



**CHEMISTRY**

**Higher Level**

Thursday 6 May 1999 (afternoon)

**KEY**

*Subm.*

Paper 2

2 hours 15 minutes

A

Candidate name:	Candidate category & 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 the 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 below with the number of the questions answered in Section B.

**B**

QUESTIONS ANSWERED	
A/ ALL	
B/	
B/	
Number of extra sheets attached	

**C**

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

**D**

IBCA
/40
/25
/25
TOTAL
/90

**EXAMINATION MATERIALS**

Required:

Calculator

Chemistry Data Booklet

Millimetre square graph paper

Allowed:

A simple translating dictionary

## SECTION A

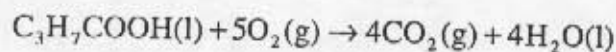
Answer ALL questions.

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.

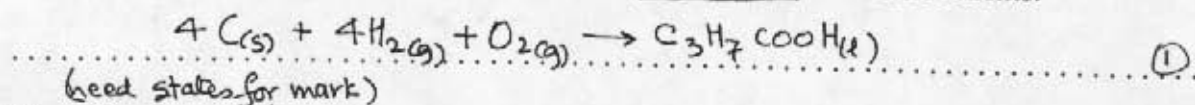
Substance	Standard Enthalpy of Formation, $\Delta H_f^\circ$ / $\text{kJ mol}^{-1}$	Absolute Entropy, $S^\circ$ , / $\text{J mol}^{-1} \text{K}^{-1}$
C(s)	0.0	5.7
CO <sub>2</sub> (g)	-393.5	213.6
H <sub>2</sub> (g)	0.0	130.6
H <sub>2</sub> O(l)	-285.9	69.9
O <sub>2</sub> (g)	0.0	205.0
C <sub>3</sub>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

The enthalpy change for the combustion of butanoic acid at 25° C is  $-2183.5 \text{ kJ mol}^{-1}$ . The combustion reaction is:



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

[1]



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

[3]

.....  $\Delta H_{\text{rxn}}^\circ = \sum \Delta H_{\text{f,p}}^\circ - \sum \Delta H_{\text{f,R}}^\circ$  ..... (1)  
 .....  $\therefore -2183.5 \text{ kJ} = [4(-393.5) + 4(-285.9)] - [\Delta H_f^\circ + 5(0)]$  ..... (1)  
 .....  $= [(-1574) + (-1143.6)] - \Delta H_f^\circ$  .....  
 .....  $\therefore = -2717.6 - \Delta H_f^\circ$  .....  
 .....  $\therefore \Delta H_f^\circ = (2183.5 \text{ kJ} - 2717.6) \text{ kJ}$  .....  
 .....  $= -534.1 \text{ kJ (or kJ mol}^{-1}\text{)}$  ..... (1)

can be  
implicit  
in step 2.

(This question continues on the following page)

(Question 1 continued)

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

$$\begin{aligned}\Delta S^\circ &= \sum S^\circ_f - \sum S^\circ_R = S^\circ_{BA} - (4S^\circ_C + 4S^\circ_{H_2} + S^\circ_{O_2}) \quad (1) \quad (1) \\ &= (226.3) - (4(5.7) + 4(130.6) + 205.0) \text{ J mol}^{-1} \text{ K}^{-1} \quad (1) \\ &= -523.9 \frac{\text{J}}{\text{mol K}} \text{ OR } -0.5239 \frac{\text{kJ}}{\text{mol K}} \quad (1)\end{aligned}$$

If units in (b) & or (c) are wrong/omitted penalise by 1 mark (U-1))

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

$$\begin{aligned}\Delta G^\circ &= \Delta H^\circ - T\Delta S^\circ \quad (\text{can be implicit in next step}) \\ &= -534.1 \frac{\text{kJ}}{\text{mol}} - 298\text{K}(-0.5239 \frac{\text{kJ}}{\text{mol K}}) \quad (1)\end{aligned}$$

$$= -378.0 \text{ kJ (mol}^{-1}\text{)} \quad (1)$$

(no double jeopardy if  $\Delta H$  or  $\Delta S$  incorrect)

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

Since  $\Delta G^\circ$  is negative, it is spontaneous at 25° C. (1)

(no double jeopardy if  $\Delta G = +$  in d; then non-spontaneous)

(Answers to (b), (c), (d) must be consistent with 2(a) for full marks)

2. (a)  $C_{20}H_{41}OH$  is the formula of an alcohol.

