Term-II

'd' AND 'f' BLOCK ELEMENTS

Syllabus

- ***General introduction, electronic configuration, occurrence and characteristics of transition metals, general trends in properties of the first row transition metals – metallic character, ionization enthalpy, oxidation states, ionic radii, colour, catalytic property, magnetic properties, interstitial compounds, alloy formation.***
- ***Lanthanoids - Electronic configuration, oxidation states and lanthanoid contraction and its consequences.***

STAND ALONE MCQs [1 Mark each]

Q. 1. Electronic configuration of a transition element X in +3 oxidation state is $[Ar]3d^5$. What is its atomic number?

(A) 25 **(B)** 26

(C) 27 **(D)** 24

Ans. Option (B) is correct.

Explanation: It is formed by the loss of 3 electrons, the configuration of element *X* is $[Ar]\ 3d^6 4s^2$. Therefore, Atomic number = 26.

AI **Q. 2.** The electronic configuration of Cu(II) is $3d^9$ whereas that of Cu(I) is $3d^{10}$. Which of the following is correct?

(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. U

Ans. Option (A) is correct.

Explanation: Cu(II) is more stable due to nuclear charge of Cu.

Q. 3. When $KMnO_4$ solution is added to oxalic acid solution, the decolourisation is slow in the beginning but becomes instantaneous after some time because

(A) CO_2 is formed as the product.

(B) Reaction is exothermic.

(C) MnO_4^- catalyses the reaction.

(D) Mn^{2+} acts as auto-catalyst. A&E

Ans. Option (D) is correct.

Explanation: When $KMnO_4$ solution is added to oxalic acid solution, the decolourisation is slow in the beginning but becomes instantaneous after sometime because Mn^{2+} acts as an auto-catalyst.

Reduction half-reaction:

$[MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O] \times 2$

Oxidation half-reaction:

$[C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-] \times 5$

Overall equation:

$2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$

End point of this reaction : Colourless to light pink.

Q. 4. The oxidation state of Ni in $[Ni(CO)_4]$ is

(A) 0 **(B)** 2

(C) 3 **(D)** 4

U **[CBSE Delhi Set-I 2020]**

Ans. Option (A) is correct.

Explanation: Let oxidation state of Ni = x

$x + 0 = 0$ (CO is neutral ligand)

$x = 0$

AI **Q. 5.** Which of the following is the reason for Zinc not exhibiting variable oxidation state ?

(A) inert pair effect
(B) completely filled 3d subshell
(C) completely filled 4s subshell
(D) common ion effect

Ans. Option (B) is correct.

Explanation: Zinc does not exhibit a variable oxidation state as it has completely filled 3d subshell.
Zn — [Ar] $3d^{10}$ $4s^2$ (Atomic number 30)

Q. 6. Which of the following is a diamagnetic ion ? (Atomic numbers of Sc, V, Mn and Cu are 21, 23, 25 and 29 respectively)

(A) V^{2+} **(B)** Sc^{3+}
(C) Cu^{2+} **(D)** Mn^{3+}

Ans. Option (B) is correct.

Explanation: Sc^{3+} is a diamagnetic ion. Atomic number is 21.
$[Ar]3d^0$ is Sc^{3+} electronic configuration. Since its d subshell is empty it is diamagnetic as it has noble gas configuration.

AI **Q. 7.** Which set of ions exhibit specific colours? (Atomic number of Sc = 21, Ti = 22, V=23, Mn = 25, Fe = 26, Ni = 28 Cu = 29 and Zn =30)

(A) Sc^{3+}, Ti^{4+}, Mn^{3+} **(B)** Sc^{3+}, Zn^{2+}, Ni^{2+}
(C) V^{3+}, V^{2+}, Fe^{3+} **(D)** Ti^{3+}, Ti^{4+}, Ni^{2+}

A&E **[CBSE SQP 2021]**

Ans. Option (C) is correct.

Explanation: V^{3+}, V^{2+}, Fe^{3+} ions exhibit specific colours.
Atomic number of V = 23,
Electronic configuration of V - [Ar]$3d^3$ $4s^2$
Electronic configuration of V^{2+} - [Ar]$3d^3$
Electronic configuration of V^{3+} - [Ar] $3d^2$
Atomic number of Fe = 26
Electronic configuration of Fe - [Ar]$3d^6$ $4s^2$
Electronic configuration of Fe^{3+} - [Ar]$3d^5$
Since these ions have partially filled d- subshells, they exhibit colour. Most transition-metal ions have a partially filled d subshell.
As for other ions,
Atomic number of Sc = 21
Electronic configuration of Sc - [Ar]$3d^1$ $4s^2$
Electronic configuration of Sc^{3+} - [Ar]$3d^0$
Since d subshell is empty, it shows no colour.
Atomic number of Ti = 22
Electronic configuration of Ti- [Ar]$3d^2$ $4s^2$
Electronic configuration of Ti^{4+} - [Ar]$3d^0$
Since d subshell is empty, it shows no colour.
Atomic number of Mn =25
Electronic configuration of Mn- [Ar]$3d^5$ $4s^2$
Electronic configuration of Mn^{2+} [Ar]$3d^5$
Since d subshell is partially filled, it shows colour.

