MEGA LECTURE · A LEVEL CHEMISTRY

Module 6: Organic Chemistry and Analysis

OCR A Level Chemistry A (H432) — Structured Practice Paper with answer spaces

SPECIFICATION	TOTAL MARKS	SUGGESTED TIME
6.1 Aromatic compounds, carbonyls & acids · 6.2 Nitrogen compounds, polymers & synthesis · 6.3 Analysis	150	3 hours (or attempt in sections)

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Instructions to candidates

- Answer **all** questions in the spaces provided. If you need extra space, use lined paper and label your answer clearly.
- Draw mechanisms with **curly arrows starting from a bond or a lone pair**, and show all relevant dipoles, charges and lone pairs.
- Displayed or skeletal formulae are acceptable unless a specific type of formula is asked for.
- Marks are shown in brackets [ ] at the end of each part. Question 14 is marked using a level of response.
- You may use a scientific calculator and the OCR Data Sheet (IR absorption and NMR chemical shift tables).

Question 1 — Bonding and structure of benzene

6.1.1

a. The enthalpy change of hydrogenation of cyclohexene is −120 kJ mol^{-1}. The value predicted for the Kekulé structure of benzene is −360 kJ mol^{-1}, but the experimental value is −208 kJ mol^{-1}. Explain what this information tells you about the bonding and stability of benzene. **[3]**

b. X-ray diffraction shows that every carbon–carbon bond in benzene has the same length, 0.139 nm. Explain how this evidence contradicts the Kekulé model. **[2]**

c. State the shape around each carbon atom in benzene and the C–C–C bond angle. **[2]**

d. Explain why benzene undergoes electrophilic *substitution* rather than electrophilic *addition*. **[2]**

Question 1 total: 9 marks

Question 2 — Electrophilic substitution

6.1.1

a. Benzene is nitrated using concentrated nitric acid and concentrated sulfuric acid. Write an equation to show the generation of the nitronium ion, NO_2^+. **[2]**

b. Draw the full mechanism for the nitration of benzene, including the structure of the intermediate. **[3]**

Draw your mechanism in this box

c. State the reaction conditions and explain why the temperature is kept below 60 °C. **[2]**

d. Benzene reacts with ethanoyl chloride in the presence of an aluminium chloride catalyst. Write the equation for this reaction and name the organic product. **[2]**

e. Show, using two equations, how $AlCl_3$ acts as a halogen carrier in the reaction in (d) and is regenerated at the end of the reaction. **[3]**

Question 2 total: 12 marks

Question 3 — Phenol

6.1.1

a. Phenol reacts with bromine water at room temperature, whereas benzene does not react. State the observations and write an equation for the reaction of phenol with an excess of bromine water. **[3]**

b. **[3]**

Explain, in terms of electron density, why phenol reacts with electrophiles more readily than benzene.

c. Phenol reacts with aqueous sodium hydroxide but does not react with aqueous sodium carbonate. Write the equation for the reaction with NaOH and state what this shows about the acidity of phenol compared with carboxylic acids. **[2]**

d. Phenol is nitrated with *dilute* nitric acid at room temperature. State the positions on the ring at which substitution occurs, and explain why nitrobenzene, in contrast, is substituted at the 3-position. **[2]**

Question 3 total: 10 marks

Question 4 — Carbonyl compounds

6.1.2

a. Propanone is reduced by $NaBH_4$ in aqueous solution. Draw the mechanism of this nucleophilic addition, using H^- as the nucleophile, and name the organic product. **[3]**

Draw your mechanism in this box

b. Butanone reacts with KCN followed by dilute acid. Name the organic product and give its molecular formula. **[2]**

c. Explain why the product in (b) forms as a racemic mixture. **[2]**

d.

A student is given two unlabelled colourless liquids: propanal and propanone. Describe one chemical test, including the observation with *each* liquid, that would distinguish between them. **[3]**

e. Both liquids give an orange precipitate with 2,4-dinitrophenylhydrazine (2,4-DNPH). Explain in full how this precipitate can be used to confirm the exact identity of each carbonyl compound. **[3]**

Question 4 total: 13 marks

Question 5 — Carboxylic acids, esters and acyl chlorides 6.1.3

a. Write an equation for the reaction of ethanoic acid with sodium carbonate and state the observation. **[2]**

b. Ethanol and propanoic acid are heated under reflux with a few drops of concentrated sulfuric acid. Name the organic product, write the equation for the reaction, and explain why the yield is less than 100%. **[3]**

c. Methyl propanoate can be hydrolysed by heating under reflux either with dilute sulfuric acid or with aqueous sodium hydroxide. Give the organic products of each hydrolysis and explain one advantage of the alkaline method. **[4]**

d.

