Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2023

Centre Number

Candidate Number

Life and Health Sciences

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

SZ031

[SZ031]

MONDAY 5 JUNE, 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.
You must answer the questions in the spaces provided.
Do not write outside the boxed area on each page or on blank pages.
Complete in black ink only. **Do not write with a gel pen.**
Answer **all five** questions.

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 **2(a)(i)**.

1 Ammonia is produced in the Haber process.

(a) The costs involved in this process can be classified as capital costs, direct costs and indirect costs.

(i) Define the term **direct cost**.

_____

_____ [1]

(ii) Give one example of each type of cost related to this process.

Capital cost _____

Direct cost _____

Indirect cost _____ [3]

The Haber process is a continuous one.

(iii) Define the term **continuous process**.

_____

_____ [1]

(b) In the Haber process, gaseous nitrogen and hydrogen are reacted to make ammonia.

(i) Write a balanced symbol equation for this **equilibrium** reaction.

_____ [3]

(ii) Complete the table below giving the conditions used in the Haber process. Include units in your answer where appropriate.

Temperature	Pressure	Catalyst
450°C		

[3]

(c) The Haber process uses heterogeneous catalysis.

(i) Define the term **heterogeneous catalysis**.

_____

_____

_____ [1]

(ii) Explain how a heterogeneous catalyst works, naming the process involved.

Process name _____

_____

_____

_____

_____

_____ [4]

[Turn over

(d) The reaction of nitrogen and hydrogen in the Haber process can reach dynamic equilibrium.

(i) Define the term **dynamic equilibrium**.

[2]

(ii) The enthalpy change for this reaction is $-92\,kJmol^{-1}$.

State and explain the effect of an **increase** in temperature on the position of equilibrium in this reaction.

[2]

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(Questions continue overleaf)

2 **(a)** A technician is asked to determine the enthalpy of neutralisation for the reaction between 1 M sodium hydroxide solution (NaOH) and 1 M hydrochloric acid solution (HCl).
The equation for the reaction is shown below.

$$NaOH + HCl \rightarrow NaCl + H_2O$$

(i) Describe in detail how the technician could carry out this experiment.

In your description you should include:

- the equipment used; and
- the measurements taken.

Quality of written communication will be assessed in this question.

[6]

(ii) State the equation used to calculate the energy change (Q) of this experiment.
State the meaning of each term used in the equation.

Equation: _____

Meaning of terms: _____

_____

_____ [4]

(iii) Suggest two possible sources of error for this experiment.

1. _____

2. _____ [2]

(b) Average bond enthalpies can be used to calculate enthalpy changes.

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

_____

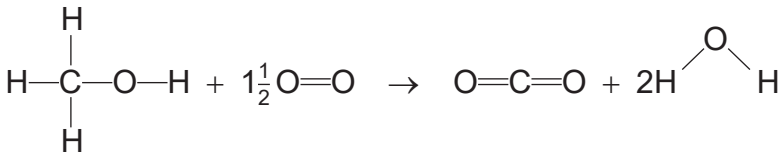
_____

_____ [2]

[Turn over

(ii) Using the average bond enthalpy data in the table below, calculate a value for the enthalpy change of combustion of methanol.

$$CH_3OH(l) + 1\tfrac{1}{2}O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$



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

You are advised to show your working.

Enthalpy of combustion = _____ kJ mol^{-1} [4]

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(Questions continue overleaf)

3 **(a)** A solution of nitric acid (HNO_3) of unknown concentration was titrated against a standard solution of sodium hydroxide (NaOH) of concentration 0.1 M.
The results were used to calculate the concentration of the nitric acid.

(i) Calculate the mass of solid sodium hydroxide used to make 1 dm^3 of the 0.1 M standard solution.

Mass = _____ g [2]

(ii) Define the term **standard solution**.

_____

_____ [1]

(b) 25.0 cm^3 of the nitric acid solution was placed in a conical flask and indicator added.
It was then titrated with the standard solution of sodium hydroxide.
Name an appropriate indicator for this titration and state the colour change at the end-point.

Indicator: _____

Colour change: _____ to _____ [3]

(c) Several titrations were carried out and the results recorded are shown in the table below.

	Initial burette reading /cm^3	Final burette reading /cm^3	Titre /cm^3
Rough	0.0	23.5	23.5
Accurate (1)	26.5	_____	22.5
Accurate (2)	0.0	22.4	22.4
	Mean titre: _____ cm^3		

(i) Complete the table of results above by adding in the missing values. [2]

(ii) Write a balanced symbol equation for the reaction between sodium hydroxide and nitric acid.

_____ [1]

(iii) Using the mean titre value and the information provided, calculate the number of moles of 0.1 M sodium hydroxide used in the titration.

