Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2019

Centre Number

Candidate Number

Life and Health Sciences

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

SZ031

[SZ031]
TUESDAY 21 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 **4(b)(iii)**.

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

Examiner Only	
Marks	Remark

1 Methanol can be manufactured from carbon dioxide and hydrogen as shown by the equation below.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g) \qquad \Delta H = -49\,kJ\ mol^{-1}$$

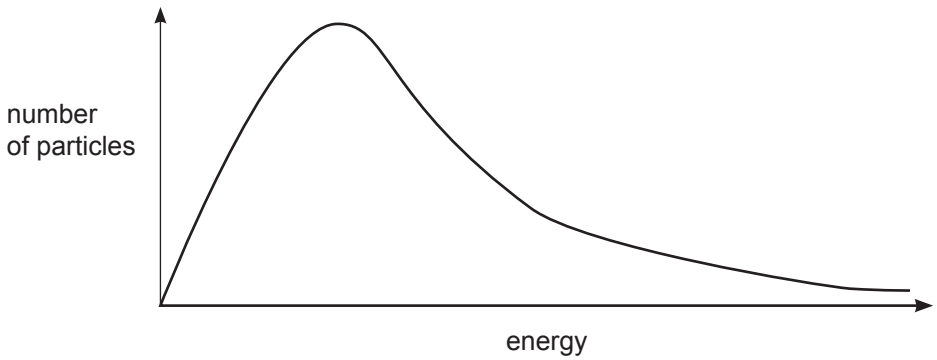
The most common catalyst is a mixture of solid copper and zinc oxides and the reaction is usually carried out at a pressure of 50–100 atm and a temperature of 250°C.

(a) Explain why this is an example of heterogeneous catalysis.

_____

_____ [1]

(b) The distribution of molecular energies in the reaction mixture at 250°C is shown below.



(i) What name is given to this type of distribution?

_____ [1]

(ii) Sketch, on the axes above, the distribution of molecular energies for the reaction at a temperature of 450°C. [3]

(c) Define the following terms.

Examiner Only	
Marks	Remark

Activation Energy:

_____

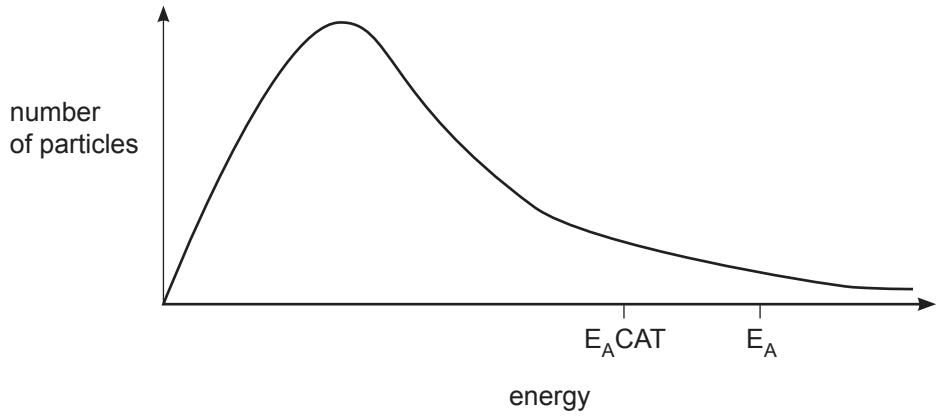
_____ [2]

Catalyst:

_____

_____ [2]

The graph below shows the relative positions of the activation energy for the reaction without a catalyst (E_A) and with a catalyst (E_ACAT).



(d) With reference to the graph above, explain why adding a catalyst increases the rate of formation of methanol.

_____

_____

_____

_____ [2]

Examiner Only	
Marks	Remark

(e) (i) Using your knowledge of equilibrium, state and explain what would happen to the **yield** of this reaction if a higher pressure was used.

You will need to refer to the equation for the production of methanol.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

_____

_____

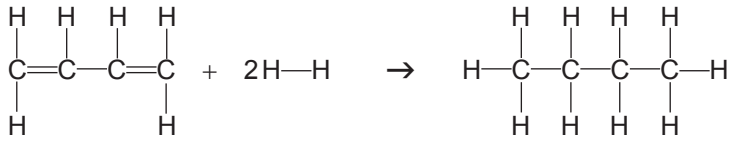
_____ [2]

(ii) State one **disadvantage** of using high pressures in industry.

_____

_____ [1]

2 Buta-1,3-diene reacts with hydrogen to form butane as shown in the equation below.



The standard enthalpy (ΔH^{θ}) for this reaction is –240 kJ mol^{-1}.

