

Please write clearly in block capitals.

Centre number

--	--	--	--	--

Candidate number

--	--	--	--

Surname

StemUp Model Solution

Forename(s)

Candidate signature

I declare this is my own work.

A-level CHEMISTRY

Paper 1 Inorganic and Physical Chemistry

Monday 12 June 2023

Morning

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 scientific 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 this 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.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- 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	
TOTAL	



Answer **all** questions in the spaces provided.

0 1

This question is about complexes of the transition metal chromium.

0 1 . 1

State the meaning of the term transition metal complex.

[1 mark]

A central metal atom or ion surrounded by ligands (bonded to it by co-ordinate bonds).

$\text{Cr}(\text{PF}_3)_6$ is a complex of chromium that contains molecules of PF_3

0 1 . 2

The electron pair repulsion theory can be used to predict the shape of a PF_3 molecule.

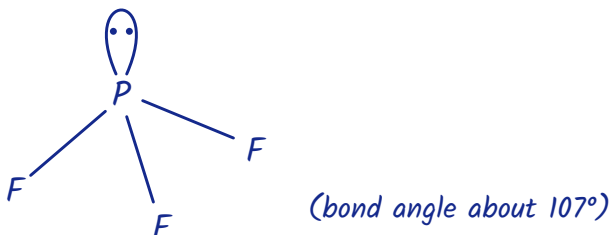
Draw the shape of a PF_3 molecule.

Include any lone pairs of electrons that influence the shape.

Name the shape.

[2 marks]

Shape



Name of shape *Pyramidal (trigonal pyramidal)*

0 1 . 3

Suggest why the oxidation state of chromium is zero in $\text{Cr}(\text{PF}_3)_6$

[1 mark]

PF_3 is a neutral molecule (it has no charge) and the complex $\text{Cr}(\text{PF}_3)_6$ is also neutral (no overall charge), so the chromium must be 0.



The compound $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$ contains ammonia molecules.

0 1 . 4

Deduce the oxidation state of chromium in $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$

[1 mark]

+3

0 1 . 5

Name the type of bond between N and H in ammonia.

[1 mark]

Covalent bond

0 1 . 6

The compound $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$ contains a complex ion that shows isomerism.

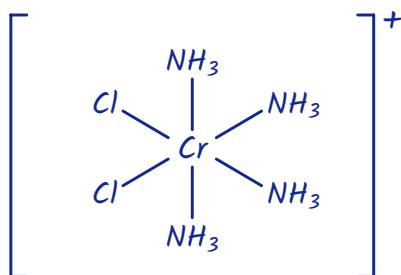
Draw the two isomers of the complex ion.

State the type of isomerism shown.

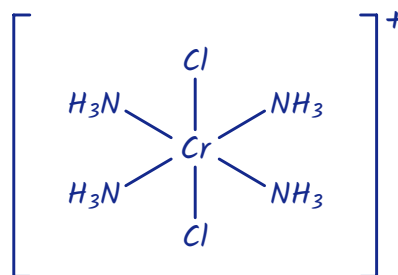
[3 marks]

Isomer 1

Isomer 2



cis



trans

Type of isomerism Cis-trans (geometric, E-2) isomerism

0 1 . 7

Complete the equation to show the formation of **one** complex that contains chromium in its +3 oxidation state.

[1 mark]



0 2

Figure 1 shows a cell used to measure the standard electrode potential for the half-cell

