SL Paper 3

Rhodium and palladium are often used together in catalytic converters. Rhodium is a good reduction catalyst whereas palladium is a good oxidation catalyst.

a. In a catalytic converter, carbon monoxide is converted to carbon dioxide. Outline the process for this conversion referring to the metal used. [3]

b.i. Nickel is also used as a catalyst. It is processed from an ore until nickel(II) chloride solution is obtained. Identify **one** metal, using sections 24 and 25 of the data booklet, which will not react with water and can be used to extract nickel from the solution. [1]

b.ii. Deduce the redox equation for the reaction of nickel(II) chloride solution with the metal identified in (b)(i). [1]

c. Another method of obtaining nickel is by electrolysis of a nickel(II) chloride solution. Calculate the mass of nickel, in g, obtained by passing a current of 2.50 A through the solution for exactly 1 hour. Charge (Q) = current (I) × time (t). [2]

Water purity is often assessed by reference to its oxygen content.

The Winkler method uses redox reactions to find the concentration of oxygen in water. of water was taken from a river and analysed using this method. The reactions taking place are summarized below.

a. Outline the meaning of the term *biochemical oxygen demand* (BOD). [2]

c.i. State what happened to the in step 1 in terms of electrons. [1]

c.ii. State the change in oxidation number for manganese in step 2. [1]

c.iii 0.0002 moles of were formed in step 3. Calculate the amount, in moles, of oxygen, , dissolved in water. [1]

Rechargeable nickel-cadmium batteries are used in portable electrical equipment and emergency lighting.

The **discharge** process can be summarized by the equation below.

a. State the change in oxidation number of the cadmium and deduce if it is acting as the positive or negative electrode during the discharge process. [2]

b. Identify a physical property of $Cd(OH)_2$ which allows this process to be reversed and the battery recharged. [1]

The biochemical oxygen demand (BOD) is a measure of water pollution.

State what is meant by the term *biochemical oxygen demand* (BOD).

Depressants can have different effects depending on their doses.

A breathalyser containing crystals of potassium dichromate(VI) can be used by the police to detect whether a driver has consumed alcohol.

b.i. State the chemical formula for potassium dichromate(VI). [1]

b.ii. Describe the colour change observed during its reaction with ethanol. [1]

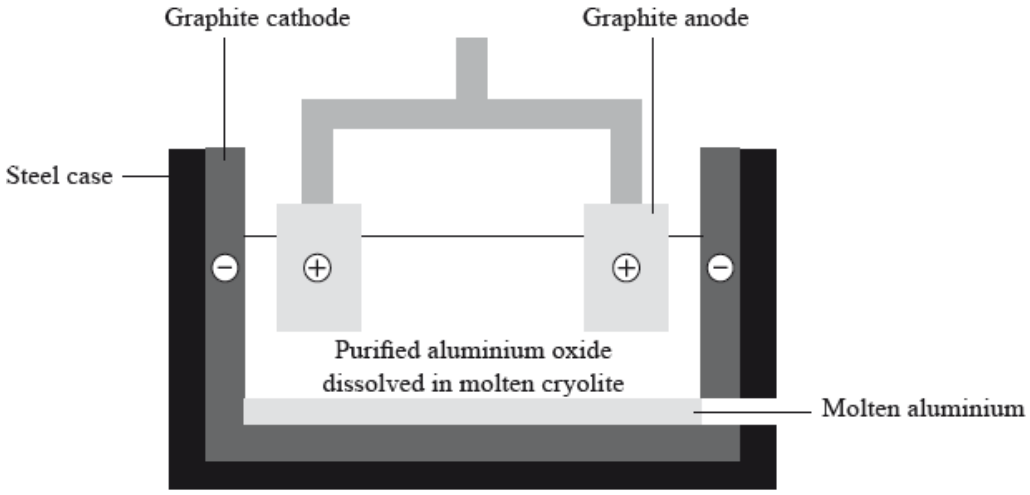
b.iii. State the oxidation number of chromium in the product. [1]

b.iv. Deduce the **full** balanced chemical equation for the redox reaction of ethanol with acidified potassium dichromate(VI). [2]

b.v. State the name of the organic product formed. [1]

c. An intoximeter is used to determine an accurate value for the concentration of ethanol in the breath. Explain **one** technique used for the detection of ethanol in an intoximeter. [3]

Aluminium is chemically reactive so it has to be extracted by the electrolysis of aluminium oxide dissolved in molten cryolite.



a. Deduce an equation for the discharge of the ions at each electrode. [2]

Positive electrode (anode):

Negative electrode (cathode):

b. (i) Outline why aluminium is alloyed with copper and magnesium when used to construct aircraft bodies. [2]

(ii) State **two** properties of aluminium that make it suitable for use in overhead power cables.

