ANDERSON SERANGOON JUNIOR COLLEGE

2024 JC 2 PRELIMINARY EXAMINATION

NAME:____________________________ (   ) **CLASS:** 24 / ___

CHEMISTRY **8873/02**

Higher 1 **11 September 2024**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and register number in the spaces provided at the top of this page.
Write in dark blue or black pen.
You may use a pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.
The number of marks is given in brackets [ ] at the end of each question or part question.

Section A	**1**	**/ 10**	**Section B**	**7/8**	**/ 20**
	2	**/ 11**	**Paper 1**		**/ 30**
	3	**/ 14**	**Paper 2**		**/ 80**
	4	**/7**	**Percentage Overall**		
	5	**/ 7**			
	6	**/11**	**Grade**		

This document consists of 22 printed pages and 2 blank pages.

Section A

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

1 **(a)** Phosphorus, sulfur and chlorine are Period 3 elements of the Periodic Table.

Table 1.1 shows some properties of the elements P to C*l*.

Table 1.1

	P	**S**	**C*l***
number of electrons in 3p subshell			
number of unpaired electrons			

Complete Table 1.1 to show the number of electrons in the 3p subshell and the number of unpaired electrons in an atom of P, S and C*l*.

[2]

(b) Fig. 1.1 shows successive ionisation energies of sulfur, S.

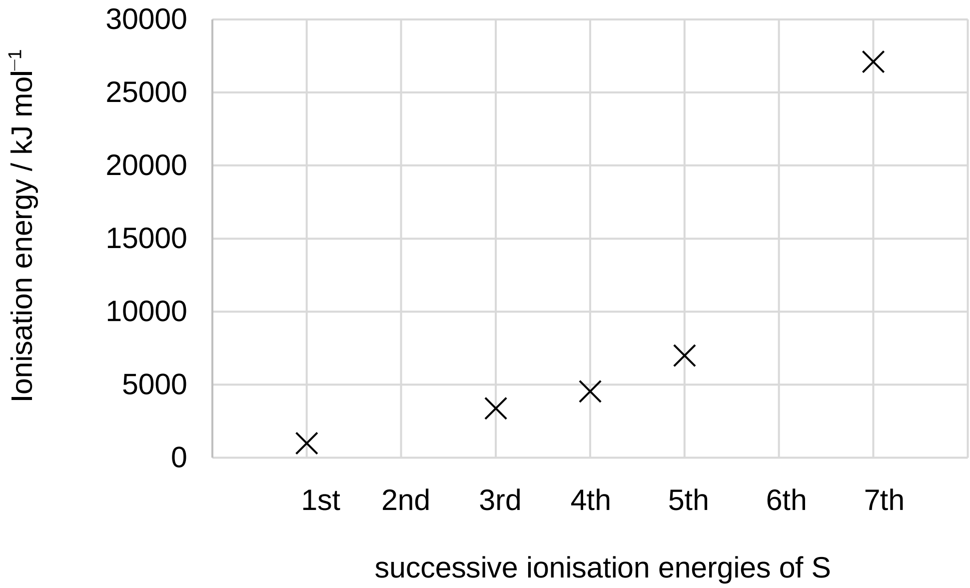

Fig. 1.1

(i) Explain the general increase in successive ionisation energies for any atom.

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(ii) Complete Fig. 1.1 by plotting approximate values for the 2nd successive ionisation energy and the 6th successive ionisation energy of S. [2]

(c) Describe the variation in the electrical conductivity of the elements in the third period, sodium to chlorine. Explain this variation in terms of the structures and bonding of the elements.

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[Total: 10]

2 **(a)** When ionic compounds are dissolved in water, the ions form electrostatic attractions with water molecules. These attractions are known as ion–dipole interactions. Enthalpy change of hydration, $\Delta H_{hyd}^{\ominus}$ is a measure of the strength of the ion–dipole attraction.

The ionic radius of the Group 1 ions affects the strength of the attraction between the Group 1 ions and water molecules. The larger the ionic radius, the weaker the electrostatic forces of attraction between the ion and water molecules.

Enthalpy change of hydration, $\Delta H_{hyd}^{\ominus}$ is defined as the amount of heat evolved when one mole of free gaseous ions is dissolved in a large amount of water forming a solution at infinite dilution.

$$Na^{+}(g) \longrightarrow Na^{+}(aq)$$

(i) Describe and explain how ionic radius varies down Group 1 ions.

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....[2]

(ii) Hence, state the trend in the magnitude of enthalpy change of hydration, $\Delta H_{hyd}^{\ominus}$, down the Group 1 ions.

