Additional Assessment Materials

Summer 2021

Pearson Edexcel GCE in Chemistry 9CH0

Resource Set 2 – Topic Group 3

Topics included:

Topic 14: Redox II

Topic 15: Transition Metals

(Public release version)

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Additional Assessment Materials, Summer 2021

General guidance to Additional Assessment Materials for use in 2021

Context

- Additional Assessment Materials are being produced for GCSE, AS and A levels (with the exception of Art and Design).
- The Additional Assessment Materials presented in this booklet are an **optional** part of the range of evidence teachers may use when deciding on a candidate's grade.
- 2021 Additional Assessment Materials have been drawn from previous examination materials, namely past papers.
- Additional Assessment Materials have come from past papers both published (those materials available publicly) and unpublished (those currently under padlock to our centres) presented in a different format to allow teachers to adapt them for use with candidate.

Purpose

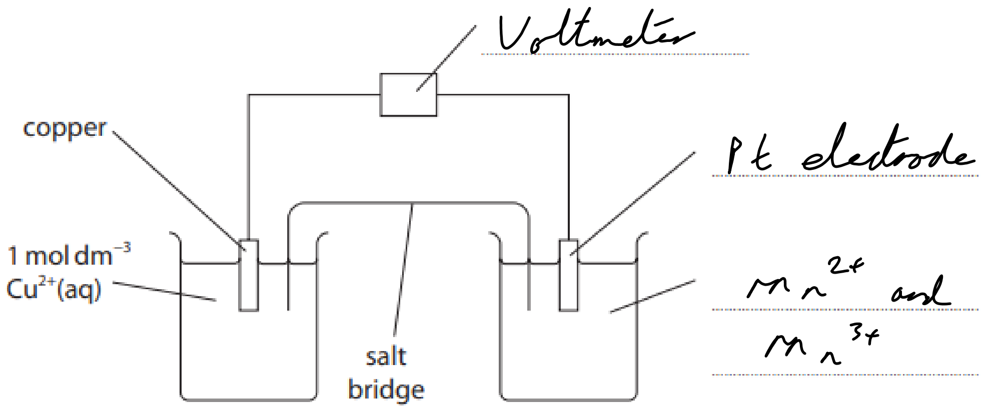
- The purpose of this resource to provide qualification-specific sets/groups of questions covering the knowledge, skills and understanding relevant to this Pearson qualification.
- This document should be used in conjunction with the mapping guidance which will map content and/or skills covered within each set of questions.
- These materials are only intended to support the summer 2021 series.

5 An electrochemical cell is made from the electrode systems represented by these half-equations.

$$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$$

$$Mn^{3+}(aq) + e^- \rightleftharpoons Mn^{2+}(aq)$$

The $E^\ominus_{cell}$ value is measured using the apparatus shown.



(a) Complete the diagram by adding labels on the dotted lines provided.

(3)

(b) A salt bridge is used to connect the two half-cells.

(i) State what chemical is contained in the salt bridge.

(1)

Potassium nitrate

(ii) Give a possible reason why the salt bridge cannot be replaced by an unreactive metal wire.

(1)

The wire would not allow the flow of ions, it would only enable flow of electrons.

(c) In this cell, the copper is oxidised and $E^{\ominus}_{cell}$ = +1.15 V.

$$Cu^{2+}(aq) + 2e^{-} \rightleftharpoons Cu(s) \qquad E^{\ominus} = +0.34\,V$$

$$Mn^{3+}(aq) + e^{-} \rightleftharpoons Mn^{2+}(aq)$$

(i) Write the overall ionic equation for the reaction taking place.
State symbols are not required.

(1)

$2Mn^{3+} + Cu \rightarrow 2Mn^{2+} + Cu^{2+}$

(ii) Calculate the value of the standard electrode potential for the Mn^{3+}(aq) I Mn^{2+}(aq) half-cell.

(1)

$E^{\theta} = 115 - -0.34 = 149V$

(Total for Question 5 = 7 marks)

1 (e) A student stated that 'the elements scandium and zinc are d-block elements but are not transition metals'.

Discuss this statement, using appropriate electronic configurations to support your answer.

(4)

A transition metal is a metal that forms an ion with an incomplete d-sub shell.

Sc^{3+} : $1s^2 2s^2 2p^6 3s^2 3p^6$

Here the d-sub shell is not filled at all so this is not a transition metal

Zn^{2+} : $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$

Here the d-sub shell is full so this is not a transition metal either.

They are however d-block elements, as the elemental atoms have their outer electrons in the d sub shell:

Sc: $[Ar] 4s^2 3d^1$, Zn: $[Ar] 4s^2 3d^{10}$

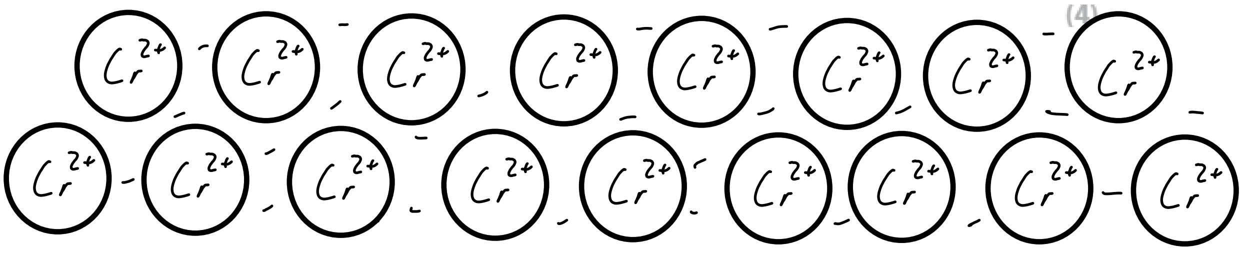
Total for Question 1 = 4 marks

3 This question is about transition metals and transition metal complexes.

(a) Describe the bonding in the element chromium and use your answer to justify why it has such a high melting temperature.

