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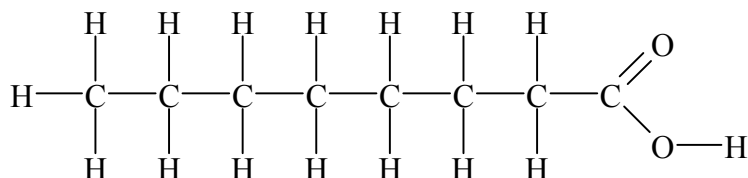
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BACCALAUREATE
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MARKSCHEME

November 2001

CHEMISTRY

Higher Level

Paper 3

17 pages

OPTION C – HUMAN BIOCHEMISTRY

C1. (a) $CH_2OH–CHOH–CH_2OH$ *[1]*

   (b) $–COOH$ *[1]*

   (Accept $CH_3(CH_2)_6COOH$ or any correct alternative, including branched structures or alkenoic acids.)   *[1]*

   (c)   Molecules of saturated fats contain only single C—C bonds in the carbon chains / contain no double bonds.   *[1]*
         Molecules of unsaturated fats contain at least one $C＝C$ double bond.   *[1]*
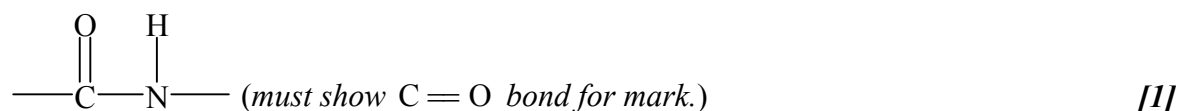   The degree of unsaturation can be found by determining the number of moles of iodine that react with one mole (or a stated mass) of fat.   *[1]*
         Iodine adds across the $C＝C$ double bond in a $1:1$ stoichiometric ratio.   *[1]*

                                                                    Total [7 marks]

C2. (a) $–NH_2$ / amino group / amine.   *[1]*

   (b)   Peptide bond (*accept amide bond*)   *[1]*

         (*must show $C＝O$ bond for mark.*)   *[1]*

   (c)   First hydrolyse the peptide bonds to release individual amino acids   *[1]*
         then use chromatography (comparison of R_f values) (*accept electrophoresis / mass spectrometry*).   *[1]*
         (Award both marks if X-ray crystallography is given.)

   (d)   The secondary structure describes the type of coil or sheet / folding of polypeptide / α-helix and β-pleated sheet.   *[1]*
         Tertiary structure describes the interactions between the R groups of the amino acid residues.   *[1]*
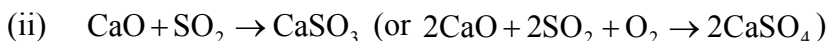
   (e)   Hydrogen bond.   *[1]*

                                                                    Total [8 marks]

C3. (a)   Enzymes provide an alternative pathway with a lower activation energy.   *[1]*
              Enzymes posses an active site where the substrate binds to the enzyme.   *[1]*
              Mention of 'lock and key' and/or induced fit hypothesis.   *[1]*

              Competitive inhibitors (resemble the substrate in shape) compete with the   *[1]*
              substrate for the active site (and therefore slow the rate of reaction).
              Non-competitive inhibitors bind to the enzyme away from the active site.   *[1]*

       (b) K_m for uninhibited enzyme $\left(= \frac{1}{2}V_{max}\right) = 7 \pm 1 \ \mu\,mol\,dm^{-3}$ *[1]*

              With a competitive inhibitor K_m is higher, V_{max} is the same.   *[1]*
              At high [S] effect of inhibitor is negligible so no change to V_{max} but more substrate
              needed to reach $\frac{1}{2}V_{max}$ so K_m is higher.   *[1]*

