



**Topic Test: Oxford AQA
International A level Chemistry**
A2 Inorganic Chemistry

Name: _____

Class: _____

Date: _____

Time: **79 minutes**

Marks: **74 marks**

Comments:

1

This question is about compounds of the elements in Period 3.

- (a) Phosphorus burns in air to form phosphorus(V) oxide.

Write an equation for this reaction.

(1)

- (b) Sulfur forms two oxides, SO_2 and SO_3
Both oxides react with water to form acidic solutions.

State the formula of each acid formed and the approximate pH of a 0.1 mol dm^{-3} solution of each acid.

Formula of acid formed by SO_2 _____

pH _____

Formula of acid formed by SO_3 _____

pH _____

(2)

- (c) Aluminium oxide can act as an acid and can act as a base.

Write an equation to show aluminium oxide acting as an acid.

(1)

- (d) Silicon reacts with oxygen to form SiO_2 and with chlorine to form SiCl_4

The table shows the melting points of SiO_2 and SiCl_4

Compound	Melting point / °C
SiO_2	1710
SiCl_4	-69

Explain, in terms of structure and bonding, why SiO_2 has a very high melting point but SiCl_4 has a very low melting point.

SiO_2 _____

SiCl_4 _____

(4)
(Total 8 marks)

2 This question is about some Period 3 oxides and chlorides.

(a) Suggest why silicon dioxide can be described as an acidic oxide even though it is insoluble in water.

(1)

The table below shows the melting points of some Period 3 oxides.

	Na_2O	SO_2	SO_3
Melting point/K	1548	200	290

(b) Explain, in terms of structure and bonding, why sodium oxide has a high melting point.

(3)

(c) Explain why sulfur trioxide has a higher melting point than sulfur dioxide.

(2)

A small amount of each of the Period 3 chlorides NaCl, MgCl₂, AlCl₃ and PCl₅ is added to separate samples of deionised water.

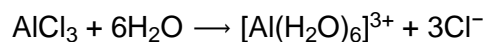
The pH values of the resulting solutions are measured.

(d) State why NaCl forms a neutral solution.

(1)

Both AlCl₃ and PCl₅ form acidic solutions.

(e) The equation for the reaction of AlCl₃ with water is



Explain why the solution formed is acidic. Use an equation in your answer.

(2)

(f) Identify the **two** acids formed when PCl₅ reacts with water.

(1)

(Total 10 marks)

3

Which of the following is **not** able to act as a ligand?

- A Cl^-
- B $\text{CH}_3\text{CH}_2\text{CH}_3$
- C H_2O
- D $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$

(Total 1 mark)

4

A solution containing EDTA^{4-} ions is added to a solution containing $[\text{CuCl}_4]^{2-}$ ions. The EDTA^{4-} ions replace the Cl^- ligands in the copper complex to form $[\text{CuEDTA}]^{2-}$ ions.

Why does this reaction occur?

- A EDTA^{4-} is more highly charged than Cl^-
- B EDTA^{4-} is larger than Cl^-
- C The enthalpy change is positive.
- D The entropy change is positive.

(Total 1 mark)

5

In acid solution, manganate(VII) ions react with ethanedioate ions ($\text{C}_2\text{O}_4^{2-}$) to form carbon dioxide.

What is the mole ratio of MnO_4^- : $\text{C}_2\text{O}_4^{2-}$ in this reaction?

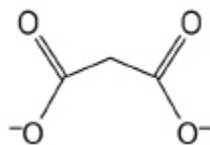
- A 1:5
- B 2:5
- C 4:5
- D 5:2

(Total 1 mark)

6

A propanedioate ion can act as a bidentate ligand.

The skeletal formula of a propanedioate ion is shown.

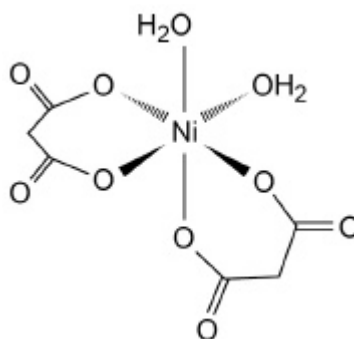


(a) Give the meaning of the term bidentate ligand.

