AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



EXAM QUESTION PACK

3.2.6 REACTIONS OF IONS IN AQUEOUS SOLUTION

SCORE	PERCENTAGE
/205	%

STEMUP

These questions belong to AQA, not to us.

The examination questions, mark schemes and examiner reports in this pack were written and published by AQA. They are past assessment materials, reproduced here so that students can revise from them.

What we do not own

STEMUP is not affiliated with AQA and does not own, and makes no claim to own, any of the question, mark scheme or examiner report material in this pack. AQA has not endorsed, approved or been involved in the production of it. AQA and the qualification titles used here belong to their respective owners and appear for identification only.

Where to find the originals

AQA publishes its past papers, mark schemes and examiner reports free of charge. Always check the current specification at aqa.org.uk before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

Q1.

(a) When anhydrous aluminium chloride reacts with water, solution **Y** is formed that contains a complex aluminium ion, **Z**, and chloride ions.

Give an equation for this reaction.

_____

(1)

(b) Give an equation to show how the complex ion **Z** can act as a Brønsted–Lowry acid with water.

_____

(1)

(c) Describe **two** observations you would make when an excess of sodium carbonate solution is added to solution **Y**.

Give an equation for the reaction. In your equation, include the formula of each complex aluminium species.

Observation 1 _____

_____

Observation 2 _____

_____

Equation _____

(3)

(d) Aqueous potassium hydroxide is added, until in excess, to solution **Y**.

Describe **two** observations you would make.
For each observation give an equation for the reaction that occurs.
In your equations, include the formula of each complex aluminium species.

Observation 1 _____

_____

Equation 1

_____

Observation 2 _____

_____

Equation 2

_____

(4)

(Total 9 marks)

STEMUP.CO.UK

Q2.

The following tests were carried out to identify an unknown green salt **Y**.

An aqueous solution of **Y** gave a cream precipitate of compound **A** when reacted with silver nitrate solution.

Compound **A** gave a colourless solution when reacted with concentrated ammonia solution.

Another aqueous solution of **Y** gave a green precipitate **B** when reacted with sodium carbonate solution.

The green precipitate **B** was filtered and dried and then reacted with sulfuric acid to give a pale green solution containing compound **C** and a colourless gas **D**.

(a) Identify by name or formula the compounds **A**, **B**, **C**, **D** and **Y**.

Identity of **A** _____

Identity of **B** _____

Identity of **C** _____

Identity of **D** _____

Identity of **Y** _____

(5)

(b) Write the simplest ionic equation for the reaction of silver nitrate solution with the anion that is present in compound **Y**.

_____

(1)

(c) Write the simplest ionic equation for the reaction that occurs between the green precipitate **B** and sulfuric acid.

_____

(1)

(Total 7 marks)

Q3.

Iron forms many complexes that contain iron in oxidation states +2 and +3.

(a) Hexaaquairon(III) ions react with an excess of hydrochloric acid in a ligand substitution reaction.

Write an equation for this reaction.

STEMUP.CO.UK

_____

(1)

(b) Explain why the initial and final iron(III) complexes in the equation above have different shapes.

_____

_____

_____

_____

_____

(2)

(c) Hexaaquairon(II) ions react with an excess of $H_2NCH_2CH_2NH_2$ in a ligand substitution reaction.

Draw the structure of the iron(II) complex formed showing its charge.

(2)

(d) Hexaaquairon(II) ions react with an excess of $H_2NCH_2CH_2NH_2$ in a ligand substitution reaction.

Which of the following shows the correct change in entropy for a reaction of hexaaquairon(II) ions with $H_2NCH_2CH_2NH_2$?

Tick (✓) **one** box.

change in entropy is negative ☐

change in entropy is close to zero ☐

change in entropy is positive ☐

(1)

(e) The percentage of iron(II) sulfate in iron tablets can be determined by titration with potassium manganate(VII) in acidic solution.

Deduce an ionic equation for the reaction of iron(II) ions with manganate(VII) ions.

