Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2018

Centre Number

Candidate Number

Life and Health Sciences

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

MV18

[SZ031]

FRIDAY 18 MAY, AFTERNOON

Time

1 hour 30 minutes, plus your additional time allowance.

Instructions to Candidates

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

Information for Candidates

The total mark for this paper is 75.
Figures in brackets printed at the end of each question 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(b)(i)**.

1 The catalytic converter in a car exhaust converts nitrogen(II) oxide to less harmful nitrogen. Nitrogen(II) oxide (NO) and carbon monoxide (CO) are present in the exhaust fumes.

(a) Define the term **catalyst**. [2 marks]

(b) **Fig. 1.1** below shows the Maxwell–Boltzmann distribution curve for a mixture of carbon monoxide (CO) and nitrogen(II) oxide (NO) at a temperature T_1.

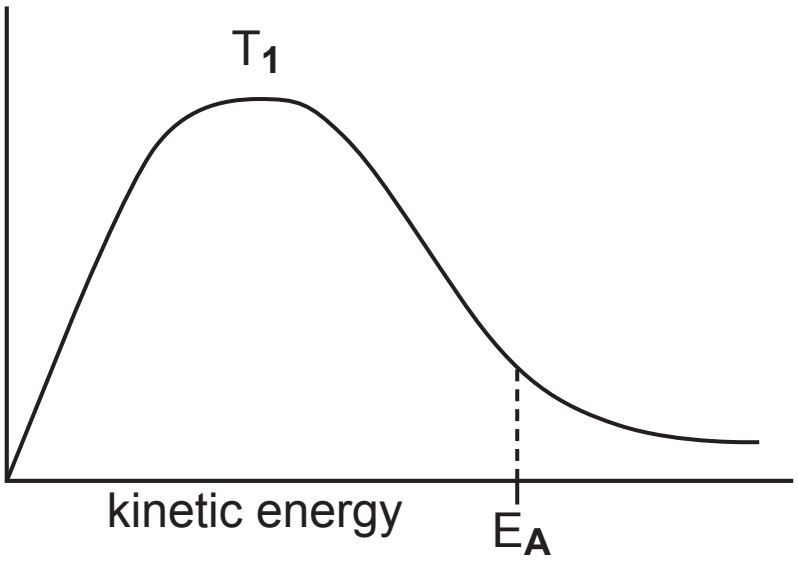


Fig. 1.1

(i) What label should be placed on the y-axis of the Maxwell–Boltzmann distribution curve? [1 mark]

(ii) The activation energy (E_A) is labelled on the x-axis. Define the term **activation energy**. [2 marks]

(iii) With reference to the Maxwell–Boltzmann distribution curve opposite, suggest a reason why most collisions between CO and NO at temperature T_1 do not result in a product being formed. [1 mark]

(iv) On **Fig. 1.1**, draw another distribution curve for the same mixture at a higher temperature, T_2. [3 marks]

(v) Using the distribution curves, explain why the reaction between CO and NO is faster at the higher temperature, T_2. [2 marks]

2 **(a)** To create a new chemical, industrial chemists carry out experiments to find the best conditions for the reaction. They use a batch process to initially make the product. When they work out the best conditions for the reaction they set up a continuous process to manufacture the product.

(i) Give two advantages of using a **batch** process for the initial experiments. [2 marks]

1. _____

_____

2. _____

_____

(ii) Give two advantages of using a **continuous** process for the final manufacture of the chemical. [2 marks]

1. _____

_____

2. _____

_____

(b) Describe two factors that a company must take into account with regard to **waste management** when choosing a site for their production plant. [2 marks]

1. _____

_____

2. _____

_____

3 **(a)** Define the term **standard enthalpy change of combustion**. [2 marks]

(b) **(i)** A student wants to carry out an experiment to find the enthalpy change of combustion of ethanol. Describe the procedure he should use and state the measurements he should record. Do not give details of any calculations required. [8 marks]

