Additional Assessment Materials

Summer 2021

Pearson Edexcel GCE in Chemistry 9CH0

Resource Set 1 – 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- Additional Assessment Materials have come from past papers both published (those materials available publicly) and unpublished (those currently under padlock to our centres) presented in a different format to allow teachers to adapt them for use with candidate.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.

4 This question is about transition metals.

(a) Which of these ions has the electronic configuration $[Ar]3d^5$?

(1)

☐ **A** Cr^{3+}

☐ **B** Fe^{2+}

☒ **C** Mn^{2+}

☐ **D** Mn^{3+}

(b) In which of these complex ions does the transition metal have the oxidation number +3?

(1)

☐ **A** $[Ag(CN)_2]^-$ $x - 2 = -1 \rightarrow x = +1$

☐ **B** $[CuCl_4]^{2-}$ $x - 4 = -2 \rightarrow x = +2$

☒ **C** $[Fe(CN)_6]^{3-}$ $x - 6 = -3 \rightarrow x = +3$

☐ **D** $[Ni(EDTA)]^{2-}$

(c) Which type or types of bonding exist **within** the complex ion $[Cr(H_2O)_6]^{3+}$?

(1)

☒ **A** dative covalent only

☐ **B** dative covalent and covalent only

☐ **C** dative covalent and ionic only

☐ **D** dative covalent, covalent and ionic

(d) Which **best** explains why $[Cu(NH_3)_2]^+$ ions are colourless?

(1)

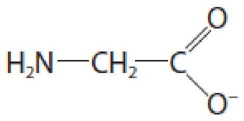
☐ **A** all complex ions having a metal ion with a +1 charge are colourless

☒ **B** no electronic transitions can take place between *d*-orbitals

☐ **C** the *d*-orbitals cannot split in energy

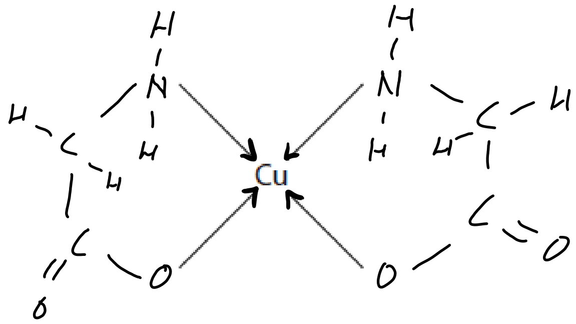
☐ **D** there are no electrons in the *d*-subshell

(e) Glycinate ions are bidentate ligands and can be represented by the structure



Complete the diagram below to show the structure of the $[Cu(NH_2CH_2COO)_2]$ complex, which is square planar.

(2)



(f) Manganate(VII) ions, MnO_4^-, react with ethanedioate ions in acid solution.

$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

The reaction starts slowly, the rate of reaction then increases, before it decreases again. Explain this sequence.

(3)

- Initially it is slow, as the reacting species are both negatively charged, and so repel each other.

- The rate then increases as Mn^{2+} is formed. This acts as a catalyst. (autocatalyst) Mn^{2+} react with MnO_4^- ions to form Mn^{3+} intermediate species, which reform Mn^+ when react with $C_2O_4^{2-}$ ions

- It then decreases as the concentration of reactants decreases and so collisions are less frequent. per unit time

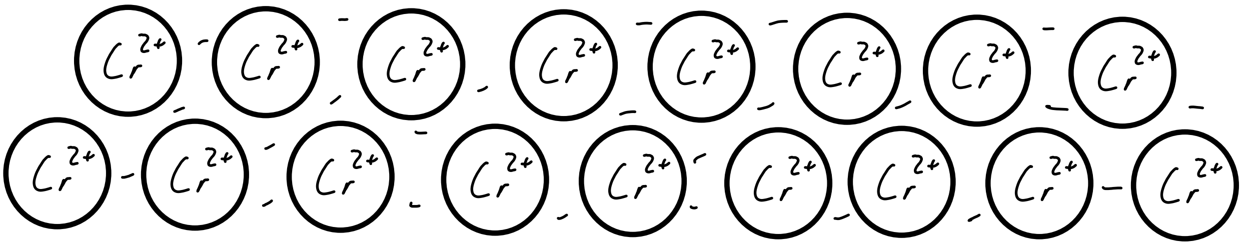
(Total for Question 4 = 9 marks)

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 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)

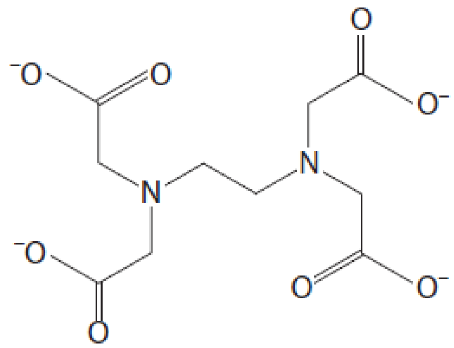
Octahedral

(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 other wavelengths/light not absorbed are reflected & combine as a single colour seen

(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)

Sum of 2 moles on left side of reaction is smaller than the sum of 7 moles on right side. This means the reaction is favoured to the right due to higher entropy level, positive entropy change. Position of equilibrium shifts to the right thus would increase 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

