

For all Agricultural, Medical, Pharmacy and Engineering Entrance Examinations held across India.

Absolute

NEET – UG & JEE (Main)

CHEMISTRY Vol. 2.1

Salient Features

- Precise theory for every topic.
- Exhaustive subtopic wise coverage of MCQs.
- 2498 MCQs including questions from various competitive exams.
- Includes MCQs from AIPMT & Re-Test 2015, NEET P-I & P-II 2016, JEE (Main) 2015 & 16.
- Relevant Hints provided.
- Quick Review and Additional Information to build concepts.
- Topic-wise test at the end of each chapter.

*Solutions/hints to Topic Test available in downloadable PDF format at
www.targetpublications.org/tp12103*

Printed at: **Repro Knowledgecast Ltd., Mumbai**

© Target Publications Pvt. Ltd.

No part of this book may be reproduced or transmitted in any form or by any means, C.D. ROM/Audio Video Cassettes or electronic, mechanical including photocopying, recording or by any information storage and retrieval system without permission in writing from the Publisher.

P.O. No. 136545

TEID: 12103_JUP

PREFACE

Target's "Absolute Chemistry Vol - 2.1" is compiled according to the notified Std. XII syllabus for NEET-UG & JEE (Main). The content of this book is framed after reviewing various state syllabi as well as the ones prepared by CBSE, NCERT and COBSE.

The sections of **Theory, Quick Review, Formulae, MCQs and Topic Test** form the backbone of every chapter and ensure adequate revision.

These MCQs are framed considering the importance given to every topic as per the NEET-UG & JEE (Main) exam. They are a healthy mix of theoretical, numerical, multi-step reactions and graphical based questions.

The level of difficulty of these questions is at par with that of various competitive examinations like CBSE, AIIMS, CPMT, JEE, AIEEE, TS EAMCET (Med. and Engg.), BCECE, Assam CEE, AP EAMCET (Med. and Engg.) & the likes. Also to keep students updated, questions from most recent

examinations such as AIPMT/NEET, MHT CET, KCET, GUJ CET, WB JEEM, JEE (Main), of years 2015 and 2016 are exclusively covered.

In the development of each chapter, we have ensured the inclusion of important points that are enclosed within a box. These topics will enhance students' knowledge and provide them an edge to score better in the highly competitive exams.

We are confident that this book will cater to needs of students across a varied background and effectively assist them to achieve their goal. We welcome readers' comments and suggestions which will enable us to refine and enrich this book further.

Please write to us at: mail@targetpublications.org

All the best to all Aspirants!

Yours faithfully,

Authors

Edition: Second

Disclaimer

This reference book is transformative work based on textual contents published by Bureau of Textbook. We the publishers are making this reference book which constitutes as fair use of textual contents which are transformed by adding and elaborating, with a view to simplify the same to enable the students to understand, memorize and reproduce the same in examinations.

This work is purely inspired upon the course work as prescribed by the National Council of Educational Research and Training (NCERT). Every care has been taken in the publication of this reference book by the Authors while creating the contents. The Authors and the Publishers shall not be responsible for any loss or damages caused to any person on account of errors or omissions which might have crept in or disagreement of any third party on the point of view expressed in the reference book.

© reserved with the Publisher for all the contents created by our Authors.

No copyright is claimed in the textual contents which are presented as part of fair dealing with a view to provide best supplementary study material for the benefit of students.

Index

No.	Topic Name	Page No.
1	Solid State	1
2	Solutions	58
3	Electrochemistry	128
4	Chemical Kinetics	212
5	Surface Chemistry	271
6	General Principles and Processes of Isolation of Elements	327
7	p-Block Elements	382
8	d and f-Block Elements	511
9	Coordination Compounds	564

'Chapters 10 to 16 are a part of Absolute Chemistry Vol - 2.2'

08 | d and f-Block Elements

8.0 General introduction

d-Block Elements

8.1 Electronic configuration, occurrence and general characteristics of transition elements

8.2 General trends in the properties of first row transition metals

8.3 Preparation, properties and uses of potassium dichromate ($K_2Cr_2O_7$)

** marked section is for NEET-UG

8.4 Preparation, properties and uses of potassium permanganate ($KMnO_4$)

f-Block Elements

8.5 Lanthanoids

8.6 Lanthanoid contraction and its consequences

8.7 Actinoids

**8.8 Comparison between lanthanoids and actinoids

8.9 Applications of d- and f-block elements

8.0 General introduction

➤ d and f-block elements:

- i. *The elements in which the last electron enters the d-orbital of the penultimate (last but one) shell i.e., (n-1) d-orbital (where n is the outermost shell) are called **d-block elements**.*
- ii. The d-block elements are also known as **transition elements**.
- iii. *The **transition elements** are those elements which have incompletely (partly) filled (n-1) d-orbital in their ground (elementary) state or in any of their oxidation states.*
- iv. *The elements in which the last electron enters the f-orbital of the antepenultimate (third to the outermost) shell i.e. (n-2) f-orbital are called **f-block elements**.*
- v. The f-block elements are also known as **inner transition elements**. 4f and 5f series of inner transition elements are called as lanthanoids and actinoids respectively.
- vi. The s-block elements are highly electropositive while the p-block elements are highly electronegative. The d-block elements occupy position in between that of s- and p-block elements (in groups 3-12 of the periodic table).
- vii. The d-block elements exhibit the intermediate properties; thus the name, '**transition elements**'.
- viii. The transition elements (starting from fourth period of the periodic table) consists of the following series:
 - a. **3d (or first transition) series:** This is a complete series comprising of elements from Sc(Z = 21) to Zn(Z = 30) i.e., scandium (Sc), titanium (Ti), vanadium (V), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu) and zinc (Zn). In this series, 3d-orbitals are gradually filled.
 - b. **4d (or second transition) series:** This is a complete series comprising of elements from Y(Z = 39) to Cd (Z = 48) i.e., yttrium (Y), zirconium (Zr), niobium (Nb), molybdenum (Mo), technetium (Tc), ruthenium (Ru), rhodium (Rh), palladium (Pd), silver (Ag) and cadmium (Cd). In this series, 4d-orbitals are gradually filled.
 - c. **5d (or third transition) series:** This is a complete series comprising of elements from La(Z = 57), Hf(Z = 72) to Hg (Z = 80) i.e., lanthanum (La), hafnium (Hf), tantalum (Ta), tungsten (W), rhenium (Re), osmium (Os), iridium (Ir), platinum (Pt), gold (Au) and mercury (Hg). In this series, 5d-orbitals are gradually filled.
 - d. **6d (or fourth transition) series:** This is an incomplete series beginning with Ac(Z = 89) i.e., actinium (Ac), rutherfordium (Rf), dubnium (Db), seaborgium (Sg), bohrium (Bh), hassium (Hs), meitnerium (Mt), darmstadtium (Ds), roentgenium (Rg), copernicium (Cn). In this series, 6d-orbitals are gradually filled.



d-Block Elements

8.1 Electronic configuration, occurrence and general characteristics of transition elements

➤ **Position in periodic table:**

The d-block elements are present in the middle of the periodic table, in groups 3 to 12 and periods 4 to 7.

The position of d-block elements in the periodic table

IA	d-block elements										VIIIA					
1	IIA	IIIIB	IVB	VB	VIB	VIIB	VIIIB		IB	IIB	13	14	15	16	17	18
2		21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn					
	s-block elements	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd					p-block elements
		57 La [*]	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg					
		89 Ac ^{**}	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn					

* Lanthanoids

** Actinoids

f-block elements

➤ **Electronic configuration:**

- The general electronic configuration of the d-block elements is $(n-1) \text{d}^{1-10} \text{ ns}^{1-2}$. (where n is the outermost shell). The d-orbitals are successively filled.
- Following table lists the general electronic configurations of the four transition metal series.

Period	Series	Elements	Electronic configuration
4 th	3d	₂₁ Sc to ₃₀ Zn	[Ar] 3d ¹⁻¹⁰ 4s ¹⁻²
5 th	4d	₃₉ Y to ₄₈ Cd	[Kr] 4d ¹⁻¹⁰ 5s ⁰⁻²
6 th	5d	₅₇ La, ₇₂ Hf to ₈₀ Hg	[Xe] 4f ^{0/14} 5d ¹⁻¹⁰ 6s ¹⁻²
7 th	6d	₈₉ Ac, ₁₀₄ Rf to ₁₁₂ Cn	[Rn] 5f ^{0/14} 6d ¹⁻¹⁰ 7s ¹⁻²

- Following table lists the electronic configuration of the elements of 3d series.

Elements	Symbol	Atomic number	Expected electronic configuration	Observed electronic configuration
Scandium	Sc	21	[Ar]3d ¹ 4s ²	[Ar]3d ¹ 4s ²
Titanium	Ti	22	[Ar]3d ² 4s ²	[Ar]3d ² 4s ²
Vanadium	V	23	[Ar]3d ³ 4s ²	[Ar]3d ³ 4s ²
Chromium	Cr	24	[Ar]3d ⁴ 4s ²	[Ar]3d ⁵ 4s ¹
Manganese	Mn	25	[Ar]3d ⁵ 4s ²	[Ar]3d ⁵ 4s ²
Iron	Fe	26	[Ar]3d ⁶ 4s ²	[Ar]3d ⁶ 4s ²
Cobalt	Co	27	[Ar]3d ⁷ 4s ²	[Ar]3d ⁷ 4s ²
Nickel	Ni	28	[Ar]3d ⁸ 4s ²	[Ar]3d ⁸ 4s ²
Copper	Cu	29	[Ar]3d ⁹ 4s ²	[Ar]3d ¹⁰ 4s ¹
Zinc	Zn	30	[Ar]3d ¹⁰ 4s ²	[Ar]3d ¹⁰ 4s ²

- The atomic number of first member of the 3d series of transition elements, scandium (Sc) is 21.



- v. The s-block element preceding Sc in the fourth period is $_{20}\text{Ca}$ with atomic number 20 and configuration $[\text{Ar}] 4\text{s}^2$ where $[\text{Ar}] = 1\text{s}^2 2\text{s}^2 2\text{p}^6 3\text{s}^2 3\text{p}^6$.
- vi. The electronic configuration of Sc ($Z = 21$) is $[\text{Ar}] 3\text{d}^1 4\text{s}^2$. Thus, the 21st electron enters the 3d subshell.
- vii. The 3d orbital in case of Cu ($Z = 29$) is completely filled in the elementary state. However in the +2 oxidation state, it is partly filled (3d^9). Therefore copper is considered as member of transition metal series.
- viii. Half filled and completely filled subshells have extra stability due to symmetrical distribution of electrons resulting in maximum electron exchange. This provides more stability to the element. This explains the exceptional electronic configuration of chromium and copper.
- a. The expected electronic configuration of chromium is $[\text{Ar}] 3\text{d}^4 4\text{s}^2$. The observed electronic configuration of chromium is $[\text{Ar}] 3\text{d}^5 4\text{s}^1$ which contains half filled 3d and 4s subshells and is more stable than the expected electronic configuration containing partly filled 3d and completely filled 4s subshell.
- b. The expected electronic configuration of copper is $[\text{Ar}] 3\text{d}^9 4\text{s}^2$. The observed electronic configuration of copper is $[\text{Ar}] 3\text{d}^{10} 4\text{s}^1$ which contains completely filled 3d and half filled 4s subshells and is more stable than the expected electronic configuration containing partly filled 3d and completely filled 4s subshell.
- ix. The general electronic configuration of Zn, Cd and Hg is $(n-1)\text{d}^{10} \text{ns}^2$. The 3d orbitals are completely filled in the elementary (ground) state and in their common oxidation state (+2). Therefore, Zn, Cd and Hg are not considered as member of transition metal series. However, their chemistry is studied along with that of the transition metals as they are the end members of the three transition series.

➤ **Occurrence:**

- i. Sulphide minerals contain soft d-block elements. Roasting of sulphide minerals in air gives metal or metal oxide, which on reduction gives metal.
- ii. Oxide minerals contain hard d-block elements. Reduction of oxide minerals with carbon gives metal.
- iii. Hard d-block elements (metals) are more electropositive than soft d-block elements.

Transition element	Occurrence
Titanium	Coal, clay, rocks, sand, etc.
Vanadium	Ores like vanadinite and carnotite
Chromium	Ores like chromite ($\text{FeO} \cdot \text{Cr}_2\text{O}_3$), chrome ore (Cr_2O_3), crocoisite (PbCrO_4)
Manganese	Pyrolusite (MnO_2) ore
Copper	Cuprite (Cu_2O), malachite [$\text{CuCO}_3 \cdot \text{Cu(OH)}_2$], azurite [$2\text{CuCO}_3 \cdot \text{Cu(OH)}_2$]

- iv. In the earth's crust, the abundance of iron is next to that of aluminium, and it occurs in free as well as in combined state.
- v. Cobalt is found in traces in the soil.
- vi. Nickel is always accompanied with cobalt in its ores.
- vii. Zinc is occurs in nature along with silver, copper, lead and platinum in their ores.

➤ **General characteristics of transition elements:**

- i. Transition elements show metallic properties such as malleability, ductility, metallic lustre, and high tensile strength.
- ii. Transition elements have higher melting and boiling points. They also have high density and compact structure. This is due to strong interatomic metallic bonding as both $(n-1)$ d and ns electrons participate in metallic bonding.
- iii. Transition elements have high thermal and electrical conductivity.
- iv. Transition elements have variable oxidation states as both $(n-1)$ d and ns electrons participate in bonding, due to nearly same energy levels.
- v. Transition elements are paramagnetic (attracted by the magnetic field) due to presence of unpaired electrons in $(n-1)$ d-orbitals.
- vi. Transition elements form organometallic compounds.
- vii. Transition elements have typical metallic structures. Mercury is an exception which is liquid at room temperature.
- viii. Transition elements have high ionisation energies. They are less reactive than s-block elements.
- ix. Transition elements form alloys with different metals.
- x. Transition elements form interstitial compounds with elements such as hydrogen, boron, carbon, nitrogen etc.
- xi. They have tendency to form large number of complexes (coordination compounds).
- xii. The transition metals exhibit catalytic property. Most of the transition metals such as Mn, Ni, Co, Cr, V, Pt, etc., and their compounds have been used as excellent catalysts.



8.2 General trends in the properties of first row transition metals

➤ Metallic character:

- Since all the transition elements are metals, they exhibit metallic properties such as high tensile strength, hardness, lustre, malleability, ductility, etc.
- Transition elements have good thermal and electrical conductivity, high density, high melting and boiling points.
- The lattice structures of transition metals are given below:

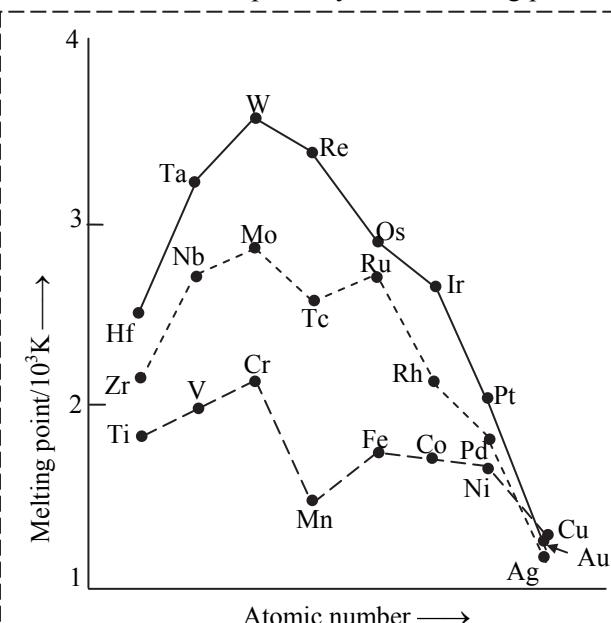
3d series	Lattice structure	4d series	Lattice structure	5d series	Lattice structure
Sc	hcp (bcc)	Y	hcp (bcc)	La	hcp (ccp, bcc)
Ti	hcp (bcc)	Zr	hcp (bcc)	Hf	hcp (bcc)
V	bcc	Nb	bcc	Ta	bcc
Cr	bcc (bcc, ccp)	Mo	bcc	W	bcc
Mn	X (hcp)	Tc	hcp	Re	hcp
Fe	bcc (hcp)	Ru	hcp	Os	hcp
Co	ccp	Rh	ccp	Ir	ccp
Ni	ccp	Pd	ccp	Pt	ccp
Cu	ccp	Ag	ccp	Au	ccp
Zn	X (hcp)	Cd	X (hcp)	Hg	X

(where, bcc = body-centred cubic; hcp = hexagonal close packed; ccp = cubic close packed; X = a typical metal structure)

- The presence of several vacant orbitals in the outermost shell of the transition elements and their low ionisation enthalpies attribute to the metallic character. The formation of interatomic metallic bonds is favoured in the transition elements and thus they exhibit the typical metallic properties.
- The d-orbitals containing unpaired electrons may overlap to form covalent bonds which are responsible for the hardness of these metals.
- As the number of unpaired electrons increases, the number of covalent bonds and the strength of the metallic bonds increase. The increase in the number of covalent bonds results in increase in the strength and hardness of metal. Therefore, they have high enthalpies of atomisation. The increase in the strength of the metallic bonds results in increase in the melting and boiling points.
- Cr, Mo and W have maximum number of unpaired d-electrons which make them very hard due to increase in the number of covalent bonds and have maximum enthalpies of atomisation.
- Zn, Cd, and Hg do not have unpaired d-electrons. Hence, they are not hard and they have low melting and boiling points.
- In a given period of transition elements, the number of unpaired electrons in (n-1) d-orbital increases upto d^5 configuration. This results in increase in the strength of metallic bonds and the melting and boiling points.
- Pairing of electrons results in decrease in the number of unpaired electrons from d^6 to d^9 configuration. This decreases the strength of metallic bonds and results in progressive decrease in the melting and boiling points, after the middle of the series. In general, greater the number of valence electrons, stronger is the resultant metallic bonding.
- In the first transition series, the number of unpaired electrons increases from Sc to Cr and then decreases. Thus the strength of metallic bonds and the melting and boiling points increase from Sc to Cr and then decrease.

Element	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
Electronic configuration	$3d^14s^2$	$3d^24s^2$	$3d^34s^2$	$3d^54s^1$	$3d^54s^2$	$3d^64s^2$	$3d^74s^2$	$3d^84s^2$	$3d^{10}4s^1$	$3d^{10}4s^2$
No. of unpaired electrons	1	2	3	6	5	4	3	2	1	0

- xii. Mn and Tc have unexpectedly lower melting points due to complicated lattice structure.

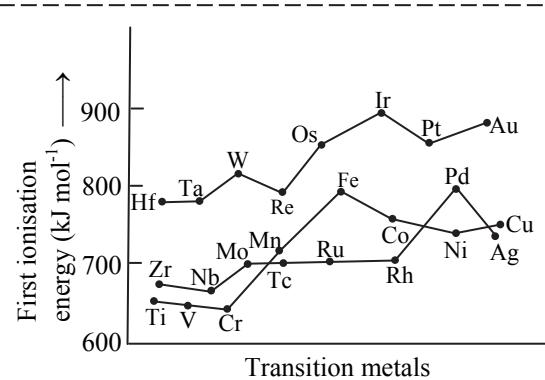


Trends in melting points of transition elements

- xiii. The occurrence of more common metal-metal bonding in compounds of heavier transition metals has resulted from the greater enthalpies of atomisation of second (4d) and third (5d) series compared to the corresponding elements of first series.

➤ Ionization enthalpy:

- Ionization enthalpy is the amount of energy required to remove the outermost electron completely from a gaseous atom in its ground state.*
- The ionization enthalpies of transition elements are higher than the ionization enthalpies of s-block elements and lower than the ionization enthalpies of p-block elements. This is due to the trends in atomic radii and nuclear charge.
- The atomic radii of transition elements are lower than the atomic radii of s-block elements and higher than the atomic radii of p-block elements.
- The nuclear charges of transition elements are higher than the nuclear charges of s-block elements and lower than the nuclear charges of p-block elements.
- As the atomic number increases in a transition series, the first ionization energy increases with some irregularities.
- The irregularities are due to shielding of the valence electrons from the nucleus by the added ($n-1$) d-electrons. This partially opposes the effect of increased nuclear charge by the screening effect.
- In case of first ionization enthalpy, the relative energies of 4s and 3d orbitals are modified by the loss of one electron. The cation, thus formed, has d^n configuration with no 4s electrons. Therefore, there is a reorganisation energy along with ionization energy and a gain in exchange energy.
- The gain in exchange energy is due to the increase in number of electrons along the period and from the transfer of s electrons into d-orbitals.
- In general, it is expected that as the effective nuclear charge increases, the ionisation enthalpy value also increases.



The first ionization enthalpies of elements of first, second and third transition series



- x. However, the value of Cr is less because the removal of one electron results in stable d⁵ configuration.
- xi. Similarly, Zn has high ionization enthalpy, because electron has to be removed from stable 3d¹⁰4s² configuration.
- xii. The increasing order of the first ionization enthalpies is
First transition series < second transition series < third transition series
- xiii. The filled 4f-orbitals present in the atoms of third transition series exhibit lesser shielding effect due to their peculiar diffused shape. Therefore, valence electrons are strongly attracted towards nucleus and it requires more energy for ionization. Hence, first ionization enthalpies of third transition series elements are much higher than those of first and second series.

Note:

- i. The energy required to remove first electron from gaseous atom in ground state is called **first ionization enthalpy**; to remove second electron, it is called **second ionization enthalpy** and for removal of third electron, it is called **third ionization enthalpy**.
- ii. The second ionization enthalpies of Cr and Cu are exceptionally high, because the removal of second electron disrupts the stable 3d⁵(Cr⁺) and 3d¹⁰(Cu⁺) configuration. Low value of Zn is resulted from the formation of stable 3d¹⁰ configuration after the removal of second electron.
- iii. The third ionization enthalpies of Mn²⁺ and Zn²⁺ are high, because of stable d⁵ and d¹⁰ configuration. But value of Fe²⁺ is very small, because loss of third electron produces stable d⁵ configuration.

➤ Ionization enthalpy and thermodynamic stability of transition metal compounds:

- i. The thermodynamic stability of transition metal compounds can be predicted on the basis of their ionization enthalpy value.
- ii. When the sum of the ionization enthalpies required to attain a particular oxidation state of transition metal ions is small, the thermodynamic stability of the compounds of the metal in that oxidation state is high.

eg.

- a. Compounds containing Ni²⁺ are more stable than compounds containing Pt²⁺. Less amount of energy is required for the ionization of Ni to Ni²⁺, than the energy required for the ionization of Pt to Pt²⁺. This is because the sum of first and second ionization enthalpies (IE₁ + IE₂) for nickel is lesser as compared to that of platinum.



- b. Compounds containing Pt⁴⁺ are more stable than compounds containing Ni⁴⁺. Less amount of energy is required for the ionization of Pt to Pt⁴⁺ than the energy required for the ionization of Ni to Ni⁴⁺. This is because the sum of first four ionization enthalpies (IE₁ + IE₂ + IE₃ + IE₄) for platinum is lesser as compared to that of nickel.



Note: K₂PtCl₆ is a well known compound of Pt⁴⁺. The corresponding compound of nickel is not known.

➤ Oxidation states:

- i. Transition elements have variable oxidation states as both (n - 1)d and ns electrons participate in bonding, due to nearly same energy levels.
- ii. Elements of first transition series show +1 and +2 as the lowest oxidation states due to presence of two 4s electrons, with the exception of copper and chromium which have only one 4s electron.
- iii. Other oxidation states are due to the presence of 3d electrons.

Elements	Outer electronic configuration	Oxidation states	Elements	Outer electronic configuration	Oxidation state
Sc	3d ¹ 4s ²	+2,+3	Fe	3d ⁶ 4s ²	+2,+3,(+4),(+5),(+6)
Ti	3d ² 4s ²	+2,+3,+4	Co	3d ⁷ 4s ²	+2,+3,(+4),+5
V	3d ³ 4s ²	+2,+3,+4,+5	Ni	3d ⁸ 4s ²	+2,+3,+4
Cr	3d ⁵ 4s ¹	+1,+2,+3,(+4),(+5),+6	Cu	3d ¹⁰ 4s ¹	+1,+2
Mn	3d ⁵ 4s ²	+2,+3,+4,(+5),+6,+7	Zn	3d ¹⁰ 4s ²	+2

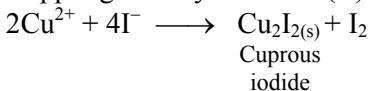
Note: The most stable oxidation states are in bold type and the oxidation states within brackets are unstable.



