Q1. Use the standard electrode potential data in the table below to answer the questions which follow.

			$E^{\ominus}$ / V
$Ce^{4+}(aq) + e^-$	$\rightleftharpoons$	$Ce^{3+}(aq)$	+1.70
$MnO^-(aq) + 8H^+(aq) + 5e^-$	$\rightleftharpoons$	$Mn^{2+}(aq) + 4H_2O(l)$	+1.51
$Cl_2(g) + 2e^-$	$\rightleftharpoons$	$2Cl^-(aq)$	+1.36
$VO_2^+(aq) + 2H^+(aq) + e^-$	$\rightleftharpoons$	$VO^{2+}(aq) + H_2O(l)$	+1.00
$Fe^{3+}(aq) + e^-$	$\rightleftharpoons$	$Fe^{2+}(aq)$	+0.77
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^-$	$\rightleftharpoons$	$H_2SO_3(aq) + H_2O(l)$	+0.17

(a) Name the standard reference electrode against which all other electrode potentials are measured.

Hydrogen electrode

(1)

(b) When the standard electrode potential for $Fe^{3+}(aq) / Fe^{2+}(aq)$ is measured, a platinum electrode is required.

(i) What is the function of the platinum electrode?

provide a surface for the reaction

(ii) What are the standard conditions which apply to $Fe^{3+}(aq)/Fe^{2+}(aq)$ when measuring this potential?

298K , Both Fe^{3+} and Fe^{2+} @ $1 moldm^{-3}$

H^+ conc. @ $1 moldm^{-3}$

(3)

(c) The cell represented below was set up under standard conditions.

$Pt|H_2SO_3(aq), SO_4^{2-}(aq)||MnO_4^-(aq), Mn^{2+}(aq)|Pt$

Calculate the e.m.f. of this cell and write an equation for the spontaneous cell reaction.

Cell e.m.f. $1{\cdot}51 - 0{\cdot}17 = 1{\cdot}34V$

Equation $5H_2SO_3 + \cancel{5H_2O} + 2MnO^- + \cancel{16H^+} \rightarrow 5SO_4^{2-} + \underset{4}{\cancel{20}}H^+ + 2Mn^{2+} + \underset{3}{\cancel{8}}H_2O$

$5H_2SO_3 + 2MnO_4^- \longrightarrow 5SO_4^{2-} + 4H^+ + 2Mn^{2+} + 3H_2O$

(3)

(d) (i) Which one of the species given in the table is the strongest oxidising agent?

Ce^{4+} (most +ve)

(ii) Which of the species in the table could convert Fe^{2+}(aq) into Fe^{3+}(aq) but could not convert Mn^{2+}(aq) into MnO_4^-(aq)?

VO^{2+} and Cl_2 (notice 2 marks')

(3)

(e) Use data from the table of standard electrode potentials to deduce the cell which would have a standard e.m.f. of 0.93 V. Represent this cell using the convention shown in part (c).

$Pt \mid Fe^{2+}(aq), Fe^{3+}(aq) \parallel Ce^{4+}(aq), Ce^{3+}(aq) \mid Pt$

(2)
(Total 12 marks)

Q2. Copper, in the form of nanoparticles of copper(II) hexacyanoferrate(II), has recently been investigated as an efficient method of storing electrical energy in a rechargeable cell.

(a) Solar cells generate an electric current from sunlight. These cells are often used to provide electrical energy for illuminated road signs.

Explain why rechargeable cells are connected to these solar cells.

Solar cells do not supply electrical energy at all times (ie. when dark). Rechargeable cells can store this for night times.

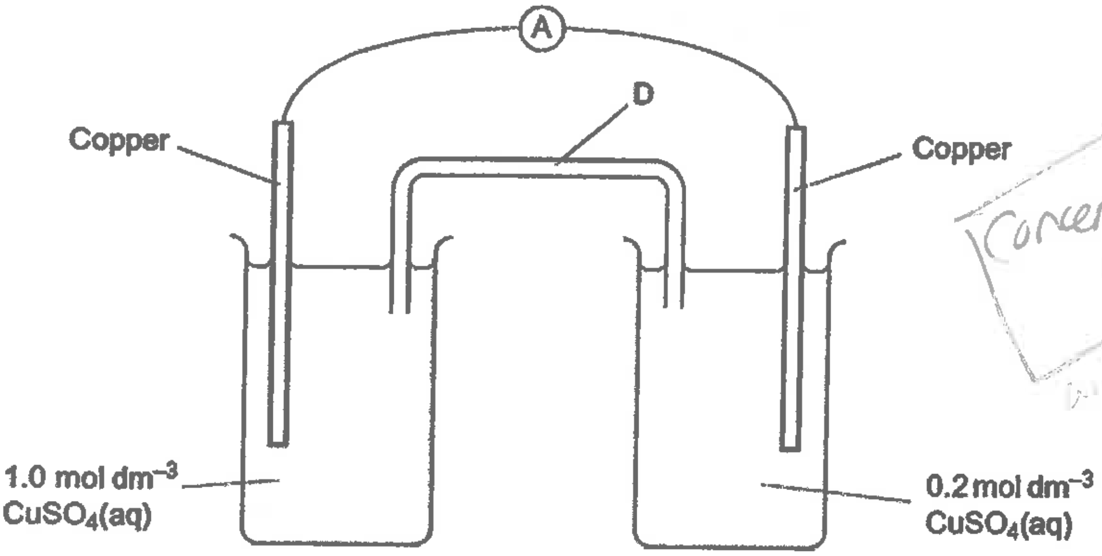
(2)

(b) Suggest **one** reason why many waste disposal centres contain a separate section for cells and batteries.

prevent toxic chemicals entering the environment.
(Also valuable!)