              With a non-competitive inhibitor K_m is the same but V_{max} is lower.   *[1]*
              Adding a non-competitive inhibitor has the same effect as lowering [enzyme]
              (hence V_{max} is lower), but does not affect the way the substrate interacts with those
              enzyme molecules that are uninhibited (hence K_m is unchanged).   *[1]*
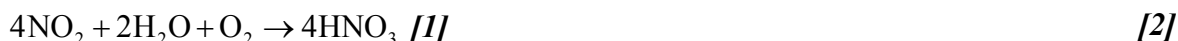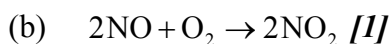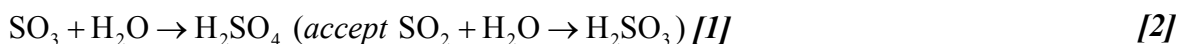
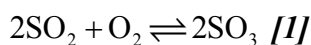   ***Total [10 marks]***

OPTION D – ENVIRONMENTAL CHEMISTRY

D1. (a) (i) $2CO + 2NO \rightarrow 2CO_2 + N_2$

(Award [1] for correct products and [1] for balanced equation.)   *[2]*

(ii) $CaO + SO_2 \rightarrow CaSO_3$ (or $2CaO + 2SO_2 + O_2 \rightarrow 2CaSO_4$)

(Award [1] for reactants and [1] for product.)   *[2]*

(b) $2NO + O_2 \rightarrow 2NO_2$ *[1]*
$4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$ *[1]*   *[2]*
OR
$2SO_2 + O_2 \rightleftharpoons 2SO_3$ *[1]*
$SO_3 + H_2O \rightarrow H_2SO_4$ (*accept* $SO_2 + H_2O \rightarrow H_2SO_3$) *[1]*   *[2]*

(c)   Irritation of the mucous membranes / fatigue / weakness / confusion (*e.g.* from exposure to $C_6H_5CH_3$) / cancer forming / respiratory problems.   *[1]*

Total [7 marks]

D2. (a) Polychlorinated biphenyls   *[1]*

(b) (i) LD_{50} – lethal dose in 50 % of the population (the amount of poison that kills half the organisms in a randomly chosen batch of a named species).   *[1]*
Maximum daily tolerance – the highest amount or concentration that has 'no effect' on any of the organisms in a specified batch.   *[1]*

(ii) LD_{50} :
Advantage: clearly measurable value.   *[1]*
Disadvantage: not done on human population so effect on humans 'unknown'.   *[1]*
OR
Maximum daily tolerance value:
Advantage: gives idea of 'safe amount'.   *[1]*
Disadvantage: same as for LD_{50} so has to be divided by 'safety factor'.   *[1]*

(c) (i)   Batteries / seed dressings to prevent mould / chlor-alkali process
(*do not accept "mercury fillings in teeth"*).   *[1]*

(ii)   *(Award [1] for any of the following:)*
inflammation of the mouth / muscle spasms / nausea / diarrhoea / kidney damage / blindness / deafness / damage to CNS / personality change.   *[1]*

(iii) The Hg^+ ions interfere with the normal functioning of enzymes (*e.g.* by replacing the Ca^{2+} or Mg^{2+} ions).   *[1]*

Total [10 marks]

D3. Water is a highly polar substance (due to shape and high electronegativity of oxygen).   *[1]*
Capable of hydrogen bonding (that allows it to dissolve many chemicals).   *[1]*

Fresh water not available uniformly around the world / 'locked up' in glaciers and icebergs.   *[1]*
Where the consumption is necessarily high it is easily contaminated with water borne diseases / by micro-organisms from human waste / from flooding / due to inadequate chemical treatment of water supplies.   *[1]*

Reverse osmosis:
     Uses high pressure   *[1]*
     to force water from salt-water through partially- (semi)-permeable membrane;   *[1]*
     the partially-permeable membrane does not allow the passage of dissolved ions.   *[1]*

OR Osmosis is the net movement of water molecules from a region of high concentration, *i.e.* pure water to one of lower concentration, *i.e.* less pure water through a partially-permeable membrane / osmosis is the tendency to equalise concentrations.   *[1]*
Due to osmosis, pure water will move through a partially-permeable membrane into salt water, thus diluting it.   *[1]*
If pressure greater than osmotic pressure is applied, the flow of solvent takes place in the opposite direction, called reverse osmosis.   *[1]*