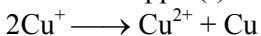
- iv. The number of oxidation states increases with increase in the number of unpaired 3d electrons.
- v. The number of oxidation states is maximum for manganese which has maximum number of unpaired 3d electrons.
- vi. The number of oxidation states increases from Sc to Mn and then decreases from Fe to Zn. This is in accordance with the number of unpaired 3d electrons.
- vii. At the beginning of the series, scandium (Sc) shows +2 and +3 oxidation states. The outer electronic configuration of Sc is $3d^1 4s^2$. Sc shows +2 oxidation state when two electrons are lost from the 4s-orbital and +3 oxidation state when one more electron from 3d orbital is lost. However, Sc (II) is virtually unknown. The stable oxidation state of Ti is Ti (IV) compared to Ti (III) or Ti (II).
- viii. Zinc is having only one oxidation state Zn^{+2} , in which no d-electrons are involved.
- ix. Upto manganese, the highest oxidation state (fairly stable) is equal to the sum of the s and d electrons.
 - eg. Highest oxidation states of transition elements in TiO_2 , VO_2^+ , CrO_4^{2-} , and MnO_4^- are +4, +5, +6, and +7 respectively. For the remaining five elements, maximum oxidation state is irrespective of their electronic configuration (eg. $Fe^{+2,+3}$, $Co^{+2,+3}$, Ni^{+2} , $Cu^{+1,+2}$, Zn^{+2}).
- x. The reason for variability of oxidation states in transition elements is due to the incomplete filling of d-orbitals in such a way that, a unit difference occurs in their oxidation states, eg., V^{+2} , V^{+3} , V^{+4} , V^{+5} . Whereas, in non-transition elements, the difference in oxidation state is generally two units.
- xi. In heavier transition elements, higher oxidation states are more stable (in p-block elements, heavier members with lower oxidation states are more stable due to inert pair effect). For example, in group 6, Mo (VI) and W(VI) are more stable than Cr(VI). Therefore, dichromate (Cr^{+6}) in acid medium is a strong oxidizing agent, whereas MoO_3 and WO_3 are not.
- xii. Transition elements exhibit low oxidation states when they form complexes with those ligands which can form π -bonds as well as σ -bonds. For example, oxidation state of nickel and iron is zero in $Ni(CO)_4$ and $Fe(CO)_5$ respectively.
- xiii. The oxidation states which result in half-filled $3d^5$ configuration are very stable.
 - eg. Cr^+ , Mn^{2+} , Fe^{3+}However, salts of chromium with +1 oxidation state is not common. But with pyridine, chromium forms stable complexes in its +1 oxidation state.
- xiv. Salts of chromium in its +2 oxidation state are known as **chromous salts**.
 - eg. Chromous chloride ($CrCl_2$) and chromous sulphate ($CrSO_4$).Salts of chromium in +3 oxidation state are known as **chromic or chromium salts**.
 - eg. Chromic chloride ($CrCl_3$).Salts of chromium in +6 oxidation state are very stable. Chromium is a very good oxidizing agent in its +6 oxidation state.
 - eg. Chromate (K_2CrO_4), dichromate ($K_2Cr_2O_7$) and chromyl chloride (CrO_2Cl_2)
- xv. Salts of manganese in its +2 oxidation state are known as **manganous or manganese salts**. eg. $MnCl_2$ In its +4 oxidation state, manganese forms manganese dioxide (MnO_2) which is very stable. In its +6 oxidation state, manganese forms manganate (K_2MnO_4) and it forms permanganate ($KMnO_4$) in its +7 oxidation state, which is a very good oxidizing agent.
- xvi. The compounds of iron in the +2 oxidation state are called **ferrous compounds**. These are good reducing agents. eg. ferrous sulphate ($FeSO_4$)
The compounds of iron in the +3 oxidation state are stable and called **ferric compounds**.
 - eg. ferric chloride ($FeCl_3$).The compounds of iron in the +6 oxidation state are known as **ferrates**.
 - eg. potassium ferrate (K_2FeO_4)
- xvii. Salts of copper in its +1 oxidation state are called **cuprous salts**.
 - eg. cuprous iodide (Cu_2I_2)Salts of copper in its +2 oxidation state are known as **cupric or copper salts**.
 - eg. cupric chloride ($CuCl_2$), Copper sulphate ($CuSO_4$)
- xviii. **Trends in stability of higher oxidation states:**
 - a. Transition metals exhibit highest oxidation states with most electronegative halide, fluorine. For example, CrF_6 and VF_6 . Fluorine has higher lattice energy and higher bond enthalpy.



- b. Copper generally forms Cu(II) halides except the iodide. This is because Cu^{2+} oxidises I^- to I_2 .



Unstable copper(I) compounds in aqueous solution undergo disproportionation.



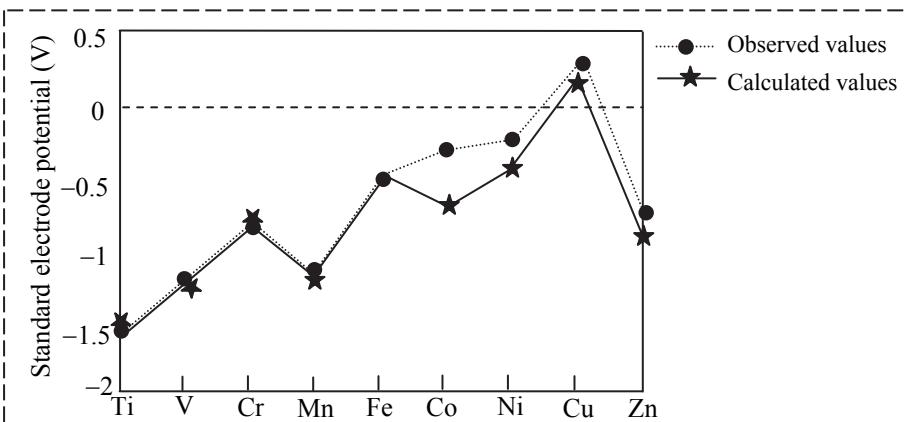
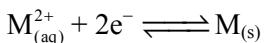
- c. $\text{Cu}_{(\text{aq})}^{2+}$ is more stable than $\text{Cu}_{(\text{aq})}^+$. This is because, the negative hydration enthalpy ($\Delta_{\text{hyd}}\text{H}^\circ$) of $\text{Cu}_{(\text{aq})}^{2+}$ is much larger than that of $\text{Cu}_{(\text{aq})}^+$, which is much more than the high value of second ionization enthalpy of copper.
- d. The highest oxidation state in the oxides Sc_2O_3 , TiO_2 , V_2O_5 , CrO_3 and Mn_2O_7 are +3, +4, +5, +6 and +7 respectively, which coincides with their respective group number. After Group 7, higher oxides of iron above Fe_2O_3 are not known.
- e. Oxocations of metals also stabilize higher oxidation states. For example, V^{5+} as VO_2^+ , V^{4+} as VO^{2+} and Ti^{4+} as TiO^{2+} .
- f. Manganese forms highest fluoride as MnF_4 (Mn^{+4}), while highest oxide is Mn_2O_7 (Mn^{+7}). This can be explained on the basis of multiple bonds formed by oxygen.
- g. In Mn_2O_7 , each Mn is tetrahedrally surrounded by the oxygen atoms including a Mn–O–Mn bridge.
- h. V^{5+} , Cr^{6+} , Mn^{5+} , Mn^{6+} and Mn^{7+} ions form tetrahedral $[\text{MO}_4]^{n-}$ units.

➤ Standard electrode potentials:

The **standard electrode potential** is defined as the potential difference developed between metal electrode and the solution of its ions of unit molarity (1 M) at 25 °C (298 K).

i. Trends in the M^{2+}/M standard electrode potentials:

The standard electrode potential of the following reaction is represented by $E^\circ (\text{M}^{2+}/\text{M})$.



Calculated and observed values for the standard electrode potentials (M^{2+}/M) of the elements of first transition series.

- a. If the value of electrode potential is small (less positive or more negative), the oxidation state of the transition metal in aqueous solution is more stable.
- b. The trend in the $E^\circ (\text{M}^{2+}/\text{M})$ values for 3d series is not regular due to the irregular variation in the sum of first and second ionization enthalpies.
- c. The positive reduction potential value [$E^\circ (\text{M}^{2+}/\text{M})$] of copper shows that, it is the least reactive metal among the first transition series. Its hydration enthalpy ($\Delta_{\text{hyd}}\text{H}^\circ$) does not balance with the high energy needed to convert $\text{Cu}_{(\text{s})}$ to $\text{Cu}_{(\text{aq})}^{2+}$.
- d. The more negative $E^\circ (\text{M}^{2+}/\text{M})$ values (higher stability) of Mn and Zn are due to the stability of half-filled $d^5(\text{Mn}^{2+})$ and the completely filled $d^{10}(\text{Zn}^{2+})$ configurations.
- e. More negative E° value of Ni^{2+} is due to the highest negative enthalpy of hydration.

ii. Trends in the M^{3+}/M^{2+} standard electrode potentials:

- The higher $E^\circ(M^{3+}/M^{2+})$ values for Zn and Mn are due to the loss of electron from the stable $d^{10}(Zn^{2+})$ and $d^5(Mn^{2+})$ configurations.
- The lower values for Fe and Sc are due to the extra stability of $d^5(Fe^{3+})$ and noble gas (Sc^{3+}) configurations. The stability of half filled t_{2g} level in V^{2+} provides comparatively low value of $E^\circ(V^{3+}/V^{2+})$.

iii. Chemical reactivity and E° values:

- Most of the transition metals (with few exceptions) dissolve in mineral acids since they are sufficiently electropositive.
 - Except copper, all the metals of first transition series are comparatively more reactive than those in other series.
 - The less negative $E^\circ(M^{2+}/M)$ values show a decreasing tendency to form divalent cations. This is due to the increase in the sum of first and second ionization enthalpies.
 - Highly positive $E^\circ(M^{3+}/M^{2+})$ values indicates that Mn^{3+} and Co^{3+} ions are strong oxidising agents. Ti^{2+} , V^{2+} and Cr^{2+} ions are strong reducing agents, and can liberate H_2 from a dilute acid.
- eg.** $2Cr_{(aq)}^{2+} + 2H_{(aq)}^+ \longrightarrow 2Cr_{(aq)}^{3+} + H_{2(g)}$

➤ **Atomic and ionic radii:**

- i. The atomic radii of first transition series show the following trends:

Elements	Trend		Reason						
Sc to Cr	Gradual decrease		Increase in the nuclear charge is greater than the increase in the shielding effect.						
Mn to Cu	Approximately constant		Increase in the nuclear charge is neutralised by the increase in the shielding effect.						
Zn	Increases		Electron-electron repulsions greater than attractive forces due to increase in the nuclear charge which results in the orbital expansion.						

- ii. This is illustrated by the following table.

Elements	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
Atomic radii (pm)	144	132	122	118	117	117	116	115	117	125

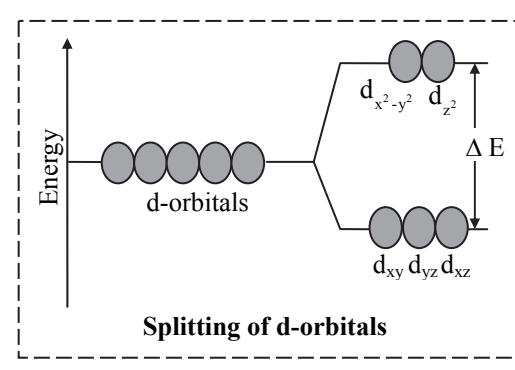
- iii. The trend in ionic radii is illustrated by the following table.

Elements	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	
Ionic radii (pm)	M^{2+}	—	90	79	80	67	78	74.5	69	73	74
	M^{3+}	74.5	76	64	61	64.5	64.5	61	60	54	—

- Considering the increase in atomic mass along with decrease in metallic radius along a period, a general increase in density of elements from Ti($Z = 22$) to Cu($Z = 29$) is noted.
- The comparison of the ionic radii should be made for the same oxidation states.
- As the oxidation state increases, ionic radii decreases due to increase in effective nuclear charge.
- For a given oxidation state, as the nuclear charge increases, the ionic radii decreases.

➤ **Colour:**

- Transition elements form compounds which contain unpaired electrons due to partly filled $(n-1)d$ orbitals.
- In a free transition metal ion, the five $(n-1)d$ orbitals are degenerate. This means that they have same energy.
- In transition metal compounds, the five $(n-1)d$ orbitals of the transition metal ion split into two groups (**crystal field splitting**).
 - Lower energy level containing three orbitals d_{xy} , d_{yz} and d_{xz} .
 - Higher energy level containing two orbitals $d_{x^2-y^2}$ and d_{z^2} .



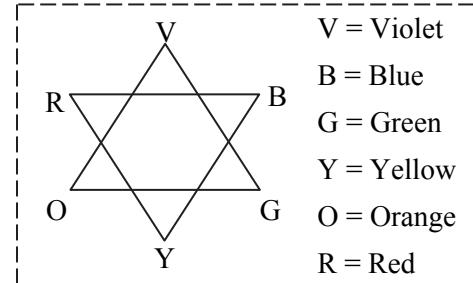


- iv. Due to small energy difference (ΔE) between these two groups, an electron can be excited from lower energy level to higher energy level by absorption of light in visible region (400 – 800 nm) which results in the appearance of colour.
- v. The wavelength of light absorbed is such that, the energy of light absorbed is equal to the energy difference ΔE .
- vi. Thus, transition metal compounds are coloured when they possess unpaired electrons. This is due to **d-d transition**.
- $3d^1$ to $3d^9$ electronic configurations contain unpaired electrons and are coloured.
eg. Ti^{3+} , Cr^{3+} , Cu^{2+} .
 - $3d^0$ and $3d^{10}$ electronic configurations contain no unpaired electrons and thus are colourless.
eg. Sc^{3+} , Cu^+ and Zn^{2+}

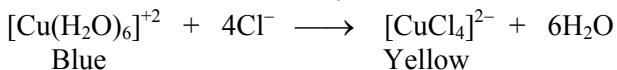
Ion	Outer Electronic configuration	Number of unpaired electrons	Colour (in aqueous solution)
Sc^{3+}	$3d^0$	0	Colourless
Ti^{3+}	$3d^1$	1	Purple
Ti^{4+}	$3d^0$	0	Colourless
V^{2+}	$3d^3$	3	Violet
V^{3+}	$3d^2$	2	Green
V^{4+}	$3d^1$	1	Blue
Cr^{3+}	$3d^3$	3	Violet
Mn^{2+}	$3d^5$	5	Light Pink

Ion	Outer electronic configuration	Number of unpaired electrons	Colour (in aqueous solution)
Mn^{3+}	$3d^4$	4	Violet
Fe^{2+}	$3d^6$	4	Pale green
Fe^{3+}	$3d^5$	5	Yellow
Co^{2+}	$3d^7$	3	Pink
Ni^{2+}	$3d^8$	2	Green
Cu^{2+}	$3d^9$	1	Blue
Cu^+	$3d^{10}$	0	Colourless
Zn^{2+}	$3d^{10}$	0	Colourless

- vii. The colour observed is different from the colour absorbed. The colour observed is the colour transmitted and is complementary to the colour absorbed. In the adjacent diagram, the complementary colours are placed diagonally opposite.
- eg. Absorption of red colour results in transmission of green colour. Thus, the transition metal compound appears green.



- viii. Ti^{3+} of $[Ti(H_2O)_6]^{3+}$ has $3d^1$ electron. This electron can be excited from lower energy level to higher energy level by absorption of light around 500 nm region. Since yellow and green lights are absorbed in this region, the colour transmitted is reddish blue (purple), which is imparted to $[Ti(H_2O)_6]^{3+}$.
- ix. $[Cu(H_2O)_6]^{2+}$ with octahedral geometry has blue colour while $[CuCl_4]^{2-}$ with tetrahedral geometry has yellow colour. Copper sulphate forms $[Cu(H_2O)_6]^{2+}$ in water which results in blue coloured solution. Addition of concentrated HCl results in conversion of $[Cu(H_2O)_6]^{2+}$ to $[CuCl_4]^{2-}$, which changes the colour of the solution from blue to yellow.



- x. Thus, the colour of transition metal compounds depends on the following:
- unpaired $(n-1)d$ electrons
 - $d - d$ transition
 - geometry of transition metal compounds
 - nature of different groups (ligands) attached to transition metal ion
- xi. Charge transfer between transition metal and the groups attached to it also results in colour.
- eg. MnO_4^- , $Cr_2O_7^{2-}$, CrO_4^{2-} , Cu_2O and Ni-DMG are coloured due to charge transfer.
- xii. Intense purple colour of MnO_4^- results from transfer of an electron from oxygen to Mn which results in momentary change in the oxidation states of Mn from +7 to +6 and O from -1 to 0. This is possible because the energy levels of Mn^{7+} and O^{1-} are fairly close.



➤ **Catalytic property:**

- Transition elements increase the rate of chemical reactions by decreasing the activation energy.
- This catalytic property is due to,

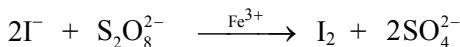
- Variable oxidation states** of transition elements due to which they can form unstable intermediates, which then decomposes to form products with regeneration of catalyst. Because of variable oxidation states, transition metals easily absorb and re-emit wide range of energies, thus providing the necessary activation energy.
- Presence of **large surface area** which adsorbs reactants and brings them closer, thereby increasing the concentration of the reactants on the surface and thus, also the rate of the reaction. This is possible due to the presence of **free valencies** on the surface.



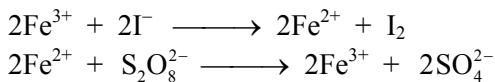
- Some examples of transition metals and their compounds as catalysts:

Catalyst	Reaction catalyzed
MnO ₂	Decomposition of H ₂ O ₂ solution
Nickel	Hydrogenation of oils to fats
V ₂ O ₅	Contact process for H ₂ SO ₄ manufacture
Fe (III)	2 I ⁻ + S ₂ O ₈ ²⁻ → I ₂ + 2 SO ₄ ²⁻
TiCl ₄ with Al(CH ₃) ₃ (Ziegler Natta catalyst)	Manufacture of high density polythene n CH ₂ = CH ₂ → $\text{CH}_2 - \text{CH}_2\text{H}_n$
Fe and Mo	Manufacture of ammonia by Haber's process
Co-Th alloy	Fischer-Tropschin process for the synthesis of gasoline
PdCl ₂	Oxidation of ethyne to ethanal (Wacker process)

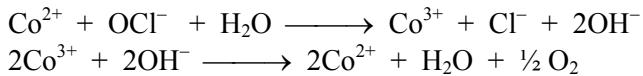
- In certain cases, the transition metal ions can become more effective as catalysts by changing their oxidation states.
- eg. Iron (III) catalyses the reaction between iodide and persulphate ions (S₂O₈)²⁻ as,



The mechanism of this reaction involves the change in oxidation state as follows:



- b. The decomposition of bleaching power is catalyzed by cobalt salts, as cobalt can easily change oxidation state from +2 to +3.



➤ **Magnetic properties:**

- Transition elements are **paramagnetic** (attracted by the magnetic field) due to presence of unpaired electrons in (n - 1)d orbitals.
eg. Ti³⁺, V³⁺ and Cr³⁺
- When there are no unpaired electrons, transition elements are **diamagnetic** (repelled by the magnetic field).
eg. Sc³⁺ and Zn²⁺
- Ferromagnetic compounds have permanent magnetic moment. They have very high paramagnetism.
eg. Fe, Co and Ni.

Metal ion	Electronic configuration	Number of unpaired electrons	Magnetic property
V	[Ar] 3d ³ 4s ²	3	Paramagnetic
V ²⁺	[Ar] 3d ³ 4s ⁰	3	Paramagnetic
V ³⁺	[Ar] 3d ² 4s ⁰	2	Paramagnetic
V ⁴⁺	[Ar] 3d ¹ 4s ⁰	1	Paramagnetic
V ⁵⁺	[Ar] 3d ⁰ 4s ⁰	0	Diamagnetic



- iv. The magnetic moment is expressed in the terms of Bohr magneton (B.M.), 1 B.M. = $\frac{e\hbar}{4\pi mc}$
 where, h represents Planck's constant, e represents the electronic charge, c represents the velocity of light and m represents the mass of electron.
- v. Usually both spin angular momentum and orbital angular momentum contributions result in the magnetic moment of a substance. However, in case of transition metal ions, only spin angular momentum contribution is present while the orbital angular momentum contribution is suppressed by the electrostatic field of atoms, ions or molecules surrounding the metal ion.
- vi. Thus, the effective magnetic moment (μ_{eff}) is given by spin only formula. $\mu_{\text{eff}} = \sqrt{n(n+2)} \text{ B.M.}$
 where, n represents the number of unpaired electrons and B.M. represents the Bohr magneton (a unit of magnetic moment).
- vii. As the number of unpaired electrons increases, the magnetic moment and the paramagnetic character increases.

Ion	Outer electronic configuration	Number of unpaired electrons	Calculated value of magnetic moment	Experimental value
Sc ³⁺	3d ⁰	0	0	0
Ti ³⁺	3d ¹	1	1.73	1.75
V ³⁺	3d ²	2	2.84	2.76
Cr ³⁺	3d ³	3	3.87	3.86
Cr ²⁺	3d ⁴	4	4.90	4.80
Mn ²⁺	3d ⁵	5	5.92	5.96
Fe ²⁺	3d ⁶	4	4.90	5.40
Co ²⁺	3d ⁷	3	3.87	4.80
Ni ²⁺	3d ⁸	2	2.84	3.15
Cu ²⁺	3d ⁹	1	1.73	1.95
Zn ²⁺	3d ¹⁰	0	0	0

➤ Formation of interstitial compounds:

- i. Small atoms such as H, C or N trapped inside the interstitial spaces in the crystal lattice of metals constitute interstitial compounds. These compounds are formed due to defect in the crystal lattice of transition metals.
- ii. Interstitial compounds have variable composition and are non-stoichiometric in nature.
- eg.** TiC, TiH_{1.7}, Mn₄N, Fe₃H, ZrH_{1.92}, VH_{0.56}, etc.
- iii. The chemical properties of interstitial compounds are similar to those of the parent transition metal.
- iv. Some properties of interstitial compounds are as follows:
- They are very hard (**eg.** Some borides are hard like diamond).
 - They are very lustrous.
 - They exhibit electrical and thermal conductivity.
 - They have melting points higher than pure metals, due to stronger metal–non metal bonds as compared to metal-metal bonds in pure metals.
 - They have lower densities, when compared to parent metals.
 - They are chemically inert. **eg.** Transition metallic carbides
 - Transition metal hydrides are powerful reducing agents.

➤ Alloy formation:

- i. Alloys are homogeneous solid solutions in which the atoms of one metal are randomly distributed among the atoms of the other metal.
- ii. Due to the almost similar atomic sizes of the transition metals, one metal can replace other from its lattice easily. Alloys are obtained by cooling the molten mixture of two or more transition metals.
- iii. For the formation of alloys, the metallic radii should be within 15 percent limit of each other.
 Transition metals form a large number of alloys and the alloys so formed are hard, more resistant to corrosion than parent metals and have high melting points.
- eg.**
- Steel and stainless steel are the alloys of iron with chromium, vanadium, molybdenum, tungsten, manganese, etc.
 - Brass (Cu – Zn) and bronze (Cu – Sn) are alloys of transition metals with non-transition metals.



➤ **Complex formation:**

- i. Transition elements have a tendency to form large number of complexes.
eg. $[\text{Cu}(\text{NH}_3)_4]^{2+}$, $[\text{Co}(\text{NH}_3)_6]^{3+}$, $[\text{Ni}(\text{CN})_4]^{2-}$, etc.
- ii. This is because of following reasons:
 - a. Transition elements have small ionic radii and high effective ionic charge. This results in high ratio of ionic charge to ionic radius.
 - b. Vacant d-orbitals of transition metals and ions can accommodate the lone pairs of electrons from the ligands to form coordination compounds.
 - c. Transition metals exhibit variable oxidation states.
 - d. Transition metal ions acquire a stable electronic configuration of the nearest inert element by accepting the electrons from the ligands.
- iii. The stability of transition metal complexes depends upon the nature of the metal ion, ligands and their bonding.

➤ **Oxides and oxoanions of transition metals:**

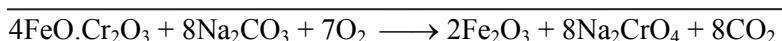
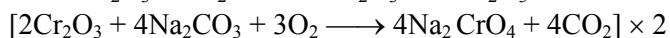
- i. The oxides of transition metals are formed by the reaction of these metals with oxygen at high temperatures.
- ii. All the transition metals except scandium form metal oxides (MO) having ionic character. They also form oxides which the metal has higher oxidation number.
- iii. Ionic character decreases with increase in oxidation number of metals. For example, Mn_2O_7 (+7) is a covalent green oil. CrO_3 (+6) and V_2O_5 (+5) have low melting points, because of their less ionic character.
- iv. Metal oxides with low oxidation states of metals are basic, whereas those with high oxidation states of metals are acidic. The oxides with intermediate oxidation states are amphoteric in nature.
- v. Mn_2O_7 is acidic and it gives HMnO_4 . Similarly, CrO_3 is also acidic and it dissolves in water and forms chromic acid (H_2CrO_4) and $\text{H}_2\text{Cr}_2\text{O}_7$.
- vi. Vanadium forms V_2O_3 (basic), V_2O_4 (less basic) and V_2O_5 (amphoteric). V_2O_5 gives VO_4^{3-} and VO_2^+ salts.
- vii. V_2O_5 being amphoteric, gives VO_4^{3-} and VO_2^+ by the reaction with alkalies and acids respectively.
- viii. CrO is basic, but Cr_2O_3 and CrO_2 are amphoteric.

8.3 Preparation, properties and uses of potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$)

➤ **Preparation of $\text{K}_2\text{Cr}_2\text{O}_7$:**

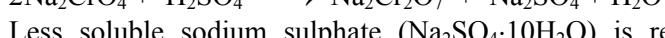
$\text{K}_2\text{Cr}_2\text{O}_7$ is prepared from chromite ore ($\text{FeO} \cdot \text{Cr}_2\text{O}_3$) also known as chrome iron ore. The following steps are involved:

- i. **Concentration of powdered chromite ore:** Powdered chromite ore is concentrated by washing with water current in a hydraulic classifier. Lighter gangue is carried away by water while the heavier chromite ore settles at the bottom.
- ii. **Conversion of chromite ore to sodium chromate:** The chromite ore is converted to sodium chromate by roasting concentrated ore with soda ash (sodium carbonate) and limestone (calcium carbonate) in reverberatory furnace, in presence of excess air. Water soluble sodium chromate (yellow coloured) is separated from water insoluble substances by extraction with water, followed by filtration.



