

AQA A-LEVEL CHEMISTRY • 7405

CHEMISTRY



EXAM QUESTION PACK

3.2.6 REACTIONS OF IONS IN AQUEOUS SOLUTION

SCORE

/205

PERCENTAGE

%

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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)

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.

(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 $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ 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 $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ in a ligand substitution reaction.

Which of the following shows the correct change in entropy for a reaction of hexaaquairon(II) ions with $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$?

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.

(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 cm³ 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.

(4)

- (c) When the complex ion $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ 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.



- | | | |
|----------|--|--------------------------|
| 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 | $[\text{Al}(\text{NH}_3)_6]^{3+}$ | ☐ |
| B | $[\text{Al}(\text{OH})_3(\text{H}_2\text{O})_3]$ | ☐ |
| C | $[\text{Al}(\text{OH})_4(\text{H}_2\text{O})_2]^-$ | ☐ |
| D | $[\text{Al}(\text{OH})(\text{H}_2\text{O})_5]^{2+}$ | ☐ |

(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.

(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.

(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 $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ 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 $0.0205 \text{ mol dm}^{-3}$ 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.

(2)

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

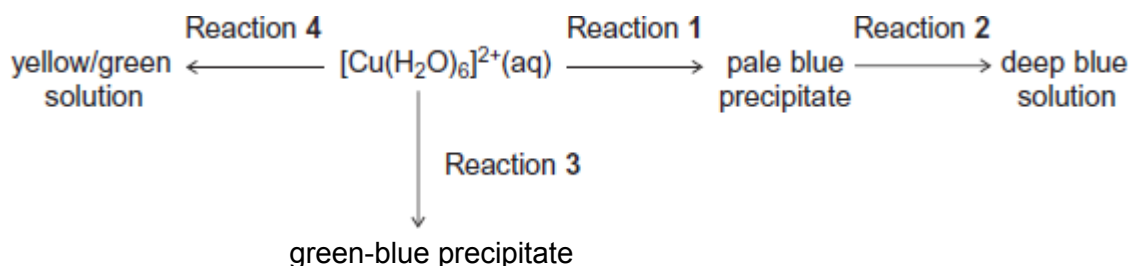
Use this equation and the information given to calculate the concentration of iron(II) ions in the original solution **X**.

(5)

(Total 11 marks)

Q11.

Consider the following reaction scheme that starts from aqueous $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ 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)

(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 $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ and $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$.

(5)

- (b) An excess of concentrated hydrochloric acid is added to separate aqueous solutions containing $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ and $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$.

(4)

- (c) An excess of dilute aqueous sodium hydroxide is added to separate aqueous solutions containing $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ and $[\text{Cr}(\text{H}_2\text{O})_6]^{3+}$.

(4)

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

(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 $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ 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 $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ ions.

Colour of original solution _____

Observation after an excess of reagent has been added _____

Equation

(3)

- (d) Sodium carbonate solution is added to a solution containing $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ 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 ($[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$) 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 ($[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$) and ammonia in which ammonia acts as a Lewis base but **not** as a Brønsted–Lowry base. State what you would observe.

(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 ($\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$), 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.

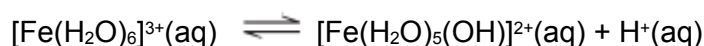
(5)
(Total 17 marks)

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.



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.

(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)

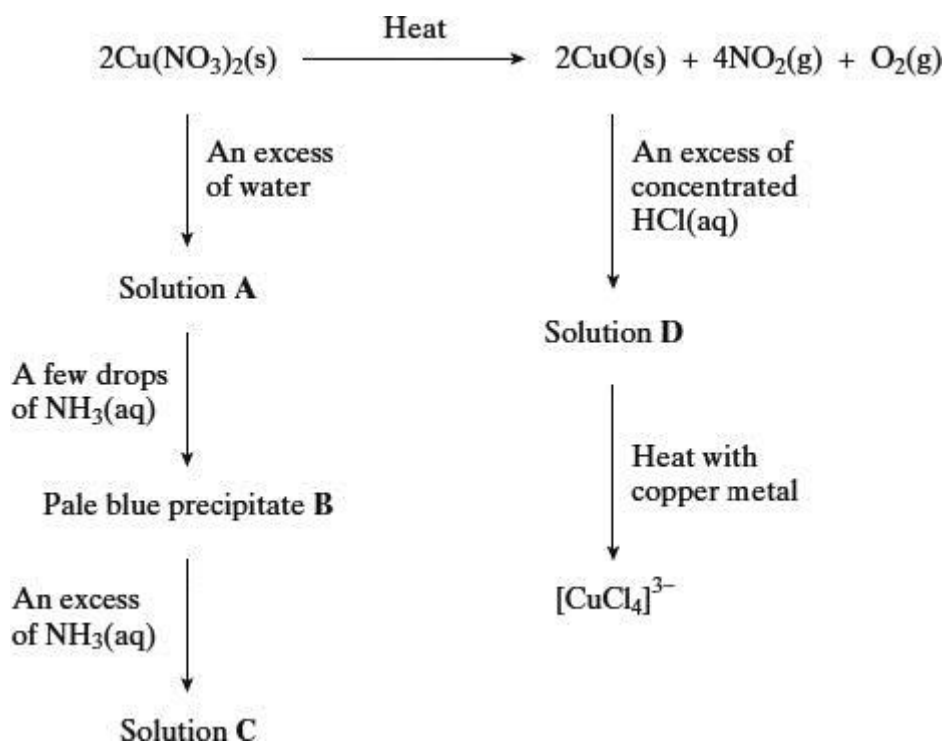
- (e) Suggest a value for the pH of a 0.100 mol dm⁻³ solution of iron(II) sulfate.

