Q1.

Brass is a metal alloy containing copper and zinc. The presence of zinc in the alloy makes brass less malleable than copper alone.

Prince's metal is one type of brass. It is used to make imitation gold because of its yellow colour.

The copper content of brass can be analysed by first reacting a known sample of the metal with concentrated nitric acid. The reaction of the copper is:

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

(a) Identify the element that is oxidised and the element that is reduced in the reaction shown. Include relevant oxidation numbers.

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(b) Suggest one precaution when carrying out this reaction, other than the use of gloves, goggles and lab coats, clearly stating the hazard concerned.

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(c) The copper ions are then reacted with excess potassium iodide.

$$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$$

The iodine formed is analysed by titration with sodium thiosulfate.

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

A 5.000 g sample of Prince's metal was analysed.
After reaction with concentrated nitric acid, the sample was diluted to 250 cm^3 and then 10.0 cm^3 aliquots or portions were titrated with 0.100 mol dm^{-3} sodium thiosulfate solution.

The mean titre was 22.65 cm^3.

Calculate the percentage of copper, by mass, in this sample of Prince's metal to an appropriate number of significant figures.

(6)

(d) In aqueous solution, copper(II) and zinc ions react differently with sodium hydroxide solution.

Describe the observations when sodium hydroxide solution is added drop by drop (until in excess) to separate samples of these two ions.

Include relevant **ionic** equations with state symbols.

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(e) Explain, in terms of electronic configurations, why copper is classified as a transition element but zinc is not.

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(f) Explain, in terms of their structures, why brass is less malleable than pure copper.

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(Total for question = 20 marks)

Q2.

A hydrogen-oxygen fuel cell contains an alkaline electrolyte. The half-equation at the anode is:

$$H_2(g) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2e^-$$

What is the half-equation at the cathode?

(1)

☐ **A** $\frac{1}{2}O_2(g) + H_2O(l) + 2e^- \rightarrow 2OH^-(aq)$

☐ **B** $O_2(g) + 2H^+(aq) + 2e^- \rightarrow H_2O_2(l)$

☐ **C** $\frac{1}{2}O_2(g) + 2H^+(aq) + 2e^- \rightarrow H_2O(l)$

☐ **D** $O_2(g) + H_2(g) + 2e^- \rightarrow 2OH^-(aq)$

(Total for question = 1 mark)

Q3.

A redox titration of iron(II) ions with potassium manganate(VII) is used to determine the amount of iron in iron tablets. The reaction is:

$$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l) + 5Fe^{3+}(aq).$$

(a) Why is no indicator necessary in this redox titration?

(1)

☐ **A** an indicator would interfere with the redox reaction

☐ **B** no suitable indicator changes colour at the end point

☐ **C** the colour change of the iron(II) ions is sufficient

☐ **D** the colour change of the manganate(VII) ions is sufficient

(b) In one such titration, the following equipment was used.

Equipment	Uncertainty for each reading
100 cm^3 measuring cylinder	±1 cm^3
250.0 cm^3 volumetric flask	±0.15 cm^3
25.0 cm^3 pipette	±0.06 cm^3
50.00 cm^3 burette	±0.05 cm^3

Which piece of equipment has the **lowest** measurement uncertainty for this experiment?

(1)

☐ **A** the measuring cylinder to measure 100 cm^3 of sulfuric acid

☐ **B** the volumetric flask to make up the solution of the iron tablet

☐ **C** the pipette to measure out the iron(II) solution

☐ **D** the burette to add a titre volume of 25.00 cm^3

(c) A 25.0 cm^3 portion of an iron(II) tablet solution required 5.00×10^{-5} mol of manganate(VII) ions to react completely. What is the mass of iron, in grams, in the 25.0 cm^3?

(1)

☐ **A** 0.00058

☐ **B** 0.0028

☐ **C** 0.010

☐ **D** 0.014

(Total for question = 3 marks)

Q4.

Standard electrode potentials can be used to show whether or not a reaction is feasible.

(a) State the conditions required, in addition to 1 mol dm^{-3}, for obtaining standard electrode potentials.

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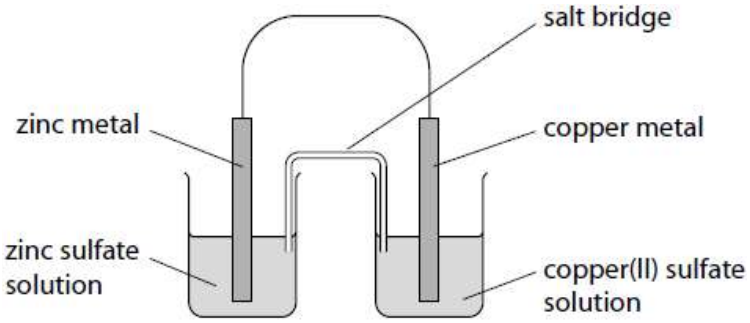
(b) A Daniell cell is a combination of standard zinc and copper electrodes.



The standard electrode potentials measured against a standard hydrogen electrode are shown in the table.

Right-hand electrode system	$E^{\ominus}$/V
$Zn^{2+}(aq) \mid Zn(s)$	–0.76
$Cu^{2+}(aq) \mid Cu(s)$	+0.34

(i) Calculate the standard electrode potential of this cell.

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(ii) Give **three** observations that would be made when current flows for several hours in the Daniell cell.

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(c) Some standard reduction potentials are:

Electrode reaction	$E^{\ominus}$ / V
$Cu^{2+}(aq) + e^- \rightleftharpoons Cu^+(aq)$	+0.15
$Cu^+(aq) + e^- \rightleftharpoons Cu(s)$	+0.52
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	–0.44
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	+0.77

State and justify, in terms of $E^{\ominus}$ cell values, whether copper(I) ions and iron(II) ions will be disproportionate.

Include any equations for reactions which occur.

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(d) State one reason why the feasibility determined from standard electrode potentials does not necessarily result in a reaction.

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(Total for question = 8 marks)