Q1. An excess of a given reagent is added to each of the following pairs of aqueous metal ions.

For each metal ion, state the initial colour of the solution and the final observation that you would make.

In each case, write an overall equation for the formation of the final product from the initial aqueous metal ion.

(a) An excess of aqueous sodium carbonate is added to separate aqueous solutions containing $[Fe(H_2O)_6]^{2+}$ and $[Fe(H_2O)_6]^{3+}$.

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(5)

(b) An excess of concentrated hydrochloric acid is added to separate aqueous solutions containing $[Cu(H_2O)_6]^{2+}$ and $[Co(H_2O)_6]^{2+}$.

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(4)

(c) An excess of dilute aqueous sodium hydroxide is added to separate aqueous

solutions containing $[Fe(H_2O)_6]^{2+}$ and $[Cr(H_2O)_6]^{3+}$.

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(4)

(d) An excess of dilute aqueous ammonia is added to separate aqueous solutions containing $[Al(H_2O)_6]^{3+}$ and $[Ag(H_2O)_2]^{+}$

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(4)
(Total 17 marks)

Q2. This question is about test-tube reactions of some ions in aqueous solution.

For each reaction in parts (a) to (d), state the colour of the original solution.
State what you would observe after the named reagent has been added to the solution.
In each case, write an equation for the reaction that occurs.

(a) An excess of dilute sulfuric acid is added to a solution containing CrO_4^{2-} ions.

Colour of original solution .....

Observation after an excess of reagent has been added .....

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Equation

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(3)

(b) Sodium hydroxide solution is added to a solution containing $[Fe(H_2O)_6]^{3+}$ ions.

Colour of original solution .....

Observation after reagent has been added .....

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Equation

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(3)

(c) An excess of ammonia solution is added to a solution containing $[Cu(H_2O)_6]^{2+}$ ions.

Colour of original solution .....

Observation after an excess of reagent has been added .....

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Equation

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(3)

(d) Sodium carbonate solution is added to a solution containing $[Al(H_2O)_6]^{3+}$ ions.

Colour of original solution .....

Observations after reagent has been added .....

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Equation

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(4)
(Total 13 marks)

Q3. Iron(II) sulfate is used to kill weeds in garden lawns. It is a by-product of the manufacture of steel.
When a lawn is treated with iron(II) sulfate, the iron(II) ions are oxidised to form iron(III) ions.

Iron(III) ions are acidic in aqueous solution as shown by the following equation.

$$[Fe(H_2O)_6]^{3+}(aq) \rightleftharpoons [Fe(H_2O)_5(OH)]^{2+}(aq) + H^+(aq)$$

In an experiment, a calibrated pH meter was used to measure the pH of an iron(III) salt in solution. At 20 °C the pH of a 0.100 mol dm^{-3} solution of iron(III) sulfate was found to be 1.62.

(a) Explain briefly why a pH meter should be calibrated before use.

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(b) Write an expression for the equilibrium constant, K_a, for the dissociation of iron(III) ions in aqueous solution.

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(1)

(c) Use your answer from part (b) to calculate the value of K_a for this reaction at 20 °C. Give your answer to the appropriate precision. Show your working.

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(d) Name the substance that is most likely to oxidise the iron(II) ions when iron(II) sulfate is used as a weed killer.

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(1)

(e) Suggest a value for the pH of a 0.100 mol dm^{-3} solution of iron(II) sulfate.

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(1)
(Total 8 marks)

Q4. In its reactions with transition metal ions, ammonia can act as a Brønsted–Lowry base and as a Lewis base.

(a) Define the term *Lewis base*.

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(b) Write an equation for a reaction between aqueous copper(II) ions ($[Cu(H_2O)_6]^{2+}$) and ammonia in which ammonia acts as a Brønsted–Lowry base. State what you would observe.

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(Extra space) .....

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(2)

(c) Write an equation for a different reaction between aqueous copper(II) ions ($[Cu(H_2O)_6]^{2+}$) and ammonia in which ammonia acts as a Lewis base but **not** as a Brønsted–Lowry base. State what you would observe.

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(Extra space) .....

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(2)

(d) An excess of dilute ammonia solution is added to an aqueous solution containing iron(II) ions in a test tube that is then left to stand for some time.
State and explain what you would observe.

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(4)

(e) Diaminoethane ($H_2NCH_2CH_2NH_2$), like ammonia, can react as a base and as a ligand.

(i) Write an equation for the reaction that occurs between an aqueous solution of aluminium chloride and an excess of aqueous diaminoethane.
Describe the appearance of the aluminium-containing reaction product.

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(Extra space) .....

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(3)

(ii) Write an equation for the reaction that occurs between an aqueous solution of cobalt(II) sulfate and an excess of aqueous diaminoethane.
Draw a diagram to show the shape of and bonding in the complex product.
Write an equation for the reaction that would occur if the complex product of this reaction were allowed to stand in contact with oxygen gas.

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(5)
(Total 17 marks)