(1)

(b) Ni^{2+} ions form a complex ion **Z** that contains two propanedioate ligands and two water ligands.

Z exists as three stereoisomers. One of these stereoisomers is shown. The charge has not been shown.

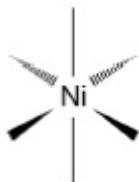


Complete the diagrams of the other two stereoisomers of **Z**.
You do **not** need to include any charges on your diagrams.

For each stereoisomer, place one or more ticks in the boxes to identify the type or types of isomer shown.



<i>cis</i>	
<i>trans</i>	
optical	

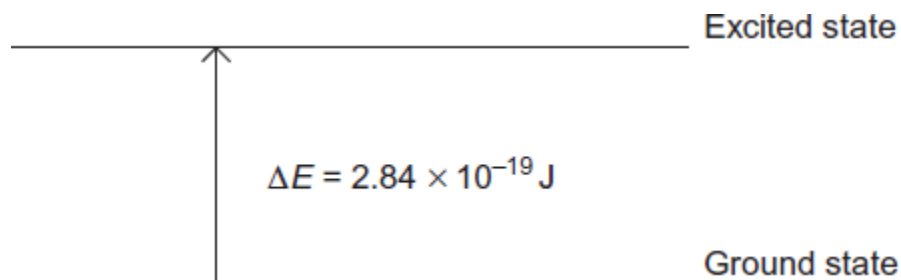


<i>cis</i>	
<i>trans</i>	
optical	

(4)
(Total 5 marks)

7

This diagram represents the energy change that occurs when a d electron in a transition metal ion is excited by visible light.



- (a) Give the equation that relates the energy change ΔE to the Planck constant h and the frequency of the visible light ν .

Use this equation and the information in the diagram to calculate a value for the frequency of the visible light, and state the units.

The Planck constant $h = 6.63 \times 10^{-34} \text{ J s}$.

Equation _____

Calculation _____

(2)

- (b) Explain why this electron transition causes a solution containing the transition metal ion to be coloured.

(2)

- (c) The energy change shown in the diagram represents the energy of red light and leads to a solution that appears blue.

Blue light has a higher frequency than red light.

Suggest whether the energy change ΔE will be bigger, smaller or the same for a transition metal ion that forms a red solution. Explain your answer.

Energy change _____

Explanation _____

(2)

- (d) State **three** different features of transition metal complexes that cause a change in the value of ΔE , the energy change between the ground state and the excited state of the d electrons.

Feature 1 _____

Feature 2 _____

Feature 3 _____

(3)

(Total 9 marks)

8

A student investigates the solubility of hydrated iron(II) ethanedioate ($\text{FeC}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$) in water.

The student uses the following method.

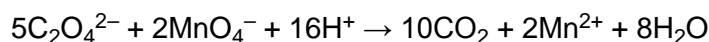
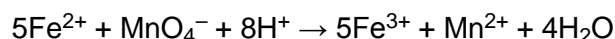
Step 1 Add hydrated iron(II) ethanedioate to approximately 500 cm^3 of water at 25°C

Step 2 Stir until no more solid dissolves and a saturated solution is formed.

Step 3 Remove a 25.0 cm^3 portion of the saturated solution. Add 25.0 cm^3 of dilute sulfuric acid and heat to about 60°C

Step 4 Titrate the hot solution with acidified potassium manganate(VII) solution.

- (a) The Fe^{2+} and $\text{C}_2\text{O}_4^{2-}$ ions react with MnO_4^- ions in acidic solution as shown.



Complete the overall equation for the reaction between FeC_2O_4 and MnO_4^- ions in acidic solution.



(1)

(b) Suggest why the solution is heated in **Step 3**.

(1)

(c) During **Step 3** some evaporation of the solution occurs.

State and explain the effect, if any, this has on the volume of potassium manganate(VII) solution needed in **Step 4**.

