

# CHEMISTRY

## Higher Level

(date)

Paper 2

2 hours 15 minutes

A

Candidate name:	Candidate Category and Number:							

This examination paper consists of 2 sections, Section A and Section B.  
The maximum mark for Section A is 40.  
The maximum mark for Section B is 50.  
The maximum mark for this paper is 90.

**INSTRUCTIONS TO CANDIDATES**

Write your candidate name and number in the boxes above.

Do NOT open this examination paper until instructed to do so.

Section A: Answer ALL of Section A in the spaces provided.

Section B: Answer TWO questions from Section B. You may use lined pages at the end of this paper or attach extra sheets of paper with your candidate number clearly marked at the top.

At the end of the examination, complete box B with the number of the questions answered in Section B.

**B**

QUESTIONS ANSWERED	
A/ALL	
B/	
B/	
No. of extra sheets attached	

**C**

EXAMINER	MODERATOR
/40	/40
/25	/25
/25	/25
TOTAL /90	TOTAL /90

**D**

IBCA
/40
/25
/25
TOTAL /90

### EXAMINATION MATERIALS

Required:

Calculator

Chemistry Data Booklet

Millimetre square graph paper

Allowed:

A simple translating dictionary for candidates not working in their own language.

## SECTION A

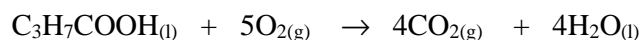
Answer ALL questions.

In order to receive full credit in Section A, the method used and the steps involved in arriving at your answer must be shown clearly. It is possible to receive partial credit but, without your supporting work, you may receive little credit. For numerical calculations, you are expected to pay proper attention to significant figures.

1.

Substance	Standard Enthalpy of Formation, $\Delta H_f^\circ$ / kJ mol <sup>-1</sup>	Absolute Entropy, $S^\circ$ , / J mol <sup>-1</sup> K <sup>-1</sup>
C <sub>(s)</sub>	0.0	5.7
CO <sub>2(g)</sub>	- 393.5	213.6
H <sub>2(g)</sub>	0.0	130.6
H <sub>2</sub> O <sub>(l)</sub>	- 285.9	69.9
O <sub>2(g)</sub>	0.0	205.0
C <sub>3</sub> H <sub>7</sub> COOH <sub>(l)</sub>		226.3

The enthalpy change for the combustion of butanoic acid at 25°C is – 2183.5 kJ mol<sup>-1</sup>. The combustion reaction is :



- (a) Write the balanced equation for the formation of butanoic acid from its elements. [1]

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- (b) Using the above data, calculate the standard enthalpy of formation,  $\Delta H_f^\circ$ , for butanoic acid. [3]

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(This question continues on the following page)

*(Question 1 continued)*

- (c) Calculate the standard entropy change,  $\Delta S^\circ_f$ , for the formation of butanoic acid at 25°C. [3]

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- (d) Calculate the standard free energy of formation,  $\Delta G^\circ_f$ , for butanoic acid at 25°C. [2]

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- (e) Is this reaction spontaneous at 25°C? Explain your answer. [1]

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**Turn over**

2. (a)  $\text{C}_{20}\text{H}_{41}\text{OH}$  is the formula of an alcohol.

(i) State and explain whether the alcohol is a solid, liquid or a gas at room temperature. [2]

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(ii) Dodecanol is only slightly soluble in water. Explain this property. [2]

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(b) The  $\text{BF}_3$  molecule has a trigonal plane (planar triangle) shape while the  $\text{NF}_3$  molecule is a trigonal pyramid (triangular pyramid). Explain this difference. [2]

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(c) Draw a diagram that represents the correct geometry of the  $\text{BF}_3$  molecule and state its shape. [2]

(d) Give the number and types of bonds between the two carbon atoms in a  $\text{C}_2\text{H}_2$  molecule. [2]

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3. Dinitrogen tetroxide,  $\text{N}_2\text{O}_4$ , decomposes endothermically according to the following equation:



- (a) Give the equilibrium constant expression,  $K_c$ , for the above reaction. [1]

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- (b) 1 mol of  $\text{N}_2\text{O}_4$  was placed in a  $1.00 \text{ dm}^3$  evacuated flask at  $25^\circ\text{C}$ . The flask was stoppered and equilibrium was allowed to establish at this temperature. State whether the yield of  $\text{NO}_2$  will increase, decrease or remain the same when equilibrium is re-established after each of the following independent changes. Give a brief explanation in each case.