....[1]

(iii) Suggest an equation to represent the enthalpy change of hydration, $\Delta H_{hyd}^{\ominus}$ of sulfide ion, S^{2-}.

....[1]

(iv) Sodium nitrate, $NaNO_3$ is soluble in water.

Draw the 'dot-and-cross' diagram of the nitrate ion. The ion contains nitrogen as the central atom and all atoms have 8 electrons in its outer shell.

State the shape and bond angle of the nitrate ion.

Shape: ....

Bond angle: ....

[3]

(b) Table 2.1 shows the boiling point of three fluorine containing compounds.

Table 2.1

formula	boiling point / °C
NaF	1695
HF	19.5
CH_3CH_2F	–37.1

Explain the difference in the boiling points in terms of the structure and type of bonding in the three compounds.

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[Total: 11]

3 **(a)** Ammonia is manufactured using the Haber process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Table 3.1 shows the number of moles of ammonia at equilibrium at various temperatures at 200 atm. In each case, 1.5 mol of N_2 and 3.0 mol of H_2 are mixed in a vessel initially.

Table 3.1

Temperature / °C	Amount of ammonia at equilibrium / mol
300	1.63
400	1.05
500	0.71

(i) Write the K_c expression for the equilibrium, stating its units.

[2]

(ii) Calculate the value of K_c at 200 atm and 300 °C, given that the volume of the vessel is 3 dm^3.

[2]

(iii) State the *Le Chatelier's Principle*.

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(iv) Using the information in Table 3.1, deduce and explain whether the forward reaction is an endothermic or exothermic reaction.

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(v) Name the catalyst used and explain its role in the production of ammonia.

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(b) An unknown alkaline solution with a concentration of 0.010 mol dm^{-3} is thought to be one of the following solutions.

- NaOH
- NH_3 (K_b = 1.78 x 10^{-5} mol dm^{-3})
- CH_3NH_2 (K_b = 1.05 x 10^{-4} mol dm^{-3})

(i) Explain what is meant by a *BrØnsted-Lowry base*.

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(ii) Identify the *weakest* BrØnsted-Lowry base from the list above. Hence, write an equation for its dissociation in water.

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…………………………………………………………………………………………..[2]

(iii) The unknown solution has a pH of 12.0.

With suitable calculations, prove that the unknown solution is NaOH.

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[Total:14]

4 Potassium sulfite, K_2SO_3, is used as a food preservative.

The concentration of sulfite ions, SO_3^{2-} is determined by titration using aqueous acidified potassium manganate(VII).

3.40 g of impure K_2SO_3 is dissolved to make a 250 cm^3 solution in a volumetric flask. 25.0 cm^3 of this solution requires 22.40 cm^3 of 0.0250 mol dm^{-3} acidified potassium manganate(VII) to reach the end-point.

Reaction 1 $$2MnO_4^- + 6H^+ + 5SO_3^{2-} \longrightarrow 2Mn^{2+} + 3H_2O + 5SO_4^{2-}$$

(a) **(i)** Describe the roles of MnO_4^- and SO_3^{2-} in Reaction 1. Explain your answer in terms of electron transfer.

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(ii) Calculate the percentage purity of the sample of K_2SO_3. Show your working.

[3]

(b) Potassium manganate(VII) is photosensitive and can be decomposed by sunlight. The solution of acidified potassium manganate(VII) used in the titration was freshly prepared to minimise decomposition.

Comment on the volume of potassium manganate(VII) required in the titration and explain its impact on the calculated value for **(a)(ii)** if the solution of potassium manganate(VII) used is not freshly prepared.

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……………………………………………………………………………………………………...[2]

[Total: 7]

5 **(a)** Use of *Data Booklet* is relevant in this question.

Using a time of flight (TOF) mass spectrometer, a sample of antimony is found to contain two isotopes – ^{121}Sb and ^{123}Sb. The spectrometer detected the presence of the two isotopes based on the different time taken by the charged isotopes, $^{121}Sb^{+}$ and $^{123}Sb^{+}$ to travel through the machine.

(i) State the number of protons, neutrons and electrons in a $^{121}Sb^{+}$ ion.

sub–atomic particle	**no.**
protons	
neutrons	
electrons	

[1]

(ii) The mass of an ion is the sum of the masses of the particles it contains.

Calculate the mass, in kg, of one $^{121}Sb^{+}$ ion. Quote relevant values from the *Data Booklet* and give your answer to three significant figures.

