WEIRD CHEMIST

d-Block Elements

Electrode Potentials – SOLUTIONS

DPP – 04

Topic: Electrode Potentials | **Questions:** 22 Questions | **Exam:** NEET / JEE

Quick Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	2	7	2	13	2	19	3
2	2	8	4	14	3	20	4
3	1	9	1	15	3	21	2
4	2	10	4	16	3	22	2
5	3	11	1	17	4		
6	4	12	2	18	1		

▶ TYPE 1 : The Irregular $E^{\ominus}(M^{2+}/M)$ Trend Across the 3d Series

[F] Master Formulae

The engine behind every $E^{\circ}(M^{2+}/M)$ value: it comes from a three-step energy cycle – $\Delta_{sub}H$ (metal → gaseous atom) + $\Delta_i H_1$+$\Delta_i H_2$ (atom → M^{2+} gas ion) – $\Delta_{hyd}H$ (M^{2+} gas → M^{2+}(aq)). Hydration enthalpies vary fairly smoothly across the row – the **irregularity comes almost entirely from the ionisation and sublimation terms**, which dip and spike depending on which elements get a stability bonus (half-filled d^5, etc.) along the way.

Q1. For the first-row transition metals, the $E^{\ominus}(M^{2+}/M)$ values are:

	V	Cr	Mn	Fe	Co	Ni	Cu
$E^{\ominus}(M^{2+}/M)$	−1.18	−0.91	−1.18	−0.44	−0.28	−0.25	+0.34

The irregular trend (rather than a steady increase) seen in the above values is best explained by–

(1) Steady increase in atomic radius across the series

(2) Irregular variation in ionisation enthalpies ($\Delta_i H_1 + \Delta_i H_2$) and sublimation enthalpies, which are relatively much lower for Mn and V

(3) Progressive filling of the $4p$ orbitals across the series

(4) Constant hydration enthalpy of all the M^{2+} ions across the series

[E] Explanation

Direct statement of the Master Formula. Notice V and Mn are tied for the *most negative* value (-1.18) in the table – both have relatively low combined ionisation costs, which is exactly what pulls their E° down further than a smooth trend would predict. (Option 3 is nonsensical here – 3d elements don't have electrons entering $4p$; option 4 is simply false, hydration enthalpies do vary.)

[Ans] Answer

Option (2)

Q2. The $E^{\ominus}$ value for the Mn^{3+}/Mn^{2+} couple is much more positive than that for Cr^{3+}/Cr^{2+} or Fe^{3+}/Fe^{2+}. This is mainly because–

(1) Mn^{3+} has a smaller ionic radius than Cr^{3+}

(2) The third ionisation energy of Mn is much larger, since the required change is a stable d^5 to d^4 configuration

(3) Mn^{2+} is more heavily hydrated than Cr^{2+}

(4) Fe^{3+} is more stable than Mn^{3+} due to its d^5 configuration

[E] Explanation

Mn^{2+} ($3d^5$) is exceptionally stable (half-filled). Pulling one more electron out to reach Mn^{3+} ($3d^4$) means *breaking* that stability – a genuinely high-energy step. Mn^{3+} "remembers" this and is correspondingly desperate to grab an electron back and revert to Mn^{2+} – which is exactly what a high, positive $E°(M^{3+}/M^{2+})$ means (M^{3+} is a strong oxidiser). Note: (4) is a factual mix-up – it's Mn^{2+} that's d^5/stable here, not Fe^{3+} (which is also d^5 and stable, but that's not what's being asked).

[Ans] Answer

Option (2)

Q3. Cr^{2+} and Mn^{3+} both have a d^4 configuration, yet Cr^{2+} is reducing while Mn^{3+} is oxidising. This is because–

(1) Cr^{2+} ($d^4 \rightarrow d^3$) moves toward a half-filled t_{2g} level, while Mn^{3+} ($d^4 \rightarrow d^5$) moves toward the extra stability of a half-filled d-subshell

(2) Cr^{2+} is more heavily hydrated than Mn^{3+}

(3) Mn^{3+} has a larger ionic radius than Cr^{2+}

(4) Cr^{2+} has a higher nuclear charge than Mn^{3+}

[E] Explanation

Same d^4 starting point, two opposite exits: Cr^{2+} is one electron *away from* (by losing) the stable t_{2g}^3 arrangement – so it gives an electron up (reducing). Mn^{3+} is one electron *away from* (by gaining) the stable half-filled $3d^5$ – so it grabs an electron (oxidising). Same configuration, opposite stable target, opposite chemical behaviour.

