



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 $E^\ominus(M^{2+}/M)$ value: it comes from a three-step energy cycle – $\Delta_{sub}H$ (metal $\rightarrow$ gaseous atom) + $\Delta_i H_1 + \Delta_i H_2$ (atom $\rightarrow M^{2+}$ gas ion) – $\Delta_{hyd}H$ (M^{2+} gas $\rightarrow M^{2+}(aq)$). 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° value for the $\text{Mn}^{3+}/\text{Mn}^{2+}$ couple is much more positive than that for $\text{Cr}^{3+}/\text{Cr}^{2+}$ or $\text{Fe}^{3+}/\text{Fe}^{2+}$. 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 $E^\circ(\text{M}^{3+}/\text{M}^{2+})$ 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 ($E_{M^{2+}/M}^\circ$) value has a positive sign? [AIPMT

(Mains)-2012]

- (1) Co ($Z = 27$) (3) Cu ($Z = 29$)
 (2) Ni ($Z = 28$) (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) $\text{Cr} > \text{Mn} > \text{Co} > \text{Fe}$
- (2) $\text{Mn} > \text{Fe} > \text{Cr} > \text{Co}$
- (3) $\text{Fe} > \text{Mn} > \text{Co} > \text{Cr}$
- (4) $\text{Co} > \text{Mn} > \text{Fe} > \text{Cr}$

[E] Explanation

This needs $E^\circ(\text{M}^{3+}/\text{M}^{2+})$, not the M^{2+}/M table: $\text{Co}^{3+}/\text{Co}^{2+}$ ($\approx +1.8\text{V}$) and $\text{Mn}^{3+}/\text{Mn}^{2+}$ ($\approx +1.5\text{V}$) are both sky-high – meaning Co^{2+} and Mn^{2+} are extremely comfortable, stable states (their +3 forms desperately want to revert). $\text{Fe}^{3+}/\text{Fe}^{2+}$ is a much milder $+0.77\text{V}$ – Fe^{2+} is reasonably stable but nowhere near as resistant to oxidation. $\text{Cr}^{3+}/\text{Cr}^{2+}$ is actually *negative* ($\approx -0.41\text{V}$) – 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: $\text{Co} > \text{Mn} > \text{Fe} > \text{Cr}$.

[!] Common Mistake

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

[Ans] Answer

Option (4) $\text{Co} > \text{Mn} > \text{Fe} > \text{Cr}$.

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 ($2\text{Cu}^+ \rightarrow \text{Cu}^{2+} + \text{Cu}$); Cu^{2+} is the stable *product*, not itself disproportionating further. (3) is false – Ag ($[\text{Kr}]4d^{10}5s^1$) 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) ${}_{23}\text{V}^{3+}$ (3) ${}_{25}\text{Mn}^{3+}$
(2) ${}_{22}\text{Ti}^{3+}$ (4) ${}_{24}\text{Cr}^{3+}$

[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 $E^\circ(M^{3+}/M^{2+})$ 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 oxidising 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

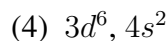
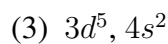
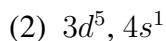
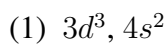
Option (3) Mn^{3+} and Co^{3+} – see Q.14.

► 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:

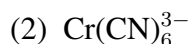
**[E] Explanation**

$3d^3 4s^2 = \text{V}$ (5 valence e^- , max +5); $3d^5 4s^1 = \text{Cr}$ (6, max +6); $3d^5 4s^2 = \text{Mn}$ (7, max +7); $3d^6 4s^2 = \text{Fe}$ (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:

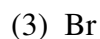
**[E] Explanation**

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

[Ans] Answer

Option (4) CrO_2Cl_2 .

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

**[E] Explanation**

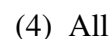
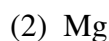
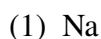
Among simple halides, fluorine's small size and high bond enthalpy make it the most effective at reaching a metal's highest accessible oxidation state (e.g. VF_5 , CrF_6 exist; the corresponding chlorides/bromides/iodides at that oxidation state typically don't).

[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?



[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 | (3) Formation of coloured compounds |
| (2) Tendency to form complexes | (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^- , $\text{Cr}_2\text{O}_7^{2-}$) – 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