Give the structural formula of the organic product formed when propanoyl chloride reacts separately with: **[3]**

i. water

ii. methanol

iii. methylamine

Question 5 total: 12 marks

Question 6 — Amines

6.2.1

a. Place ammonia, ethylamine and phenylamine in order of increasing base strength. Explain the order in terms of the availability of the lone pair of electrons on the nitrogen atom. **[4]**

b. Write an equation for the reaction of ethylamine with hydrochloric acid and name the salt formed. **[2]**

c. Ethylamine can be prepared by heating bromoethane with an excess of ammonia dissolved in ethanol. Write the equation for this reaction and explain why a large excess of ammonia is used. **[3]**

d. Describe how nitrobenzene is converted into phenylamine, giving the reagents and conditions for each of the two stages. **[3]**

Question 6 total: 12 marks

Question 7 — Amino acids and chirality

6.2.2 / 6.2.3

Alanine, $CH_3CH(NH_2)COOH$, is a naturally occurring α-amino acid.

a. Draw the zwitterion of alanine, and the species present in a solution of alanine at low pH and at high pH. **[3]**

Draw the three species in this box

b. State what is meant by a *chiral centre* and state the number of optical isomers of alanine. **[2]**

c. Glycine, H_2NCH_2COOH, is not optically active. Explain why. **[2]**

d. Write equations for the reaction of alanine with: **[3]**

i. aqueous sodium hydroxide

ii. ethanol in the presence of concentrated sulfuric acid

Question 7 total: 10 marks

Question 8 — Condensation polymers

6.2.3

Polymer **P** is made from benzene-1,4-dicarboxylic acid and ethane-1,2-diol.
Polymer **Q** is made from hexanedioyl dichloride and 1,6-diaminohexane.

a. Draw one repeat unit of **P** and one repeat unit of **Q**, and name the small molecule eliminated in the formation of each polymer. **[4]**

Draw the repeat units in this box

b. Name the type of linkage present in **P** and in **Q**. **[2]**

c. Explain why condensation polymers can be hydrolysed whereas addition polymers such as poly(propene) cannot, and state the environmental significance of this difference. **[3]**

d. Poly(lactic acid), PLA, is a biodegradable polymer with the repeat unit –[O–CH(CH_3)–CO]–. Identify the type of linkage in PLA, draw the structure of its monomer, and state the type of polymerisation by which it forms. **[3]**

Monomer structure and written answers

Question 8 total: 12 marks

Question 9 — Organic synthesis and practical skills 6.2.4 / 6.2.5

a. Devise a two-step synthesis of butanoic acid, $CH_3CH_2CH_2COOH$, starting from 1-bromopropane. Give the reagents and conditions for each step and name the intermediate compound. **[4]**

b. State the reagent(s) and conditions you would use to convert the intermediate in (a) into butylamine instead. **[2]**

c. Devise a three-step synthesis of *N*-phenylethanamide, $C_6H_5NHCOCH_3$, starting from benzene. Give the reagents and conditions for each step and name each intermediate. **[4]**

d. The product of the synthesis in (c) is an impure organic solid. Describe how you would purify it by recrystallisation and how you would then check its purity. **[4]**

Question 9 total: 14 marks

Question 10 — Chromatography 6.3.1

a. In a thin-layer chromatography (TLC) experiment, the solvent front travelled 7.5 cm and a spot travelled 4.2 cm from the baseline. Calculate the R_f value of the spot. **[2]**

b. Explain why: **[3]**

i. the baseline is drawn in pencil

ii. the solvent level must start below the baseline

iii. the tank is covered with a lid

c. State what is meant by the *stationary phase* and the *mobile phase* in TLC. **[2]**

d.

