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d- and f-Block Elements — JEE (Main) Pattern Topic Test

FREE SAMPLE TEST · CHEMISTRY · PATTERN OF JEE (MAIN)

DURATION	MAXIMUM MARKS	QUESTIONS	NAME / ROLL NO.
60 minutes	100	25 (20 + 5)	

GENERAL INSTRUCTIONS

1. This question paper has two sections, A and B. All 25 questions are compulsory.
2. Section A has TWENTY (20) multiple-choice questions. Each has FOUR options, (1), (2), (3) and (4), of which ONLY ONE is correct.
3. Section B has FIVE (05) questions whose answer is a numerical value. Enter the value rounded off to the nearest integer.
4. Marking scheme for both sections: +4 for a correct answer, −1 for an incorrect answer, 0 if the question is not attempted.
5. Use of a calculator, log tables or any other aid is not allowed.
6. The answer key and worked solutions are at the end of this booklet. Attempt the paper in 60 minutes before you look at them.

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Topics covered: Electronic configuration · Atomic properties and trends · Oxidation states and electrode potentials · Magnetic properties and colour · Catalytic and other properties · Potassium dichromate · Potassium permanganate · Lanthanoids · Actinoids

SECTION A (Q1–20) · Multiple choice · +4 / 0 / −1

Each question has FOUR options. ONLY ONE of them is correct.

1. Which of the following pairs of ions have the same number of unpaired electrons?

(1) Cr^{3+} and Fe^{2+}

(2) Co^{2+} and Ni^{2+}

(3) Mn^{2+} and Fe^{3+}

(4) Cu^{2+} and V^{3+}

2. An aqueous ion of a first-row transition metal has a spin-only magnetic moment of 4.90 BM. The ion is

(1) Cr^{3+}

(2) Cr^{2+}

(3) Mn^{2+}

(4) Cu^{2+}

3. The standard electrode potentials $E°(M^{3+}/M^{2+})$ are: Cr −0.41 V, Mn +1.57 V, Fe +0.77 V and Co +1.97 V. Which of the following statements is correct?

(1) Fe^{3+} is the strongest oxidising agent of the four M^{3+} ions.

(2) Mn^{3+} is a stronger oxidising agent than Co^{3+}.

(3) Cr^{3+} is easily reduced to Cr^{2+}.

(4) Cr^{2+} is the strongest reducing agent of the four M^{2+} ions.

4. In which of the following species does the transition metal show an oxidation state equal to the total number of its 3d and 4s electrons?

(1) $[Ni(CO)_4]$

(2) FeO_4^{2-}

(3) CoF_3

(4) VO_2^{+}

5. Statement I: The basic strength of the hydroxides decreases from $La(OH)_3$ to $Lu(OH)_3$.
Statement II: The ionic radius of the Ln^{3+} ions increases from La^{3+} to Lu^{3+}.
In the light of the above statements, choose the correct answer from the options given below:

(1) Both Statement I and Statement II are true

(2) Statement I is true but Statement II is false

(3) Statement I is false but Statement II is true

(4) Both Statement I and Statement II are false

6. In neutral or faintly alkaline solution, permanganate oxidises iodide ion to iodate ion and is itself reduced to MnO_2. The number of moles of MnO_4^- used per mole of I^- is

(1) 2

(2) 6/5

(3) 1/2

(4) 3

7. Which of the following oxides is amphoteric?

(1) Mn_2O_7

(2) CrO_3

(3) Cr_2O_3

(4) MnO

8. The colour of which of the following is due to charge transfer and not to d–d transitions?

(1) $KMnO_4$

(2) $CuSO_4 \cdot 5H_2O$

(3) $[Ti(H_2O)_6]Cl_3$

(4) $NiCl_2 \cdot 6H_2O$

9. Among the first-row transition metals (Sc to Zn), the metals with the highest and the lowest enthalpies of atomisation are, respectively,

(1) Cr and Zn

(2) V and Mn

(3) Ti and Cu

(4) V and Zn

10. Assertion A: Mn^{2+} is much more resistant to oxidation than Fe^{2+}.
Reason R: Mn^{2+} has the stable half-filled $3d^5$ configuration, whereas Fe^{2+} ($3d^6$) reaches $3d^5$ by losing one electron.
In the light of the above statements, choose the correct answer from the options given below:

(1) Both A and R are true and R is the correct explanation of A

(2) Both A and R are true but R is NOT the correct explanation of A

(3) A is true but R is false

(4) A is false but R is true

11. Consider the following statements.
(A) Interstitial compounds of transition metals are harder than the pure metals.
(B) V_2O_5 is used as the catalyst in the contact process for H_2SO_4.
(C) Zinc has the highest melting point of the first-row transition metals.
(D) Most compounds of transition metals are paramagnetic.
The correct statements are

(1) (A), (B) and (C) only

(2) (A), (B) and (D) only

(3) (B), (C) and (D) only

(4) (A) and (D) only

12. Which of the following statements about the actinoids is NOT correct?

(1) All the actinoids are radioactive.