Effect on volume of potassium manganate(VII) _____

Explanation _____

(2)

(d) Explain why no indicator is needed for this titration.
State the colour at the end point.

Explanation _____

Colour at end point _____

(2)

- (e) In **Step 4**, the concentration of potassium manganate(VII) is $6.40 \times 10^{-3} \text{ mol dm}^{-3}$
The mean titre is 12.45 cm^3

Calculate the solubility, in g dm^{-3} , of hydrated iron(II) ethanedioate at $25 \text{ }^\circ\text{C}$

Solubility _____ g dm^{-3}

(5)

- (f) Iron(II) ethanedioate solution is yellow.
Outline a method, using a colorimeter, to determine the concentration of a solution of iron(II) ethanedioate.

(2)

(Total 13 marks)

9

- (a) Use data from the table below to explain why dilute hydrochloric acid cannot be used to acidify potassium manganate(VII) in a titration.

	E^\ominus / V
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$	+1.51
$Cl_2(aq) + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$2H^+(aq) + 2e^- \rightarrow H_2(aq)$	0.00

(2)

- (b) Use information from the table in part (a) to determine the minimum volume, in cm^3 , of $0.500 \text{ mol dm}^{-3}$ sulfuric acid that is required for a titre of 25.0 cm^3 of $0.0200 \text{ mol dm}^{-3}$ potassium manganate(VII) solution.
Show your working.

(3)

- (c) In each titration using potassium manganate(VII), a large excess of dilute sulfuric acid is used to avoid any possibility of the brown solid MnO_2 forming.
- (i) Deduce a half-equation for the reduction of MnO_4^- ions in acidic solution to form MnO_2 .

(1)

- (ii) Give **two** reasons why it is essential to avoid this reaction in a titration between potassium manganate(VII) and iron(II) ions.

(2)

- (d) Potassium manganate(VII) is an oxidising agent.
Suggest **one** reason why a $0.0200 \text{ mol dm}^{-3}$ solution of potassium manganate(VII) does **not** need to be kept away from flammable material.

(1)

(Total 9 marks)

- (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)

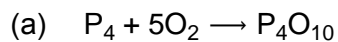
- (d) An excess of dilute aqueous ammonia is added to separate aqueous solutions containing $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ and $[\text{Ag}(\text{H}_2\text{O})_2]^+$

(4)

(Total 17 marks)

Mark schemes

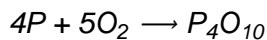
1



allow multiples or fractions

ignore state symbol

allow



reject any formula for phosphorous that is not P or P₄

1

(b) Formulae:



*If no mark awarded then award 1 mark for correct formula **and** pH for one oxide*

1

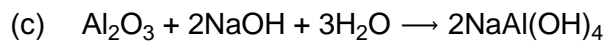
pH values

SO_2 any in range 2 to 5

AND

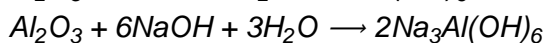
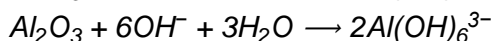
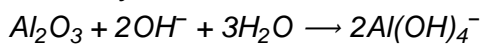
SO_3 any in range 0 to 1

1



ignore state symbols

Allow any of:



