INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

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CHEMISTRY
HIGHER LEVEL
PAPER 3

Wednesday 17 May 2000 (morning)

1 hour 15 minutes

Name: MASTER KEY

Number:

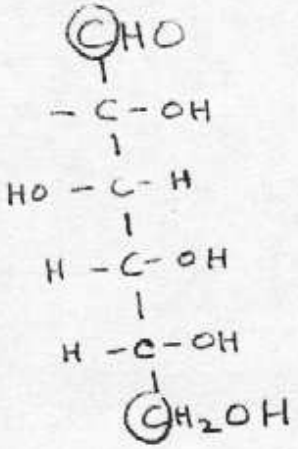
INSTRUCTIONS TO CANDIDATES

- Write your candidate name and number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options in the spaces provided. You may continue your answers in a continuation answer booklet, and indicate the number of booklets used in the box below. Write your name and candidate number on the front cover of the continuation answer booklets, and attach them to this question paper using the tag provided.
- At the end of the examination, indicate the letters of the Options answered in the boxes below.

OPTIONS ANSWERED		EXAMINER	TEAM LEADER	IBCA
		/25	/25	/25
		/25	/25	/25
NUMBER OF CONTINUATION BOOKLETS USED	.....	TOTAL /50	TOTAL /50	TOTAL /50

Option C – Human Biochemistry

C1. (a) (i) Draw the straight-chain formula of glucose and circle a carbon atom in the structure which is **not** chiral. *[2]*

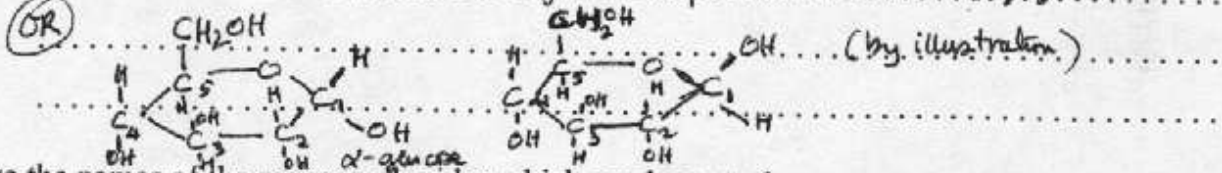


For either circled C : (1)
For the whole structure : (1)
} marks are independent

→ Allow –OH bonded to C chain
→ Do not allow ring structures

(ii) Describe the structural difference between α-glucose and β-glucose. *[2]*

In the ring structure of glucose, on C_1 atom (1)
the H/OH are in different positions in (α/β) glucose (1) (marks are independent)

(OR)  (by illustration)

(b) Give the names of the monosaccharides which condense to form

(i) sucrose; *[2]*

If 3 names given: (1)
If 4 names given: 0
} Glucose and fructose (1) (1)

(ii) starch. *[1]*

glucose (and glucose) (1)

(c) State **one** major function of a polysaccharide in the body. Any one: *[1]*

Read question carefully.

No mark for just "energy"

Food or energy reserves / resources / stores
Structure / cell walls ⇒ Cellulose / Chitin (1)
DO NOT allow cellulose or chitin

plant cell walls
↳ skeletons of some insects are composed of structural polysaccharide called chitin

(energy sources, energy reserves eg. glycogen, and as a precursor for other biologically important molecules)
Allow "precursor for other substances, eg. glycogen or starch

8

C2. (a) How many different tripeptides can be formed using three α-amino acids, glycine, alanine and valine, if each amino acid is used only once in each tripeptide? *[1]*

6 $(3 \times 2 \times 1)$ (1)

(b) (i) Name **two** methods by which an unknown tripeptide can be analysed. *[2]*

Chromatography (1)

Electrophoresis (1)

(ii) For **one** of these methods outline the experimental procedure and give the information which would be needed to identify the individual amino acids. *[4]*

Paper Chromatography: hydrolyse / release amino acids / heat with acid (1)

→ place sample (spot) on paper (1)

→ Place (paper) sample in solvent / solution (or suitable named solvent eg H_2O / $CaHgOH$ / CH_3COOH) (1)

→ Develop

→ Measure distances moved or travelled / R_f values (and comparing) with known values or standards (1)

(1 mark each for any three of the four points:)

OR Electrophoresis: → Hydrolyse / release amino acids / heat with acid (1)

→ "Loading" onto origin / Place sample on paper / gel / origin (1)

→ Apply voltage (1)

→ Develop (1)

→ Measure distances moved / Compare with known isoelectric points (standards) etc (1)

(1 mark each for any three of the four points)

(Solid support is saturated with a buffer sol. of known pH & the sample containing the mixture of amino acids is applied to the centre of the paper.)