In gas chromatography, explain how retention time is used to identify a component of a mixture, and state one limitation of using retention time alone. **[2]**

e. State how the amount of each component in a mixture can be determined from a gas chromatogram, and name the combined technique formed when GC is coupled to mass spectrometry. **[2]**

Question 10 total: 11 marks

Question 11 — NMR spectroscopy 6.3.2

a. Give three reasons why tetramethylsilane (TMS) is used as the standard reference compound in NMR spectroscopy. **[3]**

b. Explain why $CDCl_3$, rather than $CHCl_3$, is used as a solvent for ^1H NMR samples. **[2]**

c. Describe how a D_2O shake is carried out and how it identifies O–H and N–H protons. **[2]**

d. State the number of peaks you would expect in the ^{13}C NMR spectrum of: **[3]**

i. propan-2-ol

ii. methylbenzene

iii. ethyl ethanoate

Question 11 total: 10 marks

Question 12 — Structure determination: compound X

6.3.2

Compound **X** has the molecular formula $C_4H_8O_2$. The following data were obtained.

Technique	Data
Mass spectrum	Molecular ion peak at *m/z* = 88; major fragments at *m/z* = 43 and 45
Infrared	Strong sharp absorption at 1740 cm^{-1}; no broad absorption between 2500–3300 cm^{-1}
^{13}C NMR	Four peaks
^{1}H NMR	δ 4.12 (2H, quartet); δ 2.04 (3H, singlet); δ 1.26 (3H, triplet)

a. Use the infrared data to deduce which functional group is present in **X** and which is absent. **[2]**

b. Deduce the structure of **X**, explaining how each ^{1}H NMR signal (chemical shift, integration and splitting) supports your answer. **[4]**

c. Suggest the formulae of the fragment ions responsible for the peaks at *m/z* = 43 and *m/z* = 45. **[2]**

d. The mass spectrum also shows a very small peak at *m/z* = 89. Explain the origin of this peak. **[2]**

Question 12 total: 10 marks

Question 13 — Structure determination: compound Y

6.3.2

Compound **Y** is an aromatic compound with the molecular formula C_8H_8O. The following data were obtained.

Technique	Data
Mass spectrum	Molecular ion peak at *m/z* = 120; major fragments at *m/z* = 105, 77 and 43
Infrared	Strong absorption at 1680 cm^{-1}; no absorption above 3100 cm^{-1} other than weak aromatic C–H
^{1}H NMR	δ 7.4–8.0 (5H, multiplet); δ 2.60 (3H, singlet)
^{13}C NMR	Six peaks, including one at δ = 197

a. Use the infrared and ^{13}C NMR data to identify the functional group present in **Y**. **[2]**

b. Deduce the structure of **Y** and name it. Explain how the ^{1}H NMR data support your structure. **[4]**

c. Identify the fragment ions responsible for the peaks at *m/z* = 105, 77 and 43. **[3]**

Question 13 total: 9 marks

Question 14 — Extended response

Synoptic

A student is given four unlabelled bottles. Each bottle contains one of the following colourless liquids: **propan-1-ol · propanal · propanone · propanoic acid**

Plan a sequence of test-tube reactions that the student could use to identify all four liquids. For each test, state the reagent(s) and conditions, the expected observation for a positive result, and which liquid(s) each test identifies or eliminates. **[6]**

This question is marked using a level of response. Marks are awarded for a logically sequenced plan, correct chemistry, and correct observations.

Question 14 total: 6 marks

PAPER TOTAL: 150 MARKS

MARK SCHEME — Module 6 Structured Practice Paper

Award marks independently unless stated. ECF (error carried forward) applies to calculations. Accept correct alternatives throughout.

Q1 (a) [3]

- Benzene releases 152 kJ mol^{-1} *less* energy than predicted (360 − 208). (1)
- Therefore benzene is 152 kJ mol^{-1} *more stable* / lower in energy than the Kekulé structure. (1)
- The extra stability is due to delocalisation of the six p-electrons above and below the plane of the ring. (1)

Q1 (b) [2]

- Kekulé predicts alternating C=C (0.134 nm) and C–C (0.153 nm), i.e. two different bond lengths. (1)
- All bonds are identical and intermediate in length, consistent with delocalised electrons spread over all six carbons. (1)

Q1 (c) [2]

- Trigonal planar around each carbon. (1)
- Bond angle 120°. (1)

Q1 (d) [2]

- Addition would break/disrupt the delocalised π system, losing the delocalisation (stabilisation) energy. (1)
- Substitution preserves the delocalised ring, so it is the energetically favoured route. (1)

Q2 (a) [2]

- $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + 2HSO_4^- + H_3O^+$ (1 for NO_2^+, 1 for a correctly balanced equation)
- *Allow the two-step version: $HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$; then $H_2NO_3^+ \rightarrow NO_2^+ + H_2O$*

