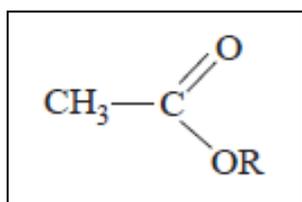


Friday Worksheet  
Revision 3

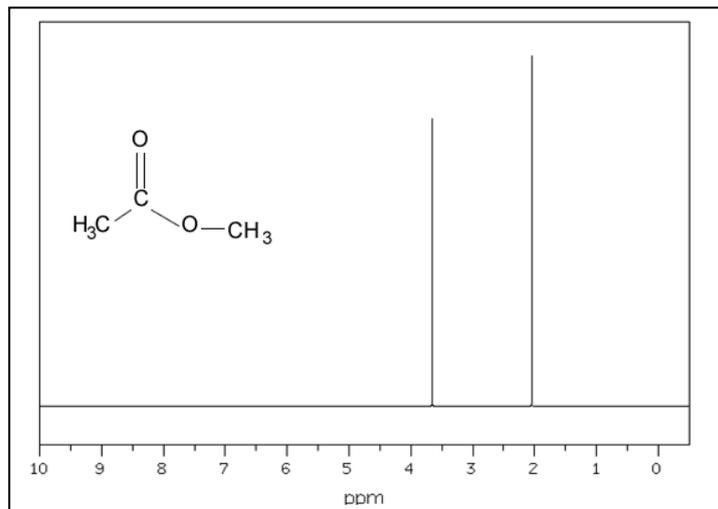
Name: .....

- 1) The  $^1\text{H}$ NMR spectrum of a compound with the chemical formula  $\text{C}_3\text{H}_6\text{O}_2$  is shown on the right.
- a) What is the chemical structure of the group of protons that formed the peak at chemical shift 2.0 ppm?

From the data sheet students should use the observed chemical shift to determine the chemical environment of the protons that formed the signal at 2.0 ppm

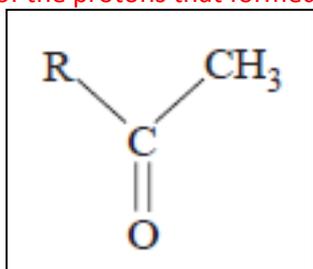


- b) Draw the chemical structure of the compound

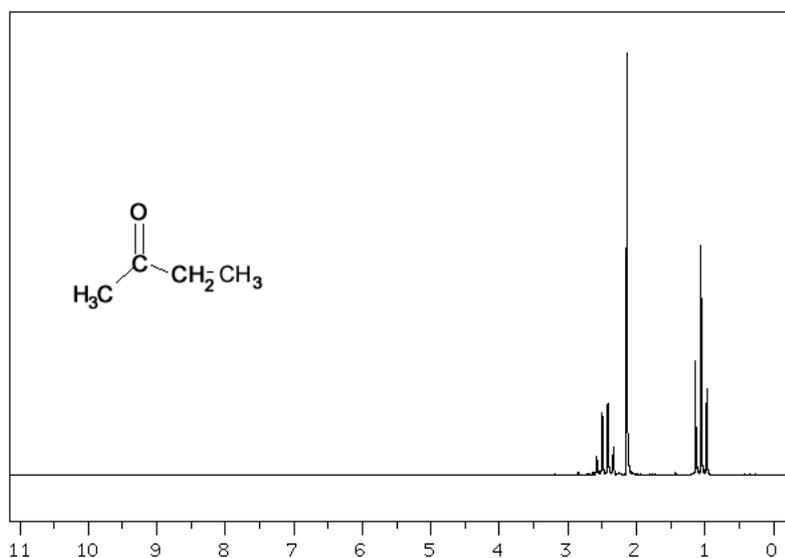


- 2) The  $^1\text{H}$ NMR spectrum of a compound with the chemical formula  $\text{C}_4\text{H}_8\text{O}$  is shown on the right.
- a) What is the likely chemical structure of the group of protons that formed the peak at chemical shift 2.1 ppm?