(one mark for any 3 of the 4 points)

(c) Alanine, $H_2N-CH(CH_3)-COOH$, has an isoelectric point of 6.0. Write the structural formulas of alanine at pH values 4.5, 6.0 and 7.5. *[3]*

pH = 6.0 $H_3^+N-CH(CH_3)-COO^-$ / $H_2N-CH(CH_3)-COOH$ → (1)

(accept $H_3^+N-COO^-$)

pH 4.5 (more acidic)

$H_3^+N-CH(CH_3)-COOH$

(accept H_3^+N-)

pH 7.5 (more basic)

$H_2N-CH(CH_3)-COO^-$ → (1)

(accept H_2N-COO^-)

(1)

→ If centre part $(-CH(CH_3)-)$ wrong, only penalise once

(10)

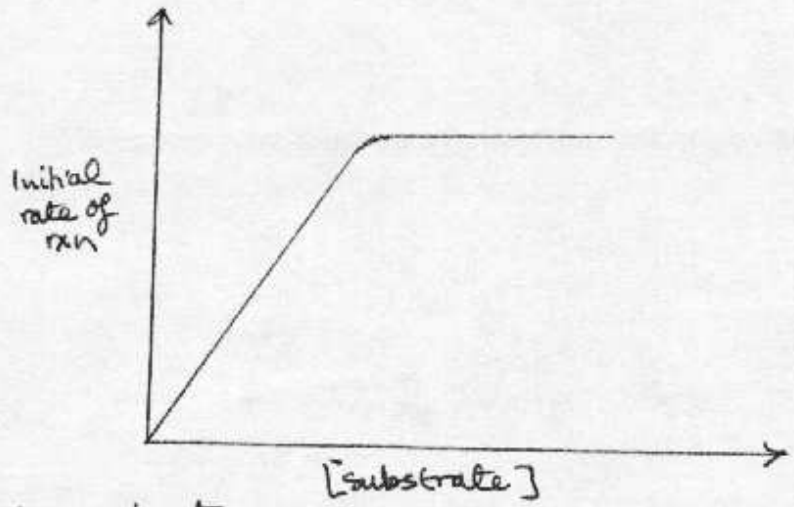
C3. Describe and explain the way in which the activity of an enzyme is influenced by an increase in

(a) substrate concentration; activity / rate increases initially (first order) (1) then flattens out / becomes constant. (1) [3]

(b) temperature. Rate increases initially (1) but then reduces markedly (→ 0) (1) (1) [4]

Labelled graphs, instead of descriptions, may be used to support your answer.

(a)

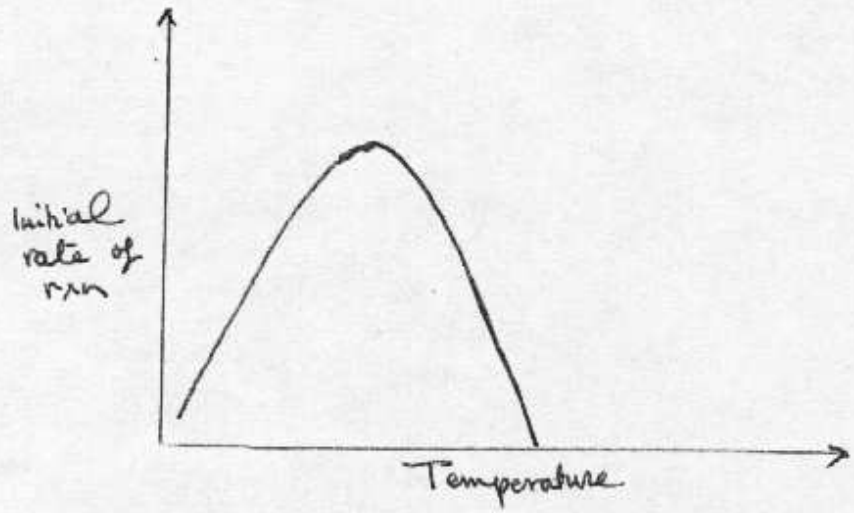


Satisfactory explanation of one region of graph :

Many free active sites available initially (1)

OR Active sites become occupied / become (more) saturated

(b)



increase due to increase in terms of molecules possessing more energy and (1)

decrease enzyme destroyed / denatured (1)

Option D – Environmental Chemistry

D1. (a) For **each** of the air pollutants listed below, state its source and **one** process in which its emission into the atmosphere could be reduced. State the product(s) formed from the pollutant in **one** of the processes. [6]

There are 7 points – Award 6 max marks for any 6 correct points

each worth 1 mark

(i) Carbon monoxide:

Incomplete combustion of C- containing fuel / named fuel (1)

