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**DUNMAN HIGH SCHOOL**  
**Preliminary Examination 2016**  
**Year 6**

**H2 CHEMISTRY**

Paper 2 Structured

**9647/02**

**16 September 2016**

**2 hours**

Additional Materials: Data Booklet

**INSTRUCTIONS TO CANDIDATES**

- 1 Write your **name**, **index number** and **class** on this cover page.
- 2 Answer **all** questions.
- 3 Write your answers in the spaces provided on the question paper.
- 4 A *Data Booklet* is provided.
- 5 The number of marks is given in brackets [ ] at the end of each question or part question.
- 6 You may use a calculator.

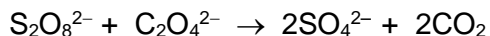
Question No.	1	2	3	4	5	Total	%
Marks	12	15	15	15	15	[72]	

This question paper consists of **16** printed pages and **2** blank pages.

Answer **all** questions in the spaces provided.

## 1 Planning (P)

The reaction between peroxodisulfate ions,  $\text{S}_2\text{O}_8^{2-}$ , and ethanedioate ions,  $\text{C}_2\text{O}_4^{2-}$ , is slow and can be catalysed by  $\text{Cu}^{2+}$  ions.



To determine the rate law of this reaction, it is necessary to selectively vary the concentrations of  $\text{S}_2\text{O}_8^{2-}$  and  $\text{C}_2\text{O}_4^{2-}$  ions and determine how the rate of reaction responds to these changes. The concentrations of the reactants are varied in such a way that one is in excess compared to the other in each experiment.

A suitable end point (the point at which the final time reading is made) for the experiments will be when the reaction produced the same volume of  $\text{CO}_2$  gas. With the measured reaction time, relative rate of the reaction can be determined.

You are required to write a plan to determine the rate law of the reaction between  $\text{S}_2\text{O}_8^{2-}$  and  $\text{C}_2\text{O}_4^{2-}$  ions.

- (a) Suggest an explanation why this reaction is slow when performed in the absence of a catalyst.

[1]

- (b) You may assume that you are provided with

- 1.00 mol dm<sup>-3</sup> peroxodisulfate ions
- 1.00 mol dm<sup>-3</sup> ethanedioate ions
- 10 cm<sup>3</sup> aqueous copper (II) ions
- the equipment and materials normally found in a school laboratory.

It can be assumed that a reactant is in excess if its volume is at least **five** times the volume of the other reactant used.

Your plan should include the following:

- quantities of reactants and condition you would use in **four** different reaction mixtures
- the measurements you would take
- an outline of how **one** of the reaction mixtures is prepared
- brief, but specific details of how the results would then be used to determine the rate law of reaction



[8]

- (c) Temperature can also affect the rate of reaction and the activation energy,  $E_a$ , of this reaction can be found by repeating the experiments at several different temperatures.

Using equation (1) and by means of a suitable graph, the activation energy of the reaction can be determined.

$$\ln (\text{relative rate}) = -\frac{E_a}{R} \left( \frac{1}{T} \right) + \ln (\text{constant}) \quad \text{--- (1)}$$

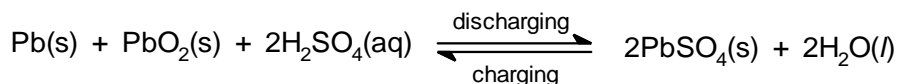
Briefly describe, with specific experimental details, of how the activation energy,  $E_a$ , of the reaction could be determined.

[3]

[Total: 12]

- 2 (a) A lead–acid car battery is a reversible cell that consists of a lead anode and a grid of lead coated with lead (IV) oxide as the cathode. The electrolyte is a 30% solution of sulfuric acid. When the cell supplies electric current to power the car, the process is known as discharging. The reversible process is thus known as charging.

The overall reaction that takes place in the lead–acid car battery is as follows:



- (i) Write the half–equations, with state symbols, for the reactions that take place at the anode and the cathode during the discharging process. Hence, state the polarity at the two electrodes.

	Half–equations	Polarity
Anode		
Cathode		

[3]

- (ii) When the lead and lead (IV) oxide have been converted to lead (II) sulfate, the cell can no longer give a current and the battery becomes flat. As the car moves, the generator then charges the battery. When the lead–acid battery is fully charged, the sulfuric acid has a relative density of about 1.275.