Q2 (b) [3]

- Curly arrow from inside the delocalised ring to the N of NO_2^+. (1)
- Intermediate: horseshoe (broken ring) over approximately four carbons with a positive charge, sp^3 carbon bearing both H and NO_2. (1)
- Curly arrow from the C–H bond back into the ring, re-forming the delocalised system and releasing H^+. (1)

Q2 (c) [2]

- Reflux/heat at 50–60 °C (water bath) with concentrated H_2SO_4 catalyst. (1)
- Above 60 °C further substitution gives 1,3-dinitrobenzene, lowering the yield of nitrobenzene. (1)

Q2 (d) [2]

- $C_6H_6 + CH_3COCl \rightarrow C_6H_5COCH_3 + HCl$ (1)
- Product: phenylethanone (accept acetophenone). (1)

Q2 (e) [3]

- Generation of the electrophile: $AlCl_3 + CH_3COCl \rightarrow CH_3CO^+ + AlCl_4^-$ (1)
- Regeneration: $AlCl_4^- + H^+ \rightarrow AlCl_3 + HCl$ (1)
- $AlCl_3$ is regenerated unchanged, so it acts as a catalyst / halogen carrier. (1)

Q3 (a) [3]

- Observations: bromine water is decolourised (orange → colourless) and a white precipitate forms. (1)
- $C_6H_5OH + 3Br_2 \rightarrow C_6H_2Br_3OH + 3HBr$ (1 for formulae, 1 for balancing)
- *Product is 2,4,6-tribromophenol; no catalyst required.*

Q3 (b) [3]

- The oxygen of the –OH group has a lone pair in a p orbital. (1)
- This lone pair is partially delocalised into the π system of the ring. (1)
- The increased electron density polarises Br_2 / attracts electrophiles more strongly than benzene does. (1)

Q3 (c) [2]

- $C_6H_5OH + NaOH \rightarrow C_6H_5ONa + H_2O$ (1)
- Phenol is a weaker acid than carbonic acid, and therefore weaker than carboxylic acids (which do liberate CO_2 from carbonates). (1)

Q3 (d) [2]

- Phenol is substituted at the 2- and 4-positions (–OH is an electron-donating, 2,4-directing group that activates the ring). (1)
- $–NO_2$ is electron-withdrawing and 3-directing, so nitrobenzene is substituted at the 3-position. (1)

Q4 (a) [3]

- Curly arrow from the lone pair on H^- to the carbon of C=O, with δ+ on C and δ− on O shown. (1)
- Curly arrow from the C=O π bond onto the oxygen, giving the negatively charged alkoxide intermediate. (1)
- Protonation: arrow from the O^- lone pair to an H of H_2O. Product: propan-2-ol. (1)

Q4 (b) [2]

- 2-hydroxy-2-methylbutanenitrile (1)
- C_5H_9NO (1)

Q4 (c) [2]

- The planar C=O group can be attacked by CN^- with equal probability from either face. (1)
- The product carbon is a chiral centre, so equal amounts of the two enantiomers form — a racemic mixture. (1)

Q4 (d) [3]

- Reagent: Tollens' reagent, warmed in a water bath. (1)
- Propanal: silver mirror forms (aldehyde oxidised to carboxylic acid). (1)
- Propanone: no visible change. (1)
- *Allow Fehling's/Benedict's (blue → brick-red ppt with propanal only) or acidified $K_2Cr_2O_7$ (orange → green with propanal only).*

Q4 (e) [3]

- The orange precipitate confirms only that a carbonyl (C=O of aldehyde/ketone) is present. (1)
- The derivative is filtered, purified by recrystallisation and dried. (1)
- Its melting point is measured and compared with known 2,4-DNPH derivative melting points in a database to identify the exact compound. (1)

Q5 (a) [2]

- $2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$ (1)
- Effervescence / gas evolved that turns limewater milky. (1)

Q5 (b) [3]

- Product: ethyl propanoate. (1)
- $CH_3CH_2COOH + CH_3CH_2OH \rightleftharpoons CH_3CH_2COOCH_2CH_3 + H_2O$ (1)
- The reaction is reversible / reaches equilibrium, so it does not go to completion. (1)

Q5 (c) [4]