The table below gives information about some of the bonds involved in this reaction.

Bond	C—C	H—H	C—H
Average bond enthalpy /kJ mol^{-1}	347	439	413

(a) Define the term **average bond enthalpy**.

_____

_____

_____

_____ [2]

(b) Using the data in the table and the standard enthalpy for this reaction, calculate a bond enthalpy value for the C═C bond.
You are advised to show your working.

_____ kJ mol^{-1} [4]

Examiner Only

Marks	Remark

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Marks	Remark

(c) The equation below shows the standard enthalpy of formation of buta-1,3-diene.

$$4C(s) + 3H_2(g) \rightarrow C_4H_6(g)$$

The information below gives some standard enthalpy data.

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\quad \Delta H^{\theta} = -393.5\,kJ\,mol^{-1}$

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\quad \Delta H^{\theta} = -286\,kJ\,mol^{-1}$

$C_4H_6(g) + 5\frac{1}{2}O_2(g) \rightarrow 4CO_2(g) + 3H_2O(l)$ $\quad \Delta H^{\theta} = -2542\,kJ\,mol^{-1}$

(i) What are standard conditions? Include units in your answer.

Pressure: _____

Temperature: _____ [2]

(ii) State **Hess's Law**.

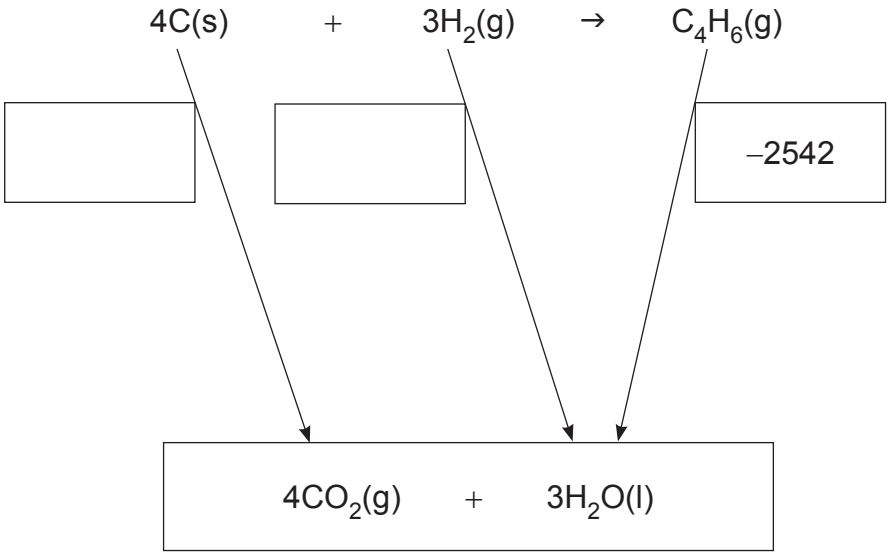
_____

_____

_____

_____ [2]

(iii) Using the information above, complete the Hess cycle by adding the correct value in kJ mol^{-1} for each reaction in the box. The last one has been done for you.



[2]

(iv) Using the Hess cycle from **(c)(iii)**, calculate the standard enthalpy of formation of buta-1,3-diene (C_4H_6).
You are advised to show your working.

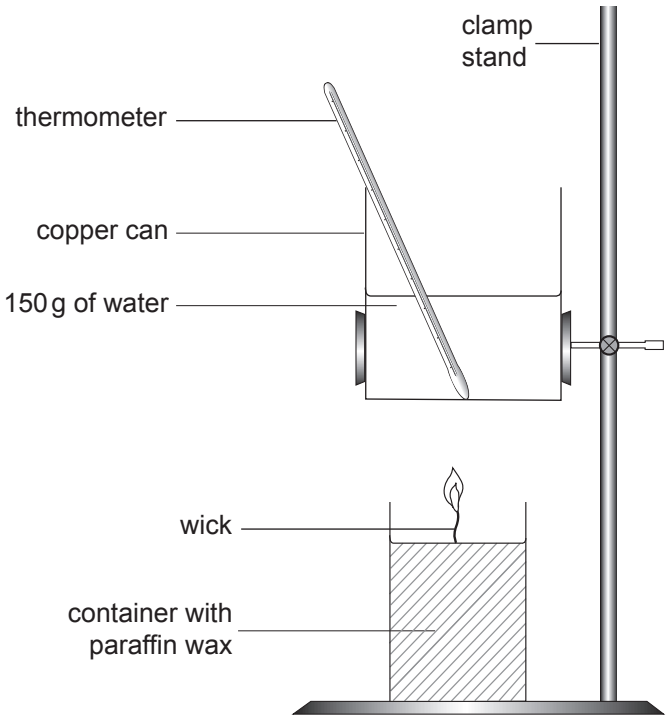
Examiner Only

Marks	Remark

_____ kJ mol^{-1} [2]

Examiner Only	
Marks	Remark

3 A calorimeter is set up as shown below. Paraffin wax was placed in a container with a wick to allow it to burn. A copper can containing 150 g of water was placed above the paraffin wax.