(1)

(Total 8 marks)

Q16.

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



- (a) A redox reaction occurs when $\text{Cu}(\text{NO}_3)_2$ is decomposed by heat. Deduce the oxidation state of nitrogen in $\text{Cu}(\text{NO}_3)_2$ and in NO_2 and identify the product formed by oxidation in this decomposition.

Oxidation state of nitrogen in $\text{Cu}(\text{NO}_3)_2$ _____

Oxidation state of nitrogen in NO_2 _____

Oxidation product _____

(3)

- (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 $[\text{CuCl}_4]^{3-}$ is +1.

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

- (ii) Deduce the role of copper metal in the formation of $[\text{CuCl}_4]^{3-}$ from the copper-containing species in solution **D**.

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 $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ ions.

(4)

- (b) The addition of aqueous sodium hydroxide, dropwise until in excess, to a solution containing $[\text{Al}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ ions.

(4)

- (c) The addition of dilute aqueous ammonia, dropwise until in excess, to a solution containing $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$ ions.

(4)

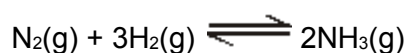
- (d) The addition of concentrated hydrochloric acid, dropwise until in excess, to a solution containing $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$ ions.

(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.



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.

(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^- , $\text{C}_2\text{O}_4^{2-}$ 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.

- (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.

(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)

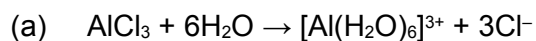
(iii) Suggest why **R** is insoluble in water.

(1)

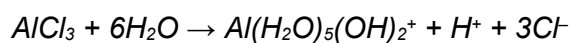
(Total 15 marks)

Mark schemes

Q1.

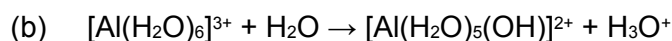


Allow



Or equation to form $\text{Al}(\text{H}_2\text{O})_4(\text{OH})_2^+$

1



allow equations to form $[\text{Al}(\text{H}_2\text{O})_4(\text{OH})_2]^+$

1

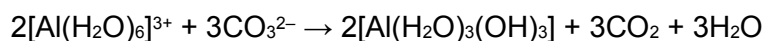
(c) white ppt/solid

M1 and M2 in either order

1

effervescence/bubbles/fizzing

1



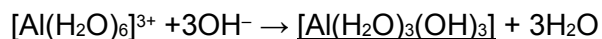
accept multiples

only allow spectator ions in a balanced equation

1

(d) White ppt/solid

1

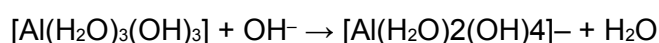


only allow spectator ions in a balanced equation

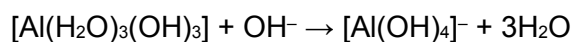
1

Colourless solution forms / ppt or solid dissolves

1



OR



only allow 6 or 4 co-ordination

Allow $[\text{Al}(\text{OH})_6]^{3-}$ in a balanced equation

1

[9]

Q2.

(a) **A** Silver bromide / AgBr

1

B Iron(II) carbonate / FeCO_3

1

C Iron(II) sulphate / FeSO_4

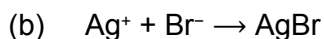
1

D Carbon dioxide / CO₂

1

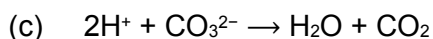
Y Iron(II) bromide / FeBr₂

1



Allow equation if state symbols missing but penalise if state symbols are incorrect

1

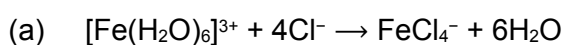


Allow $\text{FeCO}_3 + 2\text{H}^+ \rightarrow \text{Fe}^{2+} + \text{CO}_2 + \text{H}_2\text{O}$

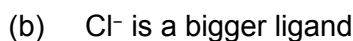
1

[7]

Q3.



1

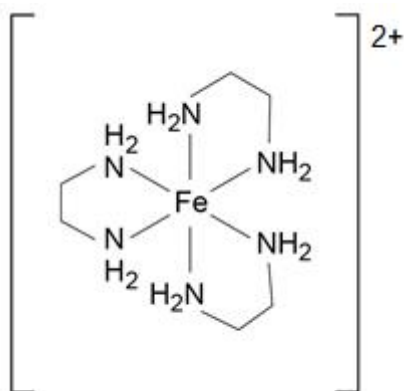


1

So only 4Cl⁻ can fit around the metal

Allow fewer Cl⁻ can fit around the metal

1



(c)

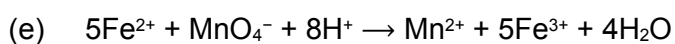
*M1 for structure of complex
M2 for correct charge*

1

1

(d) Change in entropy is positive

1



1

(f) Amount of manganate (VII) = 6.50×10^{-4} mol

1

Amount of iron(II) = 3.25×10^{-3} mol

ie M1 × 5

1

Mass of iron = 0.181 g = 181 mg

Allow $M2 \times 55.8$

1

Percentage Fe = $181/1980 \times 100 = \underline{9.14}(\%)$ 3 sf

1

(g) Colourless to pale pink

1

[12]

Q4.