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

A solid (no mark for liquid) ①  
 OR  
 Relatively large vander Waals / intermolecular forces ①  
 because of the very large size of the R group ①  
 (must have some discussion of bonding forces)

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

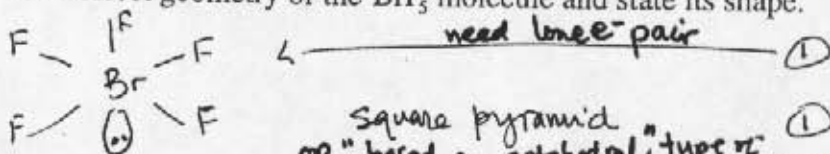
The large number of C-C and C-H bonds ①  
 OR the long non-polar chain ①  
 Outweighs the polar -OH (responsible for ①  
 H-bonding with water)  
 → comments in brackets not required to score mark

(b) The  $BF_3$  molecule has a trigonal plane (planar triangle) shape while the  $NF_3$  molecule is a trigonal pyramid (triangular pyramid). Explain this difference. [2]

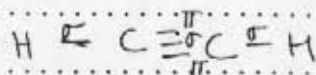
$BF_3$  has (only) three pairs of electrons ①  
 around central B atom (arranged as far apart as possible, thus trigonal planar)  
 $NF_3$  has four pairs of electrons (3 bonded + 1 lone pair) ①  
 around central N atom

OR explanation in terms of  $sp^2/sp^3$

(c) Draw a diagram that represents the correct geometry of the  $BrF_5$  molecule and state its shape. [2]



(d) Give the number and types of bond between the two carbon atoms in a  $C_2H_2$  molecule. [2]

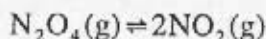


one (sp)  $\sigma$  bond ①  
 and two  $\pi$  bonds ①

(only 1 mark if answer is: triple bond)  
 or  $1\sigma/\pi = 1$

if "double", then 0.

- 3 Dinitrogen tetroxide,  $N_2O_4$ , decomposes endothermically according to the following equation:



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

[1]

$K_c = \frac{[NO_2]^2}{[N_2O_4]}$  ; need square brackets for mark (1)

- (b) 1 mol of  $N_2O_4$  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 be established at this temperature. State whether the yield of  $NO_2$  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  $N_2O_4$  is added to the equilibrium mixture in the flask.

[2]

$[NO_2]$  increases or yield decreases (1)  
 Equilibrium is disturbed; shifts to the right to use up (1)  
 Some of the  $N_2O_4$  added (Le Chatelier's principle).  
 OR Since  $[N_2O_4]$  increases and  $K_c$  is constant ( $[NO_2]$  increases)

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

[2]

$[NO_2]$  decreases or yield decreases (1)  
 Increased  $P$  favours smaller volume, thus equilibrium shifts to the left (1)

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

[2]

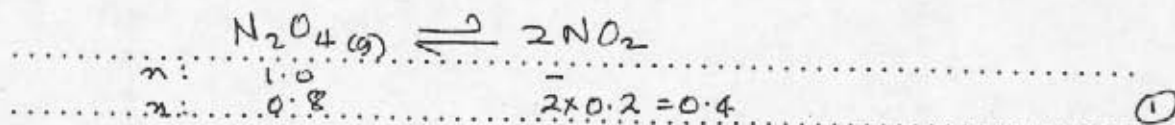
$[NO_2]$  is unchanged or yield unchanged (1)  
 Catalyst affects rate of both forward and backward rxns equally (1)  
 OR Catalyst does not affect position of equilibrium because...



(Question 3 continued)

- (c) The 1 mol of  $N_2O_4$  in the flask at  $25^\circ C$  became 0.8 mol of  $N_2O_4$  when equilibrium had been established.  
Calculate;

- (i) the mols of  $NO_2$  present at equilibrium. [1]



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

$$\begin{aligned}
 K_c &= \frac{(0.4)^2}{0.8} \\
 &= 0.2 \text{ mol dm}^{-3}
 \end{aligned}$$

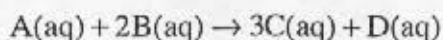
1/8 error in (i)  
no double jeopardy;

1/8 [mol] = 0.2,  
then  $K_c = 0.05$

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

Forward reaction is endothermic, forward rxn  
favoured (or equilibrium move to the right) to use up  
some of the heat provided  
 $\therefore K_c$  increases.