Ethanol is a depressant that is widely consumed in many societies. When consumed excessively it has a major impact on families and society as a whole. Other depressants such as diazepam (Valium®) may be prescribed by a doctor.

One problem associated with ethanol consumption is an increased risk of traffic accidents. Police in many countries use a breathalyser to test drivers. The breathalyser contains potassium dichromate(VI).

b.i. Describe the colour change of potassium dichromate(VI) when it reacts with ethanol. [1]

b.ii. State with a reason whether chromium in potassium dichromate(VI) is oxidised or reduced by ethanol. [1]

Dissolved oxygen is used up when organic matter is decomposed aerobically in water.

The Winkler method, which is based on redox reactions, can be used to determine the concentration of dissolved oxygen in water.

A sample of water was taken from a river and analysed using this method.

The redox reactions are shown below.

Step 1

Step 2

Step 3

(i) of was formed in step 3. Determine the amount, in mol, of oxygen, , dissolved in the water.

(ii) Determine the solubility, in , of the oxygen in the water.

In order to provide safe drinking water, a water supply is often treated with disinfectants, which aim to inactivate disease-causing bacteria in the water.

To compare the effectiveness of different disinfectants, a **CT value** is used as a measure of the dosage of disinfectant needed to achieve a certain level of inactivation of specific bacteria.

CT value (mg min dm^{-3}) = C (mg dm^{-3}) concentration of disinfectant × T (min) contact time with water

a. The table below compares the CT values of different disinfectants necessary to achieve 99% inactivation of two types of bacteria, listed as **A** and **B**. [4]

Disinfectant	CT value / mg min dm^{-3} for 99 % inactivation of bacteria	
	Bacterium A	Bacterium B
Hypochlorous acid, HOCl	4×10^{-2}	8×10^{-2}
Hypochlorite ion, OCl^-	9.2×10^{-1}	3.3
Chlorine dioxide, ClO_2	1.8×10^{-1}	1.3×10^{-1}
Monochloramine, NH_2Cl	64	94

(i) Deduce the oxidation state of chlorine in the following disinfectants.

HOCl:

. . . . . .

ClO_2:

. . . . . .

(ii) From the data on CT values, justify the statement that bacterium **B** is generally more resistant to disinfection than bacterium **A**.

(iii) CT values can be used to determine whether a particular treatment process is adequate. Calculate the CT value, in mg min dm^{-3}, when 1.50×10^{-5} g dm^{-3} of chlorine dioxide is added to a water supply with a contact time of 9.82 minutes.

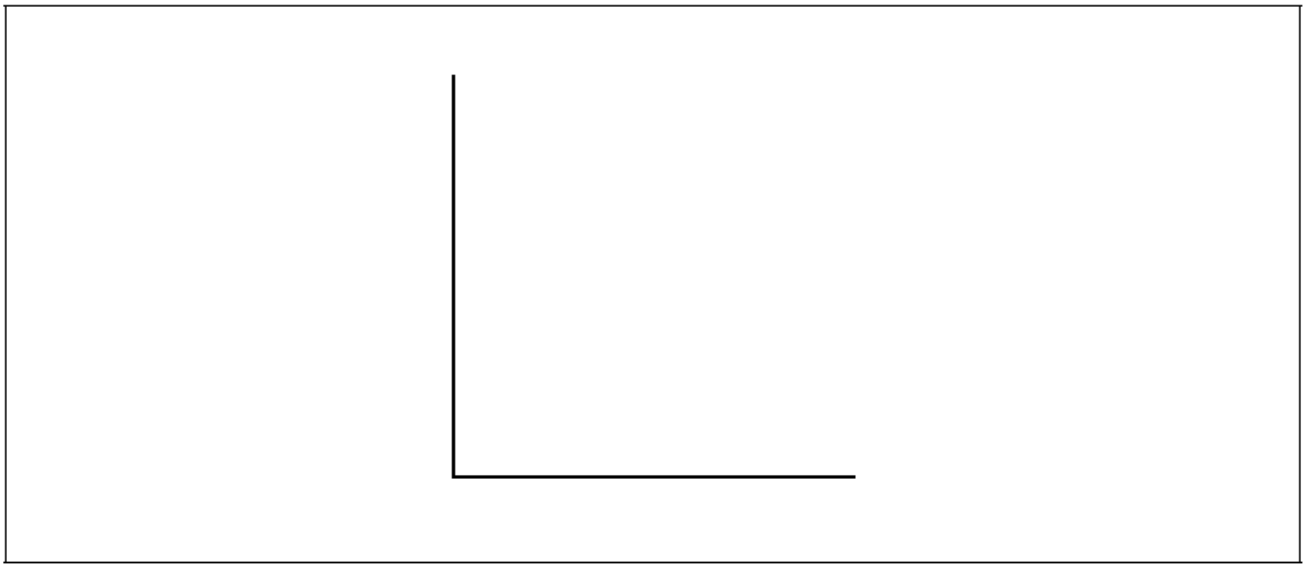
(iv) From your answer to (a) (iii) and the data in the table, comment on whether this treatment will be sufficient to inactivate 99% of bacterium **A**.