(a) An electron pair on the ligand

1

Is donated from the ligand to the central metal ion

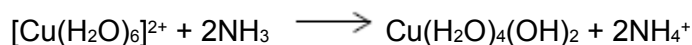
1

(b) Blue precipitate

1

Dissolves to give a dark blue solution

1



1



1

(c) $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 2\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2 \longrightarrow [\text{Cu}(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)_2(\text{H}_2\text{O})_2]^{2+} + 4\text{NH}_3$

1

(d) Cu–N bonds formed have similar enthalpy / energy to Cu–N bonds broken

1

And the same number of bonds broken and made

1

(e) 3 particles form 5 particles / disorder increases because more particles are formed / entropy change is positive

1

Therefore, the free-energy change is negative

M2 can only be awarded if M1 is correct

1

[11]

Q5.

D

[1]

Q6.

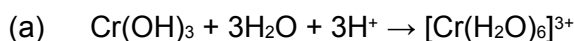
B

Q7.

B

[1]

Q8.



Can start with $\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3$ for each equation

Ignore any unnecessary preliminary preparation of $\text{Cr}(\text{OH})_3$

1

Green / grey-green solid

Mark colours independently from equations

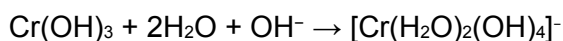
Allow green ppt.

1

Forms green / purple / ruby / violet solution

ignore shades of colours

1



Allow with 5 or 6 OH^- provided complex has co-ordination number of 6

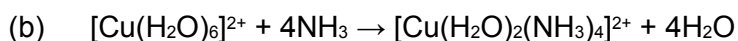
Penalise complex ions with incorrect charges overall or if shown on ligand.

1

Forms green solution

Note that for each equation final complex must be 6 co-ordinate

1



Allow two correct equations via intermediate hydroxide in both cases even if first equation uses OH^- instead of NH_3

1

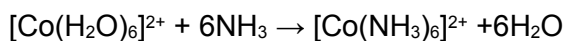
Blue (solution)

Mark colours independently from equations

1

Dark / deep / royal blue solution

1



1

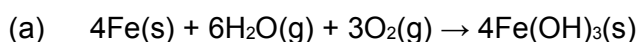
pink / red (solution)

1

Brown / straw / yellow solution

ignore darkens in air / with time

1

Q9.

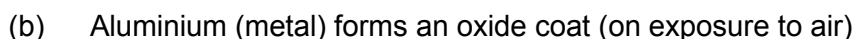
Accept fractions, multiples and equations showing formation of hydrated hydroxide.

1

Correct states as above

Lose this mark if any state is missing or incorrect.

1



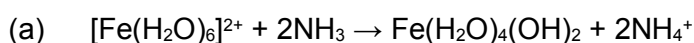
1

This coat prevents / inhibits further reaction (by water or oxygen)

Ignore references to a 'less reactive coating' unless further qualified.

1

[4]

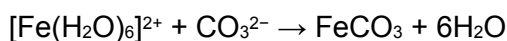
Q10.

Allow equation with OH⁻ provided equation showing formation of OH⁻ from NH₃ given

1

Green precipitate

1



1

Green precipitate

effervescence incorrect so loses M4

1

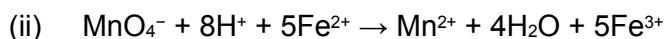


Do not allow pale pink to purple

1

Just after the end-point MnO_4^- is in excess / present

1



1

Moles $\text{KMnO}_4 = 18.7 \times 0.0205 / 1000 = (3.8335 \times 10^{-4})$

Process mark

1

Moles $\text{Fe}^{2+} = 5 \times 3.8335 \times 10^{-4} = 1.91675 \times 10^{-3}$

Mark for M2 × 5

1

Moles Fe^{2+} in $250 \text{ cm}^3 = 10 \times 1.91675 \times 10^{-3} = 0.0191675$ moles in 50

cm³

Process mark for moles of iron in titration (M3) $\times 10$

1

Original conc Fe²⁺ = $0.0191675 \times 1000 / 50 = 0.383 \text{ mol dm}^{-3}$

Answer for moles of iron (M4) $\times 1000 / 50$

Answer must be to at least 2 sig. figs. (0.38)

1

[11]

Q11.

(a) Reaction 1

General principles in marking this question

Square brackets are not essential

Penalise charges on individual ligands rather than on the whole complex

Reagent and species can be extracted from the equation

Ignore conditions such as dilute, concentrated, excess

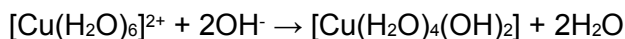
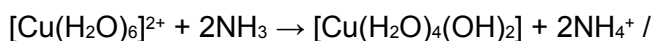
Reagent must be a compound NOT just an ion

Equations must start from [Cu(H₂O)₆]²⁺ except in part (b)

Mark reagent, species and equation independently

ammonia (NH₃) (solution) / NaOH

1



Do not allow OH⁻ for reagent

Product 1, balanced equation 1

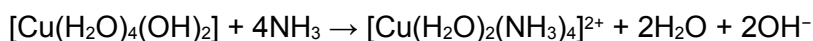
Allow either equation for ammonia

2

(b) Reaction 2

Ammonia (conc / xs)