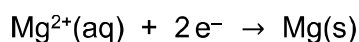
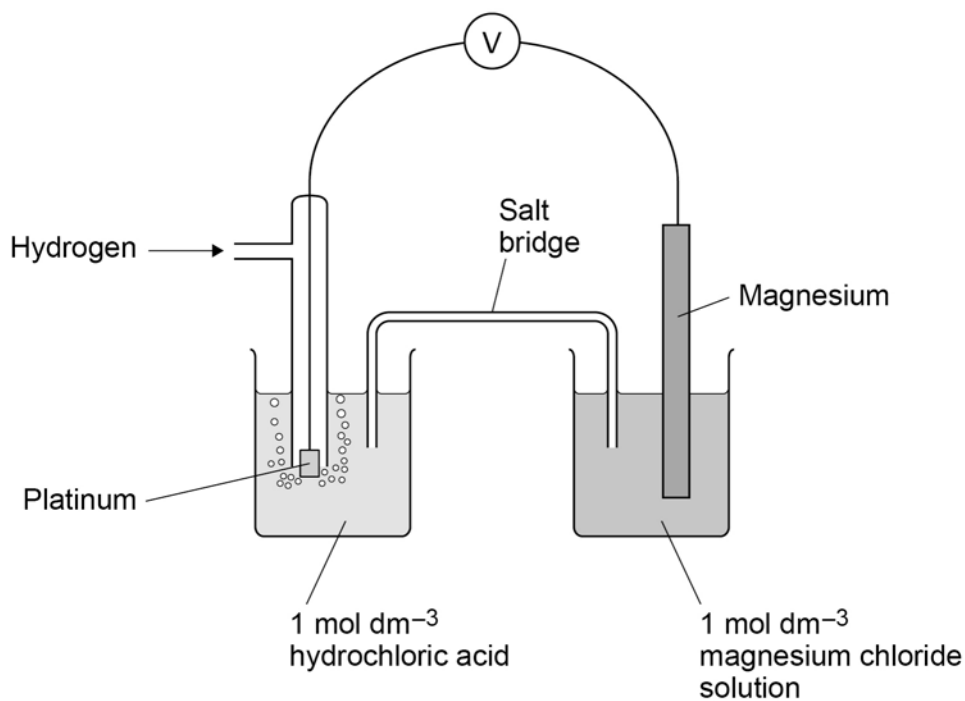


Figure 1



0 2 . 1

State the purpose of the salt bridge.

Identify an ionic compound that could be used in the salt bridge.

[2 marks]

Purpose *To complete the circuit by allowing ions to move between the two half-cells (keeps them electrically neutral).*

Identity *Potassium nitrate, KNO₃*

0 2 . 2

State how, if at all, the EMF of this cell will change if the surface area of the platinum electrode is increased.

[1 mark]

No change (the EMF stays the same).



The standard electrode potential, $E^\ominus$ for the half-cell is shown.



0 2 . 3

Water is added to the beaker containing the magnesium chloride solution.

What is the effect on the magnitude of the EMF of the cell?

[1 mark]

Tick (✓) **one** box.

EMF increases

☒

EMF stays the same

☐

EMF decreases

☐

0 2 . 4

The voltmeter **V** shown in **Figure 1** is replaced by a bulb.

Give an equation for the overall reaction that occurs when the cell is operating.

[1 mark]



5

Turn over for the next question

Turn over ►



0 3

This question is about Period 3 elements and their oxides.

0 3 . 1

Give an equation for the reaction between phosphorus and an excess of oxygen.

[1 mark]



0 3 . 2

Give an equation for the reaction between sulfur dioxide and water.

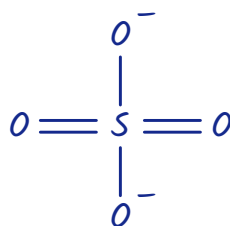
[1 mark]



0 3 . 3

Give the displayed formula for the anion formed when sulfur trioxide reacts with water.

[1 mark]



0 3 . 4

Give an equation for the reaction of magnesium with steam.

State one observation made.

[2 marks]

Equation



Observation Bright white light (white flame) and a white solid (powder) is formed.

0 3 . 5

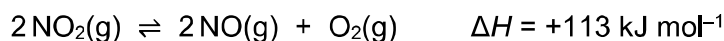
Give an equation to show how an excess of magnesium oxide reacts with phosphoric acid (H_3PO_4).

[1 mark]



0 4

Nitrogen dioxide decomposes at a high temperature.



0 4 . 1

A 0.317 mol sample of nitrogen dioxide is placed in a sealed flask and heated at a constant temperature until equilibrium is reached.

At equilibrium, the flask contains 0.120 mol of oxygen.

Calculate the mole fraction of each substance at equilibrium.

[3 marks]

$$n(\text{O}_2) = 0.120 \text{ mol, so } n(\text{NO}) = 2 \times 0.120 = 0.240 \text{ mol}$$

$$n(\text{NO}_2) = 0.317 - 0.240 = 0.077 \text{ mol}$$

$$\text{total moles} = 0.077 + 0.240 + 0.120 = 0.437 \text{ mol}$$

$$\text{mole fraction NO}_2 = 0.077 \div 0.437 = 0.176$$

$$\text{mole fraction NO} = 0.240 \div 0.437 = 0.549$$

$$\text{mole fraction O}_2 = 0.120 \div 0.437 = 0.275$$

Mole fraction of NO₂ 0.176

Mole fraction of NO 0.549

Mole fraction of O₂ 0.275

0 4 . 2

The total pressure in the flask in Question 04.1 is 120 kPa at equilibrium.