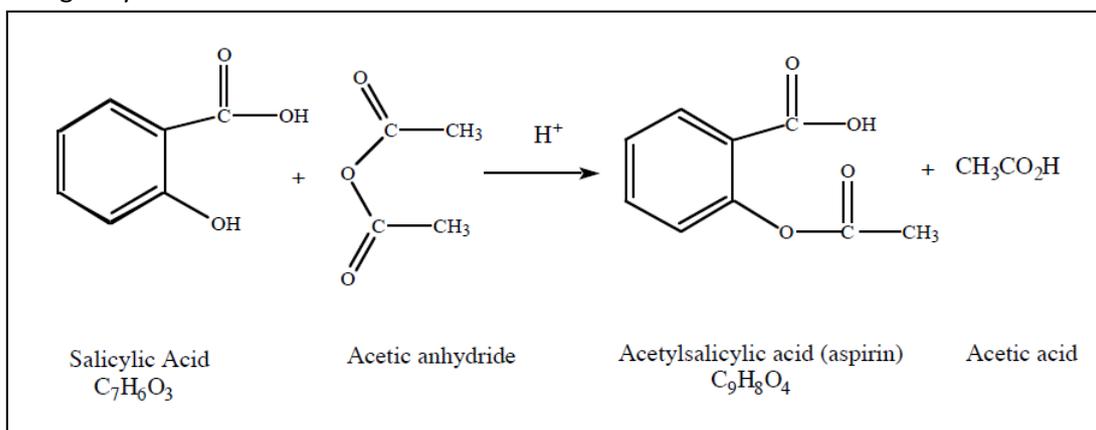
From the data sheet students should use the observed chemical shift to determine the chemical environment of the protons that formed the signal.



- b) Draw the chemical structure of the compound

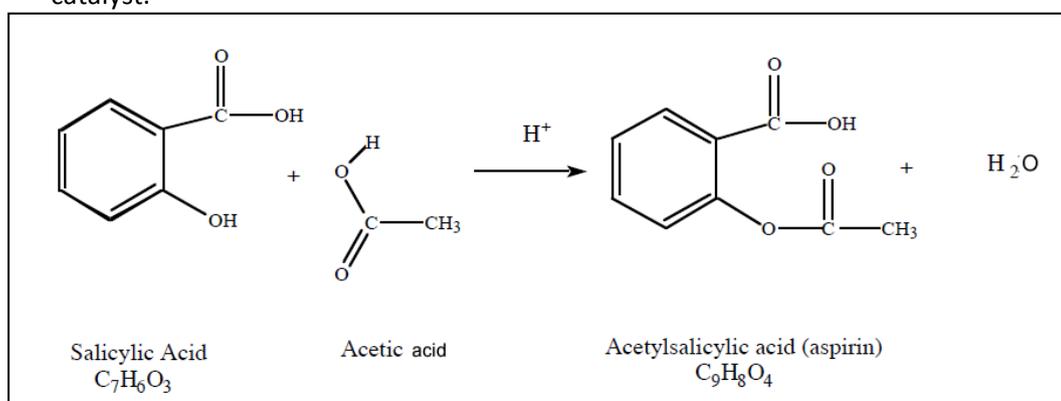


- 3) Aspirin can be made by reacting salicylic acid with acetic acid in the presence of an acid catalyst. The reaction between the phenol group (a hydroxyl group bonded directly to an aromatic ring) and the acetic acid, however, is slow and has a relatively low yield. When acetic anhydride is used, in place of acetic acid, the reaction is much faster and has a higher yield. The reaction is shown below



Iron(III) nitrate,  $Fe(NO_3)_3$  (aq) is used to identify any salicylic acid that has not reacted. The Iron (III) ion reacts with phenols to form a purple complex. Salicylic acid contains a phenol group, but acetylsalicylic acid does not. Therefore, if you add  $Fe(NO_3)_3$  to an aspirin sample and you see a purple colour, it means that there is still some salicylic acid present and there is incomplete reaction of salicylic acid and acetic anhydride.

- a) i. Write the reaction between salicylic acid and acetic acid in the presence of an acid catalyst.



- ii. What type of reaction is this? Circle the correct response

Acid/Base

Redox

Condensation

Hydrolysis

Explain.

A small molecule is produced as the bond between acetic acid and salicylic acid forms.

- iii. What functional groups are present in aspirin?

Carboxyl, carbon to carbon double bonds and ester.

iv. Calculate the percentage yield for the above reaction if the amount of salicylic acid used was 1.89 g and 2.28g of aspirin was obtained.

Molar mass of aspirin 180.16 g/mol molar mass of salicylic acid is 138.12 g/mol

If one mol of salicylic acid was used then, according to the stoichiometric ratio shown above, one mol of aspirin would be produced.

