CHEMISTRY

Higher Level

Friday 7 May 1999 (morning)

(KEY) Sadm.

Paper 3

1 hour 15 minutes

A

Candidate name:	Candidate Category and Number:

This examination paper consists of 6 options.
The maximum mark for each option is 25.
The maximum mark for this paper is 50.

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.

At the end of the examination, complete box B with the letters of the options answered.

B

OPTIONS ANSWERED

C

	EXAMINER	MODERATOR
	/25	/25
	/25	/25
TOTAL	TOTAL	
	/50	/50

D

	IBCA
	/25
	/25
TOTAL	
	/50

EXAMINATION MATERIALS

Required:
Calculator
Chemistry Data Booklet

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

Option C – Human Biochemistry

C1. Iodine index (iodine number) is defined as the number of grams of iodine able to react with 100 grams of a fat or an oil in an addition reaction.

The table below contains the values of iodine indexes for three fats/oils.

Fat / Oil	Iodine index
Coconut	8–10
Butter	26–45
Olive	74–94

(a) Explain the relationship between the iodine index and unsaturation, and select the most **saturated** fat/oil.

[2]

   ... The more unsaturated the oil, the bigger the iodine index (or vice versa) ①
   ... ∴ Coconut oil (is most saturated). ①

   ⤷ 1 double bond ⇒ will react with 1 mol I_2

(b) Oleic acid $[CH_3(CH_2)_7CH=CH(CH_2)_7COOH]$ is commonly present in fats and oils. Calculate the iodine index of this acid according to the above definition.

[3]

   ... M_r of oleic acid $= (18 \times 12.0) + 34.0 + (16.0 \times 2) = 282.0$ ①
   ... $M_r(I_2) = 126.9 \times 2 = 253.8$; ∴ I_2 index $= \dfrac{253.8 \times 100.0}{282.0} = 90$ ① ①
   253.8 g I_2 will react with 282.0 acid ⤶ ∴ 100g fat will react with ⑨

(c) Which of the above fats or oils would you recommend to be part of a healthy diet? Justify your answer.

[2]

   ... Olive oil   ①
   ... Highest degree of unsaturation / most unsaturated / highest iodine index ①

(d) State **three** functions of fats and oils in the human body.

[3]

   ... Maintain body temperature / insulation ⎫ ①
   ... Energy source   ⎬ ①
   ... Cell membranes   ⎭ ①

   all accept: to protect organs
                to carry fat soluble vitamins
                to prevent skin drying / water proofing
                ⤷ie. lubrication-keeps skin from drying

   282.0 g fat reacts with 253.8 g I_2
   ∴ 100 " " " " $\dfrac{253.8 \times 100.0}{282.0} = 90$

C2. The graph below represents the activity of an enzyme on the substrate S.
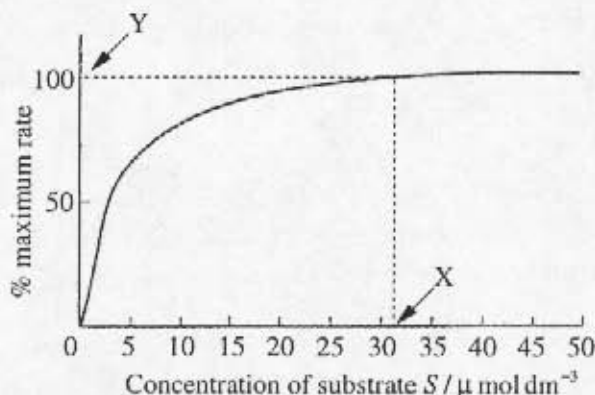
(a) What is the meaning of the point **Y**?   [1]

... **Vmax** : ... maximum ... reaction ... rate ... ①
[*this is where saturation of enzyme occurs*" is answer to part ⓑ - give mark here only if student doesn't get it in part ⓑ)

(b) Explain, on a molecular level, why the reaction rate increases with substrate concentration
from **0** to **X** but remains constant thereafter.   [2]

... O - X : Free active sites can accommodate increase in [substrate] ... ①
then : enzyme molecules are saturated with substrate ∴ all active ... ①
sites in use (so, they cannot go faster).

(c) Define the Michaelis constant (K_m) and explain its significance.   [2]

K_m represents [subs] at which the reaction rate = $\frac{1}{2} V_{max}$ ... ①
The higher the K_m value, the lower the enzyme activity ... ① ←
ⓞⓡ the lower the K_m value, the higher the enzyme activity ...
ⓞⓡ $K_m \propto \frac{1}{enzyme\ activity}$

(d) From the graph, determine the value of K_m.   [1]

... ≃ 3 μmol dm⁻³ ... ①

(accept value between 2 & 4)

(accept : the higher K_m value means the
weaker the bond between the
substrate and the enzyme
ⓞⓡ converse)

(or A lower value of K_m means a
more efficient enzyme because with
the same [S], there is a higher reaction
rate .)

C3. (a) Give the empirical formula of a monosaccharide and identify **two** functional groups that it possesses.

CH_2O ; (accept $(H_2O)_n$) (1)

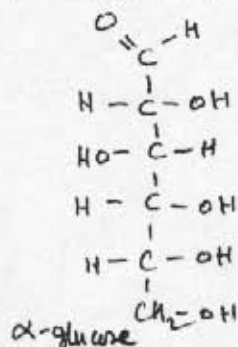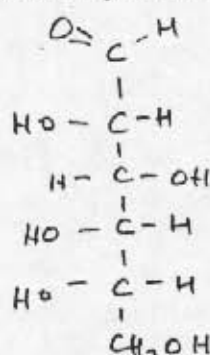Carbonyl / $C=O$; alkanal (aldehyde) also acceptable (1)

hydroxyl / OH (1)

accept R-O-R / ether

(b) Draw the straight chain formula of glucose. Describe the structural difference between α- and β-glucose and name the type of isomerism they exhibit. [3]

→ must show 2nd or 3rd OH in a different direction from the other OH groups

→ 1 mark for st. chain formula
→ 1 " for stating that -OH on C_1 is in different directions or by showing 2 correct ring structure