[1]

(iii) The relative abundance of the isotopes is analysed by accelerating both $^{121}Sb^{+}$ and $^{123}Sb^{+}$ ions to the same kinetic energy of 3.149×10^{-19} J through a 1.05 m long tube in the spectrometer.

The kinetic energy of an ion is given by the equation, $KE = \frac{1}{2}mv^2$

KE = kinetic energy / J
m = mass / kg
v = speed / m s^{-1}

Speed is the distance travelled by an ion per unit time.

Using your answer in **(a)(ii)** and the information given above, calculate the time taken by $^{121}Sb^{+}$ to travel through the tube.

[1]

(iv) A sample of antimony has a relative atomic mass, A_r, of 121.86. Calculate the percentage abundance of ^{121}Sb in this sample of antimony.

[1]

(b) **(i)** Define the term *nanoparticle*.

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(ii) Explain how using platinum nanoparticles increases the efficiency of the catalytic converter.

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(iii) Write one balanced chemical equation to show how carbon monoxide is removed in the catalytic converter.

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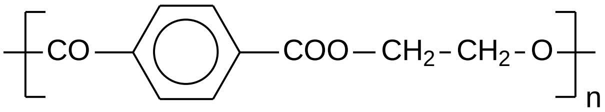
[Total: 7]

6 **(a)** The polymer poly(ethylene terephthalate), PET is also known as Terylene. It is often used to make clear beverage bottles and shirts.



PET

PET is semi-rigid at room temperature but softens when heated to around 70 °C and can be reshaped. One advantage of PET is that it can be recycled.

(i) Draw the **displayed** formula of the two monomers used to make PET.

[2]

(ii) Suggest why Terylene is used to make shirts.

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……………………………………………………………………………………………………[1]

(iii) Bottles that are made of PET cannot be used to store alkaline cleaning solution. Bottles that are made of poly(propene) are used instead.

Explain, in terms of the bonds present in both polymers, why the above statements are true.

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(iv) Predict whether PET is a thermosetting or thermoplastic polymer. Explain your answer using the information from the question **and** your knowledge of the structure and bonding in polymers.

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……………………………………………………………………………………………………[2]

(b) High density polyethene (HDPE) is a polymer commonly used with PET for liquid or beverage packaging. For example, the bottle cap of a drink bottle is usually made of HDPE while the drink bottle is made of PET.

HDPE is made by polymerising ethene, $CH_2 = CH_2$, monomers.

(i) Draw **one** repeat unit of HDPE.

[1]

(ii) HDPE is rigid and strong whereas low density polyethene (LDPE) is flexible.

Explain, with the aid of suitable diagrams, how the structure and bonding in HDPE and LDPE result in their different physical properties.

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[Total: 11]

Section B

Answer **one** question in this section in the spaces provided.

7 **(a)** The Ostwald Process is a chemical process used for making nitric acid from ammonia.

During the process, ammonia gas is oxidised by oxygen in the presence of solid alloy platinum-rhodium catalyst.

(i) State and explain the type of catalysis used in the Ostwald process.

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…………………………………………………………………………………………[1]

(ii) Define the term *activation energy*.

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(iii) Draw a Boltzmann distribution curve for the molecular energies of a sample of a gaseous reaction mixture of ammonia and oxygen.

On your diagram, draw a line to represent the activation energy. Label this line $\boldsymbol{E_a}$.

[2]

(iv) On the Boltzmann distribution curve in **(a)(iii),** show the change that would happen when platinum-rhodium catalyst is added to the reaction mixture. The temperature and pressure of the reaction mixture are kept constant.

Label the change **J**.

[1]

(b) There are several stages to the Ostwald Process, but the following equation is a summary of the overall process.

$$NH_3(g) + 2O_2(g) \longrightarrow HNO_3(l) + H_2O(l)$$

(i) It was found that the *order of reaction with respect to oxygen is zero*.

Explain the words in italics.

……………………………………………………………………………………………[1]

(ii) The reaction to produce nitric acid is an overall first order reaction with a half-life of 15 minutes. Using this and the information in **(b)(i)**, sketch a well-labelled graph of $[NH_3]$ against time.

[2]

(iii) Write an expression for the rate equation.

……………………………………………………………………………………………[1]

(iv) Calculate the rate constant, giving its units.

[1]

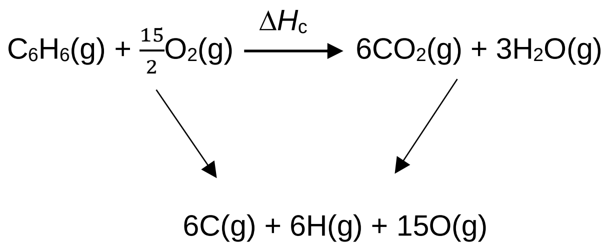
(c) The equation for the complete combustion of liquid benzene is shown.