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

(ii) The equation the student would use to help calculate the enthalpy change of combustion is $Q = mc\Delta T$. State the meaning of the following symbols used in this equation: [3 marks]

m: _____

c: _____

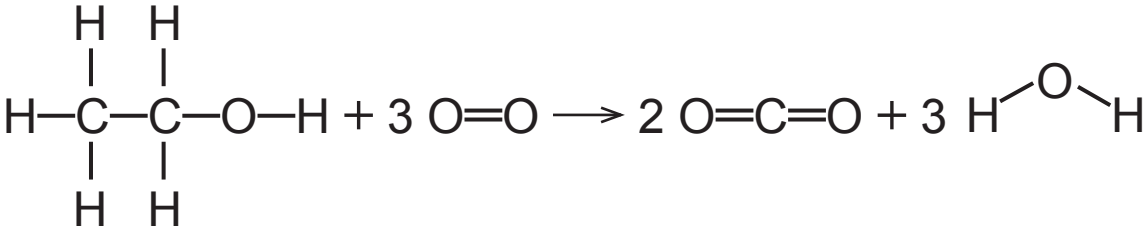
ΔT: _____

(iii) Explain why the value of the enthalpy of combustion obtained from experiments of this type is always greater than the accepted value. [1 mark]

_____

_____

(iv) Use the average bond enthalpy data in the table below to calculate a value for the enthalpy of combustion of ethanol. [4 marks]



Bond	Average bond enthalpy/ kJ mol^{-1}
C—C	347
C—H	413
C=O	799
O—H	467
O=O	495
C—O	358

You are advised to show your working.

_____ kJ mol^{-1}

(v) Explain why the enthalpy value in **(iv)** is different from the accepted value of −1370.7 kJ mol^{-1} for this combustion reaction. [1 mark]

4 Sulfuric acid is manufactured by the Contact process. One of the steps involves converting sulfur dioxide (SO_2) to sulfur trioxide (SO_3), according to the equation below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196\,kJ\,mol^{-1}$$

(a) This is an example of a reaction involving heterogeneous catalysis.

(i) Name the catalyst used in this reaction. [1 mark]

_____

(ii) Define the term **heterogeneous** as used to describe the catalyst. [1 mark]

_____

_____

(iii) Describe how a heterogeneous catalyst works, naming the process involved. [4 marks]

_____

_____

_____

_____

_____

(b) This reaction is an example of dynamic equilibrium. What is meant by the term **dynamic equilibrium**? [2 marks]

_____

_____

(c) **(i)** What information has been given to show that this reaction is exothermic? [1 mark]

_____

(ii) On the axes below, draw an energy level diagram for this reaction. Label the axes. [3 marks]

(d) The table below shows the percentage of sulfur dioxide (SO_2) which is converted to sulfur trioxide (SO_3) under different conditions.

Percentage of SO_2 converted to SO_3/%	**Temperature/°C**	**Pressure/atm**
98.5	100	2
99.0	100	100
98.0	400	2
98.5	400	100
55.0	600	2
52.5	600	100
18.0	900	2
17.0	900	100

Use the data in the table above and your knowledge to explain fully why an industrial chemist has chosen to use a temperature of 400°C and a pressure of 2 atm in this stage of the Contact process. [4 marks]

Temperature: _____

_____

_____

Pressure: _____

_____

_____

5 Sodium carbonate (Na_2CO_3) can be used to make a standard solution for volumetric analysis.

(a) (i) What is meant by the term **standard solution**? [1 mark]

_____

_____

(ii) Calculate the mass of sodium carbonate required to make 1 dm^3 of 0.100 mol dm^{-3} solution. [2 marks]
You are advised to show your working.

_____ g

(b) A standard solution of sodium carbonate with a concentration of 0.100 mol dm^{-3} was placed into a conical flask and used in volumetric analysis to find the concentration of a solution of hydrochloric acid. The equation for this reaction is shown below.