α-glucose

Optical isomerism / anomerism / stereoisomerism (1)
↳ (two diastereoisomers) / cis/trans or geom acceptable)

(c) Write a balanced equation to represent the formation of a disaccharide from glucose. Explain how this process is extended to the formation of a polysaccharide such as starch.
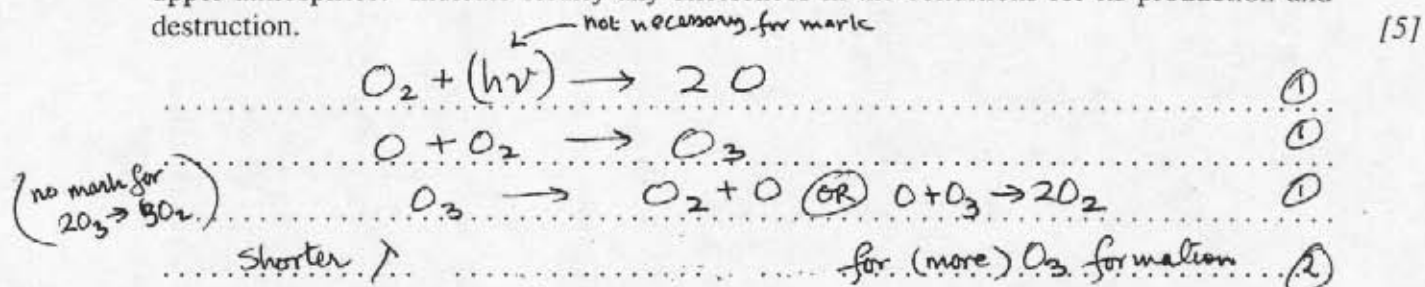
$C_6H_{12}O_6 + C_6H_{12}O_6 \rightarrow C_{12}H_{22}O_{11} + H_2O$
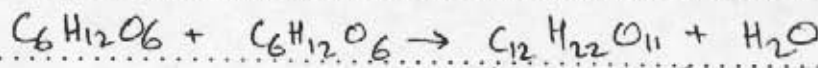
(1) ; (1) for balanced eq.

Many monomers / monosaccharides involved
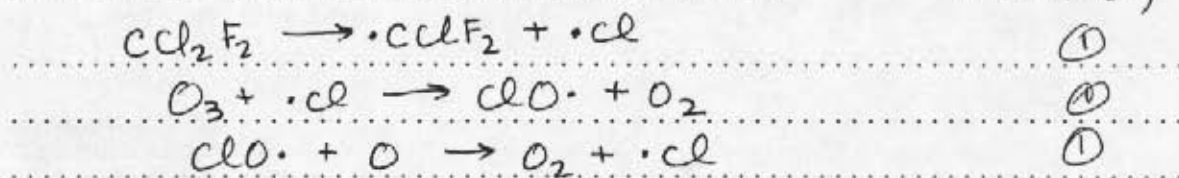
(OR) Many C-O-C bonds formed

Option D – Environmental Chemistry

D1. Ozone depletion in the upper atmosphere is currently of great concern.

(a) Write equations to show how ozone is produced and destroyed by natural processes in the upper atmosphere. Indicate clearly any differences in the conditions for its production and destruction. *← not necessary for mark* [5]

$$O_2 + (h\nu) \longrightarrow 2O \qquad \textcircled{1}$$

$$O + O_2 \longrightarrow O_3 \qquad \textcircled{1}$$

(no mark for $2O_3 \rightarrow 3O_2$) $\qquad O_3 \longrightarrow O_2 + O \; \textcircled{\small OR} \; O + O_3 \rightarrow 2O_2 \qquad \textcircled{1}$

Shorter λ .... for (more) O_3 formation .... $\textcircled{2}$

Shorter λ means higher energy $\qquad$ (or Converse)
(No mark for "U.V. light needed for O_3 production since this is not answering the question of "any differences in conditions")

(b) Give the mechanism by which ozone is destroyed by CCl_2F_2. [3]

$$CCl_2F_2 \longrightarrow \cdot CClF_2 + \cdot Cl \qquad \textcircled{1}$$

$$O_3 + \cdot Cl \longrightarrow ClO\cdot + O_2 \qquad \textcircled{1}$$

$$ClO\cdot + O \longrightarrow O_2 + \cdot Cl \qquad \textcircled{1}$$

(c) Explain why ozone depletion is greater in polar regions. [1]

Catalysis on ice particle (surface) $\qquad \textcircled{1}$

D2. This question relates to 'acid rain'.

(a) Account for the fact that natural rain has a pH of around 5.6. Give a chemical equation to support your answer. [2]

$\textcircled{1}$

$$CO_{2(g)} + H_2O_{(l)} \rightleftharpoons H_2CO_{3(aq)} \; ; \; forms \; an \; acid \quad \textcircled{1}$$

OR $\quad CO_{2(g)} + H_2O_{(l)} \rightleftharpoons H^+_{(aq)} + HCO^-_{3(aq)} \quad$ (for both marks as H^+ implies it is acidic)
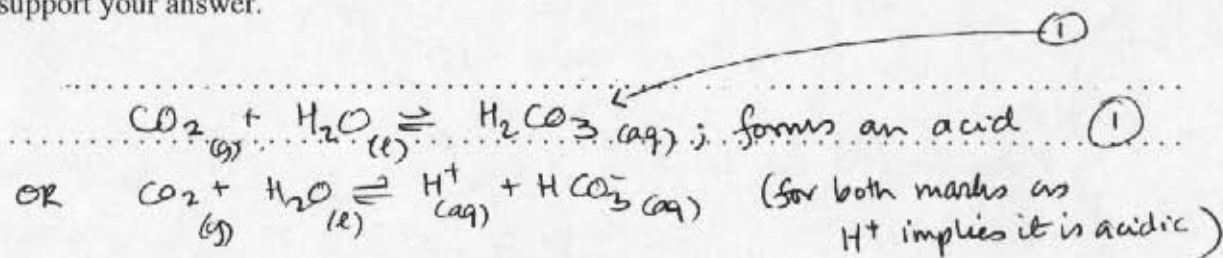
(States not required for mark)