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] doubles, rate up by 4  
 $\therefore \text{rate} \propto [\text{A}]^2$

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

2

[B] increases by 4  
 rate increases by 4  $\therefore 1^{\text{st}} \text{ order}$   
 $\text{rate} \propto [\text{B}]^1$  (1)

[1]

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

1

(1)

[1]

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

$\text{rate} = k[\text{A}]^2[\text{B}]^1$  ; need sq brackets for multi (1)

[1]

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

no double jeopardy if (c) is incorrect

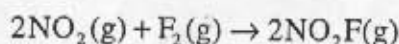
$$0.50 \frac{\text{mol}}{\text{dm}^3 \text{ h}} = k (0.2)^2 (0.2) \frac{\text{mol}^3}{\text{dm}^9}$$

$$\therefore k = 62.5 (\text{dm}^6 \text{ mol}^{-2} \text{ h}^{-1})$$

(1)

[1]

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



Step 1  $\text{NO}_2 + \text{F}_2 \rightarrow \text{NO}_2\text{F} + \text{F}$  (slow)

Step 2  $\text{F} + \text{NO}_2 \rightarrow \text{NO}_2\text{F}$  (fast)

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

[1]

Step 1 since it is the slow step (1)  
 (need explanation for mark)

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

[2]

Step 1 (1)  
 It is the slow step, therefore has a higher activation energy compared to step 2. (1)

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

{1}

rate =  $k[\text{NO}_2]^1[\text{F}_2]^1$  ; need [ ] for mark (1)  
 (no double jeopardy if answer in (a) is incorrect,  
 then accept appropriate answer.)



## SECTION B

Answer TWO of the 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:  $1s^2 2s^2 2p^2 2p^1 2p^0$ . [3]  
Write the electron configuration of titanium.
- (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]
- (f) Explain the difference in the two values of ionisation energy for each of the following pairs: [6]
  - (i) the 1st ionisation energy of beryllium is  $900 \text{ kJ mol}^{-1}$  whereas the 2nd ionisation energy of beryllium is  $1757 \text{ kJ mol}^{-1}$ .
  - (ii) the 1st ionisation energy of aluminium is  $577 \text{ kJ mol}^{-1}$  whereas the 1st ionisation energy of magnesium is  $736 \text{ kJ mol}^{-1}$ .
  - (iii) the 1st ionisation energy of aluminium is  $577 \text{ kJ mol}^{-1}$  whereas the 1st ionisation energy of boron is  $799 \text{ kJ mol}^{-1}$ .

7. This question is concerned with acids and bases.

- (a) Some of the active ingredients in commercial antacids are  $\text{NaHCO}_3$ ,  $\text{Al(OH)}_3$ , and  $\text{CaCO}_3$ .
- (i) 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]
  - (ii) Write balanced equations showing the reactions that occur when excess stomach acidity, represented by the formula  $\text{HCl}$ , is decreased by each antacid. [4]
  - (iii) Calculate the number of moles of antacid present in 1 gram of each sample and hence compare their neutralising power. [6]
  - (iv) 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.
- (i) What name is given to this type of behaviour? [1]
  - (ii) 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]
  - (iii) 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

- (ii) 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]
- (ii) 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]

- (a) A compound **C** with an empirical formula of  $C_4H_{10}O$  has a mass spectrum which includes peaks at 74 and 59 and an infrared spectrum with a band at  $3230-3350\text{ cm}^{-1}$ .  
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  $3230-3350\text{ cm}^{-1}$ . [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  $1620-1680\text{ cm}^{-1}$ .  
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**,  $CH_3C(Cl)(CH_3)CH_3$ , when it reacts with hydrogen chloride. Which structural formulae of **D** produces **E**? [1]
- (e) **E** is hydrolysed with  $OH^-$  ions to produce **F** by an  $S_N1$  mechanism.
- (i) What is meant by an  $S_N1$  mechanism? [3]
  - (ii) Why does an  $S_N1$  rather than an  $S_N2$  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]
-



## SECTION B

Answer TWO of the 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.

