



Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

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Forename(s)

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Candidate signature

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# A-level CHEMISTRY

## Paper 1 Inorganic and Physical Chemistry

Tuesday 13 June 2017

Afternoon

Time allowed: 2 hours

### Materials

For this paper you must have:

- the Periodic Table/Data Booklet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a calculator, which you are expected to use where appropriate.

### Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of the page.
- Answer **all** questions.
- You must answer the questions in the spaces provided.  
Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

### Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 105.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
<b>TOTAL</b>	



J U N 1 7 7 4 0 5 1 0 1

IB/M/Jun17/E8

**7405/1**

Answer **all** questions in the spaces provided

0 1

This question is about **silver iodide**. (AgI) used to describe the strength of ionic bonding in a compound. [2 marks]

0 1 . 1

**Define** the term **enthalpy of lattice formation**.

Enthalpy change when one mole of a solid, ionic compound is formed from its gaseous ions.

0 1 . 2

Some **enthalpy change data** are shown in **Table 1**.

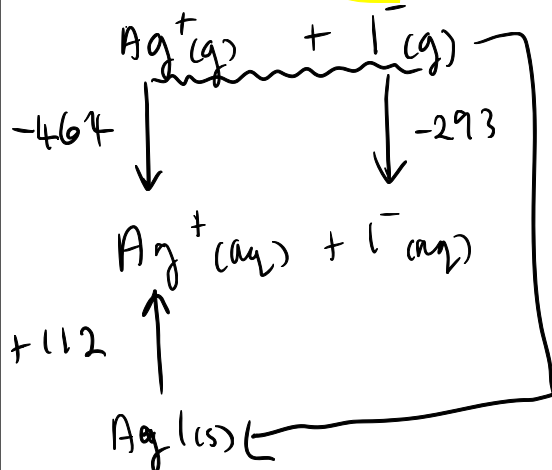
Table 1

	<b>Enthalpy change</b> / $\text{kJ mol}^{-1}$
$\text{AgI(s)} \rightarrow \text{Ag}^+(\text{aq}) + \text{I}^-(\text{aq})$	+112
$\text{Ag}^+(\text{g}) \rightarrow \text{Ag}^+(\text{aq})$	-464
$\text{I}^-(\text{g}) \rightarrow \text{I}^-(\text{aq})$	-293

mini Hess  
cycle

Use the data in **Table 1** to **calculate** the **enthalpy of lattice formation** of **silver iodide**.

[2 marks]



$\Delta H$  (lattice  
formation)

$$CW = ACW$$

lattice formation  
enthalpies always need  
to be exothermic

$$\Delta H_{LF} + (+112) = -464 + (-293)$$

$$\Delta H_{LF} = -464 + (-293) - (+112) = -869 \text{ kJ mol}^{-1}$$

Enthalpy of lattice formation -869  $\text{kJ mol}^{-1}$



0 1 . 3

A calculation of the enthalpy of lattice formation of silver iodide based on a perfect ionic model gives a smaller numerical value than the value calculated in Question 1.2

Explain this difference.

due to a smaller difference in electronegativities.

[2 marks]

Silver iodide is not perfectly ionic - it shows some covalent character. Therefore, the bonding in the lattice will be stronger.

0 1 . 4

Identify a reagent that could be used to indicate the presence of iodide ions in an aqueous solution and describe the observation made.

[2 marks]

Reagent Aqueous silver nitrate ( $\text{AgNO}_3$ )

Observation yellow precipitate formed.

OR:  $\text{Cl}_2$ , brown solution, OR:  $\text{Br}_2$ , black precipitate

Turn over for the next question

(displacement reactions of halogens/halides).

8



0 2

This question is about acidic solutions.

0 2 . 1

The acid dissociation constant,  $K_a$  for ethanoic acid is given by the expression

$$K_a = \frac{[\text{CH}_3\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{COOH}]}$$

The value of  $K_a$  for ethanoic acid is  $1.74 \times 10^{-5} \text{ mol dm}^{-3}$  at  $25^\circ\text{C}$ A buffer solution with a pH of 3.87 was prepared using ethanoic acid and sodium ethanoate. In the buffer solution, the concentration of ethanoate ions was  $0.136 \text{ mol dm}^{-3}$ Calculate the concentration of the ethanoic acid in the buffer solution.  
Give your answer to three significant figures.

[3 marks]

$$\text{pH} = -\log_{10} [\text{H}^+] \therefore [\text{H}^+] = 10^{-\text{pH}}$$

$$[\text{H}^+] = 10^{-3.87} = 1.3489 \times 10^{-4} \text{ mol dm}^{-3} \quad \checkmark$$

( $[\text{H}^+]$  in buffer solution)

$$K_a = \frac{[\text{CH}_3\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{COOH}]} \rightarrow [\text{CH}_3\text{COOH}] = \frac{[\text{CH}_3\text{COO}^-][\text{H}^+]}{K_a}$$

$$[\text{CH}_3\text{COOH}] = \frac{0.136 \times 1.3489 \times 10^{-4}}{1.74 \times 10^{-5}} = 1.05436 \text{ mol dm}^{-3} \quad \checkmark$$

$$\therefore = 1.05 \text{ mol dm}^{-3} \quad \underline{\underline{3.54}}$$

Concentration of acid 1.05 mol  $\text{dm}^{-3}$   $\checkmark$ 

0 2 . 2

In a different buffer solution, the concentration of ethanoic acid was  $0.260 \text{ mol dm}^{-3}$  and the concentration of ethanoate ions was  $0.121 \text{ mol dm}^{-3}$

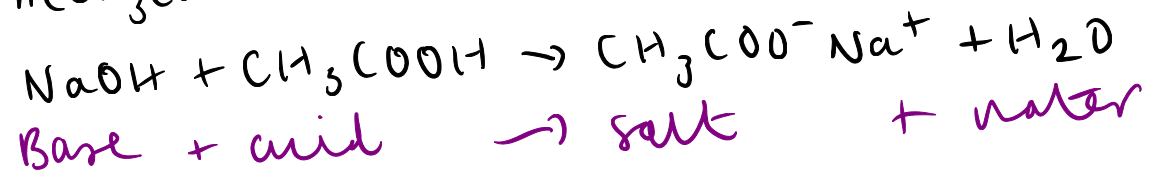
A  $7.00 \times 10^{-3} \text{ mol}$  sample of sodium hydroxide was added to  $500 \text{ cm}^3$  of this buffer solution.