Addition of limestone makes the mass porous and aids easier oxidation.

- iii. **Conversion of sodium chromate to sodium dichromate:** Sodium chromate is converted to sodium dichromate by treatment with concentrated sulphuric acid.



Less soluble sodium sulphate ($\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$) is removed by crystallization and filtration giving a concentrated solution of sodium dichromate.

- iv. **Conversion of sodium dichromate to potassium dichromate:** Sodium dichromate is converted to potassium dichromate by treatment with calculated quantity of potassium chloride. This takes place by double decomposition.



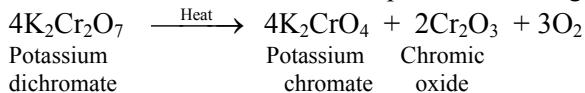
Orange red crystals of potassium dichromate are obtained by crystallisation and purified by recrystallisation.



➤ **Properties of $K_2Cr_2O_7$:**

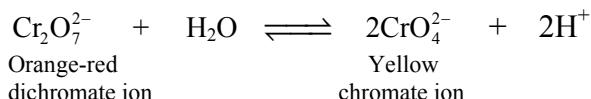
i. **Physical properties:** $K_2Cr_2O_7$ is orange coloured crystalline solid, moderately soluble in cold water and readily soluble in hot water.

ii. **Action of heat:** $K_2Cr_2O_7$ decomposes on heating to form potassium chromate, chromic oxide and oxygen.

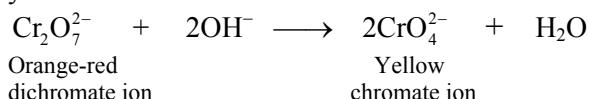


iii. **Action of alkali:**

a. In neutral solution, water soluble orange red coloured potassium dichromate is in equilibrium with yellow coloured potassium chromate.



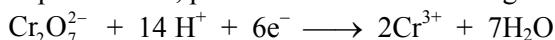
b. Addition of alkali shifts the equilibrium to right as OH^- combines with H^+ to form water. Thus, yellow coloured chromate ion is formed.



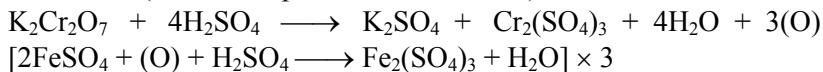
Note: On addition of an acid, the H^+ ion concentration increases and thereby the equilibrium shifts to the left, thus resulting in the formation of dichromate ions, which turns the solution orange-red.

iv. **Oxidizing properties:**

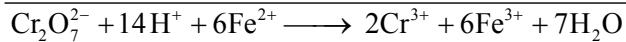
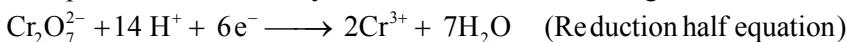
In acidic medium, Cr(VI) of potassium dichromate gains 3 electrons and is reduced to Cr(III) of chromium sulphate. Thus, potassium dichromate is a good oxidizing agent.



a. **Action on Ferrous sulphate:** Ferrous sulphate is oxidized to ferric sulphate by acidified potassium dichromate ($K_2Cr_2O_7$ in presence of dil. H_2SO_4). Colour of the solution changes from orange red to green.



Ionic equations in which only active ions are written are given below:



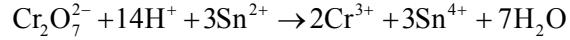
b. **Action on potassium iodide:** Potassium iodide is oxidized to iodine by acidified potassium dichromate. Colour of the solution changes to brown due to the liberated iodine.



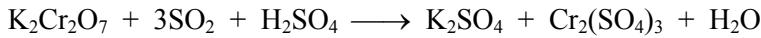
c. **Action on hydrogen sulphide:** Hydrogen sulphide gas is oxidized to pale yellow precipitate of sulphur, when passed through acidified $K_2Cr_2O_7$ solution. Solution colour changes from orange to green.



d. **Action on stannous salts:** In the presence of acidified $K_2Cr_2O_7$ solution, stannous salts, Sn (II) are oxidized to stannic salts, Sn(IV).

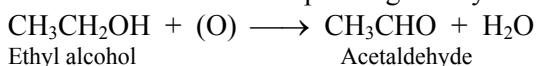


e. **Action on sulphur dioxide:** Sulphur dioxide gas is oxidized to sulphuric acid when passed through acidified $K_2Cr_2O_7$ solution. Colour of the solution changes from orange to green.

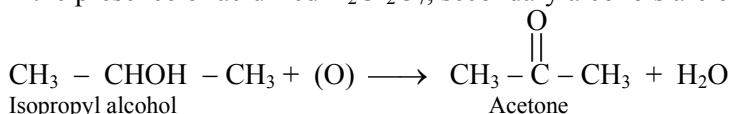


This reaction is used as a test to detect SO_2 gas.

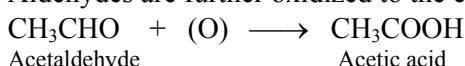
- f. Action on primary and secondary alcohols:** In the presence of acidified $K_2Cr_2O_7$, primary alcohols are oxidized to the corresponding aldehydes.



In the presence of acidified $K_2Cr_2O_7$, secondary alcohols are oxidized to the corresponding ketones.



Aldehydes are further oxidized to the corresponding carboxylic acids



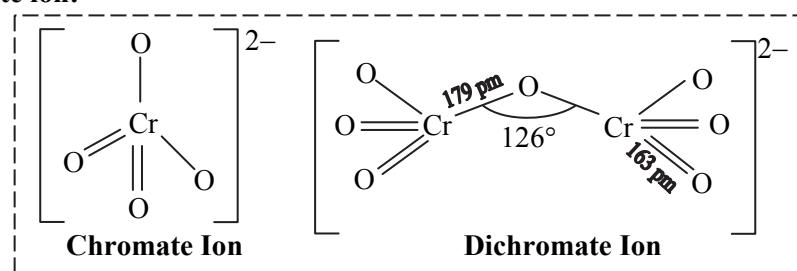
- v. **Formation of chromyl chloride (CrO_2Cl_2):** Chromyl chloride is obtained by heating a mixture of potassium dichromate crystals and sodium chloride in presence of concentrated sulphuric acid. First red vapours of chromyl chloride are evolved, which on condensation forms oily red liquid.

$$\text{K}_2\text{Cr}_2\text{O}_7 + 6\text{H}_2\text{SO}_4 + 4\text{NaCl} \longrightarrow 2\text{KHSO}_4 + 4\text{NaHSO}_4 + 2\text{CrO}_2\text{Cl}_2 + 3\text{H}_2\text{O}$$

(Chromyl chloride)

➤ Structure of chromate and dichromate ion:

- i. Chromate ion has tetrahedral structure.
 - ii. Dichromate ion has two tetrahedral units sharing one corner. The Cr—O—Cr bond angle is 126° .



➤ Uses of $K_2Cr_2O_7$:

Uses of $K_2Cr_2O_7$

- $K_2Cr_2O_7$ is used,

 - as an oxidizing agent.
 - in the manufacture of lead chromate and chrome alum.
 - in the tanning of leather.
 - in dyeing and calico printing.
 - in the manufacture of pigments and inks.
 - in the detection of chloride ion by chromyl chloride test.
 - as primary standard, in the volumetric analysis for the determination of ferrous ammonium sulphate (Mohr's salt) and iodine.
 - in the manufacture of Chromic acid (potassium dichromate + sulphuric acid) which is used as degrease glassware.

8.4 Preparation, properties and uses of potassium permanganate (KMnO_4)

➤ Preparation of KMnO₄:

KMnO₄ is prepared from pyrolusite ore(MnO₂). The following steps are involved:

- i. Pyrolusite ore (MnO_2) is converted to green coloured potassium manganate (K_2MnO_4) by any one of the following four methods.

 - Pyrolusite ore (MnO_2) is fused with KOH in presence of air.
$$2\text{MnO}_2 + 4\text{KOH} + \text{O}_2 \longrightarrow 2\text{K}_2\text{MnO}_4 + 2\text{H}_2\text{O}$$
 - Pyrolusite ore (MnO_2) is fused with K_2CO_3 in presence of air.
$$2\text{MnO}_2 + 2\text{K}_2\text{CO}_3 + \text{O}_2 \longrightarrow 2\text{K}_2\text{MnO}_4 + 2\text{CO}_2$$
 - Pyrolusite ore (MnO_2) is fused with KOH and oxidizing agent KNO_3
$$\text{MnO}_2 + 2\text{KOH} + \text{KNO}_3 \longrightarrow \text{K}_2\text{MnO}_4 + \text{KNO}_2 + \text{H}_2\text{O}$$
 - Pyrolusite ore (MnO_2) is fused with KOH and oxidizing agent KClO_3
$$3\text{MnO}_2 + 6\text{KOH} + \text{KClO}_3 \longrightarrow 3\text{K}_2\text{MnO}_4 + \text{KCl} + 3\text{H}_2\text{O}$$

ii. The reaction mixture is treated with water and K_2MnO_4 is then converted to KMnO_4 either by oxidation or by electrolysis.

- a. **Oxidation:** This can be achieved by any one of the following:

- ### 1. Disproportionation with H_2SO_4





2. Disproportionation with CO_2

$$3\text{K}_2\text{MnO}_4 + 4\text{CO}_2 + 2\text{H}_2\text{O} \longrightarrow 2\text{KMnO}_4 + \text{MnO}_2 + 4\text{KHCO}_3$$
3. Disproportionation with Cl_2

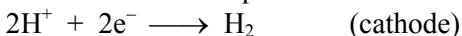
$$2\text{K}_2\text{MnO}_4 + \text{Cl}_2 \longrightarrow 2\text{KMnO}_4 + 2\text{KCl}$$
4. Disproportionation with O_3

$$2\text{K}_2\text{MnO}_4 + \text{H}_2\text{O} + \text{O}_3 \longrightarrow 2\text{KMnO}_4 + 2\text{KOH} + \text{O}_2$$

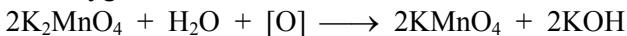
- b. **Electrolysis:** Electrolysis between iron electrodes separated by diaphragm results in oxidation of K_2MnO_4 to KMnO_4 . The electrode reactions are as follows:



Green Purple



The oxygen evolved at anode converts K_2MnO_4 to KMnO_4



Purple black crystals of KMnO_4 are obtained, when the solution is filtered and evaporated under controlled conditions.

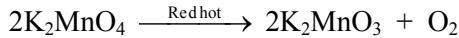
➤ Properties of KMnO_4 :

- i. **Physical properties:** KMnO_4 is a deep purple coloured (almost black), crystalline solid with moderate solubility in water (6.4 g/100 g) at room temperature. These crystals are isostructural with those of KClO_4 .

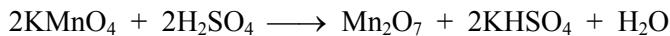
- ii. **Action of heat:** KMnO_4 decomposes at 473 K, liberating oxygen.



K_2MnO_4 further decomposes when red hot.



- iii. **Action of H_2SO_4 :** KMnO_4 is converted to Mn_2O_7 (an explosive green oil) upon reaction with cold conc. H_2SO_4 .



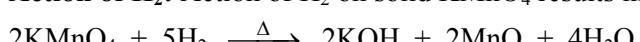
Mn_2O_7 decomposes to MnO_2 on warming.



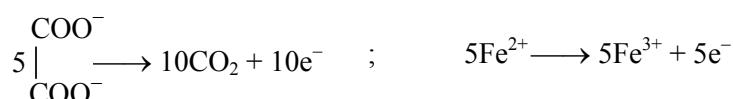
Action of warm conc H_2SO_4 on KMnO_4 results in conversion to MnSO_4 with the evolution of O_2 gas.



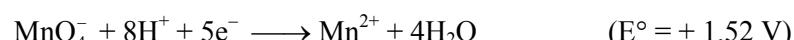
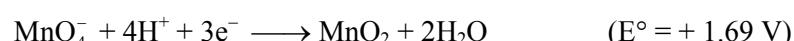
- iv. **Action of H_2 :** Action of H_2 on solid KMnO_4 results in formation of MnO , KOH and water vapours.



- v. **Oxidation and reduction:** Potassium permanganate solution in acidic medium, oxidises oxalates to carbon dioxide, Fe(II) to Fe(III) , iodides to free iodine and nitrites to nitrates.



The reduction half reactions of permanganate to manganate, manganese dioxide and manganese (II) salt are as follows:



It is clear that, these reactions are mainly influenced by the hydrogen ion concentration of the solution. Although redox potential provides an idea about the nature of the reaction, kinetics of the reaction also should be considered. Ideally, at $[\text{H}^+] = 1$, permanganate should oxidize water, but at low temperature and in the absence of Mn(II) ions, the reaction is very slow.

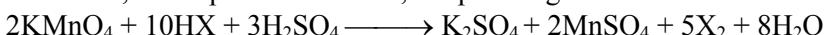


8. KMnO_4 oxidizes sulphurous acid or sulphite to a sulphate or sulphuric acid.



9. KMnO_4 oxidizes hydrogen halides (HX ; $\text{X} = \text{Cl}, \text{Br}$ or I) to the corresponding halogen (X_2).

Therefore, in the presence of HCl , the permanganate titrations are not good enough.



➤ Structure of manganate and permanganate ion:

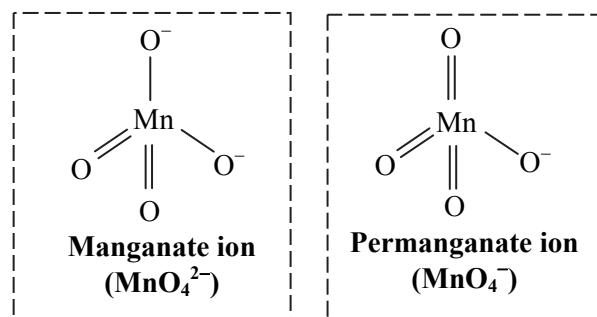
- i. Manganate ion has tetrahedral structure, green colour and weak temperature dependant paramagnetic properties (due to presence of one unpaired electron). Mn is sp^3 hybridized resulting in the tetrahedral arrangement of the four oxygen atoms around manganese. π bonds are formed due to overlap of p-orbitals of oxygen with d-orbitals of Mn.

- ii. Permanganate ion has tetrahedral structure, purple colour (due to ligand to metal charge transfer transition) and diamagnetic properties (due to d^0 configuration of Mn(VII)).

➤ Uses of KMnO_4 :

KMnO_4 is used,

- as disinfectant.
- as an oxidizing agent in industry and laboratory.
- as Baeyer's reagent (alkaline KMnO_4) for detecting the presence of unsaturation in organic compounds.
- in the estimation of ferrous salts, oxalic acid, hydrogen peroxide by volumetric analysis.
- in the qualitative analysis for halide detection.
- for bleaching of wool, silk, cotton and other textile fibres and for decolourisation of oils.



f-Block Elements

8.5 Lanthanoids

➤ Lanthanoid series (4f-block elements):

- Lanthanoid series (4f-block elements) comprise a group of 14 elements from Cerium ($Z = 58$) to Lutetium ($Z = 71$).
- In these elements, the differentiating electron enters 4f orbital.
- The name lanthanoid series is derived from the element lanthanum ($Z = 57$) which is the prototype of lanthanoids.

➤ Position in the periodic table:

- Lanthanoids are placed in group 3 and period 6 of the periodic table.
- They are shown at the bottom of the periodic table as lanthanoid series. However, they interrupt the third transition series of d-block elements in period 6.
- Lanthanoids are actually placed between lanthanum ($Z = 57$) and hafnium ($Z = 72$).
- This position in the periodic table is justified due to following facts:
 - The number of valency electrons is same for all elements, i.e., one in 5d and two in 6s.
 - Group valency of all lanthanoids is 3.
 - Physical and chemical properties of all these elements are similar.
 - Atomic numbers of lanthanoids are in between lanthanum (57) and hafnium (72).
 - The symmetry of periodic table is maintained which would be otherwise disrupted by placing the lanthanoids as per increasing order of atomic number.

➤ Electronic configuration:

- General electronic configuration of lanthanides is $[\text{Xe}] 4\text{f}^{1-14} 5\text{d}^{0-1} 6\text{s}^2$.
- The atomic number of lanthanum (La) is 57.

- iii. The s-block element preceding La in period 6 is Ba with atomic number 56 and electronic configuration $[Xe] 4f^0 5d^0 6s^2$, where $[Xe]$ is the electronic configuration of noble gas xenon in the period 5 and is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^6$.
- iv. The electronic configuration of La is $[Xe] 4f^0 5d^1 6s^2$. The last electron enters 5d-orbital while the 4f orbital is empty.
- v. Cerium ($Z = 58$) has expected electronic configuration, $[Xe] 4f^1 5d^1 6s^2$ and observed electronic configuration $[Xe] 4f^2 5d^0 6s^2$. This can be explained on the basis of extra stability of empty 5d orbital.
- vi. The electrons are successively added to 4f subshell. 5d orbital contains one electron in case of La, Gd and Lu while it is empty in case of other lanthanoids.
- vii. f^0 , f^7 and f^{14} configurations have extra stability due to empty, half filled and completely filled f orbitals respectively.
eg. $La(4f^0)$ and $Lu(4f^{14})$
- viii. Higher outer orbitals shield the 4f electrons in the (n-2) shell.

Elements	Symbol	Atomic number	Electronic configuration	
			Expected (idealized)	Observed
Lanthanum	La	57	$[Xe] 4f^0 5d^1 6s^2$	$[Xe] 4f^0 5d^1 6s^2$
Cerium	Ce	58	$[Xe] 4f^1 5d^1 6s^2$	$[Xe] 4f^2 5d^0 6s^2$
Praseodymium	Pr	59	$[Xe] 4f^2 5d^1 6s^2$	$[Xe] 4f^3 5d^0 6s^2$
Neodymium	Nd	60	$[Xe] 4f^3 5d^1 6s^2$	$[Xe] 4f^4 5d^0 6s^2$
Promethium	Pm	61	$[Xe] 4f^4 5d^1 6s^2$	$[Xe] 4f^5 5d^0 6s^2$
Samarium	Sm	62	$[Xe] 4f^5 5d^1 6s^2$	$[Xe] 4f^6 5d^0 6s^2$
Europium	Eu	63	$[Xe] 4f^6 5d^1 6s^2$	$[Xe] 4f^7 5d^0 6s^2$
Gadolinium	Gd	64	$[Xe] 4f^7 5d^1 6s^2$	$[Xe] 4f^7 5d^1 6s^2$
Terbium	Tb	65	$[Xe] 4f^8 5d^1 6s^2$	$[Xe] 4f^9 5d^0 6s^2$
Dysprosium	Dy	66	$[Xe] 4f^9 5d^1 6s^2$	$[Xe] 4f^{10} 5d^0 6s^2$
Holmium	Ho	67	$[Xe] 4f^{10} 5d^1 6s^2$	$[Xe] 4f^{11} 5d^0 6s^2$
Erbium	Er	68	$[Xe] 4f^{11} 5d^1 6s^2$	$[Xe] 4f^{12} 5d^0 6s^2$
Thullium	Tm	69	$[Xe] 4f^{12} 5d^1 6s^2$	$[Xe] 4f^{13} 5d^0 6s^2$
Ytterbium	Yb	70	$[Xe] 4f^{13} 5d^1 6s^2$	$[Xe] 4f^{14} 5d^0 6s^2$
Lutetium	Lu	71	$[Xe] 4f^{14} 5d^1 6s^2$	$[Xe] 4f^{14} 5d^1 6s^2$

► General characteristics:

- Lanthanoids are silvery white soft metals and tarnish quickly in air.
- Lanthanoids have more resemblance with one another than do the transition elements of any other series.
- Hardness of lanthanoids increases with atomic number (eg. Samarium is steel hard). Their melting point lies between 1000 and 1200 K but exceptionally samarium possesses melting point of 1623 K.
- They have good thermal and electrical conductivity due to their characteristic metallic structure.
- Except La^{3+} and Lu^{3+} (no unpaired f electron), all trivalent lanthanoid ions are coloured.
- Most of the trivalent lanthanoid ions are paramagnetic. La^{3+} and Lu^{3+} ions having $4f^0$ and $4f^{14}$ electronic configuration are diamagnetic.
- The first and second ionization enthalpies of lanthanoids are nearly 600 kJ mol^{-1} and 1200 kJ mol^{-1} respectively, which is almost same as that of calcium.
- The unusual low value of third ionization enthalpy of $La(4f^0)$, $Gd(4f^7)$ and $Lu(4f^{14})$ are attributed to the stability of empty, half filled and completely filled f-levels.
- Lanthanoids form oxides M_2O_3 and hydroxides $M(OH)_3$ which are basic in nature. Their hydroxides are stronger bases than $Al(OH)_3$ and weaker than $Ca(OH)_2$. The basicity of these hydroxides decreases from $La(OH)_3$ to $Lu(OH)_3$ as the ionic size decreases from La^{3+} to Lu^{3+} .
- The strongest base is $La(OH)_3$ and the weakest base is $Lu(OH)_3$.

► Oxidation states:

- Lanthanoids have oxidation states +2, +3 and +4
- +3 oxidation state is most common and stable. It is a characteristic of this series.
- +3 oxidation state is formed by loss of two 6s and one 5d or 4f electron.



- iv. La³⁺ has configuration of Xe, formed by loss of two 6s and one 5d electron. This is a highly stable configuration.
- v. The electronic configurations of Gd³⁺ and Lu³⁺ are [Xe] 4f⁷ and [Xe] 4f¹⁴ respectively. They are stable due to half filled and completely filled f-orbitals.
- vi. The electronic configurations of Ce⁴⁺ and Tb⁴⁺ are [Xe] 4f⁰ and [Xe] 4f⁷ respectively. They are stable due to empty and half filled f-orbitals.
- vii. The electronic configurations of Eu²⁺ and Yb²⁺ are [Xe] 4f⁷ and [Xe] 4f¹⁴ respectively. They are stable due to half filled and completely filled f-orbitals.
- viii. Thermodynamic factors are responsible for the stability of Sm²⁺ and Tm²⁺.
- ix. In solutions Sm²⁺, Eu²⁺, Yb²⁺ etc. act as good reducing agents while Ce⁴⁺ and Tb⁴⁺ are good oxidizing agents.
- x. Some elements show +2 and +4 oxidation states even though corresponding ions do not have 4f⁰, 4f⁷ or 4f¹⁴ configurations.
eg. Pr⁴⁺ (4f¹), Nd²⁺ (4f⁴), Sm²⁺ (4f⁶), Dy⁴⁺ (4f⁸), etc.

Outer electronic configurations in different (common) oxidation states of lanthanum and lanthanoids:

Element	Oxidation states	Outer electronic configuration of:			
		Ln	Ln ²⁺	Ln ³⁺	Ln ⁴⁺
La	+3	5d ¹ 6s ²	—	5d ⁰ 6s ⁰	—
Ce	+3, +4	4f ¹ 5d ¹ 6s ²	—	4f ⁰ 6s ⁰	4f ⁰ 6s ⁰
Pr	+3, +4	4f ³ 6s ²	—	4f ² 6s ⁰	4f ¹ 6s ⁰
Nd	+2, +3, +4	4f ⁴ 6s ²	4f ⁴ 6s ⁰	4f ³ 6s ⁰	4f ² 6s ⁰
Pm	+3	4f ⁵ 6s ²	—	4f ⁴ 6s ⁰	—
Sm	+2, +3	4f ⁶ 6s ²	4f ⁶ 6s ⁰	4f ⁵ 6s ⁰	—
Eu	+2, +3	4f ⁷ 6s ²	4f ⁷ 6s ⁰	4f ⁶ 6s ⁰	—
Gd	+3	4f ⁷ 5d ¹ 6s ²	—	4f ⁷ 6s ⁰	—
Tb	+3, +4	4f ⁹ 6s ²	—	4f ⁸ 6s ⁰	4f ⁷ 6s ⁰
Dy	+3, +4	4f ¹⁰ 6s ²	—	4f ⁹ 6s ⁰	4f ⁸ 6s ⁰
Ho	+3	4f ¹¹ 6s ²	—	4f ¹⁰ 6s ⁰	—
Er	+3	4f ¹² 6s ²	—	4f ¹¹ 6s ⁰	—
Tm	+2, +3	4f ¹³ 6s ²	4f ¹³ 6s ⁰	4f ¹² 6s ⁰	—
Yb	+2, +3	4f ¹⁴ 6s ²	4f ¹⁴ 6s ⁰	4f ¹³ 6s ⁰	—
Lu	+3	4f ¹⁴ 5d ¹ 6s ²	—	4f ¹⁴ 6s ⁰	—

➤ Chemical reactivity of lanthanoids:

- i. The chemical reactivity of earlier members of lanthanoid series is similar to that of calcium. This behaviour changes to that of aluminum as the atomic number increases.
- $\text{Ln}_{(\text{aq})}^{+3} + 3\text{e}^- \longrightarrow \text{Ln}_{(\text{s})}; \quad E^\ominus = -2.2 \text{ to } -2.4 \text{ V}$
- For Eu, $E^\ominus = -2.0 \text{ V}$ (exceptional case)
- ii. Lanthanoids react with carbon at 2500°C, to form lanthanoid carbides having formulae Ln₃C, LnC₂ and Ln₂C₃
 $\text{Ln} + \text{C} \xrightarrow{2500^\circ\text{C}} \text{Lanthanoid carbides}$
- iii. Gentle heating with hydrogen gas gives lanthanoid hydrides.
 $2\text{Ln} + 3\text{H}_2 \xrightarrow{\Delta} 2\text{LnH}_3$
- iv. Combustion of lanthanoids in presence of oxygen, gives lanthanide oxide (Ln₂O₃).
 $2\text{Ln} + 3\text{O}_2 \xrightarrow{\Delta} 2\text{Ln}_2\text{O}_3$
 Reaction with water, converts lanthanoid oxides to insoluble lanthanoid hydroxides.
 $\text{Ln}_2\text{O}_3 + 3\text{H}_2\text{O} \longrightarrow 2\text{Ln}(\text{OH})_3$
 Reaction with CO₂ further converts lanthanoid oxides to lanthanoid carbonates.
 $\text{Ln}_2\text{O}_3 + 3\text{CO}_2 \longrightarrow \text{Ln}_2(\text{CO}_3)_3$
- v. Reaction with nitrogen, forms lanthanoid nitride (LnN).
 $2\text{Ln} + \text{N}_2 \xrightarrow{\Delta} 2\text{LnN}$



- vi. Reaction with mineral acids, liberates H₂ gas as they have reduction potential of -2.0 to -2.4 V

$$2\text{Ln} + 6\text{HCl} \longrightarrow 2\text{LnCl}_3 + 3\text{H}_2$$
- vii. Reaction with water, forms ionic and basic lanthanoid hydroxides with liberation of H₂.

$$2\text{Ln} + 6\text{H}_2\text{O} \longrightarrow 2\text{Ln(OH)}_3 + 3\text{H}_2$$
- viii. Reaction with sulphur, forms lanthanoid sulphide (Ln₂S₃).

$$2\text{Ln} + 3\text{S} \longrightarrow \text{Ln}_2\text{S}_3$$
- ix. Reaction with halogens form lanthanoid halides.

$$2\text{Ln} + 3\text{X}_2 \xrightarrow{\Delta} 2\text{LnX}_3 (\text{X} = \text{F}, \text{Cl}, \text{Br or I})$$

➤ **Uses of lanthanoids:**

- i. A well known lanthanoid alloy mischmetall (Lanthanoid metal - 95%, iron – 5% and traces of S, C, Ca and Al) is used in Mg-based alloy for making bullets, shell and lighter flint.
- ii. Mixed oxides of lanthanoids are used in petroleum cracking as catalysts.
- iii. Some of lanthanoid oxides are used as phosphors in television screens and other fluorescing surfaces.