$C_6H_6(l) + \frac{15}{2}O_2(g) \longrightarrow 6CO_2(g) + 3H_2O(g)$ ΔH_c = -3267 kJ mol^{-1}

(i) On the axes below, draw a labelled energy profile diagram for the combustion of benzene. Label the activation energy, E_a, and the enthalpy change of combustion, ΔH_c.

[2]

(ii) Calculate a value for enthalpy change of combustion of gaseous benzene using bond energy values from the *Data Booklet* and the energy cycle shown below.



[3]

(iii) The accepted value for the standard enthalpy change of combustion of benzene, $\Delta H_c^{\ominus}$ is different from the value of ΔH_c calculated in **(c)(ii)**.

One reason is that the bond energy values are only average values.

Suggest another reason why the accepted value for the enthalpy change of combustion of benzene obtained under standard conditions is different from the value of ΔH_c calculated in **(c)(ii)**.

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(d) **(i)** Hydrofluoric acid, HF, is a weak acid.

A buffer solution **A** can be made from sodium fluoride, NaF and hydrofluoric acid, HF.

Write two equations to show how solution **A** behaves as a buffer when small amounts of OH^- (aq) and H_3O^+ (aq) are separately added to portions of **A**.

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(ii) The buffer solution **A** can be used to maintain an almost constant pH of 7.4. The equilibrium that applies to this buffer solution is shown.

$$HF\,(aq) \rightleftharpoons F^-\,(aq) + H^+\,(aq) \qquad K_a = 5.62 \times 10^{-4}\ \text{mol dm}^{-3}$$

Write the K_a expression and use it to calculate the $\frac{[HF]}{[F^-]}$ ratio that gives a pH of 7.4.

[2]

[Total: 20]

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8 **(a)** Magnesium oxide reacts with hydrochloric acid in an exothermic reaction.

$$MgO(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2O(l) \qquad \Delta H_{\text{reaction 1}}$$

In an experiment to determine the maximum change in temperature of the above reaction, solid magnesium oxide is added to 50.0 cm^3 of hydrochloric acid in a polystyrene cup. HC*l* is in excess.

The initial temperature of the hydrochloric acid before magnesium oxide is added is measured and recorded at a regular interval for 3 minutes.

At **exactly the fourth minute**, 0.500 g of solid magnesium oxide is added into the polystyrene cup and the mixture is quickly covered with a lid and stirred.

The temperature of the mixture was measured and recorded at the 5th min, and at regular time intervals until 10 min.

The results are as shown in Fig. 8.1.

