

MARKSCHEME

November 2001

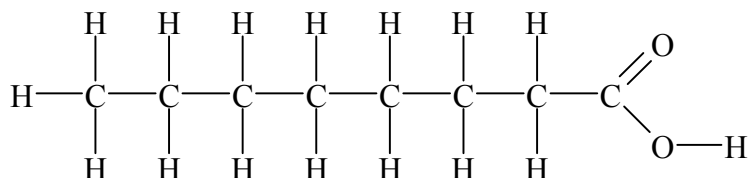
CHEMISTRY

Higher Level

Paper 3

OPTION C – HUMAN BIOCHEMISTRY

- C1.** (a) $\text{CH}_2\text{OH}-\text{CHOH}-\text{CH}_2\text{OH}$ [1]
 (b) $-\text{COOH}$ [1]

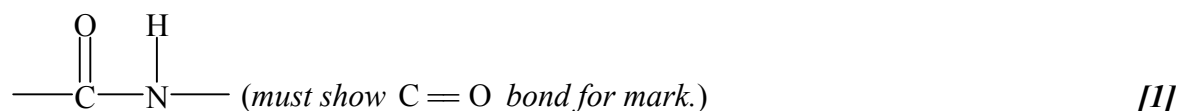


(Accept $\text{CH}_3(\text{CH}_2)_6\text{COOH}$ or any correct alternative, including branched structures or alkenoic acids.) [1]

- (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) $-\text{NH}_2$ / amino group / amine. [1]
 (b) Peptide bond (accept amide bond) [1]



- (c) First hydrolyse the peptide bonds to release individual amino acids then use chromatography (comparison of R_f values) (accept electrophoresis / mass spectrometry). [1]
 (Award both marks if X-ray crystallography is given.) [1]
 (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 possess 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 substrate for the active site (and therefore slow the rate of reaction). [1]

Non-competitive inhibitors bind to the enzyme away from the active site. [1]

- (b) K_m for uninhibited enzyme ($= \frac{1}{2} V_{max}$) = $7 \pm 1 \mu\text{mol dm}^{-3}$ [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) $2\text{CO} + 2\text{NO} \rightarrow 2\text{CO}_2 + \text{N}_2$
(Award [1] for correct products and [1] for balanced equation.) [2]
- (ii) $\text{CaO} + \text{SO}_2 \rightarrow \text{CaSO}_3$ (or $2\text{CaO} + 2\text{SO}_2 + \text{O}_2 \rightarrow 2\text{CaSO}_4$)
(Award [1] for reactants and [1] for product.) [2]
- (b) $2\text{NO} + \text{O}_2 \rightarrow 2\text{NO}_2$ [1]
 $4\text{NO}_2 + 2\text{H}_2\text{O} + \text{O}_2 \rightarrow 4\text{HNO}_3$ [1] [2]
- OR**
 $2\text{SO}_2 + \text{O}_2 \rightleftharpoons 2\text{SO}_3$ [1]
 $\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$ (accept $\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3$) [1] [2]
- (c) Irritation of the mucous membranes / fatigue / weakness / confusion (e.g. from exposure to $\text{C}_6\text{H}_5\text{CH}_3$) / 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]

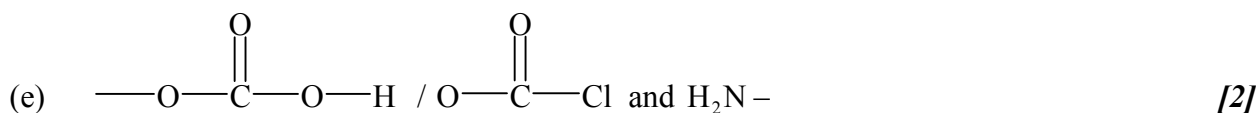
Total [10 marks]

OPTION E – CHEMICAL INDUSTRIES

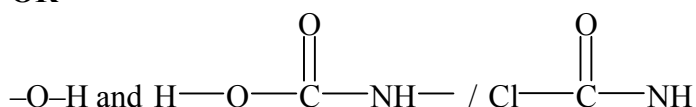
- E1.** (a) (i) N_2 obtained from the fractional distillation of liquid air. [1]
(Not enough to just state 'from air'.)
- (ii) H_2 obtained from cracking of petroleum products / from water using reduction with methane / from water using reduction with naphtha / catalytic reforming / electrolysis of sodium 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]



