RIVER VALLEY HIGH SCHOOL
YEAR 6 PRELIMINARY EXAMINATION

CANDIDATE NAME									
CLASS	6								
CENTRE NUMBER	S					INDEX NUMBER				

H2 CHEMISTRY 9647/02

Paper 2 Structured Questions **24 September 2013**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class, Centre number and index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Answer **all** questions in the space provided.
A Data Booklet is provided. Do NOT write anything on it.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use									
Paper 2									
Question Number	1	2	3	4	5	6			Total
Marks	/12	/14	/4	/11	/16	/15			/72
Paper 1		/40		Paper 3		/80		Total	/192

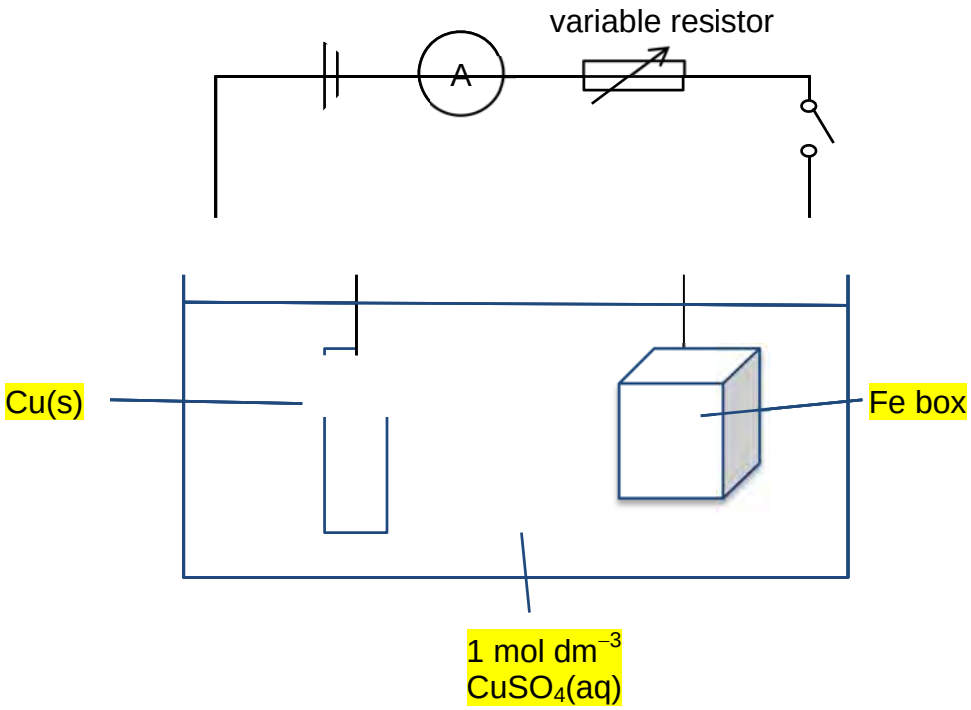
This document consists of **17** printed pages and **1** blank page.

1 Planning (P)

Rust is mainly made up of iron (III) oxide. An old rusty iron box can be restored by submerging the box in acid solution to remove the rust, followed by coating the iron box with a layer of metals such as chromium, aluminium or zinc using electrolysis.

A student tries to adapt this process to restore a rusty iron box using only materials that are available in the school laboratory.

She removed the rust on the box by submerging it in 1 mol dm^{-3} sulfuric acid. Then she coats the rust free box with a layer of copper using electrolysis. The diagram below shows part of the experimental set up.



(a) Write a balanced equation, including state symbols, for the reaction that removes rust from the box using sulfuric acid. **[1]**

$3H_2SO_4(aq) + Fe_2O_3(s) \rightarrow Fe_2(SO_4)_3(aq) + 3H_2O(l)$

(b) Other than safety issues, what is the disadvantage of using strong acid to remove rust from the box? **[1]**

Acid will also react with freshly exposed iron after rust is removed.