Ion exchange:
     Requires the use of both a positive ion exchange (which can replace metal ions in sea water with H^+ ions)   *[1]*
     and a negative ion exchange (which can replace anions with OH^- ions).   *[1]*
   The H^+ and OH^- ions combine to form fresh/pure water.   *[1]*

Total [10 marks]

## OPTION E – CHEMICAL INDUSTRIES

E1. (a) (i) N_2 obtained from the fractional distillation of liquid air.   **[1]**
                  (Not enough to just state 'from air'.)

(ii) H_2 obtained from cracking of petroleum products / from water using reduction with methane / from water using reduction with naptha / catalytic reforming / electrolysis of sodium chloride solution.   **[1]**

(b) There are four volumes (moles) of gas on LHS and only two on RHS   **[1]**
     so increasing the pressure will move the position of equilibrium to the right   **[1]**
     Increasing the pressure increases the concentration of the gases   **[1]**
     So reaction rate increases.   **[1]**

(c) The yield of ammonia is low   **[1]**
     so most of the N_2 and H_2 needs to go round again (to save waste/cost).   **[1]**

Total [8 marks]

E2. (a) The free radical electron ($HO–CH_2–CH_2^{\cdot}$) attacks one of the C atoms in $H_2C = CH_2$.   **[1]**
            An electron from one of the bonds in the double bond joins this electron to form a single C–C bond.   **[1]**
            The double bond is now a single bond with the electron on the end carbon.   **[1]**

(b) $HO–CH_2–CH_2–CH_2–CH_2^{\cdot} + H_2C = CH_2 \rightarrow HO–CH_2–CH_2–CH_2–CH_2–CH_2–CH_2^{\cdot}$ **[1]**

(c) High density is ionic.   **[1]**

(d) *(Award **[1]** each for two conditions from the following:)*
- Temperature about $60\,^{\circ}C$;
- Pressure 2–6 atmospheres;
- Ziegler (Natta) catalyst/triethylaluminium with titanium(IV) chloride.   **[2]**

(e)   **[2]**
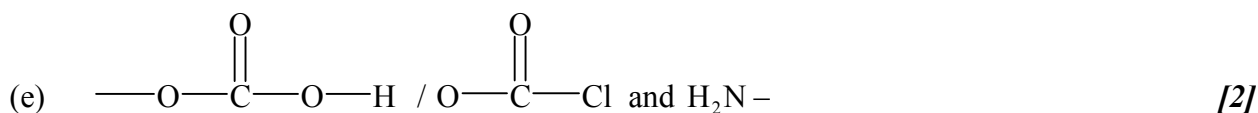
OR
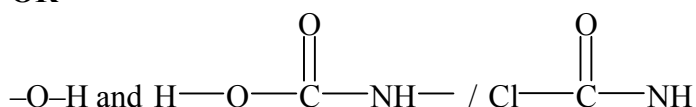
Total [9 marks]

E3. Tabulated form of answer.

(For each, give [1] for the process, [1] for the reactants, [1] for the products, and [1] for explaining the conditions.)

Choose from the following:

Temperature	
Thermal cracking / coking	Thermal decomposition of **very heavy fractions** to give mainly lower alkanes and alkenes **and a high coke yield**.
Steam cracking	Thermal cracking of C_2+ **hydrocarbons ($C_4 - C_{12}$) to alkenes (ethene, 1,3-butadiene, *etc.*)** in the presence of steam. Temperature around 800 °C.
Catalyst	
Catalytic cracking	Accelerated decomposition, with some aromatisation, of **middle/higher fractions** over **solid acidic catalysts/zeolites**. Gives **lower alkanes, alkenes, aromatics**.
Hydrocracking	Accelerated hydrogenolysis / decomposition of **heavy fractions** to **naptha** over **metal/acid catalysts *e.g.* palladium on zeolite**.
Catalytic reforming (platforming *etc.*)	**Metal/acid-catalysed *e.g.* platinum on acidic alumina rearrangement / cyclisation and dehydrogenisation of alkanes and aromatisation of napthas.**
Thermal / autothermal	More general term, including methane to ethene – cracking autothermal, with partial combustion.