b. CT values are influenced by temperature and by pH. The table below shows the CT values for chlorine needed to achieve 99% inactivation of a specific bacterium at stated values of pH and temperature. [4]

pH	Temperature / °C				
	0.5	5.0	10.0	15.0	20.0
6.0	97	69	52	35	26
7.0	137	97	73	49	37
8.0	197	140	105	70	53
9.0	281	201	151	101	75

(i) With reference to the temperature data in the table, suggest why it may be more difficult to treat water effectively with chlorine in cold climates.

(ii) Sketch a graph on the axes below to show how the CT value (at any temperature) varies with pH.



(iii) Comment on the relative CT values at pH 6.0 and pH 9.0 at each temperature.

(iv) Chlorine reacts with water as follows:

$$Cl_2\,(g) + H_2O\,(l) \quad HOCl\,(aq) + HCl\,(aq)$$

$$HOCl\,(aq) \quad OCl^-\,(aq) + H^+\,(aq)$$

Predict how the concentrations of each of the species HOCl (aq) and OCl^- (aq) will change if the pH of the disinfected water increases.

HOCl (aq):

. . . . . .

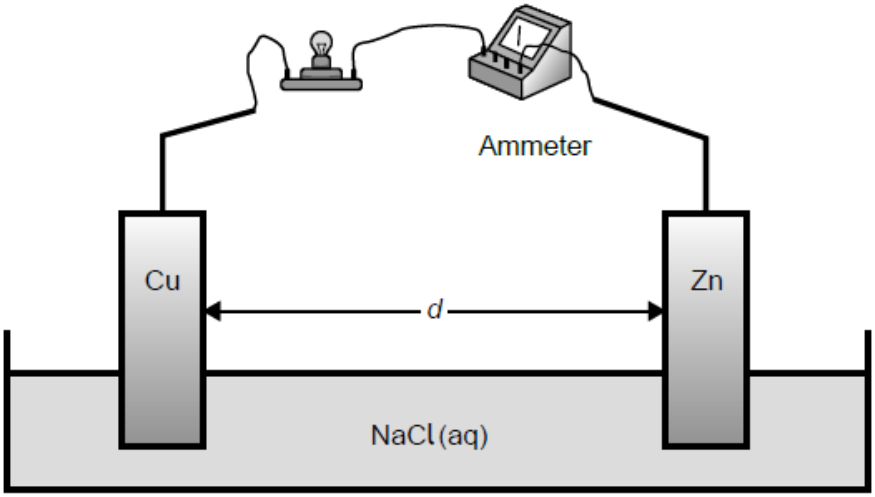
OCl^- (aq):

. . . . . .

c. Despite widespread improvements in the provision of safe drinking water, the sale of bottled water has increased dramatically in recent years. [1]

State one problem caused by this trend.

A student set up a simple voltaic cell consisting of a copper electrode and a zinc electrode dipped in sodium chloride solution.



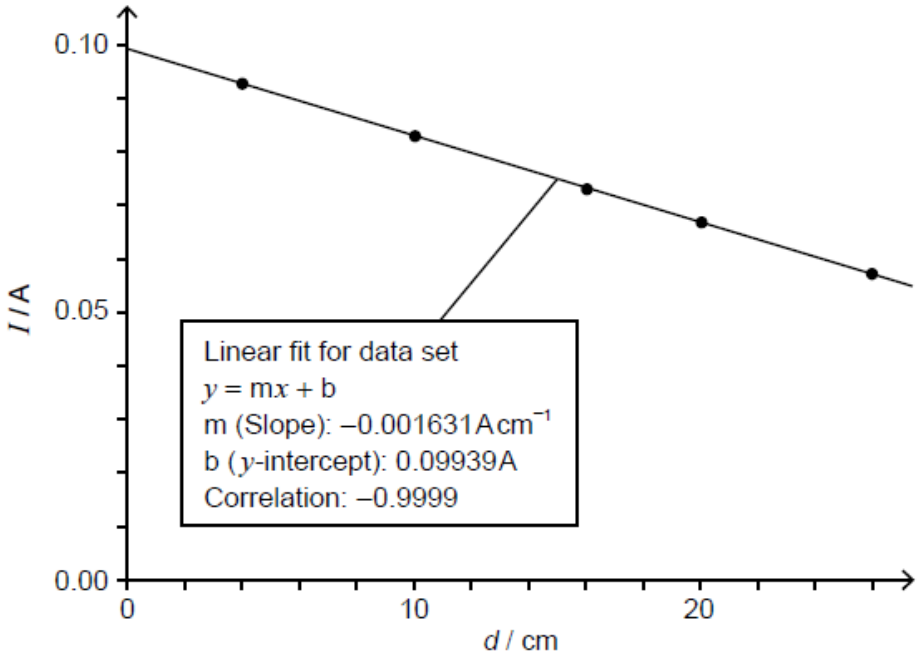
The student gradually increased the distance, *d*, between the electrodes to study the effect on the initial current, *I*, passing through the light bulb.