- Acid hydrolysis: propanoic acid + methanol. (1)
- Alkaline hydrolysis: sodium propanoate + methanol. (1)
- Acid hydrolysis is an equilibrium; alkaline hydrolysis is effectively irreversible (the carboxylate is resistant to attack). (1)
- Advantage: alkaline hydrolysis goes to completion → higher yield. (1)

Q5 (d) [3]

- (i) CH_3CH_2COOH (propanoic acid) (1)
- (ii) $CH_3CH_2COOCH_3$ (methyl propanoate) (1)
- (iii) $CH_3CH_2CONHCH_3$ (*N*-methylpropanamide) (1)
- *HCl is also produced in each reaction (misty white fumes).*

Q6 (a) [4]

- Order: phenylamine < ammonia < ethylamine. (1)
- Base strength depends on the availability of the N lone pair to accept a proton. (1)
- Ethylamine: the alkyl group donates electron density (positive inductive effect), making the lone pair more available. (1)
- Phenylamine: the N lone pair is delocalised into the ring, so it is much less available. (1)

Q6 (b) [2]

- $CH_3CH_2NH_2 + HCl \rightarrow CH_3CH_2NH_3^+Cl^-$ (1)
- Ethylammonium chloride. (1)

Q6 (c) [3]

- $CH_3CH_2Br + 2NH_3 \rightarrow CH_3CH_2NH_2 + NH_4Br$ (1)
- The amine product is itself a nucleophile and can attack more bromoethane, giving secondary/tertiary amines and quaternary salts. (1)
- Excess ammonia makes collision of bromoethane with NH_3 more likely, maximising the yield of the primary amine. (1)

Q6 (d) [3]

- Stage 1: heat under reflux with tin and concentrated hydrochloric acid. (1)
- This reduces $–NO_2$ and forms the salt $C_6H_5NH_3^+Cl^-$. (1)
- Stage 2: add excess NaOH(aq) to liberate free phenylamine. (1)

Q7 (a) [3]

- Zwitterion: $CH_3CH(NH_3^+)COO^-$ (1)
- Low pH: $CH_3CH(NH_3^+)COOH$ (1)
- High pH: $CH_3CH(NH_2)COO^-$ (1)

Q7 (b) [2]

- A chiral centre is a carbon attached to four different atoms/groups. (1)
- Alanine has 2 optical isomers (a pair of enantiomers). (1)

Q7 (c) [2]

- The central carbon of glycine carries two H atoms. (1)
- So it has no carbon with four different groups — no chiral centre; the mirror images are superimposable. (1)

Q7 (d) [3]

- (i) $CH_3CH(NH_2)COOH + NaOH \rightarrow CH_3CH(NH_2)COO^-Na^+ + H_2O$ (1)
- (ii) $CH_3CH(NH_2)COOH + C_2H_5OH \rightleftharpoons CH_3CH(NH_2)COOC_2H_5 + H_2O$ (1 for correct ester, 1 for balanced equation with water)
- *Accept the $–NH_3^+$ form of the amine group in the acidic conditions of (ii).*

Q8 (a) [4]

- **P** repeat unit: $–[O–CH_2CH_2–O–CO–C_6H_4–CO]–$ with continuation bonds at both ends. (1)
- Eliminated from **P**: water. (1)
- **Q** repeat unit: $–[NH–(CH_2)_6–NH–CO–(CH_2)_4–CO]–$ with continuation bonds. (1)
- Eliminated from **Q**: hydrogen chloride, HCl (a diacyl dichloride is used). (1)

Q8 (b) [2]

- **P**: ester linkage — a polyester (PET/Terylene). (1)
- **Q**: amide linkage — a polyamide (nylon-6,6). (1)

Q8 (c) [3]

- Ester/amide linkages contain polar C=O (and C–O/C–N) bonds; the δ+ carbon is attacked by nucleophiles such as H_2O/OH^-. (1)
- Addition polymers have a non-polar, saturated C–C backbone that is unreactive towards nucleophiles. (1)
- Condensation polymers are therefore biodegradable / can be chemically recycled to monomers; addition polymers persist in the environment. (1)

Q8 (d) [3]

- Linkage: ester. (1)
- Monomer: lactic acid / 2-hydroxypropanoic acid, $CH_3CH(OH)COOH$. (1)
- Condensation polymerisation (each monomer has both –OH and –COOH). (1)

Q9 (a) [4]