Reduced: Through use of a catalytic converter (1)

Product formed: CO_2 / carbon dioxide

OR Thermal exhaust reactor

(ii) Sulphur dioxide:

Burning sulfur-containing fuel / coal / smelting sulfide ores / volcanoes (1)

Desulfurisation / scrubbing (flue gases) (1)

sulfur / sulfate / H_2S

only any one asked for

(iii) Nitrogen oxides:

Reaction of gases in air / N_2 and O_2 (at high T) (1)

Use a catalytic converter OR Lean burning engines (1)

OR Recirculation of exhaust gases

Product formed (on use of catalytic converter): N_2

(b) Identify **one** gas, from the above list, which contributes to acid rain and write an equation for its reaction with water. [2]

SO_2 or NO_x (1)

$SO_2 + H_2O \rightleftharpoons H_2SO_3$ (1)

OR $2NO + \frac{3}{2}O_2 + H_2O \longrightarrow 2HNO_3$

OR $2NO_2 + \frac{1}{2}O_2 + H_2O \longrightarrow 2HNO_3$

D2. (a) Explain what is meant by *Biological Oxygen Demand* (BOD) and describe the effect of a high BOD in water.

oxygen-demanding wastes

Amount of O_2 needed to break down organic wastes (and NH_3) (1)

(in a given amount of water over a period of time).

Reduced availability of O_2 / fewer living organisms (1)

OWTTE

(b) Identify the stage of sewage treatment which removes the substances responsible for BOD and explain how this is done. [3]

Secondary treatment (1)

Activated sludge process / aeration of bacteria-laden sludge / aeration / bacteria (1)

Organic matter or waste matter broken down or oxidised (1)

(c) Discuss how the addition of nitrates **or** phosphates to water can contribute to the BOD. [2]

Plant growth is encouraged (1)

[Oxygen] is reduced by plant decay / increases BOD (1)

Accept: Eutrophication leading to bodies of water that can die following increase of organic wastes as alternate answers

D3. (a) (i) Explain the meaning of the term LD_{50}. [2]

Lethal dose / amount needed to kill (1)
Amount needed to kill 50% of animals
given the dose / amount needed to kill 50% of population (1)

(ii) State **one** advantage and **one** disadvantage of the use of LD_{50}. [2]

Advantage: Gives good indication of relative toxicities (1)
(of different chemicals)
Disadvantage: Does not indicate acceptable environmental level of (1)
chemical / doesnot help to make accurate assumptions regarding effect on humans / ethical reasons

(b) Lead and nitrates represent a health hazard in polluted water. Identify a source of **each** of these pollutants, state a health hazard caused by **each** pollutant, and indicate a way by which the concentration of **each** can be reduced. [6]

(i) Lead: Source: (lead) paints / TEL OR $Pb(C_2H_5)_4$ in petrol/gasoline/petrol / lead pipes in plumbing (1)
Effect: brain damage (specially in children) / low birth mass / still birth (1)
Reduction: Unlead petrol / lead-free paints / use of Cu or plastic pipes (1)
accept chemical method of reducing [Pb] eg. ion exchange/precipitation

(ii) Nitrates: Source: leaching of nitrate fertilizers into rivers / intensive farming (1)
Effect: (Stomach) cancer / affects haemoglobin (in the young) / (1)
"blue baby" syndrome
Reduction: Use less (nitrate) fertilizer / avoid use before rain is due (1)
Accept tertiary treatment such as algal ponds / ion exchange etc

OR Data based on animals not necessarily applicable to humans
OR Adult data cannot be used for children

Option E – Chemical Industries

E1. (a) Complete the table below to show the conditions used in the Haber and Contact processes, for the manufacture of ammonia and sulphur trioxide, respectively. *[4]*

	HABER	CONTACT
Temperature / °C	400 – 500 °C (accept range) → 1000	400 – 550°C
Pressure / atm	150 – 500 atm	1–2 atm / normal
Identity of catalyst	iron / iron oxide	Vanadium (pent/V) oxide / Vanadium pentoxide / Vanadium(V) oxide

(1) (1) (1)+(1)

For temp & Pressure values: ⇒ 4 correct: (2); 3/2 correct (1); correct (0)

(b) Write a balanced equation for the manufacture of ammonia (ΔH is negative). Explain the choice of the temperature used. *[4]*

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ (+heat) (no penalty) (states not required) (1)

High temperature increases rate / gives greater rate of rxn (1)

But low yield of NH_3 / reverse reaction favoured (1)

Compromise or compromise / optimum / best conditions (1)

→ even though maximum yield of ammonia is not obtained for economical reasons

(c) The hydrogen used in the manufacture of ammonia can be obtained by the process of *reforming*. Give the raw material(s), the conditions and a possible equation for the process. *[3]*