The student hypothesized that the initial current would be inversely proportional to the distance between the electrodes.

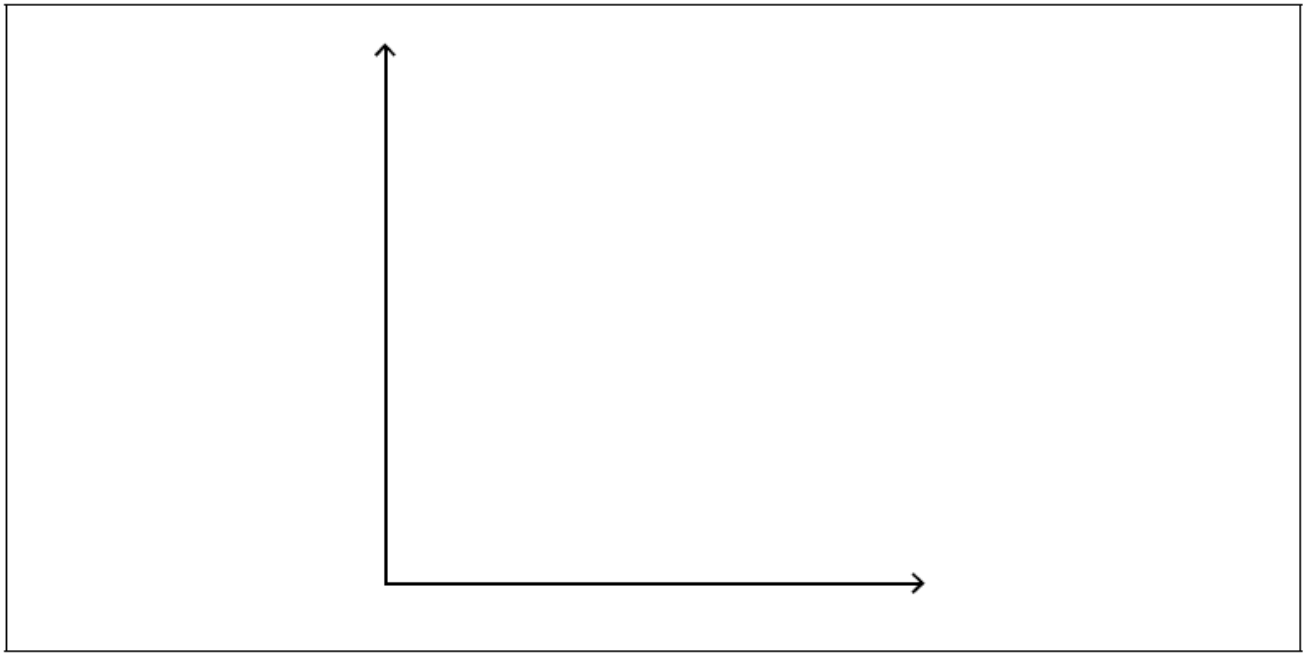
The following data was collected over five trials.

***d* / ±0.1 cm**	**Average *I* / ±0.04 A**
4.0	0.093
10.0	0.083
16.0	0.073
20.0	0.067
26.0	0.057

The data did not support the student's hypothesis. He investigated other possible relationships by plotting a graph of the average current against the distance between the electrodes. He obtained the following best-fit line with a correlation coefficient (r) of −0.9999.



a. Sketch a graph that would support the student's hypothesis. [1]



b.i. Suggest what the correlation coefficient of −0.9999 indicates. [1]

b.ii. State the equation of the straight line obtained using the data. [1]

b.iii. Outline how current flows in the sodium chloride solution. [1]