[8]

By choosing a suitable catalyst, the temperature required is lower which makes it more efficient (and less costly) / helps to give the desired products by dictating the mechanism.

Total [8 marks]

OPTION F – FUELS AND ENERGY

F1. (a) Anode: zinc *[1]*
Cathode: graphite (carbon) *[1]*
Electrolyte: ammonium chloride **OR** zinc chloride and ammonium chloride and water. *[1]*

(b) Anode: $Zn \rightarrow Zn^{2+} + 2e^{-}$ *[1]*
Cathode: $2NH_4^+ + 2e^- \rightarrow 2NH_3 + H_2$ *[1]*
OR $2MnO_2 + 2NH_4^+ + 2e^- \rightarrow Mn_2O_3 + 2NH_3 + H_2O$
(State symbols are not required.)

(c) *(Award [1] each for any **two** from the following:)*
No decline in performance under high loads / no gases formed at cathode / longer shelf life / able to produce more current for a longer time / good for emergency lighting. *[2]*

(d) Voltage does not change *[1]*
voltage depends primarily on materials used. *[1]*

Total [9 marks]

F2. (a) (i) $_{0}^{1}n + {}_{92}^{235}U \rightarrow {}_{37}^{90}Rb + {}_{55}^{144}Cs + 2\,{}_{0}^{1}n$ *[2]*
(Give [1] for correct isotopes and [1] for two neutrons.)

(ii) $E = mc^2 = 1 \times 0.001 \times (3.0 \times 10^8)^2$ *[1]*
$= 9.0 \times 10^{13}$ J $(9.0 \times 10^{10}$ kJ$)$ *[1]*

(b) Four half-lives *[1]*
so $t_{1/2} = \dfrac{57.2}{4} = 14.3$ days *[1]*

Total [6 marks]

F3. (a) The crude oil is heated;   *[1]*
Fed into the base of a fractionating column;   *[1]*
Temperature gradient across column / lower boiling fractions distil first;   *[1]*
Fractions emerging in boiling range **not** pure compounds.   *[1]*

(Award [1] each for any three correct fractions from: (any two from number of C atoms, boiling range, and uses must be correct for each mark).)   *[3]*

Fraction	Number of C atoms	Boiling range / ˚C	Uses
Gases	1–4	0–200	cooking, heating
Naptha	5–7	20–100	solvents
Gasoline (petrol)	5–12	40–175	motor car fuel
Kerosene	12–18	175–300	jets / diesel
Gas oil	18–24	300–400	diesel fuel
Lubricating oil	20–30	non volatile	lubricants
Paraffin wax	25–40	solid	candles
Bitumen / tar	> 30	solid	road surfaces

(b) $C_{12}H_{26} \rightarrow C_8H_{18} + 2C_2H_4$ (or C_4H_8)
(must show an alkene for mark).   *[1]*
Octane for car engines and alkenes for polymers.   *[2]*

Total [10 marks]

OPTION G – MODERN ANALYTICAL CHEMISTRY

G1. (a) (i) The positive molecular ion or M^+ / parent ion.   *[1]*
            The molecular formula of compound **A** is $C_9H_{10}O$ *[1]*
            (Accept "the relative molecular mass of compound A is 134".)

         (ii) Due to the presence of ^{13}C isotopes in the compound.   *[1]*

         (iii) 105 due to $(M–C_2H_5)^+$ / $(C_7H_5O^+)$ *[1]*
              (also accept $(M – CHO)^+$ / $(C_8H_9^+)$ *)*
              77 due to $(M–C_3H_5O)^+$ / $C_6H_5^+$
              (must have + sign to gain mark, but only penalize once if omitted)   *[1]*

     (b) (i) It contains a carbonyl / either alkanal or alkanone / $C = O$ group.   *[1]*
             (Do not accept acid or ester.)

