One Drop, Blood Red: Why Transition Metals Form Complexes

A complex is a central metal ion bonded to several ligands (anions or neutral molecules) by coordinate bonds, in which the ligand gives both electrons. One drop of KSCN turns pale-yellow Fe^{3+} blood red as $[Fe(SCN)(H_2O)_5]^{2+}$ forms, while the K^+ from the same drop grabs nothing. Transition-metal ions form far more complexes because they are small (Fe^{3+} 65 pm vs K^+ 138 pm), highly charged (+3 vs +1) and have d orbitals available for bond formation.

Name: Date: Score: ____ / 25

A. Fill in the blanks

1. A species in which a metal ion binds a number of anions or neutral molecules is called a ____.

2. The molecules or ions bound to the central metal ion are called ____.

3. In a coordinate bond, both electrons of the bond come from the ____.

4. A ligand donates a ____ pair of electrons to the metal ion.

5. Fe^{3+} with thiocyanate gives a ____-red complex.

6. Transition-metal ions are small, highly charged and have ____ orbitals available for bonding.

B. True or False

7. K^+ forms the blood-red complex in the KSCN test for Fe^{3+}. True / False

8. A smaller, more highly charged ion attracts a ligand's lone pair more strongly. True / False

9. Only transition metals can form complexes. True / False

10. $[Cu(NH_3)_4]^{2+}$ contains four coordinate bonds from N to Cu. True / False

11. In a coordinate bond the metal supplies one electron and the ligand one. True / False

C. Assertion and reason

12. Assertion (A): Fe^{3+} forms complexes more readily than K^+.
Reason (R): Fe^{3+} is smaller and more highly charged than K^+.

(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: _____

13. Assertion (A): NH_3 acts as a ligand.
Reason (R): NH_3 has a lone pair of electrons on nitrogen.

(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

14. Which ion forms complexes most readily?

(a) K^+ (b) Na^+

(c) Fe^{3+} (d) Rb^+

Answer: _____

15. The charge on the complex of Fe^{3+} with six CN^- is:

(a) +3 (b) −3

(c) −4 (d) −6

Answer: _____

16. Which is a ligand?

(a) Na^+ (b) NH_3

(c) Fe^{3+} (d) K^+

Answer: _____

17. In $[PtCl_4]^{2-}$ the central ion is:

(a) Pt^{2+} (b) Pt^{4+}

(c) Cl^- (d) Pt^0

Answer: _____

18. Haemoglobin carries oxygen using a complex of:

(a) copper (b) cobalt

(c) iron (d) zinc

Answer: _____

19. Which pair shows the larger ion first?

(a) Fe^{3+}, K^+ (b) K^+, Fe^{3+}

(c) Fe^{3+}, Fe^{2+} (d) Cu^{2+}, K^+

Answer: _____

E. Numerical problems

20. Find the charge on the complex formed by Cr^{3+} and six NH_3.

21. Using radii Fe^{3+} = 65 pm and K^+ = 138 pm, compare charge ÷ radius.

F. Short answer questions

22. Give three reasons why transition metals form a large number of complexes.

23. What is a coordinate bond? Explain with $[Cu(NH_3)_4]^{2+}$.

24. Why does a drop of KSCN turn an Fe^{3+} solution blood red but not a KCl solution?

G. Match the columns

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

Column A	Column B	Your answer
1. $[Fe(CN)_6]^{3-}$	(a) blood red, test for Fe^{3+}	1 → ____
2. $[Cu(NH_3)_4]^{2+}$	(b) Fe^{3+} with six CN^-	2 → ____
3. $[PtCl_4]^{2-}$	(c) Pt^{2+} with four Cl^-	3 → ____
4. $[Fe(SCN)(H_2O)_5]^{2+}$	(d) Fe holds O_2 in blood	4 → ____
5. haem	(e) deep blue, four NH_3	5 → ____

Detailed solutions

1. complex

2. ligands

3. ligand

4. lone

5. blood

6. d

7. False. K^+ is a spectator; the red complex is $[Fe(SCN)(H_2O)_5]^{2+}$.

8. True. High charge density.

9. False. Others can (Al^{3+}, Mg^{2+}), but transition metals form far more.

10. True. Each NH_3 donates its lone pair on N.

11. False. The ligand supplies both electrons.

12. (a) The correct reason; available d orbitals also help.

13. (a) It donates the pair to the metal ion.

14. (c) Fe^{3+}. Small size and +3 charge.

15. (b) −3. +3 − 6 = −3.

16. (b) NH_3. NH_3 has a lone pair on N.

17. (a) Pt^{2+}. x + 4(−1) = −2, x = +2.

18. (c) iron. Haem: Fe bound to four N atoms.

19. (b) K^+, Fe^{3+}. K^+ 138 pm > Fe^{3+} 65 pm.

20. +3 + 6(0). **Answer: +3: $[Cr(NH_3)_6]^{3+}$**

21. 3/65 ≈ 0.046; 1/138 ≈ 0.0072; ratio ≈ 6.4. **Answer: Fe^{3+} about 6 times larger**

22. Comparatively small size of their ions; high ionic charge; availability of d orbitals for bond formation (NCERT 4.3.11).

23. A bond in which both shared electrons come from one atom. In $[Cu(NH_3)_4]^{2+}$ each NH_3 donates the lone pair on N to Cu^{2+} (N → Cu), giving four coordinate bonds.

24. SCN^- replaces a water ligand on Fe^{3+} forming the blood-red complex $[Fe(SCN)(H_2O)_5]^{2+}$. K^+ (big, +1) does not hold the ligand, and KCl has no Fe^{3+}.

25. 1 → (b), 2 → (e), 3 → (c), 4 → (a), 5 → (d). Match each complex with its description.