Reject reactions with carbonates and hydrogen carbonates

1

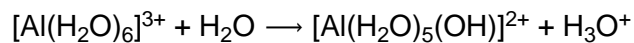
- (d) **M1** SiO₂ giant (lattice) and covalent
Allow “macromolecular” for “giant lattice” and “giant covalent” for M1 1
- M2** strong (covalent) bonds (between atoms) / require lots of energy to overcome – break
If SiO₂ is not covalent, lose M2 1
- M3** SiCl₄ (simple) molecular 1
- M4** weak forces between molecules / weak van der Waal's forces / weak intermolecular forces
and
 require little energy to overcome
if breaking covalent bonds in SiCl₄ then do not award M4 1
If SiO₂ stated as not covalent, do not award M1 or M2
If SiCl₄ stated as not covalent, do not award M3 or M4 1
- [8]**
- 2** (a) SiO₂ reacts with bases / NaOH / CaO / CaCO₃ 1
- (b) It is an ionic lattice / giant ionic
Allow giant lattice if ions mentioned in answer 1
- Contains oppositely charged ions/ + and – ions 1
- with strong forces of attraction between the ions 1
Allow a lot of energy to separate oppositely charged ions.
M3 dependent on M2
Max 1/3 if mention of electronegativity ie M1 only
CE = 0/3 if mention of atoms / molecules / metallic
- (c) SO₃ is a bigger molecule than SO₂
CE = 0 if mention of ions 1
- so van der Waals' forces between molecules are stronger 1
- (d) no reaction or no hydrolysis or only dissolving occurs
Allow NaCl is the salt of a strong acid and a strong alkali 1

- (e) Al^{3+} small and highly charged (and weakens the O–H bond the ligand)

Allow Al^{3+} is highly polarising

Allow Al^{3+} weakens the O–H bond

1



Accept equations with more than one H_2O reacting

Allow formation of H^+

1

- (f) phosphoric(V) acid or H_3PO_4

allow phosphoric acid

AND

hydrochloric acid or HCl

1

[10]

3 B

[1]

4 D

[1]

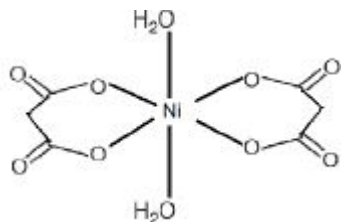
5 B

[1]

- 6 (a) **M1** donates an electron pair (to a metal atom/ion) from two different atoms

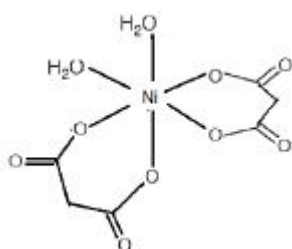
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(b)



<i>cis</i>	
<i>trans</i>	✓
optical	

1



<i>cis</i>	✓
<i>trans</i>	
optical	✓

1

1

1

[5]

7

(a) $\Delta E = h\nu$

Allow = hf

1

$$\nu = \Delta E / h = 2.84 \times 10^{-19} / 6.63 \times 10^{-34} = 4.28 \times 10^{14} \text{ s}^{-1} / \text{Hz}$$

Allow $4.3 \times 10^{14} \text{ s}^{-1} / \text{Hz}$

Answer must be in the range:

$$4.28 - 4.30 \times 10^{14}$$

1

(b) (One colour of) light is absorbed (to excite the electron)

If light emitted, CE = 0

1

The remaining colour / frequency / wavelength / energy is transmitted (through the solution)

Allow light reflected is the colour that we see.

1

(c) Bigger 1

Blue light would be absorbed

OR light that has greater energy than red light would be absorbed
OR higher frequency (of light absorbed / blue light) leads to higher ΔE

Can only score M2 if M1 is correct.

1

(d) Any **three** from:

- (Identity of the) metal
- Charge (on the metal) / oxidation state / charge on complex
- (Identity of the) ligands
- Co-ordination number / number of ligands
- Shape

3 max

[9]

8 (a) $(5\text{FeC}_2\text{O}_4 + 3\text{MnO}_4^-) + 24\text{H}^+ \rightarrow 10\text{CO}_2 + 3\text{Mn}^{2+} + 12\text{H}_2\text{O} + 5\text{Fe}^{3+}$ 1

(b) the reaction is slow (at room temperature)

allow the activation energy is high

allow "to increase the rate of the reaction"

reject to remove water

1

(c) **M1** no effect

If M1 incorrect, CE = 0/2

1

M2 moles of iron(II) ethanedioate do not change

allow only water lost

1

(d) **Explanation** when all of the iron(II) ethanedioate has reacted manganese(VII) remains unreacted **OR** self indicating