(2) The actinoid contraction is greater, from element to element, than the lanthanoid contraction.

(3) The 5f electrons shield the outer electrons more effectively than the 4f electrons do.

(4) The actinoids show a wider range of oxidation states than the lanthanoids.

13. The $E^\circ(M^{2+}/M)$ values of Mn (−1.18 V) and Zn (−0.76 V) are more negative than expected from the general trend across the 3d series. The best reason is

(1) Mn and Zn have the highest enthalpies of atomisation in the series

(2) Mn^{2+} is $3d^5$ and Zn^{2+} is $3d^{10}$, extra-stable half-filled and filled configurations

(3) Mn and Zn have the largest atomic radii in the series

(4) Mn^{2+} and Zn^{2+} have the lowest hydration enthalpies in the series

14. Which of the following first-row transition metal atoms has the largest number of unpaired electrons in its ground state?

(1) Mn

(2) Fe

(3) Cr

(4) V

15. As a consequence of the lanthanoid contraction, which pair of elements have almost the same metallic radius?

(1) Sc and Y

(2) V and Nb

(3) Nb and Ta

(4) Ti and Zr

16. In acid solution, $Cr_2O_7^{2-}$ oxidises Fe^{2+} to Fe^{3+}, SO_3^{2-} to SO_4^{2-} and I^- to I_2. The numbers of moles of $Cr_2O_7^{2-}$ needed to oxidise one mole of Fe^{2+}, one mole of SO_3^{2-} and one mole of I^- are, respectively,

(1) 1/6, 1/3 and 1/6

(2) 1/6, 1/6 and 1/3

(3) 1/3, 1/3 and 1/6

(4) 6, 3 and 6

17. Which of the following pairs of ions have the same number of 4f electrons?

(1) Sm^{2+} and Gd^{3+}

(2) Eu^{3+} and Tb^{3+}

(3) Yb^{2+} and Tm^{3+}

(4) Eu^{2+} and Gd^{3+}

18. The first-row transition element with the highest first ionisation enthalpy is

(1) Cu

(2) Zn

(3) Fe

(4) Ni

19. Acidified potassium permanganate oxidises hydrogen peroxide to oxygen. The number of moles of O_2 evolved per mole of $KMnO_4$ is

(1) 1.5

(2) 5

(3) 2.5

(4) 0.5

20. The atom of which of the following elements has no electron in its outermost s subshell in the ground state?

(1) Pt

(2) Pd

(3) Ag

(4) Cr

SECTION B (Q21–25) · Numerical value · +4 / 0 / −1

The answer to each question is a NUMERICAL VALUE. Enter it rounded off to the nearest integer.

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21. The total number of unpaired electrons in the ions Ce^{3+}, Gd^{3+}, Yb^{3+} and Lu^{3+} taken together is _____.

Answer: _____

22. MnO_2 is fused with KOH in air to give K_2MnO_4, and the manganate is then made to disproportionate in acid solution to give $KMnO_4$ and MnO_2. The mass (in g) of $KMnO_4$ obtained from 87 g of MnO_2 in the first step is _____ (to the nearest integer; K = 39, Mn = 55, O = 16).

Answer: _____

23. The volume (in mL) of 0.06 M $KMnO_4$ needed in acid solution to oxidise completely 30 mL of 0.1 M ferrous oxalate (FeC_2O_4) is _____.

Answer: _____

24. The number of the following ions whose spin-only magnetic moment is greater than 4 BM is _____.
Sc^{3+}, Ti^{3+}, V^{3+}, Cr^{3+}, Mn^{2+}, Mn^{3+}, Fe^{2+}, Fe^{3+}, Co^{2+}, Ni^{2+}, Cu^{2+}, Zn^{2+}

Answer: _____

25. The spin-only magnetic moment of the manganese ion in the manganate ion, MnO_4^{2-}, is x BM. The value of 100x (to the nearest integer) is _____.