(c) Complete and label the diagram above to show the experimental set-up for coating the rust free box with copper metal by electrolysis. Give the composition of a suitable electrolyte. **[2]**

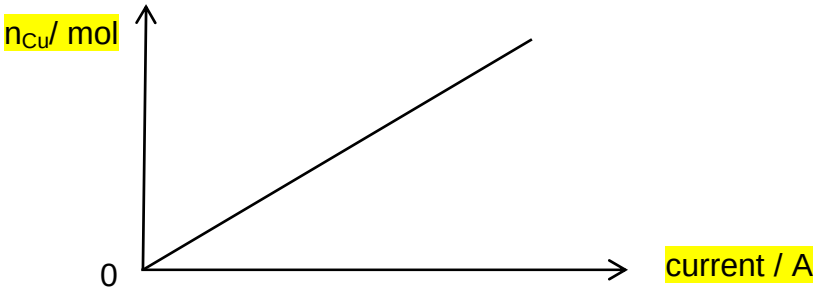
(d) Write the equation for the reaction at the anode and cathode. **[1]**

Cathode: $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

Anode: $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$

(e) The variable resistor can be used to vary the current that is passed through a closed circuit.

Predict how does the amount of copper deposited in a fixed duration (t) varies as current is increased from 0.00A until 1.00A. Display your prediction in the form of a sketch graph. **[1]**



(f) Design a laboratory experiment to investigate your prediction in **(e)** and hence allow an experimental value for Faraday's Constant to be obtained.

The following apparatus and chemicals are available for used.

Wires	Batteries
Switch	Mass balance (± 0.001g)
Digital Ammeter (± 0.001A)	Pure copper strips
Variable resistor	Copper (II) sulfate solution

(i) The percentage error for the mass weighed using the mass balance should not exceed 1%. Calculate the minimum duration of time, in minutes, for 0.400 A of current to be passed through the circuit.

Considering the max percentage error of mass balance,

minimum mass of copper deposited = 0.100g

$n_{Cu} = 0.100 \div 63.5 = 0.00157$ mol

$n_e = n_{Cu} \times 2 = 0.00315$

$Q = I \times t = n_e \times F$

$$\min t = \frac{0.00315 \times 96500}{0.400} = 760s = 12.7 \min$$

(ii) Considering your answer in **(f)(i)**, write a detailed plan for your experiment. Your plan should contain the following

- all essential experimental details
- the precautions taken to ensure accuracy
- outline of how the results would be used to verify your predicted graph in **(e)**.
- hence explain how the results can be used to determine a value for the Faraday constant. **[6]**

Procedure + Precautions

1. Set up the apparatus as in **(c)**.
2. Close the circuit and set the current to ____A using the variable resistor.
3. Open the circuit and disconnect the iron box/Cu electrode.
4. Wash and dry the iron box/Cu electrode carefully.
5. Weigh and record the mass of iron box/Cu electrode.
6. Reconnect the iron box/ Cu electrode, closed the circuit and allows the current to flow for t minutes.
7. Open the circuit and disconnect the iron box/ Cu electrode.
8. Wash and dry the iron box/Cu electrode carefully
9. Weigh and record the mass of iron box/Cu electrode again.
10. Repeat the experiment 2 times by setting the current to 2 other reasonable current.

Data and Results

Expt	I /A	X = Mass of Cu electrode at 0 min /g	Y = Mass of Cu electrode at t min / g	X–Y = Mass of Cu deposited / g	n_{Cu} =(X-Y)÷ 63.5 / mol
1	0.400				
2	0.800				
3	1.20				

With these results, a graph of n_{Cu} against current may be plotted for verification.

OR

Calculate for each experiment at a fixed current,

Mass of Cu deposited

= (Mass of Fe box at t min) - (Mass of Fe box at 0 min)

n_{Cu} = Mass of Cu deposited ÷ 63.5

With these results, a graph of n_{Cu} against current may be plotted for verification.

To determine a value for Faraday's Constant:

$Q = I \times t \times 60 = n_e \times F = 2 \times n_{Cu} \times F$ (t in min)

Find the gradient of the graph of n_{Cu} against current.