(Just "CO_2 decreases pH of water not sufficient - must indicate an acid formed)

(Question D2 continued)

(b) Because of pollution, acid rain may be 50 times more acidic than natural rain. Identify the **two** acids that cause this high acidity and indicate their origins. Show by means of an equation how **one** of these acids is produced. ① [5]

HNO_3 ; H_2SO_4 or H_2SO_3 ①
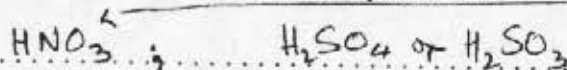
ACCEPT $NO_2 \rightarrow$ or NO_x $\quad$ NO — automobiles (rxn between N_2 & O_2) ①
(subsequent rxn of NO with O_2 to produce NO_2; then $NO_2 + H_2O$)
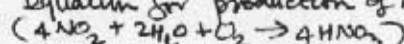
MUST say SO_2 or sulfur dioxide (no mark for SO_x or sulfur oxides - SO_2 in the origin)
$\rightarrow$ SO_2 — smelters in Cu production OR coal or oil or fossil fuel (containing S) ①
$SO_2 + H_2O \rightarrow H_2SO_3$ $\quad$ OR $\quad$ $SO_3 + H_2O \rightarrow H_2SO_4$ ①
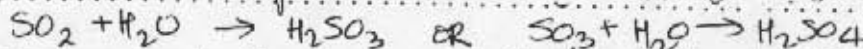
(c) State **two** consequences of acid rain. $\quad$ OR equation for production of HNO_3 [1]
$\rightarrow$ or basic nutrients $\quad$ ($4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$)

Leaching minerals from soil, fishless lakes, damage to stone buildings, damage to trees/forests, iron/steel objects rust more quickly, poorer health.
(Any two for one mark)

D3. Briefly describe the primary, secondary and tertiary stages of sewage treatment and indicate the types of pollutants removed by each. Explain why tertiary treatment is becoming increasingly important and state briefly the chemical basis of **one** type of tertiary treatment. [8]

Primary : Filteration / sedimentation / flocculation $\}$ any one method ①
$\qquad$ Mostly insoluble materials / large particles ①

Secondary : Activated (bacterial) sludge ①
$\qquad$ Oxidisable waste (organic products) ①

Tertiary : Reverse osmosis OR electrodialysis $\}$ any one ①
$\qquad$ OR Chemical precipitation OR ion exchange
$\qquad$ Soluble materials (Nitrates (NO_3^-), or detergents) ①

Due to greater levels of NO_3^- / fertilizers OR PO_4^{3-} / detergents ①
Reverse osmosis : semipermeable membrane & high pressure ①
(OR) Electrodialysis : Electrodes / cells and semipermeable membranes
(OR) Chem. precipitation : chemicals added combines with dissolved
$\qquad$ ions to give a ppt (eg. urea for nitrate)
(OR) Ion exchange : unwanted ions (eg Ca^{2+}) exchanged for harmless ions
(OR) use of algae ponds to remove nitrates

(carbon bed, cascoal filters not acceptable as these would not be part of tertiary stages of sewage treatment)

Option E – Chemical Industries

E1. (a) Aluminium is manufactured by the electrolysis of alumina dissolved in molten cryolite.

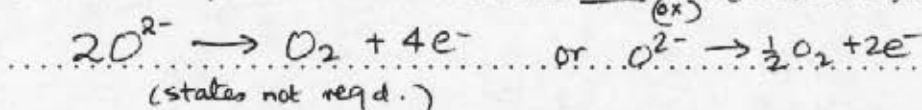(i) Explain the function of the cryolite. [1]

The electrolysis can be carried out at a much lower
T or lowers melting point of alumina ①
(Al$_2$O$_3$ has a very high m.pt; Al$_2$O$_3$ in cryolite melts at much lower T)

(ii) Give an ionic equation for the reaction at the <u>anode</u> during the electrolysis. [1]
(ox)

$2O^{2-} \longrightarrow O_2 + 4e^-$ or $O^{2-} \longrightarrow \frac{1}{2}O_2 + 2e^-$ ①
(states not reqd.)

(iii) Explain with the aid of an equation why the anode slowly disappears. (need equation for mark) [1]
$C + O_2 \longrightarrow CO_2$
② O$_2$ produced at anode reacts with Carbon electrode or ①
Carbon anode burns in O$_2$ formed (to produce CO$_2$ CO$_3$)

note: Ti anode also used

(b) Explain how the production of pure alumina from bauxite takes advantage of the amphoteric nature of aluminium oxide. [2]

Al$_2$O$_3$ reacts/dissolves with/in NaOH/KOH ①
Basic impurities/oxides donot react/dissolve ①
└ must say "BASIC" to gain mark

(c) Give **two** properties **and** related uses which make aluminium an important metal in today's world. [2]

Resistance to corrosion - window frames
Electrical conductivity & low density - overhead power cables ②
Low density - aircraft (fuselage)
note: Link between property & use essential; 1 mark each.