Calculate the partial pressure, in kPa, of NO₂

If you were unable to answer Question 04.1 you should assume that the mole fraction of NO₂ is 0.380. This is **not** the correct answer.

[1 mark]

$$p(\text{NO}_2) = \text{mole fraction} \times \text{total pressure}$$

$$= 0.176 \times 120 = 21.1 \text{ kPa}$$

Partial pressure 21.1 kPa

Turn over ►



0 4 . 3 **Table 1** shows the mole fractions of the three gases in a different equilibrium mixture.

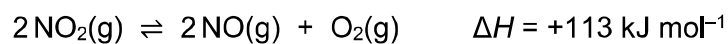


Table 1

Gas	Mole fraction
NO ₂	0.310
NO	0.460
O ₂	0.230

For this equilibrium mixture, $K_p = 59.7 \text{ kPa}$

Give an expression for K_p for this reaction.

Use your expression and the data in **Table 1** to calculate the total pressure, in kPa, in the flask.

[3 marks]

$$K_p = \frac{p(\text{NO})^2 \times p(\text{O}_2)}{p(\text{NO}_2)^2}$$

$$\text{partial pressure} = \text{mole fraction} \times \text{total pressure } (P)$$

$$59.7 = \frac{(0.460P)^2 \times (0.230P)}{(0.310P)^2}$$

$$59.7 = \frac{0.460^2 \times 0.230 \times P}{0.310^2}$$

$$P = \frac{59.7 \times 0.310^2}{0.460^2 \times 0.230}$$

$$P = 5.737 \div 0.04867 = 117.9 \text{ kPa}$$

Total pressure 118 kPa



0 4 . 4

The equilibrium mixture in Question 04.3 is compressed into a smaller volume.

Deduce the effect, if any, of this change on the equilibrium yield of oxygen and on the value of K_p

[2 marks]

Effect on yield of oxygen Decreases

Effect on K_p No change

0 4 . 5

The equilibrium mixture in Question 04.3 is allowed to reach equilibrium at a lower temperature.

Explain why the equilibrium yield of oxygen decreases.

[2 marks]

The forward reaction is endothermic ($\Delta H = +113$), so the backward reaction is exothermic.

At a lower temperature the equilibrium shifts to the left (backward direction) to oppose the decrease in temperature, so less O_2 forms.

11

Turn over for the next question

Turn over ►



0 5

This question is about metal chlorides.

0 5 . 1

Table 2 shows some enthalpy change data.**Table 2**

	Enthalpy change / kJ mol ⁻¹
Ca ²⁺ (g) → Ca ²⁺ (aq)	-1650
Cl ⁻ (g) → Cl ⁻ (aq)	-364
Ca ²⁺ (g) + 2 Cl ⁻ (g) → CaCl ₂ (s)	-2237

Use the data in **Table 2** to calculate the molar enthalpy change when calcium chloride dissolves in water.

[2 marks]

$$\begin{aligned}\Delta H_{\text{solution}} &= \Delta H_{\text{lattice dissociation}} + \Delta H_{\text{hyd}}(\text{Ca}^{2+}) + 2\Delta H_{\text{hyd}}(\text{Cl}^{-}) \\ &= +2237 + (-1650) + (2 \times -364) \\ &= +2237 - 1650 - 728 = -141 \text{ kJ mol}^{-1}\end{aligned}$$

Molar enthalpy change -141 kJ mol⁻¹

0 5 . 2

Use your answer to Question **05.1** to deduce how the temperature changes when calcium chloride dissolves in water.

[1 mark]

The temperature increases (goes up), because dissolving calcium chloride is exothermic.

0 5 . 3

Explain why the enthalpy of hydration of fluoride ions is more negative than the enthalpy of hydration of chloride ions.

[2 marks]

Fluoride ions (F⁻) are smaller than chloride ions with the same charge, so F⁻ has a higher charge density.

