CHEM1612 Worksheet 9 – Answers to Critical Thinking Questions

The worksheets are available in the tutorials and form an integral part of the learning outcomes and experience for this unit.

Model 1: The Stability of Complexes

1. (a) $[Cu(NH_3)_4]^{2+}$

   (b) $Zn^{2+}(aq)$

2. (a) $[Pb(EDTA)]^{2-}$. If it were not, then the therapy would not work.

   (b) $EDTA^{4-}$ forms strongly bonded complexes with Ca^{2+} and it would strip them from the bones.

3. *Very* little.

4. $[Ag^+]_{init} = 0.0100$ M $\qquad [CN^-]_{init} = 0.50$ M

5. $[CN^-]_{equilibrium} = (0.50 - 2 \times 0.0100)$ M $= 0.48$ M

6. $[Ag(CN)_2^-]_{equilibrium} \approx [Ag^+]_{init} = 0.0100$ M

7. $K_{stab} = \dfrac{[Ag(CN)_2{}^-]}{[Ag^+][CN^-]^2} = \dfrac{(0.0100)}{[Ag^+](0.48)^2} = 1 \times 10^{20}$ so $[Ag^+] = 4 \times 10^{-22}$ M

8. Nothing as $[Ag(CN)_2^-]$ is more stable than $[Ag(NH_3)_2]^+$.

9. $[Cu^{2+}(aq)] = 2 \times 10^{-16}$ M.

   Hint: $K_{stab} = \dfrac{[Cu(NH_3)_4{}^{2+}]}{[Cu^{2+}][NH_3]^4} = \dfrac{(0.200)}{[Cu^{2+}](3.20)^4}$

Model 2: Using Complexation to Increase Solubilty

1. The solubility of Fe_2O_3 is *very* small - the equibrium for the reaction below lies far to the left:

   $$Fe_2O_3(s) + \text{excess } H_2O \rightleftharpoons 2Fe^{3+}(aq) + 6OH^-(aq)$$

   Complexation of Fe^{3+} ions with *Desferal* is very favourable – the equilibrium for the complexation reaction far to the right (as K for this reaction is $10^{30.6}$). The Desferal complexes all free $Fe^{3+}(aq)$ ions, so more Fe_2O_3 must dissolve to re-establish the first equilibrium (le Chatelier's principle). Eventually all the Fe_2O_3 will dissolve.

2. All of the O atoms could potentially form metal-ligand bonds. The N atoms are either in amide groups or are protonated. These are not basic also cannot act as Lewis bases to a metal ion.

3. (a) $K = \dfrac{[HgI_4{}^{2-}]}{[I^-]^2}$

   (b) $K_{stab} = \dfrac{[HgI_4{}^{2-}]}{[Hg^{2+}][I^-]^4} \qquad K_{sp} = [Hg^{2+}][I^-]^2$

   (c) $K = K_{stab} \times K_{sp}$ as $\dfrac{[HgI_4{}^{2-}]}{[Hg^{2+}][I^-]^4} \times [Hg^{2+}][I^-]^2 = \dfrac{[HgI_4{}^{2-}]}{[I^-]^2}$

   $K = 10^{30.28} \times 10^{-10.37} = 10^{19.91}$

(d) The reaction is Hg^{2+} (aq) + $4I^-$(aq) $\rightleftharpoons$ HgI_4^{2-}(aq), which corresponds to K_{stab}. The calculation is the same as in Model 1.

$[Hg^{2+}]_{init} = 0.030$ M $[I^-]_{init} = 0.200$ M

$[I^-]_{equilibrium} = (0.200 - 4 \times 0.030)$ M $= 0.080$ M

$[HgI_4^{2-}]_{equilibrium} \approx [Hg^{2+}]_{init} = 0.030$ M

$$K_{stab} = \frac{[HgI_4^{2-}]}{[Hg^{2+}][I^-]^4} = \frac{(0.030)}{[Hg^{2+}](0.080)^4} = 10^{30..28} \text{ so } [Hg^{2+}] = 3.8 \times 10^{-28} \text{ M}$$

Model 3: The electronic configuration of transition metal cations

1 – 2. See table below.

Coordination Compound or Complex	Oxidation Number	*d* Configuration	Electron Arrangement	Paramagnetic?
$Na[MnO_4]$	+7	d^0	[ ][ ][ ][ ][ ]	No
$(NH_4)_2[CoCl_4]$	+2	d^7	[↑↓][↑↓][↑][↑][↑]	Yes
$[Cr(NH_3)_5(H_2O)]Cl_3$	+3	d^3	[↑][↑][↑][ ][ ]	Yes
$[Zn(en)_2Cl_2]$	+2	d^{10}	[↑↓][↑↓][↑↓][↑↓][↑↓]	No

Model 4: Transferrin

Iron is found in many biological molecules. Typical of its coordination chemistry in fairly recently evolved systems is *transferrin*, which is used to transport iron in the blood. The Fe(III) atom is bonded to O and N atoms through five ligands: 4 amino acids and 1 carbonate anion (CO_3^{2-}).

Critical thinking questions

1. Five unpaired electrons.
2. Coordination number is 6 and coordination geometry is approximately octahedral. CO_3^{2-} bonds through 2 O atoms (it is bidentate).
3. CO_3^{2-} is a weak base and will become protonated at low pH. This will lead to it detaching from the iron.