(1)
(Total 3 marks)

Q3. An electrochemical cell is shown in the diagram. In this cell, the amount of copper in the electrodes is much greater than the amount of copper ions in the copper sulfate solutions.



Concentration cell!
will dilute the conc solution + vice versa

(a) Explain how the salt bridge **D** provides an electrical connection between the two electrodes.

Ions are able to move through it.

(1)

(b) Suggest why potassium chloride would **not** be a suitable salt for the salt bridge in this cell.

Chloride ions react with the copper ions.

(1)

(c) In the external circuit of this cell, the electrons flow through the ammeter from right to left.

Suggest why the electrons move in this direction.

Cu^{2+} ions more concentrated in left hand side, so $Cu^{2+} \rightarrow Cu$ will occur and $Cu \rightarrow Cu^{2+}$ @ right electrode.

(2)

(d) Explain why the current in the external circuit of this cell falls to zero after the cell has operated for some time.

Eventually concentrations will become equal.

(1)

(e) The simplified electrode reactions in a rechargeable lithium cell are

Electrode **A** $Li^+ + MnO_2 + e^- \longrightarrow LiMnO_2$ $E = -0.15$ V

Electrode **B** $Li^+ + e^- \longrightarrow Li$ -3.05 ✓

Electrode **B** is the negative electrode.

(i) The e.m.f. of this cell is 2.90 V.

Use this information to calculate a value for the electrode potential of electrode **B**.

$2.90V = -0.15 - (?)$ $? = -3.05$

(1)

(ii) Write an equation for the overall reaction that occurs when this lithium cell is being **recharged**.

$\cancel{Li^+} + LiMnO_2 \rightarrow Li + \cancel{Li^+} + MnO_2$

$LiMnO_2 \rightarrow Li + MnO_2$

(2)

(iii) Suggest why the recharging of a lithium cell may lead to release of carbon dioxide into the atmosphere.

Using electricity which may have used fossil fuels at power station.

(1)
(Total 9 marks)

Q4. Hydrogen–oxygen fuel cells are used to provide electrical energy for electric motors in vehicles.

(a) In a hydrogen–oxygen fuel cell, a current is generated that can be used to drive an electric motor.

(i) Deduce half-equations for the electrode reactions in a hydrogen–oxygen fuel cell.

Half-equation 1 $H^+ + 2OH^- \rightarrow 2H_2O + 2e^-$

Half-equation 2 $O_2 + 4e^- + 2H_2O \rightarrow 4OH^-$

or acidic version

(2)

(ii) Use these half-equations to explain how an electric current can be generated.

Hydrogen electrode oxidised releasing electrons.

Oxygen electrode reduced, accepting electrons.

(2)

(b) Explain why a fuel cell does **not** need to be recharged.

Hydrogen continuously supplied.

(1)

(c) To provide energy for a vehicle, hydrogen can be used either in a fuel cell or in an internal combustion engine.

Suggest the main advantage of using hydrogen in a fuel cell rather than in an internal combustion engine.

very efficient → High energy output (useful).

(1)

(d) Identify **one** major hazard associated with the use of a hydrogen–oxygen fuel cell in a vehicle.

Hydrogen is explosive.

(1)
(Total 7 marks)

Q5. A sealed flask containing gases **X** and **Y** in the mole ratio 1:3 was maintained at 600 K until the following equilibrium was established.

$$X(g) + 3Y(g) \rightleftharpoons 2Z(g)$$

The partial pressure of **Z** in the equilibrium mixture was 6.0 MPa when the total pressure was 22.0 MPa.

(a) (i) Write an expression for the equilibrium constant, K_p, for this reaction.

$$Kp = \frac{(Pz)^2}{(Px) \times (Py)^3}$$

(ii) Calculate the partial pressure of **X** and the partial pressure of **Y** in the equilibrium mixture.

*Partial pressure of **X*** $22 - 6 = \frac{16}{4} = 4 MPa.$

Partial pressure of Y $4 \times 3 = 12 MPa.$

(iii) Calculate the value of K_p for this reaction under these conditions and state its units.

Value of K_p $kp = \frac{6^2}{4 \times 12^3}$ $kp = 5.21 \times 10^{-3}$

Units of K_p MPa^{-2}

(6)

(b) When this reaction is carried out at 300 K and a high pressure of 100 MPa, rather than at 600 K and 22.0 MPa, a higher equilibrium yield of gas **Z** is obtained.

Give two reasons why an industrialist is unlikely to choose these reaction conditions.