Predict and explain what happens to the relative density of the sulfuric acid during the discharging process.

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[2]

- (iii) Overcharging the lead–acid battery with high voltages causes hydrogen and one other gas to form. In addition, the electrolyte level is observed to have dropped.

Explain briefly what happens during overcharging and hence, suggest the identity of the other gas that is formed.

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[2]

- (iv) A simple rechargeable cell similar to that of lead–acid car battery may be constructed by dipping two lead electrodes into aqueous lead (II) nitrate and passing a current for a few minutes. During the charging process, lead (IV) oxide is deposited on one of the electrodes. By reference to the *Data Booklet*, calculate the value of  $E^\ominus$  when the cell discharges.

[2]

- (v) The voltage of a typical lead–acid battery is 2.0 V. Explain the difference in the voltage and the  $E^\ominus$  calculated in (a)(iv), based on the concentration of ions.

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[2]

- (b) (i)  $\text{Pb}^{2+}$  ions are often used in qualitative analysis to identify halide ions as they form insoluble precipitates. However, it is not an ideal test to distinguish between  $\text{Cl}^-$  and  $\text{Br}^-$  ions as both ions form white precipitate with  $\text{Pb}^{2+}$  ions.

Suggest another simple chemical test involving precipitation that could be used to distinguish between  $\text{Cl}^-$  and  $\text{Br}^-$  ions, stating clearly the steps and reagents involved and the expected observations.

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- (ii) With reference to your answer in (b)(i), explain the chemistry involved and writing equations where appropriate.

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[2]

[Total: 15]

- 3 Cobalt and vanadium are transition elements with more than one oxidation state and many of its compounds are coloured.

- (a) When a few drops of aqueous ammonia is added to a test-tube containing  $\text{Co}^{3+}(\text{aq})$ , a brown precipitate, **X** is observed. The chemical formula of **X** does not contain water molecules. The precipitate then dissolves in excess aqueous ammonia to give a cation **Y** which has a co-ordination number of 6.

- (i) Complete the electronic configuration of cobalt (III) ions.

$\text{Co}^{3+}$ :  $1s^2 2s^2 2p^6$  .....

[1]

- (ii) Suggest the identities of **X** and **Y**.

**X**: .....

**Y**: .....

[2]

- (iii) With the use of appropriate ionic equations, explain the formation of **X** and **Y**.

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[3]

- (b) When concentrated hydrochloric acid is added to  $\text{Co}^{2+}(\text{aq})$ , the colour changes from pink to blue. When water is added to the blue solution, it returns to the pink colour.

The chemistry of  $\text{Co}^{2+}(\text{aq})$  with concentrated hydrochloric acid closely resembles that of  $\text{Cu}^{2+}(\text{aq})$ .

Write a balanced ionic equation to account for the observations. In your answer, state the change in co-ordination number of cobalt ion in this reaction (if any).

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[2]

- (c) Vanadium is also another commercially important transition element.

- (i) Explain why  $\text{V}^{2+}$  is coloured.

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[2]



- (ii)  $\text{V}_2\text{O}_5$  is used as a catalyst to speed up the conversion of  $\text{SO}_2$  into  $\text{SO}_3$  in the contact process for making sulfuric acid.



For the reaction above, explain clearly how the catalyst works.

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[2]

- (iii) When a 2:1 ratio of sulfur dioxide and oxygen is passed over  $\text{V}_2\text{O}_5$ , the catalyst in a fixed volume steel vessel at  $430^\circ\text{C}$ , the percentage conversion of  $\text{SO}_2$  to  $\text{SO}_3$  is 95%.

Given that  $K_p$  is  $7200 \text{ atm}^{-1}$  at  $430^\circ\text{C}$ , calculate the initial total pressure, in atm, in the steel vessel.

[2]

- (iv) Comment on the effect on the rate of conversion if another unreactive but toxic gas was accidentally added to  $\text{V}_2\text{O}_5$ .