         (ii) C–H bond vibration (in alkanes, alkenes, arenes)   *[1]*

         (iii) It does not contain an alkanol or phenol group / no –OH group present.   *[1]*

     (c) (i) Molecular formula: SiC_4H_{12} *(accept* $Si(CH_3)_4$*)*   *[1]*

             (Award [1] each for any two from the following:)
             • Gives a sharp single peak;
             • Strong peak as 12 protons in identical environment;
             • Volatile so can be easily removed from the sample afterwards;
             • Occurs well away from other peaks (which are shifted downfield from it).   *[2]*

         (ii) They are in the ratio $3:2:5$ (since there are only 10 protons this is the actual
             number).   *[1]*

         (iii) It contains $(–C_2H_5)$ group / a $–CH_3$ group next to a $–CH_2–$ group   *[1]*
              The $–C_2H_5–$ group is attached to a C atom containing no other H atoms
              bonded to it.   *[1]*

         (iv) It contains an aromatic (benzene) ring.   *[1]*

Question G1 continued

(d)
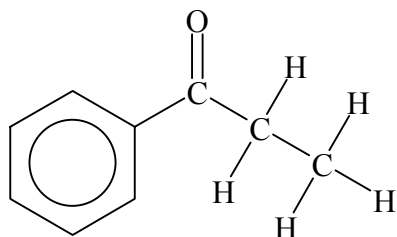
(Give [1] for correctly showing aromatic ring and [1] for *group.)* **[2]**

Total [17 marks]

G2. (a) The five d orbitals are split into different levels. **[1]**
When an electron is excited from a lower to a higher level it absorbs light/energy. **[1]**
The wavelength of the transmitted light / complementary colour lies in the visible region of the spectrum. **[1]**

(b) A spectrum is run with the copper(II) sulfate solution to determine the wavelength of maximum absorption / λ_{max}. **[1]**

The standard solution is diluted to give several solutions of different known concentrations. **[1]**
The absorbance for each of these solutions at a fixed wavelength / λ_{max} is recorded. **[1]**

A calibration curve of absorption versus concentration is plotted. **[1]**
The absorption of the unknown solution is recorded at the same wavelength and the concentration obtained from the graph. **[1]**

Total [8 marks]
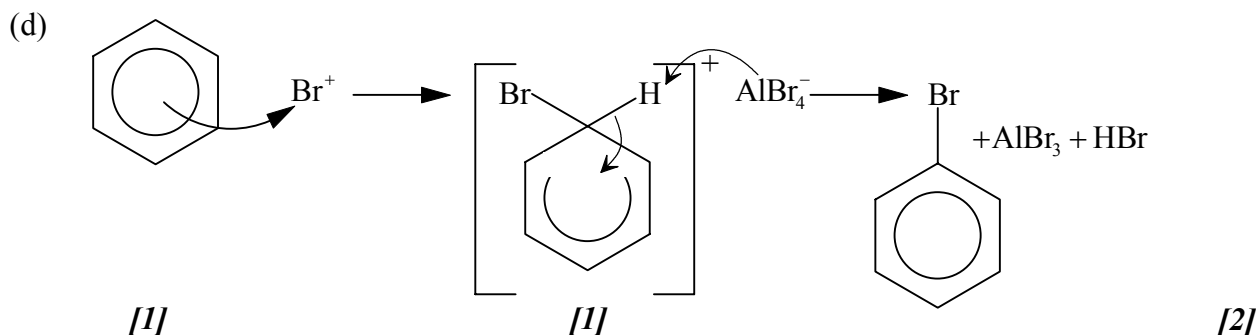
OPTION H – FURTHER ORGANIC CHEMISTRY