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 C₂+ hydrocarbons (C₄-C₁₂) 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 naphtha 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 naphthas .
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: $\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^{-}$ [1]
 Cathode: $2\text{NH}_4^{+} + 2\text{e}^{-} \rightarrow 2\text{NH}_3 + \text{H}_2$ [1]
OR $2\text{MnO}_2 + 2\text{NH}_4^{+} + 2\text{e}^{-} \rightarrow \text{Mn}_2\text{O}_3 + 2\text{NH}_3 + \text{H}_2\text{O}$
(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) ${}^1_0\text{n} + {}^{235}_{92}\text{U} \rightarrow {}^{90}_{37}\text{Rb} + {}^{144}_{55}\text{Cs} + 2{}^1_0\text{n}$ [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]
 $= 9.0 \times 10^{13} \text{ J } (9.0 \times 10^{10} \text{ kJ})$ [1]
- (b) Four half-lives [1]
 so $t_{\frac{1}{2}} = \frac{57.2}{4} = 14.3 \text{ days}$ [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) [1]
 (must show an alkene for mark).
 Octane for car engines and alkenes for polymers. [2]

Total [10 marks]

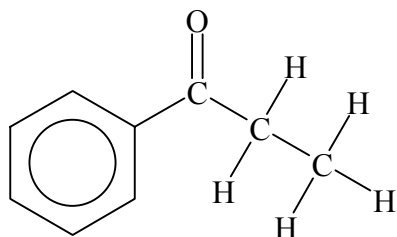
OPTION G – MODERN ANALYTICAL CHEMISTRY

- 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 $(M-C_3H_5O)^+$ / $C_6H_5^+$ [1]
(must have + sign to gain mark, but only penalize once if omitted)
- (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]

continued...

Question G1 continued

(d)



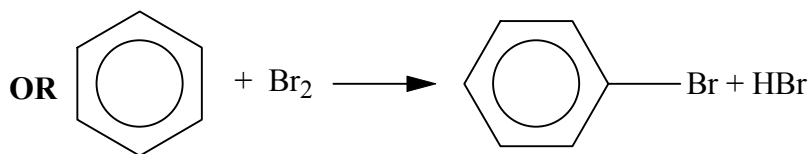
(Give [1] for correctly showing aromatic ring and [1] for $\text{—}\overset{\text{O}}{\parallel}{\text{C}}\text{—C}_2\text{H}_5$ group.) [2]

Total [17 marks]

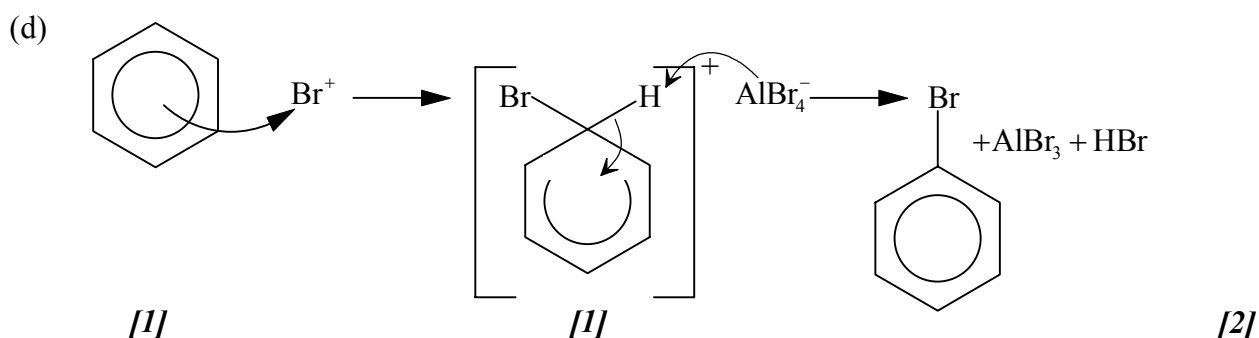
- G2.** (a) The five d orbitals are split into different levels. [1]
 When an electron is excited from a lower to a higher level it absorbs light/energy. [1]
 The wavelength of the transmitted light / complementary colour lies in the visible region of the spectrum. [1]
- (b) A spectrum is run with the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

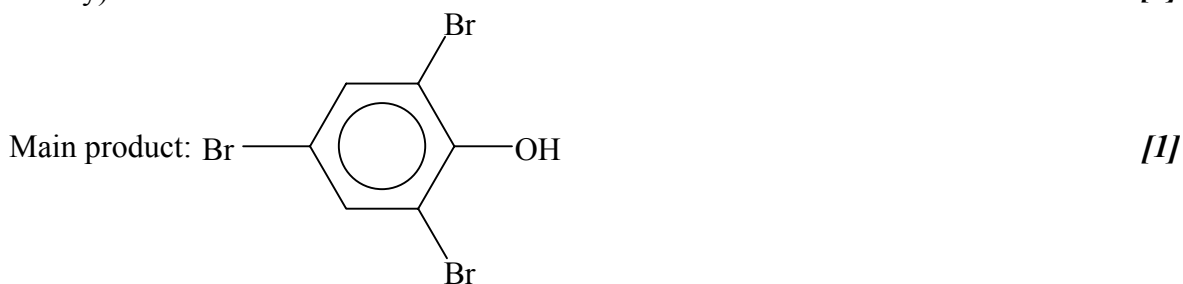


Heat / reflux [1]