STEMUP.CO.UK

_____

(1)

(f) A student dissolved 1980 mg of iron tablets in an excess of dilute sulfuric acid. The solution was titrated with 0.0200 mol dm^{-3} potassium manganate(VII) solution. A 32.50 cm^3 volume of potassium manganate(VII) solution was required to reach the end point in the titration.

Calculate the percentage of iron in the sample of iron tablets.
Give your answer to the appropriate number of significant figures.

Percentage _____ %

(4)

(g) State the colour change at the end point in this titration.

_____

(1)

(Total 12 marks)

Q4.

(a) A co-ordinate bond is formed when a transition metal ion reacts with a ligand.

Explain how this co-ordinate bond is formed.

_____

_____

_____

_____

_____

(2)

(b) Describe what you would observe when dilute aqueous ammonia is added dropwise, to excess, to an aqueous solution containing copper(II) ions.
Write equations for the reactions that occur.

_____

_____

_____

_____

STEMUP.CO.UK

_____

_____

_____

_____

_____

_____

(4)

(c) When the complex ion $[Cu(NH_3)_4(H_2O)_2]^{2+}$ reacts with 1,2-diaminoethane, the ammonia molecules but not the water molecules are replaced.

Write an equation for this reaction.

_____

(1)

(d) Suggest why the enthalpy change for the reaction in part **(c)** is approximately zero.

_____

_____

_____

_____

_____

(2)

(e) Explain why the reaction in part **(c)** occurs despite having an enthalpy change that is approximately zero.

_____

_____

_____

_____

_____

(2)

(Total 11 marks)

Q5.

What forms when a solution of sodium carbonate is added to a solution of gallium(III) nitrate?

A A white precipitate of gallium(III) carbonate. 

STEMUP.CO.UK

B A white precipitate of gallium(III) hydroxide. ⬭

C A white precipitate of gallium(III) carbonate and bubbles of carbon dioxide. ⬭

D A white precipitate of gallium(III) hydroxide and bubbles of carbon dioxide. ⬭

(Total 1 mark)

Q6.

Which compound gives a colourless solution when an excess of dilute aqueous ammonia is added?

A $MgCl_2$ ⬭

B $AgCl$ ⬭

C $CuCl_2$ ⬭

D $AlCl_3$ ⬭

(Total 1 mark)

Q7.

What is the final species produced when an excess of aqueous ammonia is added to aqueous aluminium chloride?

A $[Al(NH_3)_6]^{3+}$ ⬭

B $[Al(OH)_3(H_2O)_3]$ ⬭

C $[Al(OH)_4(H_2O)_2]^-$ ⬭

D $[Al(OH)(H_2O)_5]^{2+}$ ⬭

(Total 1 mark)

Q8.

(a) A sample of solid chromium(III) hydroxide displays amphoteric character when treated separately with dilute hydrochloric acid and with dilute aqueous sodium hydroxide.

Write an ionic equation for each of these reactions. Include the formula of each complex ion formed.
Describe the changes that you would observe in each reaction.

_____

_____

STEMUP.CO.UK

(5)

(b) Aqueous solutions of copper(II) sulfate and cobalt(II) sulfate undergo ligand substitution reactions when treated separately with an excess of dilute aqueous ammonia.

Write equations for these reactions. Include the formulae for any complex ions. Describe the changes that you would observe in each reaction.

(6)

(Total 11 marks)

Q9.

Corrosion can be defined as the degradation of a material when it comes into contact with the environment. For iron, this process is called rusting.

(a) When iron rusts it reacts with oxygen and water vapour in the air initially to form a brown, flaky solid that can be regarded as iron(III) hydroxide

Write an equation, including state symbols, for the overall reaction of the iron with oxygen and water vapour to form iron(III) hydroxide.

STEMUP.CO.UK

(2)

(b) Explain why this type of corrosion is not seen on aluminium structures that have been exposed to the environment for a similar time as iron structures.

_____

_____

_____

(2)

(Total 4 marks)

Q10.

A green solution, **X**, is thought to contain $[Fe(H_2O)_6]^{2+}$ ions.

