Answer all the questions below as fully as you can then check your answers

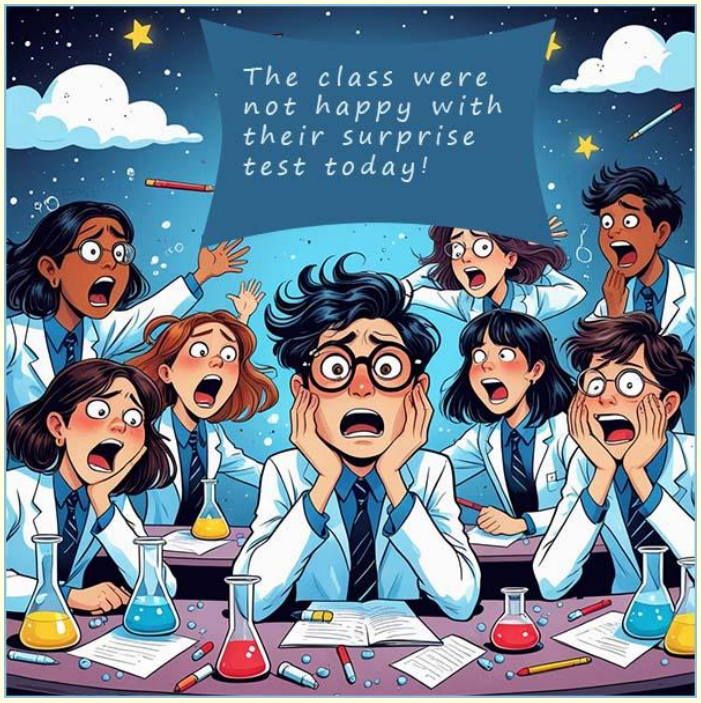
1. Which of the following statements is true about a hexaaquacopper(II) complex?

A. The central metal ion forms covalent bonds with the ligands.

B. The water ligands act as Lewis acids.

C. The geometry of the complex is octahedral.

D. Substitution of water ligands with chloride ligands results in no geometry change.



2. What is the primary reason why $[Cu(NH_2CH_2CH_2NH_2)_3]^{2+}$ is more stable than $[Cu(H_2O)_6]^{2+}$?

A. Chelate effect and entropy increase

B. Decrease in coordination number

C. Presence of stronger hydrogen bonds

D. Reduced ionic charge

3. Define a ligand substitution reaction and give an example involving copper(II) ions.

4. Explain why the geometry of a complex changes from octahedral to tetrahedral during the substitution of water ligands with chloride ligands.

5. In the reaction:

$$[Cu(H_2O)_6]^{2+} + 3(en) \rightleftharpoons [Cu(en)_3]^{2+} + 6H_2O$$

a. Is the entropy change for this reaction a favourable one?

b. Considering your answer to part a how does this affect the stability of the complex?

6. When concentrated hydrochloric acid is added to a solution of hexaaquacobalt(II) ions, a colour change occurs.

a) What is the initial and final colour of the solution?

b) Write the equation for the reaction.

c) Explain the role of Le Chatelier's Principle in this reaction.

7. Compare the stability of $[Cu(NH_3)_4(H_2O)_2]^{2+}$ and $[CuCl_4]^{2-}$ based on their equilibrium constants. Why might $[Cu(NH_3)_4(H_2O)_2]^{2+}$ be more stable?

8. A dilute solution of copper(II) chloride appears blue but as the concentration of the solution increases a solution of copper(II) chloride appears green. Use Le Chatelier's Principle to explain this observation.

9. Explain the chelate effect and why it contributes to the formation of more stable complexes. Use the example of ethylenediamine (en) replacing water ligands in $[Cu(H_2O)_6]^{2+}$.

10. Predict the geometry and coordination number of a complex formed when ethylenediamine (en) reacts with cobalt(III) ions. Explain your reasoning.