Step 1 find the mol of salicylic acid

$$\Rightarrow 1.89 / 138.12 = 0.0137 \text{ mol}$$

Step 2 find the mass of aspirin that should have formed

$$\Rightarrow \text{mass} = \text{mol} \times \text{formula mass} = 0.0137 \times 180.16 = 2.47 \text{ grams}$$

Step 3 find the percentage yield

$$\Rightarrow \text{actual yield} / \text{theoretical yield}$$

$$\Rightarrow (2.28 / 2.47) \times 100 = 92.3\%$$

- b) A student was asked to work out the purity of a sample of aspirin derived from the reaction above. Given a sample of the dried aspirin the student decided to dissolve the sample and titrate the resultant solution with NaOH using phenolphthalein as an indicator.

i. Will this method work? Explain

No. Aspirin has a carboxyl group (COOH) that will also react with NaOH.

ii. Describe a way that the purity can be tested

Test with  $\text{Fe}(\text{NO}_3)_3$ . If the sample turns purple then salicylic acid is present in the aspirin.

- c) A student weighed 2.00 g of salicylic acid. What volume of acetic anhydride is needed to completely react with this amount of salicylic acid if the density of acetic anhydride is 1.082 g/mL. Molar mass of acetic anhydride is 102.1 g/mol

Step 1 find the mol of salicylic acid formed.

$$\Rightarrow 2.00 \text{ g} / 138.12 = 0.0145 \text{ mol}$$

Step 2 Find the mol of acetic anhydride

According to the stoichiometric ratio for every one mol of salicylic acid one mol of acetic anhydride is needed.

$$\Rightarrow 0.0145 \text{ mol of acetic anhydride}$$

Step 3 Find the mass of acetic anhydride

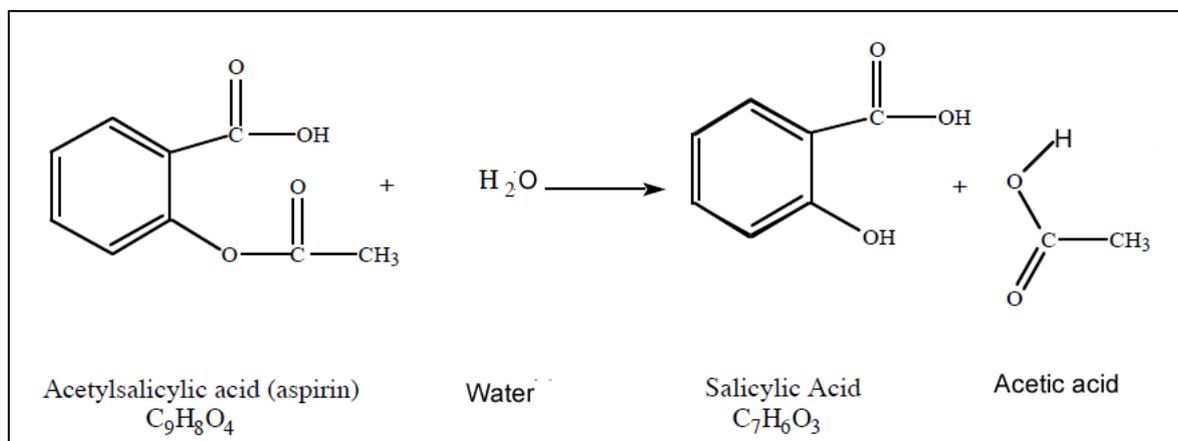
$$\Rightarrow \text{mass} = \text{mol} \times \text{molar mass} = 0.0145 \times 102.1 = 1.48 \text{ g}$$

Step 4 Find the volume of the acetic anhydride

$$\Rightarrow v = \text{mass} / \text{density} = 1.48 \text{ g} / 1.082 \text{ g/mL} = 1.37 \text{ mL}$$

- d) A bottle of aspirin was opened by a chemist after several years of been stored on the shelf. The chemist noticed a strong smell of vinegar. When tested with  $\text{Fe}(\text{III})$  (aq) ions the solid aspirin turned purple.

i. Write a balanced equation for the reaction that most likely occurred.



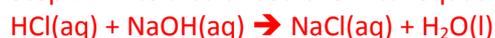
ii. What type of reaction took place?

**Hydrolysis**

- e) A chemist analysed aspirin tablets for quality control. The initial step of the analysis was the standardisation of a NaOH solution. Three 25.00 mL samples of a 0.1014 mol L<sup>-1</sup> solution of standardised HCl were titrated with the NaOH solution. The average volume required to reach the endpoint was 25.50 mL.
- i. Calculate the concentration of the NaOH solution in mol/Litre.