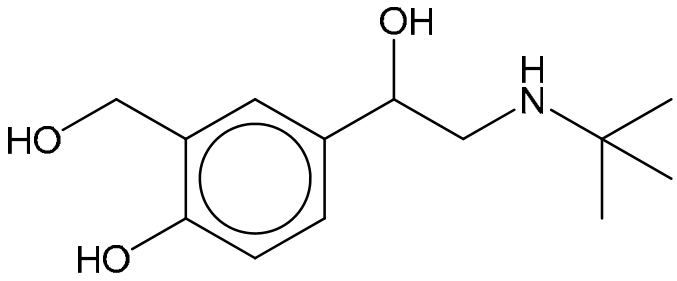
$$gradient = \frac{n_{Cu}}{I} = \frac{t \times 60}{2F}$$

$$F = \frac{t \times 60}{2 \times gradient}$$

[Total: 12]

2 Haze levels in Singapore hit a record high of PSI 401 on 21 June this year, as a consequence of widespread forest fires in Indonesia. Many hospitals and clinics reported a spike in the number of patients seeking medical attention for respiratory problems, such as asthma and rhinitis.

To provide quick relief from asthma symptoms, the drug salbutamol is commonly prescribed.



salbutamol

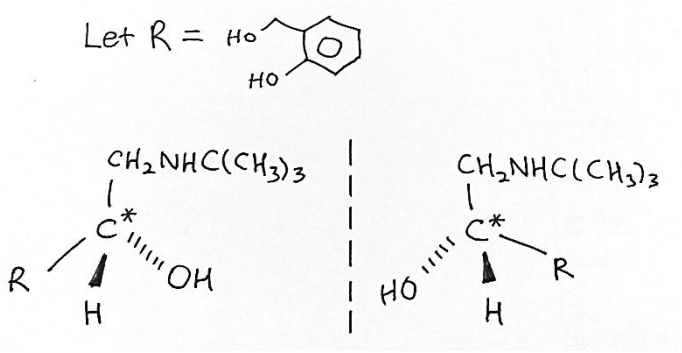
(a) Identify two functional groups, other than phenyl, that are present in salbutamol. **[1]**

Primary alcohol, secondary alcohol, phenol, secondary amine

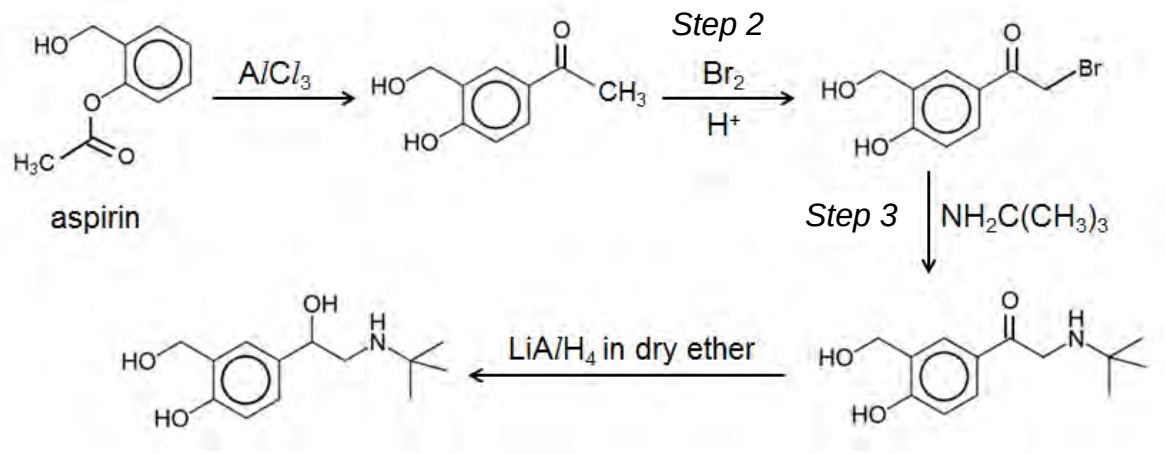
(b) Salbutamol is sold in pharmacies as a racemic mixture, mainly because the (*S*)-enantiomer blocks metabolism pathways while the (*R*)-enantiomer shows activity.

