter.** Read every question once and mark the ones that repeat. Pick three, write them by hand against the clock (about 7 minutes for 10 marks), then compare with the model answers on vkcscience.com.

## 2026

### CSE 2026 · Q5(j) Actinide contraction [5 marks]

What is actinide contraction? Explain.

### CSE 2026 · Q8(c) Magnetic moments of $Sm^{3+}$ and $Eu^{3+}$ at 300 K; Metallic radii from La to Lu, and the exceptions Eu and Yb; Separation of the lanthanides by complex formation (ion exchange); Why $Ce^{3+}$ and $Yb^{3+}$ are colourless but absorb in the UV [20 marks]

(i) Why do $Eu^{3+}$ and $Sm^{3+}$ not follow the trend of magnetic moment of lanthanides at 300 K? Explain.
(ii) Why do the metallic radii decrease from La to Lu except at Eu and Yb? 3+2=5
(iii) How are lanthanides separated by a complex formation method? Give description.
(iv) Why do $Ce^{3+}$ and $Yb^{3+}$ not absorb in the visible region, but show sharp absorption in the ultraviolet region?

## 2025

### CSE 2025 · Q5(h) Magnetic moment: spin only in the d-block, not in the f-block [5 marks]

The magnetic moment of d-block elements arises mainly from the contribution of spin motion of the electrons but in case of f-block elements, it is not valid. Justify the statement.

### CSE 2025 · Q8(c) Lanthanides separated by change of valency [10 marks]

How many lanthanides can be easily separated from the lanthanide mixture by using valency change method? Justify your answer.

### CSE 2025 · Q8(d) Magnetic moments of $Pr^{3+}$ and $Tb^{3+}$ [10 marks]

Write electronic configuration (outer) of the following lanthanide ions and calculate the magnetic moment in BM from L-S coupling.
(i) $Pr^{3+}$ ($g$ = 4/5) (ii) $Tb^{3+}$ ($g$ = 3/2)

### IFoS 2025 · Q8(b) Lanthanide separation by valence change; Similarity of second and third transition series [15 marks]

(i) Explain how the lanthanides are separated using valency change method. [5]
(ii) The atomic (covalent) radii of the pairs of elements Zr–Hf, Nb–Ta, Mo–W, Ru–Os, Rh–Ir and Pd–Pt are almost same. Justify your answer. [10]

## 2024

**CSE 2024 · Q5(e) Lanthanide contraction; Why Hf is placed below Zr** [10 marks]

(i) Explain lanthanide contraction. *5*

(ii) Hf is placed below Zr in the periodic table. Justify the statement. *5*

**CSE 2024 · Q8(c) Principles of four methods of separating the lanthanides** [20 marks]

Briefly explain the principles involved in the following methods of separation of the lanthanides:
(i) Repeated fractional crystallisation (ii) Solvent extraction (iii) Fractional precipitation (iv) Change of oxidation state

**IFoS 2024 · Q5(d) Relativity and lanthanide contraction** [8 marks]

Explain how 'Relativistic effect' contributes in 'Lanthanide contraction'.

**IFoS 2024 · Q7(c) Divalent europium and samarium** [10 marks]

Explain why 2+ oxidation state is stabilized in Eu (At. No. 63). With the help of your explanation, predict among Ce (At. No. 58), Tb (At. No. 65) and Sm (At. No. 62), which one is most likely to show 2+ oxidation state.

## 2023

**CSE 2023 · Q5(d) Electronic transitions in the spectra of actinide ions** [10 marks]

Explain three main types of electronic transitions observed in UV-visible absorption spectra of actinide ions.

**CSE 2023 · Q7(b) Configurations of Pr, Eu and Gd and the moments of their $M^{3+}$ ions** [10 marks]

Write the ground-state electronic configuration of lanthanides mentioned below:
(i) $_{59}$Pr (Praseodymium) (ii) $_{63}$Eu (Europium) (iii) $_{64}$Gd (Gadolinium)
Calculate the predicted effective magnetic moment ($\mu_{S+L}$) for the metal ions in +3 oxidation state in the units of Bohr magneton.