Raw Materials: Naphtha, methane, other hydrocarbons (saturated), electrolysis of water (1)

Conditions: high temperature / heat / catalyst / electrical energy (1)

Accept any equation: $C_7H_8 \rightarrow C_6H_5CH_3 + 4H_2$ (1)

$C_6H_{14} \rightarrow C_6H_6 + 4H_2$

$C_2H_6 \rightarrow C_2H_4 + H_2$ etc

$CH_4 + H_2O \rightarrow CO + 3H_2$

$2H_2O \rightarrow 2H_2 + O_2$

E2. (a) List **two** important factors which should be considered when choosing a location for the manufacture of polythene. [2]

For any transport factor: close to oil refinery / energy supply / near port / near source of C_2H_4 (1)

For any social factor: Work force nearby, not in residential area (1)

(b) Explain why polyvinyl chloride is less flexible than polythene.

Polar C–Cl bonds in PVC (1)

Thus stronger intermolecular forces (than in polythene) (1)

(c) Write an equation for the (complete) combustion of polythene and polyvinyl chloride and explain why these polymers are first separated **before** combustion. [3]

$(-(C_2H_4)-)_n + 3n O_2 \longrightarrow 2n CO_2 + 2n H_2O$ (1)

$(-(C_2H_3Cl)-)_n + \frac{5}{2}n O_2 \longrightarrow 2n CO_2 + n H_2O + n HCl$ (1)

or $(-(CH_2{=}CHCl)-)_n$

HCl is a toxic or poisonous / no poisonous gases released from combustion of polythene (1)

For simplified equations (eg. without n), give a total of (1) if CO_2, H_2O and HCl are all included as products.

(not true if combustion is not complete) OR separation necessary because PVC produces a poisonous gas.

(Question E2 continued)

(d) Discuss and compare the radical mechanism for the manufacture of low density polythene with the ionic mechanism for the manufacture of high density polythene. *[7]*

DO NOT award marks for different conditions, eg. temp & pr.

(Free) Radical Mechanism:

Free radical indicated, eg. $R\cdot$ or $A\cdot$ or $R-O-O\cdot$

or $R-CH_2-CH_2\cdot$ (1)

→ brief descriptions should be awarded full marks

$R\cdot + CH_2=CH_2 \longrightarrow R-CH_2-CH_2\cdot$ (1)

$R-CH_2-CH_2\cdot + CH_2=CH_2 \longrightarrow R-CH_2-CH_2-CH_2-CH_2\cdot$ (1)

→ If none of these are scored, (1) may be awarded for mention of initiation, propagation & termination.

Termination step, e.g. $2R\cdot \longrightarrow R_2$ or

$2\ R-CH_2-CH_2-CH_2-CH_2\cdot \longrightarrow (R-CH_2-CH_2-CH_2-CH_2)_2$ or ... (1)

Ionic Mechanism:

(Ziegler / Ziegler-Natta) Catalyst (1)

$A-B + CH_2-CH_2 \longrightarrow A-CH_2-CH_2^+ (+B^-)$ (1)

$A-CH_2-CH_2^+ + CH_2=CH_2 \longrightarrow A-CH_2-CH_2-CH_2-CH_2^+$ (1)

word descriptions should be award marks:

Accept insertion of ethene molecule between catalyst and chain as one step

Polymerisation occurs through the insertion of the alkene monomer between the metal and the growing polymer chain.

$Ti^{\delta+} - {}^{\delta-}CH_2-CH_3 \longrightarrow Ti-CH_2-CH_2-CH_2-CH_3$

$CH_2=CH_2$ $\qquad$ $CH_2=CH_2$

(Organo Titanium compound plays a key role)

(Polymerisation occurs at the metal atoms)

$^{223}_{88}Ra \rightarrow {}^{4}_{2}\alpha + {}^{219}_{86}X$ ($X = Rn$)

→ allow #s for loss of two or more α-particles

Option F – Fuels and Energy

F1. (a) Radium-223, ^{223}Ra, emits α-particles when it decays.

(i) Write the mass number and atomic number of the heavier product formed by this decay. *[2]*

Mass number: 219 / 215 (1)

Atomic number: 86 / 84 (1)

(ii) What happens to the mass number and the atomic number of an element if it undergoes β-decay? *[2]*

$^{219}_{86}Rn \rightarrow {}^{0}_{-1}e + {}^{219}_{87}$

Mass number: No change (1)

Atomic number: +1 (1)

(b) The intensity of radiation emitted by a certain mass of ^{223}Ra falls to $\frac{1}{8}$ of its original value after 35.1 days.