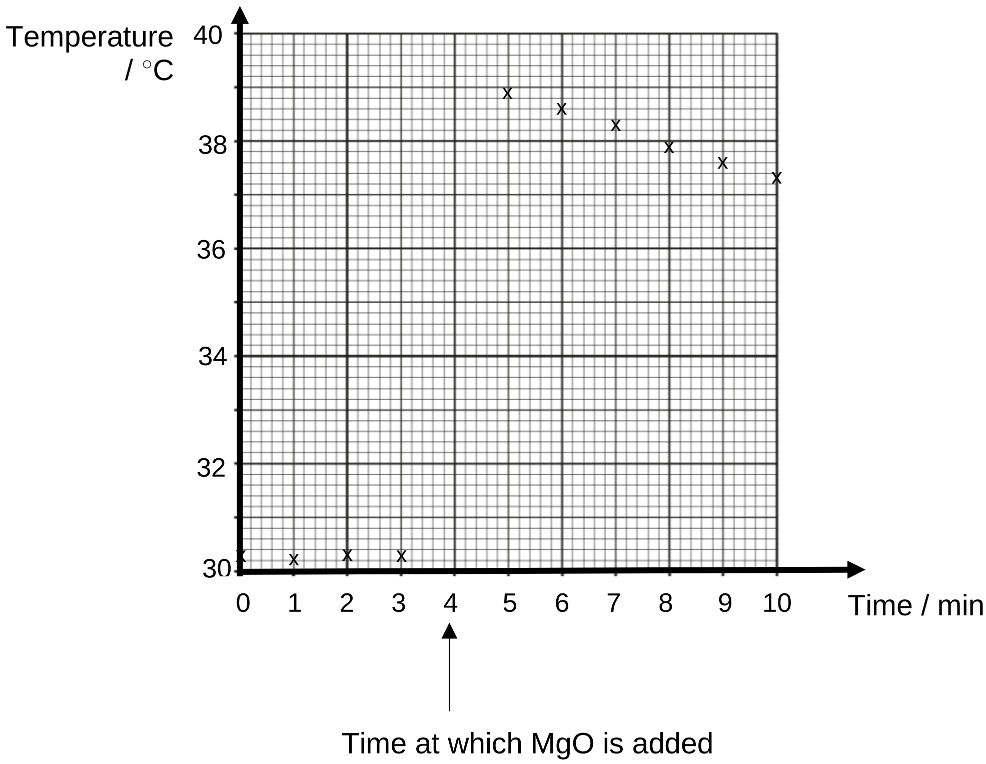

Fig. 8.1

(i) Draw two separate straight lines of best fit.

The first line should take into account the temperatures for the points before 4.0 min. Extend this line to the 4.0 min mark.

The second line should take into account the decreasing temperatures for the points after 4.0 min. Extend this line to the 4.0 min mark.

Use your graph to determine the minimum temperature, maximum temperature and temperature rise, ΔT, of the experiment at the fourth minute.

Temperature at the fourth minute:

minimum = ……..…°C

maximum = ……..…°C

temperature rise, ΔT = …..…… °C

[3]

(ii) Using your results from **(a)(i)**, calculate the energy, in J, evolved during the reaction.

You should assume that the specific heat capacity of the reaction mixture is 4.18 J g^{-1} K^{-1} and its density is 1.00 g cm^{-3}.

[1]

(iii) Calculate the number of moles of magnesium oxide used in the experiment and hence calculate the enthalpy change for the reaction, $\Delta H_{\text{reaction 1}}$.

[2]

(b) Magnesium bromide, $MgBr_2$, is often used as a mild sedative and as an anticonvulsant for treatment of nervous disorders.

(i) Write an equation to represent the lattice energy of magnesium bromide.

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(ii) How would you expect the lattice energy of barium bromide to compare with that of magnesium bromide? Explain your answer, using relevant data from the *Data Booklet*.

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…………………………………………………………………………………………[3]

(c) The Contact Process is used in the manufacture of sulfuric acid. There are several stages to the reaction. At the heart of the process is the reversible reaction of converting sulfur dioxide to sulfur trioxide shown below.

$$SO_2(g) + \frac{1}{2} O_2(g) \rightleftharpoons SO_3(g)$$

(i) Draw a Boltzmann distribution curve for the molecular energies of the gaseous reaction mixture.

Label the curve **A** and label the activation energy $\boldsymbol{E_a}$.

[2]

(ii) On the axes that you have drawn, draw a second Boltzmann distribution curve for the molecular energies of the same gaseous reaction mixture at a higher temperature. Label this curve **B**.

Use curves **A** and **B** to describe and explain the effect of an increase in temperature on the rate of reaction.

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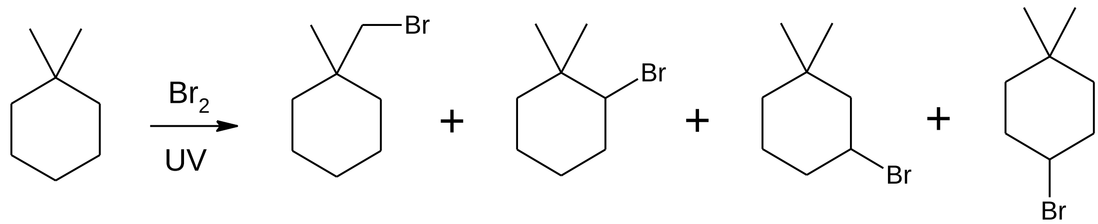
(d) Hydrocarbon **T** reacts with limited bromine in the presence of ultraviolet light to form a mixture of four mono-brominated products, **W** to **Z**.



T **W** **X** **Y** **Z**

(i) Give the IUPAC name for hydrocarbon **T**.

………………………………………………………………………………………….[1]

(ii) Assuming all the hydrogen atoms present in **T** are equally reactive, what is the expected ratio of **W** : **X** : **Y** : **Z** formed?

………………………………………………………………………………………….[1]

(iii) Compound **Z** forms different products when heated separately with aqueous NaOH and NaOH in ethanol.

In Table 8.1 below, draw the products formed and state the type of reaction.

Table 8.1

Regents and conditions	Product	Type of reaction
Aqueous NaOH, heat		
NaOH in ethanol, heat		

[3]

[Total: 20]

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