Identify the type of stereoisomerism salbutamol exhibits and draw two structures to illustrate this. **[2]**

Optical isomerism



A 4-step synthesis route of salbutamol is shown as follows:



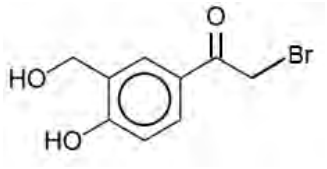
(c) An organic chemist suggested the use of bromine gas under ultraviolet light in *Step 2*. Explain why his choice of reagent and condition may not be appropriate for the conversion. **[1]**

There is a possibility of many side products as random substitution of hydrogen atoms on any alkyl group found in the compound can occur.

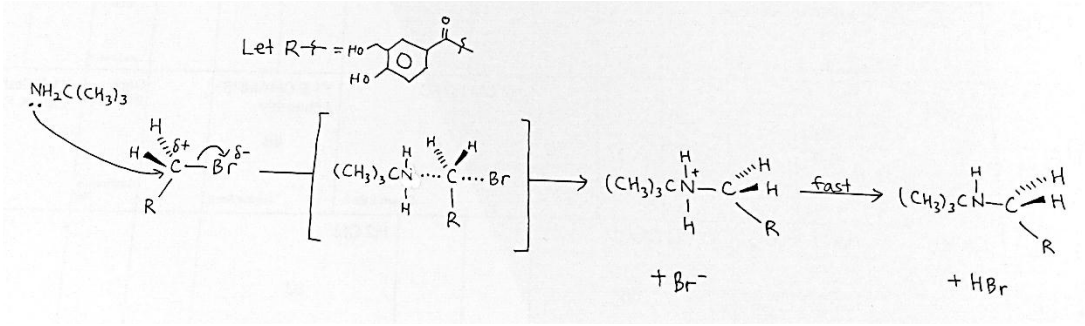
(d) Name the reaction in *Step 3* and outline the mechanism.

You may use **R** to denote bulky alkyl groups in your mechanism. **[4]**

Nucleophilic substitution



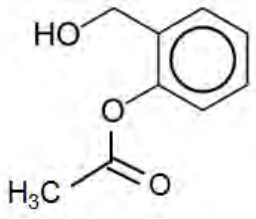
is a primary alkyl halide and it undergoes the S_N2 mechanism.



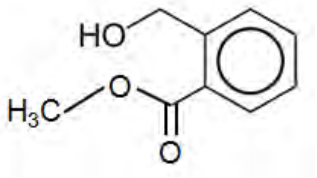
(e) Explain why $LiAlH_4$ must be used in dry ether during the final step? **[1]**

$LiAlH_4$ reacts violently with water.

(f) A laboratory technician realised that the labels to the bottles containing aspirin and another compound had fallen off.



aspirin



compound X

Suggest a simple chemical test to distinguish between these two compounds. **[2]**

Test: Heat with HC*l*(aq), followed by adding neutral $FeCl_3$(aq).

Observations: Aspirin gives a violet colouration while compound X does not.

OR

Test: Heat with HC*l*(aq), followed by adding Br_2(aq).

Observations: Reddish-brown Br_2 decolourises for aspirin but not for compound X.

OR

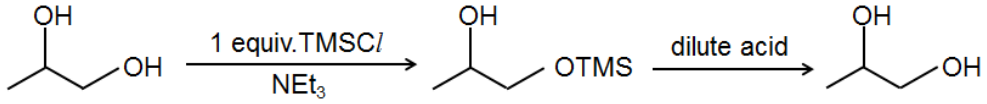
Test: Heat with H_2SO_4(aq) and $KMnO_4$(aq). Pass any gaseous products into limewater.

Observations: For compound X, purple $KMnO_4$ decolourises and gas evolved gives a white precipitate in limewater. For aspirin, purple

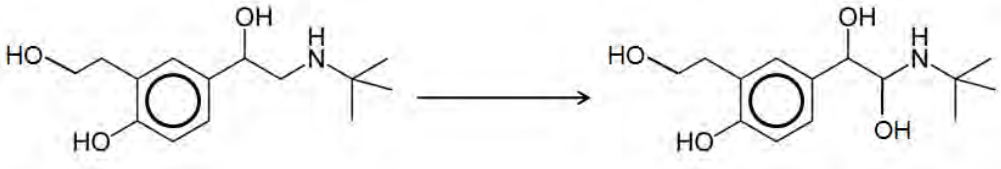
$KMnO_4$ decolourises and no gas is evolved.