(a) The presence of these ions can be confirmed by reacting separate samples of solution **X** with aqueous ammonia and with aqueous sodium carbonate.

Write equations for each of these reactions and describe what you would observe.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(b) A 50.0 cm^3 sample of solution **X** was added to 50 cm^3 of dilute sulfuric acid and made up to 250 cm^3 of solution in a volumetric flask.

A 25.0 cm^3 sample of this solution from the volumetric flask was titrated with a 0.0205 mol dm^{-3} solution of $KMnO_4$
At the end point of the reaction, the volume of $KMnO_4$ solution added was 18.70 cm^3.

(i) State the colour change that occurs at the end point of this titration and give a reason for the colour change.

_____

_____

STEMUP.CO.UK

_____

_____

(2)

(ii) Write an equation for the reaction between iron(II) ions and manganate(VII) ions.

Use this equation and the information given to calculate the concentration of iron(II) ions in the original solution **X**.

_____

_____

_____

_____

_____

_____

_____

_____

_____

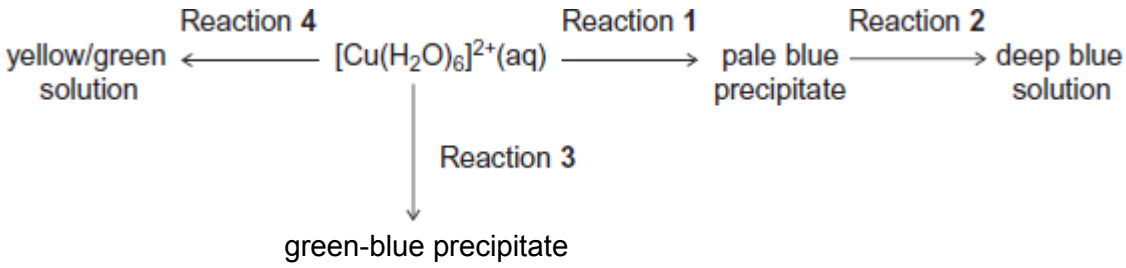
_____

(5)

(Total 11 marks)

Q11.

Consider the following reaction scheme that starts from aqueous $[Cu(H_2O)6]^{2+}$ ions.



For each of the reactions **1** to **4**, identify a suitable reagent, give the formula of the copper-containing species formed and write an equation for the reaction.

(a) Reaction **1**

Reagent _____

Copper-containing species _____

Equation _____

(3)

STEMUP.CO.UK

(b) Reaction **2**

Reagent _____

Copper-containing species _____

Equation _____

(3)

(c) Reaction **3**

Reagent _____

Copper-containing species _____

Equation _____

(3)

(d) Reaction **4**

Reagent _____

Copper-containing species _____

Equation _____

(3)

(Total 12 marks)

Q12.

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 $[Fe(H_2O)_6]^{3+}$.

_____

_____

_____

_____

_____

_____

_____

_____

STEMUP.CO.UK

(5)

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

(4)

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

(4)

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

STEMUP.CO.UK

_____

_____

_____

(4)

(Total 17 marks)

Q13.

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 _____

_____

Equation

_____

(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 _____

_____

Equation

_____

(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 _____

_____

Equation

STEMUP.CO.UK

_____

(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 _____

_____

_____

_____

Equation

_____

(4)

(Total 13 marks)

Q14.

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*.

_____

_____

_____

(1)

(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.

_____

_____

_____

_____

(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.

_____

_____

STEMUP.CO.UK

_____

_____

(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.

_____

_____

_____

_____

_____

_____

_____

_____

(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.

_____

_____

_____

_____

(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.

_____

_____

_____

_____

_____

STEMUP.CO.UK

_____

_____

_____

_____

_____

_____

_____

(5)

(Total 17 marks)

Q15.

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.

_____

_____

(1)

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

_____

_____

(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.