(d) Despite aluminium being the most abundant metal in the earth's crust, it is frequently recycled. Give **two** reasons which favour recycling. [2]
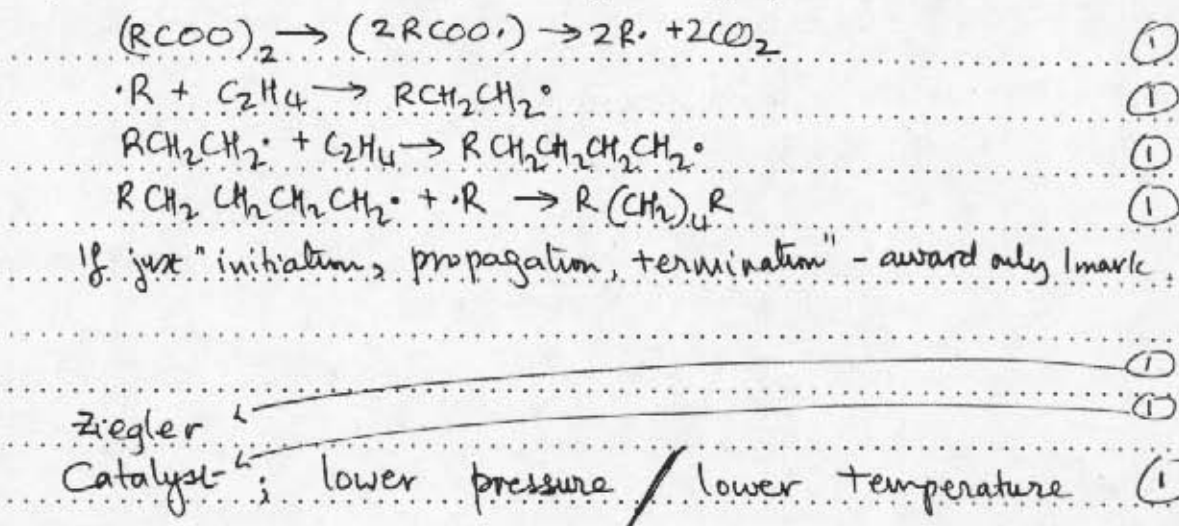or
Expensive to produce lower cost in energy terms if recycled ①
Conserves resources ①

OR . . . .

E2. (a) Give the radical mechanism for the manufacture of low density polythene and explain how the process conditions are altered to produce high density polythene.   [
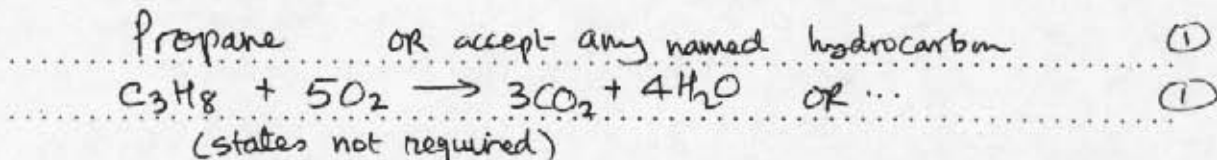
$(RCOO)_2 \longrightarrow (2RCOO\cdot) \longrightarrow 2R\cdot + 2CO_2$ ①

$\cdot R + C_2H_4 \longrightarrow RCH_2CH_2^\circ$ ①

$RCH_2CH_2^\cdot + C_2H_4 \longrightarrow RCH_2CH_2CH_2CH_2^\circ$ ①

$RCH_2CH_2CH_2CH_2^\cdot + \cdot R \longrightarrow R(CH_2)_4R$ ①

If just "initiation, propagation, termination" - award only 1 mark.

① ①

Ziegler
Catalyst; lower pressure / lower temperature   ①

(b) Silicones are obtained by condensation polymerisation. Explain how this polymerisation differs from that used to obtain polythene.   [2]
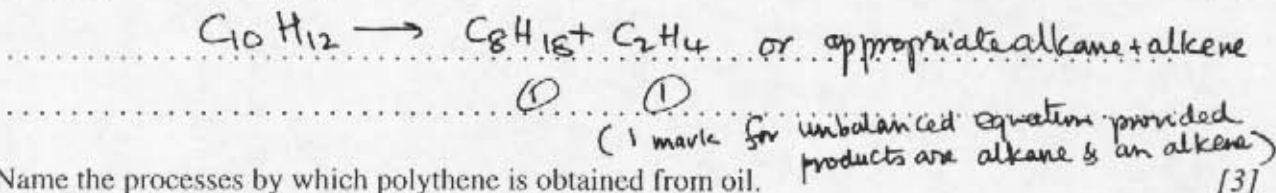
→ Polyethene: addition (polymerisation) or Not free radical "as above

Silicones: (condensation polymerisation) where 2 larger molecules combine
(OR) Monomers must contain two functional groups / with the elimination of a (small) one (eg. H_2O)
                                    (eg. H_2O) has to be removed/eliminated

E3. Oil is used as an energy source and as a chemical feedstock.

(a) Name **one** compound obtained from oil which is used as a fuel and give an equation for its complete combustion.   [2]

Propane   OR accept any named hydrocarbon   ①

$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$ OR ...   ①
(states not required)

(b) Decane has been used as an energy source but has greater value as a source of other chemicals. Use an equation to show the formation of **two** organic products from the cracking of decane, $C_{10}H_{22}$.   [2]

$C_{10}H_{12} \longrightarrow C_8H_{18} + C_2H_4$ or appropriate alkane + alkene
                ①   ①
                    (1 mark for unbalanced equation provided
   products are alkane & an alkene)

(c) Name the processes by which polythene is obtained from oil.   [3]

(stage 1:) Fractional Distillation   ①
(stage 2:) Ethene produced by cracking less valuable fractions ①
(stage 3:) Polymerisation is used to convert ethene
        into polythene (or polyethene)   ①

Option F – Fuels and Energy

F1. (a) When coal is burned several gases are produced in addition to carbon dioxide. Write an equation for the combustion of an *element* in coal to form **one** of these gases. [1]

$$2C_{(s)} + O_{2\,(g)} \longrightarrow 2CO_{(g)} \quad \text{or} \quad S_{(s)} + O_{2(g)} \rightarrow SO_{2\,(g)} \qquad ①$$
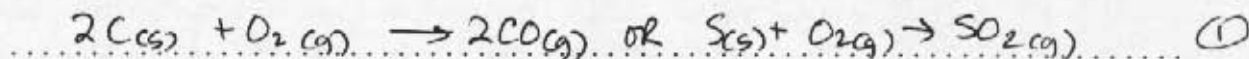
BUT **not** NO or NO$_{2\,(g)}$

(b) State how the emissions of the gas identified in (a) could be minimised [1]

CO: efficient combustion/burning OR Ensure excess air/O_2 ①

If NO$_2$ in ⓐ then person through an alkali (NOT just "scrubbing")

(OR) SO$_2$: (scrubbing) by passing through an alkali/absorb in (slurry) powdered limestone – water OR Desulfurised coal OR fluidised bed combustion

(c) In countries lacking natural gas reserves, coal is sometimes converted into synthesis gas, a mixture of carbon monoxide and hydrogen. Synthesis gas is then converted into liquid methanol, CH_3OH. Give **two** advantages of a liquid fuel compared with a solid fuel. [2]

Can be pumped.