(g) Chlorotrimethylsilane (TMSC*l*) in the presence of triethylamine (NEt_3) is usually used as a protecting group for alcohols in organic synthesis. This allows the alcohol group to remain unreactive while the rest of the molecule undergoes reaction. To regenerate the alcohol group, dilute acid can be added.

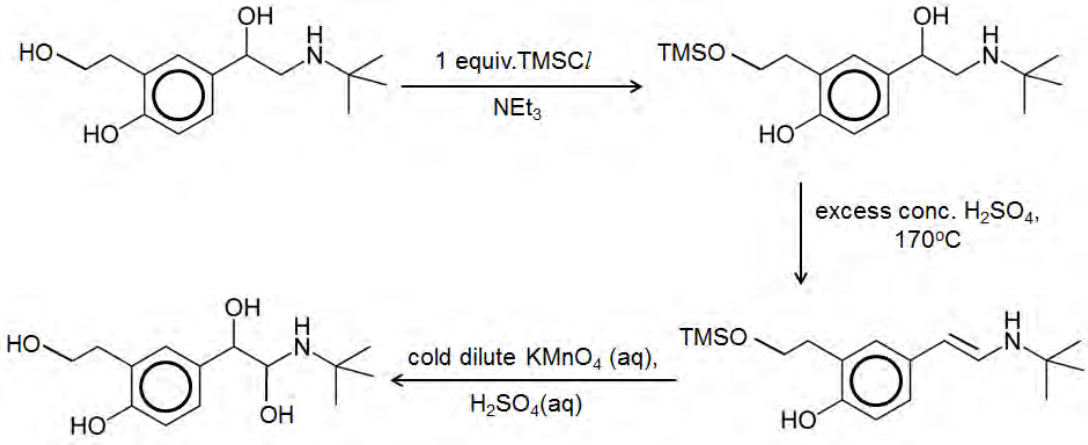
A representative equation is shown as follows:



Using the information provided, suggest a method to perform the following conversion.



[3]



[Total: 14]

3 *Use of Data Booklet is relevant to this question.*

Zinc has similar properties to Group II metals. For example, zinc and calcium reacts with oxygen to give their respective metallic oxide. Also, zinc carbonate and calcium carbonate decompose when heated to give similar products.

(a) Suggest why zinc carbonate is thermally less stable compared to calcium carbonate. **[2]**

Ionic radius of Zn^{2+} is smaller than Ca^{2+}. Hence, Zn^{2+} has a larger charge density **[1]** and is able to polarise the CO_3^{2-} ion to a greater extent which weaken the C–O bond to a greater extent.

(b) Zinc however, reacts much more slowly with oxygen compared to calcium. Explain why this is so. **[2]**

	1st IE/ kJmol^{-1}	2nd IE/ kJmol^{-1}	Total (1st IE + 2nd IE)/ kJmol^{-1}
Ca	590	1150	1740
Zn	908	1730	2638

More energy is required to form Zn^{2+} from Zn compared to forming Ca^{2+} from Ca./ Activation energy for the formation of ZnO is higher compared to CaO. Hence, the reaction would be slower.

[Total: 4]

4 A 2.80 g sample mixture of zinc chloride and calcium chloride was melted to form a homogeneous molten mixture. An electric current was applied to this mixture for 30 min using inert electrodes. The gas produced at the anode, gas **X**, was reacted with excess $H_2(g)$, and dissolved in distilled water to make up to a 250 cm^3 solution. 25 cm^3 of this solution requires 27.95 cm^3 of 0.100 mol dm^{-3} of NaOH(aq) for complete reaction.