8.6 Lanthanoid contraction and its consequences

➤ **Lanthanoid contraction:**

- i. **Lanthanoid contraction** is the gradual decrease in the atomic and ionic radii of lanthanoids with increase in the atomic number.
- ii. The nuclear positive charge increases by +1, when the atomic number increases by 1.
- iii. An electron is added in the partly filled 4f orbital.
- iv. The shielding of 4f electrons is less effective than the shielding of 5d electron as 4f orbital is more diffused in shape than 5d orbital.
- v. Thus, greater effective nuclear charge is experienced with the increase in the atomic number. This results in slight pull of the valence shell towards the nucleus.
- vi. Thus, the atomic and ionic radii decrease slightly with increase in the atomic number, thereby causing lanthanoid contraction.
- vii. In a given lanthanoid series, atomic radii decrease by 10 pm and the ionic radii decrease by 18 pm. Thus, the extent of decrease is very small.

Variation of atomic and ionic radii (pm) of lanthanum and lanthanoids:

Element	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Radii (Ln)	187	183	182	181	181	180	199	180	178	177	176	175	174	173	—
Radii (Ln ³⁺)	106	103	101	99	98	96	95	94	92	91	89	88	87	86	—

➤ **Consequences of lanthanoid contraction:**

- i. **Decrease in basicity:**
 - a. As per **Fajan's principle**, "With increase in the size of cation, the tendency of the hydroxide to dissociate, increases. This increases the strength of base."
 - b. The size of Ln³⁺ cation decreases with increase in the atomic number, due to lanthanoid contraction.
 - c. This decreases the ionic character of M–OH bond and increases the covalent character of M–OH bond.
 - d. Therefore, the basic strength of the corresponding hydroxides decreases from La(OH)₃ to Lu(OH)₃.
 - e. Thus, La(OH)₃ is most basic and Lu(OH)₃ is least basic.
 - ii. **Ionic radii of post lanthanoids:**
 - a. Post lanthanoids are the elements that follow lanthanoids in the third transition series.
 - b. Due to lanthanoid contraction, the atomic and ionic radii of post lanthanoid elements are similar to that of the elements of previous periods.
 - c. The size increases regularly from Sc to Y to La. Similarly there will be increase in size in other groups as:

$$\text{Ti} \longrightarrow \text{Zr} \longrightarrow \text{Hf}$$

$$\text{V} \longrightarrow \text{Nb} \longrightarrow \text{Ta}$$
- This increase in size down the group is compensated by the decrease in size due to lanthanoid contraction.



- d. The size (atomic radius) is similar for following pairs of elements due to lanthanoid contraction.
1. Zr – Hf (group 4)
 2. Nb – Ta (group 5)
 3. Mo – W (group 6)
 4. Tc – Re (group 7)
- e. These pairs of elements are called **chemical twins** due to similar properties and similar number of valence electrons.

8.7 Actinoids

➤ Actinoid series (5f-block elements):

- i. Actinoid series (5f-block elements) comprises a group of 14 elements from Thorium ($Z = 90$) to Lawrencium ($Z = 103$).
- ii. In these elements, the differentiating electron enters 5f orbital.
- iii. The name actinoid series is derived from the element actinium ($Z = 84$) which is the prototype of actinoids.
- iv. All the actinoids are radioactive elements and the earlier members of the series have long half-life periods.

➤ Position in periodic table:

- i. Actinoids are placed in group 3 and period 7 of the periodic table.
- ii. They are shown at the bottom of the periodic table as actinoid series. However, they interrupt the fourth transition series of d block elements in period 7.

➤ Electronic configuration:

- i. General electronic configuration of actinoids is $[Rn] 5f^{0-14} 6d^{0-2} 7s^2$.
- ii. The electronic configuration of actinium ($Z = 89$) is $[Rn] 5f^0 6d^1 7s^2$.
- iii. Thorium ($Z = 90$) has expected electronic configuration $[Rn] 5f^1 6d^1 7s^2$ and observed electronic configuration $[Rn] 5f^0 6d^2 7s^2$. This can be explained on the basis of extra stability of empty 5f orbital. The electrons are successively added to 5f subshell.

Elements	Symbol	Atomic number	Electronic configuration	
			Expected (idealized)	Observed
Actinium	Ac	89	$[Rn] 5f^0 6d^1 7s^2$	$[Rn] 5f^0 6d^1 7s^2$
Thorium	Th	90	$[Rn] 5f^1 6d^1 7s^2$	$[Rn] 5f^0 6d^2 7s^2$
Protactinium	Pa	91	$[Rn] 5f^2 6d^1 7s^2$	$[Rn] 5f^2 6d^1 7s^2$
Uranium	U	92	$[Rn] 5f^3 6d^1 7s^2$	$[Rn] 5f^3 6d^1 7s^2$
Neptunium	Np	93	$[Rn] 5f^4 6d^1 7s^2$	$[Rn] 5f^4 6d^1 7s^2$
Plutonium	Pu	94	$[Rn] 5f^5 6d^1 7s^2$	$[Rn] 5f^6 6d^0 7s^2$
Americium	Am	95	$[Rn] 5f^6 6d^0 7s^2$	$[Rn] 5f^7 6d^0 7s^2$
Curium	Cm	96	$[Rn] 5f^7 6d^1 7s^2$	$[Rn] 5f^7 6d^1 7s^2$
Berkelium	Bk	97	$[Rn] 5f^8 6d^1 7s^2$	$[Rn] 5f^9 6d^0 7s^2$
Californium	Cf	98	$[Rn] 5f^9 6d^1 7s^2$	$[Rn] 5f^{10} 6d^0 7s^2$
Einsteinium	Es	99	$[Rn] 5f^{10} 6d^1 7s^2$	$[Rn] 5f^{11} 6d^0 7s^2$
Fermium	Fm	100	$[Rn] 5f^{11} 6d^1 7s^2$	$[Rn] 5f^{12} 6d^0 7s^2$
Mendelevium	Md	101	$[Rn] 5f^{12} 6d^1 7s^2$	$[Rn] 5f^{13} 6d^0 7s^2$
Nobelium	No	102	$[Rn] 5f^{14} 6d^0 7s^2$	$[Rn] 5f^{14} 6d^0 7s^2$
Lawrencium	Lr	103	$[Rn] 5f^{14} 6d^1 7s^2$	$[Rn] 5f^{14} 6d^1 7s^2$

- iv. The systematic decrease in the atomic and ionic radii of actinoids along the series with the increase in atomic number is called **actinoid contraction**.
- v. Actinoid contraction is much more pronounced from element to element as compared to lanthanoid contraction due to poor shielding of 5f electrons.

➤ Oxidation states:

- i. Actinoids have variable oxidation states ranging from +2 to +7 due to availability of 5f, 6d and 7s orbitals.
- ii. +3 oxidation state is most common and stable and it is shown by all actinoids.
- iii. +3 oxidation state is formed by loss of two 7s and one 5f or 6d electrons.
- iv. Actinoids have more compounds in +3 oxidation state than in +4 oxidation state.
- v. Compounds of actinoids in +3 and +4 oxidation states have tendency to undergo hydrolysis.



Oxidation states of actinium and actinoids:

Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
+2	+2					+2								
+3	+3	+3	+3	+3	+3	+3	+3	+3	+3	+3	+3	+3	+3	+3
+4	+4	+4	+4	+4	+4	+4	+4	+4						
	+5	+5	+5	+5	+5	+5								
			+6	+6	+6	+6								
				+7	+7									

➤ **General characteristics:**

- Actinoids are all silvery in appearance.
- They are highly reactive metals (especially when they are in finely divided state.)
- They react with boiling water to form a mixture of oxide and hydride.
- They react with non-metals at moderate temperatures.
- They react with HCl, but are affected only slightly by HNO_3 . This is due to the formation of protective oxide layers in case of HNO_3 .
- They do not react with alkalies.
- Their magnetic properties are more complex as compared to that of lanthanoids.
- The ionisation enthalpies of earlier members of actinoid series are lower than for the earlier members of lanthanoid series.

8.8 Comparison between lanthanoids and actinoids

	Lanthanoids	Actinoids
i.	In lanthanoids, last differentiating electron occupies 4f orbital.	In actinoids, last differentiating electron occupies 5f orbital.
ii.	They are the elements of first inner transition series.	They are the elements of second inner transition series.
iii.	They are present in period 6.	They are present in period 7.
iv.	Most of lanthanoids (with exception of promethium) occur in nature.	Most of actinoids (with exception of uranium and thorium) are prepared in laboratory.
v.	Most of lanthanoids (with exception of promethium) are non-radioactive.	All the actinoids are radioactive.
vi.	Lanthanoids do not form oxo cation.	Actinoids form oxo cation such as UO_2^{2+} , PuO_2^{2+} , UO^+ .
vii.	4f orbitals in lanthanoids have higher binding energy.	5f orbitals in actinoids have lower binding energy.
viii.	Contraction in atomic and ionic radii is relatively less in lanthanoids.	Contraction in atomic and ionic radii is relatively greater in actinoids due to poor shielding of 5f electrons.
ix.	Lanthanoids shows +2, +3 and +4 oxidation states.	Actinoids show +3, +4, +5, +6, +7 oxidation states.
x.	Lanthanoids have less tendency to form complexes.	Actinoids have greater tendency to form complexes.
xi.	Some ions of lanthanoids are coloured.	Most of the ions of actinoids are deeply coloured.
xii.	Lanthanoid hydroxides are less basic in nature.	Actinoid hydroxides are more basic in nature.



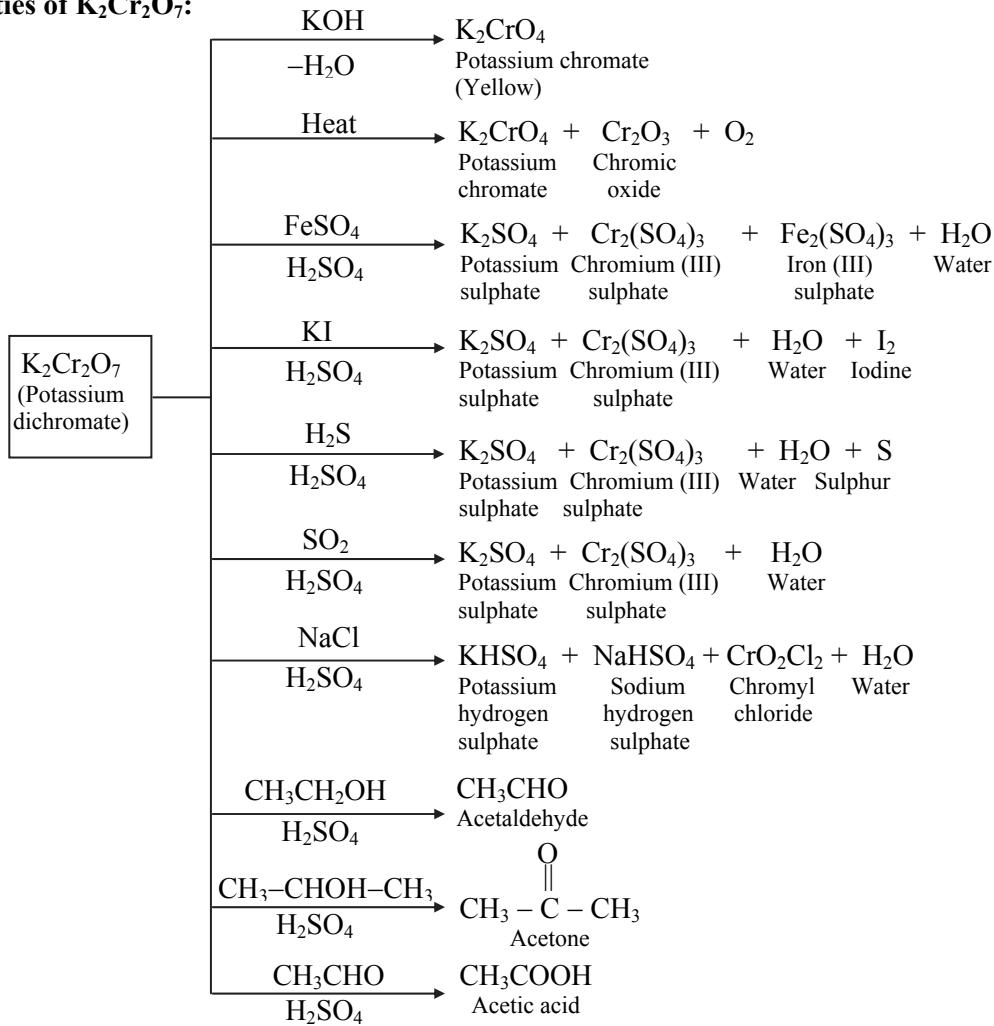
8.9 Applications of d- and f-block elements

- i. The production of iron and steels (construction materials) are carried out by the reduction of iron oxides, the removal of impurities followed by addition of copper and other alloying metals (Cr, Mn and Ni).
- ii. TiO is used in pigment industry and Zn, Ni/Cd and MnO₂ is used in battery industry.
- iii. The group 11 elements are called as coinage metals. UK ‘copper’ coins are made up of copper-coated steel and ‘silver’ UK coins are Cu/Ni alloy.
- iv. In chemical industry, these metals and their compounds are used as important catalysts.
- v. In the manufacture of sulphuric acid, oxidation of SO₂ is catalysed by V₂O₅. In the preparation of polythene, TiCl₄ with Al(CH₃)₃ (Ziegler catalyst) is used. In the production of ammonia from N₂/H₂ mixture (Haber process), iron oxide is used as catalyst. Hydrogenation of fats are favoured by nickel catalyst. PdCl₂ is employed as catalyst in Wacker process (oxidation of ethyne to ethanal).
- vi. Polymerisation of alkynes and benzene are carried out with the help of nickel complexes.
- vii. The special light-sensitive properties of AgBr is being utilised in photographic industry.
- viii. CuCl₂ is used as catalyst in Deacon process to synthesize chlorine by the oxidation of HCl.



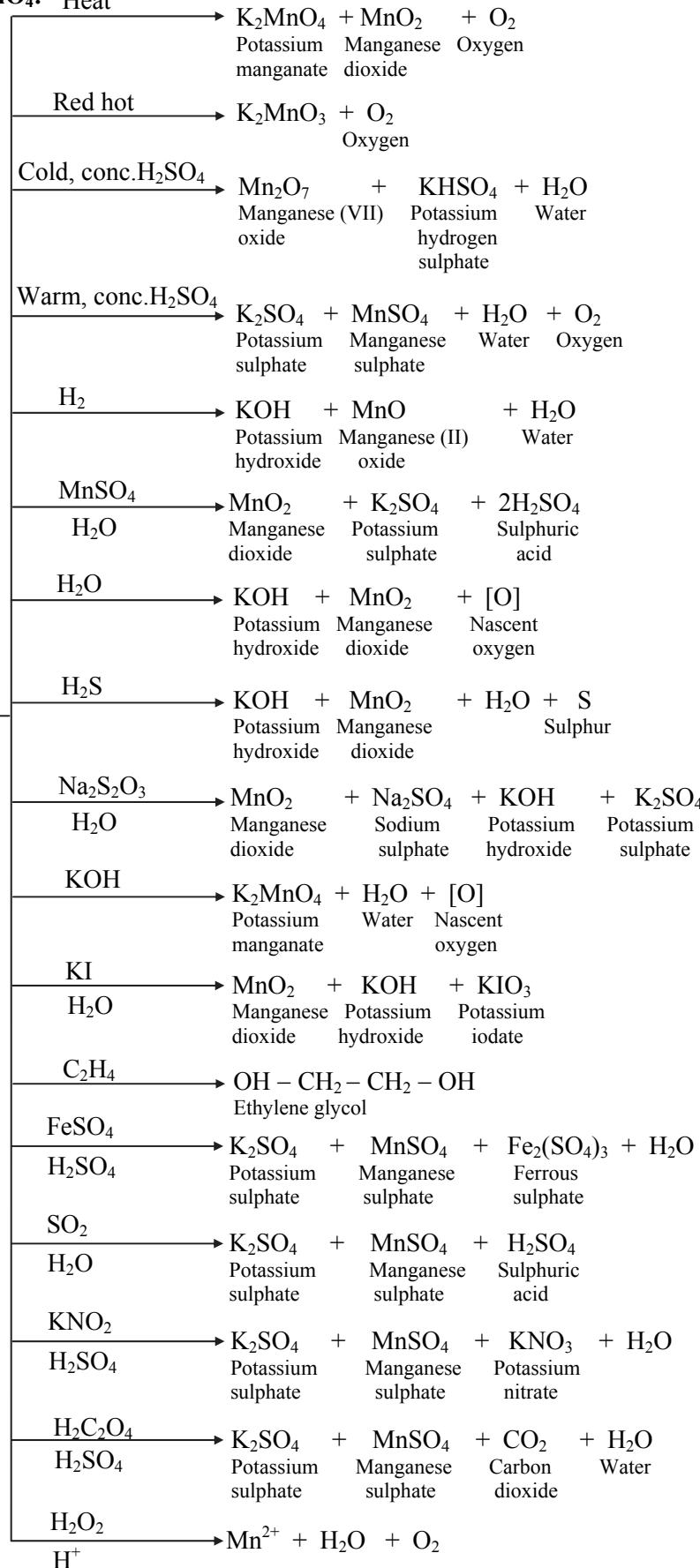
Quick Review

➤ Properties of K₂Cr₂O₇:



► Properties of KMnO_4 : Heat

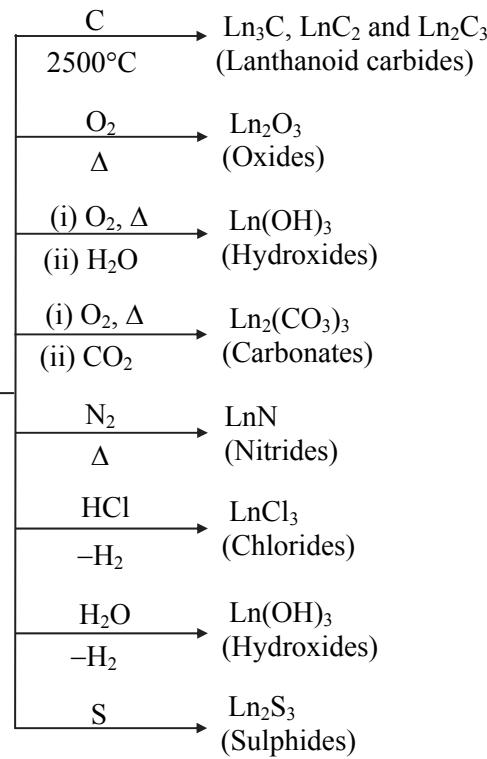
KMnO_4
(Potassium permanganate)





➤ Chemical reactivity of lanthanoids:

Ln
(Lanthanoids)




Multiple Choice Questions
8.0 General Introduction

1. In transition elements, the orbitals partially filled by electrons are _____.
[DPMT 1984; MP PMT 1999]
(A) s – orbitals (B) p – orbitals
(C) d – orbitals (D) f – orbitals
2. In transition elements, the differentiating electron enters into _____.
(A) ns subshell (B) np subshell
(C) (n – 1) d subshell (D) (n – 2) f subshell
3. The transition elements are so named because _____.
(A) they have partly filled d-orbitals
(B) their properties are similar to other elements
(C) their properties are different from other elements
(D) their properties are intermediate between the properties of s-and p-block elements
4. Electropositive nature of d-block metals is _____ elements of corresponding periods.
(A) less than that of p-block
(B) greater than that of s-block elements
(C) less than that of s-block elements
(D) equal to that of s block elements
5. Which of the following sets represents the transition series of the d-block elements?
(A) 3d, 4d, 5d, 6d (B) 2d, 3d, 4d, 5d
(C) 3d, 5d, 6d, 7d (D) 4d, 5d, 6d, 7d
6. The d-block elements include _____.
(A) metals and non-metals
(B) only non-metals
(C) only metals
(D) metals, non-metals and metalloids

8.1 Electronic configuration, occurrence and general characteristics of transition elements

7. d-Block elements belong to _____ periods of the periodic table.
(A) 3 – 6 (B) 3 – 7
(C) 4 – 7 (D) 2 – 6
8. In the long form of the periodic table, the groups to which the elements of the d-block belong are _____.
(A) 1 to 10 (B) 3 to 12
(C) 2 to 11 (D) 6 to 15

9. The elements belonging to the first transition series have atomic number from _____.
(A) 19 to 37 (B) 22 to 32
(C) 24 to 30 (D) 21 to 30
10. Which of the following elements does NOT belong to the first transition series?
[BHU 2000; MP PMT 1995]
(A) Fe (B) V
(C) Ag (D) Cu
11. To which of the following series the transition elements from Z = 39 to Z = 48 belong?
(A) 3d series (B) 4d series
(C) 5d series (D) 6d series
12. The general electronic configuration of transition elements is _____.
[CPMT 1984, 90, 2002; CBSE PMT 1991, 96; AIIMS 2001; Pb. CET 2000; MP PMT 2003]
(A) $(n-1)d^{1-5}$ (B) $(n-1)d^{1-10}ns^1$
(C) $(n-1)d^{1-10}ns^{1-2}$ (D) $ns^2(n-1)d^{10}$
13. What is the general electronic configuration for the 2nd row transition series elements?
[Orissa JEE 2002]
(A) [Ne]3d¹⁻¹⁰4s² (B) [Ar]3d¹⁻¹⁰4s¹⁻²
(C) [Kr]4d¹⁻¹⁰5s⁰⁻² (D) [Xe]5d¹⁻¹⁰5s¹⁻²
14. Which of the following represents the electronic configuration of the third transition series elements ?
(A) [Ar]3d¹⁻¹⁰4s¹⁻²
(B) [Xe]4d¹⁻¹⁰5s⁰⁻²
(C) [Xe]4f^{0/14}5d¹⁻¹⁰6s¹⁻²
(D) [Re]6d¹⁻¹⁰7s²
15. Which is the CORRECT order of increasing energy of the listed orbitals in the atom of titanium?
(At. No. Z = 22) **[AIPMT RE-TEST 2015]**
(A) 3s 3p 3d 4s (B) 3s 3p 4s 3d
(C) 3s 4s 3p 3d (D) 4s 3s 3p 3d
16. Electronic configuration of manganese (Z = 25) is _____.
(A) [Ar]3d⁴4s²4p¹ (B) [Ar]3d⁵4s¹4p¹
(C) [Ar]3d⁵4s² (D) [Ar]3d⁶4s¹
17. The electronic configuration of Cu is _____.
[WB JEEM 2014]
(A) [Ne]3s²3p⁶3d⁹4s²
(B) [Ne]3s²3p⁶3d¹⁰4s¹
(C) [Ne]3s²3p⁶3d³4s²4p⁶
(D) [Ne]3s²3p⁶3d⁵4s²4p⁴



18. Which of the following is a transition element as per the ground state electronic configuration? [GUJ CET 2014]
(A) Au (B) Hg
(C) Cd (D) Zn

19. Which of the following elements exhibits exceptional electronic configuration?
(A) Cu (B) Cr
(C) Co (D) Both (A) and (B)

20. Choose the CORRECT sentence from the following.
(A) The soft d-block elements occur as sulphide minerals.
(B) The hard d-block elements occur as oxide minerals.
(C) The hard d-block elements are more electropositive than the soft d-block elements.
(D) All of these are correct.

