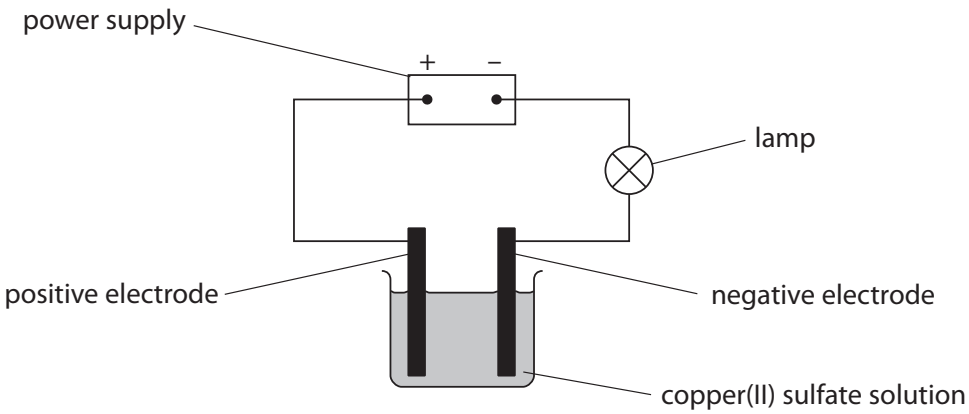
1 Most experiments involving electrolysis use inert electrodes, which do not take part in the reactions. However, in some experiments the electrodes do take part in the reactions.

A student investigates the electrolysis of copper(II) sulfate solution using copper electrodes which do take part in the reaction. She uses this apparatus.



She uses this method.

- weigh two clean strips of copper
- use one strip as the positive electrode and the other as the negative electrode
- after electrolysis wash the strips of copper with ethanol (a liquid that boils at 78 °C)
- dry the strips of copper and reweigh them

The ionic half-equations for the reactions at the electrodes are

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

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

(a) Suggest why the copper strips would dry more quickly when washed with ethanol rather than with water.

(1)

(b) The student's results are shown in the table.

	Positive electrode	Negative electrode
Mass of electrode before electrolysis in g	8.78	7.95
Mass of electrode after electrolysis in g	8.46	8.25

The table shows that the decrease in mass of the positive electrode was 0.32 g.

(i) Calculate the increase in mass, in grams, of the negative electrode.

(1)

Increase in mass = ... g

(ii) The ionic half-equations show that the increase in mass of the negative electrode should be the same as the decrease in mass of the positive electrode.

Suggest two reasons why the increase in mass of the negative electrode in the student's experiment was less than expected.

(2)

1 .....

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2 .....

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(c) Another student investigated the effect of changing the electrical charge, in faradays, passed during the electrolysis.

He wanted to find how this affected the increase in mass of the negative electrode.

One faraday is the electrical charge of one mole of electrons.