(a) Write an equation for the anode reaction. **[1]**

$2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$

(b) Write an equation for the reaction of the gas produced at the anode with $H_2(g)$. **[1]**

$Cl_2(g) + H_2(g) \rightarrow 2HCl(g)$

(c) Calculate the number of moles of gas **X** produced. Hence, calculate the average current that was applied to the electrolyte. **[3]**

$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

$$n_{HCl}\ produced = \frac{250}{25} \times \left(\frac{27.95}{1000} \times 0.100\right)$$

$$n_{HCl}\ produced = 0.0280\ mol$$

$$n_{Cl_2}\ produced = \frac{0.0280}{2}$$

$$n_{Cl_2}\ produced = 0.0140\ mol$$

$n_{e^-} = 0.0280\ mol$

$$n_{e^-} = \frac{It}{F}$$

$$0.0280 = \frac{I(30 \times 60)}{96500}$$

$I = 1.50A$

(d) State the possible cathode reactions, and deduce which reaction is more likely to take place at the start of the electrolysis process. **[2]**

$Ca^{2+}(l) + 2e^- \rightarrow Ca(l)$ (1) $E^\ominus = -2.87$ V

$Zn^{2+}(l) + 2e^- \rightarrow Zn(l)$ (2) $E^\ominus = -0.76$ V

(2) is more likely to take place at the start of the process

(e) Given that 0.0729 g of calcium metal was produced at the end of the electrolytic process, calculate the percentage mass of zinc chloride in the original solid sample. State any assumptions that you made. **[4]**

$$n_{CaCl_2}\ electrolysed = \frac{0.0729}{40.1}$$

$$= 1.81 \times 10^{-3}\ mol$$

$$n_{ZnCl_2}\ electrolysed = 0.0140 - 1.82 \times 10^{-3}$$

$$= 0.0122\ mol$$

$$m_{ZnCl_2}\ in\ sample = 0.0122 \times (65.4 + 2 \times 35.5)$$

$= 1.66\ g$

$$\%\ mass\ of\ ZnCl_2 = \frac{1.66}{2.80} \times 100$$

$$= 59.3\%$$

Assumption: All the $ZnCl_2$ were electrolysed before any of the $CaCl_2$ begins to be electrolysed.

[Total: 11]

4 **(a)** Selective precipitation of sulfides may be used to separate the cations present in a solution containing Cu^{2+} and Ni^{2+}.

Aqueous hydrogen sulfide behaves as a dibasic acid.

$H_2S\ (aq) = H^+\ (aq) + HS^-\ (aq)$ $\qquad K_{a1} = 8.9 \times 10^{-8}$ mol dm^{-3}

$HS^-\ (aq) = H^+\ (aq) + S^{2-}\ (aq)$ $\qquad K_{a2} = 1.2 \times 10^{-13}$ mol dm^{-3}

Metal sulfides are precipitated by the following reaction.

$M^{2+}\ (aq) + S^{2-}\ (aq) = MS\ (s)$

Relevant K_{sp} values are given in the table.

Salt	K_{sp}/ mol^2 dm^{-6}
CuS	6.0×10^{-36}
NiS	3.0×10^{-19}

(i) Given that a solution contains 0.20 mol dm^{-3} Ni^{2+} and 0.10 mol dm^{-3} Cu^{2+}, determine the maximum sulfide concentrations for each metal cation so that no precipitation occurs.

$[S^{2-}\ max]$ for NiS $= \frac{3\times10^{-19}}{0.20} = 1.5 \times 10^{-18}$ mol dm^{-3}

$[S^{2-}\ max]$ for CuS $= \frac{6\times10^{-36}}{0.10} = 6 \times 10^{-35}$ mol dm^{-3}

(ii) Show that $[H^+] = \sqrt{\frac{K_{a1}K_{a2}[H_2S]}{[S^{2-}]}}$

$H_2S\ (aq) = 2H^+\ (aq) + S^{2-}\ (aq)$

$K_{a1}\ K_{a2} = \frac{[H^+]^2][S^{2-}]}{[H_2S]}$

Rearranging, $[H^+] = \sqrt{\frac{K_{a1}K_{a2}[H_2S]}{S^{2-}}}$

(iii) Considering the answer in **(i)** and using the expression in **(ii)**, calculate the maximum pH that must be maintained to separate Ni^{2+} and Cu^{2+} ions, given that the concentration of H_2S in the solution is 0.10 mol dm^{-3}.