**Step 1 Write a balanced chemical equation for the reaction between HCl and NaOH.**



**Step 2 Find the mol of HCl in the average titre.**

$$\Rightarrow n_{\text{HCl}} = C \times V = 0.1014 \times 0.025 = 0.002535$$

**Step 3 Calculate the mol of NaOH in the 25.00 mL aliquot.**

$\Rightarrow$  NaOH reacts with HCl in a 1:1 ratio so

$$\Rightarrow n_{\text{NaOH}} = 0.002535$$

**Step 4 Calculate the concentration of the standard of the NaOH solution**

$$\Rightarrow C_{\text{NaOH}} = n/V = 0.002535 / 0.0255 = 0.09941 \text{ M}$$

ii. What is a standard solution?

**It is a solution whose concentration is known accurately.**

iii. Why is NaOH not used as a primary standard?

**It reacts with the atmosphere and so its purity is not always known.**

iv Three flasks were prepared each containing a mixture of 20 mL of water and 10 mL of ethanol. An aspirin tablet was dissolved in each flask. The aspirin in each solution was titrated with the standardised NaOH

- Write a balanced equation for the reaction between aspirin and NaOH.



- If the average titre was 16.32 mL find the mass in mg of aspirin in each tablet.

**Step 1 Find the mol of NaOH needed for neutralisation of a tablet of aspirin.**

$$\Rightarrow n_{\text{NaOH}} = C \times V = 0.0994 \times 0.0162 = 1.62 \times 10^{-3}$$

**Step 2 Calculate the mol of aspirin**

$\Rightarrow$  According to the stoichiometry for every mol of NaOH one mol of aspirin reacts.

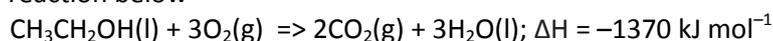
$$\Rightarrow n_{\text{aspirin}} = 1.62 \times 10^{-3}$$

**Step 3 Calculate the mass of aspirin in each tablet.**

$$\Rightarrow \text{mass} = n \times F_m = 1.62 \times 10^{-3} \times 180.16 = 0.292 \text{ g or } 292 \text{ mg}$$

4) Ethanol can be used in two ways to generate energy. It can be burnt to release heat or used in a fuel cell to generate electricity.

a) Ethanol is directly burnt for the purposes of heating and cooking, according to the reaction below



What mass of ethanol is needed to supply 650 MJ of energy, assuming no energy is lost.

$$1 \text{ MJ} = 10^3 \text{ kJ}$$

From the equation we know that 1 mol of ethanol produces 1370 kJ of energy.

Step 1 find how many mol of ethanol are needed to produce 650,000 kJ of energy

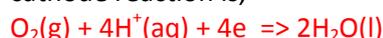
$$\Rightarrow 650,000 / 1370 = 474.5$$

Step 2 Find the mass of ethanol

$$\Rightarrow \text{mass} = n \times \text{Fm} = 474.5 \times 46.1 = 21.9 \text{ kg}$$

b) Ethanol may also be used to supply electrical energy. This can be provided by a fuel cell with an acidic electrolyte. The overall cell reaction is identical to the equation given in a) above. In the fuel cell the

i. cathode reaction is,



ii. anode reaction is.



c) If the voltage across the fuel cell is 1.18 V calculate the electrical energy produced by one mole of ethanol.

$E = QV$  where Q is charge in Coulombs and V is voltage in volts.

Step 1 find the charge.

$\Rightarrow$  Since one mole of ethanol produces 12 mol of electrons the charge is

$$\Rightarrow 12 \times 96500 \text{ C} = 1.16 \times 10^6$$

Step 2 Find the energy

$$E = QV = 1.16 \times 10^6 \times 1.18 = 1.37 \times 10^6 \text{ J}$$

d) An alternative way of generating electricity from ethanol is to use it as the fuel to run a generator. Suggest with reasons which is more efficient the fuel cell or the generator.

The more energy conversion that take place the more energy is wasted as heat.

Generators have moving parts and hence there is energy loss as heat due to friction.

Burning the ethanol there is heat lost as not all the heat goes into mechanical energy and not all the mechanical energy is converted into electrical energy.

The fuel cell has a one step conversion of chemical energy into electrical.

Fuel cell

Chemical energy  $\Rightarrow$  electrical energy.