[A] Approach

Ek hi starting point (d^4) se do alag directions – Cr niche jaake t_{2g}^3 (3 electron stability) pakadta hai, Mn upar jaake d^5 (5 electron stability) pakadta hai. Jis taraf stability paas ho, usi taraf electron flow hoga.

[Ans] Answer

Option (1)

Q4. The standard reduction potential $E^\circ(M^{2+}/M)$ value for copper is positive ($+0.34$ V), unlike most other first-row transition metals. What is the possible reason for this?

(1) Low ionisation enthalpy of copper alone

(2) High enthalpy of atomisation of Cu combined with low hydration enthalpy of Cu^{2+}, which together outweigh the ionisation energy term

(3) High hydration enthalpy of Cu^{2+} alone

(4) Copper has a completely filled $3d$ subshell in its $+2$ state

[E] Explanation

Cu metal has unusually strong metallic bonding (high $\Delta_{sub}H$ – hard to atomise), and once formed, Cu^{2+}'s hydration enthalpy isn't quite generous enough to pay back that cost plus the ionisation energy the way it does for a typical 3d metal. Net result: the overall $Cu(s) \rightarrow Cu^{2+}(aq)$ process is *not* favourable the way it is for Fe, Zn, etc. – giving Cu a rare positive (non-spontaneous-oxidation) E°. (Option 4 is simply wrong on the chemistry: Cu^{2+} is d^9, not completely filled – d^{10} belongs to Cu^+.)

[!] Common Mistake

Note for continuity: this also resolves the ambiguity I flagged on DPP-03 Q.29 option (4) – that statement ("the high energy to transform Cu(s) to $Cu^{2+}(aq)$ is not balanced by its hydration enthalpy") turns out to be the standard, correct explanation for *this specific* fact (Cu's anomalous positive E°), which is a different comparison from Cu^+ vs Cu^{2+} stability. I'd lean towards revising that earlier flag if it comes up again.

[Ans] Answer

Option (2)

▶ TYPE 2 : Comparing Reducing Power & E° Values Among 3d Metals

[F] Master Formulae

Two different E° couples answer two different questions – don't mix them up:

- **$E^\circ(M^{2+}/M)$** tells you if the *metal* dissolves in simple (non-oxidising) acid: negative $\Rightarrow$ yes; positive $\Rightarrow$ no (only Cu, among the 3d row, is positive).

- **$E^\circ(M^{3+}/M^{2+})$ tells you how stable the $+2$ state is:** a high, positive value means M^{3+} desperately wants to revert to M^{2+} (so $+2$ is very stable – true for Mn, Co); a low/negative value means M^{2+} readily gives up another electron to become M^{3+} ($+2$ is unstable – true for Cr).

Q5. Four successive members of the first series of the transition metals are listed below. For which one of them the standard potential ($E^\circ_{M^{2+}/M}$) value has a positive sign? [AIPMT (Mains)-2012]

(1) Co ($Z = 27$)
(2) Ni ($Z = 28$)
(3) Cu ($Z = 29$)
(4) Fe ($Z = 26$)

[E] Explanation

Straight from the Q.1 table: Fe $= -0.44$, Co $= -0.28$, Ni $= -0.25$, Cu $= +0.34$. Only copper is positive.

[Ans] Answer

Option (3) Cu.

Q6. In first series of transition metal, which of the following metal can't be oxidised by 1M H^+(aq) solution? [NCERT Pg. 224]

(1) Zn
(2) Mn
(3) Cr
(4) Cu

[E] Explanation

A metal gets oxidised by H^+ (releasing H_2 gas) only if it's a *better* reducing agent than H_2 itself – i.e. its $E^\circ(M^{2+}/M)$ must be negative. Zn, Mn, Cr all have negative E° (Zn ≈ -0.76, Mn $= -1.18$, Cr $= -0.91$) and dissolve readily in dilute acid. Cu's E° is positive ($+0.34$) – H_2 would rather reduce Cu^{2+} than the reverse, so plain H^+ simply can't touch copper (that's why dissolving Cu needs an oxidising acid like HNO_3, not dilute HCl).