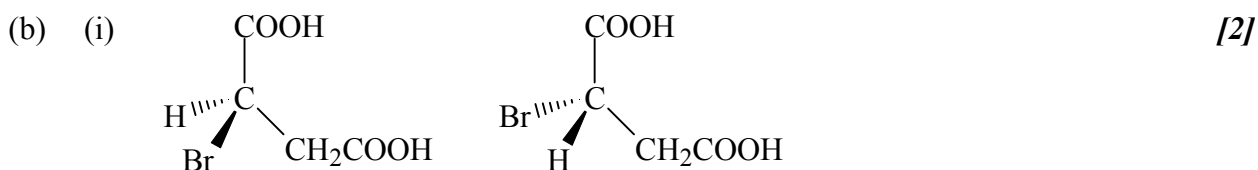
No halogen carrier necessary for the reaction to proceed. [1]

A pair of electrons on the oxygen atom delocalises with the π electrons in the ring (thus attracting electrophiles more readily). [1]



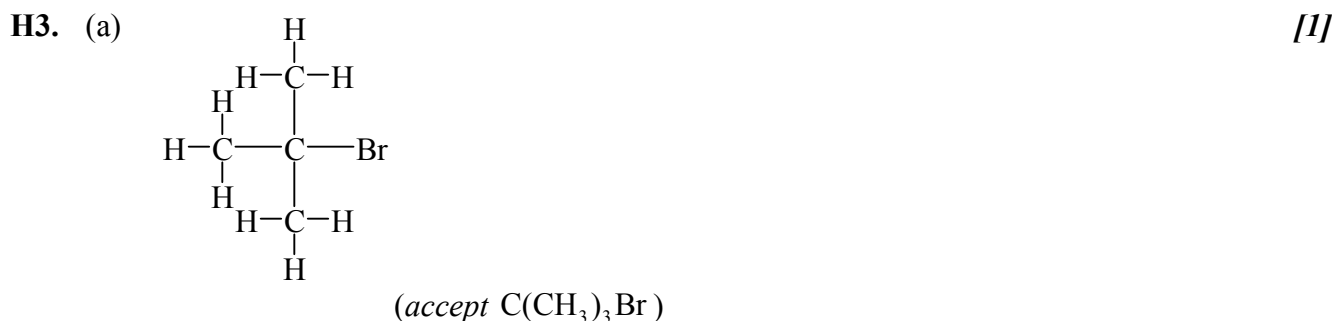
Total [11 marks]

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]

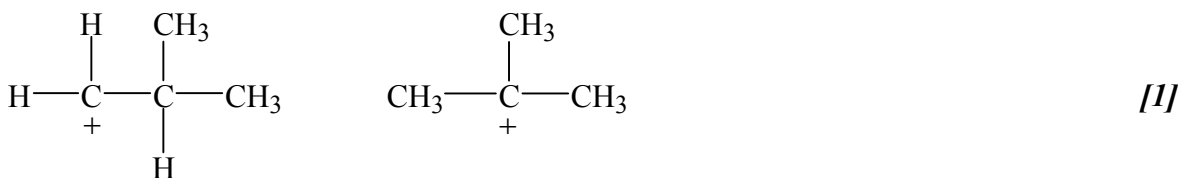
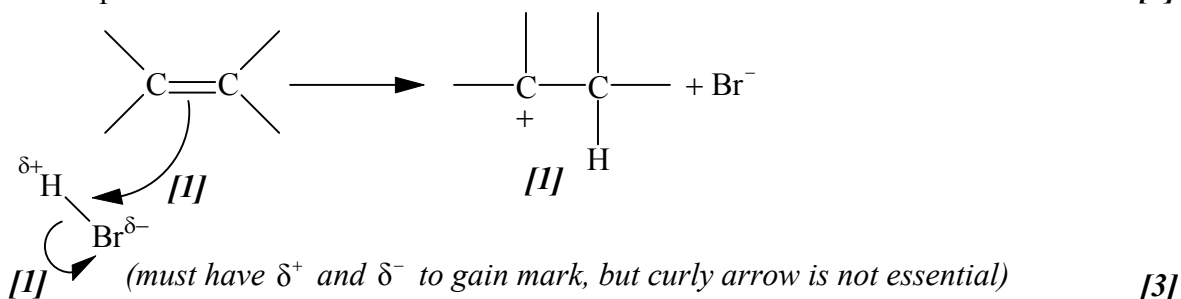


(ii) They rotate the plane of polarised light in opposite directions. [1]
 Due to the presence of an asymmetric carbon atom / enantiomers / chirality. [1]

Total [6 marks]

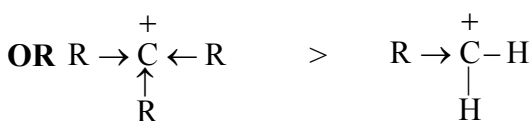


(b) Electrophilic addition [1]



OR primary carbocation tertiary carbocation

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



Total [8 marks]