Generator

Chemical energy  $\Rightarrow$  heat energy  $\Rightarrow$  mechanical energy  $\Rightarrow$  electrical energy.

5) The energy content of food can be determined by completely burning a sample of the food in a bomb calorimeter and then calculating the energy released.

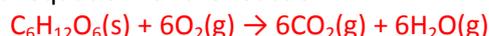
a. The calorimeter to be used contained water and was calibrated by passing an electric current of 1.80 A at 5.70 V for 141 seconds through the heating coil. The temperature of the water rose 1.20 °C.

- i. Use the data above to calculate the calibration factor, in  $\text{kJ } ^\circ\text{C}^{-1}$ , for this calorimeter.

$$\text{Calibration factor} = \text{Energy} / \Delta T$$

$$\Rightarrow C_f = VIt / \Delta T = 5.70 \times 1.80 \times 141 / 1.20 = 1.21 \text{ kJ}/^\circ\text{C}$$

- ii. The carbohydrate, glucose, burns in excess oxygen according to the following equation to produce carbon dioxide and water. Write a balanced chemical equation for the reaction.



- iii. When a 1.44 g sample of glucose was burned in this calorimeter the temperature of the water increased from 17.22°C to 34.60°C. Calculate the molar heat of combustion of glucose in  $\text{kJ mol}^{-1}$ .

Molar mass of glucose = 180.0 g/mol

Step 1 Find the mol of glucose

$$\Rightarrow 1.44 / 180.0 = 0.00800$$

Step 2 Find the total energy released

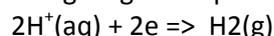
$$\Rightarrow (34.60 - 17.22) ^\circ\text{C} \times 1.206 \text{ kJ}/^\circ\text{C} = 20.96 \text{ kJ}$$

Step 3 Find  $\Delta H$

$$\Rightarrow 20.96 / 0.00800 = 2.63 \times 10^3 \text{ kJ/mol}$$

$$\Rightarrow \Delta H = -2.63 \times 10^3 \text{ kJ/mol}$$

6) The following diagram represents a  $\text{H}^+(\text{aq})/\text{H}_2(\text{g})$  half cell for the reaction



a) For this to be a standard half cell what should be the:

- i. temperature of the solution

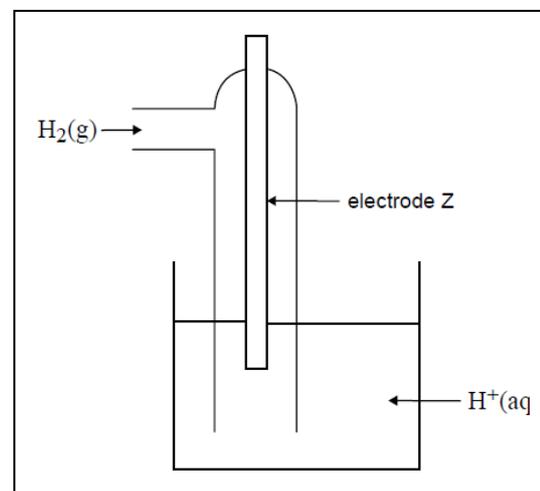
25 °C

- ii. pH of the solution

0.

Since the concentration of standard cells is 1.0 M

$$\Rightarrow -\log[1] = 0$$



b) A galvanic cell consists of the following half cells which have been set up under standard conditions.

- Half cell 1: the  $\text{H}^+(\text{aq})/\text{H}_2(\text{g})$  half cell described in **part a**.
- Half cell 2: a cadmium (Cd) electrode in a solution containing  $\text{Cd}^{2+}(\text{aq})$

After some time, the pH in half cell 1 increases.