↳ 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

⇒ final oxidation state is +5

(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 → green

Final → yellow

(Total for Question 3 = 18 marks)

2 This question is about the $Ag^+(aq)|Ag(s)$ half-cell.

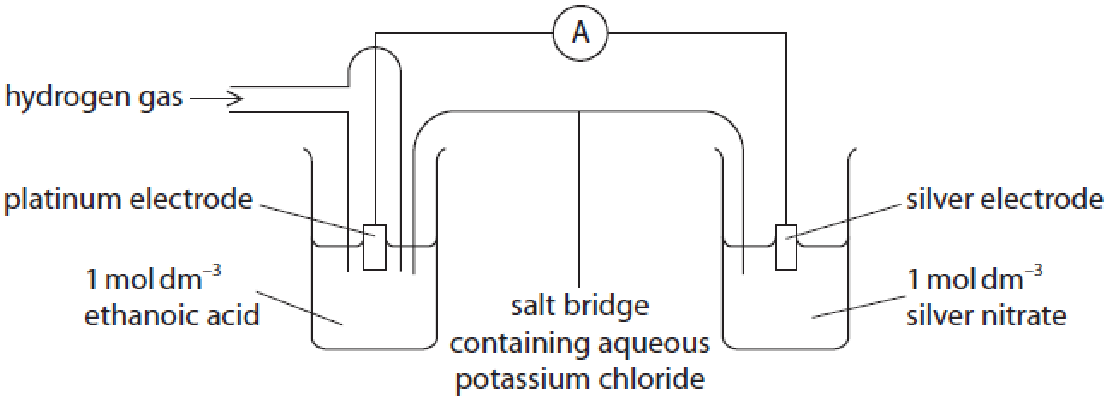
(a) A student was asked to plan an experiment to measure the standard electrode potential of the $Ag^+(aq)|Ag(s)$ half-cell.

(i) State the conditions of temperature and pressure under which standard electrode potentials are measured.

(1)

25°C and 100kPa

(ii) The student drew the diagram shown.



Identify **three** mistakes in this diagram and the modifications that should be made to correct them.

(3)

Mistake in diagram	Modification needed to correct mistake
Ammeter should be a voltmeter.	Replace ammeter symbol with voltmeter symbol.
Salt bridge should contain sodium iodide, not potassium chloride.	Replace potassium chloride with sodium iodide.
Strong acid should be used in left hand beaker, e.g. HCl	Replace ethanoic acid with e.g. HCl

Total for Question 2 = 4 marks

10 Yellow gold is used to make jewellery. It is an alloy of copper, gold and silver. The purity of gold is measured in carats. The higher the carat, the higher the percentage of gold in the alloy. Pure gold is 24 carat.

A sample of yellow gold is analysed using the steps below.

Step **1** Excess concentrated nitric acid is reacted with 1.250 g of the alloy. The gold does **not** react but the copper and silver do react. The half-equations are

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

$$Ag(s) \rightarrow Ag^+(aq) + e^-$$

$$2HNO_3(aq) + e^- \rightarrow NO_3^-(aq) + NO_2(g) + H_2O(l)$$

Step **2** The mixture is diluted with distilled water and the gold is filtered off.

Step **3** Excess hydrochloric acid is added to the filtrate. It reacts with the silver ions to form a precipitate of silver chloride.

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

Step **4** The silver chloride precipitate is filtered off, washed, dried and weighed. The mass of silver chloride formed is 0.706 g.

Step **5** Excess potassium iodide is added to the remaining solution. A precipitate of copper(I) iodide and a solution of iodine forms.

$$2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$$

Step **6** The resulting mixture is titrated with 0.100 mol dm^{-3} sodium thiosulfate solution.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow 2I^-(aq) + S_4O_6^{2-}(aq)$$

The titre is 39.40 cm^3.

(a) Write the equation for the reaction of copper with concentrated nitric acid, using the half-equations given in Step **1**. State symbols are not required.

(1)

$Cu + 4HNO_3 \rightarrow Cu^{2+} + 2NO_3 + 2NO_2^- + 2H_2O$

(b) State the indicator used and its colour change at the end-point in the titration in Step **6**.

(2)

Starch, blue/black → colourless

(c) The table shows the percentage by mass of gold in four different carats of yellow gold.

Carat	Percentage by mass of gold
9	37.5
10	41.7
14	58.3
18	75.0

Determine, using the experimental data, the carat of the sample of yellow gold that was analysed.

(6)

$n\ AgCl = \frac{0.706}{107.9+35.5} = 4.92 \times 10^{-3}$

$m\ Ag = 4.92 \times 10^{-3} \times 107.9 = 0.531$

$n\ Cu^{2+} = 394 \times 0.1 \times 10^{-3} = 3.94 \times 10^{-3}$

$m\ Cu = 3.94 \times 10^{-3} \times 63.5 = 0.250$

$\therefore\ m\ Au = 1.25 - 0.531 - 0.25 = 0.469$

$\%\ Au = \frac{0.469}{1.25} \times 100 = 37.5\%$

9 carat

(Total for Question 10 = 9 marks)

Total for Test = 40 marks