Calculate the pH of the buffer solution after the sodium hydroxide was added. Give your answer to two decimal places.

All in  $500 \text{ cm}^3$  sol. (total volume =  $500 \text{ cm}^3$ ) [6 marks]  
 $\text{cm}^3 \xrightarrow{\div 1000} \text{dm}^3 \therefore \text{total vol.} = 0.5 \text{ dm}^3$

$n = V \times C \quad n(\text{CH}_3\text{COOH}) = 0.5 \times 0.260 = 0.130 \text{ mol}$   
*↳ needs to be in  $\text{dm}^3$  to match  $\text{mol dm}^{-3}$*

$n(\text{CH}_3\text{COO}^- \text{Na}^+) = 0.5 \times 0.121 = 0.0605 \text{ mol}$



$n(\text{NaOH}) = 0.007 \text{ mol}$   
 $\text{NaOH} : \text{CH}_3\text{COOH} \quad 1 : 1 \quad \therefore n(\text{CH}_3\text{COOH REACTED}) = 0.007 \text{ mol.}$

so  $n(\text{CH}_3\text{COOH})$  AFTER adding NaOH =  $0.130 - 0.007 = 0.123 \text{ mol}$

$\text{NaOH} : \text{CH}_3\text{COO}^- \text{Na}^+$  (from equation above)  
 $1 : 1 \quad \therefore n(\text{CH}_3\text{COO}^- \text{Na}^+ \text{ MADE}) = 0.007 \text{ mol}$

so  $n(\text{CH}_3\text{COO}^- \text{Na}^+)$  AFTER adding NaOH =  $0.0605 + 0.007 = 0.0675 \text{ mol.}$

$K_a = \frac{[\text{CH}_3\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{COOH}]} \rightarrow [\text{H}^+] = \frac{K_a \times [\text{CH}_3\text{COOH}]}{[\text{CH}_3\text{COO}^-]}$

(teacher)  $[\text{CH}_3\text{COOH}]$   
 $\therefore [\text{H}^+] = \frac{1.74 \times 10^{-5} \times 0.123}{0.0675}$  } can use moles as all in  $500 \text{ cm}^3$

$[\text{H}^+] = 3.171 \times 10^{-5}$   
 $\text{pH} = -\log_{10}[\text{H}^+] = -\log_{10}(3.171 \times 10^{-5})$   
 $\text{pH} = 4.4988$

pH of buffer solution 4.50 (2dp)

9



Turn over ▶

0 3

The ionic product of water,  $K_w = 2.93 \times 10^{-15} \text{ mol}^2 \text{ dm}^{-6}$  at  $10^\circ\text{C}$

0 3 . 1

Which is the correct expression for  $K_w$ ?  
Tick (✓) one box.

↓  
represents the dissociation of water

[1 mark]

A  $K_w = \frac{[\text{H}_2\text{O}]}{[\text{H}^+][\text{OH}^-]}$

B  $K_w = [\text{H}^+][\text{H}_2\text{O}]$

C  $K_w = [\text{H}^+][\text{OH}^-]$

D  $K_w = \frac{[\text{H}^+][\text{OH}^-]}{[\text{H}_2\text{O}]}$

0 3 . 2

Calculate the pH of pure water at  $10^\circ\text{C}$   
Give your answer to two decimal places.

[2 marks]

$K_w = [\text{H}^+][\text{OH}^-]$   
 $K_w \approx [\text{H}^+]^2$   
 $\therefore [\text{H}^+] = \sqrt{K_w}$   
 $\rightarrow$  for every one  $\text{H}_2\text{O}$  molecule dissociation, you get  $1 \times [\text{H}^+]$  and  $1 \times [\text{OH}^-]$  so we assume they are equal.  
 $[\text{H}^+] = \sqrt{2.93 \times 10^{-15}} = 5.4129 \times 10^{-8} \text{ mol dm}^{-3}$   
 $\text{pH} = -\log[\text{H}^+] = -\log(5.4129 \times 10^{-8})$   
 $\text{pH} = 7.26656... = 7.27$  (2dp)  
 pH of water 7.27

0 3 . 3

Suggest why this pure water at  $10^\circ\text{C}$  is not alkaline.

[1 mark]

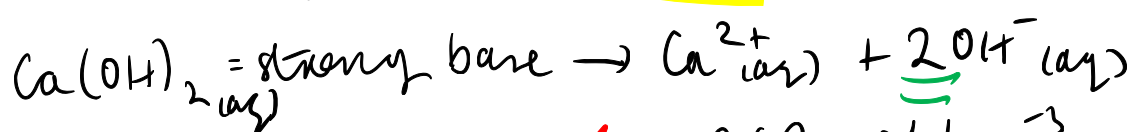
Because the concentration of  $\text{H}^+$  is equal to the concentration of  $\text{OH}^-$ .  
 $([\text{H}^+] = [\text{OH}^-])$

$\rightarrow$  as you get  $1 \times \text{H}^+$  and  $1 \times \text{OH}^-$  for every water molecule that dissociates so they are equal in concentration.



- 0 3 . 4 Calculate the pH of a  $0.0131 \text{ mol dm}^{-3}$  solution of calcium hydroxide at  $10^\circ\text{C}$ . Give your answer to two decimal places.

[3 marks]



$\therefore [\text{OH}^-] = 0.0131 \times 2 = 0.0262 \text{ mol dm}^{-3}$

$K_w = [\text{H}^+] \times [\text{OH}^-] \therefore [\text{H}^+] = K_w \div [\text{OH}^-]$

$[\text{H}^+] = \frac{2.93 \times 10^{-15}}{0.0262} = 1.118 \times 10^{-13} \text{ mol dm}^{-3}$   
(needed to calc. pH)

$\text{pH} = -\log_{10} [\text{H}^+] = -\log_{10} (1.118 \times 10^{-13})$

$\text{pH} = 12.9514 = 12.95$

pH of solution 12.95 ✓ (2dp)

- 0 3 . 5 The  $0.0131 \text{ mol dm}^{-3}$  calcium hydroxide solution at  $10^\circ\text{C}$  was a saturated solution.