1

Colour (pale) pink

ignore purple

1

(e) **M1** amount MnO_4^- ($= 6.40 \times 10^{-3} \times 12.45/1000$) $= 7.968 \times 10^{-5}$ mol

1

M2 amount FeC_2O_4 ($= 7.968 \times 10^{-5} \times 5/3$) $= 1.328 \times 10^{-4}$ mol

$$M2 = M1 \times 5/3$$

1

M3 = amount FeC_2O_4 in 1 dm^3 ($= 1.328 \times 10^{-4} \times 1000/25$) $= 5.312 \times 10^{-3}$ mol

$$M3 = M2 \times 40$$

1

M4 = solubility $= 5.312 \times 10^{-3} \times 179.8$

$$M4 = M3 \times 179.8$$

1

M5 = 0.955 (g dm^{-3})

If arithmetic error only, allow max 4/5

1

OR

M1 amount MnO_4^- ($= 6.40 \times 10^{-3} \times 12.45/1000$) $= 7.968 \times 10^{-5}$ mol

M2 amount FeC_2O_4 ($= 7.968 \times 10^{-5} \times 5/3$) $= 1.328 \times 10^{-4}$ mol

$$M2 = M1 \times 5/3$$

M3 = mass FeC_2O_4 $= (1.328 \times 10^{-4} \times 179.8) = 0.02388$

$$M3 = M2 \times 179.8$$

M4 = solubility $= 0.02388 \times 1000/25$

$$M4 = M3 \times 40$$

M5 = 0.955 (g dm^{-3})

(f) **M1** (make up solutions of known concentrations and) find absorbance of known concentrations

M2 read concentration of unknown from calibration graph

2

[13]

9

(a) Manganate would oxidise / react with Cl^-

1

Because E^\ominus for MnO_4^- is more positive than that for Cl^- / $1.51 - 1.36 = +0.15$ (V)

Must refer to data from the table for M2.

1

(b) Moles of H^+ $= 25 \times 0.0200 \times 8 / 1000 = 4.00 \times 10^{-3}$

1

Moles of $\text{H}_2\text{SO}_4 = 2.00 \times 10^{-3}$ ($4.00 \times 10^{-3} / 2$)

Allow consequential marking on incorrect moles of H^+

1

Volume $\text{H}_2\text{SO}_4 = 4.00$ (cm^3) ($2.00 \times 10^{-3} \times 1000 / 0.500$)

Allow consequential marking on incorrect moles of H_2SO_4

Accept 4 cm^3 .

8 cm^3 scores 2 marks.

Do not penalise precision.

Correct answer without working scores M3 only.

1

(c) (i) $\text{MnO}_4^- + 4\text{H}^+ + 3\text{e}^- \rightarrow \text{MnO}_2 + 2\text{H}_2\text{O}$

Allow multiples, including fractions.

Ignore state symbols.

1

(ii) Can't see end point due to brown colour

1

Larger titre (than expected)

Allow the idea that with two reactions can't make use of titre in calculations.

Do not allow 'an inaccurate result' without qualification.

1

(d) Solution (very) dilute / lots of water

1

[9]

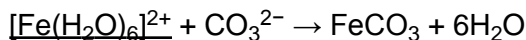
10

(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

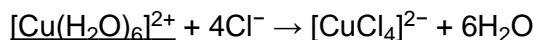


1

- (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

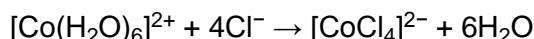


Allow equations with HCl

1

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

1

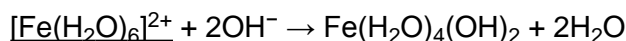


1

- (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



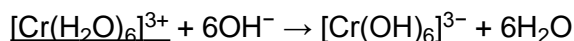
Allow equations with NaOH

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.

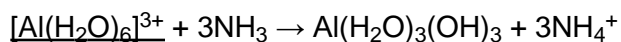
Also allow two correct equations showing $\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3$ as intermediate.

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

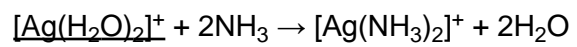
$\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^-$ also

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]