Atomic number of Ni = 28
Electronic configuration of Ni- [Ar]$3d^8$ $4s^2$
Electronic configuration of Ni^{2+} [Ar]$3d^8$
Since d subshell is partially filled, it shows colour.
Atomic number of Zn =30
Electronic configuration of Zn- [Ar]$3d^{10}$ $4s^2$
Electronic configuration of Zn^{2+}- [Ar]$3d^{10}$
Since d subshell is full, it shows no colour.

Q. 8. Which of the following oxidation state is common for all lanthanoids?

(A) +2 **(B)** +3
(C) +4 **(D)** +5

Ans. Option (B) is correct.

Explanation: Most common oxidation state for lanthanoids is +3.

Q. 9. There are 14 elements in actinoid series. Which of the following element does not belong to this series?

(A) U **(B)** Np
(C) Tm **(D)** Fm

Ans. Option (C) is correct.

Explanation: Tm (Thulium) is a lanthanoid.

Q. 10. Gadolinium belongs to *4f* series. Its atomic number is 64. Which of the following is the correct electronic configuration of Gadolinium?

(A) [Xe] $4f^7 5d^1 6s^2$ **(B)** [Xe] $4f^6 5d^2 6s^2$
(C) [Xe] $4f^8 6d^2$ **(D)** [Xe] $4f^9 5s^1$

Ans. Option (A) is correct.

Explanation: 64Gd : [Xe] $4f^7$ $5d^1$ $6s^2$

AI **Q. 11.** 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?

(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.

Ans. Option (D) is correct.

Explanation: Interstitial compounds are chemically inert.

AI **Q. 12.** Which of the following statements is not correct?

(A) La is actually transition element.
(B) In Lanthanide series, Ionic radii decrease from La^{3+} to Lu^{3+}.
(C) $La(OH)_3$ is less basic than $Lu(OH)_3$
(D) Ionic radii of Zr and Hf are almost similar due to Lanthanoid contraction. U

Ans. Option (C) is correct.

Explanation: $La(OH)_3$ is more basic than $Lu(OH)_3$. It is because of the fact that
Due to lanthanoid contraction the size of lanthanoid ion decreases regularly with increase in atomic size. Thus covalent character between lanthanoid ion and OH^- increases from La^{3+} to Lu^{3+}. Thus the basic character of hydroxides decreases from $La(OH)_3$ to $Lu(OH)_3$.

AI **Q. 13.** Lanthanoid contraction is caused due to
(A) Atomic number
(B) Size of 4f orbitals
(C) Effective nuclear charge
(D) Poor shielding effect of 4f electrons R

Ans. Option (D) is correct.

Explanation: The lanthanoid contraction is due to poor shielding effect of 4f electrons.

Q. 14. In which of the following elements, 5f orbitals are progressively filled?
(a) Alkaline earth metals
(b) Actinoids
(c) Lanthanoids
(d) Transition elements R

Ans. Option (B) is correct.

Explanation: Actinoids are 5f block elements so in actinoids, 5f orbitals are progressively filled.

ASSERTION AND REASON BASED MCQs [1 Mark each]

Directions: In the following questions, A statement of Assertion (A) is followed by a statement of Reason (R). Mark the correct choice as.
(A) Both A and R are true and R is the correct explanation of A.
(B) Both A and R are true but R is NOT the correct explanation of A.
(C) A is true but R is false.
(D) A is false and R is True.

Q. 1. Assertion (A): Cu^{2+} iodide is not known.
Reason (R): Cu^{2+} oxidises I^- to iodine. R

Ans. Option (A) is correct.

Explanation: Cu^{2+} oxidises iodide to iodine hence cupric iodide is converted to cuprous iodide.

Q. 2. Assertion (A): The highest oxidation state of osmium is +8.
Reason (R): Osmium is a 5d-block element. R

Ans. Option (B) is correct.