(i) Define *half-life*. *[1]*

Time taken for activity to decrease by half OR (1)
Time for half the original sample (of nuclei) to decay

If reference is made to mass decreasing by ½, than mass of 'isotopes' or radioactive atom' must be mentioned.

(ii) Calculate, showing your working, the half-life of ^{223}Ra. *[2]*

$1 \xrightarrow{t_{1/2}} \frac{1}{2} \xrightarrow{t_{1/2}} \frac{1}{4} \xrightarrow{t_{1/2}} \frac{1}{8}$ ⇒ requires 3 half lives (1)

$\therefore \frac{35.1}{3} = 11.7$ days (1)

$(= 280.8\,h)$

(iii) Calculate the fraction of ^{223}Ra which has decayed after 35.1 days. *[1]*

$\frac{7}{8}$ OR 0.875 OR 87.5% (1)

(iv) Calculate the fraction of ^{223}Ra **remaining** at this time if the original mass had been twice as great. *[1]*

12.5% OR $\frac{1}{8}$ or 0.125 (ECF from iii) (1)

F2. (a) Identify the two electrodes in the Leclanché dry cell. [2]

Zinc (1)

Graphite (accept carbon) (1)

(b) Describe the difference between *voltage* and *power* for such a cell **and** identify the factors that affect the voltage and the power. [4]

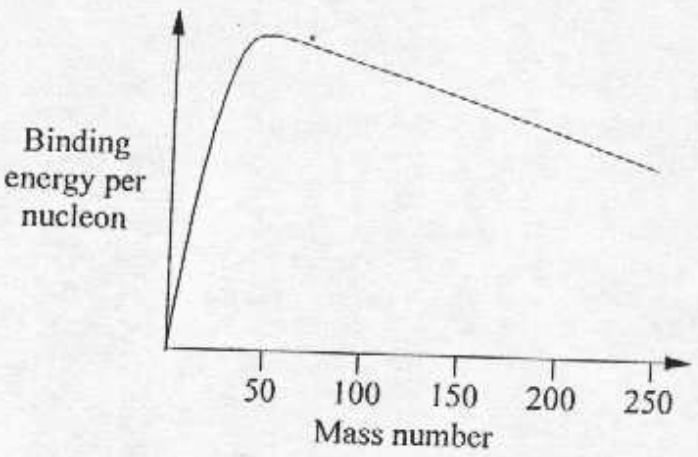
Voltage : Potential difference (between electrodes) (1)

Power : $P = I \times V$ / Rate of delivery of energy / WATTS (1)

Voltage is affected by materials used / on the chemical nature of the cell (1)

Power is affected by the quantity of materials used (1)

F3. (a)



Define the term *nuclear binding energy*. By using the above curve, explain why ^{223}Ra undergoes the loss of an α-particle as stated in **F1.** (a). *[3]*

Mass defect / Binding energy is the energy released when a nucleus is formed from protons and neutrons / It is the energy needed to split a nucleus into protons and neutrons (1)

Refer to curve ie. binding energy increases towards peak (1)

This is achieved by loss of α-particles (1)

(b) Nuclear waste is often divided into low-level and high-level waste. Discuss the differences between these types with regard to their sources, characteristics and appropriate methods of storage. *[7]*

no mark for just "hospital" or "power plant"

Low-Level Waste: Source: MUST BE SPECIFIC eg. Radioactive isotopes used in hospitals / Coolant from nuclear power plant / Monitoring thickness of paper or plastic (1)

Characteristic: Activity is low / short half-life / high volume (1)

(Activity is the # of decays per second)

Storage: Stored until activity is reduced (to safe level) / dilution (1)

High-level Waste:

Source: Nuclear industry / military (complex) (1)

Characteristic: Activity is high / long half-life / low volume (1)

