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ST ANDREW'S JUNIOR COLLEGE



JC2 PRELIMINARY EXAMINATION

Chemistry (9729)

11 September 2017

Paper 2 Structured Questions

2 hours

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS:

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.

The use of an approved scientific calculator is expected, where appropriate.

A Data Booklet is provided.

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:

Question	1	2	3	4	5	6	Total
Marks	17	5	10	16	6	21	75

This document consists of **19** printed pages (including this page).

Turn Over

Answer **all** the questions

- 1** Sulfur is a common element on Earth that forms many important chemical compounds.

One of these compounds is sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$, an ionic compound used to treat several medical conditions, such as cyanide poisoning and fungal growths.

- (a) (i)** Draw a dot-and-cross diagram for sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3$. State the shape and bond angle in the thiosulfate ion.

[2]

- (ii)** Below are the melting points of sodium thiosulfate and sulfur.

Compound	Melting point / °C
Sodium thiosulfate	49
Sulfur, S_8	115

Explain why sulfur has a higher melting point than sodium thiosulfate.

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.....[3]

- (b) Another important sulfur compound is sulfuric acid, H_2SO_4 . Before the Contact Process was discovered, concentrated sulfuric acid for industrial purposes was produced by the following method.

The mineral pyrite, FeS_2 , was first heated in air and oxidised to solid $\text{Fe}_2(\text{SO}_4)_3$ and sulfur dioxide gas.

$\text{Fe}_2(\text{SO}_4)_3$ decomposes at 480°C to form iron(III) oxide and sulfur trioxide gas. The sulfur trioxide gas could be mixed with any volume of water to produce sulfuric acid of the desired concentration. However, this process was expensive and not efficient.

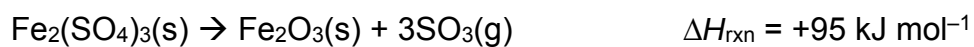
- (i) Write a balanced equation, with state symbols for the reaction between pyrite, FeS_2 , and oxygen to form $\text{Fe}_2(\text{SO}_4)_3$.

.....[1]

- (ii) With the aid of an equation, define the term standard enthalpy change of formation of gaseous sulfur trioxide, SO_3 .

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.....[2]

- (iii) Given the following information, determine the enthalpy change of formation of gaseous sulfur trioxide SO_3 .



Substance	$\Delta H_f / \text{kJ mol}^{-1}$
$\text{Fe}_2(\text{SO}_4)_3(\text{s})$	-2107
$\text{Fe}_2\text{O}_3(\text{s})$	-824

[3]

- (iv) Use the appropriate bond energies given in the *Data Booklet* and the data below to calculate another value for the standard enthalpy change of formation of gaseous sulfur trioxide SO_3 .

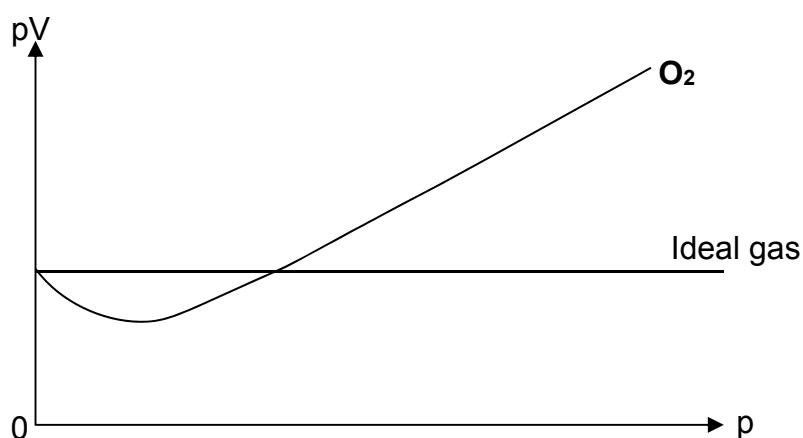


[3]

- (v) Suggest a reason for the discrepancy between the values in (b)(iii) and (b)(iv).

.....
[1]

- (c) The value of pV is plotted against p for 1 mol of oxygen O_2 , where p is the pressure and V is the volume of the gas at 300 K.