Answers

1. Which of the following statements is true about a hexaaquacopper(II) complex?

A. The central metal ion forms covalent bonds with the ligands.

B. The water ligands act as Lewis acids.

C. The geometry of the complex is octahedral.

D. Substitution of water ligands with chloride ligands results in no geometry change.

Answer: A and C

2. What is the primary reason why $[Cu(NH_2CH_2CH_2NH_2)_3]^{2+}$ is more stable than $[Cu(H_2O)_6]^{2+}$?

A. Chelate effect and entropy increase

B. Decrease in coordination number

C. Presence of stronger hydrogen bonds

D. Reduced ionic charge

Answer: A

3. Define a ligand substitution reaction and give an example involving copper(II) ions.

Answer: A ligand substitution reaction involves the replacement of one or more ligands in a complex ion with different ligands, breaking and forming coordinate bonds. For example:

$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightleftharpoons [CuCl_4]^{2-} + 6H_2O$

4. Explain why the geometry of a complex changes from octahedral to tetrahedral during the substitution of water ligands with chloride ligands.

Answer: Chloride ligands are larger and negatively charged, causing repulsion between them. As a result, only four chloride ligands can fit around the central metal ion, leading to a tetrahedral geometry.

5. In the reaction:

$[Cu(H2O)6]2+ + 3(en) \rightleftharpoons [Cu(en)3]2+ + 6H2O$

a. Is the entropy change for this reaction a favourable one?

b. Considering your answer to part a how does this affect the stability of the complex?

Answer: The increase in the number of particles from 4 to 7 results in an increase in entropy. Higher entropy favours the formation of the product ($[Cu(en)_3]^{2+}$), making it more stable due to the chelate effect.

6. When concentrated hydrochloric acid is added to a solution of hexaaquacobalt(II) ions, a colour change occurs.

a) What is the initial and final colour of the solution?

b) Write the equation for the reaction.

c) Explain the role of Le Chatelier's Principle in this reaction.

Answers:

a) The solution changes from pink to blue.

b) $[Co(H_2O)_6]^{2+} + 4Cl^- \rightleftharpoons [CoCl_4]^{2-} + 6H_2O$

c) Adding Cl^- shifts the equilibrium towards the product ($[CoCl_4]^{2-}$), favouring the blue complex. Dilution shifts it back towards the pink reactant complex.

7. Compare the stability of $[Cu(NH_3)_4(H_2O)_2]^{2+}$ and $[CuCl_4]^{2-}$ based on their equilibrium constants. Why might $[Cu(NH_3)_4(H_2O)_2]^{2+}$ be more stable?

Answer: $[Cu(NH_3)_4(H_2O)_2]^{2+}$ has a larger equilibrium constant, indicating greater stability. Ammonia ligands form stronger coordinate bonds with copper(II) due to their lone pairs and higher donor strength compared to chloride ligands.

8. A dilute solution of copper(II) chloride appears blue but as the concentration of the solution increases a solution of copper(II) chloride appears green. Use Le Chatelier's Principle to explain this observation.

Answer: In a dilute solution, the blue $[Cu(H_2O)_6]^{2+}$ complex predominates. As the concentration of Cl^- increases, the equilibrium shifts to form more yellow $[CuCl_4]^{2-}$ ions. The green colour is due to the mixture of blue and yellow complexes.

9. Explain the chelate effect and why it contributes to the formation of more stable complexes. Use the example of ethylenediamine (en) replacing water ligands in $[Cu(H_2O)_6]^{2+}$.

Answer: The chelate effect arises because replacing monodentate ligands with multidentate ligands increases entropy. In the example:

$[Cu(H_2O)_6]^{2+} + 3(en) \rightleftharpoons [Cu(en)_3]^{2+} + 6H_2O$

The number of particles increases from 4 to 7, increasing disorder and driving the equilibrium towards the product. This effect enhances the stability of the complex.

10. Predict the geometry and coordination number of a complex formed when ethylenediamine (en) reacts with cobalt(III) ions. Explain your reasoning.

Answer: Ethylenediamine is a bidentate ligand, so three en molecules can replace six monodentate water ligands. The resulting complex will have a coordination number of 6 and an octahedral geometry.