1



Product 1, balanced equation 1

Note that the equation must start from the hydroxide

[Cu(H₂O)₄(OH)₂]

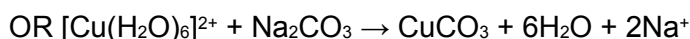
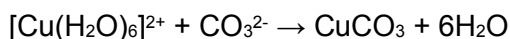
2

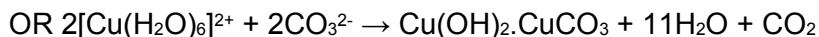
(c) Reaction 3

Na₂CO₃ / any identified soluble carbonate / NaHCO₃

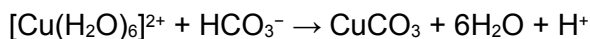
Do not allow NaCO₃ or any insoluble carbonate but mark on

1





OR with NaHCO_3



Product 1, balanced equation 1

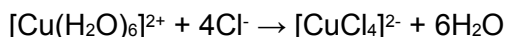
2

(d) **Reaction 4**

HCl (conc / xs) / NaCl

Allow any identified soluble chloride

1



Product 1, balanced equation 1

2

[12]

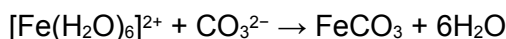
Q12.

- (a) Iron(II): green (solution) gives a green precipitate

Apply list principle throughout if extra colours and / or extra observations given. Ignore state symbols in equations.

Not blue-green ppt.

1



Must start from $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$

Allow equations with Na_2CO_3

1

Iron(III): yellow / purple / brown / lilac / violet (solution) gives a brown / rusty precipitate

1

Effervescence / gas / bubbles

Allow CO_2 evolved but not just CO_2

1

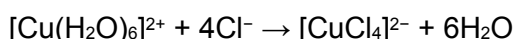


1

- (b) Copper(II): blue (solution) gives a green / yellow solution **OR** blue solution (turns) to green / yellow / olive green

Apply list principle throughout if extra colours and / or extra observations given. Ignore state symbols in equations.

1

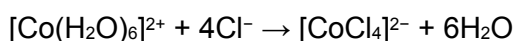


Allow equations with HCl

1

Cobalt(II): pink (solution) gives a blue solution **OR** pink solution turns blue

1

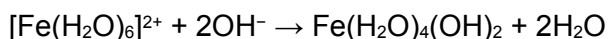


1

- (c) Iron(II): green (solution) gives a green precipitate

Apply list principle throughout if extra colours and / or extra observations given. Ignore state symbols in equations.

1



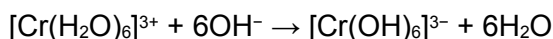
Allow equations with NaOH

1

Chromium(III): green / ruby / purple / violet / red-violet (solution) gives a green solution **OR** green / ruby / purple / violet / red-violet solution turns green

Ignore green ppt.

1



Allow also with 4 or 5 OH balanced with 2 or 1 waters.

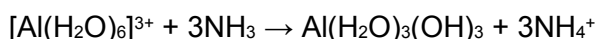
Also allow two correct equations showing $\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3$ as intermediate.

1

- (d) Al: colourless (solution) gives a white ppt

Apply list principle throughout if extra colours and / or extra observations given. Ignore state symbols in equations.

1



Allow $+ 3\text{OH}^- \rightarrow 3\text{H}_2\text{O}$ if

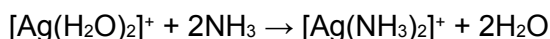
$\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^-$ also

1

Ag: colourless (solution) remains a colourless solution / no visible change

Ignore brown ppt.

1



Allow 2 / 3 equations involving Ag_2O or $\text{Ag}(\text{OH})_2$

1

[17]

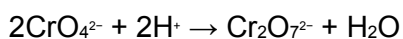
Q13.

- (a) Yellow (solution)

1

Orange solution

1



Allow equation with H_2SO_4

1

- (b) Yellow / purple (solution)

Allow orange / brown (solution)

1

Brown precipitate / solid	1
$[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 3\text{OH}^- \rightarrow \text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3 + 3\text{H}_2\text{O}$	1
(c) Blue (solution) <i>Allow pale blue</i>	1
Dark / deep blue <u>solution</u> <i>Ignore any reference to blue ppt</i>	1
$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+} + 4\text{H}_2\text{O}$ <i>Can be in two equations</i>	1
(d) Colourless (solution)	1
White precipitate / solid <i>Do not allow grey</i>	1
Bubbles / effervescence / gas evolved / given off <i>Do not allow just CO₂</i>	1
$2[\text{Al}(\text{H}_2\text{O})_6]^{3+} + 3\text{CO}_3^{2-} \rightarrow 2\text{Al}(\text{H}_2\text{O})_3(\text{OH})_3 + 3\text{CO}_2 + 3\text{H}_2\text{O}$	1
	[13]

Q14.