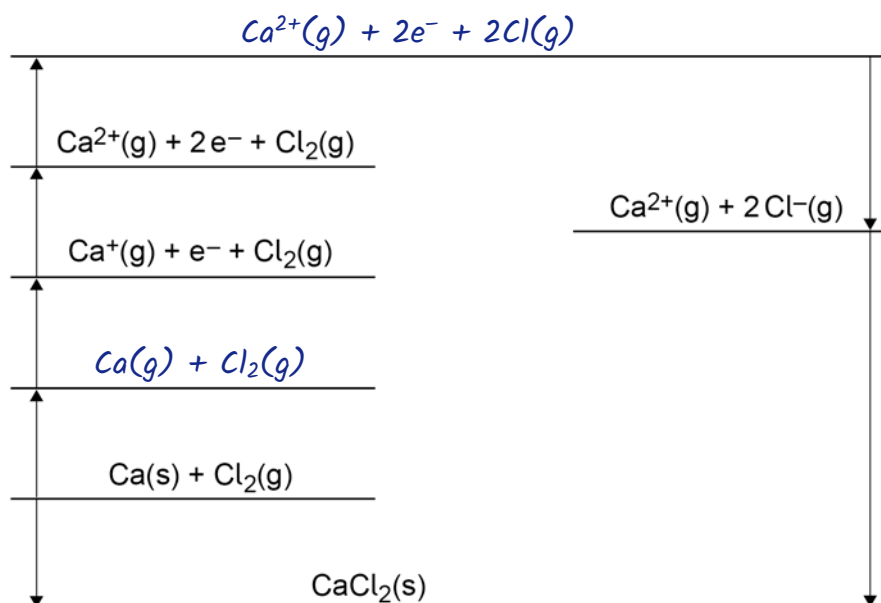
So there is a stronger attraction between the F⁻ ion and the δ⁺ hydrogen atoms of the water molecules.



0 5 . 4

Figure 2 shows an incomplete Born–Haber cycle for calcium chloride.

Figure 2



Complete the Born–Haber cycle by writing the formulas of the missing species on each of the two blank lines.

[2 marks]

0 5 . 5

Table 3 shows some enthalpy change data.

Table 3

	Enthalpy change / kJ mol^{-1}
Enthalpy of atomisation of calcium	+193
First ionisation energy of calcium	+590
Enthalpy of atomisation of chlorine	+121
Electron affinity of chlorine	–364
Enthalpy of formation of calcium chloride	–795
Enthalpy of lattice formation of calcium chloride	–2237

Use Figure 2 and data from Table 3 to calculate the second ionisation energy of calcium.

[2 marks]

$$\Delta H_f = \Delta H_{at}(\text{Ca}) + IE_1 + IE_2 + 2\Delta H_{at}(\text{Cl}) + 2EA(\text{Cl}) + \Delta H_L$$

$$-795 = 193 + 590 + IE_2 + (2 \times 121) + (2 \times -364) + (-2237)$$

$$-795 = -1940 + IE_2, \text{ so } IE_2 = -795 + 1940 = +1145 \text{ kJ mol}^{-1}$$

Second ionisation energy +1145 kJ mol^{-1}

Turn over ►



0 5 . 6

Explain why the second ionisation energy of calcium is greater than the first ionisation energy of calcium.

[1 mark]

The second electron is removed from a positive ion (Ca^+), so the electron is closer to the nucleus and more strongly attracted.

0 5 . 7

Table 4 shows lattice enthalpies based on a perfect ionic model and lattice enthalpies from Born–Haber cycles for three metal chlorides.

Table 4

	Lattice enthalpy of dissociation / kJ mol^{-1}	
	Perfect ionic model	Born–Haber cycle
Calcium chloride	2223	2237
Potassium chloride	690	701
Silver chloride	770	905

Discuss the values in **Table 4**.

In your answer you should

- compare the three values based on a perfect ionic model
- compare the values based on a perfect ionic model to the values from a Born–Haber cycle for each compound.

[6 marks]

Perfect ionic model values: the value for calcium chloride (2223) is much larger than the values for potassium chloride (690) and silver chloride (770), which are similar to each other ($\text{CaCl}_2 > \text{AgCl} > \text{KCl}$). This is because the Ca^{2+} ion has a larger charge (2+) than K^+ and Ag^+ (1+) and is a smaller ion. So there is a stronger electrostatic attraction between the oppositely charged ions (Ca^{2+} and Cl^-), so CaCl_2 has stronger ionic bonding. Ag^+ and K^+ have a smaller charge and are larger ions, so the attraction between the + and – ions in AgCl and KCl is weaker.

Comparing with the Born–Haber values: for calcium chloride (2223 and



2237) and for potassium chloride (690 and 701) the perfect ionic model values are very similar to the Born-Haber cycle values.

This shows that CaCl_2 and KCl have almost perfect ionic bonding: the ions behave as perfectly spherical ions with point charges, just as the perfect ionic model assumes.

For silver chloride the Born-Haber value (905) is much larger than the perfect ionic model value (770), a difference of 135 kJ mol^{-1} , which is a much bigger difference than for the other two compounds.