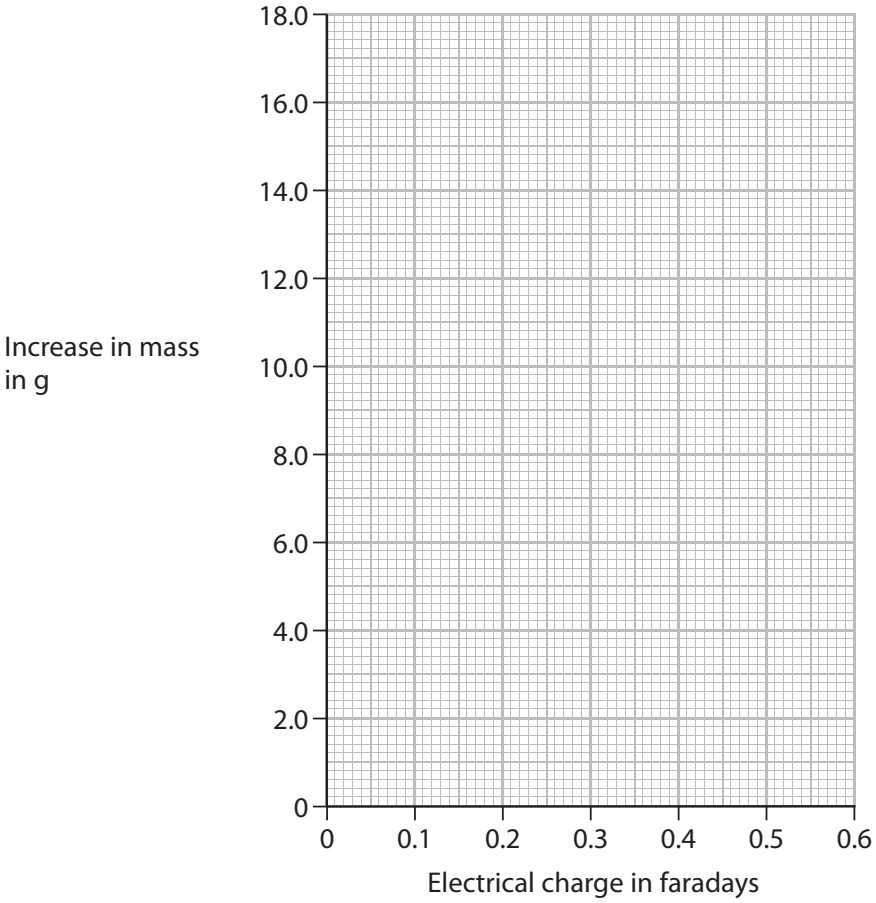
His results are shown in the table.

Experiment	1	2	3	4	5	6	7	8	9
Electrical charge in faradays	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
Increase in mass in g	3.20	4.80	7.40	8.00	9.60	11.20	12.80	14.40	16.00

(i) On the grid, plot a graph of increase in mass against electrical charge.

Draw a straight line of best fit. Start your line at the origin (0,0).

(3)



(ii) Draw a circle around the anomalous result

(1)

(iii) Suggest why the straight line should go through the origin.

(1)

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(iv) Explain why the graph shows that the increase in mass is directly proportional to the electrical charge passed.

(1)

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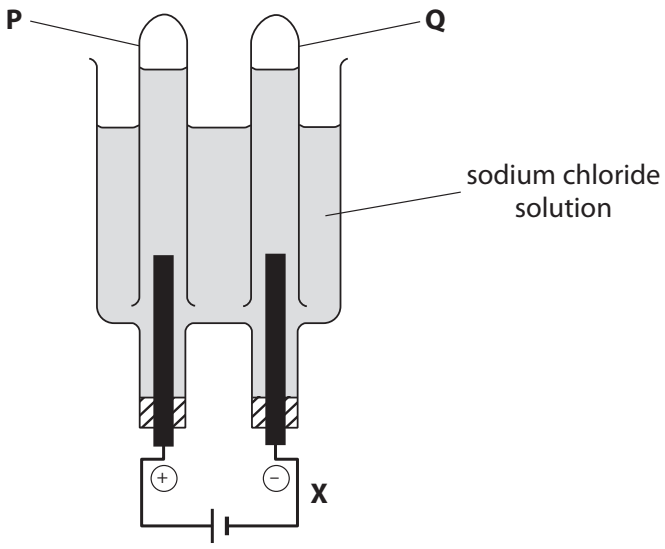
(v) Use your graph to estimate the increase in mass, in grams, of the copper electrode that would be produced by passing an electrical charge of 0.55 faradays.

(2)

Increase in mass = ... g

(Total for Question 1 = 12 marks)

2 The diagram shows how sodium chloride solution can be electrolysed and the products of electrolysis collected.



(a) (i) Draw an arrow on the diagram to show the direction of electron flow at point **X**.

(1)

(ii) The diagram shows one of the gases being collected in test tube **Q**.

Identify this gas.

(1)

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(iii) When the concentration of the sodium chloride solution is low, the gas collected in test tube **P** is mostly oxygen. The formation of this gas can be represented by an ionic half-equation.

Balance the equation.