(a) Electron <u>pair</u> donor <i>Allow lone <u>pair</u> donor</i>	1
(b) $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow \text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2 + 2\text{NH}_4^+$	1
(Blue solution) gives a (pale) <u>blue precipitate/solid</u> <i>M2 only awarded if M1 shows Bronsted–Lowry reaction</i>	1
(c) $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+} + 4\text{H}_2\text{O}$ <i>Allow formation in two equations via hydroxide</i>	1
(Blue solution) gives a <u>dark/deep blue solution</u> <i>If (b) and (c) are the wrong way around allow one mark only for each correct equation with a correct observation (max 2/4)</i> <i>M2 only awarded if M1 shows Lewis base reaction</i>	1
(d) (Start with) green (solution)	

1

Green precipitate of $\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2$ / $\text{Fe}(\text{OH})_2$ / iron(II) hydroxide

Do not allow observation if compound incorrect or not given

1

Slowly changes to brown solid

Allow red-brown ppt

Allow turns brown or if precipitate implied

Can only score M3 if M2 scored

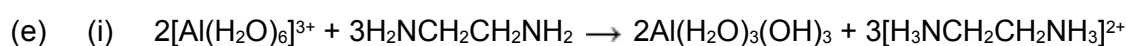
1

(Iron(II) hydroxide) oxidised by air (to iron(III) hydroxide)

Allow $\text{Fe}(\text{OH})_2$ oxidised to $\text{Fe}(\text{OH})_3$ by air / O_2

Ignore equations even if incorrect

1



For correct Al species

1

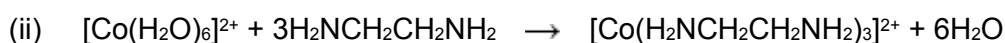
For correct balanced equation

Allow equation with formation of $3[\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_3]$ + from 1 mol $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$

1

White precipitate

1



1

Complex with 3 en showing 6 correct bonds from N to Co

Ignore charge

Accept N – N for ligand

Ignore incorrect H

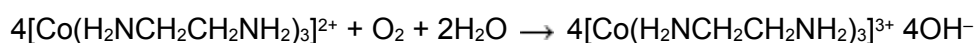
If C shown, must be 2 per ligand

1

Co-ordinate bonds (arrows) shown from N to Co

Can only score M3 if M2 correct

1



For Co(III) species

1

For balanced equation (others are possible)

Allow $+ \text{O}_2 + 4\text{H}^+ \rightarrow 2\text{H}_2\text{O}$

If en used can score M4 and M5 only

If Cu not Co, can only score M2 and M3

Allow $\text{N}_2\text{C}_2\text{H}_8$ in equations

1

[17]

Q15.

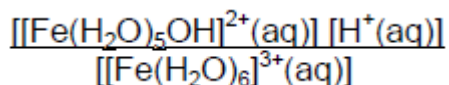
- (a) Idea that over time / after storage meter does not give accurate readings

Do not accept 'to get an accurate reading' without further qualification.

Allow 'temperature variations affect reading'.

1

- (b)



Allow without (aq) symbols.

Need at least one set of square brackets around complex ions

1

- (c) $\text{pH} = -\log [\text{H}^+]$

1

$$[\text{H}^+] = 0.0240$$

Do not penalise precision of $[\text{H}^+]$

Correct answer scores M1 and M2.

1

$$K_a = (0.0240)^2 / 0.1 = 5.75 \times 10^{-3} \text{ or } 5.76 \times 10^{-3}$$

Correct answer without working loses M1 and M2.

Allow 7.58×10^{-3}

1

Answer, even if incorrect, given to 3 sig figs

1

- (d) Oxygen (in the air) / O_2

Ignore 'air' or 'the atmosphere' or 'chemicals in soil'.

List principle.

1

- (e) $4.0 - 6.9$

Do not penalise precision.

[7]

Q16.

- (a) oxidation state of N in $\text{Cu}(\text{NO}_3)_2$: +5;

1

oxidation state of N in NO_2 : +4;

1

oxidation product: oxygen;

1

- (b) copper-containing species: $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$;

1

shape: octahedral;

- (c) (i) precipitate B: $\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2$ or $\text{Cu}(\text{OH})_2$ or name; 1
- equation: $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow \text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2 + 2\text{NH}_4^+$ 1
- OR
- $\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^-$
- and
- $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2 + 2\text{H}_2\text{O};$ 1
- (ii) NH_3 accepts a proton; 1
- (d) (i) identity: $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+};$ 1
- colour: deep blue; 1
- equation: 1
- $\text{Cu}(\text{H}_2\text{O})_4(\text{OH})_2 + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 2\text{H}_2\text{O} + 2\text{OH}^-;$ 1
- (ii) NH_3 is an electron pair donor; 1
- (e) identity: $[\text{CuCl}_4]^{2-};$ 1
- colour: yellow-green; 1
- shape: tetrahedral; 1
- (f) (i) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10};$ 1
- (ii) role of Cu: a reducing agent; 1

[17]

Q17.