A student added  $0.0131 \text{ mol}$  of magnesium hydroxide to  $1.00 \text{ dm}^3$  of water at  $10^\circ\text{C}$  and stirred the mixture until no more solid dissolved.

Predict whether the pH of the magnesium hydroxide solution formed at  $10^\circ\text{C}$  is larger than, smaller than or the same as the pH of the calcium hydroxide solution at  $10^\circ\text{C}$ .

Explain your answer.

[2 marks]

pH of magnesium hydroxide compared to calcium hydroxide

Lower (less alkaline) ✓

Explanation As the solubility of the group 2 metal hydroxides increases down the group.

(due to weaker ionic bonding within the lattice  $\rightarrow$  easier to dissociate + dissolve in water).



0 4

A sample of titanium was ionised by electron impact in a time of flight (TOF) mass spectrometer. Information from the mass spectrum about the isotopes of titanium in the sample is shown in Table 2.

Table 2

m/z	46	47	48	49
Abundance / %	9.1	7.8	74.6	8.5

$$9.1 + 7.8 + 74.6 + 8.5 = 100\%$$

0 4 . 1

Calculate the relative atomic mass of titanium in this sample. Give your answer to one decimal place.

[2 marks]

$$RAM = \frac{(m/z \times \text{abundance}) \text{ of isotopes}}{\# \text{ atoms / total \%}}$$

$$RAM = \frac{(46 \times 9.1) + (47 \times 7.8) + (48 \times 74.6) + (49 \times 8.5)}{100\%}$$

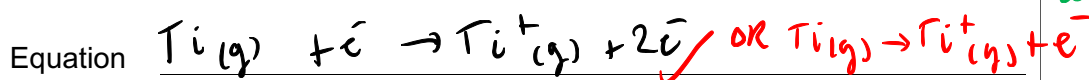
$$RAM = 47.825$$

Relative atomic mass of titanium in this sample 47.8 (1dp)

0 4 . 2

Write an equation, including state symbols, to show how an atom of titanium is ionised by electron impact and give the m/z value of the ion that would reach the detector first.

[2 marks]



m/z value 46 (isotope with lowest mass moves fastest so reaches detector first).

0 4 . 3

Calculate the mass, in kg, of one atom of  $^{49}Ti$

The Avogadro constant  $L = 6.022 \times 10^{23} \text{ mol}^{-1}$

[1 mark]

$$\text{mass} = 49 \text{ g mol}^{-1}$$

$$\therefore \text{mass of one atom (g)} = \frac{\text{g mol}^{-1}}{\text{mol}^{-1}} = \frac{49}{6.022 \times 10^{23}}$$

$$= 8.1368 \times 10^{-23} \text{ g}$$

$$\text{g} \xrightarrow{\div 1000} \text{kg}$$

$$\therefore m = 8.1368 \times 10^{-26} \text{ kg}$$

Mass  $8.1 \times 10^{-26}$  kg

2sf as data is given to a MINIMUM of 2sf.





0 4 . 4

In a **TOF mass spectrometer** the time of flight,  $t$ , of an **ion** is shown by the equation

$$t = d \sqrt{\frac{m}{2E}} \rightarrow d = \frac{t}{\sqrt{\frac{m}{2E}}} \checkmark$$

In this equation  $d$  is the **length of the flight tube**,  $m$  is the **mass, in kg**, of an ion and  $E$  is the **kinetic energy** of the ions.

In this spectrometer, the **kinetic energy of an ion in the flight tube** is  $1.013 \times 10^{-13} \text{ J}$

The time of flight of a  $^{49}\text{Ti}^+$  ion is  $9.816 \times 10^{-7} \text{ s}$

Calculate the time of flight of the  $^{47}\text{Ti}^+$  ion.

Give your answer to the **appropriate number of significant figures**.

[3 marks]

*Both ions travel same distance*

$$\therefore d(^{47}\text{Ti}^+) = d(^{49}\text{Ti}^+) \rightarrow \frac{t(^{47}\text{Ti}^+)}{\sqrt{m/2E}} = \frac{t(^{49}\text{Ti}^+)}{\sqrt{m/2E}} \checkmark$$

$$\text{so } \frac{t(^{47}\text{Ti}^+)}{\sqrt{47/2 \times 1.013 \times 10^{-13}}} = \frac{9.816 \times 10^{-7}}{\sqrt{49/2 \times 1.013 \times 10^{-13}}}$$

$$\rightarrow \frac{t(^{47}\text{Ti}^+)}{152.31} = \frac{9.816 \times 10^{-7}}{155.517} \quad (= 6.31185 \times 10^{-9})$$

$$\rightarrow t(^{47}\text{Ti}^+) = 6.31185 \times 10^{-9} \times 152.31$$

$$t = 9.61357 \dots \times 10^{-7} \text{ s}$$

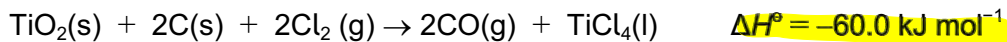
$$\text{so } 9.6 \times 10^{-7} \text{ s}$$

Time of flight  $9.6 \times 10^{-7} \text{ s}$   $\checkmark$  (2 dp)



0 5

Titanium(IV) chloride can be made from titanium(IV) oxide as shown in the equation.



0 5 . 1

Some entropy data are shown in Table 3.

Table 3

Substance	TiO <sub>2</sub> (s)	C(s)	Cl <sub>2</sub> (g)	CO(g)	TiCl <sub>4</sub> (l)
S° / J K <sup>-1</sup> mol <sup>-1</sup>	50.2	5.70	223	198	253

Use the equation and the data in Table 3 to calculate the Gibbs free-energy change for this reaction at 989 °C

Give your answer to the appropriate number of significant figures.

Use your answer to explain whether this reaction is feasible.