A student carried out an experiment, the results of which are shown below.

Initial mass of paraffin wax	28.5 g
Final mass of paraffin wax	27.4 g
Mass of paraffin wax used	
Initial water temperature	20°C
Final water temperature	84°C
Increase in temperature	

(a) Complete the table above by calculating the mass of paraffin wax used and the increase in temperature during the experiment. [1]

(b) Calculate the heat energy released by the combustion of the paraffin wax. The specific heat capacity of water is 4.2 J $g^{-1}°C^{-1}$. Give your answer in kilojoules.
You are advised to show your working.

Examiner Only | Marks | Remark

_____ kJ [3]

(c) **(i)** The main component of paraffin wax has the formula $C_{31}H_{64}$. Calculate the relative formula mass (RFM) of $C_{31}H_{64}$.

_____ [1]

(ii) Calculate the number of moles of paraffin wax used in this experiment.

_____ moles [1]

(d) Using the answers to parts **(b)** and **(c)(ii)**, calculate the molar enthalpy of combustion of paraffin wax in kJ mol^{-1}.

_____ kJ mol^{-1} [1]

(e) Suggest **one** source of error in this experiment and how this could be minimised.

_____

_____

_____ [2]

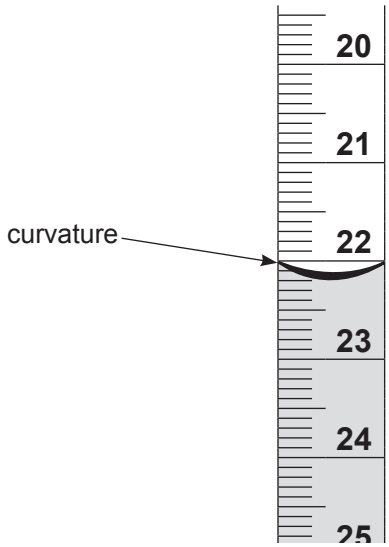
Examiner Only	
Marks	Remark

4 Titrations can be used to find the concentration of an unknown solution. The main pieces of apparatus involved are a burette, a pipette, a safety pipette filler and conical flasks.

(a) The reading from a burette should be taken at the lowest point at the top of the liquid.

(i) What name is given to the curvature of the solution in the burette as shown below?

_____ [1]



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(ii) What is the reading on the burette above?

_____ cm^3 [1]

Examiner Only	
Marks	Remark

(b) A science technician has a bottle of hydrochloric acid, but is unsure of its exact concentration. She decides to carry out a titration with a standard solution of 0.1M potassium hydroxide to find the concentration of the acid. First the technician has to prepare the 0.1M standard solution of potassium hydroxide from its solid.

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

_____

_____ [1]

(ii) Calculate the mass of solid potassium hydroxide (KOH) needed to make 1dm^3 of 0.1M potassium hydroxide solution.

mass: _____ g [2]

(iii) Describe the method the technician should use to accurately prepare 1dm^3 of a standard solution of 0.1M potassium hydroxide.

Quality of written communication will be assessed in this question.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____ [6]

Examiner Only

Marks	Remark

(iv) The technician then fills the burette with the standard solution and places 25 cm^3 of acid into the conical flask.
Suggest a suitable indicator that she should add to the acid in the conical flask.
Give the colour change at the end point.

Indicator: _____

Colour change: _____ to _____ [3]

(v) The technician collected the following results from her titrations.
Complete the table by filling in the missing titre values.

	Initial burette reading /cm^3	Final burette reading /cm^3	Titre /cm^3
Rough	0.0	23.5	23.5
1st accurate	23.5	46.5	
2nd accurate	0.0	22.8	

[1]

(vi) Calculate the mean titre.

_____ cm^3 [2]

(vii) Write a balanced symbol equation for the reaction of potassium hydroxide and hydrochloric acid.

_____ [1]

(viii) Using the information provided and your answer from **(vi)**, calculate the concentration of the hydrochloric acid used.