_____

_____

_____

_____

STEMUP.CO.UK

_____

_____

(4)

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

_____

(1)

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

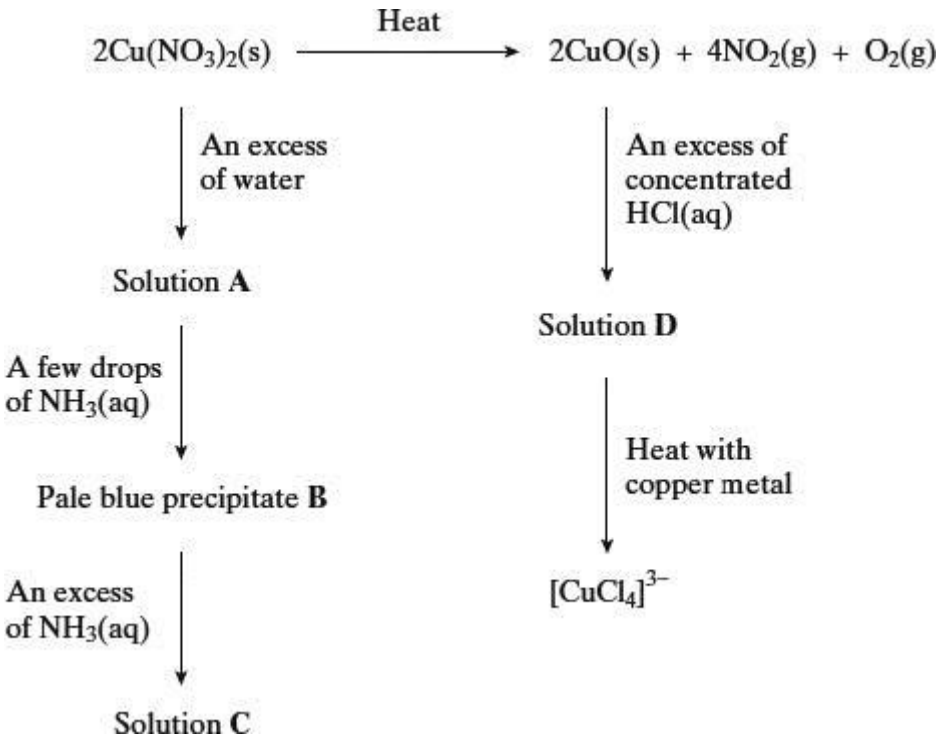
_____

(1)

(Total 8 marks)

Q16.

Consider the reaction scheme below and answer the questions which follow.



(a) A redox reaction occurs when $Cu(NO_3)_2$ is decomposed by heat. Deduce the oxidation state of nitrogen in $Cu(NO_3)_2$ and in NO_2 and identify the product formed by oxidation in this decomposition.

Oxidation state of nitrogen in $Cu(NO_3)_2$ _____

Oxidation state of nitrogen in NO_2 _____

Oxidation product _____

_____

(3)

STEMUP.CO.UK

(b) Identify and state the shape of the copper-containing species present in solution **A**.

Copper-containing species _____

Shape _____

(2)

(c) (i) Identify the pale blue precipitate **B** and write an equation, or equations, to show how **B** is formed from the copper-containing species in solution **A**.

*Identity of precipitate **B*** _____

Equation(s) _____

_____

(ii) In what way does the NH_3 behave as a Brønsted–Lowry base?

_____

(3)

(d) (i) Identify the copper-containing species present in solution **C**. State the colour of this copper-containing species and write an equation for its formation from precipitate **B**.

Identity _____

Colour _____

Equation _____

_____

(ii) In what way does the NH_3 behave as a Lewis base?

_____

(4)

(e) Identify the copper-containing species present in solution **D**. State the colour and shape of this copper-containing species.

Identity _____

Colour _____

Shape _____

_____

(3)

(f) The oxidation state of copper in $[CuCl_4]^{3-}$ is +1.

(i) Give the electron arrangement of a Cu^+ ion.

_____

(ii) Deduce the role of copper metal in the formation of $[CuCl_4]^{3-}$ from the copper-containing species in solution **D**.

STEMUP.CO.UK

_____

(2)

(Total 17 marks)

Q17.

Aqueous metal ions can be identified by test-tube reactions.

For each of the following, describe what you would observe.

