The d- and f-Block Elements

Standard difficulty · 20 questions · 40 marks · Time: 42 minutes

Name: _____ Date: _____ Score: ____ / 40

Show your working for Sections B and C. Answers are on the last page — try every question first!

Section A — Choose the correct answer 8 × 1 = 8 marks

1. Transition elements have partly filled:

(a) p orbitals **(b)** f orbitals only

(c) s orbitals only **(d)** d orbitals in the atom or a common ion

2. The ground-state electronic configuration of chromium (Cr, Z = 24) is:

(a) [Ar] $3d^5\ 4s^1$ **(b)** [Ar] $3d^6$ **(c)** [Ar] $4s^2\ 4p^4$ **(d)** [Ar] $3d^3\ 4s^2$

3. The electronic configuration of Ni^{2+} (Z of Ni = 28) is:

(a) [Ar] $3d^7\ 4s^1$ **(b)** [Ar] $3d^9$ **(c)** [Ar] $3d^8$ **(d)** [Ar] $3d^6\ 4s^2$

4. The spin-only magnetic moment of Ti^{4+} (Z of Ti = 22) is:

(a) $\sqrt{8} \approx 2.83$ BM **(b)** $\sqrt{3} \approx 1.73$ BM

(c) 0 BM (diamagnetic) **(d)** $\sqrt{35} \approx 5.92$ BM

5. The oxidation state of Mn in MnO_4^- is:

(a) +7 **(b)** +6 **(c)** +8 **(d)** +5

6. Which of these ions is colourless in aqueous solution?

(a) Cr^{3+} **(b)** Ti^{4+} **(c)** Mn^{2+} **(d)** Cr^{2+}

7. Which has the larger spin-only magnetic moment, Fe^{2+} or Ti^{3+}?

(a) Fe^{2+} **(b)** neither; both are diamagnetic

(c) Ti^{3+} **(d)** both have the same moment

8. Assertion (A): Aqueous solutions of V^{2+} salts are coloured.
Reason (R): All transition-metal ions are coloured, whatever their d-electron count.

(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, but R is true.

Section B — Short answer 8 × 2 = 16 marks

9. Why are transition metal ions usually coloured?

10. Write the electronic configuration of Sc^{3+} (Z of Sc = 21), and find the number of unpaired electrons and the spin-only magnetic moment.

11. Find the oxidation state of Fe in FeO_4^{2-}, and the number of 3d electrons the Fe atom has in that state.

12. How many moles of oxalic acid are oxidised by 0.015 mol of $KMnO_4$ in acid solution?

13. A metal ion has a spin-only magnetic moment of 4.90 BM. How many unpaired electrons does it have? Name one ion that fits.

14. How many 4f electrons does Lu^{3+} (Z = 71) have, and how many of them are unpaired?

15. 45 mL of 0.16 M $KMnO_4$ solution reacts completely with H_2O_2 in acid. How many moles of H_2O_2 react?

16. Compare Ti^{4+} and Co^{3+}: give the d-electron configuration and spin-only magnetic moment of each, and say which would be coloured.

Section C — Word problems — 4 × 4 = 16 marks

17. Describe the preparation of potassium dichromate from chromite ore, with equations.

18. For each of Cu^{2+}, Cu^{+}, Co^{2+}: write the 3d configuration, the number of unpaired electrons, the spin-only magnetic moment, and say whether its aqueous solution is coloured.

19. 25 mL of a oxalic acid solution needs 37 mL of 0.07 M $KMnO_4$ for complete reaction in acid. Write the ionic equation and find the molarity of the oxalic acid solution.

20. Compare Lu^{3+} ($Z = 71$) and Gd^{3+} ($Z = 64$): give the number of 4f electrons and unpaired electrons in each, and say which ion is smaller and why.

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Answer key

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Q	Answer	Working
1	**(d) d orbitals in the atom or a common ion**	—
2	**(a) [Ar] $3d^5$ $4s^1$**	a half-filled or filled 3d set is extra stable
3	**(c) [Ar] $3d^8$**	4s electrons are removed before 3d
4	**(c) 0 BM (diamagnetic)**	$3d^0$: 0 unpaired electrons
5	**(a) +7**	O is −2, K is +1; the sum equals the charge
6	**(b) Ti^{4+}**	Ti^{4+} is $3d^0$: no d–d transition is possible
7	**(a) Fe^{2+}**	Fe^{2+}: 4 unpaired; Ti^{3+}: 1 unpaired
8	**(c) A is true, but R is false.**	A is true: V^{2+} is $3d^3$. R is false.
9	**Their partly filled d orbitals split in the presence of ligands, and an electron absorbs visible light to jump to a higher d level (d–d transition); the colour seen is the complementary colour.**	—
10	**[Ar] $3d^0$; 0 unpaired; 0 BM (diamagnetic)**	$\mu = \sqrt{(n(n+2))}$ BM
11	**+6; 2 ($3d^2$)**	Z of Fe = 26; d electrons = Z − 18 − oxidation state
12	**0.0375 mol**	$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$
13	**4 unpaired; e.g. Cr^{2+} or Mn^{3+} or Fe^{2+} or Co^{3+}**	$\sqrt{(n(n+2))} = 4.90 \Rightarrow n = 4$
14	**$4f^{14}$: 14 electrons; 0 unpaired**	Ln^{3+} has [Xe] $4f^n$ with n = Z − 57
15	**0.018 mol**	moles of $KMnO_4$ = 0.16 × 45/1000; $2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 2Mn^{2+} + 5O_2 + 8H_2O$
16	**Ti^{4+}: $3d^0$, 0 BM (diamagnetic), colourless; Co^{3+}: $3d^6$, $\sqrt{24} \approx 4.90$ BM, coloured**	d^0 and d^{10} ions are colourless
17	**Chromite is fused with sodium carbonate in air: $4FeCr_2O_4 + 8Na_2CO_3 + 7O_2 \rightarrow 8Na_2CrO_4 + 2Fe_2O_3 + 8CO_2$. The yellow sodium chromate is acidified: $2Na_2CrO_4 + 2H^+ \rightarrow Na_2Cr_2O_7 + 2Na^+ + H_2O$. Adding KCl gives the less soluble orange $K_2Cr_2O_7$: $Na_2Cr_2O_7 + 2KCl \rightarrow K_2Cr_2O_7 + 2NaCl$.**	—
18	**Cu^{2+}: $3d^9$, 1 unpaired, $\sqrt{3} \approx 1.73$ BM, coloured; Cu^+: $3d^{10}$, 0 unpaired, 0 BM**	Z: Cu 29, Cu 29, Co 27

Q	Answer	Working
	(diamagnetic), colourless; Co^{2+}: $3d^7$, 3 unpaired, $\sqrt{15} \approx 3.87$ BM, coloured	
19	**$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$; 0.259 M**	moles of oxalic acid = 2.5 × moles of $KMnO_4$
20	**Lu^{3+}: $4f^{14}$, 0 unpaired; Gd^{3+}: $4f^7$, 7 unpaired; Lu^{3+} is smaller because of the lanthanoid contraction (poor shielding by 4f electrons as Z rises)**	Ln^{3+}: $4f^n$, $n = Z - 57$