$K_{a1}\ K_{a2} = 1.1 \times 10^{-20}$ mol^2 dm^{-6}

$[H^+] = \sqrt{\frac{1.1\times10^{-20}\times0.10}{1.5\times10^{-18}}} = 0.027$ mol dm^{-3}

pH = – log 0.027 = 1.57

(iv) Calculate the actual concentrations of both metal ions in solution at the pH used in **(iii).**

$[Ni^{2+}]$ remains as 0.20 mol dm^{-3}

$[Cu^{2+}] = 6 \times 10^{-36} / 1.5 \times 10^{-18} = 4.0 \times 10^{-18}$ mol dm^{-3}

[8]

(b) Ni and Cu are transition metals. Explain why transition metal complexes and compounds are usually coloured.

In complexes/ compounds of Ni and Cu, the **3d orbitals are split into 2 sets of non-degenerate orbitals/ different energies.**

An energy gap (Δ*E*) exists between these 2 sets of 3d orbitals.

Radiation from the visible region of the electromagnetic spectrum is absorbed when an electron undergoes d-d transition/ moves from a lower energy d-orbital to another unfilled/partially-filled d orbital of higher energy.

The colour observed corresponds to the **complement of the absorbed colours .**

[3]

(c) **(i)** The melting points of NiS and H_2S are as shown below. Explain the difference in their boiling points in term of structure and bonding.

Compound	Melting point / °C

NiS	797
H_2S	− 82

H_2S has **a simple covalent structure** while NiS has a **giant ionic lattice structure.**

More energy is needed to overcome the **stronger electrostatic attraction between oppositely charged Ni^{2+} and S^{2-} ions** in NiS than the **weak Van Der Waals forces between H_2S molecules.**

(ii) The Claus process is used in the industry to partially oxidise H_2S to form water and elemental sulfur, S_8. Write a balanced equation and calculate the mass of elemental sulfur produced when 1 tonne of H_2S is used.

[1 tonne = 1000 kg]

$H_2S + \frac{1}{2} O_2 \rightarrow H_2O + \frac{1}{8} S_8$

Amt of $H_2S = 1000 \times 10^3 / 34.0 = 2.94 \times 10^4$ mol

Mass of S_8

$= 1/8 \times 2.94 \times 10^4 \times (32.0 \times 8)$

$= 9.41 \times 10^5$ g or 941 kg **[5]**

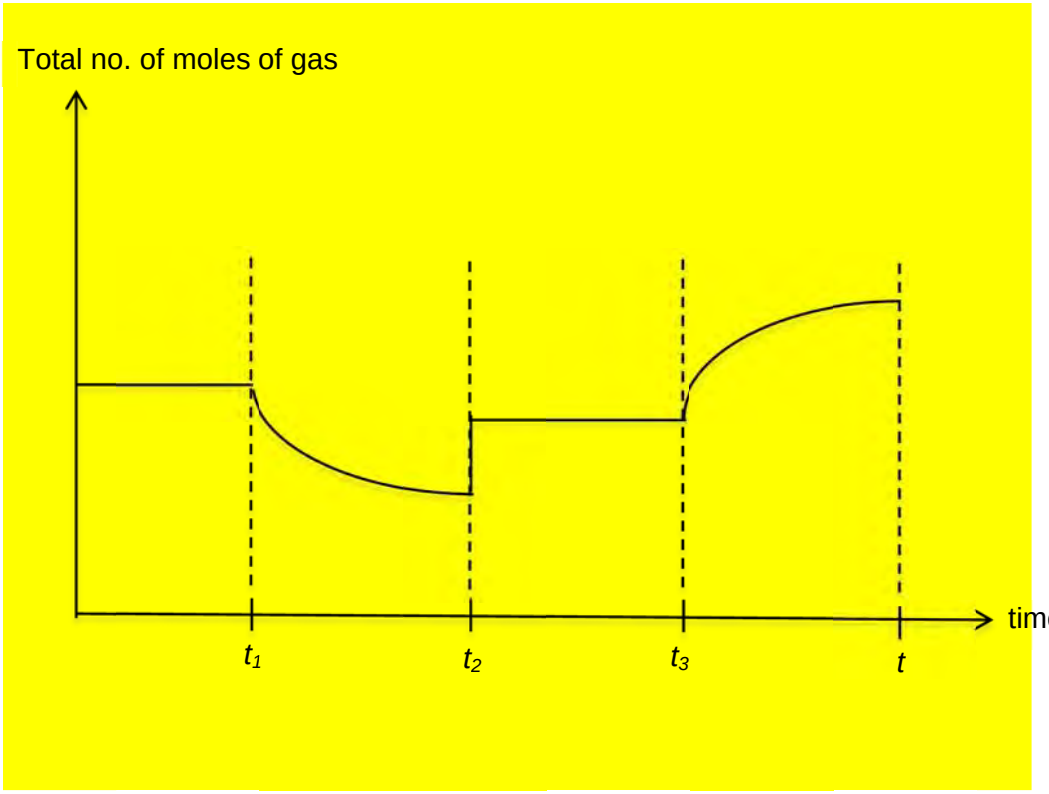
[Total: 16]