(1)

$$\text{.....}OH^- \rightarrow \text{.....}H_2O + \text{.....}O_2 + \text{.....}e^-$$

(b) When the concentration of sodium chloride solution is high, the gas that collects in test tube **P** is mostly chlorine. The equation for its formation is:

$$2Cl^- \rightarrow Cl_2 + 2e^-$$

In one experiment, the volume of chlorine gas collected was 18 cm^3.

(i) Calculate the amount, in moles, of chlorine gas in 18 cm^3.

(The volume of 1 mol of a gas at room temperature and pressure is 24 000 cm^3)

(2)

Amount = ... mol

(ii) Calculate the quantity of electricity, in coulombs, needed to produce this volume of chlorine gas.

(1 faraday = 96 500 coulombs)

(2)

Quantity = ... C

(c) Chlorine reacts with potassium bromide solution. The equation for this reaction is:

$$Cl_2(g) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(aq)$$

This reaction can be described as both a displacement reaction and a redox reaction.

(i) Identify the element that is displaced in this reaction.

(1)

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(ii) State the meaning of the term **redox**.

(1)

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(d) Chlorine is used in the manufacture of phosphorus pentachloride, PCl_5

The equation for the reaction is:

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g) \qquad \Delta H = -124 \text{ kJ/mol}$$

(i) What does the $\rightleftharpoons$ symbol indicate about this reaction?

(1)

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(ii) Predict and explain the effect of increasing the pressure on the equilibrium position of this reaction.

(2)

Prediction .....

Explanation .....

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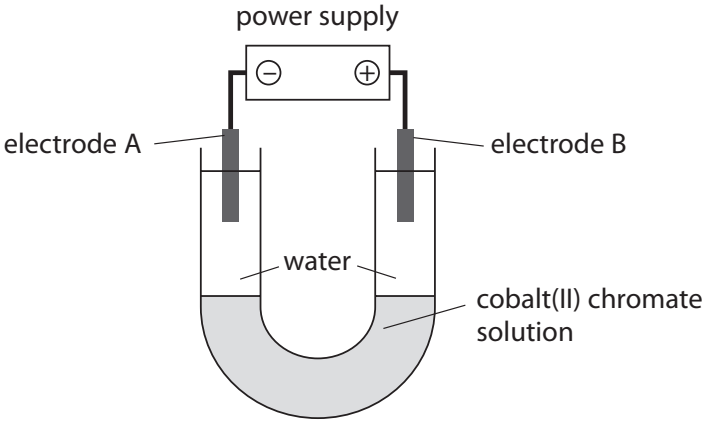
(Total for Question 2 = 12 marks)

3 The apparatus shown in the diagram can be used to investigate the colours of the cobalt(II) ion (Co^{2+}) and the chromate ion (CrO_4^{2-}) in cobalt(II) chromate.



These are the results of the experiment.

- a pink colour moves towards electrode A
- a yellow colour moves towards electrode B

(a) Explain how the results show that the chromate ion is yellow.

(2)

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(b) (i) Chromate ions in aqueous solution can be converted into dichromate ions ($Cr_2O_7^{2-}$) by the addition of hydrogen ions.

Balance the equation that represents this reaction.

(1)

$$\text{.....}CrO_4^{2-}(aq) + \text{.....}H^+(aq) \rightarrow \text{.....}Cr_2O_7^{2-}(aq) + \text{.....}H_2O(l)$$

(ii) Which solution is a source of hydrogen ions for this reaction?

(1)

☒ **A** $H_2O_2(aq)$

☒ **B** HCl(aq)

☒ **C** NaOH(aq)

☒ **D** $NH_3(aq)$

(c) When aqueous potassium chromate is added to aqueous lead(II) nitrate, a bright yellow precipitate is formed.

(i) Complete the equation for the reaction by inserting the missing state symbols.

$$K_2CrO_4(\ldots\ldots) + Pb(NO_3)_2(\ldots\ldots) \rightarrow 2KNO_3(aq) + PbCrO_4(\ldots\ldots)$$

(1)

(ii) Describe how you could obtain a pure, dry sample of the insoluble solid from the final reaction mixture.

(3)

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(Total for Question 3 = 8 marks)