- (i) On the diagram above, draw and label the graph of pV against p for SO_3 at 300 K. [1]

- (ii) Explain the difference between the graph of SO_3 and the graph of O_2 .

.....
[1]

[Total: 17]

- 2 Transition elements show typical properties that distinguish them from s-block elements, such as calcium. These include variable oxidation states in their compounds, and the formation of coloured complex ions.

(a) An ion of manganese has 3 electrons in its 3d subshell. Suggest the oxidation state of this manganese ion.

.....[1]

(b) The following table gives data about some physical properties of the elements calcium, chromium, and manganese.

Property	Ca	Cr	Mn
Atomic radius (metallic) / nm	0.197	0.129	0.132
Ionic radius (2+) / nm	0.099	0.073	0.083
Melting point / K	1112	1907	1246
Density / g cm ⁻³	1.54	7.19	7.43
Electrical conductivity / x 10 ⁶ S cm ⁻¹	0.298	0.0774	0.00695

(i) Explain why the atomic radii of chromium and manganese are similar to each other.

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[2]

- (ii) Explain why the density of manganese is significantly greater than that of calcium, using relevant data from the table and the *Data Booklet*. (No calculations are required.)

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[2]

[Total: 5]

- 3 A student investigated the thermal decomposition of two carbonates, calcium carbonate and barium carbonate in the following way to determine its exact composition. He used the same amount, in moles, of each carbonate.



He heated the carbonates separately for 5 minutes. The solid obtained after heating was then shaken with distilled water to form an alkaline solution. A portion of the solid remained insoluble and was filtered. A sample of the alkaline filtrate was titrated with hydrochloric acid. No effervescence was observed during the titration.

- (a) (i) Suggest which carbonate is less likely to decompose completely. Explain your answer.

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[2]

Turn Over

- (ii) It was observed that the volume of acid used in the titration was smaller for the carbonate which did not decompose completely.

Explain how the incomplete decomposition can result in a lower volume of acid used in the titration.

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.....[2]

- (b) Explain the difference between the magnitude of the lattice energies of calcium carbonate and calcium oxide.

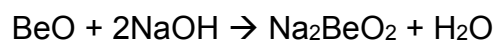
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.....[2]

- (c) Given that the decomposition of calcium carbonate is an endothermic reaction.

$$\Delta H = +178 \text{ kJ mol}^{-1} \text{ and } \Delta S = +159 \text{ J K}^{-1} \text{ mol}^{-1}$$

Calculate the minimum temperature at which this reaction becomes spontaneous.

- (d) Beryllium oxide can react with sodium hydroxide.



Explain this behaviour despite Be being a Group 2 element.

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.....[2]

[Total: 10]

- 4 Gaseous phosphorus(V) chloride dissociates according to the following equation.



Different amounts of the three gases were placed in a closed container and allowed to come to equilibrium at 200 °C. The experiment was repeated at 425 °C.

The equilibrium partial pressure of the three gases at each temperature are given in the table below.

	Partial pressure / $\times 10^{-3} \text{ N m}^{-2}$		
temperature/°C	PCl_5	PCl_3	Cl_2
200	1.46	11.8	2.77
425	7.61	0.211	0.368

- (a) (i) Write the expression for the equilibrium constant, K_p , for this reaction. Give the units.

Expression.....

Units.....[2]

- (ii) Calculate the value of K_p at each of the temperatures given.

[2]

- (iii) Is the forward reaction exothermic or endothermic? Explain your answer.

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.....[2]

- (b) What will be the effect on the equilibrium partial pressure of PCl_5 when the following changes are carried out on this new equilibrium? Explain your answers clearly.

- (i) The pressure of the system is halved at constant temperature.

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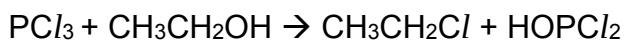
[2]

- (ii) Helium gas is added at constant volume and temperature.

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[2]

Chloroethane can be made by reacting PCl_3 with ethanol, via nucleophilic substitution mechanism.



- (c) Outline a simple chemical test that can be carried out to see if chloroethane is produced in the mixture after reacting with PCl_3 .

