Rewarding Learning

Centre Number

Candidate Number

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2017

Life and Health Sciences

Assessment Unit AS 3
assessing
Aspects of Physical Chemistry in Industrial Processes

SZ031

[SZ031]
FRIDAY 19 MAY, AFTERNOON

TIME

1 hour 30 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
Answer **all five** questions.
Write your answers in the spaces provided in this question paper.

INFORMATION FOR CANDIDATES

The total mark for this paper is 75.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.
A Periodic Table of Elements is included in this question paper.
You may use an electronic calculator.
Quality of written communication will be assessed in Question **3(a)(ii)**.

For Examiner's use only	
Question Number	**Marks**
1	
2	
3	
4	
5	
Total Marks	

Examiner Only	
Marks	Remark

1 Butane gas can be used in portable home heaters or camping stoves, however recently there have been some health and safety issues regarding the use of these. If there is not a sufficient supply of oxygen then the poisonous gas carbon monoxide will form on combustion rather than carbon dioxide.

(a) Define the term **enthalpy of combustion**.

_____

_____

_____ [2]

(b) A chemistry student has been asked to find the enthalpy change for the combustion of butane in the laboratory, using a camping stove as the source of butane.

(i) List the **main** pieces of apparatus and materials needed for this experiment.

_____

_____

_____ [3]

(ii) Suggest two sources of error for this experiment.

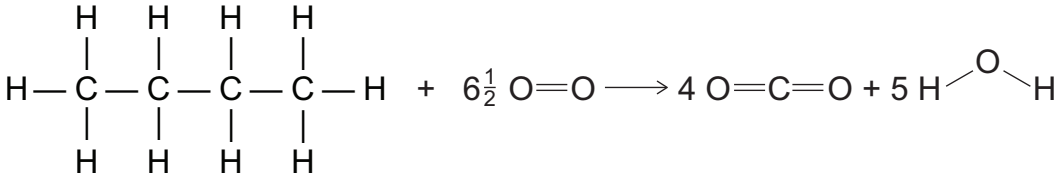
1. _____

_____

2. _____

_____ [2]

(c) Butane burns to release energy according to the equation below.



(i) Use the average bond enthalpy data given below to calculate the enthalpy change for the combustion of one mole of butane.
Show your working.

Bond	Average bond enthalpy/kJ mol^{-1}
C—C	347
C—H	413
C=O	799
O—H	467
O=O	495

_____ kJ mol^{-1} [4]

(ii) Suggest why the enthalpy change for the combustion of propane (C_3H_8) has a lower value than that of butane (C_4H_{10}).

_____

_____ [1]

Examiner Only

Marks	Remark

Examiner Only	
Marks	Remark

(d) Hess's law can be used to calculate enthalpy changes such as the enthalpy of formation of butane (C_4H_{10}), which cannot be measured directly by experiment. Hess's law is based on the principle of conservation of energy.

(i) State the principle of conservation of energy.

_____

_____

_____ [2]

(ii) Complete and balance the equation for the enthalpy of formation of butane.

$$C \quad + \quad H_2 \quad \rightarrow \qquad [1]$$

(iii) Use the standard enthalpy of combustion data below to calculate the standard enthalpy of formation of butane.

	Standard enthalpy of combustion/kJ mol^{-1}
Butane (C_4H_{10})	–2877.5
Carbon (C)	–393.5
Hydrogen (H_2)	–285.8

_____ kJ mol^{-1} [3]

Examiner Only	
Marks	Remark

2 Industrial chemists often use heterogeneous catalysts; for example a vanadium(V) oxide catalyst is used in the manufacture of sulfuric acid.

(a) The second stage in the manufacture of sulfuric acid is the reaction of sulfur dioxide with oxygen. Write a balanced symbol equation for this stage.

_____ [2]

(b) Define the term **heterogeneous catalyst**.

_____

_____

_____ [3]

(c) **(i)** Define the term **activation energy**.

_____

_____

_____ [2]

(ii) On the axes below, draw a Maxwell–Boltzmann distribution curve for the reaction in part **(a)**. Include labels on the axes and a label showing the activation energy (E_A).

[3]

(iii) Explain, in terms of activation energy, why using a catalyst increases the rate of the reaction.

_____

_____

_____ [3]

(iv) Describe how the Maxwell–Boltzmann distribution curve would change if this reaction was carried out at a higher temperature.

_____

_____

_____ [2]

Examiner Only	
Marks	Remark

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(Questions continue overleaf)

Examiner Only	
Marks	Remark

3 A student is required to carry out a titration to determine the concentration of a sulfuric acid sample. 25.0 cm^3 portions of sulfuric acid were titrated against a standard solution of 0.100 M sodium hydroxide. The equation for the reaction is shown below.

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

(a) (i) What is meant by the term **standard solution**?

_____

_____ [1]

(ii) Describe how the student would carry out the titration to determine accurately the concentration of the sulfuric acid sample.

Your answer should include how to:

- measure out and transfer 25.0 cm^3 of sulfuric acid solution to the conical flask
- prepare and fill the burette
- carry out the titration

You will be assessed on the quality of your written communication.

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Examiner Only

Marks	Remark

[8]

(b) (i) The student has chosen to use phenolphthalein indicator to identify the end point of the reaction. Suggest why this is a suitable indicator.

[1]

(ii) State the colour change of phenolphthalein at the end point.

From _____ to _____ [2]

(c) The student's results are shown below.

	Initial burette reading/cm^3	Final burette reading/cm^3	Titre/cm^3
Rough	0.00	24.50	24.50
1st accurate	24.50	47.90	
2nd accurate	0.00	23.30	

(i) Complete the results table above. [1]

(ii) Calculate the mean titre.