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$$

(i) 25.0 cm^3 of the standard solution required 35.0 cm^3 of the acid for neutralisation to occur. Calculate the concentration of the acid giving your answer to 3 significant figures. [3 marks]

_____ mol dm^{-3}

(ii) State **two** ways in which a scientist could ensure that accurate results were obtained for this titration. [2 marks]

1. _____

_____

2. _____

_____

(iii) State **one** way that the scientist could ensure that reliable results were obtained. [1 mark]

_____

_____

(c) Indicators are substances that are different colours in acid and alkali. Complete the table below to show the colours of different indicators in acid and alkali. [4 marks]

Indicator	**Colour in acid**	**Colour in alkali**
phenolphthalein		
methyl orange		

6 Ethyne (C_2H_2) is used in industry for welding. When it burns in oxygen the flame can reach temperatures of over 3000°C. Ethyne burns to produce carbon dioxide and water.

Below are some enthalpy values involving ethyne and the elements it is made from.

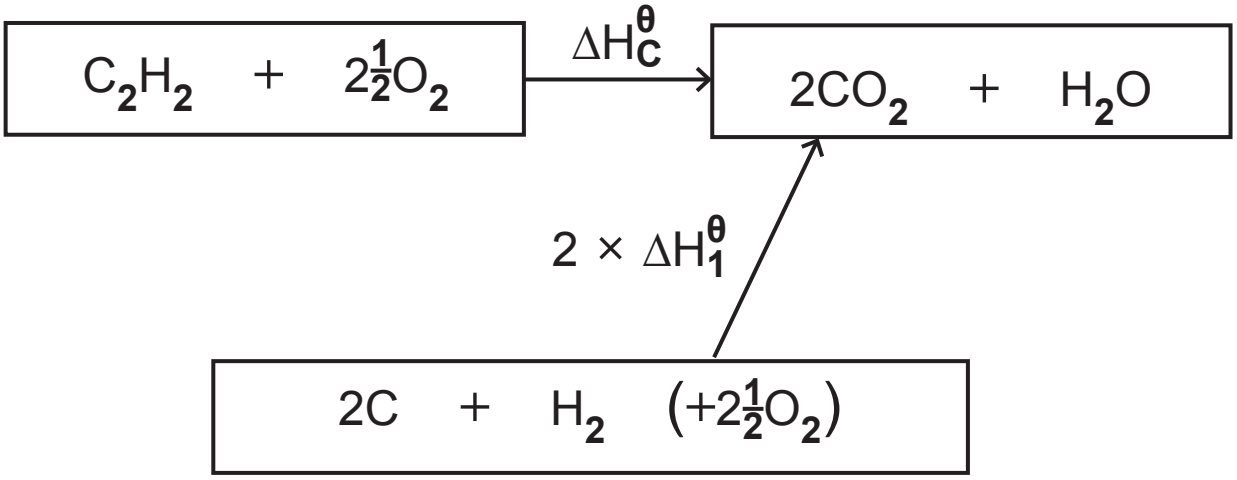
$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H_1^{\theta} = -394\ kJ\ mol^{-1}$$

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(l) \qquad \Delta H_2^{\theta} = -286\ kJ\ mol^{-1}$$

$$2C(s) + H_2(g) \rightarrow C_2H_2(g) \qquad \Delta H_3^{\theta} = +226\ kJ\ mol^{-1}$$

(a) State **Hess's law**. [2 marks]

(b) (i) Part of the enthalpy cycle for the combustion of ethyne is shown below. Add arrows with labels to show ΔH_2^θ and ΔH_3^θ. [2 marks]



(ii) Calculate the enthalpy of combustion, ΔH_C^θ, for ethyne.
Your answer must include the unit. [3 marks]
You are advised to show your working.

(c) Ethyne is made when calcium carbide (CaC_2) reacts with water. Calcium hydroxide is also produced in this reaction. Construct a balanced symbol equation for this reaction. [3 marks]

THIS IS THE END OF THE QUESTION PAPER

SOURCES

Q1(b) . . . . Source: *Principal Examiner*

For Examiner's use only	
Question Number	**Marks**
1	
2	
3	
4	
5	
6	
Total Marks	