H1. (a) $C_6H_6 + Br_2 \rightarrow C_6H_5Br + HBr$ *[1]*

OR $+ \; Br_2 \longrightarrow$ $Br + HBr$
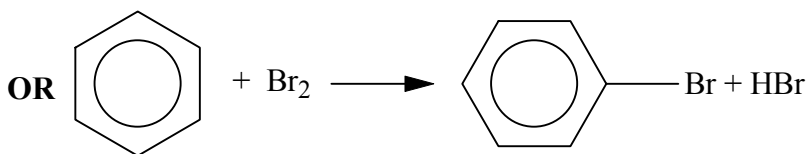
(b) Addition of a halogen carrier / $AlBr_3$ / Fe / $FeBr_3$ *[1]*
Heat / reflux   *[1]*

(c) Electrophile: Br^+ *[1]*

$Br{-}Br \qquad AlBr_3 \rightarrow Br^+ + AlBr_4^-$ *[1]*

(d)

[1]   *[1]*   *[2]*
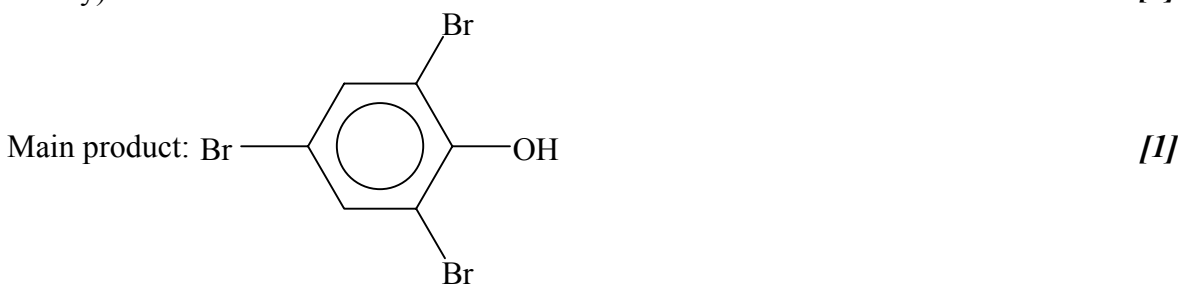
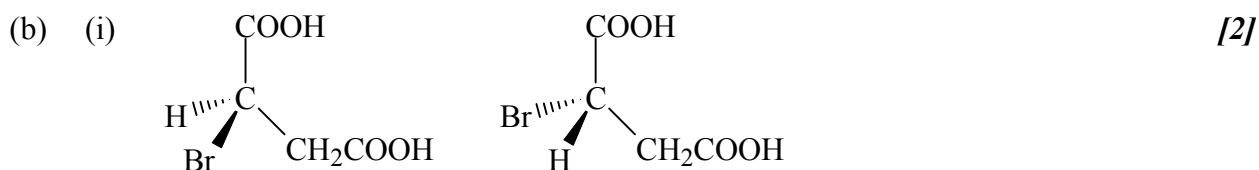(e) Phenol is more reactive than benzene.   *[1]*
No halogen carrier necessary for the reaction to proceed.   *[1]*
A pair of electrons on the oxygen atom delocalises with the π electrons in the ring which increases the electron density on the ring (thus attracting electrophiles more readily).   *[1]*

Main product: *[1]*

Total [11 marks]
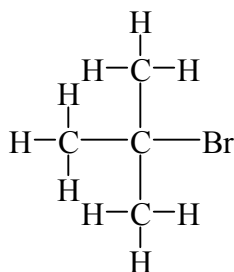
H2. (a) The π bond prevents the double bond from rotating in both cases.   *[1]*
In but-2-ene the atoms in the two isomers are arranged differently in space / contain
two different groups attached to each carbon atom.   *[1]*

(b) (i)   *[2]*

$$\text{H}\overset{\text{COOH}}{\underset{\text{Br}}{\overset{|}{\text{C}}}}\text{CH}_2\text{COOH} \qquad \text{Br}\overset{\text{COOH}}{\underset{\text{H}}{\overset{|}{\text{C}}}}\text{CH}_2\text{COOH}$$