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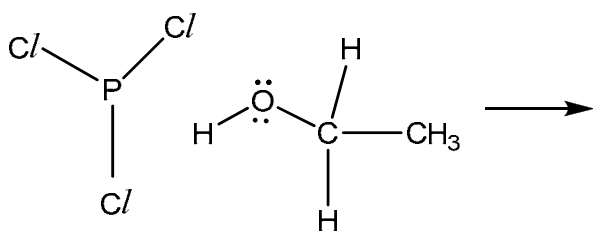
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(d) The mechanism is thought to involve these steps.

- The first step is where P-Cl bond breaks. P is electron deficient and reacts with alcoholic O to form a protonated oxygen intermediate.
- The C-O bond is broken. Cl^- act as a nucleophile.

Complete the diagram to suggest a mechanism to show how chloroethane is formed. Show all charges and relevant lone pairs and show the movement of electron pairs by using curly arrows.



[3]

(e) Explain why chlorobenzene cannot be made in the same way using phenol and PCl_3 .

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.....[1]

[Total: 16]

5 Bromine reacts with organic compounds in different ways.

- (a)** When butane reacts with gaseous bromine in the presence of ultraviolet light, the major product was 2-bromobutane instead of 1-bromobutane. Using the stability of the intermediates, explain the observation.

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.....[3]

- (b)** A solution of 2-bromobut-2-ene, upon heating with ethanolic silver nitrate solution, does not form a cream precipitate.

Upon addition of concentrated sulfuric acid in the cold and followed by heating with ethanolic silver nitrate, 2-bromobut-2-ene formed a cream precipitate.

Explain the above observations.

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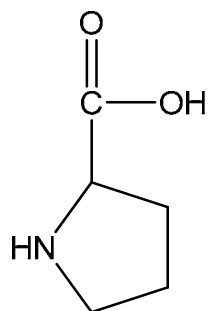
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[Total: 6]

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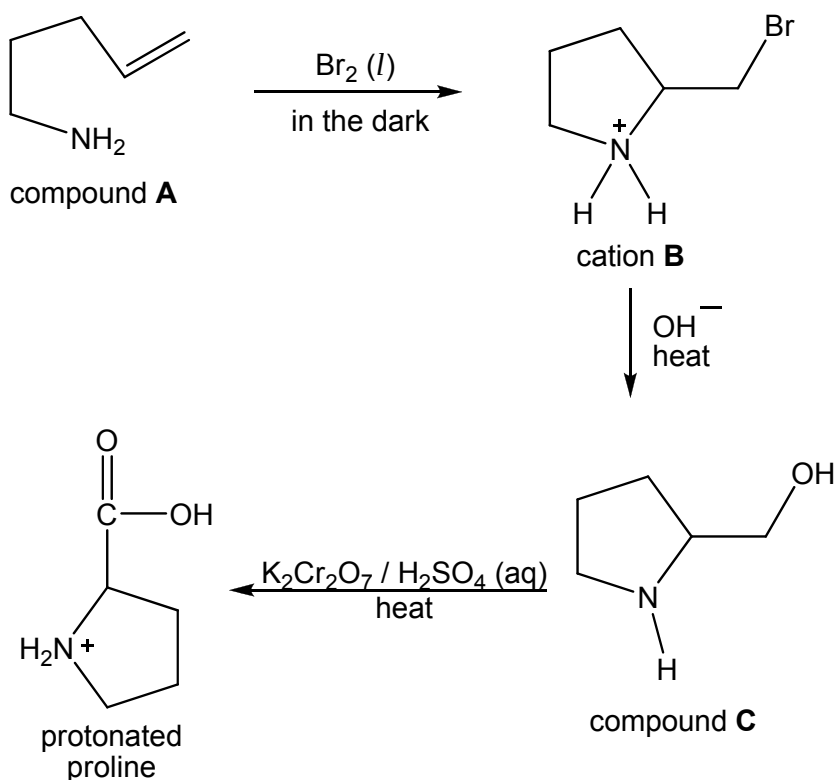
- 6 Proteins, found within the human body, are formed by amino acids. These amino acids are classified as either essential (cannot be synthesised by the human body) or non-essential (can be synthesised by the human body) amino acids.

