No d Electrons, Still Purple: Why $KMnO_4$ Is So Intensely Coloured

In MnO_4^- manganese is +7 ($3d^0$), so no d–d transition is possible. The colour comes from ligand-to-metal charge transfer: visible light moves an electron from an oxygen into the empty d orbitals of Mn. This absorbs green-yellow light (≈ 525 nm), so the solution looks purple. Charge transfer is an allowed transition, so it absorbs far more light than restricted d–d transitions: $KMnO_4$ is intensely coloured while $Ti^{3+}(aq)$ or $Mn^{2+}(aq)$ are pale. Chromate (yellow) and dichromate (orange), also d^0, are coloured the same way.

Name: _____ Date: _____ Score: ____ / 24

A. Fill in the blanks

1. In MnO_4^-, manganese is in the ____ oxidation state.

2. Mn^{7+} has the configuration 3d____.

3. The colour of $KMnO_4$ is due to ligand-to-metal ____ transfer.

4. $KMnO_4$ absorbs ____-yellow light.

5. In MnO_4^-, the electron moves from ____ to manganese.

B. True or False

6. The purple colour of $KMnO_4$ comes from d–d transitions. True / False

7. Charge-transfer transitions are usually more intense than d–d transitions. True / False

8. Chromate and dichromate are coloured by charge transfer. True / False

9. $KMnO_4$ appears purple because it absorbs purple light. True / False

10. $Sc^{3+}(aq)$ is colourless. True / False

C. Assertion and reason

11. Assertion (A): MnO_4^- is coloured although Mn is d^0.
Reason (R): An electron moves from O to the empty d orbitals of Mn on absorbing visible light.

(a) Both A and R are true, and R explains A
(b) Both A and R are true, but R does not explain A
(c) A is true, R is false
(d) A is false, R is true

Answer: _____

12. Assertion (A): $KMnO_4$ solution is far more intensely coloured than $Ti^{3+}(aq)$.
Reason (R): Charge transfer is allowed; d–d transitions are restricted.

(a) Both A and R are true, and R explains A
(b) Both A and R are true, but R does not explain A
(c) A is true, R is false
(d) A is false, R is true

Answer: _____

D. Choose the correct option

13. The number of d electrons in Mn^{7+} is:

(a) 0
(b) 2
(c) 5
(d) 7

Answer: _____

14. The colour of MnO_4^- is due to:

(a) d–d transition
(b) LMCT
(c) MLCT
(d) f–f transition

Answer: _____

15. Which is coloured by charge transfer?

(a) $[Ti(H_2O)_6]^{3+}$
(b) $[Cu(H_2O)_6]^{2+}$
(c) $Cr_2O_7^{2-}$
(d) $[Ni(H_2O)_6]^{2+}$

Answer: _____

16. At the same concentration, which is most intensely coloured?

(a) $Ti^{3+}(aq)$
(b) $Mn^{2+}(aq)$
(c) MnO_4^-
(d) $Sc^{3+}(aq)$

Answer: _____

17. $KMnO_4$ absorbs most strongly near:

(a) 400 nm
(b) 525 nm
(c) 650 nm
(d) 750 nm

Answer: _____

18. Why is d–d absorption weak?

(a) it is restricted (forbidden by symmetry)
(b) there are no electrons
(c) it is in the UV
(d) it needs a magnet

Answer: _____

E. Numerical problems

19. Find the oxidation state of Mn in $KMnO_4$.

20. Find the oxidation state of Cr in $K_2Cr_2O_7$ and its d-electron count.

F. Short answer questions

21. Explain the colour of $KMnO_4$.

22. Why are charge-transfer colours intense?

23. Name two ions other than MnO_4^- coloured by charge transfer.

G. Match the columns

24. Match each item in Column A with the correct item in Column B.

Column A	Column B	Your answer
1. MnO_4^-	(a) d^1, pale purple, d–d	1 → ____
2. $Ti^{3+}(aq)$	(b) d^0, purple, O → Mn charge transfer	2 → ____

Detailed solutions

1. +7

2. ^{0}

3. charge

4. green

5. oxygen

6. False. Mn^{7+} is d^0.

7. True. They are allowed.

8. True. Cr(VI) is d^0.

9. False. It absorbs green-yellow.

10. True. d^0, no visible absorption.

11. (a) Charge transfer.

12. (a) Many more photons absorbed.

13. (a) 0. $3d^0$.

14. (b) LMCT. O → Mn.

15. (c) $Cr_2O_7^{2-}$. Cr(VI), d^0.

16. (c) MnO_4^-. Allowed CT absorption.

17. (b) 525 nm. Green-yellow.

18. (a) it is restricted (forbidden by symmetry). Laporte rule.

19. +1 + x + 4(−2) = 0. **Answer: +7**

20. 2(+1) + 2x + 7(−2) = 0. **Answer: +6, $3d^0$**

21. Mn is +7 ($3d^0$), so no d–d transition. Visible light (green-yellow, ≈ 525 nm) moves an electron from oxygen to the empty d orbitals of Mn (ligand-to-metal charge transfer); the remaining red + blue light looks purple.

22. Charge-transfer transitions are allowed, whereas d–d transitions are restricted by symmetry (Laporte rule), so many more photons are absorbed in charge transfer.

23. CrO_4^{2-} (yellow) and $Cr_2O_7^{2-}$ (orange); both contain Cr(VI), d^0, with O → Cr charge transfer.

24. 1 → (b), 2 → (a).