21. The ore chromite is _____. [WB JEE 2013]
(A) FeCr_2O_4 (B) CoCr_2O_3
(C) CrFe_2O_4 (D) FeCr_2O_3

22. Which of the following properties is NOT expected to be shown by copper?
[MP PET/PMT 1988; NCERT 1975;
MP PET 1989]
(A) High thermal conductivity
(B) Low electrical conductivity
(C) Ductility
(D) Malleability

23. All the following statements about the transition elements are TRUE, EXCEPT that, _____. [Kerala (Med.) 2003]
(A) The transition elements have compact structure
(B) They form alloys with different metals
(C) Transition elements are paramagnetic due to the presence of unpaired electrons
(D) Most of the transition elements show only one valence state

24. Which is NOT TRUE for transition elements?
(A) They have high density.
(B) They form organometallic compounds.
(C) They have high melting and boiling points.
(D) They do not form coordination compounds.

25. Transition metals and their oxides are used in industrial processes as _____.
(A) catalysts (B) detergents
(C) insecticides (D) dyes

8.2 General trends in the properties of first row transition metals

26. **Assertion:** The transition metals Cr, Mo and W are very hard.
Reason: Cr, Mo and W have maximum number of unpaired d-electrons which can form covalent bonds.

(A) Assertion and Reason are true. Reason is correct explanation of Assertion.
(B) Assertion and Reason are true. Reason is not the correct explanation of Assertion.
(C) Assertion is true, Reason is false.
(D) Assertion is false, Reason is true.

27. In which of the following, the metallic bond is strongest? [MP PET 2003]
(A) Fe (B) Sc (C) V (D) Cr

28. From chromium to nickel, the number of metallic bonds, _____.
(A) decreases continuously
(B) increases continuously
(C) does not change
(D) first increases, then decreases

29. Which of the following transition metals has the lowest boiling point?
(A) Zn (B) Sc (C) Ti (D) V

30. The ionisation potential values of transition metals are _____ the values of p-block elements.
(A) less than
(B) greater than
(C) equal to
(D) greater than or equal to

31. As the atomic number increases, the first ionisation energy of the elements of the first transition series _____.
(A) increases with few irregularities
(B) decreases with few irregularities
(C) does not show any change as the addition of electrons takes place in the inner ($n - 1$) d-orbitals
(D) increases from Ti to Mn and then decreases from Mn to Zn

32. The atomic number of vanadium (V), chromium (Cr), manganese (Mn) and iron (Fe) are 23, 24, 25 and 26 respectively. Which one of these may be expected to have the highest second ionization enthalpy? [AIEEE 2003]
(A) V (B) Cr
(C) Mn (D) Fe

33. Mn^{2+} compounds are more stable than Fe^{2+} compounds towards oxidation to their + 3 state. Because _____. [KCET 2016]
- Mn^{2+} is more stable with high 3rd ionisation energy.
 - Mn^{2+} is bigger in size
 - Mn^{2+} has completely filled d-orbitals
 - Mn^{2+} does not exist
34. **Assertion:** Transition elements show variable oxidation states.
Reason: Transition elements have high enthalpies of atomisation.
- Assertion and Reason are true. Reason is correct explanation of Assertion.
 - Assertion and Reason are true. Reason is not the correct explanation of Assertion.
 - Assertion is true, Reason is false.
 - Assertion is false, Reason is true.
35. Maximum number of oxidation states of the transition metal is derived from _____.
 (A) ns electrons
 (B) (n – 1) d electrons
 (C) nd electrons
 (D) Both (A) and (B)
36. The electronic configuration of transition element is $3d^34s^2$. The possible oxidation states are _____.
 (A) +1, +2, +3, +4 (B) +2, +3
 (C) +1, +2, +3 (D) +2, +3, +4, +5
37. Common oxidation state(s) of scandium, is/are [atomic number of Sc = 21] _____.
 (A) + 4 (B) + 1
 (C) + 3 (D) + 2 and + 4
38. Which of the following transition metals can have highest oxidation states? [RPET 2003]
 (A) Cr (B) Co
 (C) Ni (D) Cu
39. Highest (+7) oxidation state is shown by _____. [MP PMT 1990, 2001; RPMT 1999; AIIMS 1999; JIPMER 2001; CBSE PMT 1994, 2002; MP PET 1989, 2003]
 (A) Co (B) Cr
 (C) V (D) Mn
40. The number of possible oxidation states of manganese is _____.
 (A) 4 (B) 6
 (C) 3 (D) 8
41. Electronic configuration of a transition element X in +3 oxidation state is [Ar]3d⁵. What is its atomic number? [NCERT Exemplar]
 (A) 25 (B) 26 (C) 27 (D) 24
42. Among the following series of transition metal ions, the one where all metals ions have 3d² electronic configuration is _____. [CBSE PMT 2004]
 (A) $Ti^{4+}, V^{3+}, Cr^{2+}, Mn^{3+}$
 (B) $Ti^{2+}, V^{3+}, Cr^{4+}, Mn^{5+}$
 (C) $Ti^{3+}, V^{2+}, Cr^{3+}, Mn^{4+}$
 (D) $Ti^{+}, V^{4+}, Cr^{6+}, Mn^{7+}$
43. An element is in M³⁺ form. Its electronic configuration is [Ar]3d¹. The ion is _____. [JIPMER 2002]
 (A) Ti^{3+} (B) Ti^{4+}
 (C) Cr^{2+} (D) Cr
44. The electronic configuration of Cu(II) is 3d⁹ whereas that of Cu(I) is 3d¹⁰. Which of the following is CORRECT? [NCERT Exemplar]
 (A) Cu(II) is more stable.
 (B) Cu(II) is less stable.
 (C) Cu(I) and Cu(II) are equally stable.
 (D) Stability of Cu(I) and Cu(II) depends on nature of copper salts.
45. In which of the following species, the oxidation state of Mn is +2 ?
 (A) Mn_2O_7 (B) MnO_4^{2-}
 (C) MnO_2 (D) MnO
46. An element in +2 oxidation state has 24 electrons. The atomic number of the element and the number of unpaired electrons present in it respectively are _____. [TS EAMCET (Engg.) 2015]
 (A) 24, 4 (B) 26, 4
 (C) 24, 2 (D) 26, 5
47. In which of the following compounds chromium has +6 oxidation state?
 (A) $K_2Cr_2O_7$ (B) $CrCl_3$
 (C) $Cr_2(SO_4)_3$ (D) Cr_2O_3
48. Which one of the following sets of ions have same outer shell electronic configuration? [AP EAMCET (Med.) 2016]
 (A) $Cr^{3+}, Mn^{3+}, Fe^{2+}$ (B) Cr^+, Mn^{3+}, Fe^{3+}
 (C) $Cr^{3+}, Mn^{2+}, Fe^{2+}$ (D) Cr^+, Mn^{2+}, Fe^{3+}



49. The atomic number of an element is 22. The highest oxidation state exhibited by it in its compounds is _____. [MP PMT 1996]
 (A) 1 (B) 2
 (C) 3 (D) 4

50. Which of the following exhibits maximum oxidation state of vanadium?
 (A) VOCl_3 (B) VCl_4
 (C) VCl_3 (D) VCl_2

51. Salts of chromium in its +3 oxidation state are known as _____ salts.
 (A) chromous (B) chromic
 (C) chromium (D) both (B) and (C)

52. Manganese forms _____ in its +6 oxidation state.
 (A) manganese dioxide
 (B) potassium manganate
 (C) potassium permanganate
 (D) All of these

53. Match the compounds to the CORRECT oxidation states of the underlined metal.

Compounds	Oxidation states
i. $\underline{\text{Cr}}\text{SO}_4$	a. +1
ii. $\text{K}_2\underline{\text{Mn}}\text{O}_4$	b. +2
iii. $\underline{\text{Cu}}_2\text{I}_2$	c. +3
iv. $\underline{\text{Fe}}\text{Cl}_3$	d. +6

- (A) (i) – (b), (ii) – (d), (iii) – (a), (iv) – (c)
 (B) (i) – (d), (ii) – (a), (iii) – (c), (iv) – (b)
 (C) (i) – (a), (ii) – (c), (iii) – (b), (iv) – (d)
 (D) (i) – (b), (ii) – (c), (iii) – (d), (iv) – (a)

54. The compounds of iron in the +6 oxidation state are known as _____.
 (A) ferrous compounds
 (B) ferrates
 (C) ferric compounds
 (D) all of these

55. Highest oxidation state of manganese in fluorides is +4 (MnF_4) but highest oxidation state in oxides is +7 (Mn_2O_7) because _____. [NCERT Exemplar]

- (A) fluorine is more electronegative than oxygen.
 (B) fluorine does not possess d-orbitals.
 (C) fluorine stabilises lower oxidation state.
 (D) in covalent compounds, fluorine can form single bond only while oxygen forms double bond.

56. Which one of these is NOT known? [KCET 2014]
 (A) CuCl_2 (B) CuI_2
 (C) CuF_2 (D) CuBr_2

57. For the first row transition metals, the E values are given below:

E(V) (M^{2+}/M)	V	Cr	Mn	Fe	Co	Ni	Cu
-1.18	-0.90	-1.18	-0.44	-0.28	-0.25	+0.34	

What is the reason for the non-regularity in the above values? [TS EAMCET (Med.) 2015]

- (A) Non-regular variation of ionization enthalpies.
 (B) Different number of electrons present in M^{2+} ions.
 (C) Non-regular variation of ionic radii.
 (D) The variation in densities of transition metals.

58. Which of the following statements is NOT correct? [NCERT Exemplar]

- (A) Copper liberates hydrogen from acids.
 (B) In its higher oxidation states, manganese forms stable compounds with oxygen and fluorine.
 (C) Mn^{3+} and Co^{3+} are oxidising agents in aqueous solution.
 (D) Ti^{2+} and Cr^{2+} are reducing agents in aqueous solution.

59. The observed trend in the atomic radii from Sc to Cr is due to which of the following reasons?

- (A) Increase in the nuclear charge is greater than the increase in the shielding effect.
 (B) Increase in the nuclear charge is less than the increase in the shielding effect.
 (C) Increase in the nuclear charge is equal to the increase in the shielding effect.
 (D) Shielding effect is not present.

60. The atomic radii from Cr to Cu is almost identical because _____.
 (A) increase in the nuclear charge from Cr to Cu is not significant

- (B) repulsion due to added electrons is not significant
 (C) increased screening effect nullifies increased nuclear charge
 (D) electrons are added in same valence shell



61. The observed trend in the atomic radii from Cu to Zn is due to which of the following reason?
 (A) Electron-electron repulsions are greater than attractive forces due to increase in the nuclear charge.
 (B) Increase in the nuclear charge is less than the increase in the shielding effect.
 (C) Increase in the nuclear charge is equal to the increase in the shielding effect.
 (D) All of these.

62. Which of the following has highest ionic radii? [MP PMT 1990]
 (A) Cr⁺³ (B) Mn⁺³
 (C) Fe⁺³ (D) Co⁺³

63. Metallic radii of some transition elements are given below. Which of these elements will have highest density? [NCERT Exemplar]

Elements	Fe	Co	Ni	Cu
Metallic radii / pm	126	125	125	128

(A) Fe (B) Ni
 (C) Co (D) Cu

64. As the oxidation state of a transition metal increases, _____.
 (A) ionic radii remains the same
 (B) ionic radii decreases due to increase in effective nuclear charge
 (C) ionic radii increases due to decrease in effective nuclear charge
 (D) ionic radii decreases due to decrease in effective nuclear charge

65. Colour of transition metal ions is due to _____.
 (A) d-s transition (B) s-d transition
 (C) s-s transition (D) d-d transition

66. Of the ions Zn²⁺, Ni²⁺ and Cr³⁺ [atomic number of Zn = 30, Ni = 28, Cr = 24] [MP PET 1996]
 (A) Zn²⁺ is colourless while Ni²⁺ and Cr³⁺ are coloured
 (B) all the three are colourless
 (C) all the three are coloured
 (D) Ni²⁺ is coloured while Zn²⁺ and Cr³⁺ are colourless

67. Which one of the following ions is colourless? [MP PET 1999; RPET/PMT 1999]
 (A) Cu⁺ (B) Co²⁺
 (C) Ni²⁺ (D) Fe³⁺

68. The following ion in its aqueous solution is colourless:
 (Atomic number: Sc = 21, Fe = 26, Ti = 22, Mn = 25) [BCECE 2015]
 (A) Sc³⁺ (B) Fe²⁺
 (C) Ti³⁺ (D) Mn²⁺

69. The metal ion which does NOT form coloured compound is _____. [Kurukshetra CET 2002]
 (A) chromium (B) manganese
 (C) zinc (D) iron

70. Generally transition elements form coloured salts due to the presence of unpaired electrons. Which of the following compounds will be coloured in solid state? [NCERT Exemplar]
 (A) Ag₂SO₄ (B) CuF₂
 (C) ZnF₂ (D) Cu₂Cl₂

71. Colour of hydrated Cu⁺² ion will be _____.
 (A) green (B) violet
 (C) blue (D) colourless

72. If a compound absorbs orange colour from the white light, then the observed colour of the compound is _____.
 (A) yellow (B) orange
 (C) blue (D) violet

73. For the same transition metal ion, the colour of its compound will depend upon the _____.
 (A) temperature
 (B) pressure
 (C) nature of ligands or Lewis bases attached to the metal ion
 (D) concentration of the ligands

74. The colour of KMnO₄ is due to _____. [JEE (MAIN) 2015]
 (A) M → L charge transfer transition
 (B) d - d transition
 (C) L → M charge transfer transition
 (D) σ - σ* transition

75. Which of the following characteristics of the transition metals is associated with their catalytic activity? [AP EAMCET (Engg.) 2016]
 (A) Colour of hydrated ions
 (B) Diamagnetic behaviour
 (C) Paramagnetic behaviour
 (D) Variable oxidation states



76. Metals are used in finely divided state as catalyst in catalytic processes to _____.
 (A) increase the adsorption capacity
 (B) increase the surface area
 (C) increase the rate of reaction
 (D) all of these
77. Ni has valuable catalytic properties in process involving _____.
 (A) halogenation (B) oxidation
 (C) hydrogenation (D) nitration
78. V_2O_5 is useful as catalyst in manufacture of _____.
 (A) H_2SO_4 (B) HNO_3
 (C) Na_2CO_3 (D) NH_3
79. Which of the catalyst is used in contact process?
 (A) V_2O_5 (B) Fe and Mo
 (C) Pd (D) Cu
80. Which of the following forms the basis of Ziegler-Natta catalyst?
 (A) V_2O_5 (B) $TiCl_4$
 (C) $CuCl_2$ (D) $NiCl_2$
81. Which metal is used as a part of catalyst in Fischer-Tropschin method? [BCECE 2015]
 (A) Mn (B) Co
 (C) Fe (D) Pt
82. Decomposition of bleaching powder is catalyzed by cobalt salts, as cobalt can easily change oxidation state from _____.
 (A) + 4 to + 5 (B) + 3 to + 2
 (C) + 2 to + 3 (D) + 1 to + 2
83. Transition metals show paramagnetism due to _____. [BHU 2005]
 (A) their characteristic configuration
 (B) high lattice energy
 (C) variable oxidation states
 (D) unpaired electrons
84. Magnetic moment is expressed in _____.
 (A) Faraday (B) Calorie
 (C) Bohr Magneton (D) Debye
85. The spin only formula for effective magnetic moment (μ_{eff}) is _____.
 (A) $\sqrt{(n+2)} B.M$
 (B) $\sqrt{(n+4)} B.M$
 (C) $\sqrt{n(n+2)} B.M$
 (D) $\sqrt{(n+2)(n+4)} B.M$
86. Which one of the following has the maximum number of unpaired electrons? [UPSEAT 2001]
 (A) Sc^{3+} (B) Ti^{3+}
 (C) V^{3+} (D) Fe^{2+}
87. Which of the following have maximum number of unpaired electrons? [BHU 2005]
 (A) Fe^{3+} (B) Cr^{2+}
 (C) Co^{2+} (D) Co^{3+}
88. Which one of the following ions would you predict to be diamagnetic?
 (A) Mn^{2+} (B) Cu^+
 (C) Co^{3+} (D) Cr^{2+}
89. Which of the following ions is paramagnetic?
 (A) Zn^{2+} (B) Ni^{2+}
 (C) Sc^{3+} (D) all of these
90. Which of the following exhibits maximum paramagnetism? [DCE 2001]
 (A) Fe^{+2} (B) Fe^{+3}
 (C) Cr^{+3} (D) Mn^{+3}
91. Among the following, the lowest degree of paramagnetism per mole of the compound at 298 K will be shown by _____.
 (A) $MnSO_4 \cdot 4H_2O$ (B) $CuSO_4 \cdot 5H_2O$
 (C) $FeSO_4 \cdot 6H_2O$ (D) $NiSO_4 \cdot 6H_2O$
92. Which one of the following is ferromagnetic ?
 (A) Co (B) Au
 (C) Al (D) Ag
93. Which of the following pairs is expected to have effective magnetic moment equal?
 (A) Cr^{+3} and Mn^{+2}
 (B) Cr^{+2} and Fe^{+2}
 (C) V^{+2} and Sc^{+3}
 (D) Ti^{+2} and V^{+2}
94. The spin magnetic moment of cobalt in the compound $Hg[Co(SCN)_4]$ is _____. [IIT JEE Screening 2004]
 (A) $\sqrt{3}$ (B) $\sqrt{8}$
 (C) $\sqrt{15}$ (D) $\sqrt{35}$
95. The magnetic moment is associated with its spin angular momentum and orbital angular momentum. Spin only magnetic moment value of Cr^{3+} ion is _____. [NCERT Exemplar]
 (A) 2.87 B.M. (B) 3.87 B.M.
 (C) 3.47 B.M. (D) 3.57 B.M.

96. Magnetic moment 2.83 BM is given by which of the following ions? [AIPMT 2014]
 (A) Ti^{3+} (B) Ni^{2+}
 (C) Cr^{3+} (D) Mn^{2+}
97. The magnetic nature of elements depends on the presence of unpaired electrons. Identify the configuration of transition element, which shows highest magnetic moment. [NCERT Exemplar]
 (A) $3d^7$ (B) $3d^5$
 (C) $3d^8$ (D) $3d^2$
98. Which of the following ion is diamagnetic? [MH CET 2013]
 (A) Sc^{3+} (B) V^{3+}
 (C) Ni^{2+} (D) Fe^{2+}
99. Which of the following ions has the maximum theoretical magnetic moment? [GUJ CET 2015]
 (A) Fe^{3+} (B) Cr^{3+}
 (C) Ti^{3+} (D) Co^{3+}
100. The metal ion having maximum paramagnetic behaviour among the first transition series elements is _____. [KCET 2016]
 (A) Mn^{2+} (B) Cu^{2+}
 (C) Sc^{2+} (D) Cu^+
101. Interstitial compounds are formed due to _____.
 (A) metallic bonding
 (B) hydrogen bonding
 (C) covalent bonding
 (D) defect in the crystal lattice of transition metals
102. Interstitial compounds have _____ composition and are _____ in nature.
 (A) variable, non-stoichiometric
 (B) fixed, stoichiometric
 (C) variable, stoichiometric
 (D) fixed, non-stoichiometric
103. _____ is an interstitial compound.
 (A) NaCl (B) $\text{TiH}_{1.73}$
 (C) $\text{K}_2\text{Cr}_2\text{O}_7$ (D) KMnO_4
104. Which of the following forms interstitial compounds? [BHU 1982; MP PMT 1983]
 (A) Fe (B) Mn
 (C) Ni (D) All of these
105. Which of the following atoms does NOT form interstitial compounds with transition elements?
 (A) C (B) Pb
 (C) H (D) N
106. The chemical properties of interstitial compounds are similar to those of _____.
 (A) parent transition metals
 (B) alkali metals
 (C) alkaline earth metals
 (D) inner transition elements
107. Interstitial compounds are formed when small atoms are trapped inside the crystal lattice of metals. Which of the following is NOT the characteristic property of interstitial compounds? [NCERT Exemplar]
 (A) They have high melting points in comparison to pure metals.
 (B) They are very hard.
 (C) They retain metallic conductivity.
 (D) They are chemically very reactive.
108. Alloys are obtained by cooling the molten mixture of two or more _____.
 (A) alkali metals
 (B) transition metals
 (C) alkaline earth metals
 (D) inner transition elements
109. Stainless steel is an alloy of iron with _____. [DCE 1999]
 (A) Cr (B) Ni (C) C (D) N
110. Which of the following elements is alloyed with copper to form brass? [MP PET 2003; MP PMT 2004]
 (A) Lead (B) Silver
 (C) Zinc (D) Antimony
111. Which of the following elements is alloyed with copper to form bronze?
 (A) Lead (B) Tin
 (C) Zinc (D) Antimony
112. Transition elements have a tendency to form large number of complexes because of which of the following reasons?
 (A) Transition elements have high ratio of ionic charge to ionic radius.
 (B) Vacant d-orbitals of transition metals and ions can accommodate the lone pairs of electrons from the ligands.
 (C) Transition metals exhibit variable oxidation states.
 (D) All of these.
113. The stability of transition metal complexes depends upon _____.
 (A) the nature of metal ion
 (B) ligands
 (C) bonding
 (D) all of these



114. Which of the following is amphoteric oxide?
 $\text{Mn}_2\text{O}_7, \text{CrO}_3, \text{Cr}_2\text{O}_3, \text{CrO}, \text{V}_2\text{O}_5, \text{V}_2\text{O}_4$
[NCERT Exemplar]
- (A) $\text{V}_2\text{O}_5, \text{Cr}_2\text{O}_3$ (B) $\text{Mn}_2\text{O}_7, \text{CrO}_3$
(C) $\text{CrO}, \text{V}_2\text{O}_5$ (D) $\text{V}_2\text{O}_5, \text{V}_2\text{O}_4$

8.3 Preparation, properties and uses of potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$)

115. Chromite ore is converted to _____ by roasting with soda ash and lime stone.
(A) sodium chromate
(B) sodium carbonate
(C) calcium carbonate
(D) sodium dichromate
116. How is sodium chromate converted into sodium dichromate in the manufacture of potassium dichromate from chromite ore?
[MHT CET 2016]
- (A) By the action of concentrated sulphuric acid
(B) By roasting with soda ash
(C) By the action of sodium hydroxide
(D) By the action of limestone
117. In the preparation of $\text{K}_2\text{Cr}_2\text{O}_7$, sodium sulphate is removed by _____.
(A) crystallization and filtration
(B) extraction with water
(C) sublimation
(D) extraction with organic solvent
118. Sodium dichromate is converted to potassium dichromate by treatment with calculated quantity of _____.
(A) KOH (B) KCl
(C) K_2SO_4 (D) KMnO_4
119. $4\text{K}_2\text{Cr}_2\text{O}_7 \xrightarrow{\text{heat}} 4\text{K}_2\text{CrO}_4 + 3\text{O}_2 + \text{X}$. In the above reaction X is _____.
[DCE 2004]
- (A) CrO_3 (B) Cr_2O_7
(C) Cr_2O_3 (D) CrO_5
120. The colour of $\text{K}_2\text{Cr}_2\text{O}_7$ changes from red orange to lemon yellow on treatment with aqueous KOH because of _____.
[MP PMT 1994]
- (A) the reduction of Cr^{VI} to Cr^{III}
(B) the formation of chromium hydroxide
(C) the conversion of dichromate to chromate
(D) the oxidation of potassium hydroxide to potassium peroxide

121. $\text{K}_2\text{Cr}_2\text{O}_7$ on heating with aqueous NaOH gives _____.
[CBSE PMT 1997]
- (A) CrO_4^{2-} (B) $\text{Cr}(\text{OH})_3$
(C) $\text{Cr}_2\text{O}_7^{2-}$ (D) $\text{Cr}(\text{OH})_2$
122. One mole of potassium dichromate completely oxidises the following number of moles of ferrous sulphate in acidic medium.
[MP PET 1997]
- (A) 1 (B) 3
(C) 5 (D) 6
123. Potassium dichromate is a good oxidizing agent, in acidic medium, the oxidation state of chromium changes by _____.
[MH CET 2015]
- (A) 2 (B) 3
(C) 4 (D) 5
124. In the reduction of dichromate by Fe (II), the number of electrons involved per chromium atom is _____.
[Pb. PMT 2001]
- (A) 2 (B) 3
(C) 4 (D) 1
125. Which one of the following statements is CORRECT when SO_2 is passed through acidified $\text{K}_2\text{Cr}_2\text{O}_7$ solution?
[NEET P-I 2016]
- (A) SO_2 is reduced.
(B) Green $\text{Cr}_2(\text{SO}_4)_3$ is formed.
(C) The solution turns blue.
(D) The solution is decolourized.
126. When acidified $\text{K}_2\text{Cr}_2\text{O}_7$ solution is added to Sn^{2+} salts then Sn^{2+} changes to _____.
[NCERT Exemplar]
- (A) Sn (B) Sn^{3+}
(C) Sn^{4+} (D) Sn^+
127. In acidic medium, H_2O_2 changes $\text{Cr}_2\text{O}_7^{2-}$ to CrO_5 which has two $(-\text{O}-\text{O}-)$ bonds. Oxidation state of Cr in CrO_5 is _____.
[AIPMT 2014]
- (A) +5 (B) +3
(C) +6 (D) -10
128. The reaction of $\text{K}_2\text{Cr}_2\text{O}_7$ with NaCl and conc. H_2SO_4 gives _____.
[MP PET 1994]
- (A) CrCl_3 (B) CrOCl_2
(C) CrO_2Cl_2 (D) Cr_2O_3
129. Chromate ion has _____ structure.
(A) octahedral (B) tetrahedral
(C) square planar (D) square pyramidal