(a)



Proline

Proline, one of the non-essential amino acids, is associated with the production of collagen which promotes healthy skin and heart muscle. Protonated proline can potentially be synthesised in the following manner.



The reaction of compound **A** with liquid bromine occurs via a two-step mechanism.

- compound **A** reacts with bromine to form a carbocation intermediate in the first step.
- the ammonium ion is formed in the second step.

- (i) Name and suggest the mechanism for this reaction. Show any relevant lone pairs, dipoles and charges, and indicate the movement of electron pairs with curly arrows.

[3]

- (ii) This synthesis also produces another organic compound (molecular formula $C_5H_{10}NO_3Br$). Suggest the skeletal formula of the cation.

[1]

- (iii) Compound **C** was extracted and reacted with 1 mole of ethanoyl chloride to form a neutral compound **D** with molecular formula $C_7H_{13}NO_2$. Draw the structure of compound **D**. Explain why this product is formed.

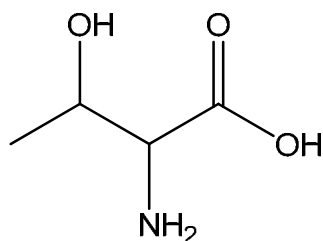
Structure

Explanation.....

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.....[2]

(b)



Threonine

Threonine, one of the essential amino acids, maintains protein balance within the human body and supports the cardiovascular, liver, central nervous and immune system functions.

In the laboratory, threonine could be synthesised from but-2-enoic acid.

- (i) State the type of isomerism exhibited by but-2-enoic acid.

.....[1]

- (ii) Suggest a 2-step synthesis for the formation of threonine from but-2-enoic acid, showing the intermediate clearly in your answer.

[3]

- (iii) By considering the stereoisomers of threonine, suggest why only 25% of the synthesised threonine could be used in the human body.

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.....[2]

- (c) (i) Suggest whether threonine or proline has the more basic amine group. Explain your answer.

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.....[2]

- (ii) Explain, in terms of their structures, the higher solubility of threonine in water as compared to benzoic acid in water.

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[2]

- (d) According to dieticians, a teenager requires approximately 1.00 g of calcium each day. This particular mineral is found predominantly in milk, cheeses and yogurts, which most individuals consume in the morning.

- (i) Procedure to extract calcium ions is stated as follows :

1. A cup of milk (300 ml) was first filtered to remove impurities before excess amounts of sodium carbonate was added to form CaCO_3 .
2. The mixture was then refiltered and the white residue (assumed to be solely calcium carbonate) was washed once again with deionised water and filtered again.
3. The white residue was then dissolved in 0.500 dm^3 of $0.160 \text{ mol dm}^{-3}$ hydrochloric acid. 25.0 cm^3 of this resulting solution was then titrated against $0.125 \text{ mol dm}^{-3}$ sodium hydroxide. The titre volume was found to be 26.45 cm^3 .

What is the recommended number of cups of milk each day a teenager should consume to meet the daily requirements?

(ii)	Compound	Amount per serving
	Vitamin A	5000 IU
	Vitamin C	300 mg
	Vitamin D	600 IU
	Vitamin E	30 IU
	Vitamin K	80 mcg
	Thiamin (Vitamin B-1)	50 mcg
	Riboflavin (Vitamin B-2)	50 mg
	Vitamin B-12 (as Cyanocobalamin)	50 mcg
	Calcium (as in calcium carbonate)	200 mg
	Magnesium (as magnesium oxide)	50 mg
	Zinc (as zinc oxide)	25 mg
	Selenium (as L-Selenomethionate)	200 mcg
	Molybdenum (as sodium molybdate)	75 mcg

A typical multivitamin dietary supplement tablet would have the above composition. Given that the teenager does not consume any form of dairy products, how many tablets would a teenager need to take to achieve the daily requirement of calcium?

[1]

- (iii) A student wants to test the validity of the composition of calcium in this tablet and decided to follow the steps mentioned in (d)(i).

State 1 possible problem that the student would face.

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.....[1]

[Total: 21]

~END OF PAPER~

Turn Over