You may find it helpful to draw a labelled diagram.

(4)



Lattice of positive Cr^{2+} ions

Sea of delocalised electrons between ions

Attraction (metallic bonding) between positive ions and negative electrons holds the structure together.

This attraction is very strong, so it takes a lot of energy to separate the structure → high melting temperature.

(b) When chromium(III) sulfate dissolves in water, a green solution containing the $[Cr(H_2O)_6]^{3+}$ ion forms.

(i) Give the shape of this complex ion.

(1)

Octahedral

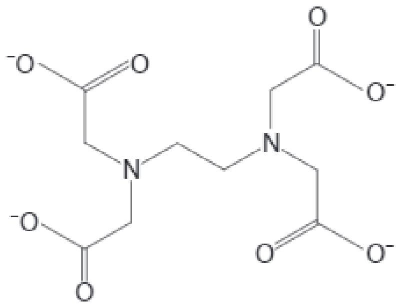
(ii) Explain why the chromium complex ion is coloured.

(3)

Cr^{3+} ions have structure: $[Ar]3d^3$

The d orbitals split into two energy levels, one higher and one lower. This is caused by the bonding of the ligands. The electrons in the lower state can be excited up to the higher state by absorbing a photon. The energy gap corresponds to a certain wavelength of light. When this wavelength is in the visable spectrum, this wavelength is absorbed and the solution is coloured.

(c) The ligand ethylenediaminetetraacetate, $EDTA^{4-}$, has the structure shown.



When a solution of $EDTA^{4-}$ is added to a solution of $[Cr(H_2O)_6]^{3+}$ ions, a new complex ion is formed.

$$[Cr(H_2O)_6]^{3+} + EDTA^{4-} \rightleftharpoons [Cr(EDTA)]^{-} + 6H_2O$$

The equilibrium constant for this equilibrium is 2.51×10^{23} $dm^3\ mol^{-1}$.

By considering the equilibrium for this reaction and changes in entropy, comment on the value of the equilibrium constant. No calculations are required.

(3)

There are only 2 moles on the left and there are 7 moles on the right. Hence the entropy increases greatly favouring the reaction towards the right. As a result, the equilibrium is greatly shifted towards right giving a high value for equilibrium constant.

(d) Aqueous vanadium(II) chloride, $VCl_2(aq)$, can be oxidised by bubbling gaseous chlorine, $Cl_2(g)$, through the solution in the absence of air.

$40.0\ cm^3$ of $0.100\ mol\ dm^{-3}$ VCl_2 solution was oxidised by $144\ cm^3$ of chlorine gas, at room temperature and pressure (r.t.p.).
The chlorine was reduced to chloride ions, according to the half-equation

$$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$$

[Molar volume of a gas at r.t.p. = $24.0\ dm^3\ mol^{-1}$]

(i) Use these data to calculate the final oxidation state of vanadium.
You **must** show your working.

(5)

$n\ Cl_2 = \frac{V}{V_m} = \frac{144 \times 10^{-3}}{24} = 6 \times 10^{-3}$ mol) ×2

↳ n of electrons taken = 1.2×10^{-2} mol } ÷3

$n\ VCl_2 = cV = 0.1 \times 40 \times 10^{-3} = 4 \times 10^{-3}$ mol

⇒ 3 electrons lost per vanadium

initial oxidation state of V = +2

⇒ final oxidation state is +5 ← +3

(ii) State the initial and final colours you would see as the chlorine bubbles through the aqueous vanadium(II) chloride, $VCl_2(aq)$.

(2)

Initial → purple

Final → yellow

(Total for Question 3 = 18 marks)

1 This question is about transition metal chemistry.

(a) The **amphoteric** character of solid chromium(III) hydroxide is shown by the fact that it reacts separately with both dilute hydrochloric acid and dilute sodium hydroxide solution.

(i) Write an **ionic** equation for the reaction of solid chromium(III) hydroxide with dilute hydrochloric acid, showing the formula of the complex ion formed. Include state symbols in your answer.

(2)

$Cr(OH)_{3\,(s)} + 3H^{+}_{(aq)} + 3H_2O_{(l)} \rightarrow [Cr(H_2O)_6]^{3+}_{(aq)}$

(ii) Describe the changes you would **see** when the reaction in (a)(i) is carried out.

(2)

Green solid dissolves to form a green solution.

(iii) Write an **ionic** equation for the reaction of solid chromium(III) hydroxide with dilute sodium hydroxide solution, showing the formula of the complex ion formed. Include state symbols in your answer.

(2)

$Cr(OH)_{3\,(s)} + 3OH^{-}_{(aq)} \rightarrow [Cr(OH)_6]^{3-}_{(aq)}$

(iv) State the final appearance of the reaction mixture in (a)(iii).

(1)

Green solution

(b) Dilute aqueous ammonia is added, drop by drop, to an aqueous solution of copper(II) sulfate until the aqueous ammonia is in excess.

(i) Describe what you would **see** during this experiment.

(2)

Initially a blue precipitate forms, which then redissolves to give a royal blue solution.

(ii) The reaction between aqueous copper(II) sulfate and **excess** aqueous ammonia is an example of a **ligand substitution** reaction.

Write an equation for the ligand substitution reaction that occurs, showing the formulae of the complex ions involved. State symbols are not required.

(2)

$$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 4H_2O$$

(Total for Question 1 = 11 marks)

Total for Test = 40 marks