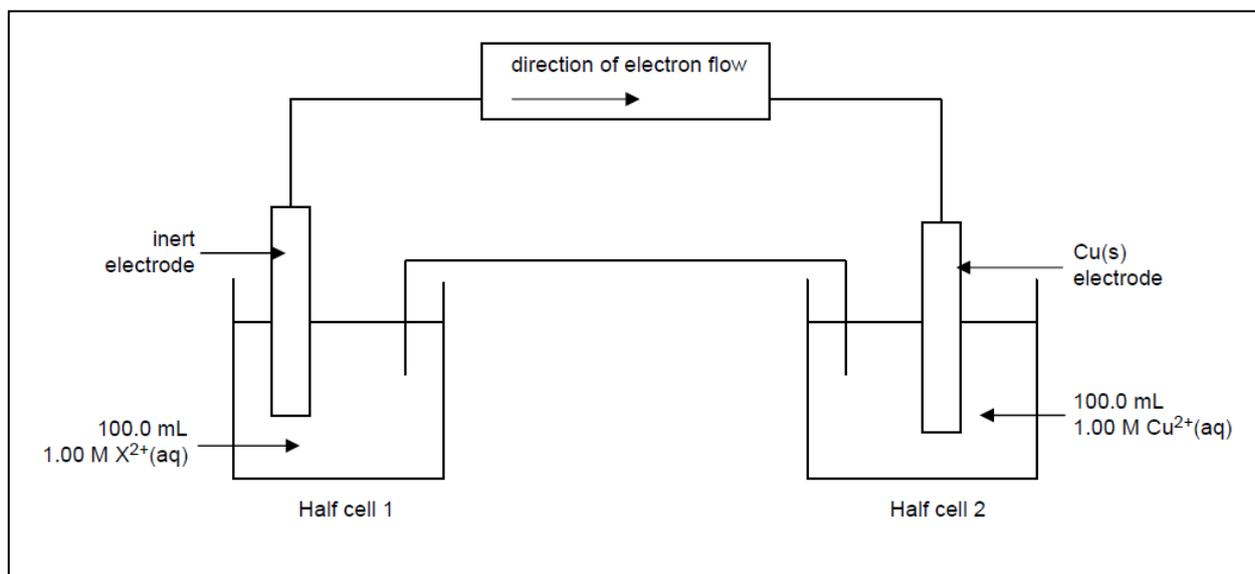
- i. Using this information identify the species in this galvanic cell which is the stronger reductant and explain how you reached this conclusion.

Since the pH increases in cell 1  $\text{H}^+$  ions are reduced to  $\text{H}_2$  gas. Cd is therefore the stronger reductant

ii. Explain what will happen to the mass of the anode and give a reason.

It will decrease as Cd is oxidised to  $\text{Cd}^{2+}$

- c) Consider the galvanic cell shown below. After discharging 3860 C of electricity, the concentration of the  $\text{X}^{2+}(\text{aq})$  in solution in half cell 1 was found to be 0.600 M. The volume of the solutions in the two half cells had not changed.



- i. Calculate the ratio of mol, of  $\text{X}^{2+}(\text{aq})$  that reacted in half cell 1 to the mol of electrons produced.

Step 1 calculate the mol of  $\text{X}^{2+}$

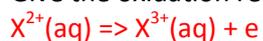
$$\Rightarrow (1.00 - 0.600) \times 0.100 = 0.0400$$

Step 2 calculate the mol of electrons

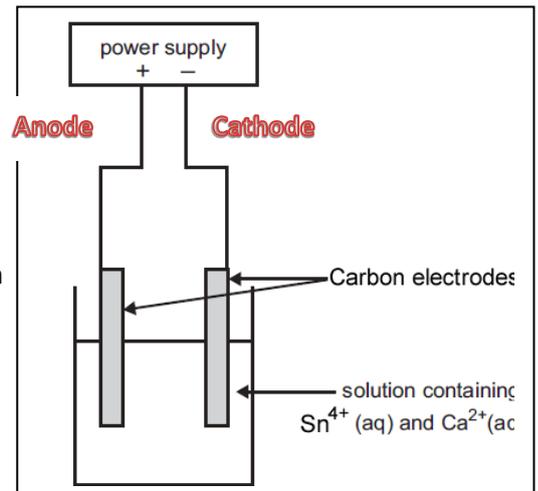
$$\Rightarrow 3860 / 96500 = 0.0400$$

Ratio is 1:1

- ii. Give the oxidation reaction occurring in half cell 1



- 7) A mineral ore contains a mixture of compounds of tin and calcium, in approximately equal proportions. A chemist extracts the metal ions by roasting the ore in air and treating the product with acid. The solution that contains the  $\text{Sn}^{4+}(\text{aq})$  and  $\text{Ca}^{2+}(\text{aq})$  is then neutralised and placed in an electrolytic cell as shown in the diagram on the right.



- a) Label the anode and cathode of the cell.  
 b) A reaction occurs at each electrode as the current begins to flow in the cell. Write equations for the half reaction that is likely to occur at the



- c) If the chemist had used copper electrodes instead of platinum electrodes, how would this have affected the half reaction at the anode? Explain

Since copper is a stronger reductant than water the following reaction would have occurred at the anode.