130. Dichromate ion has two _____ units joined by one corner.
 (A) tetrahedral (B) octahedral
 (C) square planar (D) square pyramidal
131. Cr–O–Cr bond angle in dichromate ion is _____.
 (A) 126° (B) $109^\circ 26'$
 (C) 120° (D) 180°
132. $K_2Cr_2O_7$ is used in _____.
 (A) qualitative analysis for chloride detection
 (B) estimation of Mohr's salt by volumetric analysis
 (C) manufacture of pigments and inks
 (D) all of these
133. $K_2Cr_2O_7$ is NOT used _____.
 (A) in dyeing
 (B) in tanning of leather
 (C) in manufacture of lead chromate
 (D) as disinfectant

8.4 Preparation, properties and uses of potassium permanganate ($KMnO_4$)

134. When manganese dioxide is fused with KOH in air, it gives _____.
 (A) potassium permanganate
 (B) potassium manganate
 (C) manganese hydroxide
 (D) potassium dichromate
135. When MnO_2 is fused with KOH and KNO_3 , a coloured compound is formed. The product and its colour is _____.
[AP EAMCET (Med.) 2016]
 (A) K_2MnO_4 , Green (B) $KMnO_4$, Purple
 (C) Mn_2O_3 , Blue (D) K_3MnO_2 , Red
136. K_2MnO_4 is converted to $KMnO_4$ by _____.
 (A) oxidation or electrolysis
 (B) electrolysis or reduction
 (C) hydrolysis or reduction
 (D) reduction or oxidation
137. K_2MnO_4 is converted to $KMnO_4$ by disproportionation with _____.
 (A) H_2SO_4 (B) CO_2
 (C) Cl_2 (D) All of these
138. $KMnO_4$ can be prepared from K_2MnO_4 as per the reaction:

$$3MnO_4^{2-} + 2H_2O \longrightarrow 2MnO_4^- + MnO_2 + 4OH^-$$
 The reaction can go to completion by removing OH^- ions by adding _____.
[NEET 2013]
 (A) HCl (B) KOH
 (C) CO_2 (D) SO_2

139. On heating potassium permanganate, one of the following compound is NOT obtained.
[KCET 2015]
 (A) O_2 (B) MnO
 (C) MnO_2 (D) K_2MnO_4
140. On addition of small amount of $KMnO_4$ to concentrated H_2SO_4 , a green oily compound is obtained which is highly explosive in nature. Identify the compound from the following.
[NCERT Exemplar]
 (A) Mn_2O_7 (B) MnO_2
 (C) $MnSO_4$ (D) Mn_2O_3
141. $KMnO_4$ acts as an oxidising agent in alkaline medium. When alkaline $KMnO_4$ is treated with KI, iodide ion is oxidised to _____.
[NCERT Exemplar]
 (A) I_2 (B) IO^-
 (C) IO_3^- (D) IO_4^-
142. $KMnO_4$ oxidizes ethylene to _____.
 (A) ethane (B) ethylene glycol
 (C) ethyne (D) ethanoic acid.
143. When $KMnO_4$ reacts with acidified $FeSO_4$, _____.
[MP PET 1996]
 (A) only $FeSO_4$ is oxidised
 (B) only $KMnO_4$ is oxidised
 (C) $FeSO_4$ is oxidised and $KMnO_4$ is reduced
 (D) $KMnO_4$ is oxidised and $FeSO_4$ is reduced
144. $KMnO_4$ acts as an oxidising agent in acidic medium. The number of moles of $KMnO_4$ that will be needed to react with one mole of sulphide ions in acidic solution is _____.
[NCERT Exemplar]
 (A) $\frac{2}{5}$ (B) $\frac{3}{5}$ (C) $\frac{4}{5}$ (D) $\frac{1}{5}$
145. When $KMnO_4$ solution is added to oxalic acid solution, the decolourisation is slow in the beginning but becomes instantaneous after some time because _____.
[NCERT Exemplar]
 (A) CO_2 is formed as the product.
 (B) Reaction is exothermic.
 (C) MnO_4^- catalyses the reaction.
 (D) Mn^{2+} acts as autocatalyst.
146. The reaction of aqueous $KMnO_4$ with H_2O_2 in acidic conditions gives _____.
[AIPMT 2014]
 (A) Mn^{4+} and O_2 (B) Mn^{2+} and O_2
 (C) Mn^{2+} and O_3 (D) Mn^{4+} and MnO_2



147. Assuming complete ionization, same moles of which of the following compounds will require the least amount of acidified KMnO_4 for complete oxidation? [AIPMT RE-TEST 2015]
 (A) FeC_2O_4 (B) $\text{Fe}(\text{NO}_2)_2$
 (C) FeSO_4 (D) FeSO_3
148. Why is HCl not used to make the medium acidic in oxidation reactions of KMnO_4 in acidic medium? [NCERT Exemplar]
 (A) Both HCl and KMnO_4 act as oxidising agents.
 (B) KMnO_4 oxidises HCl into Cl_2 which is also an oxidising agent.
 (C) KMnO_4 is a weaker oxidising agent than HCl.
 (D) KMnO_4 acts as a reducing agent in the presence of HCl.
149. Manganate ion has _____ structure.
 (A) octahedral (B) tetrahedral
 (C) square planar (D) square pyramidal
150. Manganate ion contains _____.
 (A) sigma bonds
 (B) sigma and pi bonds
 (C) coordinate bonds
 (D) sigma and coordinate bonds
151. **Assertion:** Manganate ion (MnO_4^{2-}) is paramagnetic.
Reason: Manganate ion has tetrahedral structure.
 (A) Assertion and Reason are true. Reason is correct explanation of Assertion.
 (B) Assertion and Reason are true. Reason is not the correct explanation of Assertion.
 (C) Assertion is true, Reason is false.
 (D) Assertion is false, Reason is true.
152. Permanganate ion has _____.
 (A) tetrahedral structure, purple colour and diamagnetic properties
 (B) octahedral structure, green colour and paramagnetic properties
 (C) tetrahedral structure, green colour and diamagnetic properties
 (D) octahedral structure, purple colour and paramagnetic properties
153. _____ is used for detecting the presence of unsaturation in organic compounds.
 (A) Alkaline potassium permanganate
 (B) Acidified potassium permanganate
 (C) Neutral potassium permanganate
 (D) Alkaline potassium manganate
154. _____ is used in the estimation of oxalic acid and hydrogen peroxide.
 (A) KMnO_4 (B) $\text{K}_2\text{Cr}_2\text{O}_7$
 (C) Cr_2O_3 (D) K_2MnO_4
155. Which of the following statements is INCORRECT for KMnO_4 ? [GUJ CET 2015]
 (A) It is an oxidising agent.
 (B) It is used as antiseptic.
 (C) It is used as bleaching agent in textile industries.
 (D) It is dark purple coloured amorphous substance.

8.5 Lanthanoids

156. In lanthanoids, last electron enters the _____ orbital.
 (A) s (B) p (C) d (D) f
157. Lanthanoid series contain _____ elements.
 (A) 12 (B) 14 (C) 16 (D) 18
158. Lanthanoids are placed in group _____ of the periodic table.
 (A) 2 (B) 3 (C) 4 (D) 5
159. Lanthanoids are placed in period _____ of the periodic table.
 (A) 4 (B) 5 (C) 6 (D) 7
160. General electronic configuration of lanthanoids is _____.
 (A) $[\text{Xe}] 4f^{1-14} 5d^{0-1} 6s^2$
 (B) $[\text{Ar}] 4f^{1-14} 5d^{0-1} 6s^2$
 (C) $[\text{Rn}] 5f^0 6d^1 7s^2$
 (D) $[\text{Xe}] 5f^0 6d^1 7s^2$
161. Gadolinium belongs to 4f series. Its atomic number is 64. Which of the following is the CORRECT electronic configuration of gadolinium? [AIPMT RE-TEST 2015; NCERT Exemplar]
 (A) $[\text{Xe}] 4f^7 5d^1 6s^2$ (B) $[\text{Xe}] 4f^6 5d^2 6s^2$
 (C) $[\text{Xe}] 4f^8 6d^2$ (D) $[\text{Xe}] 4f^9 5s^1$
162. 5d orbital contains one electron in 5d subshell in case of _____.
 (A) La, Gd and Lu (B) Tb, Nd and Ho
 (C) Ce, Pr and Sm (D) Tm, Yb and Dy
163. Which of the following option is the CORRECT order for the basic strength of metallic hydroxides? [GUJ CET 2014]
 (A) $\text{Al(OH)}_3 < \text{Lu(OH)}_3 < \text{Ce(OH)}_3 < \text{Ca(OH)}_2$
 (B) $\text{Ca(OH)}_2 < \text{Al(OH)}_3 < \text{Lu(OH)}_3 < \text{Ce(OH)}_3$
 (C) $\text{Lu(OH)}_3 < \text{Ce(OH)}_3 < \text{Al(OH)}_3 < \text{Ca(OH)}_2$
 (D) $\text{Lu(OH)}_3 < \text{Ce(OH)}_3 < \text{Ca(OH)}_2 < \text{Al(OH)}_3$

164. Which of the following lanthanoid ions is diamagnetic? [NEET 2013]
 (At. no.: Ce = 58, Sm = 62, Eu = 63, Yb = 70)
 (A) Ce^{2+} (B) Sm^{2+} (C) Eu^{2+} (D) Yb^{2+}
165. Which one of the following lanthanide ions does NOT exhibit paramagnetism? [TS EAMCET (Engg.) 2015]
 (A) Lu^{3+} (B) Ce^{3+}
 (C) Eu^{3+} (D) Yb^{3+}
166. Which of the following oxidation states is common for all lanthanoids? [NCERT Exemplar]
 (A) +2 (B) +3 (C) +4 (D) +5
167. In lanthanoids, +3 oxidation state is formed by loss of _____.
 (A) two 6s and one 5d or 4f electron
 (B) one 6s, one 5d and one 4f electron
 (C) two 7s and one 6d or 5f electron
 (D) one 7s, one 6d and one 5f electron
168. The electronic configurations of _____ are stable due to half filled and completely filled f-orbitals.
 (A) Eu^{2+} and Yb^{2+} (B) Eu^{3+} and Yb^{3+}
 (C) Eu^{4+} and Yb^{4+} (D) Eu^{2+} and Yb^{4+}
169. Cerium can show the oxidation state of +4 because _____.
 (A) it resembles alkali metals
 (B) it has high value of ionization energy
 (C) of its tendency to attain noble gas configuration of xenon
 (D) of its tendency to attain 4f^7 configuration
170. The atomic number of cerium (Ce) is 58. The CORRECT electronic configuration of Ce^{3+} ion is _____. [WB JEEM 2015]
 (A) $[\text{Xe}] 4\text{f}^1$ (B) $[\text{Kr}] 4\text{f}^1$
 (C) $[\text{Xe}] 4\text{f}^3$ (D) $[\text{Kr}] 4\text{d}^1$
171. The electronic configuration of Gd^{2+} is _____. (Atomic number of Gd is 64). [KCET 2015]
 (A) $[\text{Xe}] 4\text{f}^8$ (B) $[\text{Xe}] 4\text{f}^7$
 (C) $[\text{Xe}] 4\text{f}^7 5\text{d}^1 6\text{s}^2$ (D) $[\text{Xe}] 4\text{f}^7 5\text{d}^1$
172. Lanthanoids react with carbon to form lanthanoid _____.
 (A) carbonates (B) carbides
 (C) hydroxides (D) all of these
173. Reaction of lanthanoids with mineral acids liberates _____.
 (A) carbon dioxide (B) oxygen
 (C) hydrogen (D) halogen

174. What is the general molecular formula of the product obtained on heating lanthanoids (Ln) with sulphur? [MHT CET 2016]
 (A) LnS (B) LnS_3
 (C) Ln_3S_2 (D) Ln_2S_3
175. Which of the following is used in bullets and lighter flint?
 (A) CeO_2
 (B) Mischmetall
 (C) Actinoids
 (D) Mixed oxides of lanthanoids
- ### 8.6 Lanthanoid contraction and its consequences
176. A reduction in atomic size with increase in atomic number is a characteristic of _____. [AIEEE 2003]
 (A) inert gases
 (B) transition element
 (C) inner transition elements
 (D) halogens
177. Reason of lanthanoid contraction is _____. [AMU 2000; BHU 2003; AIPMT 2014]
 (A) negligible screening effect of 'f' orbitals
 (B) increasing nuclear charge
 (C) decreasing nuclear charge
 (D) decreasing screening effect
178. Arrange Ce^{+3} , La^{+3} , Pm^{+3} and Yb^{+3} in increasing order of their ionic radii _____. [AIEEE 2002]
 (A) $\text{Yb}^{+3} < \text{Pm}^{+3} < \text{Ce}^{+3} < \text{La}^{+3}$
 (B) $\text{Ce}^{+3} < \text{Yb}^{+3} < \text{Pm}^{+3} < \text{La}^{+3}$
 (C) $\text{Yb}^{+3} < \text{Pm}^{+3} < \text{La}^{+3} < \text{Ce}^{+3}$
 (D) $\text{Pm}^{+3} < \text{La}^{+3} < \text{Ce}^{+3} < \text{Yb}^{+3}$
179. As the size of cation increases, the strength of base _____.
 (A) increases
 (B) remains the same
 (C) decreases
 (D) increases and then decreases
180. **Assertion:** $\text{La}(\text{OH})_3$ is weak base compared to $\text{Lu}(\text{OH})_3$.
Reason: With increase in the size of the cation, the tendency of the hydroxide to dissociate increases, thus increasing the strength of the base.
 (A) Assertion and Reason are true. Reason is correct explanation of Assertion.
 (B) Assertion and Reason are true. Reason is not the correct explanation of Assertion.
 (C) Assertion is true, Reason is false.
 (D) Assertion is false, Reason is true.



181. Although Zirconium belongs to 4d transition series and Hafnium to 5d transition series even then they show similar physical and chemical properties because _____.

[NCERT Exemplar]

- (A) both belong to d-block.
- (B) both have same number of electrons.
- (C) both have similar atomic radius.
- (D) both belong to the same group of the periodic table.

182. Identify a 'chemical twin' among the following.

[MH CET 2015]

- | | |
|-----------|-----------|
| (A) Zr-Ta | (B) Nb-Tc |
| (C) Hf-Re | (D) Nb-Ta |

8.7 Actinoids

183. Actinoids are elements of _____.

- (A) first inner transition series
- (B) second inner transition series
- (C) third transition series
- (D) fourth transition series

184. Which orbital is progressively filled in actinoids?

- | | |
|--------|--------|
| (A) 4f | (B) 5f |
| (C) 6d | (D) 7s |

185. There are 14 elements in actinoid series. Which of the following elements does NOT belong to this series? [NCERT Exemplar]

- | | |
|--------|--------|
| (A) U | (B) Np |
| (C) Tm | (D) Fm |

186. Actinoids are placed in group _____ of the periodic table.

- | | |
|-------|-------|
| (A) 3 | (B) 4 |
| (C) 5 | (D) 6 |

187. Actinoids are placed in period _____ of the periodic table.

- | | |
|-------|-------|
| (A) 4 | (B) 5 |
| (C) 6 | (D) 7 |

188. Actinoids interrupt the _____ transition series of d-block elements.

- | | |
|-----------|------------|
| (A) first | (B) second |
| (C) third | (D) fourth |

189. The expected electronic configuration of actinium ($Z = 89$) is _____.

- | | |
|---------------------------|---------------------------|
| (A) $[Rn] 5f^0 6d^1 7s^2$ | (B) $[Rn] 5f^1 6d^1 7s^2$ |
| (C) $[Rn] 5f^1 6d^1 7s^2$ | (D) $[Rn] 5f^2 6d^1 7s^2$ |

190. Common oxidation state of actinoids is _____.

- | | |
|--------|--------|
| (A) +2 | (B) +3 |
| (C) +4 | (D) +5 |

191. Which of the following is INCORRECT?
- (A) Actinoids react vigorously with nitric acid.
 - (B) Actinoids are silvery in appearance.
 - (C) Actinoids react with boiling water.
 - (D) Actinoids are unaffected by alkalies.

8.8 Comparison between lanthanoids and actinoids

192. The only radioactive element among the lanthanoids is _____. [MH CET 2015]

- | | |
|----------------|---------------|
| (A) gadolinium | (B) holmium |
| (C) promethium | (D) neodymium |

193. _____ do not form oxo cations, whereas _____ form oxo cation.

- | |
|--|
| (A) Lanthanoids, actinoids |
| (B) Actinoids, lanthanoids |
| (C) Transition metals, inner transition metals |
| (D) Inner transition elements, transition elements |

194. **Assertion:** Contraction in atomic and ionic radii is greater in actinoids than that in lanthanoids.

- Reason:** All the actinoids are non-radioactive.

- (A) Assertion and Reason are true. Reason is correct explanation of Assertion.
- (B) Assertion and Reason are true. Reason is not the correct explanation of Assertion.
- (C) Assertion is true, Reason is false.
- (D) Assertion is false, Reason is true.

8.9 Applications of d- and f-block elements

195. Match the catalysts to the CORRECT processes:

	Catalyst		Process
i.	TiCl ₄	a.	Wacker process
ii.	PdCl ₂	b.	Ziegler - Natta polymerization
iii.	CuCl ₂	c.	Contact process
iv.	V ₂ O ₅	d.	Deacon's process

[JEE (MAIN) 2015]

- (A) (i) – (c), (ii) – (b), (iii) – (d), (iv) – (a)
- (B) (i) – (b), (ii) – (a), (iii) – (d), (iv) – (c)
- (C) (i) – (b), (ii) – (c), (iii) – (d), (iv) – (a)
- (D) (i) – (c), (ii) – (a), (iii) – (b), (iv) – (d)

Miscellaneous

196. Which of the following group belongs to transition series?

- | | |
|-------|--------|
| (A) 1 | (B) 2 |
| (C) 7 | (D) 13 |

197. An atom has electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$. In which group would it be placed?
 (A) Group 5 (B) Group 2
 (C) Group 3 (D) Group 4
198. Manganese belongs to which block of the periodic table? [MP PMT 2003]
 (A) s-block (B) p-block
 (C) d-block (D) f-block
199. An element having the electronic configuration $[Ar]3d^2 4s^2$ belongs to _____.
 [MP PMT 1993]
 (A) s - block elements
 (B) p - block elements
 (C) d - block elements
 (D) f - block elements
200. Fe has been placed in the eighth group, the number of electrons in the outermost orbit is _____.
 (A) 1 (B) 2
 (C) 3 (D) 4
201. The electronic configuration of Ag atom is _____. [CPMT 1984]
 (A) $[Kr]3d^{10} 4s^1$ (B) $[Xe]4f^{14} d^{10} 6s^1$
 (C) $[Kr]4d^{10} 5s^1$ (D) $[Kr]4d^9 5s^2$
202. The number of d-electrons in Fe^{2+} ($Z = 26$) is NOT equal to the number of electrons in which one of the following? [AIPMT 2015]
 (A) s-electrons in Mg ($Z = 12$)
 (B) p-electrons in Cl ($Z = 17$)
 (C) d-electrons in Fe ($Z = 26$)
 (D) p-electrons in Ne ($Z = 10$)
203. Due to covalent bonding, the transition metals are _____.
 (A) lustrous (B) conductors
 (C) hard (D) ductile
204. Which one of the following is TRUE for the transition metals?
 (A) All their ions are coloured.
 (B) They do not show catalytic activity.
 (C) They have low melting points.
 (D) They exhibit large number of positive oxidation states.
205. The elements of d- block are characterized by _____.
 (A) the filling of d – subshells
 (B) the presence of vacant d – orbitals
- (C) the presence of unpaired electrons in d – subshells
 (D) all of these
206. Which of the following statements is CORRECT?
 (A) Iron belongs to first transition series.
 (B) Iron belongs to f-block of the periodic table.
 (C) Iron belongs to Group VIII of the periodic table.
 (D) Both (A) and (C)
207. The tendency to form complexes is maximum for _____.
 (A) alkali metals
 (B) transition elements
 (C) inner-transition elements
 (D) metals containing fully filled d-orbitals
208. Which of the following metal does NOT show variable valency? [RPET 2000]
 (A) Fe (B) V (C) Zn (D) Cu
209. In the following transition elements, the lowest melting point and boiling point is exhibited by _____.
 (A) Cr (B) Hg
 (C) Cu (D) Au
210. The transition metal which shows oxidation state from +2 to +7 belong to group _____.
 (A) 7 (B) 6 (C) 12 (D) 3
211. The electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ corresponds to _____. [MP PET 1994]
 (A) Mn^{2+} (B) Fe^{+2}
 (C) Co (D) Ge
212. The electronic configuration of Fe^{3+} is _____.
 (A) $[Ar]3d^6$ (B) $[Ar]3d^5$
 (C) $[Ar]3d^4$ (D) $[Ar]3d^6 4s^2$
213. A transition element X has a configuration $[Ar]3d^4$ in its + 3 oxidation state. Its atomic number is _____. [CBSE PMT 1996; JIPMER 2002]
 (A) 25 (B) 26
 (C) 22 (D) 19
214. Of the following outer electronic configurations of atoms, the highest oxidation state is achieved by which one of them? [AIEEE 2004]
 (A) $(n-1)d^3 ns^2$ (B) $(n-1)d^5 ns^1$
 (C) $(n-1)d^8 ns^2$ (D) $(n-1)d^5 ns^2$



230. Select the coloured compound amongst the following.

(Atomic no. Ti = 22, Cr = 24, Cu = 29, Zn = 30) [MH CET 2014]

- (A) TiCl_4 (B) CrCl_3
(C) ZnCl_2 (D) CuCl

231. Complex forming tendency increases with the _____.

- (A) increase in size of cation
(B) decrease in size of cation
(C) increase in size of anion
(D) decrease in size of anion

232. Potassium permanganate is used _____.

[MH CET 2013]

- (A) as Baeyer's reagent
(B) in dyeing
(C) in the tanning of leather
(D) in the manufacture of pigment

233. 3d-series elements show variable oxidation states because _____.

- (A) they contain unpaired electrons in 3d
(B) 4s – electrons are readily involved in bonding
(C) energy difference between 3d and 4s orbitals is small
(D) 3d – electrons are only involved in bonding

234. Which of the following sets of elements exhibits decreasing order of atomic radii?

- (A) Co, Ni, Cu (B) Ti, V, Cr
(C) Ni, Cu, Zn (D) Cr, Mn, Fe

235. The coloured ion is _____.

[Assam CEE 2015]

- (A) Zn^{2+} (B) Sc^{3+}
(C) V^{3+} (D) Na^+

236. Which of the following compounds give colour due to charge transfer?

- (A) $\text{K}_2\text{Cr}_2\text{O}_7$ (B) KMnO_4
(C) Cu_2O (D) All of these

237. Oxidation number of Mn in K_2MnO_4 and in KMnO_4 are respectively _____.

[MP PET 1991, 2001]

- (A) + 6 and + 7 (B) + 6 and + 6
(C) + 7 and + 7 (D) + 7 and + 6

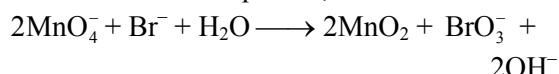
238. Oxygen gas can be prepared from solid KMnO_4 by _____.

[DPMT 2001]

- (A) strongly heating the solid
(B) treating the solid with H_2 gas

- (C) dissolving the solid in cold.conc. H_2SO_4
(D) all of these

239. In the redox ionic equation,



The equivalent weight of potassium permanganate of molar mass 'M' g mol⁻¹ is _____.

[AP EAMCET (Med.) 2016]

- (A) $\frac{M}{5}$ (B) $\frac{M}{3}$
(C) $\frac{M}{6}$ (D) $\frac{M}{2}$

240. General configuration of outermost and penultimate shell is $(n-1)s^2(n-1)p^6(n-1)d^xns^2$. If n = 4 and x = 5 then the total number of electrons around the nucleus will be _____.