_____ mol dm^{-3} [2]

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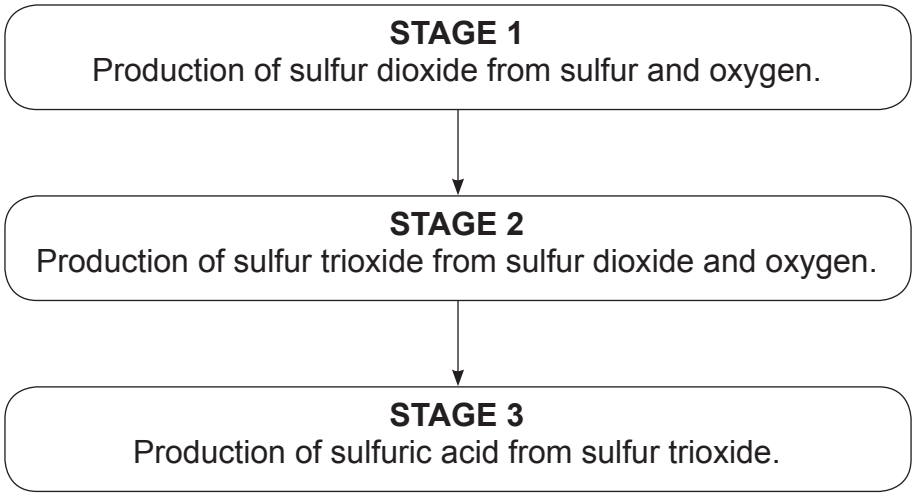
(Questions continue overleaf)

Examiner Only	
Marks	Remark

5 The Contact process produces sulfuric acid. There are several stages, as shown below:



(a) The balanced symbol equation for **STAGE 2** is shown below:

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

(i) State the conditions required for this stage of the process. Include units in your answer.

Temperature: _____

Pressure: _____

Catalyst: _____ [3]

(ii) Platinum was once used as the catalyst for **STAGE 2** in the Contact process but during the reaction it became poisoned with arsenic impurities from the feedstock. Explain the process of **catalytic poisoning**.

_____

_____

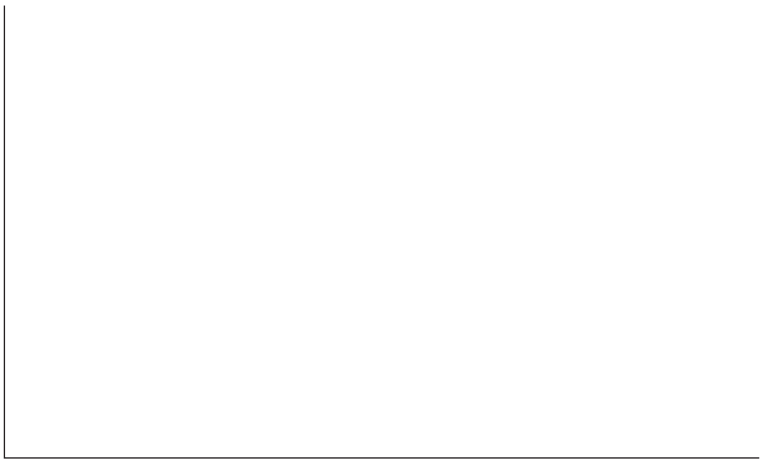
_____

_____

_____

_____ [2]

(iii) Draw a reaction profile for **STAGE 2** in the Contact process.
Label both axes.



[2]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

(b) The production of sulfuric acid is described as a **continuous process**.

(i) Explain the term **continuous process**.

_____

_____ [1]

(ii) Suggest **two** reasons why a company may prefer to manufacture a chemical by a continuous process.

1. _____

_____

2. _____

_____ [2]

(c) The costs involved in manufacturing chemicals can be classified as **capital** costs, **direct** costs and **indirect** costs.

Complete the table below to classify each of the following costs involved in the Contact process by placing a tick (✔) in the appropriate column.

	Capital cost	**Direct cost**	**Indirect cost**
Cost of sulfur			
Building the chemical plant			
Cost of electricity to maintain the process			
Sales and advertising			

[4]

(d) The following data was obtained for the percentage yields of product in a similar gaseous reaction at different temperatures and pressures.

Temperature /°C	Pressure /kPa		
	200	**400**	**600**
400	20%	40%	60%
500	15%	35%	55%
600	10%	30%	50%
700	5%	25%	45%
800	0%	20%	40%

(i) Use the table to describe the trends in the percentage yield of product under the different conditions shown.

_____

_____

_____

_____ [2]

(ii) State the conditions that produce the maximum yield as shown in the table.

_____

_____ [1]

(iii) If the trends remain the same for all temperatures and pressures, predict the percentage yield for a temperature of 900°C and a pressure of 800 kPa.