Explanation: The highest oxidation state of osmium (Os) is +8. It is due to its ability to expand octet by using its all 8 electrons.

AI **Q. 3. Assertion (A):** Separation of Zr and Hf is difficult.
Reason (R): Because Zr and Hf lie in the same group of the periodic table. R

Ans. Option (B) is correct.

Explanation: Separation of Zr and Hf is difficult as both have same size.

Q. 4. Assertion (A): Cu cannot liberate hydrogen from acids.
Reason (R): Because it has positive electrode potential. R

Ans. Option (A) is correct.

Explanation: Copper (Cu) does not liberate hydrogen from acids due to the presence of positive electrode potential.

AI **Q. 5. Assertion (A):** Transition metals have low melting points.
Reason (R): The involvement of greater number of $(n-1)d$ and ns electrons in the interatomic metallic bonding. U **[CBSE O.D. Set-I, 2020]**

Ans. Option (D) is correct.

Explanation: Transition metals have high melting points because of the involvement of greater number of $(n-1)d$ and ns electrons in the interatomic metallic bonding.

Q. 6. Assertion (A): Transition metals have high melting point.
Reason (R): Transition metals have completely filled d-orbitals. U **[CBSE O.D. Set-II, 2020]**

Ans. Option (C) is correct.

Explanation: Transition metals have high melting points because of the involvement of greater number of $(n-1)d$ and ns electrons in the interatomic metallic bonding.

AI **Q. 7. Assertion:** Separation of Zr and Hf is difficult.
Reason: Because Zr and Hf lie in the same group of the periodic table.

Ans. Option (B) is correct.

Explanation: Separation of Zr and Hf is difficult as both have same size.

Q. 8. Assertion (A): Chromium is an actinoid.
Reason (R): In Chromium, 3d orbitals are filled. U

Ans. Option (D) is correct.

Explanation: Chromium is a transition element and it belongs to 3d series because in chromium, 3d orbitals are filled.

Q. 9. Assertion (A): Chemistry of Actinoids is more complicated than Lanthanoids.
Reason (R): Actinoid elements are radioactive in nature. U

Ans. Option (A) is correct.

Explanation: Chemistry of actinoids is more complicated than Lanthanoids because actinoids are radioactive elements having relatively short half-lives.

Q. 10. Assertion (A): Cerium (Ce) exhibits +4 oxidation state.
Reason (R): Ce^{4+} has $4f^4$ electronic configuration which is less stable. U

Ans. Option (C) is correct.

Explanation: Cerium exhibits +4 oxidation state because Ce^{4+} has $4f^0$ electronic configuration which is most stable.

CASE-BASED MCQs

I. Read the passage given below and answer the following questions:

Within the 3d series, manganese exhibits oxidation states in aqueous solution from +2 to +7, ranging from $Mn^{2+}(aq)$ to MnO^{-}_{4} (aq). Likewise, iron forms both $Fe^{2+}(aq)$ and $Fe^{3+}(aq)$ as well as the FeO^{2-}_{4} ion. Cr and Mn form oxyions CrO^{2-}_{4}, MnO^{-}_{4}, owing to their willingness to form multiple bonds. The pattern with the early transition metals—in the 3d series up to Mn, and for the 4d, 5d metals up to Ru and Os—is that the maximum oxidation state corresponds to the number of "outer shell" electrons. The highest oxidation states of the 3d metals may depend upon complex formation (e.g., the stabilization of Co^{3+} by ammonia) or upon the pH (thus MnO_4^{2-} (aq) is prone to disproportionation in acidic solution). Within the 3d series, there is considerable variation in relative stability of oxidation states, sometimes on moving from one metal to a neighbour; thus, for iron, Fe^{3+} is more stable than Fe^{2+}, especially in alkaline conditions, while the reverse is true for cobalt. The ability of transition metals to exhibit a wide range of oxidation states is marked with metals such as vanadium, where the standard potentials can be rather small, making a switch between states relatively easy. **[CBSE QB 2021]**

In the following questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices on the basis of the above passage.

(A) Assertion and reason both are correct statements and reason is correct explanation for assertion.

(B) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

(C) Assertion is correct statement but reason is wrong statement.

(D) Assertion is wrong statement but reason is correct statement.

AI **Q. 1. Assertion (A):** Highest oxidation state is exhibited by transition metal lying in the middle of the series.
Reason (R): The highest oxidation state exhibited corresponds to number of (n−1)d electrons.
Ans. Option (C) is correct.

Q. 2. Assertion (A): Fe^{3+} is more stable than Fe^{2+}.
Reason (R): Fe^{3+} has $3d^5$ configuration while Fe^{2+} has $3d^6$ configuration.
Ans. Option (A) is correct.