- (a) Brown ppt/solid 1
- Gas evolved/effervescence 1
- $2[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 3\text{CO}_3^{2-} \rightarrow 2\text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3 + 3\text{CO}_2 + 3\text{H}_2\text{O}$
- Must be stated, Allow CO_2 evolved. Do not allow CO_2 alone*
- Correct iron product (1) allow $\text{Fe}(\text{OH})_3$ and in equation*

	Balanced equation (1)	2
(b)	White <u>ppt/solid</u>	1
	Colourless <u>Solution</u>	
	Only award M2 if M1 given or initial ppt mentioned	1
	$[Al(H_2O)_6]^{3+} + 3OH^- \rightarrow Al(H_2O)_3(OH)_3 + 3H_2O$	
	Allow $[Al(H_2O)_6]^{3+} + 3OH^- \rightarrow Al(OH)_3 + 6H_2O$	1
	$Al(H_2O)_3(OH)_3 + 3OH^- \rightarrow [Al(OH)_6]^{3-} + 3H_2O$	
	Allow formation of $[Al(H_2O)_{6-x}(OH)_x]^{(x-3)-}$ where $x = 4, 5, 6$	
	Allow product without water ligands	
	Allow formation of correct product from $[Al(H_2O)_6]^{3+}$	1
(c)	Blue <u>ppt/solid</u>	1
	(Dissolves to give a) deep blue <u>solution</u>	
	Only award M2 if M1 given or initial ppt mentioned	1
	$[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(H_2O)_4(OH)_2 + 2NH_4^+$	
	Allow $[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(OH)_2 + 2NH_4^+ + 4H_2O$	
	Allow two equations: $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$	
	then $[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(OH)_2 + 4H_2O$ etc	1
	$Cu(H_2O)_4(OH)_2 + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 2OH^- + 2H_2O$	
	Allow $[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 4H_2O$	1
(d)	Green/yellow <u>solution</u>	1
	$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$	1

[14]

Q18.

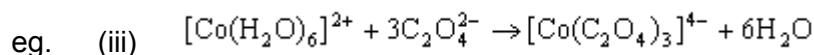
(a)	Iron	1
	Heterogeneous; catalyst in a different phase from that of the reactants	1
	Poison; a sulphur compound (allow sulphur)	1
	Poison strongly adsorbed onto active sites/ blocked	1

Poison not desorbed or reactants not adsorbed or catalyst surface area reduced	1
(b) Pale green solution	1
Green precipitate formed	1
Insoluble in excess ammonia	1
Equation:	
e.g. $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow [\text{Fe}(\text{H}_2\text{O})_4(\text{OH})_2] + 2\text{NH}_4^+$ Species	1
Balance	1
<i>NB Allow equations with H₂O and OH⁻ if reaction of H₂O with NH₃ also given</i>	
	Max 4

[9]

Q19.

(a) (i) An atom, ion or molecule which can donate a lone electron pair	1
(ii) A central metal ion/species surrounded by co-ordinately bonded ligands or ion in which co-ordination number exceeds oxidation state	1
(iii) The number of co-ordinate bonds formed to a central metal ion or number of electron pairs donated or donor atoms	1
(b) (i) <i>Allow the reverse of each substitution</i>	
$[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 6\text{NH}_3 \rightarrow [\text{Co}(\text{NH}_3)_6]^{2+} + 6\text{H}_2\text{O}$	
Complex ions	1
Balanced	1
<i>Allow partial substitution</i>	
(ii) $[\text{Co}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \rightarrow [\text{CoCl}_4]^{2-} + 6\text{H}_2\text{O}$	
Complex ions	1
Balanced	
<i>or H₂O or NH₃ or C₂O₄²⁻ by Cl⁻</i>	1



Complex ions

1

Balanced

1

Allow all substitution except

(i) NH_3 by H_2O

(ii) more than 2 Cl^- substituted for NH_3 or H_2O



Complex ions

1

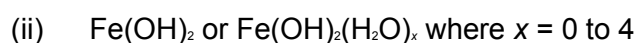
Balanced

or H_2O or NH_3 by $\text{C}_2\text{O}_4^{2-}$ and NH_3 or Cl^- by EDTA^{4-}

1



1



1



1

By oxygen in the air

1

[15]

Q20.

(a) (i) Deductions:

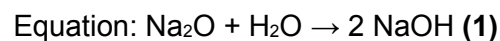
Ionic (1)

Ions not free to move in the solid state (1)

Ions free to move when molten or in aqueous solution (1)

Identity of **P**: Na_2O or sodium oxide (1)

N.B. If a formula given this must be correct



5

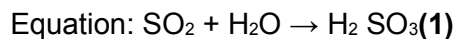
(ii) Deductions:

Covalent

Intermolecular forces are weak or van der Waals forces,
or dipole-dipole

*N.B. Any answer including a reference to hydrogen bonding
is incorrect*

Identity of **Q**: SO_2 or sulphur dioxide (1)

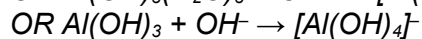
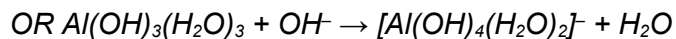
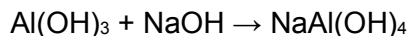


NB Allow max one for SO_3

4

(b) (i) Amphoteric (1)

(ii) Equation with NaOH



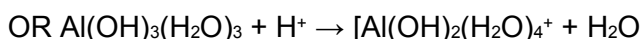
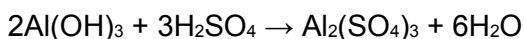
R identified as $\text{Al}(\text{OH})_3$ or $\text{Al}(\text{OH})_3(\text{H}_2\text{O})_3$ (1)

A balanced equation (1)

N.B. Allow equation with six co-ordinate Aluminium and up to six OH^- ligands

N.B. Allow equation mark if $\text{M}(\text{OH})_3$ given in a balanced equation

Equation with H_2SO_4



NB Allow equations with six co-ordinate Aluminium and up to six H_2O ligands NB Allow equation mark if $\text{M}(\text{OH})_3$ given in a balanced equation

Correct Al species as product (1)

A balanced equation (1)

(iii) Large lattice energy
or strong covalent bonds
or ΔH_{soln} is very positive
or ΔG is positive

or sum of hydration energies less than covalent bond energies (1)

6

[15]

Examiner reports

Q1.