- (i) More  $\text{N}_2\text{O}_4$  is added to the equilibrium mixture in the flask. [2]

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- (ii) The pressure on the system is increased. [2]

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- (iii) A catalyst is added to the system. [2]

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*(This question continues in the following page)*

**Turn over**

(Question 3 continued)

- (c) The 1 mol of  $\text{N}_2\text{O}_4$  in the flask at  $25^\circ\text{C}$  became 0.8 mol of  $\text{N}_2\text{O}_4$  when equilibrium had been established.  
Calculate:

- (i) the mols of  $\text{NO}_2$  present at equilibrium. [1]

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- (ii) the numerical value of  $K_c$  with its units. [2]

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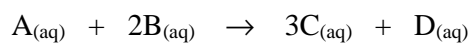
- (d) State and explain the effect on the value of  $K_c$  if the temperature of the reaction were raised to  $100^\circ\text{C}$ . [2]

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4. The following data were obtained for the reaction between A and B:



Experiment	Initial concentration of reactants ( $\text{mol dm}^{-3}$ )		Initial rate of reaction ( $\text{mol dm}^{-3} \text{ hr}^{-1}$ )
	A	B	
1	0.200	0.200	0.50
2	0.400	0.200	2.00
3	0.400	0.800	8.00

- (a) Give the order with respect to A. [1]

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- (b) Give the order with respect to B. [1]

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- (c) Write the rate expression for this reaction. [1]

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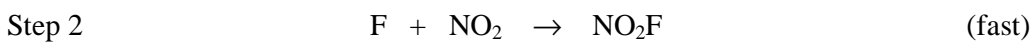
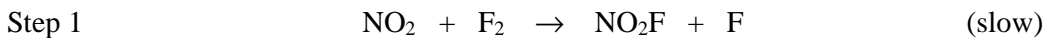
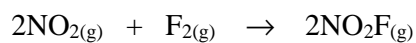
- (e) Using the data from the first experiment, calculate the value of the rate constant and give its units. [1]

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5. Evidence suggests that reaction between the gases nitrogen dioxide and fluorine is a two-step process:



- (a) State and explain which step is the rate determining step. [1]

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- (b) State and explain which of the two steps is expected to have the higher activation energy. [2]

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- (c) Give the rate expression of the reaction based on your answer to (a) [1]

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## SECTION B

Answer TWO of the following questions in this section. You may use the lined pages at the end of this paper or attach extra sheets of paper with your candidate number clearly marked at the top.

6. Use the modern theory of the atom to answer each of the following.

- (a) List the *d*, *f*, *p*, and *s* orbitals in order of **increasing** relative energy. [2]
- (b) Give the **number** of each type of orbital, *d*, *f*, *p* and *s* at each energy level. [2]
- (c) Describe the changes which occur when hydrogen produces a line spectrum. [2]
- (d) Explain why the electron configuration of the nitrogen atom is written as N:  $1s^2 2s^2 2p^1 2p^1 2p^1$  rather than N:  $1s^2 2s^2 2p^2 2p^1 2p^0$ .  
Write the electron configuration of titanium. [3]
- (e) (i) Name the instrument used to determine the atomic masses of the two naturally occurring isotopes of gallium. Briefly describe each step involved in the operation of the instrument. [6]
- (ii) A certain sample of gallium contains 60% Ga-69 and 40% Ga-71. Give the nuclear structures of these isotopes and calculate the relative atomic mass of gallium in this sample. [4]
- (e) Explain the difference in the two values of ionisation energy for each of the following pairs [6]
  - (i) the 1<sup>st</sup> ionisation energy of beryllium is  $900 \text{ kJ mol}^{-1}$  whereas the 2<sup>nd</sup> ionisation energy of beryllium is  $1757 \text{ kJ mol}^{-1}$ .
  - (ii) the 1<sup>st</sup> ionisation energy of aluminium is  $577 \text{ kJ mol}^{-1}$  whereas the 1<sup>st</sup> ionisation energy of magnesium is  $736 \text{ kJ mol}^{-1}$ .
  - (iii) the 1<sup>st</sup> ionisation energy of aluminium is  $577 \text{ kJ mol}^{-1}$  whereas the 1<sup>st</sup> ionisation energy of boron is  $799 \text{ kJ mol}^{-1}$ .