Reason 1 High Pressure is expensive

Reason 2 Rate slow @ low temps.

(2)
(Total 8 marks)

Q6. This question is about the chemical properties of chlorine, sodium chloride and sodium bromide.

(a) Sodium bromide reacts with concentrated sulfuric acid in a different way from sodium chloride.

Write an equation for this reaction of sodium bromide and explain why bromide ions react differently from chloride ions.

Equation $2NaBr + 2H_2SO4 \rightarrow Na_2SO4 + Br_2 + SO_2 + 2H_2O$

Explanation Br^- ions larger than Cl^- ions are therefore more easily oxidised.

(3)

(b) A colourless solution contains a mixture of sodium chloride and sodium bromide.

Using aqueous silver nitrate and any other reagents of your choice, develop a procedure to prepare a pure sample of silver bromide from this mixture.
Explain each step in the procedure and illustrate your explanations with equations, where appropriate.

$AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$ white ppt.

$AgNO_3 + NaBr \rightarrow AgBr + NaNO_3$ cream ppt.

- Add dil. NH_3 which will dissolve the AgCl but <u>NOT</u> AgBr.
- filter oFF AgBr ppt
- Wash to remove any soluble impurities
- Dry to remove water.

(6)

(c) Write an ionic equation for the reaction between chlorine and cold dilute sodium hydroxide solution.
Give the oxidation state of chlorine in each of the chlorine-containing ions formed.

$2Cl_2 + 2NaOH \rightarrow 2NaClO + Cl_2 + H_2O$

Ionic $Cl_2 + 2OH^- \rightarrow OCl^- + Cl^- + H_2O$

Cl in OCl^- = +1 Cl^- is -1.

(2)
(Total 11 marks)

Q7. Compound **A** is an oxide of sulphur. At 415 K, a gaseous sample of **A**, of mass 0.304 g, occupied a volume of 127 cm^3 at a pressure of 103 kPa.

State the ideal gas equation and use it to calculate the number of moles of **A** in the sample, and hence calculate the relative molecular mass of **A**.
(The gas constant $R = 8.31$ J K^{-1} mol^{-1})

Ideal gas equation $PV = nRT$ $n = \frac{PV}{RT}$

Calculation

$n = \frac{103000 \times 1.27\times10^{-4}}{8.31 \times 415}$ $n = 3.79\times10^{-3}$ moles

$\frac{0.304}{3.79\times10^{-3}} = 80.2$

(Total 5 marks)

Q8. Which change requires the largest amount of energy?

A $He^+(g) \longrightarrow He^{2+}(g) + e^-$ ☒

B $Li(g) \longrightarrow Li^+(g) + e^-$ ☐

C $Mg^+(g) \longrightarrow Mg^{2+}(g) + e^-$ ☐

D $N(g) \longrightarrow N^+(g) + e^-$ ☐

smallest atom
- close to
nuclus

(Total 1 mark)

Q9. A saturated aqueous solution of magnesium hydroxide contains 1.17×10^{-3} g of $Mg(OH)_2$ in 100 cm^3 of solution. In this solution, the magnesium hydroxide is fully dissociated into ions.

What is the concentration of $Mg^{2+}(aq)$ ions in this solution?

A 2.82×10^{-2} mol dm^{-3} ☐

B 2.01×10^{-3} mol dm^{-3} ☐

C 2.82×10^{-3} mol dm^{-3} ☐

D 2.01×10^{-4} mol dm^{-3} ☒

$\frac{1.17\times10^{-3}}{58} = 2.017\times10^{-5}$ moles

$\frac{2.017\times10^{-5}}{(100/1000)} = \underline{\underline{2.017\times10^{-4}}}$

(Total 1 mark)

Q10. The table below shows some information about three hydrochloric acid solutions used to clean bricks and concrete.

Cleaner	Acid content by mass / %	Price per 25dm^3 / £
① Plattern Concrete Acid	24.0	14.39
② Dub-Lit Brick Cleaner	28.9	16.99
③ Conpat Brick Acid	35.9	24.99

Use the data in the table above to determine the cleaner that offers the best value for money, based on acid content. Show your working.

① $\frac{24}{14.39}$ ~~*~~ = 1.667

③ $\frac{35.9}{24.99}$ = 1.44

② $\frac{28.9}{16.99}$ = 1.701

Dub LiT

(Total 1 mark)

Q11. Which of these pieces of apparatus has the lowest percentage uncertainty in the measurement shown?

A Volume of 25 cm³ measured with a burette with an uncertainty of ±0.1 cm³. ☒ $\frac{0.1}{25} \times 100 = 0.4\%$

B Volume of 25 cm³ measured with a measuring cylinder with an uncertainty of ±0.5 cm³. ☐ $\frac{0.5}{25} \times 100 = 2\%$

C Mass of 0.150 g measured with a balance with an uncertainty of ±0.001 g. ☐ $\frac{0.001}{0.150} \times 100 = 0.6\%$

D Temperature change of 23.2 °C measured with a thermometer with an uncertainty of ±0.1 °C. ☐ $\frac{0.1}{23.2} \times 100 = 0.43\%$

(Total 1 mark)