_____ moles [1]

(iv) Use your answer from **(iii)** and your balanced symbol equation to calculate the concentration of nitric acid used.

_____ mol dm^{-3} [2]

[Turn over

4 The equation below shows the standard enthalpy of formation of methane.

$$C(s) + 2H_2(g) \rightarrow CH_4(g)$$

(i) Define the term **standard enthalpy change ($\Delta H^{\ominus}$)**.

_____

_____ [2]

(ii) What are the standard conditions of temperature and pressure?
Include a correct unit for temperature in your answer.

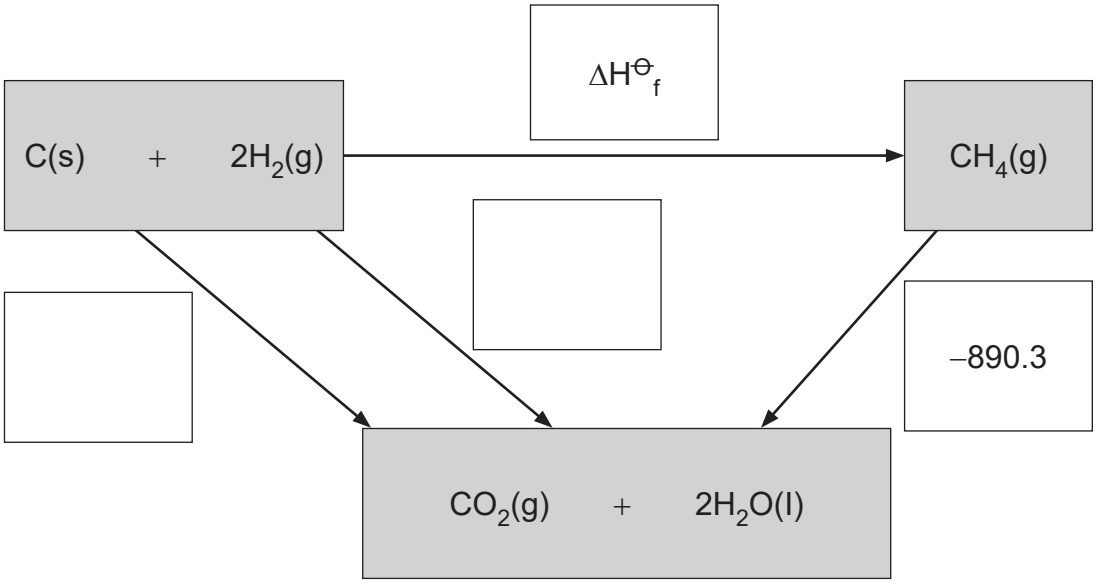
Temperature: _____ Unit: _____

Pressure: _____ kPa [3]

The table below contains some enthalpy data involving methane and the elements it is made from.

Reaction	Enthalpy change /kJ mol^{-1}
$C(s) + O_2(g) \rightarrow CO_2(g)$	–393.5
$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$	–285.8
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$	–890.3

(iii) Using the information opposite, complete the Hess cycle by adding the correct enthalpy change value in kJ mol^{-1} for each reaction in the empty boxes.



[2]

(iv) Using the Hess cycle from **(iii)** calculate the standard enthalpy of formation of methane.

You are advised to show your working.

_____ kJ mol^{-1} [2]

(v) Using your answer to **(iv)**, state **with a reason** whether this reaction is exothermic or endothermic.

_____ [1]

[Turn over

5 **(a)** There are three main steps in the production of sulfuric acid via the Contact process.
Stage 2 of the process involves a reversible reaction between sulfur dioxide and oxygen.

(i) Define the term **reversible reaction**.

_____ [1]

(ii) Write a balanced symbol equation for the reversible reaction between sulfur dioxide and oxygen.

_____ [2]

(iii) Reversible reactions can establish dynamic equilibrium if the system is closed.
Assuming dynamic equilibrium is reached, state and explain the effect of an increase in pressure on the yield in Stage 2 of the Contact process.

_____

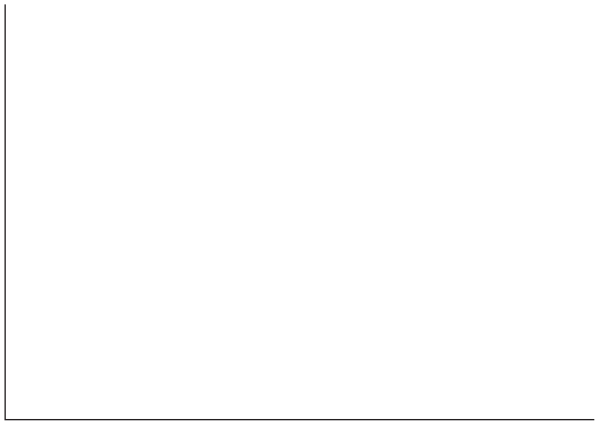
_____

_____

_____ [2]

(iv) Stage 2 in the Contact process involves an exothermic reaction.