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[1]

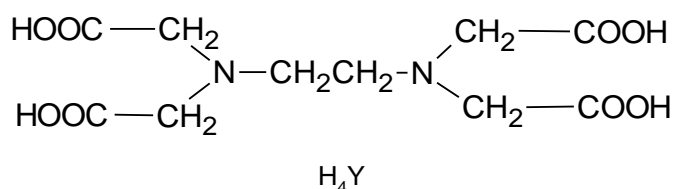
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- 4 One of the factors that establishes the quality of a water supply is its degree of hardness. Water hardness is usually reported as parts per million (ppm) of calcium carbonate in the water sample.

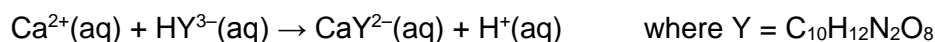
$$\text{ppm CaCO}_3 = \frac{\text{mass of CaCO}_3}{\text{mass of water}} \times 10^6$$

Water Supply Classification	
calcium carbonate (ppm)	Hardness Level
0–43	soft
43–150	slightly hard
150–300	moderately hard
300–450	hard
>450	very hard

Water hardness can be determined by titrating  $\text{Ca}^{2+}$  ions with ethylenediaminetetraacetic acid (represented by  $\text{H}_4\text{Y}$ ).



The titration is often carried out in a buffered basic medium, where  $\text{H}_4\text{Y}$  exists mainly as  $\text{HY}^{3-}$  (buffered solution).



- (a) A 50 g sample of hard water was titrated against the buffered solution of concentration  $0.0149 \text{ mol dm}^{-3}$ . The volume of the buffered solution required was  $25.55 \text{ cm}^3$ .

- (i) Calculate the mass of  $\text{CaCO}_3$  present in the water sample.

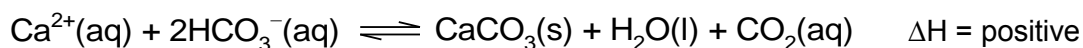
[1]

- (ii) Hence calculate the ppm of  $\text{CaCO}_3$  in the water sample and determine its hardness level.

[2]

There are two types of water hardness, temporary and permanent. The difference is due to the presence of different dissolved calcium compounds in the water.

Temporary hardness is caused by the presence of dissolved calcium hydrogencarbonate,  $\text{Ca}(\text{HCO}_3)_2$ . This type of hardness is called temporary hardness because the calcium ions can be removed from the water causing it to precipitate as  $\text{CaCO}_3$ .



- (b) Using the given equilibrium, suggest and explain one way how the removal of  $\text{Ca}^{2+}$  from the water sample can be enhanced.

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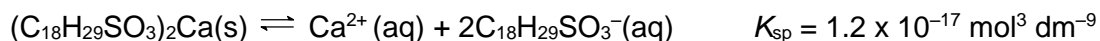
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[2]

A common detergent contains sodium dodecylbenzenesulfonate,  $\text{C}_{18}\text{H}_{29}\text{SO}_3\text{Na}$ . In hard water, it is ineffective as a detergent because it reacts with calcium ions to give a precipitate.



A typical sample of hard water has a concentration of calcium ions of  $2.5 \times 10^{-4} \text{ mol dm}^{-3}$ .

- (c) (i) Calculate the maximum concentration of  $\text{C}_{18}\text{H}_{29}\text{SO}_3^{-}$  in a solution of hard water.

[1]

The manufacturers claim that the detergent contains 17.4% by mass of  $\text{C}_{18}\text{H}_{29}\text{SO}_3\text{Na}$  [ $M_r = 348$ ]. In hard water, 1.0 g of the detergent should be used per  $\text{dm}^3$  of hard water.

- (ii) Calculate the number of moles of  $\text{C}_{18}\text{H}_{29}\text{SO}_3\text{Na}$  added to 1  $\text{dm}^3$  of hard water.

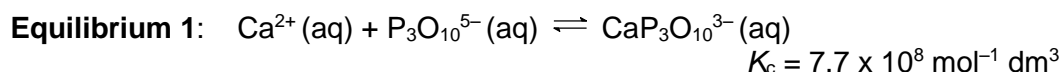
[1]

- (iii) Using your answer in (c)(i) and (c)(ii), show that 99% of  $\text{C}_{18}\text{H}_{29}\text{SO}_3\text{Na}$  in the detergent added will precipitate out of the hard water.