[6 marks]

$$\Delta G = \Delta H - T \Delta S \quad \checkmark$$

$$\Delta H = -60.0 \text{ kJ mol}^{-1}$$

$$T = 989^\circ\text{C} \rightarrow +273 = 1262 \text{ K} \quad (\text{needs to be in Kelvin})$$

$$\Delta S = \sum S (\text{products}) - \sum S (\text{reactants})$$

$$\Delta S = [(2 \times 198) + 253] - [50.2 + (2 \times 5.70) + (2 \times 223)] \quad \checkmark$$

$$= 649 - 507.6 = 141.4 \text{ J K}^{-1} \text{ mol}^{-1} \quad \checkmark$$

→ units need to be the same (J or kJ) for S + H

$$\text{J} \div \frac{1000}{\text{kJ}} \quad \therefore \Delta S = 141.4 \times 10^{-3} \text{ kJ K}^{-1} \text{ mol}^{-1}$$

$$\Delta G = -60 - [1262 \times 141.4 \times 10^{-3}] = -238.4468$$

$$\Delta G = -238 \text{ kJ mol}^{-1}$$

→ as data is given to 3 sf.  
(3 sf)

Gibbs free-energy change -238 ✓ kJ mol<sup>-1</sup>

Explanation Reaction is feasible as  $\Delta G$  is less than zero. ✓

$$\Delta G < 0 \Rightarrow \checkmark$$

$$\Delta G > 0 \Rightarrow \times$$

$$\Delta G = 0 \Rightarrow \rightleftharpoons$$



0 6

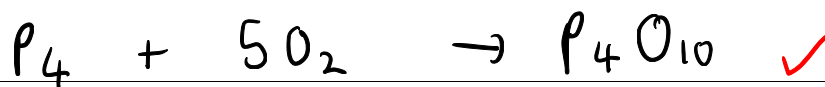
This question is about some **Period 3 elements** and their **oxides**.

0 6 . 1

Write an **equation** for the **reaction of phosphorus with an excess of oxygen**.

[1 mark]

(Recall)



0 6 . 2

Describe a **test** you could carry out in a **test tube** to **distinguish between sodium oxide** and the product of the reaction in Question 6.1  $\rightarrow P_4O_{10}$  <sup>Na<sub>2</sub>O</sup>

[3 marks]

(Add a sol. to measure pH).

1. Add water to Na<sub>2</sub>O / P<sub>4</sub>O<sub>10</sub> (make a solution)  $\checkmark$  (needed for rest of the marks).
2. Add litmus paper  $\checkmark$  (measure pH)
3. litmus = blue with Na<sub>2</sub>O and red with P<sub>4</sub>O<sub>10</sub>  $\checkmark$

(Na<sub>2</sub>O = base, P<sub>4</sub>O<sub>10</sub> = acid)

0 6 . 3

State the type of **crystal structure** shown in **silicon dioxide** and in **sulfur trioxide**.

[2 marks]

(recall)

Silicon dioxide Giant covalent  $\checkmark$ Sulfur trioxide simple molecular  $\checkmark$ 

0 6 . 4

Explain why **silicon dioxide** has a **higher melting point** than **sulfur trioxide**.

[4 marks]

There are strong covalent bonds in the giant SiO<sub>2</sub> lattice compared to van der Waals forces between molecules of SO<sub>3</sub>. Covalent bonds are stronger than van der Waals intermolecular forces so require more energy to overcome.

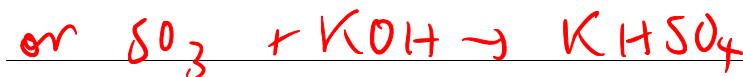
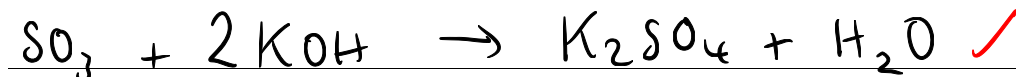


0 6 . 5

Write an equation for the reaction of sulfur trioxide with potassium hydroxide solution.

[1 mark]

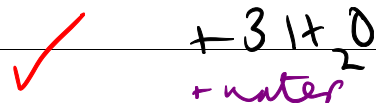
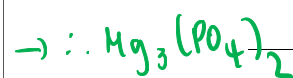
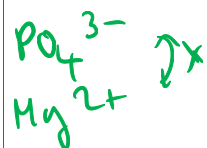
(recall)



0 6 . 6

Write an equation for the reaction of an excess of magnesium oxide with phosphoric acid.

[1 mark]

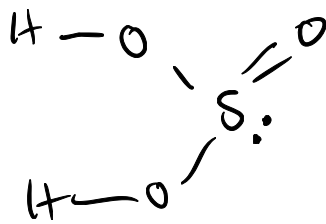


0 6 . 7

Draw the displayed formula of the undissociated acid formed when sulfur dioxide reacts with water.

[1 mark]

need to  
draw out  
bonds in  
full (not  
HO-)



Turn over for the next question



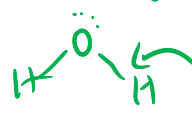
0 7

Solution A contains the compound  $[Cu(H_2O)_6]Cl_2$  → Transition metal complex

0 7 . 1

State the type of bonding between the oxygen and hydrogen in this compound. [1 mark]

water ligand

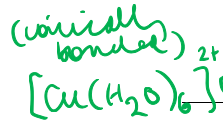


Covalent ✓

covalent bond

0 7 . 2

State why the chloride ions in this compound are not considered to be ligands. [1 mark]



$Cl^-$  not forming a coordinate bond with  $Cu^{2+}$ . (doesn't donate the pair of  $e^-$ ). (define covalent)

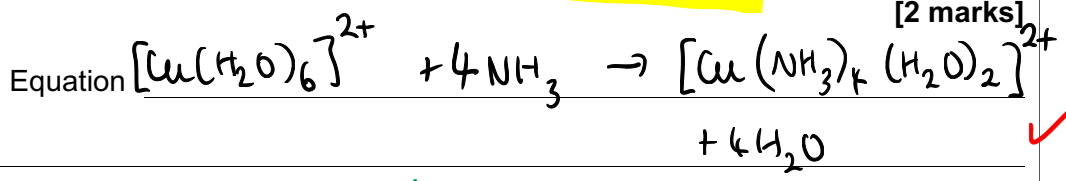
Ligand = atom/ion which forms a coordinate bond to a central metal ion.

0 7 . 3

An excess of ammonia was added to a sample of solution A to form solution B.

Write an ionic equation for the reaction that occurs when solution A is converted into solution B and state the colour of solution B.

Ligand substitution reaction



$Cl^-$  = spectator ions

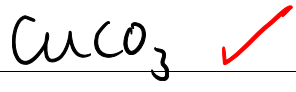
Colour Deep blue solution. ✓ (recall)

0 7 . 4

Aqueous sodium carbonate was added to another sample of solution A to form a blue-green solid C.