Q. 3. Assertion (A): Vanadium had the ability to exhibit a wide range of oxidation states.
Reason (R): The standard potentials Vanadium are rather small, making a switch between oxidation states relatively easy.
Ans. Option (A) is correct.

AI **Q. 4. Assertion (A):** Transition metals like Fe, Cr and Mn form oxyions.
Reason (R): Oxygen is highly electronegative and has a tendency to form multiple bonds.
Ans. Option (B) is correct.

Q. 5. Assertion (A): The highest oxidation states of the 3d metals depends only on electronic configuration of the metal.
Reason (R): The number of electrons in the (n-1) d and ns subshells determine the oxidation states exhibited by the metal.
Ans. Option (D) is correct.

II. Read the passage given below and answer the following questions:

The transition metals when exposed to oxygen at low and intermediate temperatures form thin, protective oxide films of up to some thousands of Angstroms in thickness. Transition metal oxides lie between the extremes of ionic and covalent binary compounds formed by elements from the left or right side of the periodic table. They range from metallic to semiconducting and deviate by both large and small degrees from stoichiometry. Since d-electron bonding levels are involved, the cations-exist in various valence states and hence give rise to a large number of oxides. The crystal structures are often classified by considering a cubic or hexagonal close-packed lattice of one set of ions with the other set of ions filling the octahedral or tetrahedral interstices. The actual oxide structures, however, generally show departures from such regular arrays due in part to distortions caused by packing of ions of different size and to ligand field effects. These distortions depend not only on the number of d-electrons but also on the valence and the position of the transition metal in a period or group. **[CBSE QB 2021]**

In the following questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices on the basis of the above passage.

(A) Assertion and reason both are correct statements and reason is correct explanation for assertion.

(B) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

(C) Assertion is correct statement but reason is wrong statement.

(D) Assertion is wrong statement but reason is correct statement.

Q. 1. Assertion (A): Cations of transition elements occur in various valence states
Reason (R): Large number of oxides of transition elements are possible.

Ans. Option (B) is correct.

Q. 2. Assertion (A): Crystal structure of oxides of transition metals often show defects.
Reason (R): Ligand field effect cause distortions in crystal structures.

Ans. Option (A) is correct.

AI **Q. 3. Assertion (A):** Transition metals form protective oxide films.
Reason (R): Oxides of transition metals are always stoichiometric.

Ans. Option (C) is correct.

Q. 4. Assertion (A): CrO crystallises in a hexagonal close-packed array of oxide ions with two out of every three octahedral holes occupied by chromium ions.
Reason (R): Transition metal oxide may be hexagonal close-packed lattice of oxide ions with metal ions filling the octahedral voids.

Ans. Option (D) is correct.

III. Read the passage given below and answer the following questions:

The d block elements are the 40 elements contained in the four rows of ten columns (3-12) in the periodic table. As all the d block elements are metallic, the term d-block metals is synonymous. This set of d-block elements is also often identified as the transition metals, but sometimes the group 12 elements (zinc, cadmium, mercury) are excluded from the transition metals as the transition elements are defined as those with partly filled d or f shells in their compounds. Inclusion of the elements zinc, cadmium and mercury is necessary as some properties of the group 12 elements are appropriate logically to include with a discussion of transition metal chemistry. The term transition element or transition metal appeared to derive from early studies of periodicity such as the Mendeleev periodic table of the elements. His horizontal table of the elements was an attempt to group the elements together so that the chemistry of elements might be explained and predicted. In this table there are eight groups labeled I-VIII with each subdivided into A and B subgroups. Mendeleev recognized that certain properties of elements in Group VIII are related to those of some of the elements in Group VII and those at the start of the next row Group I. In that sense, these elements might be described as possessing properties transitional from one row of the table to the next.

[CBSE QB 2021]

In the following questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices on the basis of the above passage.

(A) Assertion and reason both are correct statements and reason is correct explanation for assertion.
(B) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
(C) Assertion is correct statement but reason is wrong statement.
(D) Assertion is wrong statement but reason is correct statement.

Q. 1. Assertion (A): Group 12 elements are not considered as transition metals.
Reason (R): Transition metals are those which have incompletely filled d shell in their compounds.

Ans. Option (A) is correct.

AI **Q. 2. Assertion (A):** All d block elements are metallic in nature.
Reason (R): The d –block elements belong to Group 3 -12 of the periodic table.

Ans. Option (B) is correct.