_____ cm^3 [2]

(d) The equation for the reaction is:

$$H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

(i) Use the mean titre from **(c)(ii)** to calculate the number of moles of 0.100 M sodium hydroxide used in the titration.

_____ moles [2]

(ii) Use your answer to **(d)(i)** and the equation to calculate the concentration of the sulfuric acid in the sample.

_____ mol dm^{-3} [2]

Examiner Only

Marks	Remark

Examiner Only	
Marks	Remark

4 **(a)** Chemical engineers must consider many costs when developing industrial processes. Two of these costs are capital and direct. Explain these terms.

Capital costs _____

_____

Direct costs _____

_____ [2]

(b) Suggest three effects on the **environment** that the construction of a new chemical manufacturing plant may have.

1. _____

_____

2. _____

_____

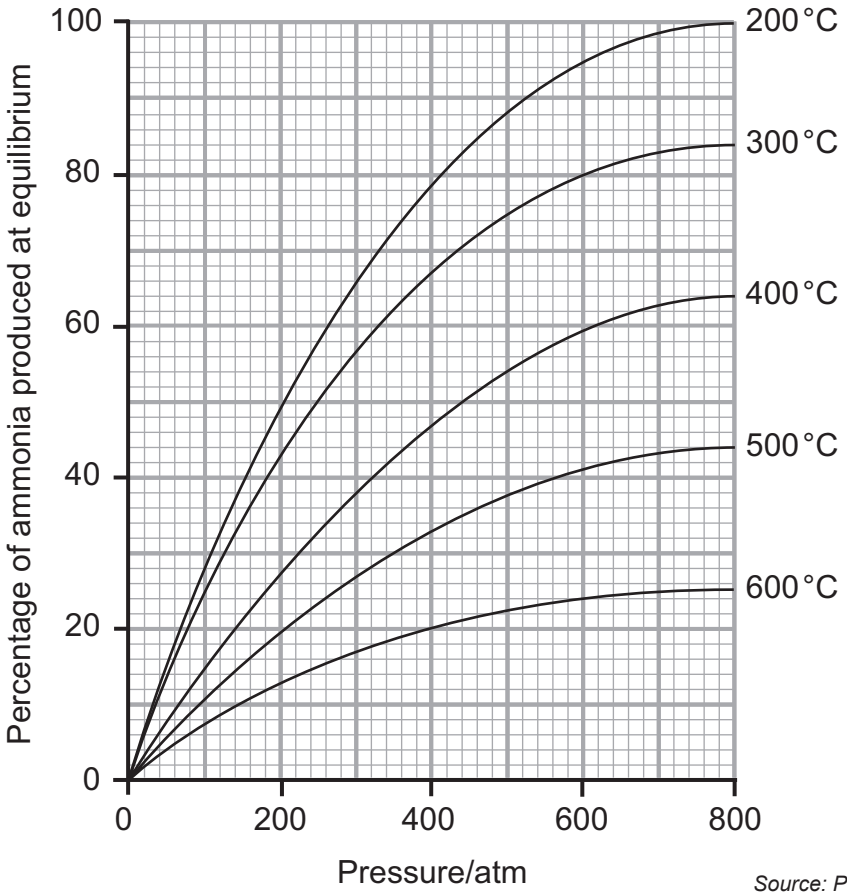
3. _____

_____ [3]

Examiner Only	
Marks	Remark

5 Ammonia is produced using the Haber process. The conditions are carefully selected to produce the ammonia efficiently.

(a) The graph below shows the percentage of ammonia produced at equilibrium when different conditions of pressure and temperature are used.



Source: Principal Examiner

(i) Use the graph to describe the trends in the percentage of ammonia produced at equilibrium under different conditions.

_____

_____

_____

_____

_____

_____ [2]

(ii) Use the graph to determine the percentage of ammonia produced at equilibrium if a temperature of 400 °C and a pressure of 300 atm were used.

_____ % [1]

Examiner Only	
Marks	Remark

(iii) The equation for the Haber process is:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

State and explain the effect of **increasing** each of the following on the position of equilibrium in this reaction.

Temperature _____

_____

_____

Pressure _____

_____

_____ [4]

(b) Ammonia gas can be reacted with hydrogen chloride gas to produce solid ammonium chloride, which is used as a fertiliser. This is shown in the equation below:

$$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$$

(i) Calculate the relative formula mass of ammonium chloride.

_____ [1]

(ii) Calculate the maximum mass in **kilograms** of ammonium chloride that can be produced from 912.5 g of hydrogen chloride.

_____ kg [4]

Examiner Only	
Marks	Remark

(iii) In an experiment a yield of 1.15 kg of ammonium chloride was obtained. Using your answer to **(b)(ii)**, calculate the percentage yield giving your answer to 2 decimal places.

_____ % [2]

(c) Selective catalytic reduction (SCR) involves injecting ammonia into flue gases of factory chimneys. This is done in the presence of a catalyst such as tungsten oxide and it removes harmful nitrogen monoxide from the emissions. This produces nitrogen which is a less polluting gas.

(i) Balance the equation below for this process.

$$NO + NH_3 \rightarrow N_2 + H_2O$$ [1]

(ii) Every hour a chimney in a factory produces 33 moles of nitrogen monoxide. Using your answer to **(c)(i)**, calculate how many moles of ammonia would be needed to completely change this into nitrogen gas.

_____ moles [1]

(iii) The catalyst involved in SCR needs to be monitored closely to ensure it does not become poisoned. Explain the process of catalytic poisoning.

_____

_____

_____

_____

_____

_____ [2]

THIS IS THE END OF THE QUESTION PAPER