- List the  $d, f, p$  and  $s$  orbitals in order of increasing relative energy. [2]
- Give the number of each type of orbital,  $d, f, p$  and  $s$  at each energy level. [2]
- Describe the changes which occur when hydrogen produces a line spectrum. [2]
- Explain why the electron configuration of the nitrogen atom is written as  $N: 1s^2 2s^2 2p^3$  rather than  $N: 1s^2 2s^2 2p^2 2p^1$ . Write the electron configuration of titanium. [3]
- 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]
  - 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]
  - Explain the difference in the two values of ionisation energy for each of the following pairs: [6]
    - the 1st ionisation energy of beryllium is  $900 \text{ kJ mol}^{-1}$  whereas the 2nd ionisation energy of beryllium is  $1757 \text{ kJ mol}^{-1}$ .
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    - the 1st ionisation energy of aluminium is  $577 \text{ kJ mol}^{-1}$  whereas the 1st ionisation energy of boron is  $799 \text{ kJ mol}^{-1}$ .

- $s, p, d, f$   
1 error, for examples  $s, p, f, d$  or  $p, s, d, f$  deduct 1 mark  
 $p, s, f, d$  0 marks

[2 marks]

- $d = 5, f = 7, p = 3, s = 1$

4 correct [2 marks]

2 or 3 correct [1 mark]

1 correct [0 marks]

[1 mark]

[1 mark]

[1 mark]

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[1 mark]

(c) { electrons move (to lower) energy levels/orbitals  
emitting energy as they do so  
any 3 { excitation and/or promotion to higher energy level

(d) Fill singly before doubling  
since two electrons in the same orbital will repel  
Ti  $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^2$  or  $[Ar] 3d^2 4s^2$  or reversed

(e) (i) Mass spectrometer.  
A sample of naturally occurring gallium vapour  
is injected into the evacuated ionising chamber where an electron  
beam ionises a part of the sample by knocking electrons from the  
neutral atoms or molecules.  
Charged plates accelerate the positive ions towards the detector  
and the ions pass through a magnetic field perpendicular to their  
path  
where the charged ions are separated (deflected) into different  
paths.  
The detector detects the paths according to the masses of the  
particles. **Accept labelled diagram + adequate explanation.**  
Any five points from the six given.

(ii) Ga-69 31p 38n  
Ga-71 31p 40n  
 $(60 \times 69) + (40 \times 71)$   
100  
69.8

(f) (i) removed from a positively charged ion,  $Be^+(g)$ , whereas  
the first electron is removed from a neutral atom,  $Be(g)$ .

(ii) 1st electron is removed from a full sub-orbital; 2nd electron is  
removed from a singly occupied sub-orbital, gains [1 mark] only

(iii) Electron from 3p in Al but  
electron from 3s in Mg  
which is of lower energy

(iv) Electron from 4p in B  
Electron from 3p in Al

The latter is further from the nucleus / the former is nearer to the  
nucleus

The latter is further from the nucleus / the former is nearer to the  
nucleus

The latter is further from the nucleus / the former is nearer to the  
nucleus

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nucleus



7. This question is concerned with acids and bases.

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- (i) 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]
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- (iii) Calculate the number of moles of antacid present in 1 gram of each sample and hence compare their neutralising power. [6]
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- (ii) 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]
- (iii) Define a Lewis acid. Explain why transition metal ions can function as Lewis acids and give an equation to support your answer. [4]

- (a) (i)  $\text{NaHCO}_3$ ; Brønsted-Lowry base because proton acceptor, Lewis base because electron pair donor.  $\text{CaCO}_3$ ; Both. [1 mark] [1 mark] [1 mark]

*need for mark*

- (ii)  $\text{HCO}_3^- + \text{H}^+ \rightarrow \text{H}_2\text{O} + \text{CO}_2$  OR  $\text{NaHCO}_3 + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$ ; If  $\text{H}_2\text{CO}_3 \rightarrow$  no mark [1 mark]

- $\text{Al}(\text{OH})_3 + 3\text{H}^+ \rightarrow \text{Al}^{3+} + 3\text{H}_2\text{O}$  OR  $\text{Al}(\text{OH})_3 + 3\text{HCl} \rightarrow \text{AlCl}_3 + 3\text{H}_2\text{O}$  [1 mark]

- OR  $\text{Al}(\text{OH})_3 + (\text{H}_2\text{O})_3 + 3\text{H}^+ \rightarrow [\text{Al}(\text{H}_2\text{O})_6]^{3+}$  [1 mark]