Precipitation reaction

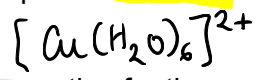
Identify the blue-green solid C.



[1 mark]

0 7 . 5

Reagent D was added to another sample of solution A to form a yellow-green solution. (recall)

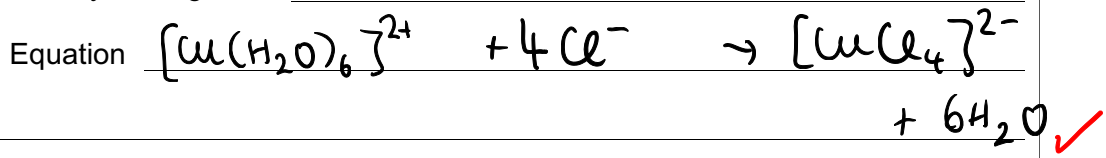


Ligand substitution reaction

Identify reagent D and write an ionic equation for the reaction that occurs when the yellow-green solution is formed from solution A.

[2 marks]

Identity of reagent D  $HCl$  ✓



uses light absorption  
to determine concentration

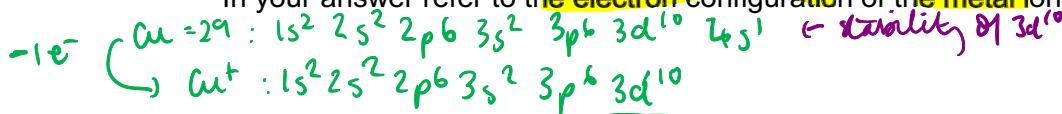
Ce<sup>-</sup>  
Cu<sup>+</sup>

0 7 . 6

Explain why colorimetry cannot be used to determine the concentration of solutions containing [CuCl<sub>2</sub>]

In your answer refer to the electron configuration of the metal ion.

[2 marks]



Full d orbital (3d<sup>10</sup>) for Cu<sup>+</sup> ion, stability.  
 Colourless solution, can't absorb visible  
 light.

9

Turn over for the next question



0 8

This question is about **ion testing**.

0 8 . 1

Describe how a student could **distinguish between aqueous solutions of potassium nitrate,  $\text{KNO}_3$ , and potassium sulfate,  $\text{K}_2\text{SO}_4$** , using **one simple test-tube reaction**.*or  $\text{Ba}(\text{OH})_2$ ,  $\text{Ba}(\text{NO}_3)_2$* 

[3 marks]

 *$\text{BaCl}_2 =$   
test for  
 $\text{SO}_4^{2-}$  ions.*Reagent Barium chloride,  $\text{BaCl}_2$  ✓Observation with  $\text{KNO}_3(\text{aq})$  identical solutions ✓  
(no change).Observation with  $\text{K}_2\text{SO}_4(\text{aq})$  white precipitate ✓*(recall)*

0 8 . 2

Describe how a student could **distinguish between aqueous solutions of magnesium chloride,  $\text{MgCl}_2$ , and aluminium chloride,  $\text{AlCl}_3$** , using **one simple test-tube reaction**.*(or other group 2 hydroxides)*

[3 marks]

Reagent Sodium hydroxide,  $\text{NaOH}$  ✓Observation with  $\text{MgCl}_2(\text{aq})$  white precipitate ✓Observation with  $\text{AlCl}_3(\text{aq})$  white precipitate which dissolves in excess  $\text{NaOH}$  ✓*(recall)*

0 9

There are several stages in the industrial production of methanol from methane.

0 9 . 1

The first stage involves a gaseous equilibrium between the reactants (methane and steam), and some gaseous products. Figures 1 and 2 show the percentage conversion of methane into the gaseous products under different conditions at equilibrium.

Figure 1

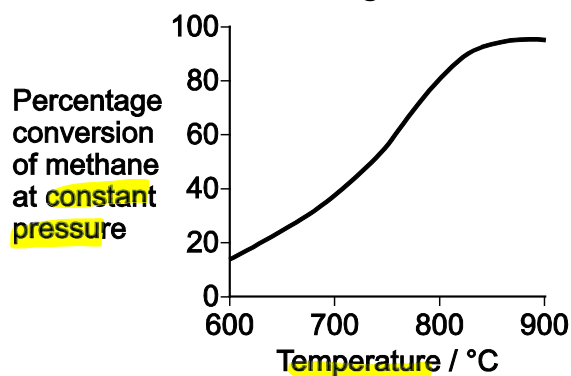
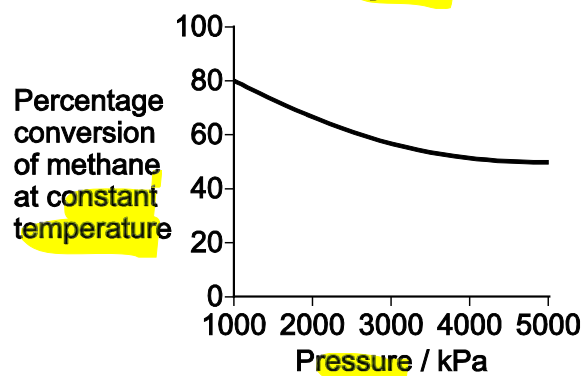


Figure 2



Deduce the optimum conditions for the industrial conversion of methane and steam into the gaseous products.

Explain your deductions.

[6 marks]

Figure 1: as temperature increases, the yield of products increases. After a certain temp. (around 850°C), yield no longer increases. Higher temp. results in higher energy costs and there is no gain to using a temperature > 850°C as yield decreases. Therefore, the optimum temperature is between 780-880°C.

Figure 2: as pressure increases, yield decreases. However, using very low pressures would lead to the reaction being too slow by affecting the rates.

Turn over ►



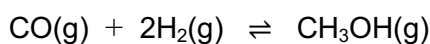


Therefore, compromised pressure is needed and the optimum pressure is 1000-2000 kPa (moderate pressure).

→ Need to talk about temp. AND pressure to get into level 2 (1-2) of marks.