This shows that the bonding in AgCl has some covalent character. The Ag^+ ion is more polarising: it distorts the electron cloud of the Cl^- ion towards itself, so there is extra attraction (partial covalent bonding) between the ions. This makes the lattice stronger than the perfect ionic model predicts, so more energy is needed to break it.



0 6

The concentration of dilute hydrochloric acid can be found by titration using a standard solution of barium hydroxide.

0 6 . 1

Calculate the mass, in g, of solid barium hydroxide ($M_r = 171.3$) needed to prepare 250 cm³ of 0.100 mol dm⁻³ barium hydroxide solution.

[1 mark]

$$n = 0.100 \times 250 \div 1000 = 0.0250 \text{ mol}$$

$$\text{mass} = 0.0250 \times 171.3 = 4.28 \text{ g}$$

Mass 4.28 g**0 6 . 2**

The mass of barium hydroxide from Question **06.1** is dissolved in a beaker containing 150 cm³ of distilled water.

Describe how this solution is used to make 250 cm³ of the 0.100 mol dm⁻³ barium hydroxide solution.

[3 marks]

Transfer (pour) the solution into a 250 cm³ volumetric flask using a funnel.

Rinse the beaker and funnel with distilled water and add the washings to the flask.

Make up to the 250 cm³ graduation mark with distilled water, adding the last drops dropwise until the bottom of the meniscus is on the line.

Stopper the flask and invert it many times (shake) to mix the solution thoroughly.

0 6 . 3

Before the first titration, the 25 cm³ pipette is rinsed with a small volume of the 0.100 mol dm⁻³ barium hydroxide solution.

State why it is good practice to rinse the pipette in this way.

[1 mark]

So that any water left in the pipette does not dilute the solution, so the titration is done with the known concentration of Ba(OH)₂.



0 6 . 4

Hydrochloric acid is added to the burette using a funnel.

State why it is good practice to remove the funnel from the burette before the titration.

[1 mark]

Drops of acid left in the funnel could fall into the burette during the titration, so you would no longer know how much acid has been added from the burette (the titre would be too low).

0 6 . 5

In a different experiment, 0.952 g of solid barium hydroxide is used to make 250 cm³ of standard barium hydroxide solution.

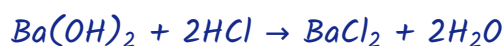
25.0 cm³ of this barium hydroxide solution reacts with exactly 24.50 cm³ of hydrochloric acid.

Calculate the concentration of the hydrochloric acid.

[3 marks]

$$n(\text{Ba}(\text{OH})_2) \text{ in } 250 \text{ cm}^3 = 0.952 \div 171.3 = 5.557 \times 10^{-3} \text{ mol}$$

$$n(\text{Ba}(\text{OH})_2) \text{ in } 25.0 \text{ cm}^3 = 5.557 \times 10^{-3} \div 10 = 5.56 \times 10^{-4} \text{ mol}$$



$$n(\text{HCl}) \text{ in } 24.50 \text{ cm}^3 = 2 \times 5.56 \times 10^{-4} = 1.11 \times 10^{-3} \text{ mol}$$

$$[\text{HCl}] = 1.11 \times 10^{-3} \times 1000 \div 24.50 = 0.0454 \text{ mol dm}^{-3}$$

Concentration 0.0454 mol dm⁻³

0 6 . 6

The uncertainty in the 25.0 cm³ of solution from the pipette is $\pm 0.05 \text{ cm}^3$

The total uncertainty in the 24.50 cm³ of solution from the burette is $\pm 0.15 \text{ cm}^3$

Calculate the total percentage error in using the pipette and burette.

[1 mark]

$$(0.05 \div 25.0 \times 100) + (0.15 \div 24.50 \times 100)$$

$$= 0.20 \% + 0.61 \% = 0.81 \%$$

Percentage error 0.81 %

10

Turn over ►



0 7

This question is about complexes containing the aluminium ion.

0 7 . 1

Give the electron configuration of the Al^{3+} ion.

[1 mark]



0 7 . 2

When anhydrous aluminium sulfate, $\text{Al}_2(\text{SO}_4)_3$, is added to water a solution forms that contains the complex aluminium ion, $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$

Give the equation for the reaction.

[1 mark]



0 7 . 3

Explain why the solution containing $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ is acidic.

[2 marks]

Al^{3+} is a small ion with a high charge (high charge density), so it is very polarising.

It attracts electrons from (polarises) the O-H bonds in the water ligands, weakening them, so H^+ is released and forms H_3O^+ with water:



0 7 . 4

State why the concentration of aluminium sulfate solution can **not** be determined by colorimetry.