- (a) Just over half of the students (50.2%) could give the correct equation; common errors included giving chlorine as a product, incorrect balancing and sometimes an incorrect formula for aluminium chloride.
- (b) Only a small proportion of students (22.6%) could give a correct equation here; many did not include protonation of water, as implied in the question. A surprisingly high proportion of students (10.8%) failed even to attempt this question.
- (c) Here, students were more able to state observations than to write the equations. Some students stated that carbon dioxide was evolved, but this is not an observation – it is a deduction from the effervescence seen. Just over 25% of students scored all the marks in this part of the question.
- (d) Students were better able to state observations than write equations but only 35% of students scored all of the marks available. Again, just over 10% of students failed to attempt this part.

Q8.

In part (a) the observations were usually described accurately. Attempts at the equations were less successful. Again, students should be encouraged to read the question carefully before starting to answer it. Many students attempted to start from an aqueous solution of chromium(III) ions instead of the solid hydroxide. Students were asked to write ionic equations because it was thought that this would make the equations simpler and easier to write. A significant number of students ignored this instruction and were penalised. In part (b) of this question students were asked to write equations for ligand substitution reactions. It was not possible to answer this question correctly unless it was realised that the initial complex ion, in aqueous solution, was a hexaaqua ion with six water ligands. When describing an observation it is important to give the phase to which the colour applies so that the product of reacting an excess of aqueous ammonia with copper(II) sulphate solution is a 'deep blue solution', not just 'deep blue'.

Q9.

Better students had little problem with this question but there was some poor marking of part (a) with equation errors and missing state symbols often overlooked. Marking was sometimes overgenerous in (b) where a clearer statement was needed for the second mark.

Q10.

Most students gave correct observations in part (a) but their attempts at equations were less successful and often unbalanced. Very few correct answers to part (b)(i) were seen. The most usual response was to suggest, without any explanation, that the colour change was from purple to colourless. Part (b)(ii) produced a whole range of responses. Good students were able to score all 5 marks in impressive style but others lost marks. The most common mistake was an incorrect equation and the use of an incorrect molar ratio for moles of iron(II) to manganate(VII). Many students were also unable to calculate the concentration of iron(II) ions in the original solution from the number of moles of iron(II) ions in the 250 cm³ flask. A factor of 1000/50 was required but factors such as 1000/250 or 250/25 were common mistakes.

Q11.

This question was answered well and students of all abilities were able to score a reasonable number of marks. The most common errors were to give wrong overall charges for some of the complex ions and a failure to give a complete name or formula for the reagent. In part (b), some students lost the equation mark because an aqueous copper ion rather than the hydroxide precipitate was used as the starting material. Part (c) was answered least well. Some students did not recognise that the green-blue precipitate was copper carbonate and many who did were unable to give a correct formula for sodium carbonate.

Q12.

Answers to this type of question demand careful attention to the colour and state of the transition metal ions or compounds before and after reaction and careful attention to balancing of equations with numbers of atoms and charges on ions. Some students continue to lose marks because they give charges on ligands within the formula for a complex ion. The only charge required on a complex ion is the overall charge that, ideally, should appear outside square brackets, although a lack of brackets was not penalised. In part (a), the most common error was to omit the observation that a gas is evolved when sodium carbonate is added to a solution containing iron(III) ions. Part (b) was answered well although some students just gave the colour of the products and did not state that solutions rather than precipitates are formed. In part (c), the most usual errors were unbalanced equations. Part (d) proved to be the hardest part of this question. Many students gave an unbalanced equation for the reaction between ammonia and aluminium ions and most students stated incorrectly that the solution of $[\text{Ag}(\text{H}_2\text{O})_2]^+$ ions appeared to be a silver colour.

Q13.

This question depended on accurate recall of the reactions of metal ions in solution. It discriminated well. Good students were able to score full marks. Weaker students found the equations difficult and did not always recall correct colours. In questions of this nature, it has been reported previously but it is worthwhile repeating that an observation of a colour is only complete if the colour is tied to the species that is coloured. For instance, in part (b), a brown precipitate is formed but in part (c) the product is a deep blue solution.

Q14.

Parts (a) and (b) were usually correct. Part (c) proved to be more difficult than part (b). Weaker students gave an ammine complex with six rather than four ammonia molecules and the charge of the ammine complex was often incorrect. Part (d) was very discriminating. Only the best students identified the initial green precipitate as a form of iron(II) hydroxide and went on to explain that this would be oxidised to a brown solid by oxygen in the air. Part (e)(i) was set as a 'stretch and challenge' question and it proved to be so. It was disappointing to find that only a very few students could draw a parallel with the reaction in part (b) and hence predict that aluminium hydroxide would be formed. Part (e)(ii) was very discriminating; most students could gain some credit but only the very best students were able to gain four or more marks out of the five available. Only about 2% of students were able to write a correct equation for the oxidation of the cobalt(II) complex.

Q15.