*1 for correct species [2 marks] 1 for balanced eq.*

- $\text{CaCO}_3 + 2\text{H}^+ \rightarrow \text{Ca}^{2+} + \text{H}_2\text{O} + \text{CO}_2$  OR  $\text{CaCO}_3 + 2\text{HCl} \rightarrow \text{CaCl}_2$  [1 mark]

*If  $\text{H}_2\text{CO}_3$  again, no penalty*

- (iii)  $n_{\text{NaHCO}_3} = 1 \text{ g} \times \frac{1 \text{ mol}}{84 \text{ g mol}^{-1}} = 0.012$  [1 mark]

- $n_{\text{Al}(\text{OH})_3} = 1 \text{ g} \times \frac{1 \text{ mol}}{78 \text{ g mol}^{-1}} = 0.013$  [1 mark]

- $n_{\text{CaCO}_3} = 1 \text{ g} \times \frac{1 \text{ mol}}{100 \text{ g mol}^{-1}} = 0.010$  [1 mark]

- $\text{Al}(\text{OH})_3$  reacts with 3 mol of  $\text{H}^+$  so it is more effective than  $\text{CaCO}_3$  which reacts with 2 mol of  $\text{H}^+$  which is more effective than  $\text{NaHCO}_3$  which reacts with 1 mol of  $\text{H}^+$  [3 marks]

- OR  $\text{Al}(\text{OH})_3$  best;  $\text{CaCO}_3$  worst [1 mark]

*3 a further 2 marks if justified making  $\text{NaHCO}_3$  worst } has been used to explain the rest of the order*

Note: If order is wrong look for consequential marking

- (iv)  $\text{NaOH}$  is a strong alkali [1 mark]

- damages body tissues / corrosive to body [1 mark]

- (b) (i) antipruritic [1 mark]

*except other answer on merit*

- (ii)  $\text{Zn}(\text{OH})_2 + 2\text{H}^+ \rightarrow \text{Zn}^{2+} + 2\text{H}_2\text{O}$  [2 marks]

- $\text{Zn}(\text{OH})_2 + 2\text{OH}^- \rightarrow \text{Zn}(\text{OH})_4^{2-}$  (OR  $\text{ZnO}_2^{2-} + 2\text{H}_2\text{O}$ ) [2 marks]

- OR  $\text{H}_2\text{O}$   $\text{Al}(\text{OH})_3$  /  $\text{Pb}(\text{OH})_2$  /  $\text{Sn}(\text{OH})_2$  /  $\text{M}_2\text{O}_3$  /  $\text{Cr}(\text{OH})_3$  [1 mark]

- (iii) Electron pair acceptor. [1 mark]

- They have available / empty orbitals. [1 mark]

*Equation need not be balanced*  $\text{e.g. } \text{Cu}^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4]^{2+}$  ;  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$  [2 marks]

*Choice of base 1, formula of complex 1*  $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$  with Total [25 marks] acceptable. [2 marks]

- (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.

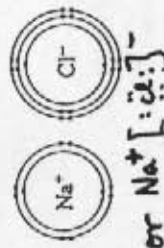
Chloride	m.p./K	b.p./K
Sodium chloride	1074	1686
Aluminium chloride	451 <sub>sublimes</sub>	
Phosphorus(III) chloride	161	349

- (ii) Describe how the chlorides behave when added to water. Give equations for any reactions which occur.
- (b) (i) State the bonding in the oxides of sodium, magnesium, silicon and phosphorus.
- (ii) 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.

8. (a) (i) NaCl – high melting and boiling points

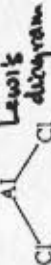
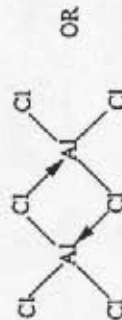
- giant structure/ionic
- strong attraction between ions

[9]



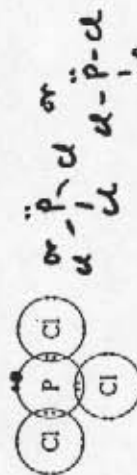
$\text{Al}_2\text{Cl}_6$  – low melting and boiling points – simple molecular/covalent