**IFoS 2023 · Q8(c) Basicity of lanthanide hydroxides; Lanthanide moments and intense UV transitions** [15 marks]

(i) Arrange the following in decreasing order of basicity giving explanation:
$Ce(OH)_3$, $Lu(OH)_3$, $Gd(OH)_3$ and $Nd(OH)_3$
Which one of these is most likely to dissolve in hot conc. NaOH solution? Why? 7

(ii) Among $Ce^{III}$, $Eu^{III}$, $Tb^{III}$ and $Yb^{III}$ ions, for which one, the calculated magnetic moment is zero? Why? Among these ions, for which two ions, appreciably higher intensity bands are found in the lower energy UV-region than the other two? Explain your answer mentioning the transition. 8

## 2022

**CSE 2022 · Q6(b) Pale colours and line-like spectra of lanthanide ions** [10 marks]

Why are 4*f* metal ions (lanthanide ions) generally pale in colour? Why do they show line like electronic spectra?

**CSE 2022 · Q7(b) Aqueous $LaCl_3$ and $LuCl_3$: which is more acidic** [10 marks]

Consider aqueous solutions of $LaCl_3$ (Lanthanum trichloride) and $LuCl_3$ (Lutetium trichloride). Which solution shows lower pH? Explain.

**IFoS 2022 · Q7(c) Lanthanide oxidation states; Sharp weak f–f spectra** [15 marks]

(i) What is the common oxidation state of lanthanides? Name two lanthanides which can exist in an oxidation state lower than the common one. What is this oxidation state? Name one lanthanide which can exist in a higher oxidation state than the common one. What is this oxidation state? Give an explanation for the existence of these uncommon oxidation states in each case. 8

(ii) Explain why the $f \rightarrow f$ transitions in lanthanide ions are much sharper and lower in intensity as compared to $d \rightarrow d$ transitions. 7

## 2021

**CSE 2021 · Q8(b) Magnetic moments of lanthanide and first-row transition metal ions** [20 marks]

The observed magnetic moments of lanthanide ions in general differ from observed magnetic moments of first row transition metal ions. Explain by giving reason(s). Identify the lanthanide ions having magnetic moments corresponding to spin-only value, and those which are diamagnetic.

**IFoS 2021 · Q5(c) Separation of lanthanoids** [8 marks]

What are the different methods used for separation of lanthanides?

**IFoS 2021 · Q8(c) Magnetic moments of Eu(III) and Sm(III)** [10 marks]

Deduce the effective magnetic moment ($\mu_{eff}$) for (i) Europium ($Eu^{3+}$) (ii) Samarium ($Sm^{3+}$)

Given: $\mu_{eff} = g\sqrt{J(J+1)}$, $g = \frac{3}{2} + \frac{S(S+1) - L(L+1)}{2J(J+1)}$

## 2020

**CSE 2020 · Q3(b) Colourless $Ce^{3+}$ ($4f^1$) and red $Ce^{4+}$ ($4f^0$)** [10 marks]

Cerium (III) ion with $4f^1$ electronic configuration is colorless while cerium (IV) ion having $4f^0$ electronic configuration is red. Explain.

**CSE 2020 · Q8(e) Magnetic moment of $Gd^{3+}$** [10 marks]

Calculate the magnetic moment of gadolinium (III) ion (in BM units).

**IFoS 2020 · Q5(c) Sharp, ligand-insensitive bands of $Ln^{3+}$ ions** [8 marks]

The absorption spectral bands of trivalent lanthanide ions are very sharp and are not affected by complexing agents appreciably. Explain why.

**IFoS 2020 · Q7(b) Oxidation states of the lanthanides** [15 marks]

Mention the important oxidation states of lanthanides. How would you account for them?