Part (a) proved to be the most demanding question in the paper. The great majority of candidates appreciated that calibration improves accuracy but did not explain why it is necessary in the first place. At A2 candidates should be wary of providing an answer such as 'to get a more accurate result' without an appropriate qualification.

The expression in part (b) was widely known and many candidates were able to complete the calculation in part (c) in full.

In part (c) the great majority of candidates remembered to record the equilibrium constant to three significant figures.

Part (d) and part (e) defeated many candidates. The likelihood of oxidation by oxygen in the air seemed to be elusive while most candidates thought the iron(II) aqua ion to be a strong acid and estimated the pH accordingly.

Q16.

Most candidates deduced correctly the oxidation state of nitrogen in NO_2 but rather less correctly determined the oxidation state of nitrogen in $\text{Cu}(\text{NO}_3)_2$. Many failed to identify the oxidation product as oxygen with CuO being the most common incorrect answer. Part (b) was generally well answered but identifying the precipitate B as copper(II) hydroxide, in (c)(i), proved more difficult. Many candidates failed to give an equation, or a pair of equations, showing the role of ammonia in the formation of this precipitate and lost a mark. Most stated correctly that ammonia is a proton acceptor in answer to (c)(ii) but many failed to correctly identify the copper-containing species in solution C as $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+}$ with $[\text{Cu}(\text{NH}_3)_6]^{2+}$ being the most common incorrect answer. The colour of this complex was generally well known but only the better candidates were able to write a correct equation for its formation. The role of ammonia as a Lewis base was generally well known but the formula and colour of the copper-containing species, $[\text{CuCl}_4]^{2-}$, present in solution D, were less well known. Part (f) proved to be particularly testing and only the better candidates gave a correct electronic arrangement for a Cu^+ ion and correctly identified copper metal as the reducing agent in the formation of $[\text{CuCl}_4]^{3-}$.

Q17.

The general standard of answers to this question was very disappointing. It was clear to examiners that a large majority of students could not recall what should be observed and what happens in the various reactions given. In part (a), only 8% of candidates scored full marks. Examiners hoped that candidates would understand that the action of carbonate ions on a metal ion with a 3+ charge always leads to a hydroxide precipitate and evolution of carbon dioxide gas, but most candidates were unable to give a full answer. In part (b) most candidates suggested either the formation of a hydroxide precipitate or a complex $[\text{Al}(\text{OH})_6]^{3-}$ (or $[\text{Al}(\text{OH})_4]^-$) ion but only the best candidates knew that one would be formed first followed by the other. The same sort of responses were common in part (c) with only the best candidates explaining correctly that a blue hydroxide precipitate would be followed by a deep blue solution containing $[\text{Cu}(\text{H}_2\text{O})_2(\text{NH}_3)_4]^{2+}$ ions. Answers to part (d) were more often correct.

Q18.

In answer to part (a), most candidates identified iron as the heterogeneous catalyst in the Haber process and explained the term *heterogeneous* correctly. Although poisoning of the iron catalyst by sulphur is clearly stated in the Specification, many other elements and compounds were stated incorrectly to poison this catalyst. The method by which the poison works was well known and well explained. Only the best candidates gave a correct equation for the reaction of an aqueous iron(II) salt with an excess of aqueous ammonia as required in part (b). Candidates who gave equations involving the reaction of either water or hydroxide ions were allowed to score full marks provided that they also gave an equation showing the equilibrium reaction of ammonia with water. Correct observations were given by most of the good candidates but others either failed to state any observations or gave incorrect answers.

Q19.

Although part (a) was generally well done, a significant number of candidates lost marks as their definitions were imprecise. This was most notable in section (iii) where candidates who stated that *the co-ordination number was the number of ligands co-ordinately bonded to the central metal ion* lost a mark as this statement is only correct if the ligands are unidentate. The ligand substitution reactions in part (b) were generally well done. Candidates should be reminded that although it is necessary to use the charges on ligands when deducing the overall charge on the complex ion, these charges should not be included in the formula of the complex. The answer to (b)(iii) was not, as a significant number thought, an acid-base reaction. Most candidates understood the chemistry required in part (c) but some lost a mark as they failed to state that the oxidation of iron(II) to iron(III) was caused by oxygen in the air.

Q20.

This was a question on the oxides of Period 3 elements. In part (a) candidates were required to identify two oxides, P and Q. Candidates who used the given information to correctly identify the bonding present in the two oxides were awarded marks even when the oxides were then identified incorrectly. Although many candidates identified P correctly as sodium oxide and gave a correct equation for its reaction with water others lost marks when they attempted to explain the electrical conductivity in terms of electron movement. Oxide Q was identified correctly as SO_2 by many candidates. Those who identified it as SO_3 were penalised by the loss of one mark. Almost every candidate stated correctly that hydroxide R was amphoteric. Most also identified it as aluminium hydroxide. Although any correct equations for the reactions of this hydroxide with sodium hydroxide, or hydroxide ions, and sulphuric acid, or hydrogen ions, were accepted, candidates often gave unbalanced equations with incorrect species. Nevertheless there were many excellent answers which scored full marks. Most candidates were unable to suggest a reason why R, aluminium hydroxide, is insoluble in water. It was hoped that candidates would realise that a great deal of energy is needed to break down the bonding in the hydroxide and that hydration would not supply sufficient energy for this change to occur. In the event any sensible suggestion such as the hydroxide had strong covalent bonds was accepted for the one mark.