[2]

- (d) In order for the detergent to be used in hard water, sodium tripolyphosphate,  $\text{Na}_5\text{P}_3\text{O}_{10}$ , is added as a water softening agent.

The sodium tripolyphosphate 'softens' water by complexing with calcium ions.



- (i) Explain qualitatively why the addition of  $\text{Na}_5\text{P}_3\text{O}_{10}$  will allow the detergent to be used in the hard water.

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[2]

- (ii) What is the oxidation state of phosphorus in sodium tripolyphosphate?

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[1]

- (iii) Suggest a likely structure for the tripolyphosphate anion.

[1]

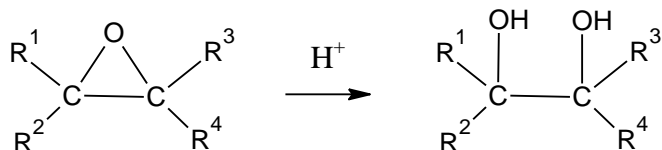
- (iv) Magnesium ions can also cause water hardness. It forms a complex with tripolyphosphate ions as well.

State the effect, if any, of adding magnesium ions on the equilibrium position and value of  $K_c$  of **Equilibrium 1** at constant temperature. Explain your answer.

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[2]

[Total: 15]

- 5 The male silk moth secretes 'juvenile hormone',  $C_{16}H_{26}O_4$ , which contains an unknown number of epoxide rings. Epoxide rings are readily hydrolysed by cold aqueous acid.



The reactions that 'juvenile hormone' and the resulting derivatives undergo are shown in the table below.

Reactant	Reagent	Result
'Juvenile hormone'	hydrogen in the presence of a palladium catalyst	<b>S</b> , $C_{16}H_{28}O_4$ , formed.
	cold dilute hydrochloric acid	<b>T</b> , $C_{16}H_{30}O_6$ , containing four alcoholic groups and three chiral centres is formed.
<b>T</b>	warmed with aqueous sodium hydroxide and then acidified	Methanol and <b>U</b> , $C_{15}H_{28}O_6$ are formed.
<b>U</b>	Mild oxidation	<b>V</b> , $C_{15}H_{24}O_6$ , which has two alcoholic groups, is formed.
<b>V</b>	hot concentrated acidified $KMnO_4$	Two moles of carbon dioxide and one mole of <b>W</b> , $C_{13}H_{22}O_5$ are formed.
<b>W</b>	2,4 – dinitrophenylhydrazine reagent	orange precipitate formed.
	alkaline aqueous iodine	yellow precipitate formed.

In addition, it is known that 'juvenile hormone' has a continuous 12-carbon long backbone. There are **three methyl substituents** on the skeletal backbone of 'juvenile hormone' and that **each** methyl substituent is five carbon atoms apart from the next methyl substituent.

- (a) Give the products that will be formed when methylethyl ether,  $CH_3OCH_2CH_3$  undergoes hydrolysis with aqueous acid.

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[1]

- (b) State and explain the number of epoxide ring(s) in 'juvenile hormone'.

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[2]

- (c) State the type of reaction that **T** has undergone and the functional group that it contains other than the four alcoholic groups.

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..... [1]

- (d) Classify the two alcoholic groups in **V** into either primary, secondary and tertiary alcohols. State the number of each alcohol and explain how you arrive at your conclusion.

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..... [2]

- (e) **V** produced an intermediate upon reacting with hot concentrated acidified  $\text{KMnO}_4$  which eventually produced carbon dioxide. Draw the displayed formula of this intermediate.

[1]

- (f) State the type of reaction between **W** and 2,4 – dinitrophenylhydrazine reagent. State the deduction about **W** from the result of **W** reacting with aqueous alkaline iodine.

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..... [2]

(g) Suggest the structures for compounds **S** to **W** and for 'juvenile hormone'.

Compound	Structure
'Juvenile hormone'	
<b>S</b>	
<b>T</b>	
<b>U</b>	
<b>V</b>	
<b>W</b>	

[6]

[Total: 15]



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