[MP PET 2003]

- (A) > 25 (B) < 24
(C) 25 (D) 30

241. Manganese achieves its highest oxidation state in its compound _____.

[MP PET 1993, 2001; MP PMT 2004]

- (A) MnO_2 (B) Mn_3O_4
(C) KMnO_4 (D) K_2MnO_4

242. Most powerful oxidizing property of manganese is shown by which of the following oxidation state? [MP PET 2003]

- (A) $\text{Mn}(+7)$ (B) $\text{Mn}(+2)$
(C) $\text{Mn}(+4)$ (D) $\text{Mn}(+5)$

243. The number of moles of KMnO_4 needed to react with 1 mole of SO_3^{2-} in acidic solution is _____.

[BCECE 2015]

- (A) $\frac{4}{5}$ (B) $\frac{2}{5}$
(C) 1 (D) $\frac{3}{5}$

244. Four successive members of the first row transition elements are listed below with their atomic numbers. Which one of them is expected to have the highest third ionization enthalpy? [CBSE PMT 2005]

- (A) Vanadium (Z = 23)
(B) Chromium (Z = 24)
(C) Iron (Z = 26)
(D) Manganese (Z = 25)

245. Select an element from the following which does NOT show +4 oxidation state.

- (A) Ti (B) Zr (C) La (D) Pt



246. How many unpaired electrons are there in Ni^{2+} ? **[MP PET 2004]**
 (A) 2 (B) 4 (C) 5 (D) 0

247. Match the element with its electronic configuration:

	Column I		Column II
i.	Cerium	a.	$[\text{Rn}]5\text{f}^26\text{d}^17\text{s}^2$
ii.	Protactinium	b.	$[\text{Rn}]5\text{f}^{14}6\text{d}^17\text{s}^2$
iii.	Europium	c.	$[\text{Xe}]4\text{f}^25\text{d}^06\text{s}^2$
iv.	Lawrencium	d.	$[\text{Xe}]4\text{f}^75\text{d}^06\text{s}^2$

- (A) (i) – (d), (ii) – (b), (iii) – (a), (iv) – (c)
 (B) (i) – (a), (ii) – (d), (iii) – (c), (iv) – (b)
 (C) (i) – (b), (ii) – (c), (iii) – (a), (iv) – (d)
 (D) (i) – (c), (ii) – (a), (iii) – (d), (iv) – (b)

248. Which of the following has the maximum number of unpaired d-electrons?

[BIT 1992; CBSE PMT 1999]

- (A) Zn (B) Fe^{2+}
 (C) Ni^{3+} (D) Cu^+

249. Number of unpaired electrons in Fe^{+3} ($Z = 26$) is _____.

- [MP PMT 1995; Rajasthan PET 2003]**
 (A) 4 (B) 5 (C) 6 (D) 3

250. Which of the following has highest paramagnetic character?

- (A) Mn (II) (B) Fe (II)
 (C) Co (II) (D) Ni (II)

251. Which ion has maximum magnetic moment?

[AIIMS 1983; MP PMT 1990]

- (A) V^{+3} (B) Mn^{+3} (C) Fe^{+3} (D) Cu^{+2}

252. Magnetic moment 2.84 B.M. is given by _____. (At. Numbers: Ni = 28, Ti = 22, Cr = 24, Co = 27) **[AIPMT 2015]**

- (A) Ni^{2+} (B) Ti^{3+}
 (C) Cr^{2+} (D) Co^{2+}

253. When an acidified solution of ferrous ammonium sulphate is treated with potassium permanganate solution, the ion oxidised is _____. **[BHU 1979]**

- (A) MnO_4^- (B) NH_4^+
 (C) Fe^{++} (D) SO_4^{2-}

254. Zinc does not show variable valency like d-block elements because _____. **[MP PET 1989; MP PMT 1992; CPMT 1984]**

- (A) it is a soft metal
 (B) its d-orbital is completely filled

- (C) it has low melting point
 (D) two electrons are present in the outermost orbit

255. Europium is _____. **[DPMT 2005]**
 (A) s-block element (B) p-block element
 (C) d-block element (D) f-block element

256. The CORRECT statement is _____. **[KCET 2014]**

- (A) the earlier members of lanthanoid series resemble calcium in their chemical properties
 (B) the extent of actinoid contraction is almost the same as lanthanoid contraction
 (C) in general, lanthanoid and actinoids do not show variable oxidation states
 (D) Ce^{+4} in aqueous solution is not known

257. Ce is a member of _____. **[Pb. CET 2002]**

- (A) s-block (B) p-block
 (C) d-block (D) f-block

258. Which is the oxidation state generally found in lanthanides? **[BCECE 2014]**

- (A) 4 (B) 2 (C) 5 (D) 3

259. Which of the following belongs to the actinides series?

- (A) Ce (B) Pu
 (C) Ca (D) Cs

260. Which of the following reactions are disproportionation reactions?

[NCERT Exemplar]

- (a) $\text{Cu}^+ \longrightarrow \text{Cu}^{2+} + \text{Cu}$
 (b) $3\text{MnO}_4^- + 4\text{H}^+ \longrightarrow 2\text{MnO}_4^- + \text{MnO}_2 + 2\text{H}_2\text{O}$
 (c) $2\text{KMnO}_4 \longrightarrow \text{K}_2\text{MnO}_4 + \text{MnO}_2 + \text{O}_2$
 (d) $2\text{MnO}_4^- + 3\text{Mn}^{2+} + 2\text{H}_2\text{O} \longrightarrow 5\text{MnO}_2 + 4\text{H}^+$
 (A) a, b (B) a, b, c
 (C) b, c, d (D) a, d

261. Which of the following oxides has the maximum basicity? **[GUJ CET 2015]**

- (A) La_2O_3 (B) Pr_2O_3
 (C) Sm_2O_3 (D) Gd_2O_3

262. Which one of the following statements related to lanthanoids is INCORRECT?

[NEET P-II 2016]

- (A) Ce (+4) solutions are widely used as oxidizing agent in volumetric analysis.
 (B) Europium shows +2 oxidation state.
 (C) The basicity decreases as the ionic radius decreases from Pr to Lu.
 (D) All the lanthanoids are much more reactive than aluminium.



Answers to MCQs

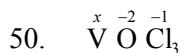
- | | | | | | | | | | |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| 1. (C) | 2. (C) | 3. (D) | 4. (C) | 5. (A) | 6. (C) | 7. (C) | 8. (B) | 9. (D) | 10. (C) |
| 11. (B) | 12. (C) | 13. (C) | 14. (C) | 15. (B) | 16. (C) | 17. (B) | 18. (A) | 19. (D) | 20. (D) |
| 21. (A) | 22. (B) | 23. (D) | 24. (D) | 25. (A) | 26. (A) | 27. (D) | 28. (A) | 29. (A) | 30. (A) |
| 31. (A) | 32. (B) | 33. (A) | 34. (B) | 35. (D) | 36. (D) | 37. (C) | 38. (A) | 39. (D) | 40. (B) |
| 41. (B) | 42. (B) | 43. (A) | 44. (A) | 45. (D) | 46. (B) | 47. (A) | 48. (D) | 49. (D) | 50. (A) |
| 51. (D) | 52. (B) | 53. (A) | 54. (B) | 55. (D) | 56. (B) | 57. (A) | 58. (A) | 59. (A) | 60. (C) |
| 61. (A) | 62. (A) | 63. (D) | 64. (B) | 65. (D) | 66. (A) | 67. (A) | 68. (A) | 69. (C) | 70. (B) |
| 71. (C) | 72. (C) | 73. (C) | 74. (C) | 75. (D) | 76. (D) | 77. (C) | 78. (A) | 79. (A) | 80. (B) |
| 81. (B) | 82. (C) | 83. (D) | 84. (C) | 85. (C) | 86. (D) | 87. (A) | 88. (B) | 89. (B) | 90. (B) |
| 91. (B) | 92. (A) | 93. (B) | 94. (C) | 95. (B) | 96. (B) | 97. (B) | 98. (A) | 99. (A) | 100. (A) |
| 101. (D) | 102. (A) | 103. (B) | 104. (D) | 105. (B) | 106. (A) | 107. (D) | 108. (B) | 109. (A) | 110. (C) |
| 111. (B) | 112. (D) | 113. (D) | 114. (A) | 115. (A) | 116. (A) | 117. (A) | 118. (B) | 119. (C) | 120. (C) |
| 121. (A) | 122. (D) | 123. (B) | 124. (B) | 125. (B) | 126. (C) | 127. (C) | 128. (C) | 129. (B) | 130. (A) |
| 131. (A) | 132. (D) | 133. (D) | 134. (B) | 135. (A) | 136. (A) | 137. (D) | 138. (C) | 139. (B) | 140. (A) |
| 141. (C) | 142. (B) | 143. (C) | 144. (A) | 145. (D) | 146. (B) | 147. (C) | 148. (B) | 149. (B) | 150. (B) |
| 151. (B) | 152. (A) | 153. (A) | 154. (A) | 155. (D) | 156. (D) | 157. (B) | 158. (B) | 159. (C) | 160. (A) |
| 161. (A) | 162. (A) | 163. (A) | 164. (D) | 165. (A) | 166. (B) | 167. (A) | 168. (A) | 169. (C) | 170. (A) |
| 171. (D) | 172. (B) | 173. (C) | 174. (D) | 175. (B) | 176. (C) | 177. (A) | 178. (A) | 179. (A) | 180. (D) |
| 181. (C) | 182. (D) | 183. (B) | 184. (B) | 185. (C) | 186. (A) | 187. (D) | 188. (D) | 189. (A) | 190. (B) |
| 191. (A) | 192. (C) | 193. (A) | 194. (C) | 195. (B) | 196. (C) | 197. (A) | 198. (C) | 199. (C) | 200. (B) |
| 201. (C) | 202. (B) | 203. (C) | 204. (D) | 205. (D) | 206. (D) | 207. (B) | 208. (C) | 209. (B) | 210. (A) |
| 211. (B) | 212. (B) | 213. (A) | 214. (D) | 215. (D) | 216. (A) | 217. (A) | 218. (A) | 219. (C) | 220. (B) |
| 221. (D) | 222. (A) | 223. (A) | 224. (A) | 225. (D) | 226. (B) | 227. (B) | 228. (C) | 229. (C) | 230. (B) |
| 231. (B) | 232. (A) | 233. (C) | 234. (B) | 235. (C) | 236. (D) | 237. (A) | 238. (A) | 239. (B) | 240. (C) |
| 241. (C) | 242. (A) | 243. (B) | 244. (D) | 245. (C) | 246. (A) | 247. (D) | 248. (B) | 249. (B) | 250. (A) |
| 251. (C) | 252. (A) | 253. (C) | 254. (B) | 255. (D) | 256. (A) | 257. (D) | 258. (D) | 259. (B) | 260. (D) |
| 261. (A) | 262. (D) | | | | | | | | |

Hints to MCQs

1. In transition elements, the penultimate d-orbitals are partly filled.
5. There are four series of transition elements viz., 3d, 4d, 5d and 6d corresponding to the filling of 3d, 4d, 5d and 6d orbitals of penultimate shell.
6. All the transition (d-block) elements are metals.
7. Four different series of d-block elements are placed in periods 4, 5, 6 and 7.
8. s-block elements belong to groups 1 and 2. p-block elements belong to groups 13 to 18. d-block elements belong to groups 3 to 12.
10. Ag belongs to second (4d) transition series.
15. Observed electronic configuration of titanium is $1s^2 2s^2 2p^6 \underline{3s^2} 3p^6 4s^2 3d^2$
The 4s orbital is lower in energy compared to the 3d orbitals.
18. Since Zn, Cd and Hg have completely filled $(n - 1)d$ orbitals in their ground states as well as in the form of ions, they are excluded from transition series. Hence, among the given options, only Au is a transition element.
- 19.
- | Elements | Expected electronic configuration | Observed electronic configuration |
|-----------------|-----------------------------------|-----------------------------------|
| Cr ($Z = 24$) | $[Ar] 3d^4 4s^2$ | $[Ar] 3d^5 4s^1$ |
| Cu ($Z = 29$) | $[Ar] 3d^9 4s^2$ | $[Ar] 3d^{10} 4s^1$ |
21. Chromite ore is $FeCr_2O_4$ (or $FeO.Cr_2O_3$).
22. Copper is a good conductor of electricity, because it is a transition element and contains unpaired electron.
23. Most of the transition elements show variable valence (oxidation) states.
24. Transition elements form large number of coordination compounds (complexes).



25. Transition metals and their oxides have catalytic property.
26. Cr, Mo and W have maximum number of unpaired d-electrons which make them very hard due to increase in the number of covalent bonds.
27. Strength of metallic bond depends upon the number of unpaired d-electrons. As number of unpaired d-electrons increases, the bond strength increases. Thus, Cr shows strongest bonding due to maximum (i.e., 6) number of unpaired d-electrons.
28. The strength of metallic bonds depends upon the number of unpaired d-electrons. Greater the number of unpaired d-electrons, stronger is the metallic bonding. Chromium has maximum number of unpaired d-electrons. The number of unpaired d-electrons decreases from chromium (i.e. 6) to nickel (i.e., 2).
29. Zn has lowest boiling point due to the absence of unpaired electrons in d-orbital.
31. The first ionization energy of the first transition series elements increases with few irregularities, with the increase in the atomic number. It increases from Sc to Fe and then decreases from Fe to Ni and again increases from Ni to Zn.
32. $V = 1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$
 $Cr = 1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$
 $Mn = 1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$
 $Fe = 1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$
 $Cr^+ ([Ar] 3d^5)$ has exact half filled d-sub shell. It will be very difficult to remove an electron (second ionization) from $3d^5$ orbital. Thus Cr has the highest second ionization enthalpy.
33. $Mn^{2+} \Rightarrow 3d^5$; $Fe^{2+} \Rightarrow 3d^6$
Third ionisation enthalpy of Mn^{2+} is high because of its stable d^5 configuration.
34. Transition elements show variable oxidation states due to the incomplete filling of ($n-1$) d-orbitals and due to very little energy difference between ($n-1$) d and ns orbitals.
36. The transition element having the electronic configuration $3d^3 4s^2$ is Vanadium (V). Since it can lose electrons from both 4s as well as 3d orbitals, the possible oxidation states are +2, +3, +4 and +5.
38. Cr($Z = 24$) with electronic configuration $3d^5 4s^1$ has many (six) unpaired electrons and can thus form +1, +2, +3, +4, +5 and +6 oxidation states.
39. Mn has maximum number of unpaired electrons. Hence, it shows highest (+7) oxidation state.
40. Mn shows six oxidation states:
+2, +3, +4, +5, +6, +7
41. Number of electrons in $X^{+3} = 18 + 5 = 23$
Number of electrons in $X = 23 + 3 = 26$
42. $Ti(Z = 22) = 3d^2 4s^2$; $Ti^{2+} = 3d^2$
 $V(Z = 23) = 3d^3 4s^2$; $V^{3+} = 3d^2$
 $Cr(Z = 24) = 3d^5 4s^1$; $Cr^{4+} = 3d^2$
 $Mn(Z = 25) = 3d^5 4s^2$; $Mn^{5+} = 3d^2$
43. Ti ($Z = 22$) has electronic configuration $[Ar]3d^2 4s^2$
 Ti^{3+} has electronic configuration $[Ar]3d^1$
44. Cu^{2+} is $3d^9$ while Cu^+ is $3d^{10}$. Although Cu^+ is having completely filled (stable) d orbitals, it is less stable than Cu^{2+} . This is because, the negative hydration enthalpy ($\Delta_{hyd}H^\circ$) of $Cu^{2+}_{(aq)}$ is much larger than that of $Cu^+_{(aq)}$, which is much more than the high value of second ionization enthalpy of copper.
45. $\overset{x}{Mn}\overset{-2}{O}$
Oxidation state of Mn: $x - 2 = 0$
 $\therefore x = +2$
46. The element with 26 electrons is $Fe(3d^6 4s^2)$ and it contains 4 unpaired electrons.
47. $\overset{+1}{K}_2\overset{x}{Cr}_2\overset{-2}{O}_7$
Oxidation state of Cr :
 $(+1) \times 2 + 2x + (-2) \times 7 = 0$
 $2 + 2x - 14 = 0$
 $2x = 12$
 $x = +6$.
48. $Cr^+ : [Ar] 3d^5$
 $Mn^{2+} : [Ar] 3d^5$
 $Fe^{3+} : [Ar] 3d^5$
49. Atomic number of element = 22
Electronic configuration = $3d^2 4s^2$
Highest oxidation state = number of s-electrons + number of d-electrons = $2 + 2 = 4$



Oxidation state of V:

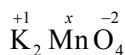
$$x + (-2) + (-1) \times 3 = 0$$

$$x - 2 - 3 = 0$$

$$x = +5$$

In VCl_4 , VCl_3 and VCl_2 , Vanadium exhibits oxidation state of +4, +3 and +2 respectively.

52. Oxidation state of Mn in potassium manganate (K_2MnO_4):



$$(1) \times 2 + x + (-2) \times 4 = 0$$

$$2 + x - 8 = 0$$

$$x = +6$$

56. Except iodide, all Cu (II) halides are well known, because Cu^{2+} oxidises I^- to I_2
- $$2\text{Cu}^{2+} + 4\text{I}^- \longrightarrow \text{Cu}_2^{+1} \text{I}_{2(s)} + \text{I}_2$$

57. The non-regular trend in the $E^\circ (\text{M}^{2+} / \text{M})$ values for the first row transition metals are due to the irregular variation in the sum of first and second ionization enthalpies.

58. Positive reduction potential value [$E^\circ(\text{M}^{2+}/\text{M})$] of copper is responsible for its inability to liberate H_2 from acids.

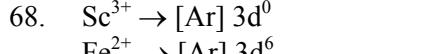
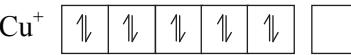
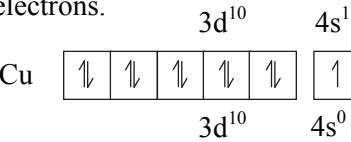
61. Towards the end of the series, there are electron-electron repulsions between the added electrons in the same orbital, which exceed the attractive forces due to increased nuclear charge. Therefore, electron cloud expands resulting in the increase in size.

62. Ionic radius decreases from left to right in a period. Ionic radii $\propto \frac{1}{\text{Atomic number}}$
Chromium has least atomic number. Hence, Cr^{3+} has highest ionic radius.

63. In general, from left to right along a period, metallic radii (i.e., volume) decreases with increase in atomic mass; therefore, density increases. Since copper has highest atomic mass, it has highest density.

66. Ni^{2+} and Cr^{3+} are coloured due to the presence of 2 and 3 unpaired electrons respectively. But Zn^{2+} is colourless because of absence of unpaired electrons.

67. $\text{Cu}^+ (3\text{d}^{10} 4\text{s}^0)$: does not contain unpaired electrons.



68. $\text{Sc}^{3+} \rightarrow [\text{Ar}] 3\text{d}^0$
 $\text{Fe}^{2+} \rightarrow [\text{Ar}] 3\text{d}^6$
 $\text{Ti}^{3+} \rightarrow [\text{Ar}] 3\text{d}^1$
 $\text{Mn}^{2+} \rightarrow [\text{Ar}] 3\text{d}^5$
 Due to absence of unpaired electrons, Sc^{3+} ion will be colourless.

69. Zinc (II) does not have any unpaired electron, so it forms only colourless compound.

70. In Ag_2SO_4 , Ag^+ : 4d¹⁰, no unpaired electrons, hence colourless.
 In CuF_2 , Cu^{2+} : 3d⁹, 1 unpaired electron, hence coloured.
 In ZnF_2 , Zn^{2+} : 3d¹⁰, no unpaired electrons, hence colourless.
 In Cu_2Cl_2 , Cu^+ : 3d¹⁰, no unpaired electrons, hence colourless.

73. Nature of ligands or Lewis bases attached to the metal ion affects the splitting of d-orbitals. This corresponds to ΔE , which in turn determines the d-d transitions and the corresponding colour of the compound.

74. Purple colour of KMnO_4 results from the transfer of an electron from oxygen (Ligand L) to Mn (Metal M).

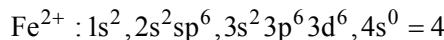
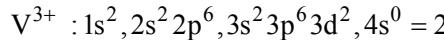
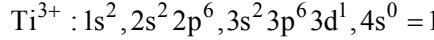
75. Due to variable oxidation states, transition metals can form unstable intermediates which then decomposes to form products with regeneration of catalyst.

76. When catalysts are finely divided, the surface area increases. This increases the adsorption capacity, which in turn increases the rate of the reaction.

81. In Fischer-Tropschin process (for the synthesis of gasoline), Co-Th alloy is used as a catalyst.

83. Paramagnetic character is due to presence of unpaired electrons.

86. Number of unpaired electrons in different ions:
 Sc^{3+} : $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^0 = 0$





87. $\text{Fe}^{3+} \rightarrow [\text{Ar}] 3d^5 4s^0$, number of unpaired electrons = 5
 $\text{Cr}^{2+} \rightarrow [\text{Ar}] 3d^4 4s^0$, number of unpaired electrons = 4
 $\text{Co}^{2+} \rightarrow [\text{Ar}] 3d^7 4s^0$, number of unpaired electrons = 3
 $\text{Co}^{3+} \rightarrow [\text{Ar}] 3d^6 4s^0$, number of unpaired electrons = 4
88. Cu^+ ($3d^{10}$) contains no unpaired electrons. Hence it is diamagnetic.
89. Ni^{2+} ($3d^8$) contains 2 unpaired electrons. Hence, it is paramagnetic.
90. Fe^{3+} has highest number of unpaired electrons, (i.e., 5) so it will be more paramagnetic.
91. Cu^{2+} ($3d^9$) contains lowest number of unpaired electrons (i.e., 1).
93. Cr^{+2} and Fe^{+2}
 Cr^{+2} ($3d^4$) : 4 unpaired electrons
 Fe^{+2} ($3d^6$) : 4 unpaired electrons
94. In this complex Co^{2+} ion have 3 unpaired electrons. So the spin only magnetic moment will be $\sqrt{3(3+2)}$ i.e., $\sqrt{15}$ B.M.
95. Cr^{3+} : $3d^3$
Spin only formula, $\mu = \sqrt{n(n+2)}$ B.M.
Here $n = 3$, $\therefore \mu = \sqrt{3(3+2)} = \sqrt{15} = 3.87$ B.M.
96. The magnetic moment $\mu = \sqrt{n(n+2)}$ BM
 $= 2.83$ BM
Where n = number of unpaired electrons
 $\therefore n(n+2) = (2.83)^2 \quad \therefore n = 2$

Ion	Outer electronic configuration	Number of unpaired electrons
Ti^{3+}	$3d^1$	1
Ni^{2+}	$3d^8$	2
Cr^{3+}	$3d^3$	3
Mn^{2+}	$3d^5$	5

97. $3d^5$ configuration contains maximum (5) unpaired electrons. Hence, it shows highest magnetic moment.
98. $\text{Sc}^{3+} \rightarrow [\text{Ar}] 3d^0$
Due to absence of unpaired electrons, it is diamagnetic.

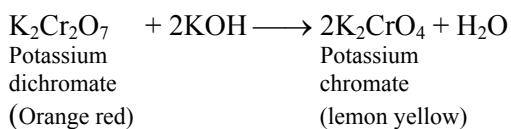
99. Magnetic moment = $\sqrt{n(n+2)}$
(where n = number of unpaired electrons)

Ion	Outer electronic configuration	Number of unpaired electrons	Calculated value of magnetic moment (in B.M.)
Fe^{3+}	$3d^5$	5	5.92
Cr^{3+}	$3d^3$	3	3.87
Ti^{3+}	$3d^1$	1	1.73
Co^{3+}	$3d^6$	4	4.90

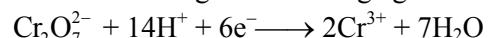
100. Mn^{2+} : $3d^5$ (5 unpaired electrons)
 Cu^{2+} : $3d^9$ (1 unpaired electron)
 Sc^{2+} : $3d^1$ (1 unpaired electron)
 Cu^+ : $3d^{10}$ (no unpaired electrons)
 Mn^{2+} has five unpaired electrons, therefore, it has maximum paramagnetic behaviour.
101. Defects in the crystal lattice of transition metals result in presence of vacant spaces which are also known as interstitial spaces. Small atoms are trapped inside these vacant spaces resulting in formation of interstitial compounds.
102. Interstitial compounds cannot be represented by definite composition and are usually non-stoichiometric.
103. The small H atoms occupy the vacant spaces in the lattice of Ti metal to form interstitial compound $\text{TiH}_{1.73}$.
104. The transition metals (such as Fe, Mn, Ni) form a large number of interstitial compounds in which small atoms like hydrogen, carbon, boron and nitrogen occupy interstitial sites in their lattices.
105. Due to large atomic size, Pb does not form interstitial compounds with transition elements.
109. Stainless steel is an alloy of iron with chromium, vanadium, molybdenum, tungsten and manganese.
114. Mn_2O_7 and CrO_3 are acidic oxides. CrO and V_2O_4 are basic oxides. V_2O_5 and Cr_2O_3 are amphoteric oxides.
116. Sodium chromate is converted to sodium dichromate by treatment with concentrated sulphuric acid.
 $2\text{Na}_2\text{CrO}_4 + \text{H}_2\text{SO}_4 \longrightarrow \text{Na}_2\text{Cr}_2\text{O}_7 + \text{Na}_2\text{SO}_4 + \text{H}_2\text{O}$.

119. Potassium dichromate, on heating gives potassium chromate, oxygen and chromic oxide (Cr_2O_3).

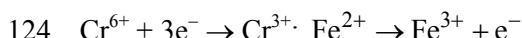
120. The conversion of dichromate to chromate:



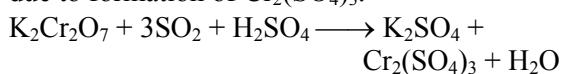
123. In acidic medium, Cr(VI) of potassium dichromate gains 3 electrons and is reduced to Cr(III) of chromium sulphate. Thus, potassium dichromate is a good oxidizing agent.



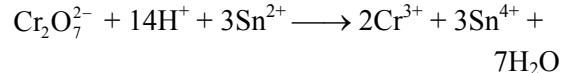
Thus, oxidation state of chromium changes by $(+6) - (+3) = 3$



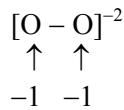
125. When SO_2 gas is passed through acidified $\text{K}_2\text{Cr}_2\text{O}_7$ solution, it is oxidized to sulphuric acid. Colour of the solution changes to green due to formation of $\text{Cr}_2(\text{SO}_4)_3$.