AI **Q. 3. Assertion (A):** Group VII elements of Mendeleev periodic table are transition elements.
Reason (R): Group I –VIII in Mendeleev periodic table is divided into two subgroups, A and B.

Ans. Option (D) is correct.

Q. 4. Assertion (A): Nickel is a transition element that belongs to group 10 and period 4 of the modern periodic table.
Reason (R): Electronic configuration of Nickel is $[Ar]_{18}3d^84s^2$

Ans. Option (A) is correct.

IV. Read the passage given below and answer the following questions:

In transition elements, generally, ions of the same charge in a given series show progressive decrease in radius with increasing atomic number. This is because the new electron enters a d orbital each time the nuclear charge increases by unity. But the radii of the third (5d) series are virtually the same as those of the corresponding members of the second series. This phenomenon is associated with the intervention of the 4f orbitals which must be filled before the 5d series of elements begin. The filling of 4f before 5d orbital results in a regular decrease in atomic radii called Lanthanoid contraction.

In these questions, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

(A) Assertion and reason both are correct statements and reason is correct explanation for assertion.
(B) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
(C) Assertion is correct statement but reason is wrong statement.
(D) Assertion is wrong statement but reason is correct statement.

Following are the transition metal ions of 3d series:
Ti^{4+}, V^{2+}, Mn^{3+}, Cr^{3+}
(Atomic number: Ti = 22, V = 23, Mn = 25, Cr = 24)

Q. 1. Assertion (A): Among the given ions, Cr^{3+} is the most stable in an aqueous environment.
Reason (R): Cr^{3+} has half filled t^32g.

Ans. Option (D) is correct.

Explanation: Cr^{3+}, half filled t^32g.

AI **Q. 2. Assertion (A):** Among the given ions, Mn^{3+} is the most strong oxidizing agent.
Reason (R): Mn^{3+} has an unstable configuration.

Ans. Option (C) is correct.

Explanation: Mn^{3+} is the strong oxidising agent because it has 4 electrons in its valence shell and when it gains one electron than it forms Mn^{2+}, it results in the half-filled (d^5) configuration that provides extra stability.

Q. 3. Assertion (A): Ti^{4+} ion is colourless.
Reason (R): All valence electrons are unpaired in Ti^{4+} ion.

Ans. Option (A) is correct.

Explanation: Ti^{4+}, No unpaired electrons.

V. Read the passage given below and answer the following questions:

Although actinoids are similar to lanthanoids in that their electrons fill the 5f orbitals in order, their chemical properties are not uniform and each element has characteristic properties. Promotion of 5f - 6d electrons does not require a large amount of energy and examples of compounds with ππ-acid ligands are known in which all the 5f, 6d, 7s, and 7p orbitals participate in bonding. Trivalent compounds are the most common, but other oxidation states are not uncommon. Especially thorium, protactinium, uranium, and neptunium tend to assume the +4 or higher oxidation state.

The following questions are multiple choice questions. Choose the most appropriate answer:

AI **Q. 1.** Which of the following oxidation state is common for all lanthanoids?

(A) +2 **(B)** +3
(C) +4 **(D)** +5

Ans. Option (B) is correct.

Explanation: All of the lanthanide elements are commonly known to have the +3 oxidation state.

Q. 2. There are 14 elements in actinoid series. Which of the following element does not belong to this series?

(A) U **(B)** Np
(C) Tm **(D)** Fm

Ans. Option (C) is correct.

Explanation: Tm is Thulium which belongs to Lanthanoids. Uranium(U), Neptunium(Np), Fermium(Fm) belong to Actinoid series.

Q. 3. General electronic configuration of actinoids is $(n-2)f^{1-14}\ (n-1)d^{0-2}\ ns^2$. Which of the following actinoids have one electron in 6d orbital?

(A) U (Atomic no. 92) **(B)** Np (Atomic no.93)
(C) Pu (Atomic no. 94) **(D)** Bk (Atomic no. 97)

Ans. Option (A) is correct.

Explanation: Uranium has an electronic configuration of $5f^3\ 6d^1\ 7s^2$.

Q. 4. Gadolinium belongs to 4*f* series. Its atomic number is 64. Which of the following is the correct electronic configuration of Gadolinium?

(A) [Xe] $4f^7 5d^1 6s^2$ **(B)** [Xe] $4f^6 5d^2 6s^2$
(C) [Xe] $4f^8 6d^2$ **(D)** [Xe] $4f^9 5s^1$

Ans. Option (A) is correct.

Explanation: Gadolinium has an electronic configuration of [Xe] $4f^7 5d^1 6s^2$.