Write an equation or equations for any reactions that occur.

(a) The addition of aqueous sodium carbonate to a solution containing $[Fe(H_2O)_6]^{3+}(aq)$ ions.

_____

_____

_____

_____

_____

_____

(4)

(b) The addition of aqueous sodium hydroxide, dropwise until in excess, to a solution containing $[Al(H_2O)_6]^{3+}(aq)$ ions.

_____

_____

_____

_____

_____

_____

(4)

(c) The addition of dilute aqueous ammonia, dropwise until in excess, to a solution containing $[Cu(H_2O)_6]^{2+}(aq)$ ions.

_____

_____

_____

_____

_____

STEMUP.CO.UK

_____

(4)

(d) The addition of concentrated hydrochloric acid, dropwise until in excess, to a solution containing $[Cu(H_2O)_6]^{2+}(aq)$ ions.

_____

_____

_____

_____

(2)

(Total 14 marks)

Q18.

(a) In the Haber Process for the manufacture of ammonia, the following equilibrium is established in the presence of a heterogeneous catalyst.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Identify the heterogeneous catalyst used in this process and state what is meant by the term *heterogeneous*.

A heterogeneous catalyst can become poisoned by impurities in the reactants. Give one substance which poisons the heterogeneous catalyst used in the Haber Process and explain how this substance poisons the catalyst.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(5)

(b) State what is observed when an excess of aqueous ammonia reacts with an aqueous iron(II) salt. Write an equation for this reaction.

_____

_____

STEMUP.CO.UK

_____

_____

_____

_____

_____

_____

(4)

(Total 9 marks)

Q19.

(a) State what is meant by each of the following terms.

(i) *Ligand* _____

_____

(ii) *Complex ion* _____

_____

(iii) *Co-ordination number* _____

_____

(3)

(b) Using complex ions formed by Co^{2+} with ligands selected from H_2O, NH_3, Cl^-, $C_2O_4^{2-}$ and $EDTA^{4-}$, give an equation for each of the following.

(i) A ligand substitution reaction which occurs with no change in either the co-ordination number or in the charge on the complex ion.

_____

(ii) A ligand substitution reaction which occurs with both a change in the co-ordination number and in the charge on the complex ion.

_____

(iii) A ligand substitution reaction which occurs with no change in the co-ordination number but a change in the charge on the complex ion.

_____

(iv) A ligand substitution reaction in which there is a large change in entropy.

_____

(8)

(c) An aqueous solution of iron(II) sulphate is a pale-green colour. When aqueous sodium hydroxide is added to this solution a green precipitate is formed. On standing in air, the green precipitate slowly turns brown.

STEMUP.CO.UK

(i) Give the formula of the complex ion responsible for the pale-green colour.

_____

(ii) Give the formula of the green precipitate.

_____

(iii) Suggest an explanation for the change in the colour of the precipitate.

_____

_____

(4)

(Total 15 marks)

Q20.

(a) **P** and **Q** are oxides of Period 3 elements.

Oxide **P** is a solid with a high melting point. It does not conduct electricity when solid but does conduct when molten or when dissolved in water. Oxide **P** reacts with water forming a solution with a high pH.

Oxide **Q** is a colourless gas at room temperature. It dissolves in water to give a solution with a low pH.

(i) Identify **P**. State the type of bonding present in **P** and explain its electrical conductivity. Write an equation for the reaction of **P** with water.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(5)

(ii) Identify **Q**. State the type of bonding present in **Q** and explain why it is a gas at room temperature. Write an equation for the reaction of **Q** with water.

_____

_____

STEMUP.CO.UK

_____

_____

_____

_____

_____

_____

(4)

(b) **R** is a hydroxide of a Period 3 element. It is insoluble in water but dissolves in both aqueous sodium hydroxide and aqueous sulphuric acid.

(i) Give the name used to describe this behaviour of the hydroxide.

_____

_____

(1)

(ii) Write equations for the reactions occurring.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(iii) Suggest why **R** is insoluble in water.

_____

_____

(1)

(Total 15 marks)

STEMUP.CO.UK