Turn over

7. This question is concerned with acids and bases.

- (a) Some of the active ingredients in commercial antacids are  $\text{NaHCO}_3$ ,  $\text{Al}(\text{OH})_3$ , and  $\text{CaCO}_3$ .
- Explain why  $\text{NaHCO}_3$  could be described as both a Brønsted-Lowry base and a Lewis base. Which of these two descriptions applies to  $\text{CaCO}_3$ ? [3]
  - Write balanced equations showing the reactions that occur when excess stomach acidity, represented by the formula  $\text{HCl}$ , is decreased by each antacid. [4]
  - Calculate the number of moles of antacid present in 1 gram of each sample and hence compare their neutralising power. [6]
  - Give **two** reasons why these antacids are used in preference to sodium hydroxide. [2]
- (b) Zinc hydroxide is a white solid that reacts with both strong acids and strong bases.
- What name is given to this type of behaviour? [1]
  - Write ionic equations for the reaction of zinc hydroxide with strong acid and strong base. Give another example of a compound which exhibits this behaviour. [5]
  - Define a Lewis acid. Explain why transition metal ions can function as Lewis acids and give an equation to support your answer. [4]

8. (a) (i) Use the data in the table below to identify the type of bonding in each of the chlorides listed and state how the given properties depend on the type of bonding. Support your answer with appropriate diagrams. [9]

Chloride	m.p./K	b.p./K
Sodium chloride	1074	1686
Aluminium chloride	451 <sub>sublimes</sub>	
Phosphorus(III) chloride	161	349

- Describe how the chlorides behave when added to water. Give equations for any reactions which occur. [5]
- (b) (i) State the bonding in the oxides of sodium, magnesium, silicon and phosphorus. [4]
- What happens to the pH of pure water when these oxides are added to separate samples of the water? Give equations for any reactions which occur. [7]

9. (a) A compound **C** with an empirical formula of  $\text{C}_4\text{H}_{10}\text{O}$  has a mass spectrum which includes peaks at 74 and 59 and an infrared spectrum with a band at  $3230\text{--}3350\text{ cm}^{-1}$ .  
Use this data to;
- (i) determine, with reasoning, the molecular formula of **C**. [2]
  - (ii) account for the peak at 59. [1]
  - (iii) identify the functional group giving the band at  $3230\text{--}3350\text{ cm}^{-1}$ . [1]
- (b) **C** reacts with acidified dichromate(VI) to produce an organic acid. Give the **two** possible structural formulae of **C**. [2]
- (c) When **C** is dehydrated it gives a compound **D** which has an infrared spectrum with a band at  $1620\text{--}1680\text{ cm}^{-1}$ .  
Use this data to;
- (i) identify the functional group present. [1]
  - (ii) give **two** possible structural formulae of **D**. [2]
  - (iii) give the **four** possible structures of the compound formed when **D** reacts with hydrogen chloride. [3]
- (d) **D** actually forms **E**,  $\text{CH}_3\text{C}(\text{Cl})(\text{CH}_3)\text{CH}_3$ , when it reacts with hydrogen chloride. Which structural formulae of **D** produces **E**? [1]
- (e) **E** is hydrolysed with  $\text{OH}^-$  ions to produce **F** by an  $\text{S}_{\text{N}}1$  mechanism.
- (i) What is meant by an  $\text{S}_{\text{N}}1$  mechanism? [3]
  - (ii) Why does an  $\text{S}_{\text{N}}1$  rather than an  $\text{S}_{\text{N}}2$  mechanism occur? [3]
  - (iii) Give the stepwise mechanism for the conversion of **E** to **F**. [5]
- (f) State and explain whether or not **F** reacts with acidified dichromate(VI). [1]