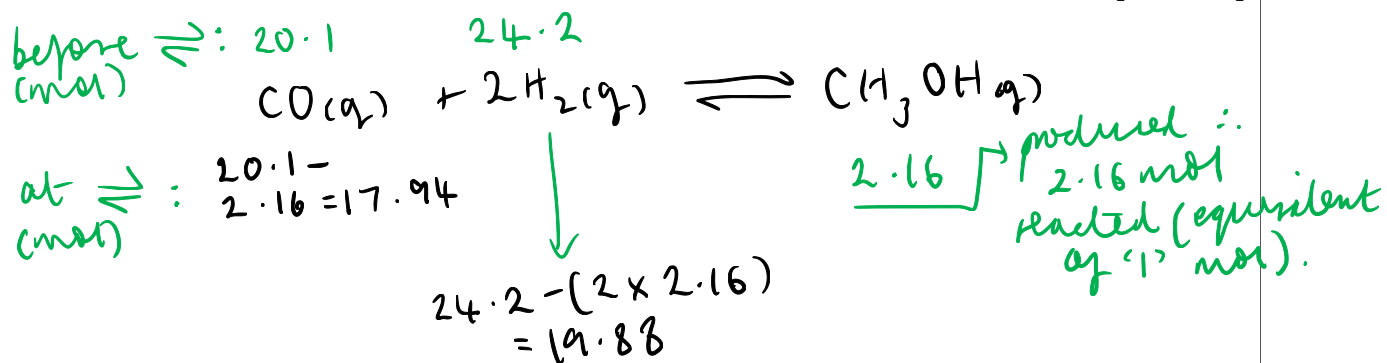
0 9 . 2 The equation shows the final stage in the production of methanol.



20.1 mol of carbon monoxide and 24.2 mol of hydrogen were placed in a sealed container. An equilibrium was established at 600 K. The equilibrium mixture contained 2.16 mol of methanol.

Calculate the amount, in moles, of carbon monoxide and of hydrogen in the equilibrium mixture.

[2 marks]



3sf as data gives to 3sf

Amount of carbon monoxide      17.9 ✓ mol

Amount of hydrogen      19.9 ✓ mol

Question 9 continues on the next page



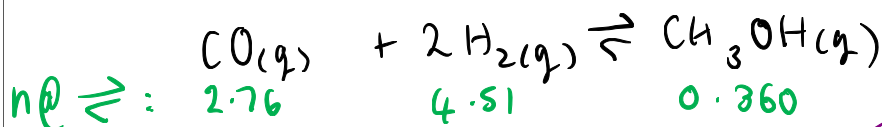
0 9 . 3

A different mixture of carbon monoxide and hydrogen was allowed to reach equilibrium at 600 K

At equilibrium, the mixture contained 2.76 mol of carbon monoxide, 4.51 mol of hydrogen and 0.360 mol of methanol. The total pressure was 630 kPa

Calculate a value for the equilibrium constant,  $K_p$ , for this reaction at 600 K and state its units.

[6 marks]



pp = partial pressure.

$$K_p = \frac{pp(\text{CH}_3\text{OH})}{pp(\text{CO}) \times pp(\text{H}_2)^2}$$

$$pp(x) = \frac{n(x)}{\text{total } n} \times \text{total pressure}$$

mol. fraction.

$$\text{Total moles } (n) = 2.76 + 4.51 + 0.360 = 7.63$$

$$pp(\text{CO}) = \frac{2.76}{7.63} \times 630 \text{ kPa} = 227.90 \text{ kPa}$$

$$pp(\text{H}_2) = \frac{4.51}{7.63} \times 630 \text{ kPa} = 372.385 \text{ kPa}$$

$$pp(\text{CH}_3\text{OH}) = \frac{0.360}{7.63} \times 630 \text{ kPa} = 29.72 \text{ kPa}$$

(need all 3 correct for both marks).

Value of  $K_p$   $9.41 \times 10^{-7}$  Units  $\text{kPa}^{-2}$

$$K_p = \frac{29.72 \text{ kPa}}{227.90 \text{ kPa} \times (372.385 \text{ kPa})^2}$$

$$K_p = 9.40567 \times 10^{-7} \text{ kPa}^{-2}$$

Keep signs to bring up top.



1 0

Table 4 shows some electrode half-equations and their standard electrode potentials.

Table 4

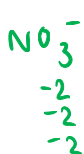
Oxidation  
Is  
Loss  
Reduction  
Is  
Gain  
(of e<sup>-</sup>)

Electrode half-equation	E° / V
Cl <sub>2</sub> (g) + 2e <sup>-</sup> → 2Cl <sup>-</sup> (aq)	+1.36
NO <sub>3</sub> <sup>-</sup> (aq) + 4H <sup>+</sup> (aq) + 3e <sup>-</sup> → NO(aq) + 2H <sub>2</sub> O(aq)	+0.96
Fe <sup>3+</sup> (aq) + e <sup>-</sup> → Fe <sup>2+</sup> (aq)	+0.77
Cu <sup>2+</sup> (aq) + 2e <sup>-</sup> → Cu(s)	+0.34
SO <sub>4</sub> <sup>2-</sup> (aq) + 4H <sup>+</sup> (aq) + 2e <sup>-</sup> → SO <sub>2</sub> (g) + 2H <sub>2</sub> O(aq)	+0.17
2H <sup>+</sup> (aq) + 2e <sup>-</sup> → H <sub>2</sub> (g)	0.00
Fe <sup>2+</sup> (aq) + 2e <sup>-</sup> → Fe(s)	-0.44

1 0 . 1

Deduce the oxidation state of nitrogen in NO<sub>3</sub><sup>-</sup> and in NO

[2 marks]



x + (3x - 2) = -1  
∴ x = +5

Nitrogen in NO<sub>3</sub><sup>-</sup> + 5 ✓

Nitrogen in NO + 2 ✓

NO<sub>-2</sub> x + (-2) = 0 ∴ x = +2

1 0 . 2

State the weakest reducing agent in Table 4.

[1 mark]

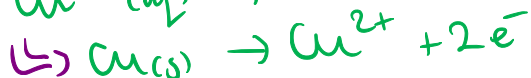
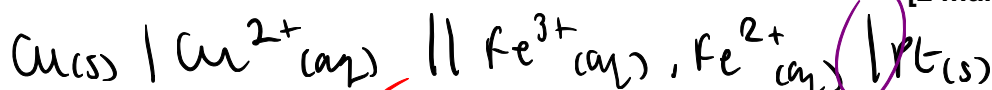
Cl<sup>-</sup> as has most ⊕ E°  
∴ is worst reducing agent.