(ii) They rotate the plane of polarised light in opposite directions.   *[1]*
Due to the presence of an asymmetric carbon atom / enantiomers / chirality.   *[1]*
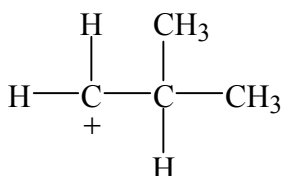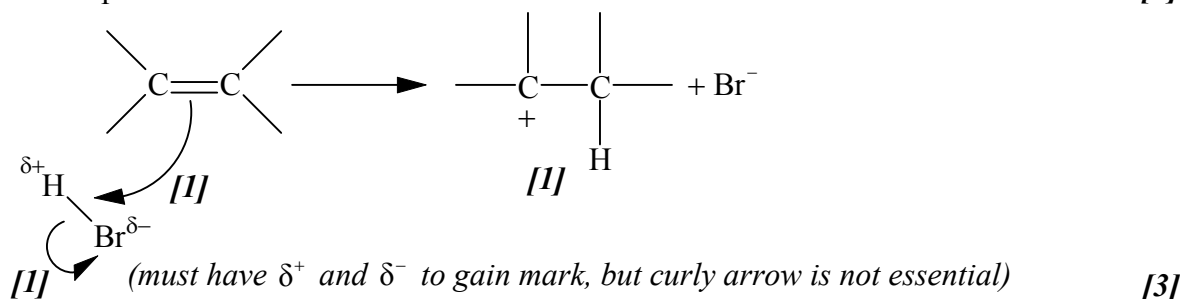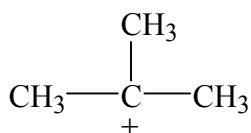
Total [6 marks]

H3. (a)   *[1]*

$$\begin{array}{c} \text{H} \\ | \\ \text{H}-\text{C}-\text{H} \\ \;\;\;\;| \\ \text{H}\;\;\;\;\text{H} \\ |\;\;\;\;\;| \\ \text{H}-\text{C}---\text{C}-\text{Br} \\ |\;\;\;\;\;| \\ \text{H}\;\;\;\;\text{H}-\text{C}-\text{H} \\ \;\;\;\;\;\;| \\ \text{H} \end{array}$$

(*accept* $\text{C(CH}_3)_3\text{Br}$)

(b) Electrophilic addition   *[1]*

$$\text{C}=\text{C} \longrightarrow -\overset{|}{\underset{+}{\text{C}}}-\overset{|}{\underset{\text{H}}{\text{C}}}- \;\; + \text{Br}^-$$

[1]   *[1]*

$$\overset{\delta+}{\text{H}} \qquad \text{Br}^{\delta-}$$

[1]   *[1]* (*must have δ⁺ and δ⁻ to gain mark, but curly arrow is not essential*)   *[3]*

$$\text{H}-\overset{\text{H}}{\underset{+}{\text{C}}}-\overset{\text{CH}_3}{\underset{\text{H}}{\text{C}}}-\text{CH}_3 \qquad\qquad \text{CH}_3-\overset{\text{CH}_3}{\underset{+}{\text{C}}}-\text{CH}_3$$

[1]

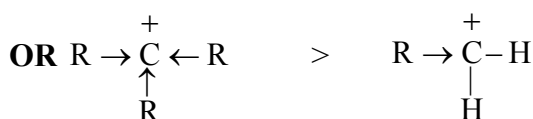**OR** primary carbocation   tertiary carbocation

Tertiary more stable   *[1]*
due to electron donating / positive inductive effect of the alkyl group.   *[1]*

$$\textbf{OR}\;\; \text{R}\rightarrow\overset{+}{\underset{\uparrow\text{R}}{\text{C}}}\leftarrow\text{R} \qquad > \qquad \text{R}\rightarrow\overset{+}{\underset{\text{H}}{\text{C}}}-\text{H}$$

Total [8 marks]