[1 mark]

The solution is colourless: Al^{3+} has no d electrons, so there are no d-d transitions and it does not absorb visible light.



07.5

An excess of aqueous ammonia is added to a solution containing $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$

Give an ionic equation for the reaction and state one observation.

[2 marks]

Equation



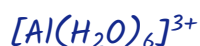
Observation *White precipitate forms*

07.6

An excess of dilute sulfuric acid is added to the products of the reaction in Question 07.5

Identify the aluminium species produced.

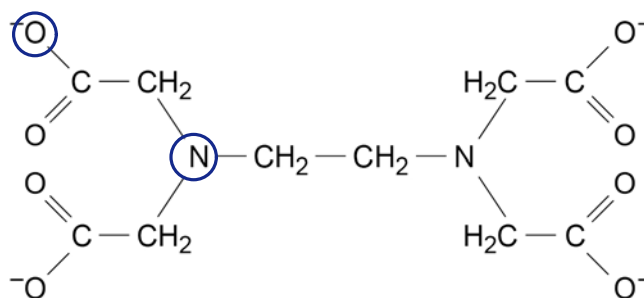
[1 mark]



07.7

Figure 3 shows the structure of the EDTA^{4-} ion.

Figure 3



Atoms of two different elements in EDTA^{4-} can form co-ordinate bonds with an aluminium ion.

On **Figure 3**, draw circles around the atoms of **two** different elements that would link to an aluminium ion by a co-ordinate bond.

[2 marks]

Turn over ►



0 7 . 8

Hydrated aluminium sulfate, $\text{Al}_2(\text{SO}_4)_3 \cdot x\text{H}_2\text{O}$, is soluble in water.

The relative formula mass and value of x can be found from a titration experiment.

Aqueous $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ ions react to form a stable complex when treated with an excess of EDTA^{4-} ions.

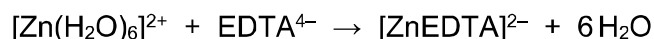
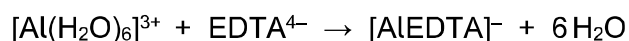
The excess of EDTA^{4-} ions is determined by titration with ZnSO_4 solution.

Method

- Dissolve 1.036 g of $\text{Al}_2(\text{SO}_4)_3 \cdot x\text{H}_2\text{O}$ in distilled water and make up to 250 cm^3
- Add 25.0 cm^3 of this solution to 50.0 cm^3 of a solution containing EDTA^{4-} ions of concentration $0.0100 \text{ mol dm}^{-3}$
- Determine the excess of EDTA^{4-} ions by titrating with ZnSO_4 solution in the presence of an indicator.

The excess of EDTA^{4-} ions requires 18.00 cm^3 of $0.0105 \text{ mol dm}^{-3}$ ZnSO_4 solution to react completely.

The equations for the reactions are



For $\text{Al}_2(\text{SO}_4)_3$ $M_r = 342.3$



Use the information given to calculate the M_r of $\text{Al}_2(\text{SO}_4)_3 \cdot x\text{H}_2\text{O}$

Calculate x

Give your answer as an integer.

[7 marks]

$$n(\text{EDTA}^{4-}) \text{ added} = 50.0 \times 0.0100 \div 1000 = 5.00 \times 10^{-4} \text{ mol}$$

$$n(\text{Zn}^{2+}) = 18.00 \times 0.0105 \div 1000 = 1.89 \times 10^{-4} \text{ mol}$$

$$\text{Zn}^{2+} \text{ reacts 1:1 with } \text{EDTA}^{4-}, \text{ so excess } \text{EDTA}^{4-} = 1.89 \times 10^{-4} \text{ mol}$$

$$n(\text{EDTA}^{4-}) \text{ reacted with } \text{Al}^{3+} \text{ in the } 25.0 \text{ cm}^3 \text{ sample}$$

$$= 5.00 \times 10^{-4} - 1.89 \times 10^{-4} = 3.11 \times 10^{-4} \text{ mol } (= n(\text{Al}^{3+}), 1:1)$$

$$n(\text{Al}^{3+}) \text{ in } 250 \text{ cm}^3 = 3.11 \times 10^{-4} \times 10 = 3.11 \times 10^{-3} \text{ mol}$$

$$\text{each } \text{Al}_2(\text{SO}_4)_3 \cdot x\text{H}_2\text{O} \text{ contains } 2 \text{ Al}^{3+}, \text{ so}$$

