



Rewarding Learning
ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2019

Centre Number

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Candidate Number

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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.

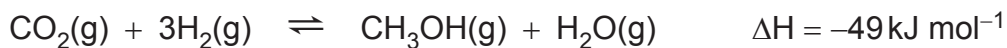
You may use an electronic calculator.

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

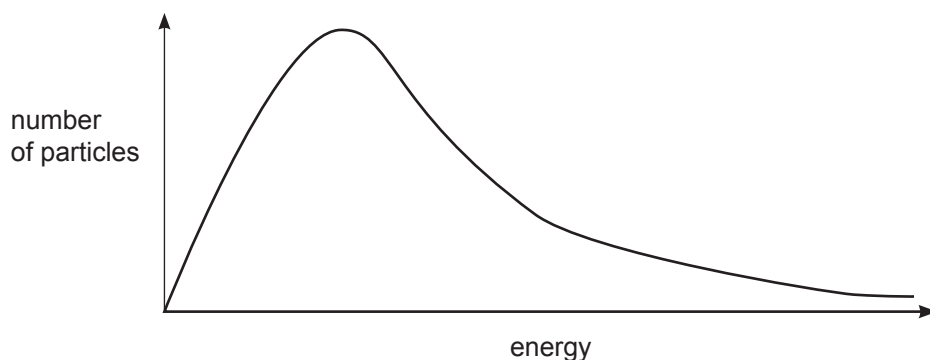


The most common catalyst is a mixture of solid copper and zinc oxides and the reaction is usually carried out at a pressure of 50–100 atm and a temperature of 250°C.

- (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]

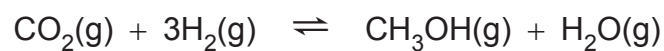
- (ii) Sketch, on the axes above, the distribution of molecular energies for the reaction at a temperature of 450°C. [3]

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.



[2]

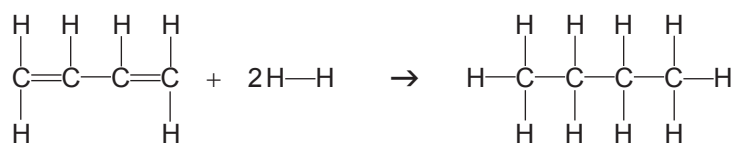
- (ii) State one **disadvantage** of using high pressures in industry.

[1]

Examiner Only

Marks Remark

- 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

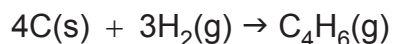
- (a) Define the term **average bond enthalpy**.

[2]

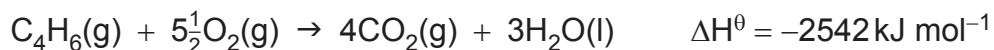
- (b) Using the data in the table and the standard enthalpy for this reaction, calculate a bond enthalpy value for the C=C bond.
You are advised to show your working.

_____ kJ mol^{-1} [4]

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



The information below gives some standard enthalpy data.



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

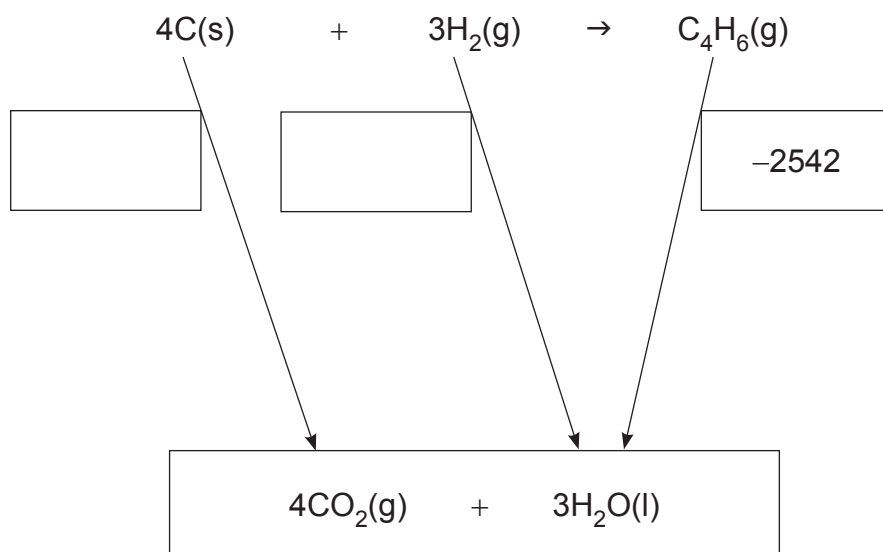
Pressure: _____

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]