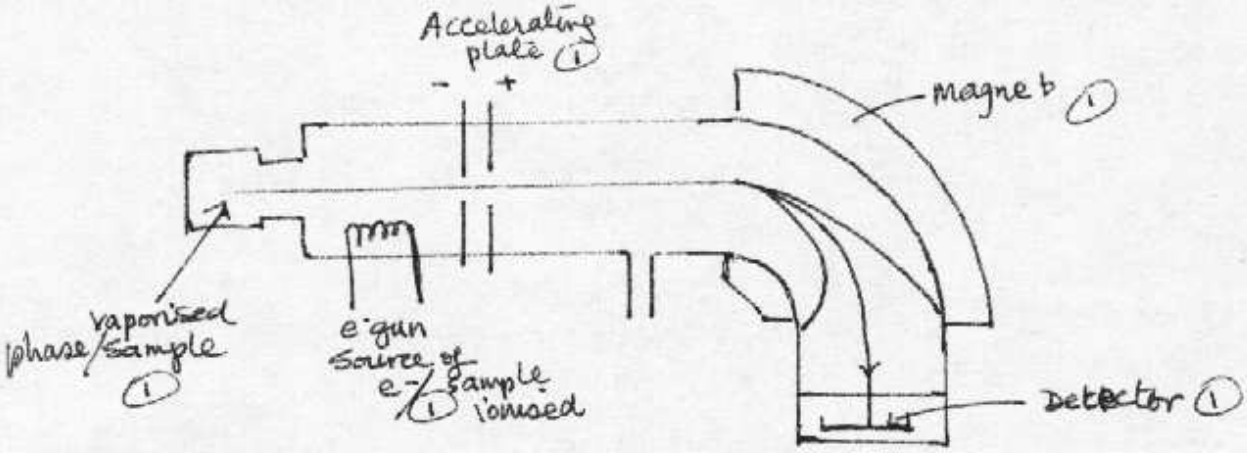
Storage: Making into glass / deep burial (1)

(This must be stated for the mark)

→ Contained / secure / non-leachable environment (1)

Option G – Modern Analytical Chemistry

G1. (a) Draw a simple diagram of a mass spectrometer. State briefly how its use could show the existence of isotopes in a gaseous sample of an element. *[6]*



Light ions deflected more than heavier ones / > 1 signal obtained (1)
OR (+)ions of different mass/charge ratio (give (>1) line(s))

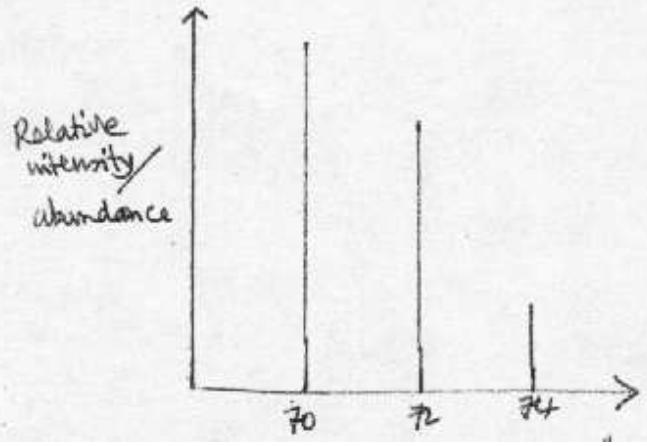
(b) Chlorine exists as a mixture of two stable isotopes ^{35}Cl and ^{37}Cl, present in the approximate ratio 3:1.

(i) Calculate the relative atomic mass of chlorine. *[2]*

$A_r = \left(35 \times \frac{75}{100}\right) + \left(37 \times \frac{25}{100}\right)$ (1)

$= 35.5$ (1)

(ii) Sketch and label a diagram of the mass spectrum of **molecular** chlorine. *[3]* 4



Both axis correctly labelled (1)
Three lines at 70, 72, 74 (1) (actual ratio 9:6:1 not req'd)
Heights of lines in correct order (70 > 72 > 74) (1)

(70 due to ^{35}Cl-^{35}Cl

G2. (a) In the use of paper chromatography, a retention factor, R_f, is determined. Define R_f. *[1]*

Ratio of distance travelled by solute over distance travelled by solvent (1)

(b) A drop of green dye is placed 2 cm from the bottom of a strip of filter paper. The filter paper is suspended in a graduated cylinder with 1 cm of the paper immersed in a water–alcohol solvent. After 30 minutes, the green spot is no longer present and there is a yellow spot and a blue spot.

(i) Describe how the R_f value of the blue spot could be determined. *[2]*

Measure distance travelled by (centre of) blue spot, and solvent (1)

From the origin (1)

(ii) Account for the difference in the R_f values of the yellow and blue dyes. *[2]*

Each dye has different attractions / affinities for the paper and the solvent (1)

(1)

→ Solvent reference may be to solubility rather than attraction / affinity (1)

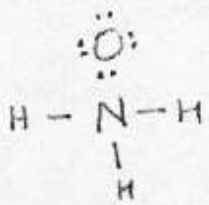
(iii) What is the significance of an R_f value of 1.0? *[2]*

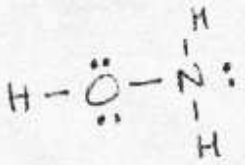
Negligible attraction between the dye and paper (1)

Compared with that of dye and solvent / solubility of dye in solvent (1)

(Do not give mark for "distance moved by the dye = distance moved by the solvent")

G3. (a) A compound of nitrogen has a molecular formula NH_3O which could have two structures, ONH_3 and $HONH_2$. Draw the Lewis structure of **each** species.