126. In acidic medium, $\text{K}_2\text{Cr}_2\text{O}_7$ changes Sn^{2+} to Sn^{4+} .

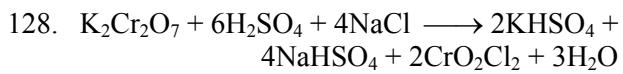
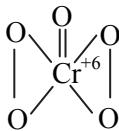


127. CrO_5 has two $(-\text{O}-\text{O}-)$ bonds.



∴ oxidation state of Cr in CrO_5 is $(-2) + (-2) + (-2) + x = 0$

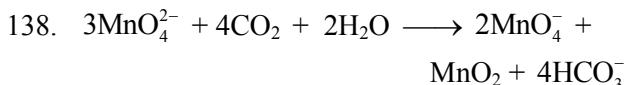
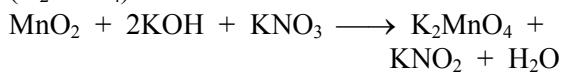
$$\therefore x = +6.$$



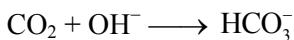
Chromyl
chloride

129. Chromate ion has tetrahedral structure. Cr atom is at centre and four oxygen atoms are at four corners of a tetrahedron.

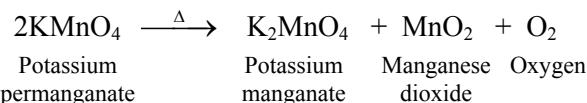
135. When MnO_2 is fused with KOH and KNO_3 , green coloured potassium manganate (K_2MnO_4) is formed.



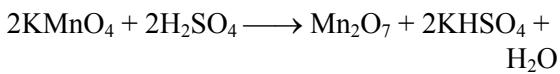
The OH^- ions formed, react with CO_2 to form HCO_3^- ions.



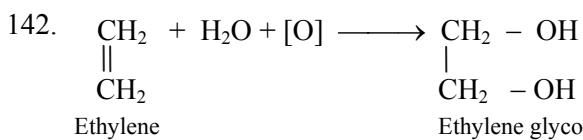
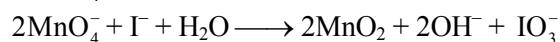
139. When heated to 473 K, potassium permanganate decomposes to give K_2MnO_4 , MnO_2 and O_2 .



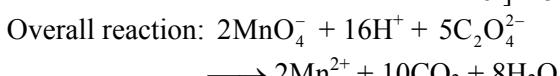
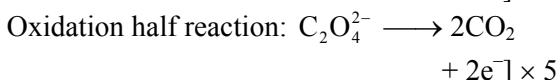
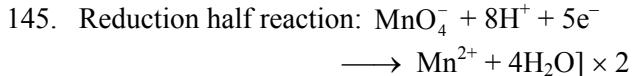
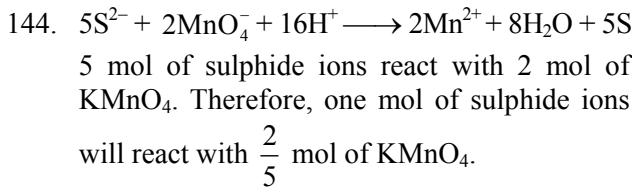
140. KMnO_4 is converted to Mn_2O_7 (an explosive green oil) upon reaction with cold and conc. H_2SO_4 .



141. KMnO_4 oxidizes iodides to iodates.

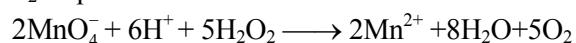


In this reaction, $\text{Fe}(\text{SO}_4)$ is oxidized to $\text{Fe}_2(\text{SO}_4)_3$, while KMnO_4 is reduced to MnSO_4 .



Mn^{2+} acts as autocatalyst and decolourisation becomes instantaneous.

146. In acidic medium, KMnO_4 oxidizes hydrogen peroxide. Thus, this reaction gives Mn^{2+} and O_2 as products.





147. (A) Oxalate ion: $2\text{MnO}_4^- + 5\text{C}_2\text{O}_4^{2-} + 16\text{H}^+ \longrightarrow 2\text{Mn}^{2+} + 8\text{H}_2\text{O} + 10\text{CO}_2$
2 moles of KMnO_4 oxidizes 5 moles FeC_2O_4 .
- (B) Nitrite ion: $2\text{MnO}_4^- + 5\text{NO}_2^- + 6\text{H}^+ \longrightarrow 2\text{Mn}^{2+} + 5\text{NO}_3^- + 3\text{H}_2\text{O}$
2 moles of KMnO_4 oxidizes 5 moles of $\text{Fe}(\text{NO}_2)_2$.
- (C) Ferrous ion: $2\text{MnO}_4^- + 10\text{Fe}^{2+} + 16\text{H}^+ \longrightarrow 2\text{Mn}^{2+} + 10\text{Fe}^{3+} + 8\text{H}_2\text{O}$
1 mole of KMnO_4 oxidizes 5 moles of FeSO_4 .
- (D) Sulphite ion: $2\text{MnO}_4^- + 5\text{SO}_3^{2-} + 6\text{H}^+ \longrightarrow 2\text{Mn}^{2+} + 5\text{SO}_4^{2-} + 3\text{H}_2\text{O}$
2 moles of KMnO_4 oxidizes 5 moles of FeSO_3 . Therefore, among these, FeSO_4 requires least amount of acidified KMnO_4 for complete oxidation.
151. MnO_4^{2-} (Mn^{+6}) ion contains one unpaired electron due to which it is paramagnetic.
152. Permanganate ion has tetrahedral structure. Mn is at the centre and the four oxygen atoms are at four corners of a regular tetrahedron. Mn(VII) has d^0 configuration. Hence, it is diamagnetic. Purple colour is due to charge transfer.
153. Alkaline potassium permanganate is used for testing unsaturation in organic compounds and is known as Baeyer's reagent.
155. KMnO_4 is dark purple coloured crystalline substance.
158. Lanthanoids are placed in group 3 of periodic table between lanthanum ($Z = 57$) and hafnium ($Z = 72$)
162. La ($Z = 57$) : $[\text{Xe}] 4f^0 5d^1 6s^2$
Gd ($Z = 64$) : $[\text{Xe}] 4f^7 5d^1 6s^2$
Lu ($Z = 71$) : $[\text{Xe}] 4f^{14} 5d^1 6s^2$
163. Lanthanoid hydroxides are stronger base than Al(OH)_3 and weaker than Ca(OH)_2 . Basicity decreases from La(OH)_3 to Lu(OH)_3 as the ionic size decreases from La^{3+} to Lu^{3+} . Thus they follow the order $\text{Al(OH)}_3 < \text{Lu(OH)}_3 < \text{Ce(OH)}_3 < \text{Ca(OH)}_2$.
164. Yb^{2+} has an electronic configuration of $[\text{Xe}] 4f^{14}$. Since there is absence of unpaired electron, it is diamagnetic in nature.

165. $\text{Lu}^{3+} \rightarrow [\text{Xe}] 4f^{14} 5d^0 6s^0$
 $\text{Ce}^{3+} \rightarrow [\text{Xe}] 4f^1 5d^0 6s^0$
 $\text{Eu}^{3+} \rightarrow [\text{Xe}] 4f^6 5d^0 6s^0$
 $\text{Yb}^{3+} \rightarrow [\text{Xe}] 4f^{13} 5d^0 6s^0$
 Lu^{3+} does not have any unpaired electron and hence, it is not paramagnetic.
168. Eu^{2+} : $[\text{Xe}] 4f^7$
 Yb^{2+} : $[\text{Xe}] 4f^{14}$
170. The observed electronic configuration of Ce is $[\text{Xe}] 4f^2 5d^0 6s^2$. Therefore, the electronic configuration of Ce^{3+} ion is $[\text{Xe}] 4f^1$.
171. The observed electronic configuration of Gd is $[\text{Xe}] 4f^7 5d^1 6s^2$. Therefore, the electronic configuration of Gd^{2+} ion is $[\text{Xe}] 4f^7 5d^1$.
172. Lanthanoids react with carbon to form lanthanoid carbides.
 $\text{Ln} + \text{C} \xrightarrow{2500^\circ\text{C}} \text{Lanthanoid carbides}$
173. $2\text{Ln} + 6\text{HCl} \longrightarrow 2\text{LnCl}_3 + 3\text{H}_2 \uparrow$
176. Due to lanthanoid contraction, the atomic size decrease with increase in atomic number.
177. Due to poor shielding of 4-f electrons, increased effective nuclear charge is experienced and the valence shell is pulled slightly towards nucleus thereby resulting in the lanthanoid contraction.
178. Yb^{+3} ($Z = 70$) $<$ Pm^{+3} ($Z = 61$) $<$ Ce^{+3} ($Z = 58$) $<$ La^{+3} ($Z = 57$). Atomic number decreases from Yb to La. Hence ionic radii increases from Yb^{+3} to La^{+3} . Due to lanthanoid contraction, the ionic radii of lanthanoids decrease with increase in atomic number.
179. According to Fajan's principle, larger the size of cation, greater is the tendency of hydroxides to dissociate and stronger will be the base.
180. The size of Ln^{3+} cation decreases with increase in the atomic number, due to lanthanoid contraction. Thus, La(OH)_3 is most basic and Lu(OH)_3 is least basic
181. Lanthanoid contraction results in similar atomic radii for Zr and Hf. Therefore, they show similar physical and chemical properties.
189. The expected electronic configuration of actinium ($Z = 89$) is $[\text{Rn}] 5f^0 6d^1 7s^2$. There is no electron in 5f shell. For actinium, the expected and observed electronic configurations are same.

193. Lanthanoids cannot form oxocations whereas actinoids form oxo cations such as UO_2^{2+} , PuO^{2+} , UO^+ .
194. Reason is due to the poor shielding of 5f electrons, in actinoids.
197. The outer electronic configuration of elements belonging to group 5 is $(n-1)d^3ns^2$. Hence, the atom with electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$ will be placed in group 5.
199. The element belongs to d-block, as the last electron enters in d-orbital.
201. The expected electronic configuration of Ag ($Z = 47$) is $[\text{Kr}] 4d^9 5s^2$. The observed electronic configuration of Ag is $[\text{Kr}] 4d^{10} 5s^1$.
202. Fe^{2+} ($Z = 26$) : $1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^6$, number of d-electrons = 6
 Mg ($Z = 12$) : $1s^2 2s^2 2p^6 3s^2$, total number of s-electrons = 6
 Cl ($Z = 17$) : $1s^2 2s^2 2p^6 3s^2 3p^5$, total number of p-electrons = 11
 Fe ($Z = 26$) : $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$, number of d-electrons = 6
 Ne ($Z = 10$) : $1s^2 2s^2 2p^6$, number of p-electrons = 6
203. The hardness of transition elements is due to the presence of covalent bonds. As the number of covalent bonds increases, hardness of transition metals increases.
204. Transition metals show variable oxidation states and catalytic properties. They have high melting and boiling points. Some of the ions are colourless and other ions are coloured.
208. Zn shows only +2 valency.
209. Hg has no unpaired electrons. Thus, the melting point and boiling point are low. Hg is therefore, liquid at room temperature with a m.p. of 234 K.
210. The transition metal with +2 to +7 oxidation states belongs to 7 group as the metal must contain 7 electrons in $(n-1)d$ and ns shell in order to show +7 oxidation state.
211. The electronic configuration of Fe ($Z = 26$) is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$. It loses two valence electrons to form Fe^{2+} with electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$.
212. The electronic configuration of Fe ($Z = 26$) is $[\text{Ar}] 3d^6 4s^2$. It loses three valence electrons to form Fe^{3+} with electronic configuration $[\text{Ar}] 3d^5$.
213. Number of electrons in excited state $X^{+3} = 18 + 4 = 22$
Number of electrons in ground state $X = 22 + 3 = 25$.
214.

1	1	1	1	1
---	---	---	---	---

 \uparrow
 $(n-1)d$
 ns
 $(n-1)d^5 ns^2$ can achieve the maximum oxidation state of +7 as it has maximum number (7) of unpaired 3d electrons.
215. Fe represents more than one oxidation state as it belongs to the transition series. Fe exhibits +2, +3, +4, +5 and +6 oxidation states while Al, Na and Mg exhibit +3, +1 and +2 oxidation states respectively.
216.

					$3d^5$	$4s^2$
Mn	1	1	1	1	1	\uparrow

 Mn^{+2}

1	1	1	1	1	
---	---	---	---	---	--

Half filled orbitals are more stable than partially filled ones. Therefore, +2 is the most stable oxidation state.
 $3d^5$ $4s^0$
 Mn^{+3}

1	1	1	1	1	
---	---	---	---	---	--
217. Applying the oxidation number rule in $[\text{Fe}(\text{H}_2\text{O})_5(\text{NO})]\text{SO}_4$
 $[x + (0) \times 5 + 0] + (-2) = 0$ ($\because \text{H}_2\text{O}$ and NO are neutral)
 $x + 0 + 0 - 2 = 0 \therefore x = +2$
Hence, oxidation number of Fe is +2.
218. With the increase in the d-electrons, screening effect increases, this counter balances the increased nuclear charge due to increase in atomic number. As a result, atomic radii remain practically same after chromium.
219. Due to lanthanoid contraction, Zr and Hf possess similar properties. This is due to similar number of valence electrons, atomic radii and almost same size of these elements. Thus, they are also called 'chemical twins'.
220. Na_2CdCl_4 does not contain any unpaired electrons.
 $4d^{10}$ $5s^0$
 Cd^{2+}

\uparrow	\uparrow	\uparrow	\uparrow	\uparrow	
------------	------------	------------	------------	------------	--



221. $\text{Sc} \longrightarrow [\text{Ar}]3\text{d}^14\text{s}^2$
 $\text{Sc}^{3+} \longrightarrow [\text{Ar}]3\text{d}^0$
 Due to absence of unpaired electrons, compounds of Sc^{3+} are colourless.
222. ${}_{21}\text{Sc} = [\text{Ar}]3\text{d}^14\text{s}^2$; $\text{Sc}^{3+} = [\text{Ar}]3\text{d}^04\text{s}^0$. Since there are no unpaired electrons in d subshell, it is diamagnetic and colourless.
226. Transition elements show multiple oxidation states due to availability of vacant d-orbitals. They are coloured due to d-d transition.
227. Transition metallic carbides are chemically inert.
230. $x - 1$
 $\text{CrCl}_3 : x + 3(-1) = 0 \Rightarrow x = 3$
 $\text{Cr} : [\text{Ar}]3\text{d}^54\text{s}^1$
 $\text{Cr}^{3+} : [\text{Ar}]3\text{d}^34\text{s}^0$
 Cr^{3+} contains three unpaired electrons. Hence, CrCl_3 will be coloured.
231. Complex forming tendency increase with decrease in size of cation.
233. As energy difference between 3d and 4s is small, both these electrons are involved in bonding. The oxidation state is determined by the number of electrons evolved.
234. Element: Ti > V > Cr
 Atomic radii (pm) $132 > 122 > 118$.
235. V^{3+} is coloured ion, due to the presence of two unpaired electrons (d^2). Zn^{2+} (d^{10}) and Sc^{3+} (d^0) are colourless due to the absence of unpaired d-electrons. Na^+ is ion of s-block element and it does not have d-orbitals.
237. K_2MnO_4
 $+1 \times -2$
 Oxidation number of manganese in $\text{K}_2\text{MnO}_4 = 2(+1) + x + 4(-2) = 0$
 $2 + x - 8 = 0$
 $x = 6$
 KMnO_4
 $+1 \times -2$
 Oxidation number of manganese in $\text{KMnO}_4 = 1 + x + 4(-2) = 0$
 $1 + x - 8 = 0$
 $x = 7$
239. $2 \text{Mn}^{+7}\text{O}_4^- + \text{Br}^- + \text{H}_2\text{O} \longrightarrow 2 \text{Mn}^{+4}\text{O}_2 + \text{BrO}_3^- + 2\text{OH}^-$
 Since conversion of Mn(VII) to Mn (IV) involves addition of 3 electrons,
 Equivalent weight of $\text{KMnO}_4 = \frac{\text{M}}{3}$
240. For $n = 4$ and $x = 5$, the outermost and penultimate shell electronic configuration will be $3s^23p^63d^54s^2$. This represents manganese with atomic number 25 and electronic configuration $1s^22s^22p^63s^23p^63d^54s^2$. Hence it contains 25 electrons around the nucleus.
241. The oxidation state of Mn in KMnO_4 is +7.
242. Manganese is a stronger oxidising agent in its +7 oxidising state. e.g. KMnO_4
243. $5\text{SO}_3^{2-} + 2\text{MnO}_4^- + 6\text{H}^+ \longrightarrow 2\text{Mn}^{2+} + 3\text{H}_2\text{O} + 5\text{SO}_4^{2-}$
 5 mol of sulphite ions react with 2 mol of KMnO_4 . Therefore, one mol of sulphite ions will react with $\frac{2}{5}$ mol of KMnO_4 .
244. ${}_{25}\text{Mn} = 3\text{d}^54\text{s}^2$
 After losing two electrons, electronic configuration of Mn^{2+} will be 3d^5 and this is the most stable configuration due to half filled orbitals. Hence, third ionization enthalpy will be highest in this case.
245. The observed electronic configuration of lanthanum is $[\text{Xe}]4f^05d^16s^2$. It loses three electrons to form La^{+3} with +3 oxidation state. To form +4 oxidation state, one electron from noble gas configuration of [Xe] should be removed which will disturb the stable noble gas configuration. Hence, La does not show +4 oxidation state.
246. $\text{Ni} : 1s^22s^22p^63s^23p^63d^84s^2$
 $\text{Ni}^{2+} : 1s^22s^22p^63s^23p^63d^8$

1l	1l	1l	1	1
----	----	----	---	---

 3d^8
 $\therefore 2$ unpaired electrons

248. Fe^{+2} : $3d^6 4s^0$ (4 unpaired electrons)
250. Mn^{+2} : $3d^5$; 5 unpaired electrons are present in d-subshell, so it has highest paramagnetic character.
251. Fe^{+3} has maximum number of unpaired electrons. Magnetic moment depends on the number of unpaired electrons.

	Outer configuration	No. of unpaired electrons
V^{+3}	$3d^2$	2
Mn^{+3}	$3d^4$	4
Fe^{+3}	$3d^5$	5
Cu^{+2}	$3d^9$	1

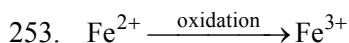
- 252.
- | Ion | Outer electronic configuration | Number of unpaired electrons |
|------------------|---------------------------------------|-------------------------------------|
| Ni^{2+} | $3d^8$ | 2 |
| Ti^{3+} | $3d^1$ | 1 |
| Cr^{2+} | $3d^4$ | 4 |
| Co^{2+} | $3d^7$ | 3 |

The magnetic moment $\mu = \sqrt{n(n + 2)}$ B.M.,

Where n = number of unpaired electrons.

When n = 2; $\mu = \sqrt{2(2 + 2)} = \sqrt{8} = 2.84$ B.M.

∴ Magnetic moment 2.84 B.M. is given by Ni^{2+} .



254. d-orbital is complete in Zn ($3d^{10} 4s^2$).

255. Europium is a f-block element as it follows the general electronic configuration of the f-block elements ($4f^{1-14} 5d^{0,1} 6s^2$). Electronic configuration of Eu = $[\text{Xe}]4f^7 5d^0 6s^2$

256. (B) The extent of actinoid contraction is greater than lanthanoid contraction. This is due to lesser shielding of 5f-electrons in actinoids as compared to the shielding of 4f-electrons in lanthanoids.
- (C) In general, both lanthanoids and actinoids show variable oxidation states.
- (D) Ce exhibits +4 oxidation state. Ce^{4+} is a good oxidising agent.

257. Ce has configuration $[\text{Xe}]4f^2 5d^0 6s^2$ Since, its last electron enters in f- sub-shell, it is a member of f-block.
259. Ce-lanthanide, Cs-alkali metal, Pu-actinide, Ca-alkaline earth metal.
260. In (a), Cu^+ undergoes oxidation as well as reduction. In (d), MnO_4^- undergoes reduction and Mn^{2+} undergo oxidation to form MnO_2 .
261. The oxides of lanthanoids (Ln_2O_3) react with water to form corresponding hydroxides $[\text{Ln}(\text{OH})_3]$, which are basic in nature. The basicity of these hydroxides decreases from $\text{La}(\text{OH})_3$ to $\text{Lu}(\text{OH})_3$. Therefore, among the given options, La_2O_3 has the maximum basicity.
262. In general, the earlier members of lanthanoids have reactivity similar to calcium but, with increasing atomic number, their reactivity is similar to aluminium.



Topic Test

1. Which of the following is coloured?
 (A) ScCl_3 (B) TiO_2
 (C) MnSO_4 (D) ZnSO_4
2. What is the oxidation state of chromium in the product formed, when H_2S gas is passed through acidified potassium dichromate solution?
 (A) +2 (B) +3
 (C) +4 (D) +6
3. The highest paramagnetic character is shown by the transition metal ion with the outer electronic configuration _____.
 (A) $3d^2$ (B) $3d^5$
 (C) $3d^8$ (D) $3d^9$
4. Which of the following is NOT an actinoid?
 (A) Curium (B) Thorium
 (C) Uranium (D) Terbium
5. $\text{Ln} \xrightarrow{\text{O}_2/\Delta} \text{A} \xrightarrow{\text{CO}_2} \text{B}$
 Identify A and B.
 (A) A = Ln(OH)_3 , B = $\text{Ln}_2(\text{CO}_3)_3$
 (B) A = Ln_2O_3 , B = Ln_2C_3
 (C) A = Ln(OH)_3 , B = Ln_2O_3
 (D) A = Ln_2O_3 , B = $\text{Ln}_2(\text{CO}_3)_3$
6. The size is similar for following pairs of elements EXCEPT _____.
 (A) Zr-Hf (B) Nb-Ta
 (C) Mo-W (D) Sc-Y
7. The magnetic moment of Fe^{3+} ion is _____.
 (A) 5.92 B.M.
 (B) 5.49 B.M.
 (C) 2.32 B.M.
 (D) 4.9 B.M.
8. Identify the products A and B in the following reaction:
 Chromite ore $\xrightarrow[\text{in presence of air}]{\text{Fused with Na}_2\text{CO}_3/\text{Limestone}} \text{A} + \text{B} + \text{carbon dioxide}$
 (A) NaCl and Fe_2O_3
 (B) $\text{Na}_2\text{Cr}_2\text{O}_7$ and FeO
 (C) Na_2CrO_4 and Fe_2O_3
 (D) $\text{Na}_2\text{Cr}_2\text{O}_7$ and Fe_2O_3
9. Which of the following pair of ions are isoelectronic?
 (A) $\text{Mn}^{3+}, \text{Cr}^{2+}$
 (B) $\text{Cr}^+, \text{Fe}^{2+}$
 (C) $\text{Mn}^{3+}, \text{Cr}^+$
 (D) $\text{Cr}^{2+}, \text{Mn}^{2+}$
10. Which of the following ions is expected to have least magnetic moment?
 (A) Cu^{+2} (B) Ni^{+2}
 (C) Co^{+3} (D) Ti^{+2}
11. The catalytic activity of transition metals are due to their _____.
 (A) Variable oxidation states
 (B) High enthalpy of atomization
 (C) Paramagnetic behaviour
 (D) Colour of hydrated ions
12. In the first transition series, the highest melting point and boiling point is shown by _____.
 (A) Cr (B) V
 (C) Ni (D) Fe
13. The second ionization enthalpy of chromium is exceptionally high, because _____.
 (A) of its high magnetic moment
 (B) of its variable oxidation state
 (C) of its stable electronic configuration
 (D) of its oxidizing nature
14. What is the valence shell electronic configuration of Cr^{2+} ?
 (A) $4s^0 3d^4$ (B) $4s^2 3d^2$
 (C) $4s^0 3d^5$ (D) $3p^6 4s^2$
15. Which of the following is NOT true for acidified potassium permanganate solution?
 (A) It oxidizes nitrites to nitrates.
 (B) It oxidizes hydrochloric acid to chlorine.
 (C) It oxidizes oxalates to carbon dioxide.
 (D) It oxidizes iodides to iodates.
16. Which of the following transition elements has the maximum density?
 (A) Ti (B) Cu
 (C) Mn (D) Fe
17. Which one is NOT the property of interstitial compounds?
 (A) Hardness
 (B) Luster
 (C) Electrical and thermal conductivity.
 (D) Higher densities compared to parent metals.

18. Match the following:

	Column I		Column II
i.	KMnO ₄	a.	Tanning of leather
ii.	K ₂ Cr ₂ O ₇	b.	Contact process
iii.	MnO ₂	c.	Baeyer's reagent
iv.	V ₂ O ₅	d.	Decomposition of KClO ₃ to O ₂

- (A) (i) – (a), (ii) – (c), (iii) – (b), (iv) – (d)
(B) (i) – (b), (ii) – (d), (iii) – (c), (iv) – (a)
(C) (i) – (c), (ii) – (a), (iii) – (d), (iv) – (b)
(D) (i) – (d), (ii) – (b), (iii) – (a), (iv) – (c)

19. The observed electronic configuration of mendelevium ($Z = 101$) is _____.

- (A) [Rn] 5f¹² 6d¹ 7s²
(B) [Rn] 5f¹³ 6d⁰ 7s²
(C) [Rn] 5f¹¹ 6d¹ 7s²
(D) [Rn] 5f¹² 6d⁰ 7s²

20. The chemical reactivity of earlier members of lanthanoid series is similar to that of _____. This behaviour changes to that of _____ as the atomic number increases.

- (A) calcium, aluminum
(B) aluminum, calcium
(C) chromium, copper
(D) copper, chromium



Answers to Topic Test

1. (C) 2. (B) 3. (B) 4. (D)
5. (D) 6. (D) 7. (A) 8. (C)
9. (A) 10. (A) 11. (A) 12. (A)
13. (C) 14. (A) 15. (D) 16. (B)
17. (D) 18. (C) 19. (B) 20. (A)