Easy to burn ; easy to mix with air ; easier to control rate of combustion
   } any two ②

(d) (i) Write an equation for the complete combustion of methanol. [1]

$$2CH_3OH + 3O_2 \longrightarrow 2CO_2 + 4H_2O \qquad ①$$

(states not reqd.)
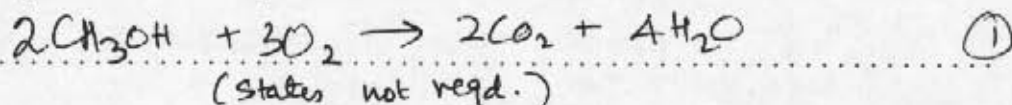
(ii) The standard enthalpies of formation, ΔH_f^0, for CO_2 and $H_2O(l)$ are −393.5 and −258.8 kJ mol^{-1} respectively. Use this information and Table 11 of the Data Booklet to calculate the enthalpy of combustion of 1 mol of liquid methanol. [4]

$$\Delta H_f^0 = -239 \text{ kJ mol}^{-1} \quad ; \quad CH_3OH + \tfrac{3}{2}O_2 \rightarrow CO_2 + 2H_2O$$ ①

$$\Delta H_{rxn}^0 = \sum \Delta H_{f,P}^0 - \sum \Delta H_{f,R}^0 \quad \text{or explicit or implicit energy cycle} \quad ①$$

$$= [(-393.5) + 2(-258.8)] - [(-239) + 0] \quad ①$$

$$= -672.1 \text{ kJ mol}^{-1} \quad (\text{need unit for mark}) \quad ①$$

(accept −672 kJ mol^{-1})

(If incorrect ΔH_f^0 from data booklet, but rest is okay, then 3 marks.)

(if value of −1344.2 kJ calculated which is for 2 mols, then 3 marks)

(mark can be implicit in the next step)

(iii) How would this value differ if the water were produced as a gas rather than as a liquid? [2]

lower or less negative or more positive ①

Energy needed to vaporise/evaporate water/steam not condensed, thus less energy released. ①

Turn over

F2. (a) State the main difference between a chemical reaction and a nuclear reaction. [1]

Chemical: rearrangement of (outer) electrons OR no new elements/atoms formed,

OR Nuclear: change in nucleus/new elements/atoms formed/(outer) electron arrangement unchanged. Only 1 mark so one statement may implicitly imply other is okay

(b) List **three** components of a nuclear reactor, other than the fuel, and describe the role of each. [6]

Shielding: To prevent escape of nuclear particles/radioactivity

Control rods: To control and maintain a safe level of fission/control number of free neutrons

(Any three)

Cooling system: Maintain temperature of reactor (core)

*Moderator : to slow the neutrons .... 2 marks each*

(3×2 = 6)

F3. (a) An important aspect of the nuclear industry is the disposal of radioactive waste. For highly radioactive waste the material is stored under suitable conditions until the activity has fallen to a safe level.

(i) ^{32}P is a β emitter. State what β particles are and name the element produced in this decay process.

electrons (1)

Sulfur $(\ ^{32}_{15}P \rightarrow \ ^{0}_{-1}\beta + \ ^{32}_{16}S \ )$ (1)
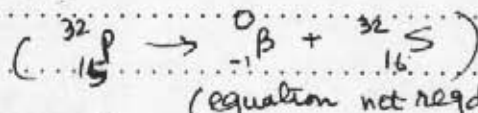
(equation not reqd)

(ii) Calculate the time taken for 32 g of ^{32}P of half life 14 days to become 1 g of the radioactive isotope. [3]

$32g \rightarrow 16 \rightarrow 8 \rightarrow 4 \rightarrow 2 \rightarrow 1 \Rightarrow 5t_{1/2}$ (1)

5×14 (1)

$= 70 \ days$ (1)

(b) Describe **two** other ways of dealing with radioactive waste. [2]

Surround waste with concrete or other suitable material

solidify wastes, encapsulating them in glass or ceramic, then bury

not acceptable → [Use rockets to shoot waste into space → NOT acceptable]

bury the waste in (deep) underground hole (created by nuclear bomb (or holes) so waste waste eventually melt & fuse with surrounding rock into glassy ball)
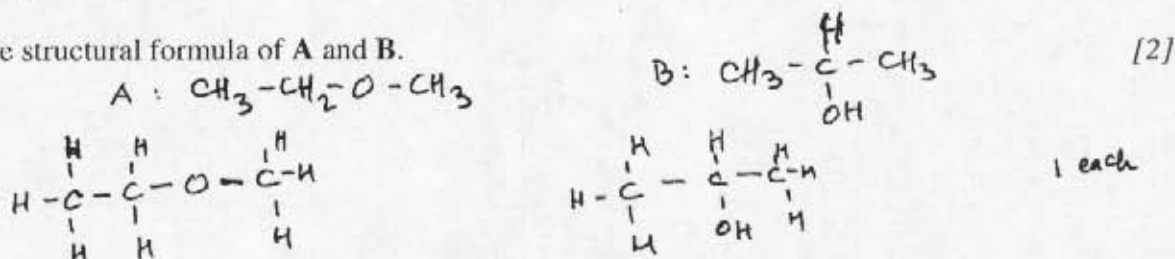
OR Encase waste in well-designed containers and drop them into the ocean

OR change harmful isotopes into harmless ones by using n bombardment, laser or nuclear rxns

Option G – Modern Analytical Chemistry

G1. Two compounds, **A** and **B**, having the same molecular formula, C_3H_8O, are methoxyethane and propan-2-ol respectively.