Answer: _____

END OF THE QUESTION PAPER

ANSWER KEY

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
(3)	(2)	(4)	(4)	(2)	(1)	(3)	(1)	(4)	(1)

Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
(2)	(3)	(2)	(3)	(3)	(1)	(4)	(2)	(3)	(2)

Q21	Q22	Q23	Q24	Q25
9	105	30	4	173

WORKED SOLUTIONS

Q1. Answer (3). Cr^{3+} $3d^3$ (3) and Fe^{2+} $3d^6$ (4); Co^{2+} $3d^7$ (3) and Ni^{2+} $3d^8$ (2); Mn^{2+} and Fe^{3+} are both $3d^5$ (5 each); Cu^{2+} $3d^9$ (1) and V^{3+} $3d^2$ (2). Only Mn^{2+} and Fe^{3+} match.

Q2. Answer (2). $\mu = \sqrt{(n(n+2))} = 4.90$ BM gives $n = 4$ unpaired electrons. Cr^{2+} is $3d^4$ (4). Cr^{3+} $3d^3$ (3.87 BM), Mn^{2+} $3d^5$ (5.92 BM), Cu^{2+} $3d^9$ (1.73 BM).

Q3. Answer (4). The most negative E° (Cr, −0.41 V) means Cr^{2+} is the most easily oxidised, so it is the strongest reducing agent: (4). The most positive E° is Co (1.97 V), so Co^{3+}, not Fe^{3+} or Mn^{3+}, is the strongest oxidising agent; and Cr^{3+} is hard to reduce (d^3 is stable).

Q4. Answer (4). Ni in $[Ni(CO)_4]$ is 0 (Ni has 10 electrons in 3d + 4s). Fe in FeO_4^{2-} is +6 (Fe has 8). Co in CoF_3 is +3 (Co has 9). V in VO_2^+ is $x - 4 = +1$, $x = +5$, and V ($3d^3\ 4s^2$) has 5. So VO_2^+.

Q5. Answer (2). The 4f electrons shield each other poorly, so the effective nuclear charge rises across the series and Ln^{3+} shrinks (La^{3+} 103, Gd^{3+} 94, Lu^{3+} 86 pm): II is false. The smaller ion holds OH^- more covalently, so basic strength falls from $La(OH)_3$ to $Lu(OH)_3$: I is true.

Q6. Answer (1). I goes from −1 to +5: 6 electrons per I^-. Mn goes from +7 to +4: 3 electrons per MnO_4^-. So 2 MnO_4^- per I^-: $2MnO_4^- + I^- + H_2O \rightarrow 2MnO_2 + IO_3^- + 2OH^-$.

Q7. Answer (3). For one metal, the oxide is basic in a low oxidation state, amphoteric in an intermediate one and acidic in a high one. Mn_2O_7 (+7) and CrO_3 (+6) are acidic, MnO (+2) is basic, and Cr_2O_3 (+3) is amphoteric.

Q8. Answer (1). A d–d transition needs a partly filled d subshell. Cu^{2+} ($3d^9$), Ti^{3+} ($3d^1$) and Ni^{2+} ($3d^8$) have one. Mn in MnO_4^- is +7, $3d^0$: its intense purple colour comes from charge transfer from O to Mn.

Q9. Answer (4). Enthalpies of atomisation (kJ/mol): Sc 326, Ti 473, V 515, Cr 397, Mn 281, Fe 416, Co 425, Ni 430, Cu 339, Zn 126. The maximum is at V (many unpaired d electrons in metallic bonding) and the minimum at Zn ($3d^{10}$, no unpaired d electrons).

Q10. Answer (1). The third ionisation enthalpy of Mn (3248 kJ/mol) is much higher than that of Fe (2957 kJ/mol): removing an electron from Mn^{2+} breaks the d^5 half-filled set, while $Fe^{2+} \rightarrow Fe^{3+}$ creates it. Both are true and R explains A.

Q11. Answer (2). (A) true: small atoms (H, C, N) in the lattice make the metal hard and high melting. (B) true. (C) false: Zn (693 K) has the lowest melting point of the series (V, 2183 K, the highest). (D) true: most have unpaired d electrons. So (A), (B) and (D).

Q12. Answer (3). The 5f orbitals are more diffuse and shield even more poorly than 4f, which is why the actinoid contraction is the greater; so (3) is wrong. (1), (2) and (4) are correct (5f, 6d and 7s are close in energy, giving many oxidation states).

