Reactions and Applications of Transition Metals

Question Paper 3

Level	International A Level
Subject	Chemistry
Exam Board	Edexcel
Topic	Transition Metals & Organic Nitrogen Chemistry
Sub Topic	Reactions and Applications of Transition Metals
Booklet	Question Paper 3

Time Allowed: **71 minutes**

Score: **/59**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 Brass is an alloy of copper and zinc, often with traces of other metals. The copper content of brass can be determined by dissolving the metal in concentrated nitric acid and measuring, by titration, the concentration of the copper(II) ions formed.

(a) When concentrated nitric acid reacts with copper, the copper dissolves and one of the products is dinitrogen tetroxide, N_2O_4.

(i) Use the data on page 15 of the Data Booklet to write the ionic half-equations for this reaction of copper with concentrated nitric acid. State symbols are not required.

(2)

(ii) Write the overall equation for the reaction of copper with concentrated nitric acid and calculate $E^{\ominus}_{cell}$ for the reaction. State symbols are not required.

(2)

(iii) State **one** observation that you would expect to make when copper dissolves in concentrated nitric acid.

(1)

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(b) 1.35 g of a sample of rivet brass was dissolved in concentrated nitric acid. The resulting mixture was boiled and then allowed to cool before being transferred to a volumetric flask. The solution was made up to 250 cm^3 with distilled water and mixed thoroughly.

Excess potassium iodide solution was added to 25.0 cm^3 samples of this solution, and the liberated iodine determined by titration with a solution of sodium thiosulfate of concentration 0.0505 mol dm^{-3}. The mean titre was 26.35 cm^3.

(i) Write the **ionic** equation for the reaction of the copper(II) ions with iodide ions to form copper(I) iodide and iodine. State symbols are not required.

(1)

(ii) Write the **ionic** equation for the reaction of iodine with thiosulfate ions. State symbols are not required.

(1)

(iii) Use the equations in (b)(i) and (b)(ii) to show that the amount of copper(II) ions is equal to the amount of thiosulfate ions.

(1)

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(iv) Calculate the percentage by mass of copper in the sample of rivet brass.

(4)

(c) (i) The reaction mixture in (b) was boiled before being transferred to a volumetric flask. This removed dissolved nitrogen oxides which would otherwise oxidize the iodide ions.

Explain the effect that omitting this step would have on the value obtained for the percentage of copper.

(2)

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(ii) Any nitrogen oxides that remain after boiling can be removed by the addition of urea. When this was done, the mean titre changed by 0.25 cm^3.
By considering the uncertainties in the various measurements, explain whether the addition of urea is worthwhile.

(2)

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(d) Both copper and zinc are d-block elements, but only copper is a transition metal.

(i) Explain the term **d-block element**.

(1)

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(ii) Explain why copper is classed as a transition metal but zinc is not.

(1)

*(iii) Explain why the complexes of copper(II) ions are coloured.

(4)

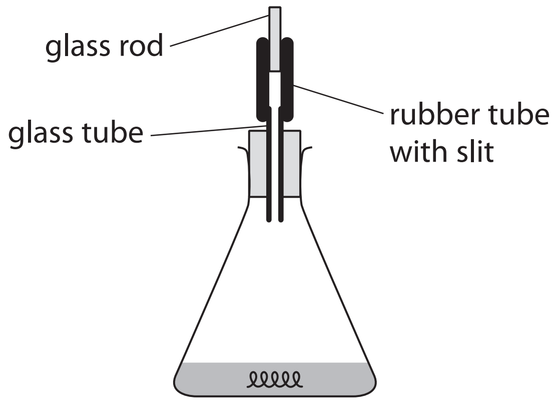
(iv) Although zinc is not a transition metal, zinc(II) ions form complexes. Explain why these complexes are colourless.

(1)

(Total for Question 1 = 23 marks)

2 Steel is the world's most important structural metal; it is strong and cheap but it corrodes rapidly if unprotected. In its simplest form, steel is an alloy of iron and carbon.

(a) The following method was used to determine the percentage of iron in a sample of wire. Exactly 1.25 g of the wire was placed in a conical flask and about 50 cm^3 of dilute sulfuric acid (an excess) was added. The flask was closed as shown in the diagram below.



When all of the iron in the wire had been converted to iron(II) sulfate, the contents of the flask were used to make 250.0 cm^3 of solution with distilled water.