(a)   Give the structural formula of **A** and **B**.   [2]

A : $CH_3 - CH_2 - O - CH_3$ B: $CH_3 - \overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle OH}{|}}{C}} - CH_3$

H $-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}} - \overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}} - O - \overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}} - H$ H $- \overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}} - \overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle OH}{|}}{C}} - \overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}} - H$ 1 each

....

....

(b)   A student said that the compounds **A** and **B** could be easily distinguished by ^{1}H NMR spectrometry.
Describe the ^{1}H NMR spectrum of:

(i)   the ether **A**.   [3]

(Hs in three different environments)
Peaks ratio 3:2:3 (or 3:3:2)   ①
Chemical shifts of Hs near 3.8 ppm (due to R-O-CH₃) ①
splitting pattern : (smallest area peaks) split into quartet
or one peak split into a triplet   ①
(or) One of the two peaks with the larger area will be a singlet /

(ii)   the alkanol **B**.   [3]

(Hs in three different environments)
Peaks ratio 6:1:1   ①
Peak corresponding to 6 split into a doublet   ①
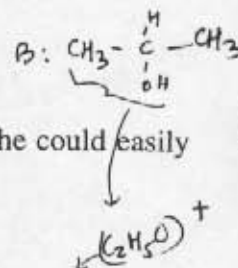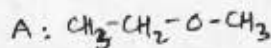OR
The O-H hydrogen chemical shift (δ) at 4.5 ppm ①

→ one of the two peaks with the smallest area
will be a singlet / the other will be a septet (or
accept a complicated pattern)
(or)

Turn over

(Question G1 continued)

A: $CH_3-CH_2-O-CH_3$

B: $CH_3-\overset{H}{\underset{OH}{C}}-CH_3$
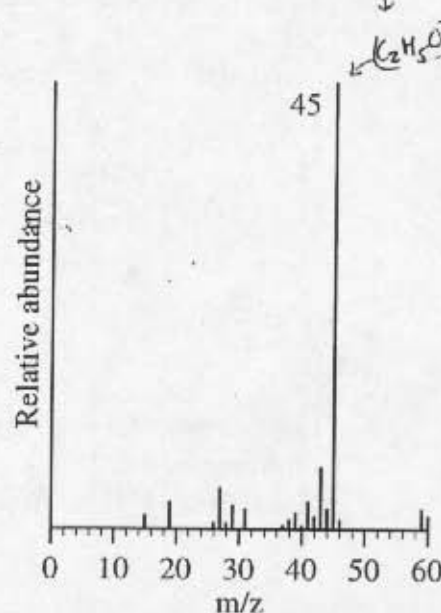
(c) (i) A second student who had access to a mass spectrometer argued that she could easily distinguish the compounds by their mass spectra.

The mass spectra are as follows:
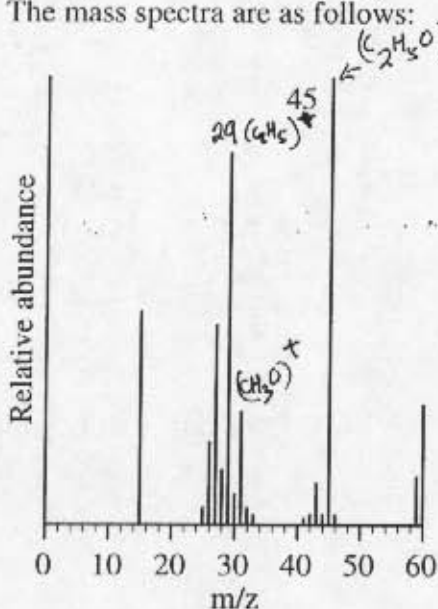
Compound **A**

Compound **B**

Do you think the second student could identify correctly the two compounds from the spectra above? Explain.

[3]

(handwritten answer)

Yes   (no mark for just saying yes or no)

A has a ~~much larger~~ peak at 29 due to $(C_2H_5)^+$ ①

A has ~~much larger~~ peak at 31 due to $(CH_3O)^+$ ①

Both have peaks at 45 due to $(C_2H_5O)^+$ ①

or compare with reference spectra

→ Further marks only for a more thorough justification

→ (If answer is yes because spectra are different - award → 1 mark)

?? (if answer is NO since spectra contain many similar peaks eg. 15, 29, 59 - give 1 mark)

(ii) Discuss the relative boiling points of **A** and **B**, and give a molecular-level explanation for any differences.

[2]

B: (Alkanol) Higher boiling point because   ①

of hydrogen bonding in alkanols   ①

OR Ether has lower boiling point because of

no H bonding / weaker van der Waal's forces and

dipole-dipole attractions

(alternate explanation)

G2. (a) Infrared spectroscopy is a powerful tool for identifying organic compounds. State what occurs at the molecular level during the absorption of infrared (ir) radiation and identify the change that is necessary for ir absorption to occur. Discuss why infrared studies are particularly helpful in the characterisation of organic molecules.   [4]

Vibrations OR Stretching / bending (of chemical bonds)   ①

Change in dipole moment is required (absorption will occur) ①

Different functional groups absorbs in different regions of the spectrum   ①

Precise absorption is affected by neighbouring atoms ①

OR mention of finger print

(b) Use information in Table 18 of the Data Booklet to list the absorption regions expected for:

(i) ethanoic acid. : CH_3COOH : $CH_3-C\overset{=O}{\underset{OH}{}}$ (no penalty of cm^{-1} is missing)   [2]

$(C=O)$: 1680 - 1750 cm^{-1} ⎱

$(O-H)$: 2500 - 3300 " ⎬ any two

$(C-H)$: 2940 - 3095 " ⎰   ②

(ii) methyl methanoate.   [2]

$H-C\overset{=O}{\underset{O-CH_3}{}}$ (no penalty if cm^{-1} is missing).