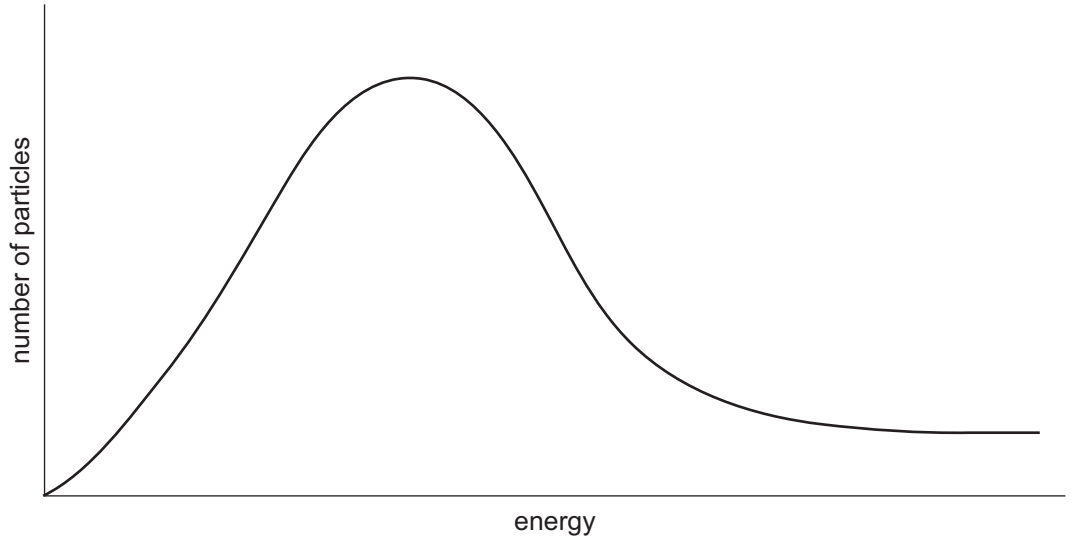
On the axes below, draw the reaction profile diagram you would expect for this reaction.
Label the axes.



[3]

[Turn over

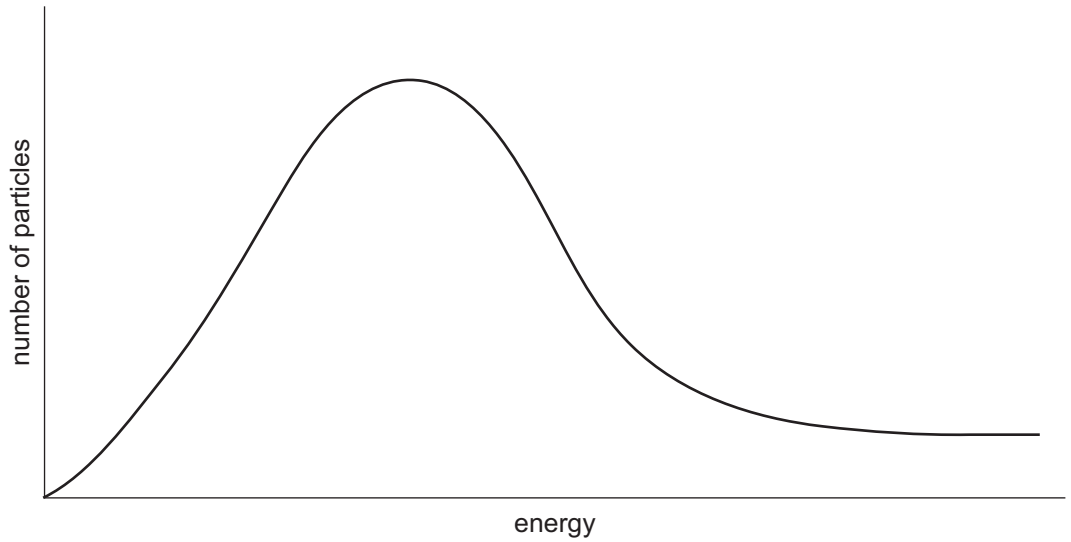
(b) The Maxwell–Boltzmann distribution of molecular energies in the reaction mixture for stage 2 of the Contact process at 450°C is shown below.



(i) Sketch on the axes above the distribution of molecular energies for the reaction at a temperature of **550°C**.

[3]

(ii) On the x-axis below, mark an approximate position for the activation energy (E_A).



[1]

(iii) Using the Maxwell–Boltzmann distribution curve and with reference to activation energy, explain what effect adding a catalyst has on the rate of formation of the product.

[3]

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

Examiner Number

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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

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Rewarding Learning

11409.02

Subject Code: 0008

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

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