$$n(\text{Al}_2(\text{SO}_4)_3 \cdot x\text{H}_2\text{O}) = 3.11 \times 10^{-3} \div 2 = 1.555 \times 10^{-3} \text{ mol}$$

$$M_r = \text{mass} \div \text{moles} = 1.036 \div 1.555 \times 10^{-3} = 666.2$$

$$342.3 + 18x = 666.2$$

$$18x = 666.2 - 342.3 = 323.9$$

$$x = 323.9 \div 18 = 17.99, \text{ so } x = 18$$

$$M_r \quad 666.2$$

$$x \quad 18$$

17

Turn over ►



There are no questions on this page

*Do not write
outside the
box*

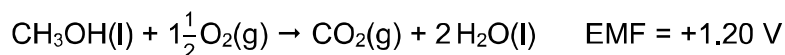
**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**



0 8

This question is about fuel cells.

In a methanol-oxygen fuel cell, the overall reaction is



0 8 . 1

At the positive electrode, oxygen reacts with hydrogen ions to form water.

Give a half-equation for this reaction.

[1 mark]



0 8 . 2

At the negative electrode, methanol reacts with water to produce carbon dioxide and hydrogen ions.

Give a half-equation for this reaction.

[1 mark]



0 8 . 3

The standard electrode potential for the $\text{CO}_2 / \text{CH}_3\text{OH}$ electrode is +0.03 V

Calculate the standard electrode potential for the $\text{O}_2 / \text{H}_2\text{O}$ electrode.

[1 mark]

$$E^\ominus = 1.20 + 0.03 = +1.23 \text{ V}$$

0 8 . 4

State why a fuel cell does **not** need to be electrically recharged.

[1 mark]

The reactants (fuel and oxygen) are supplied continuously.

0 8 . 5

Suggest **one** advantage of using methanol, rather than hydrogen, in a fuel cell for use in cars.

[1 mark]

Methanol is a liquid, so it can be stored and transported more easily than hydrogen gas.



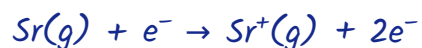
0 9

This is a question about time of flight (TOF) mass spectrometry.

0 9 . 1

Give the equation, including state symbols, for the formation of Sr^+ ions from Sr atoms by electron impact.

[1 mark]



0 9 . 2

A sample of strontium is analysed by TOF mass spectrometry. The sample is ionised using electron impact.

The ions are accelerated to have a kinetic energy (KE) of $7.02 \times 10^{-20} \text{ J}$
An ion takes $9.47 \times 10^{-4} \text{ s}$ to travel along a 95.0 cm flight tube.

$$KE = \frac{1}{2} mv^2$$

where m = mass (kg) and v = speed (m s^{-1})

Use the information given to deduce the mass number of this ion.

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

[5 marks]

$$d = 95.0 \text{ cm} = 0.950 \text{ m}$$

$$v = d \div t = 0.950 \div (9.47 \times 10^{-4}) = 1003 \text{ m s}^{-1}$$

$$KE = (1/2)mv^2, \text{ so } m = 2KE \div v^2$$

$$m = (2 \times 7.02 \times 10^{-20}) \div 1003^2 = 1.396 \times 10^{-25} \text{ kg}$$

$$\text{mass of one ion} = 1.396 \times 10^{-22} \text{ g}$$

$$\text{mass of 1 mol of ions} = 1.396 \times 10^{-22} \times 6.022 \times 10^{23} = 84.0 \text{ g}$$

$$\text{so the mass number} = 84$$

Mass number 84



0 9 . 3

Explain how the ions are detected in the TOF mass spectrometer.

State how the relative abundance of the ions is determined.

[2 marks]

How ions are detected The positive ions hit the detector and each ion gains an electron, which generates a current.

How relative abundance is determined The size of the current is proportional to the abundance of that ion.

0 9 . 4

A sample of strontium contains three isotopes, ^{86}Sr , ^{87}Sr and ^{88}Sr

82% of the sample is ^{88}Sr

The other isotopes are in a 1:2 ratio of $^{86}\text{Sr} : ^{87}\text{Sr}$

Calculate the percentage abundance of ^{87}Sr in this sample.

Use your answer to deduce the relative atomic mass (A_r) of the sample.

Give your answer to 1 decimal place.

[3 marks]

$$^{86}\text{Sr} + ^{87}\text{Sr} = 100 - 82 = 18 \%, \text{ so } ^{87}\text{Sr} = 18 \times 2 \div 3 = 12 \%$$

Abundance of ^{87}Sr 12 %

$$A_r = ((82 \times 88) + (12 \times 87) + (6 \times 86)) \div 100$$

$$= (7216 + 1044 + 516) \div 100 = 87.76 = 87.8$$

A_r 87.8

0 9 . 5

Electrospray ionisation is used instead of electron impact for the ionisation of a protein in a mass spectrometry experiment.