$C=O$: 1680 - 1750 cm^{-1} ⎱

$C-H$: 2940 - 3095 " ⎬ any two

$C-O$: 1000 - 1300 " ⎰   ②

(c) Identify the absorption listed in (b) which could be used to distinguish between these two compounds. Explain why the other absorptions could not be used.   [2]

O-H in ethanoic acid could be used   ①

Other peaks / absorptions occur in both spectra ①

OR C-O peak in ester could be used.

(d) Identify the absorption listed in (b) which has the highest energy and calculate its wavelength in cm.   ①[2]
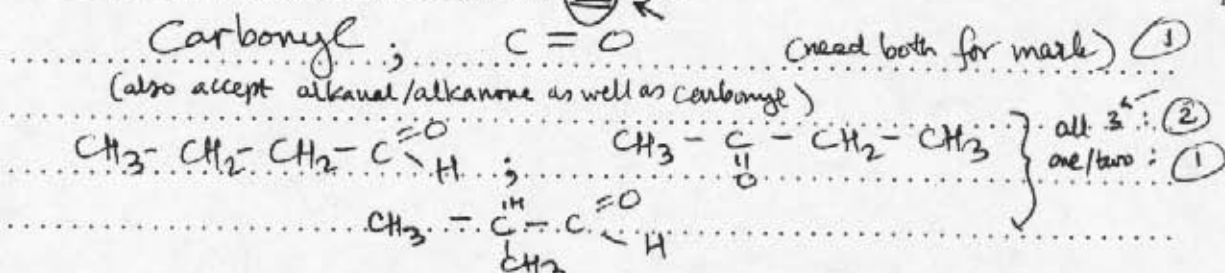
O-H : $\frac{1}{3380}$ cm^{-1} = 3.03×10^{-4} cm   ①

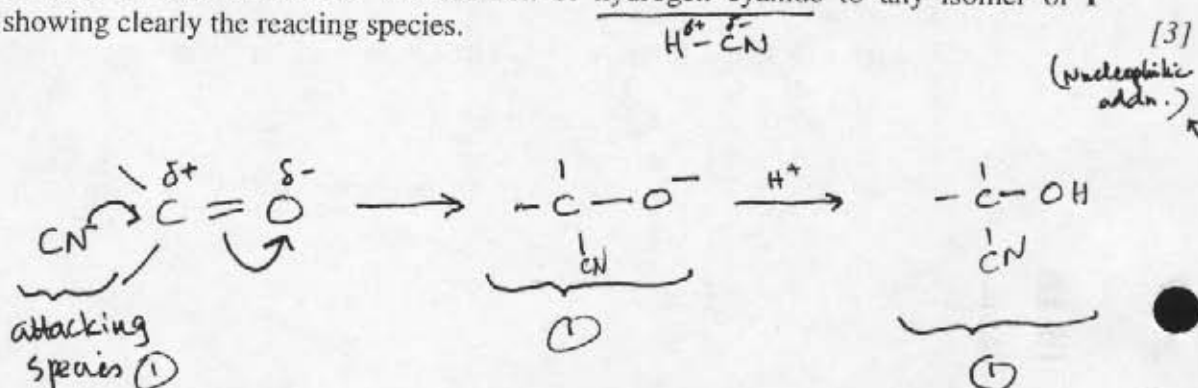✓ (gets one mark; wrong choice but correct conversion)Turn over

Option H – Further Organic Chemistry

H1. An organic compound, **P**, of molecular formula C_4H_8O reacted with 2,4-dinitrophenylhydrazine to form an orange precipitate.

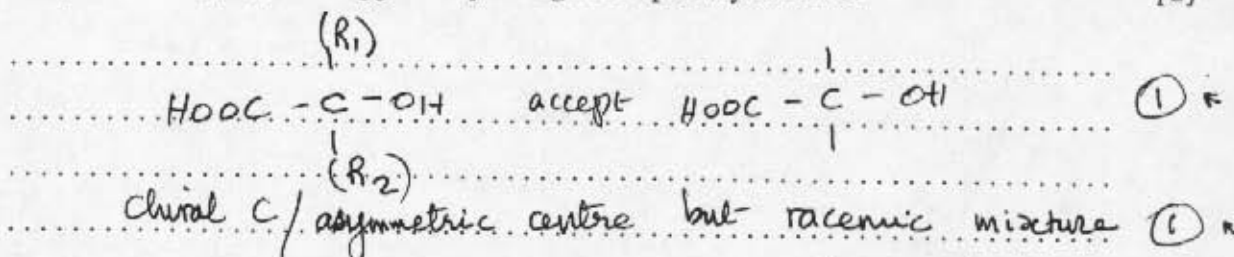(a) Give the name and structural formula of the functional group which is responsible for this reaction and deduce possible structural formulae for **P**.   [3]

Carbonyl ; $C = O$ (need both for mark) ①

(also accept alkanal/alkanone as well as carbonyl)

$CH_3 - CH_2 - CH_2 - C \overset{=O}{\underset{H}{\diagdown}}$; $CH_3 - \overset{O}{\underset{\|}{C}} - CH_2 - CH_3$ } all 3 : ②   one/two : ①

$CH_3 - \overset{CH_3}{\underset{|}{C}} - C \overset{=O}{\underset{H}{\diagdown}}$

(b) (i) Outline the mechanism for the addition of hydrogen cyanide to any isomer of **P** showing clearly the reacting species.   [3]

$H^{\delta +} - C \overset{\delta-}{N}$

(nucleophilic addn.)