## 2019

**CSE 2019 · Q3(c) Heavy-actinide separation; thorocene and uranocene** [10 marks]

(i) Suggest a method for the separation of heavy actinides like Am, Cm, Bk, Cf, Es, Fm and Md with appropriate sketch.
(ii) Write the structure of $Th(C_8H_8)_2$ and that of $U(C_8H_8)_2$.

**IFoS 2019 · Q5(b) Separation of the lanthanides** [8 marks]

Write a brief account on separation of Lanthanides.

**IFoS 2019 · Q6(c) Lanthanide contraction; lanthanide versus actinide ions** [10 marks]

What is Lanthanide contraction? Explain from the atomic radii of + 3 cations, two noticeable differences between the lanthanide and actinide series of ions.

## 2018

**CSE 2018 · Q5(e) Ground-state term symbol of $Ho^{3+}$** [10 marks]

Find out the ground state term symbol of $Ho^{3+}$ ($Z$ = 67).

**CSE 2018 · Q7(c)(i) Why +3 is the common oxidation state of lanthanoids** [5 marks]

The commonly observed oxidation state of lanthanoids in aqueous solution is +3. – Comment.

**CSE 2018 · Q7(c)(ii) Effective magnetic moment of $Ce^{3+}$** [10 marks]

Calculate the effective magnetic moment of $Ce^{3+}$ ($Z$ = 58) at room temperature.

**IFoS 2018 · Q8(b) Why the spin-only formula fails for most $Ln^{3+}$ ions** [15 marks]

The magnetic moment of $La^{3+}$ ($f^0$), $Gd^{3+}$ ($f^7$) and $Lu^{3+}$ ($f^{14}$) can be calculated using $\mu_{spin\ only}$ formula. However, for the other lanthanides $\mu_{spin\ only}$ formula fails. Explain why. Write down the formula to calculate magnetic moment for those lanthanides other than $La^{3+}$, $Gd^{3+}$ and $Lu^{3+}$.

## 2017

**CSE 2017 · Q5(e) Why the magnetic moments of $Ln^{3+}$ ions differ from spin-only values** [10 marks]

"Magnetic moment of Lanthanide (III) ions is generally different from the value predicted by spin state." Explain.

**CSE 2017 · Q8(b) High oxidation states of early actinides; stable +2 of Am and No** [10 marks]

"High oxidation states are more common in early actinides than lanthanides but the +2 oxidation state for americium and nobelium are more stable relative to those of other actinides." Explain.

**IFoS 2017 · Q8(a) Consequences of the lanthanide contraction** [10 marks]

Comment on the consequences of 'Lanthanide Contraction'.

## 2016

**CSE 2016 · Q5(e) Oxidation states of the lanthanides other than +3** [10 marks]

In general, the principal oxidation state of lanthanide elements is +3, but some elements also exhibit other oxidation states. Explain.

**CSE 2016 · Q7(a)(ii) Lanthanide contraction and its effect on 4d and 5d metals** [10 marks]

What do you understand by "Lanthanide contraction"? How does it affect the chemistry of 4*d* and 5*d* block elements.

**IFoS 2016 · Q3(a)(ii) Magnetic data and the structure of lanthanide complexes** [10 marks]

"Magnetic susceptibility measurements are of little use in structural elucidation of lanthanide complexes." Justify the statement.

**IFoS 2016 · Q5(c)(i) Actinide spectra and the ligand** [5 marks]

Explain why—
(i) the absorption spectra of actinides (ions) are independent of the nature of the ligand attached to them;

**IFoS 2016 · Q6(b)(i) General electronic configurations of the 4f and 5f elements** [5 marks]

Write the general expressions for the filling of electrons in 4*f* and 5*f* block elements.

**IFoS 2016 · Q6(b)(ii) Lanthanide contraction; effect on 4f and 5d chemistry** [5 marks]

What do you understand by 'lanthanide contraction'? How does it affect the chemistry of 4*f* and 5*d* block elements?