25.00 cm^3 portions of this final solution were placed in a conical flask, acidified with an equal volume of dilute sulfuric acid and then titrated with a potassium manganate(VII) solution of concentration 0.0195 mol dm^{-3}. The mean titre was 22.15 cm^3.

(i) Write the equation for the reaction between iron and dilute sulfuric acid. Include state symbols in your answer.

(1)

(ii) Suggest why the conical flask was not left open, and how the labelled part of the apparatus shown in the diagram works.

(2)

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(iii) State the essential steps of the procedure for making up the reaction mixture to 250.0 cm^3 for use in the titration.

(3)

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(iv) Write the **ionic** equation for the titration reaction to show that 5 mol of iron(II) ions react with 1 mol of manganate(VII) ions. State symbols are not required.

(1)

(v) Calculate the percentage by mass of iron in the wire. Give your answer to **three** significant figures.

(4)

(vi) Describe the colour change at the end-point of the titration.

(1)

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(vii) One student who carried out this experiment forgot to acidify the mixture in the conical flask before the titration.

A brown precipitate formed before the end-point.

Identify the brown precipitate and explain how this error affects the titration value.

(3)

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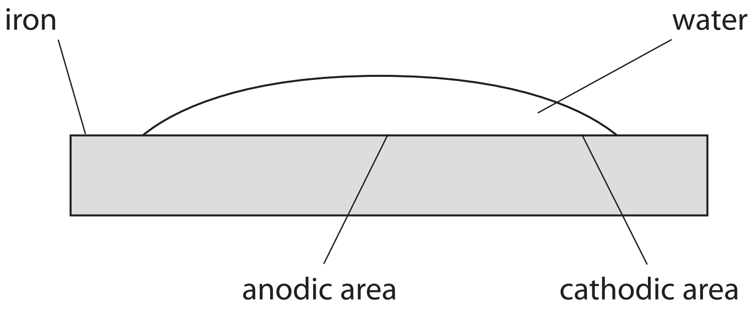
(b) The rusting of iron is an electrochemical process. A piece of iron with a droplet of water on its surface operates as an electrochemical cell. In the first stage of corrosion, iron is oxidized to iron(II) ions in the anodic area and the electrons produced travel to the cathodic area where oxygen from the air is reduced.



(i) From the information about standard electrode potentials on pages 14 and 15 of the Data Booklet, write the ionic half equations for the reactions taking place at the anodic area and at the cathodic area. State symbols are not required.

(2)

Anodic area

Cathodic area

(ii) Calculate $E^{\ominus}_{cell}$ for the overall reaction in (b)(i).

(1)

(iii) By considering the rusting mechanism described in part (b), suggest why the presence of salt in the water droplet speeds up rusting.

(1)

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(iv) The corrosion of oil pipelines made of steel is prevented by connecting the pipeline to magnesium blocks. Suggest how this method works.

(1)

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(Total for Question 2 = 20 marks)

3 The table below shows some ions of vanadium that are stable in aqueous solution.

Ion	Oxidation number of vanadium	Colour in aqueous solution
$V(H_2O)_6^{2+}$		violet
$V(H_2O)_6^{3+}$		green
VO^{2+}		blue
VO_2^{+}	+5	yellow

(a) (i) Complete the table above by adding the missing oxidation numbers.

(1)

(ii) Complete the electronic configuration of the element vanadium and hence explain the highest oxidation number shown by vanadium.

(2)

Electronic configuration of the element vanadium:

[Ar] ....

Explanation of the highest oxidation number

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*(iii) Explain why $V(H_2O)_6^{3+}$ is coloured.

(4)

(iv) Suggest why the +5 oxidation state of vanadium exists as VO_2^+ in aqueous solution, rather than $V(H_2O)_6^{5+}$.

(2)

(v) If $V(H_2O)_6^{5+}$ did exist in aqueous solution, would it be coloured? Explain your answer.

(1)

(b) (i) Sulfur dioxide dissolves in water to form sulfuric(IV) acid, H_2SO_3.

Determine the feasibility of using sulfur dioxide dissolved in water to reduce VO^{2+}(aq) to V^{3+}(aq). Quote the relevant half equations and standard electrode potentials from page 15 of the Data Booklet and write the overall equation for the reaction.

(3)

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(ii) Write an ionic equation for the disproportionation of vanadium in oxidation state +3 to vanadium in oxidation states +2 and +4.

(1)

(iii) Calculate the E_{cell} for this disproportionation and hence determine its feasibility.

(2)

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(Total for Question 3 = 16 marks)