Q13. Answer (2). $E°(M^{2+}/M)$ depends on atomisation, ionisation and hydration. The stable $3d^5$ of Mn^{2+} and $3d^{10}$ of Zn^{2+} make forming these ions easier than the trend suggests. Option (1) is false: Mn and Zn have the lowest atomisation enthalpies,

which also favours ion formation, but the configurations are the reason quoted.

Q14. Answer (3). Cr is $3d^5\ 4s^1$ (exchange energy favours the half-filled d set): 6 unpaired. Mn $3d^5\ 4s^2$ has 5, Fe $3d^6\ 4s^2$ has 4, V $3d^3\ 4s^2$ has 3.

Q15. Answer (3). Metallic radii (pm): Sc 164, Y 180; V 135, Nb 146; Nb 146, Ta 146; Ti 147, Zr 160. From the 4d to the 5d series the expected increase in size is cancelled by the lanthanoid contraction, so Nb and Ta are the same size.

Q16. Answer (1). Each $Cr_2O_7^{2-}$ takes 6 electrons (2Cr: +6 → +3). Fe^{2+} gives 1 electron (1/6 mol), SO_3^{2-} gives 2 (S: +4 → +6, 1/3 mol) and I^- gives 1 (1/6 mol).

Q17. Answer (4). Ln^{3+} is $[Xe]4f^n$ with n = Z − 57, and Ln^{2+} has one 4f electron more. Sm^{2+} $4f^6$, Gd^{3+} $4f^7$; Eu^{3+} $4f^6$, Tb^{3+} $4f^8$; Yb^{2+} $4f^{14}$, Tm^{3+} $4f^{12}$; Eu^{2+} $4f^7$ and Gd^{3+} $4f^7$. So Eu^{2+} and Gd^{3+}.

Q18. Answer (2). First ionisation enthalpies (kJ/mol): Fe 762, Ni 736, Cu 745, Zn 906. Zn ($3d^{10}\ 4s^2$) loses an electron from a filled 4s subshell and has the highest value.

Q19. Answer (3). $2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 2Mn^{2+} + 5O_2 + 8H_2O$. Each MnO_4^- takes 5 electrons and each H_2O_2 gives 2, so 5/2 = 2.5 mol O_2 per mol $KMnO_4$.

Q20. Answer (2). Pd is $[Kr]\ 4d^{10}\ 5s^0$. Pt is $[Xe]\ 4f^{14}\ 5d^9\ 6s^1$, Ag is $[Kr]\ 4d^{10}\ 5s^1$ and Cr is $[Ar]\ 3d^5\ 4s^1$.

Q21. Answer 9. 4f electrons: Ce^{3+} $4f^1$ (1 unpaired), Gd^{3+} $4f^7$ (7), Yb^{3+} $4f^{13}$ (1), Lu^{3+} $4f^{14}$ (0). Total 9.

Q22. Answer 105. 87 g MnO_2 = 1 mol, giving 1 mol K_2MnO_4. In acid, $3MnO_4^{2-} + 4H^+ \rightarrow 2MnO_4^- + MnO_2 + 2H_2O$, so 2/3 mol $KMnO_4$ = 2/3 × 158 = 105.3 g, i.e. 105.

Q23. Answer 30. Both ions are oxidised: $Fe^{2+} \rightarrow Fe^{3+}$ (1 electron) and $C_2O_4^{2-} \rightarrow 2CO_2$ (2 electrons), 3 electrons per FeC_2O_4. 3 mmol FeC_2O_4 give 9 mmol electrons; MnO_4^- takes 5, so 1.8 mmol $KMnO_4$ = 1.8/0.06 = 30 mL.

Q24. Answer 4. More than 4 BM needs at least 4 unpaired electrons (3 gives 3.87 BM). Mn^{2+} $3d^5$, Mn^{3+} $3d^4$, Fe^{2+} $3d^6$ and Fe^{3+} $3d^5$ qualify. Co^{2+} $3d^7$ has 3; the rest have fewer. Answer 4.

Q25. Answer 173. In MnO_4^{2-}, x − 8 = −2, so Mn is +6: $3d^1$, one unpaired electron. μ = √(1 × 3) = 1.732 BM, so 100x = 173.

All questions are original and © Master Testing Agency. Free to download and use for personal practice; not for resale. Every answer in this paper was checked independently by computer: configurations and unpaired electrons from the Aufbau rules with the known exceptions, spin-only moments from √(n(n + 2)), oxidation states by charge balance, redox equations balanced by an exact atom-and-charge solver, and trends against tables of measured values typed in separately from the questions.