_____ % [1]

THIS IS THE END OF THE QUESTION PAPER

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248682

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AS 3 and A2 2

Periodic Table of the Elements

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Advanced Level Examinations

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life & health sciences

For first teaching from September 2016
For first award of AS Level in Summer 2017
For first award of A Level in Summer 2018
Subject Code: 0008

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THE PERIODIC TABLE OF ELEMENTS

I	II											III	IV	V	VI	VII	0
Group																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** Hydrogen 1																	4 **He** Helium 2
7 **Li** Lithium 3	9 **Be** Beryllium 4											11 **B** Boron 5	12 **C** Carbon 6	14 **N** Nitrogen 7	16 **O** Oxygen 8	19 **F** Fluorine 9	20 **Ne** Neon 10
23 **Na** Sodium 11	24 **Mg** Magnesium 12											27 **Al** Aluminium 13	28 **Si** Silicon 14	31 **P** Phosphorus 15	32 **S** Sulfur 16	35.5 **Cl** Chlorine 17	40 **Ar** Argon 18
39 **K** Potassium 19	40 **Ca** Calcium 20	45 **Sc** Scandium 21	48 **Ti** Titanium 22	51 **V** Vanadium 23	52 **Cr** Chromium 24	55 **Mn** Manganese 25	56 **Fe** Iron 26	59 **Co** Cobalt 27	59 **Ni** Nickel 28	64 **Cu** Copper 29	65 **Zn** Zinc 30	70 **Ga** Gallium 31	73 **Ge** Germanium 32	75 **As** Arsenic 33	79 **Se** Selenium 34	80 **Br** Bromine 35	84 **Kr** Krypton 36
85 **Rb** Rubidium 37	88 **Sr** Strontium 38	89 **Y** Yttrium 39	91 **Zr** Zirconium 40	93 **Nb** Niobium 41	96 **Mo** Molybdenum 42	98 **Tc** Technetium 43	101 **Ru** Ruthenium 44	103 **Rh** Rhodium 45	106 **Pd** Palladium 46	108 **Ag** Silver 47	112 **Cd** Cadmium 48	115 **In** Indium 49	119 **Sn** Tin 50	122 **Sb** Antimony 51	128 **Te** Tellurium 52	127 **I** Iodine 53	131 **Xe** Xenon 54
133 **Cs** Caesium 55	137 **Ba** Barium 56	139 **La*** Lanthanum 57	178 **Hf** Hafnium 72	181 **Ta** Tantalum 73	184 **W** Tungsten 74	186 **Re** Rhenium 75	190 **Os** Osmium 76	192 **Ir** Iridium 77	195 **Pt** Platinum 78	197 **Au** Gold 79	201 **Hg** Mercury 80	204 **Tl** Thallium 81	207 **Pb** Lead 82	209 **Bi** Bismuth 83	210 **Po** Polonium 84	210 **At** Astatine 85	222 **Rn** Radon 86
223 **Fr** Francium 87	226 **Ra** Radium 88	227 **Ac†** Actinium 89	261 **Rf** Rutherfordium 104	262 **Db** Dubnium 105	266 **Sg** Seaborgium 106	264 **Bh** Bohrium 107	277 **Hs** Hassium 108	268 **Mt** Meitnerium 109	271 **Ds** Darmstadtium 110	272 **Rg** Roentgenium 111	285 **Cn** Copernicium 112						

140 **Ce** Cerium 58	141 **Pr** Praseodymium 59	144 **Nd** Neodymium 60	145 **Pm** Promethium 61	150 **Sm** Samarium 62	152 **Eu** Europium 63	157 **Gd** Gadolinium 64	159 **Tb** Terbium 65	162 **Dy** Dysprosium 66	165 **Ho** Holmium 67	167 **Er** Erbium 68	169 **Tm** Thulium 69	173 **Yb** Ytterbium 70	175 **Lu** Lutetium 71
232 **Th** Thorium 90	231 **Pa** Protactinium 91	238 **U** Uranium 92	237 **Np** Neptunium 93	242 **Pu** Plutonium 94	243 **Am** Americium 95	247 **Cm** Curium 96	245 **Bk** Berkelium 97	251 **Cf** Californium 98	254 **Es** Einsteinium 99	253 **Fm** Fermium 100	256 **Md** Mendelevium 101	254 **No** Nobelium 102	257 **Lr** Lawrencium 103

* 58–71 Lanthanum series
† 90–103 Actinium series

a
b x

a = relative atomic mass (approx)
x = atomic symbol
b = atomic number