Suggest why.

[1 mark]

Electrospray is a soft ionisation method, so the protein (ion) does not break up (fragment).

12

Turn over ►



1 0

This question is about weak acids.

1 0 . 1

Table 5 shows the pH ranges of some indicators.

Table 5

Indicator	pH range
Bromocresol green	3.8 – 5.4
Bromothymol blue	6.0 – 7.6
Thymol blue	8.0 – 9.6

Identify the indicator that is most suitable for use in a titration between propanoic acid and sodium hydroxide.

[1 mark]

Thymol blue

1 0 . 2

Give the expression for the acid dissociation constant (K_a) for propanoic acid ($\text{CH}_3\text{CH}_2\text{COOH}$).

[1 mark]

$$K_a = \frac{[\text{H}^+][\text{CH}_3\text{CH}_2\text{COO}^-]}{[\text{CH}_3\text{CH}_2\text{COOH}]}$$

1 0 . 3

Calculate the pH of a $0.100 \text{ mol dm}^{-3}$ propanoic acid solution. Give your answer to 2 decimal places.

For propanoic acid, $\text{p}K_a = 4.87$

[4 marks]

$$K_a = 10^{-\text{p}K_a} = 10^{-4.87} = 1.35 \times 10^{-5} \text{ mol dm}^{-3}$$

$$[\text{H}^+] = [\text{CH}_3\text{CH}_2\text{COO}^-], \text{ so } K_a = [\text{H}^+]^2 \div [\text{CH}_3\text{CH}_2\text{COOH}]$$

$$[\text{H}^+] = \sqrt{(1.35 \times 10^{-5} \times 0.100)} = 1.16 \times 10^{-3} \text{ mol dm}^{-3}$$

$$\text{pH} = -\log_{10}(1.16 \times 10^{-3}) = 2.94$$

pH 2.94

1 0 . 4 For butanoic acid, $K_a = 1.51 \times 10^{-5} \text{ mol dm}^{-3}$

20.0 cm³ of 0.100 mol dm⁻³ sodium hydroxide solution are added to
25.0 cm³ of 0.100 mol dm⁻³ butanoic acid solution.

Calculate the pH of the solution formed.

[5 marks]

$$n(\text{butanoic acid}) = 25.0 \times 0.100 \div 1000 = 2.50 \times 10^{-3} \text{ mol}$$

$$n(\text{NaOH}) = 20.0 \times 0.100 \div 1000 = 2.00 \times 10^{-3} \text{ mol}$$

$$\text{acid left (HX)} = 2.50 \times 10^{-3} - 2.00 \times 10^{-3} = 5.0 \times 10^{-4} \text{ mol}$$

$$\text{salt formed (X}^{-}\text{)} = 2.00 \times 10^{-3} \text{ mol}$$

$$K_a = [\text{H}^+][\text{X}^{-}] \div [\text{HX}], \text{ so } [\text{H}^+] = K_a \times [\text{HX}] \div [\text{X}^{-}]$$

(the total volume is the same for both, so it cancels)

$$[\text{H}^+] = 1.51 \times 10^{-5} \times 5.0 \times 10^{-4} \div (2.00 \times 10^{-3})$$

$$= 3.775 \times 10^{-6} \text{ mol dm}^{-3}$$

$$\text{pH} = -\log_{10}(3.775 \times 10^{-6}) = 5.42$$

pH 5.42

1 0 . 5 A student plans to titrate butanoic acid solution with a solution of ethylamine.

Explain why this titration could **not** be done using an indicator.

[2 marks]

*This is a weak acid (butanoic acid) and weak base (ethylamine)
titration, so the pH change at the equivalence point is too gradual (no
steep, vertical section on the pH curve), so the indicator colour change
is not sharp and is difficult to judge.*

13

END OF QUESTIONS



There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**



[illegible]

Copyright information

For confidentiality purposes, all acknowledgements of third-party copyright material are published in a separate booklet. This booklet is published after each live examination series and is available for free download from www.aqa.org.uk.

Permission to reproduce all copyright material has been applied for. In some cases, efforts to contact copyright-holders may have been unsuccessful and AQA will be happy to rectify any omissions of acknowledgements. If you have any queries please contact the Copyright Team.

Copyright © 2023 AQA and its licensors. All rights reserved.