- associated or weak forces between individual molecules



$\text{PCl}_3$  – low melting and boiling points

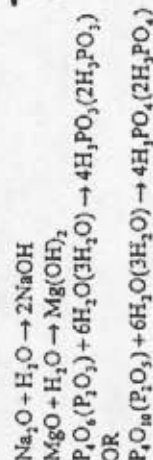
- simple molecular/covalent
- weak forces between individual molecules



- (ii) NaCl dissolves (don't accept dissociates)  
 $\text{AlCl}_3$ , vigorous reaction with water (exothermic/gaseous evolved)  
 $\text{PCl}_3$ , gives vigorous reaction with water evolved "fumes"  
 $\text{AlCl}_3 + 3\text{H}_2\text{O} \rightarrow \text{Al}(\text{OH})_3 + 3\text{HCl}$   
 $\text{PCl}_3 + 3\text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_3 + 3\text{HCl}$

- (b) (i) ionic, ionic, ~~gives~~ covalent, covalent

- (ii) strong alkali, weak alkali, nothing, acid  
 OR  
 high pH pH above 7 7 below 7



give mark if product is correct

Total [25 marks]

(a) A compound C with an empirical formula of  $C_4H_{10}O$  has a mass spectrum which includes peaks at 74 and 59 and an infrared spectrum with a band at  $3230-3350\text{ cm}^{-1}$ . Use this data to:

(i) determine, with reasoning, the molecular formula of C.

(ii) account for the peak at 59.

(iii) identify the functional group giving the band at  $3230-3350\text{ cm}^{-1}$ .

(b) C reacts with acidified dichromate(VI) to produce an organic acid. Give the two possible structural formulae of C.

(c) When C is dehydrated it gives a compound D which has an infrared spectrum with a band at  $1620-1680\text{ cm}^{-1}$ . Use this data to:

(i) identify the functional group present.

(ii) give two possible structural formulae of D.

(iii) give the four possible structures of the compound formed when D reacts with hydrogen chloride.

(d) D actually forms E,  $CH_3C(Cl)(CH_3)CH_3$ , when it reacts with hydrogen chloride. Which structural formulae of D produces E?

(e) E is hydrolysed with  $OH^-$  ions to produce F by an  $S_N1$  mechanism.

(i) What is meant by an  $S_N1$  mechanism?

(ii) Why does an  $S_N1$  rather than an  $S_N2$  mechanism occur?

(iii) Give the stepwise mechanism for the conversion of E to F.

(f) State and explain whether or not F reacts with acidified dichromate(VI).

Therefore molecular formula =  $C_4H_{10}O$

(ii) Removal of  $CH_3$  /  $C_3H_7O^+$  is present

(iii) OH

(b)  $CH_3CH_2CH_2CH_2OH$

$CH_3-CH-CH_3$   
 $CH_2OH$

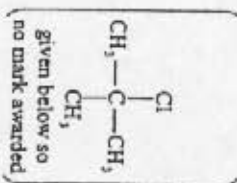
(c) (i)  $C=C$

(ii)  $CH_3CH_2CH=CH_2$

$CH_3-CH-CH_3$   
 $CH_2$

(iii)  $CH_3CH_2CH(Cl)CH_3$   
 $CH_3CH_2CH_2CH_2Cl$

$CH_3-CH-CH_3$   
 $CH_2Cl$



given below so  
no mark awarded

(d)  $CH_3-C(=O)-CH_3$

$CH_3$

(e) (i) substitution

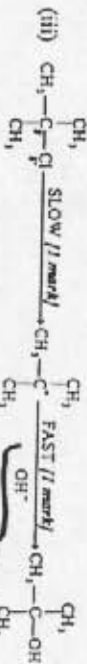
nucleophilic

1st order/unimolecular

(ii) Steric effects of  $CH_3$

$CH_3$  electron releasing

The  $(CH_3)_3C^+$  ion is stable



polarity  
(1 mark)

(1 mark)  $OH^-$  ion + product (1 mark)

[5 marks]

(f) A tertiary alcohol cannot be oxidised.

If candidate has given a lot of detail in part (e)(i), carry forward credit to e(ii) where appropriate.

Total [25 marks]

The phrasing of the question may lead candidates to offer more than one answer. Give credit for correct answer - if more the rest

[3 marks]

[1 mark]

[1 mark]

[1 mark]

[1 mark]

[1 mark]

[1 mark]

[1 mark]

[1 mark]