Cl<sup>-</sup> ✓ (has to be chloride ions not chlorine).

1 0 . 3

Write the conventional representation of the cell that has an EMF of +0.43 V

[2 marks]



0.77 - (0.34) = +0.43V

|| = salt bridge (allows flow of ions to maintain charge flow complete circuit).  
↳ max ⊖ so undergoes ex (reverse).  
↳ 4 moles change of phase.



1 0 . 4

Use data from Table 4 to identify an acid that will oxidise copper.

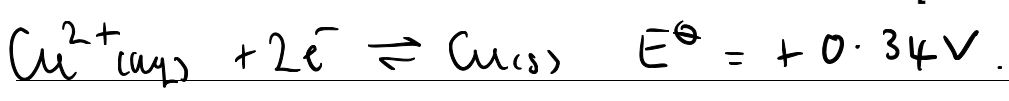
Explain your choice of acid.

Needs a more  $\oplus E^\ominus$  than Cu to oxidise Cu.

Use these data to suggest a possible equation for the reaction.

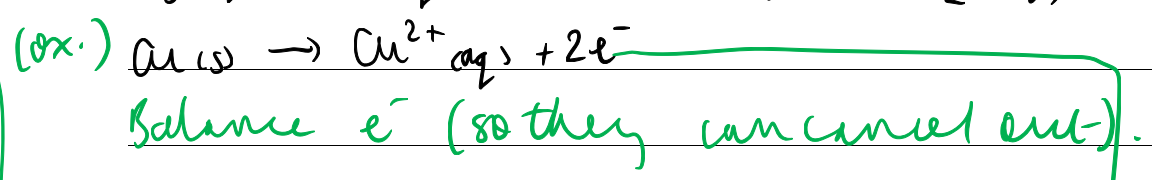
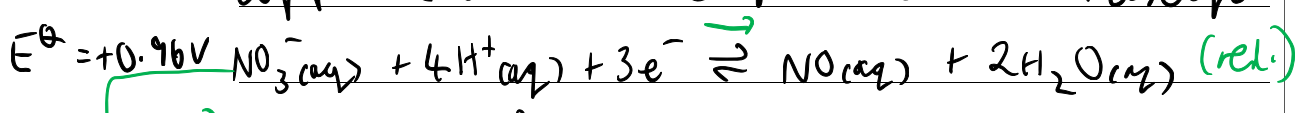
Calculate the EMF of the cell that has the same overall reaction.

[4 marks]

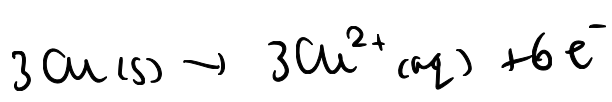
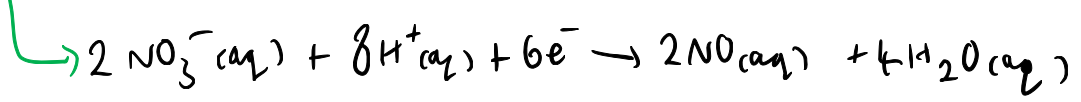


All other systems containing  $\text{H}^+$  are less  $\oplus$  than 0.34V.

Nitric acid,  $\text{HNO}_3$  has a more positive  $E^\ominus$  value so will be able to oxidise copper (and undergo reduction itself).

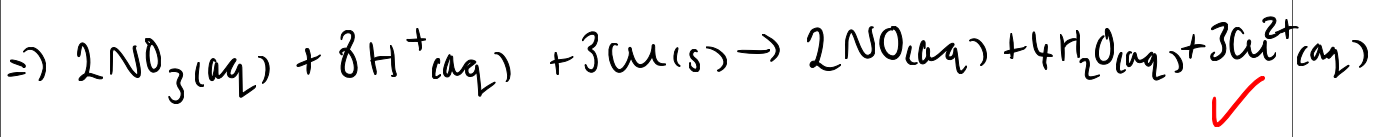
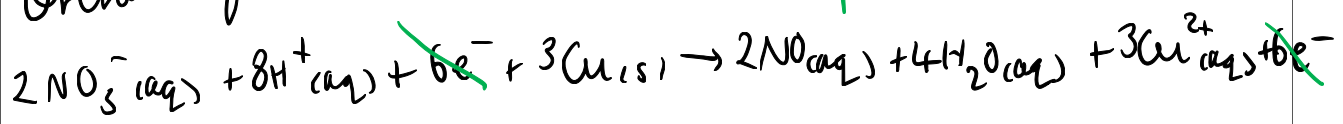


x2



x3

Overall equation ( $\Sigma$  reactants  $\rightarrow \Sigma$  prod.)



EMF for reaction = most  $\oplus$  - least  $\oplus$   

$$\text{EMF} = +0.96 - (+0.34)$$

$$= \underline{\underline{+0.62\text{V}}}$$

9



1 1

This question is about compounds containing ethanedioate ions.

1 1 . 1

A white solid is a mixture of sodium ethanedioate ( $\text{Na}_2\text{C}_2\text{O}_4$ ), ethanedioic acid dihydrate ( $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$ ) and an inert solid. A volumetric flask contained 1.90 g of this solid mixture in  $250 \text{ cm}^3$  of aqueous solution.

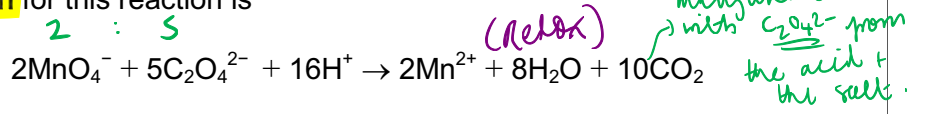
Two different titrations were carried out using this solution.

①

In the first titration  $25.0 \text{ cm}^3$  of the solution were added to an excess of sulfuric acid in a conical flask. The flask and contents were heated to  $60^\circ\text{C}$  and then titrated with a  $0.0200 \text{ mol dm}^{-3}$  solution of potassium manganate(VII). When  $26.50 \text{ cm}^3$  of potassium manganate(VII) had been added the solution changed colour.