$CN \overset{\diagdown}{\underset{\diagup}{\ }} \overset{\delta+}{C} = \overset{\delta-}{O} \longrightarrow -\overset{|}{\underset{CN}{C}} - O^- \overset{H^+}{\longrightarrow} -\overset{|}{\underset{CN}{C}} - OH$

attacking species ①   ①   ①

MUST involve attack of CN^- on $\overset{\delta+}{C}$; NO mark for 1st attack of H^+ on $O^{\delta-}$ 3

(-rxn is in basic solution ✱)

(ii) Write the structural formula of the organic molecule obtained by the acid hydrolysis of the product of (b) (i) and suggest why it might be optically inactive.   [2]
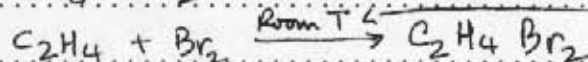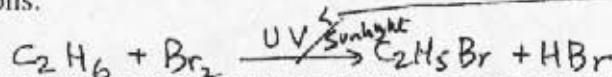
(R_1)

$HOOC - \overset{|}{\underset{|}{C}} - OH$ accept $HOOC - \overset{|}{\underset{|}{C}} - OH$ ① F

(R_2)

chiral C/asymmetric centre but racemic mixture ① R

("it has no chiral centre" is not an acceptable answer in this since $R_1 \neq R_2$; it would be true for say the carbonyl compd. being acetone but not in this case)
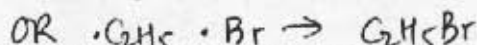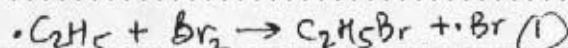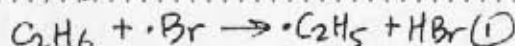
If product incorrect, e.g. $-\overset{|}{\underset{OH}{C}} - OH$ (no mark)
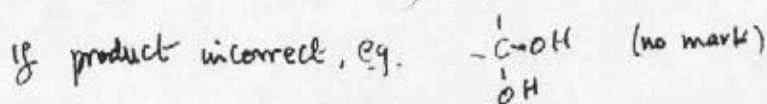
then (ECF): is. not optically active because. no 4 different groups   scores 1 mark

H2. Both ethane and ethene react with bromine, although the conditions and mechanisms are different. Give the equations and conditions for these reactions. Outline the mechanism of (one) of these reactions.   [7]

$$C_2H_6 + Br_2 \xrightarrow{UV/sunlight} C_2H_5Br + HBr$$ ① E

$$C_2H_4 + Br_2 \xrightarrow{Room\ T} C_2H_4Br_2$$ (instead of room T, accept "does not require any special conditions") ①

Either:

$$Br_2 \xrightarrow{UV} 2 \cdot Br \quad ①$$

$$C_2H_6 + \cdot Br \rightarrow \cdot C_2H_5 + HBr \quad ①$$

$$\cdot C_2H_5 + Br_2 \rightarrow C_2H_5Br + \cdot Br \quad ①$$

OR $\cdot C_2H_5 \cdot Br \rightarrow C_2H_5Br$

(no H· formed in this mech.) → no mark for ·H

(accept ·Br + ·Br → Br₂ as a terminating step) ①

then if H· + ·Br → HBr (ECF) then 1 mark

(OR)

$$\overset{\delta-}{\underset{\cap}{C}}=\overset{}{C} \quad + \quad \overset{\delta+}{Br}-\overset{\delta-}{Br} \quad ①$$

$$\rightarrow H-\overset{\oplus}{\underset{Br}{C}}-\overset{}{\underset{(+)}{C}}-H \quad + Br^- \rightarrow -\overset{}{\underset{Br}{C}}-\overset{}{\underset{Br}{C}}- \quad ①$$
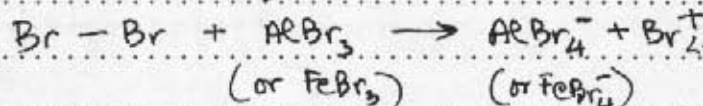
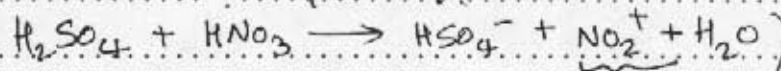(if both mechanisms given, mark the first, ignore second)
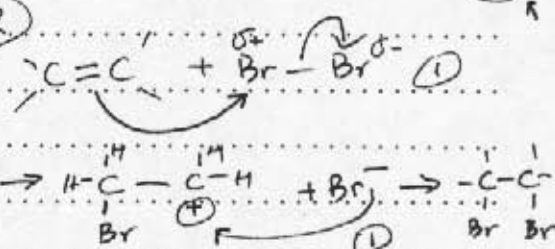
H3. The mononitration and monobromination of benzene both occur by electrophilic substitution.

(a) Describe the experimental conditions in each case. For **each** reaction, give an equation to show the formation of the electrophile.   * (need halogen carrier for mark)   [6]

Bromination: Br_2 and $FeBr_3$ (or $AlBr_3$) / reflux   ①

$$Br-Br + AlBr_3 \longrightarrow AlBr_4^- + Br^+$$ correct electrophile ①
(or $FeBr_3$)   (or $FeBr_4^-$)   balanced eq. ①

Nitration: conc. acids / heat / 60°C   ①

$$H_2SO_4 + HNO_3 \longrightarrow HSO_4^- + NO_2^+ + H_2O$$ ①   → correct electrophile
                                                             ① Balanced equation

(b) Outline the mechanism of **one** of these reactions. (must show arrows) (must show carbocation) (no arrow necessary)   [2]
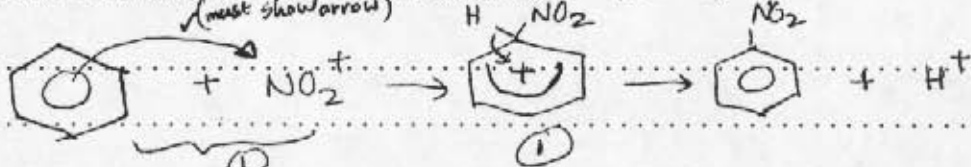
(c) Give the structure of the principal product formed during the dinitration of benzene. Explain your answer.   ①   [2]
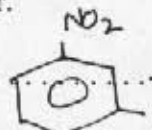
(no mark for just name of the product)

($-NO_2$: e⁻-withdrawing, deactivates ring, NO_2 withdraws e⁻-density from 2 & 4 positions so NO_2 enters in position 3)

→ Explanation in terms of stability of intermediate(s)

→ no mark for just saying 3- or meta directing as this is not an explanation