[Ans] Answer

Option (4) Cu.

Q7. Which is the stronger reducing agent, Cr^{2+} or Fe^{2+}, and why?

(1) Fe^{2+}, because $E^\circ(Fe^{2+}/Fe) = -0.44$ V is more negative than $E^\circ(Cr^{2+}/Cr)$
(2) Cr^{2+}, because $E^\circ(Cr^{2+}/Cr) = -0.90$ V is more negative than $E^\circ(Fe^{2+}/Fe) = -0.44$ V
(3) Both are equally strong reducing agents
(4) Fe^{2+}, because it has a smaller ionic radius than Cr^{2+}

[E] Explanation

-0.90 V is more negative than -0.44 V, so Cr's system is the more strongly reducing one – consistent with everything already established about Cr^{2+} being a notably strong, readily-oxidised reducing agent (it wants to shed an electron and reach the stable t_{2g}^3 Cr^{3+}). Fe^{2+}, by contrast, is comparatively unreactive/stable and needs a real oxidiser to shift to Fe^{3+}.

[Ans] Answer

Option (2) Cr^{2+}.

Q8. For the four successive transition elements (Cr, Mn, Fe and Co), the stability of $+2$ oxidation state will be there in which of the following order? (At. No. Cr $= 24$, Mn $= 25$, Fe $= 26$, Co $= 27$) **[AIPMT (Prelims)-2011]**

(1) Cr $>$ Mn $>$ Co $>$ Fe

(2) Mn $>$ Fe $>$ Cr $>$ Co

(3) Fe $>$ Mn $>$ Co $>$ Cr

(4) Co $>$ Mn $>$ Fe $>$ Cr

[E] Explanation

This needs $E°(M^{3+}/M^{2+})$, not the M^{2+}/M table: Co^{3+}/Co^{2+} ($\approx +1.8V$) and Mn^{3+}/Mn^{2+} ($\approx +1.5V$) are both sky-high – meaning Co^{2+} and Mn^{2+} are extremely comfortable, stable states (their $+3$ forms desperately want to revert). Fe^{3+}/Fe^{2+} is a much milder $+0.77V$ – Fe^{2+} is reasonably stable but nowhere near as resistant to oxidation. Cr^{3+}/Cr^{2+} is actually *negative* ($\approx -0.41V$) – Cr^{2+} practically throws away an electron to become Cr^{3+}, making $+2$ its **least** stable state of the four. Ranking by stability of $+2$: Co $>$ Mn $>$ Fe $>$ Cr.

[!] Common Mistake

Easy trap: this table ($E°(M^{2+}/M)$) is about a completely *different* couple than what the question needs ($E°(M^{3+}/M^{2+})$). Don't reach for the wrong table just because it's the one printed at the top of this TYPE.

[Ans] Answer

Option (4) Co $>$ Mn $>$ Fe $>$ Cr.

Q9. Choose the correct

(1) Cr^{2+} is stronger reducing agent than Fe^{2+} in aqueous medium

(2) Cu^{2+} undergoes disproportionation in aqueous medium

(3) Silver is not a transition element

(4) All are correct

[E] Explanation

(1) is true (Q.7). (2) is false – it's Cu^{+} that disproportionates ($2Cu^{+} \rightarrow Cu^{2+} + Cu$); Cu^{2+} is the stable *product*, not itself disproportionating further. (3) is false – Ag ($[Kr]4d^{10}5s^{1}$) qualifies as a transition metal the same way Cu does: its rare but real Ag^{2+} state (e.g. in AgF_2) is d^9, an incomplete d-subshell, satisfying the IUPAC definition. Since (2) and (3) are both false, "all are correct" (4) is automatically false too.

[Ans] Answer

Option (1) Cr^{2+} is stronger reducing agent than Fe^{2+}.

▶ TYPE 3 : Stability of Ions in Aqueous Solution

[F] Master Formulae

Two configurations are the "comfort zones" of the 3d row in aqueous solution: d^5 **high-spin** (**Mn^{2+}**) and d^3 (**Cr^{3+}**). Ions sitting in or driven toward these are exceptionally stable; ions driven *away* from them (Mn^{3+}, Co^{3+}, Cr^{2+}) are strong oxidisers or reducers instead.