$n = V \times C$

The equation for this reaction is

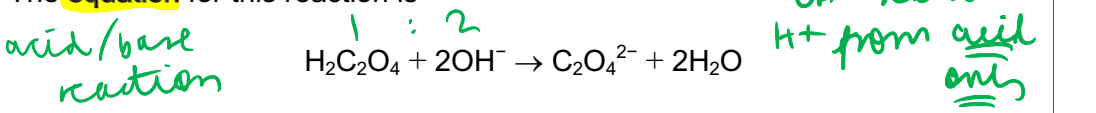


②

In the second titration  $25.0 \text{ cm}^3$  of the solution were titrated with a  $0.100 \text{ mol dm}^{-3}$  solution of sodium hydroxide using phenolphthalein as an indicator. The indicator changed colour after the addition of  $10.45 \text{ cm}^3$  of sodium hydroxide solution.

$\text{cm}^3 \rightarrow \text{dm}^3$   
 $\div 1000$

The equation for this reaction is



Calculate the percentage by mass of sodium ethanedioate in the white solid.

Give your answer to the appropriate number of significant figures. Show your working.

[8 marks]

①  $n(\text{MnO}_4^-) = \frac{26.50}{1000} \times 0.0200 = 5.3 \times 10^{-4} \text{ mol}$  ✓  
 $n(\text{C}_2\text{O}_4^{2-}) = \frac{5.3 \times 10^{-4}}{2} \times 5 = 1.325 \times 10^{-3} \text{ mol}$  ✓  
*in  $25 \text{ cm}^3$  sample (from acid + salt)*

②  $n(\text{OH}^-) = \frac{10.45}{1000} \times 0.100 = 1.045 \times 10^{-3} \text{ mol}$  ✓  
 $n(\text{H}_2\text{C}_2\text{O}_4) = \frac{1.045 \times 10^{-3}}{2} = 5.225 \times 10^{-4} \text{ mol}$  ✓  
*in  $25 \text{ cm}^3$  sample (from acid)*

$n(\text{Na}_2\text{C}_2\text{O}_4) = (1.325 \times 10^{-3}) - (5.225 \times 10^{-4}) = 8.025 \times 10^{-4} \text{ mol}$  ✓  
*in  $25 \text{ cm}^3$*

$n(\text{Na}_2\text{C}_2\text{O}_4) \text{ in } 250 \text{ cm}^3 = 8.025 \times 10^{-3} \text{ mol}$  ✓

$m(\text{Na}_2\text{C}_2\text{O}_4) = n \times M_r = 8.025 \times 10^{-3} \times 134$   
 $= 1.0735 \text{ g}$  ✓

$\therefore \% = \frac{1.0735}{1.90} \times 100 = 56.6\%$  ✓ *(3 s.f.)*

*$M_r = (2 \times 23) + (2 \times 12) + (4 \times 16) = 134$*



Turn over ►

Percentage by mass of sodium ethanedioate 56.6 %

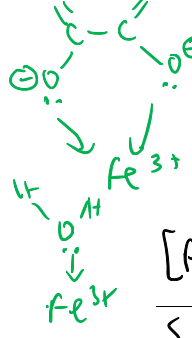


can form 2 coordinate bonds per molecule.

CN = coordination number

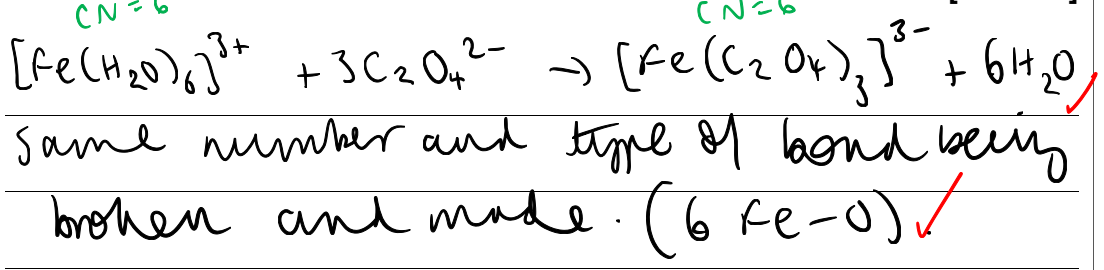
1 0 . 2 0

Ethanedioate ions react with aqueous iron(III) ions in a ligand substitution reaction.



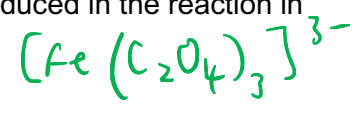
Write an equation for this reaction.

Suggest why the value of the enthalpy change for this reaction is close to zero. [2 marks]



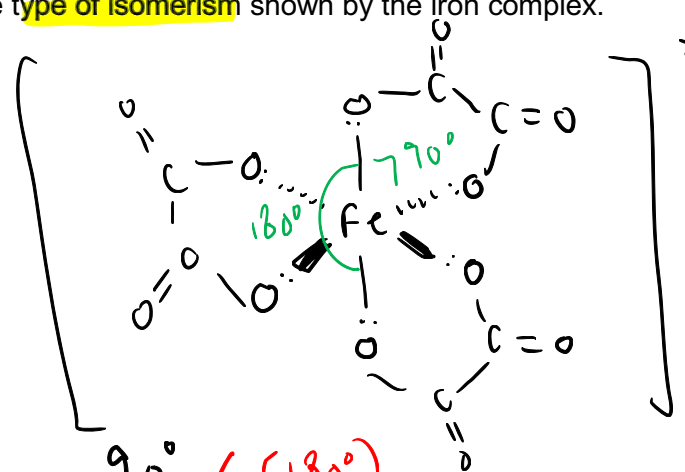
1 1 . 3

Draw the displayed formula of the iron complex produced in the reaction in Question 11.2



Indicate the value of the O-Fe-O bond angle.

State the type of isomerism shown by the iron complex.



[3 marks]

octahedral shape.

Bond angle 90° ✓ (180°)

Type of isomerism optical ✓

1 1 . 4

Ethanedioate ions are poisonous because they react with iron ions in the body. Ethanedioate ions are present in foods such as broccoli and spinach.

Suggest one reason why people who eat these foods do not suffer from poisoning.

[1 mark]

The ethanedioate ions are only present in low concentrations / small amounts.

END OF QUESTIONS