(1) (1)

→ Accept dot & cross, 2 dots or one line to represent a pair of electrons

(If both structures & bonding are correct but non-bonding es are not shown, then only (1) mark)

(b) State and explain the number and relative areas of the peaks in the ^1H NMR spectra of ONH_3 and $HONH_2$. *[5]*

ONH_3 : 1 peak (1)

All protons chemically equivalent / in chemically same environment (1)

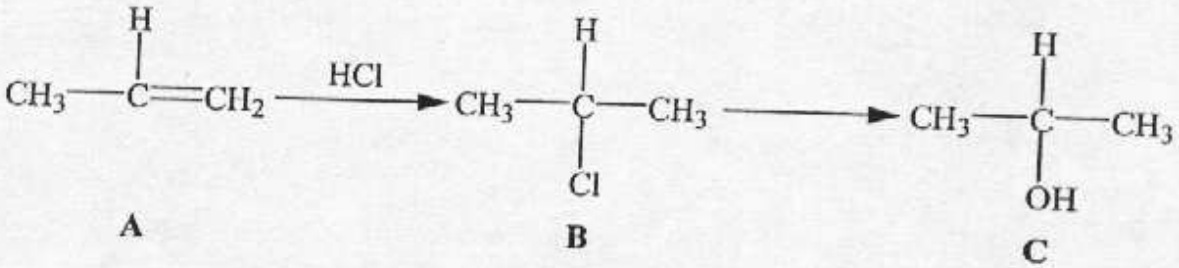
$HONH_2$: 2 peaks (1)

Relative areas : 1 : 2 ratio (1)

Protons in different / 2 chemical environments (1)

Option H – Further Organic Chemistry

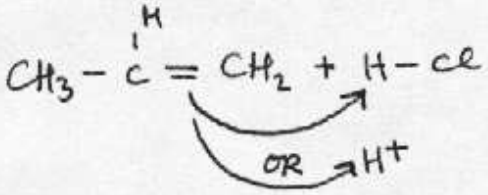
*Below is a reaction scheme involving compounds **A**, **B** and **C** (referred to in question H1 below):*



A **B** **C**

H1. (a) Name and outline the mechanism for the conversion of **A** into **B**. *[4]*

Electrophilic addition (1)



(1)

(1)

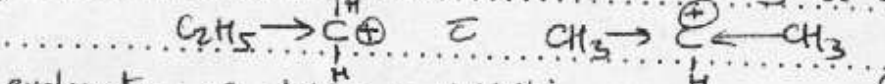
arrow showing attack of Cl^- on C^+ (1)

(b) As well as compound **B**, another product is formed. Write down the structural formula of this compound, and explain why it is only produced in small amounts. *[3]*

$CH_3-CH_2-CH_2-Cl$ (1)

Primary carbocation / $CH_3CH_2CH_2^+$ is less stable (1)

or less likely to be formed or secondary carbocation is more stable or more likely to be formed (1)



inductive effect of 2R groups has greater stabilizing effect

No mark for just stating Markovnikov's rule as an explanation

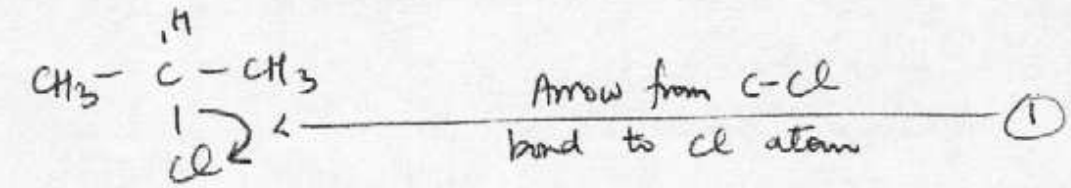
⇒ Need explanation of different stabilities of carbocations in terms of inductive effect

(Question H1 continued)

(c) The conversion of **B** into **C** is a *nucleophilic substitution* reaction. Define what is meant by **nucleophilic** substitution. *[1]*

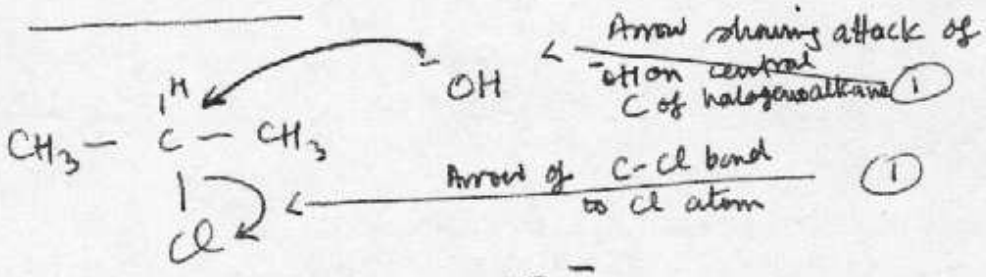
(Substitution by) An electron-rich species (eg. $\ddot{N}H_3$, OH^-) (1)
(lone e⁻ pair) / Lewis base / possess (at least one) e⁻ pair
→ (Do not accept: Bronsted base)