Q10. Which of the following ions most stable in aqueous solution?

(1) $_{23}V^{3+}$
(2) $_{22}Ti^{3+}$
(3) $_{25}Mn^{3+}$
(4) $_{24}Cr^{3+}$

[E] Explanation

Among these M^{3+} ions, Cr^{3+} (d^3, t_{2g}^3) is the famously stable one – $Ti^{3+}(d^1)$ and $V^{3+}(d^2)$ lack this special stabilisation, and $Mn^{3+}(d^4)$ is actively unstable/oxidising (Q.2, Q.3).

[Ans] Answer

Option (4) Cr^{3+}.

Q11. Which one of the following ions is the most stable in aqueous solution? (Atomic number Ti = 22, V = 23, Cr = 24, Mn = 25) [AIPMT (Prelims)-2007]

(1) Mn^{2+} (2) Cr^{3+} (3) V^{3+} (4) Ti^{3+}

[E] Explanation

This time Mn^{2+} ($3d^5$, half-filled) is in the mix – and it edges out even Cr^{3+}. d^5 high-spin gets maximum exchange-energy stabilisation regardless of field strength, making it arguably the single most robust ion configuration in the whole row, stable to both oxidation and reduction.

[Ans] Answer

Option (1) Mn^{2+}.

Q12. The most stable oxidation state of Cr in aq. medium is –

(1) Cr^{2+} (2) Cr^{3+} (3) Cr^{4+} (4) Cr^{6+}

[Ans] Answer

Option (2) Cr^{3+}.

Q13. Cu^+ ion is not stable in aqueous solution, due to–

(1) d^{10} configuration
(2) Disproportionation
(3) Less charge
(4) Pseudo inert gas configuration

[Ans] Answer

Option (2) Disproportionation.

Q14. Which of the following pair of transition metal ions are the best oxidising agents in aqueous solutions?

(1) V^{2+} and Cr^{2+}
(2) Ti^{2+} and Cr^{2+}
(3) Mn^{3+} and Co^{3+}
(4) V^{2+} and Fe^{2+}

[E] Explanation

Both Mn^{3+} and Co^{3+} have sky-high $E°(M^{3+}/M^{2+})$ values (Q.8) – each is desperate to grab an electron and revert to its far more comfortable $+2$ state, which is exactly what makes an ion a strong oxidiser.

[Ans] Answer

Option (3) Mn^{3+} and Co^{3+}.

Q15. Which of the following pairs of transition metal ions are the stronger oxodising agents in aqueous solutions?

(1) V^{2+} and Cr^{3+}
(2) Ti^{2+} and Cr^{2+}
(3) Mn^{3+} and Co^{3+}
(4) V^{3+} and Fe^{2+}

[E] Explanation

Same underlying fact as Q.14, with different distractors – Mn^{3+} and Co^{3+} remain the answer.

[Ans] Answer

Option (3) Mn^{3+} and Co^{3+} – see Q.14.

▶ TYPE 4 : Highest Oxidation States – Configurations, Species & Stabilising Halogens

[F] Master Formulae

Recall from DPP-03: up to Mn, highest oxidation state = total valence electron count ($d^n s^m$, $n+m$). Among simple **halides**, fluorine is the best at reaching a metal's highest state (small, high bond enthalpy) – oxygen only overtakes it for the very most extreme cases (multiple π bonding).

Q16. Among the following outermost configurations of transition metals, which shows the highest oxidation state:

(1) $3d^3, 4s^2$
(2) $3d^5, 4s^1$
(3) $3d^5, 4s^2$
(4) $3d^6, 4s^2$

[E] Explanation

$3d^3 4s^2$=V (5 valence e^-, max $+5$); $3d^5 4s^1$=Cr (6, max $+6$); $3d^5 4s^2$=Mn (7, max $+7$); $3d^6 4s^2$=Fe (8, but doesn't reach d^0 – practical max stays around $+3$/rare $+6$). Mn wins.

[Ans] Answer

Option (3) $3d^5 4s^2$ [Mn].