5. Water gas is a synthesis gas that consists of carbon monoxide and hydrogen. The gas is made by passing steam over coke:

$C(s) + H_2O(g) = CO(g) + H_2(g)$ $\Delta H > 0$

(a) The system was initially at equilibrium. At time t_1, the volume of the reaction vessel was then suddenly reduced and the system allowed to reach equilibrium. Pressure was then increased by adding argon at constant volume at t_2. A new equilibrium was established before temperature was increased at t_3.

Sketch on the axes the graph that should be observed from time = 0 to time = *t* when equilibrium is re-established once again.



[4]

(b) When steam was passed over coke at temperatures near 800 °C with a pressure of 8.81 atm and allowed to reach equilibrium in a 1.00 dm^3 vessel, the partial pressure of steam was found to be 2.67 atm.

(i) Write the K_p expression for the reaction. Include units in your answer.

$K_p = \frac{p_{CO}\, p_{H_2}}{p_{H_2O}}$ Units: atm

(ii) What is K_p at 800 °C?

$K_p = \frac{p_{CO}\, p_{H_2}}{p_{H_2O}} = \frac{6.14^2}{2.67} = 14.1$ atm

(iii) The numerical value of K_p at 25 °C is 1.7 x 10^{-21}. Compare the K_p values at 25 °C and 800 °C and comment on their difference in relation to ΔH of the reaction.

When temperature is increased from 25 °C to 800 °C, K_p increases, which means the product-reactant ratio increases **[1]**. Temperature increase also favours the endothermic reaction and shifts the equilibrium position to the right hence producing more CO and H_2.

[5]

(c) The behaviour of magnesium and aluminium in the presence of steam is notably different. Magnesium is observed to react vigorously with steam while that of aluminium takes place much slower.

(i) Write balanced equations for the reactions of magnesium and aluminium with steam.

$Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$

$2Al(s) + 3H_2O(l) \rightarrow Al_2O_3(s) + 3H_2(g)$

(ii) Explain why aluminium reacts more slowly than magnesium.

Aluminium reacts slowly with steam because of existing protective layer of $Al_2O_3(s)$ on the metal **[3]**

(d) Sodium belongs to the third period of the Periodic Table. 50 cm^3 of 1.3 mol dm^{-3} of its hydroxide reacted with 30 cm^3 of 2.7 mol dm^{-3} ethanoic acid in a polystyrene cup. The maximum temperature rise recorded was 11.3 °C. Specific heat capacity of the solution = 4.18 J g^{-1} K^{-1}

(i) Write an equation for the enthalpy change of neutralization for this reaction.

$NaOH(aq) + CH_3COOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$

(ii) Calculate the enthalpy change of neutralization for this reaction.

Amount of NaOH = 0.05 x 1.3 = 0.065 mol

Amount of ethanoic acid = 0.03 x 2.7 = 0.081 mol

Amount of water = amount of NaOH (limiting) = 0.065 mol

Heat released = (80)(4.18)(11.3) = 3778 J

ΔH_{neut} = -(3778 x 10^{-3}) / 0.065 = -58.1 $kJmol^{-1}$ **[3]**

[Total: 15]

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