(d) Outline the mechanism involved in this nucleophilic substitution, showing clearly the reacting species. *[3]*

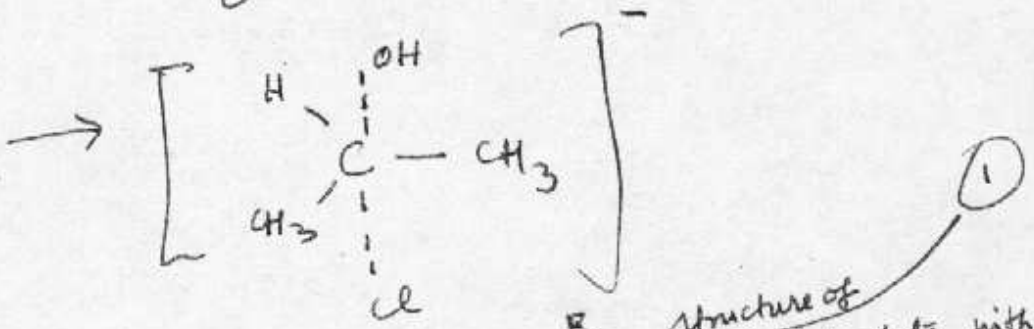


(This is SN1 mech.)

OR

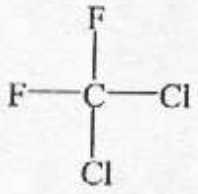


SN2

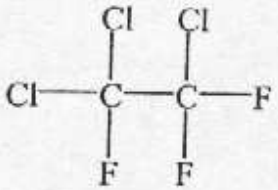


Since it is a secondary halogenoalkane, either SN1 or SN2 is acceptable.

H2. The two compounds **V** and **W**, shown below, are known as Freons or CFCs. These compounds are usually inert but are quite reactive in the upper atmosphere contributing to ozone depletion. This depletion reaction follows a free-radical mechanism involving a chlorine free radical Cl·, generated from the CFCs.



V



W

(a) Write down the systematic name of each compound. *[2]*

V: dichlorodifluoromethane (accept difluorodichloromethane) ①

W: 1,1,2-trichloro-1,2,2-trifluoroethane ①
(accept: 1,1,2-trifluoro-1,2,2-trichloroethane)

(b) State briefly the importance of ozone in the atmosphere. *[1]*

Absorbs UV radiation from the sun ①

(c) With reference to Table 10 of the Data Booklet;

(i) explain why CFCs are generally inert compounds. *[1]*

(Saturated) compounds with high bond energies ①

(ii) account for the fact that a chlorine radical Cl·, rather than a fluorine radical F·, is produced from compounds **V** and **W**. *[2]*

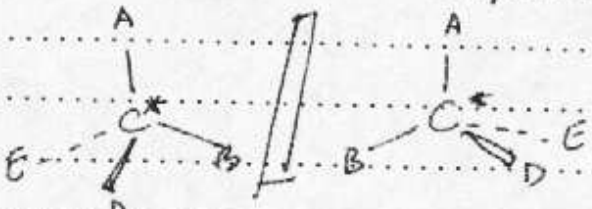
C–Cl bond is weaker than C–F bond ①
C–Cl bond is more easily broken (than C–F bond) ①

(d) Write an equation for the reaction between Cl· and ozone, O_3. *[1]*

$Cl\cdot + O_3 \longrightarrow ClO\cdot + O_2$ ①

H3. (a) State the structural feature of a molecule needed for optical activity to occur, illustrating your answer with appropriate drawings. [3]

Chiral carbon atom / C atom joined to 4 other groups (1)



one mark each (2)

need two drawings showing enantiomers / chiral structures
(object - mirror image)
(These may be incomplete, showing only the 'chiral centre')

(b) One way of studying optically active compounds is using plane-polarised light. State what is meant by *plane-polarised light* and how it is affected by optically active compounds. Under what conditions would this effect **not** be observed? [4]

Plane-polarised light is light vibrating in one plane only (1)

Optically active compounds rotate plane of polarisation of plane-polarised light. (1)

When a racemic mixture is present (1)
in which equimolar concentrations of the stereoisomers affect plane of polarised light equally but in opposite directions. (1)