Examiner Only

Marks Remark

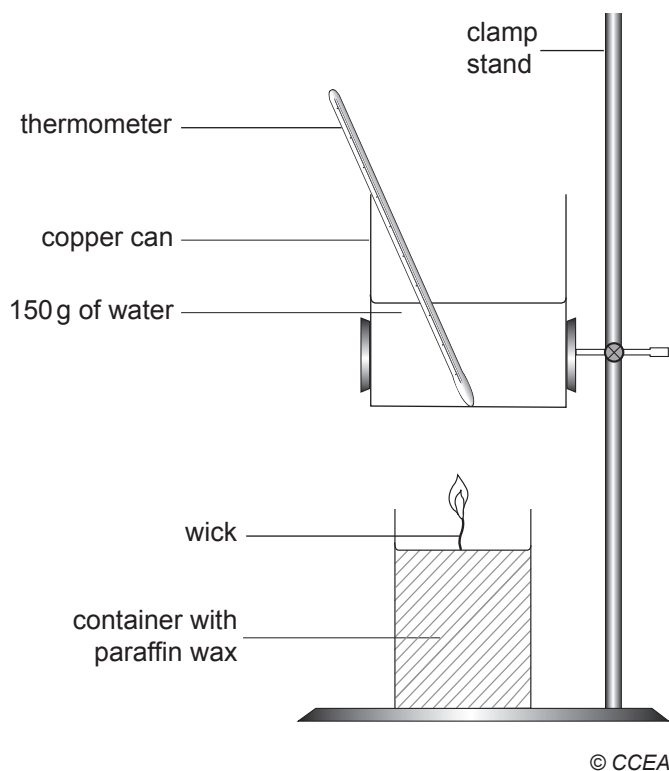
(iv) Using the Hess cycle from (c)(iii), calculate the standard enthalpy of formation of buta-1,3-diene (C₄H₆).

You are advised to show your working.

_____ 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 150g 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	28.5g
Final mass of paraffin wax	27.4g
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]

Examiner Only

Marks Remark

- (b) Calculate the heat energy released by the combustion of the paraffin wax. The specific heat capacity of water is $4.2 \text{ J g}^{-1} \text{ } ^\circ\text{C}^{-1}$. Give your answer in kilojoules.

You are advised to show your working.

_____ kJ [3]

- (c) (i) The main component of paraffin wax has the formula $\text{C}_{31}\text{H}_{64}$. Calculate the relative formula mass (RFM) of $\text{C}_{31}\text{H}_{64}$.

_____ [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

- (iv) The technician then fills the burette with the standard solution and places 25 cm³ 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.

_____ cm³ [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]

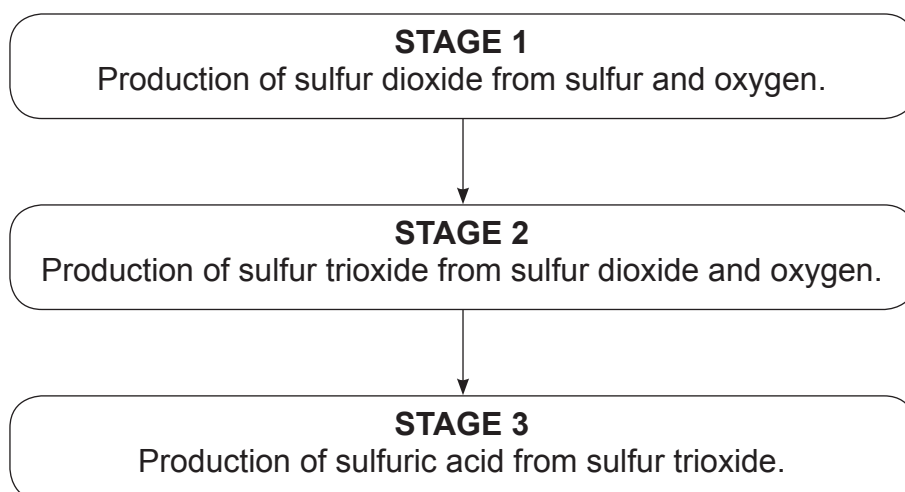
Examiner Only

Marks Remark

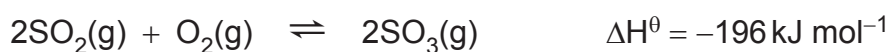
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(Questions continue overleaf)

- 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:



- (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]

Examiner Only	
Marks	Remark

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



[2]

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]

Examiner Only	
Marks	Remark

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

		Pressure /kPa		
		200	400	600
Temperature /°C	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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Marks Remark

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will be happy to rectify any omissions of acknowledgement in future if notified.

AS 3 and A2 2

Periodic Table of the Elements

For the use of candidates taking
Advanced Subsidiary and
Advanced Level Examinations

Copies must be free from notes or additions of any kind. No other type of data booklet or information sheet is authorised for use in the examinations

gce a/as examinations

life & health

sciences

THE PERIODIC TABLE OF ELEMENTS

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															20	Ne Neon 10																
23	Na Sodium 11	24	Mg Magnesium 12															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	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	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	x
b	

a = relative atomic mass (approx)

x = atomic symbol

b = atomic number