Q17. Amongst the following, identify the species with an atom in $+6$ oxidation state:

(1) MnO_4^-
(2) $Cr(CN)_6^{3-}$
(3) NiF_6^{2-}
(4) CrO_2Cl_2

[E] Explanation

MnO_4^-: Mn$+4(-2) = -1 \Rightarrow$Mn$= +7$. $Cr(CN)_6^{3-}$: Cr$+6(-1) = -3 \Rightarrow$Cr$= +3$. NiF_6^{2-}: Ni$+6(-1) = -2 \Rightarrow$Ni$= +4$. CrO_2Cl_2 (chromyl chloride, neutral): Cr$+2(-2) + 2(-1) = 0 \Rightarrow$Cr$= +6$. ✓

[Ans] Answer

Option (4) CrO_2Cl_2.

Q18. Choose from the following elements, which can bring a transition metal into its highest oxidation state:

(1) F
(2) Cl
(3) Br
(4) I

[E] Explanation

Among simple halides, fluorine's small size and high bond enthalpy make it the most effective at reaching a metal's highest accessible oxidation state (e.g. VF_5, CrF_6 exist; the corresponding chlorides/bromides/iodides at that oxidation state typically don't).

[Ans] Answer

Option (1) F.

▶ TYPE 5 : General Concepts & Statement Evaluation on Transition Elements

Q19. Which of the following metals exhibit more than one oxidation state?

(1) Na
(2) Mg
(3) Fe
(4) All

[E] Explanation

Na (s-block, Group 1) is fixed at $+1$; Mg (s-block, Group 2) is fixed at $+2$ – both have a large $ns/(n-1)p$ energy gap, locking in one valency (opposite of the d-block story). Fe is variable ($+2, +3$, rare $+6$).

[Ans] Answer

Option (3) Fe.

Q20. The property, which is not characteristic of transition metals, is:

(1) Variable oxidation states
(2) Tendency to form complexes
(3) Formation of coloured compounds
(4) Natural-radioactivity

[E] Explanation

Variable oxidation states, complex formation, and colour are the three signature transition-metal properties running through this entire DPP series. Natural radioactivity has nothing to do with d-block character – it's a nuclear (not electronic/chemical) property tied to specific unstable isotopes, unrelated to being a transition element.

[Ans] Answer

Option (4) Natural radioactivity.

Q21. Which of the following fact about d and f-block elements is wrong?

(1) Oxidation states of 'd' and 'f' block elements differ by one unit.
(2) Most common oxidation state for d & f-block elements is '$+2$'.
(3) In d-block, down the group stability of higher oxidation state increases.
(4) Lanthanum and Actinium are 'd' block elements

[E] Explanation

(1), (3), (4) are all established facts from this DPP series. (2) is wrong specifically for the **f-block**: lanthanides are overwhelmingly "$+3$ elements" (with only a handful of exceptions like Eu^{2+}, Ce^{4+}) – $+2$ is not their dominant state, $+3$ is.

[!] Common Mistake

$+2$ genuinely *is* common across the *late* 3d transition metals (Mn, Fe, Co, Ni, Cu, Zn) – the trap here is generalising that pattern onto the f-block too, where it simply doesn't hold.

[Ans] Answer

Option (2)

Q22. In context with the transition elements, which of the following statements is incorrect?

(1) In addition to the normal oxidation states, the zero oxidation state is also shown by these elements in complex

(2) In the highest oxidation states, the transition metals show basic character and form cationic complexes

(3) In the highest oxidation states of the first five transition elements (Sc to Mn), all the $4s$ and $3d$ electrons are used for bonding

(4) Once the d^5 configuration is exceeded, the tendency to involve all the $3d$ electrons in bonding decreases

[E] Explanation

(1), (3), (4) are all established facts running through this DPP series. (2) has it backwards: at their **highest** oxidation states, transition metals show **acidic** character (e.g. Mn_2O_7, CrO_3) and form **anionic** oxo-complexes (MnO_4^-, $Cr_2O_7^{2-}$) – not basic/cationic. High positive charge on a small, high-oxidation-state metal centre strongly polarises and withdraws electron density from ligands, which is an acidic (electron-accepting), not basic, character.

[Ans] Answer

Option (2)

Electrode potentials are just oxidation-state stability, quantified –
every irregular number in that table traces back to a d^3, d^5, or d^{10} you already know.

– Your Weird Chemist