- Step 1: KCN (or NaCN) in ethanol, heat under reflux. (1)
- Intermediate: butanenitrile, $CH_3CH_2CH_2CN$ — the chain is extended by one carbon. (1)
- Step 2: heat under reflux with dilute HCl (or dilute H_2SO_4). (1)
- The nitrile is hydrolysed to butanoic acid. (1)
- *Allow Step 2 via NaOH(aq) reflux followed by acidification.*

Q9 (b) [2]

- $LiAlH_4$ in dry ether (followed by dilute acid). (1)
- Accept H_2/Ni (or Pt) catalyst with heat and pressure. (1)

Q9 (c) [4]

- Step 1: conc. HNO_3 + conc. H_2SO_4, 50–60 °C → nitrobenzene. (1)
- Step 2: Sn / conc. HCl, reflux, then excess NaOH(aq) → phenylamine. (1 reagents, 1 both intermediates named correctly)
- Step 3: ethanoyl chloride (or ethanoic anhydride), room temperature → *N*-phenylethanamide. (1)

Q9 (d) [4]

- Dissolve the impure solid in the *minimum* volume of hot solvent (chosen so the compound is soluble hot, insoluble cold). (1)
- Filter the hot solution (removes insoluble impurities), then cool to allow crystals to form; soluble impurities stay in solution. (1)
- Filter under reduced pressure (Büchner), wash with a little cold solvent and dry. (1)
- Check purity by measuring the melting point: a pure sample melts sharply at the literature value; impurities lower and broaden the melting range. (1)

Q10 (a) [2]

- R_f = 4.2 ÷ 7.5 (1)
- = 0.56 (no units). (1)

Q10 (b) [3]

- (i) Pencil is insoluble in the solvent, so the baseline does not dissolve/run (ink would). (1)
- (ii) If the solvent started above the baseline the spots would dissolve into the solvent reservoir. (1)
- (iii) The lid saturates the tank with vapour, preventing solvent evaporating from the plate and giving reproducible R_f values. (1)

Q10 (c) [2]

- Stationary phase: the silica/alumina layer on the plate, which adsorbs the components. (1)
- Mobile phase: the solvent moving up the plate, carrying the components. (1)

Q10 (d) [2]

- The retention time is compared with that of a known standard run under identical conditions. (1)
- Limitation: different compounds may have the same/similar retention times, so it is not conclusive. (1)

Q10 (e) [2]

- Peak area is proportional to amount; concentrations found using a calibration curve from standards. (1)
- GC–MS. (1)

Q11 (a) [3]

- All 12 H atoms (and 4 C atoms) are equivalent → one single sharp peak. (1)
- Inert / non-toxic, does not react with the sample. (1)
- Volatile (easily removed) and absorbs upfield of nearly all other protons; defined as δ = 0. (1)

Q11 (b) [2]

- $CDCl_3$ contains deuterium, not ^1H. (1)
- So it gives no peak in the ^1H spectrum and does not obscure sample signals. (1)

Q11 (c) [2]

- Run the spectrum, add a few drops of D_2O, shake and re-run. (1)
- O–H/N–H protons exchange with D, so their peaks disappear in the second spectrum. (1)

Q11 (d) [3]

- (i) Propan-2-ol: 2 peaks. (1)
- (ii) Methylbenzene: 5 peaks (CH_3, ipso, ortho, meta, para). (1)
- (iii) Ethyl ethanoate: 4 peaks. (1)

Q12 (a) [2]

- 1740 cm^{-1}: C=O present, value typical of an ester. (1)
- No broad 2500–3300 cm^{-1} absorption: no carboxylic acid O–H present. (1)

Q12 (b) [4]

- Structure: ethyl ethanoate, $CH_3COOCH_2CH_3$. (1)
- δ 4.12 (2H, quartet): OCH_2, deshielded by O; split by 3 adjacent H (n+1 rule). (1)
- δ 2.04 (3H, singlet): $CH_3C{=}O$, no H on the adjacent carbon. (1)
- δ 1.26 (3H, triplet): CH_3 of ethyl, split by 2 adjacent H. (1)

Q12 (c) [2]

- *m/z* 43 = CH_3CO^+. (1)
- *m/z* 45 = $OCH_2CH_3^+$ / $C_2H_5O^+$. (1)

Q12 (d) [2]

- This is the M+1 peak. (1)
- About 1.1% of carbon is the ^{13}C isotope, so a small fraction of molecules are one mass unit heavier. (1)

Q13 (a) [2]

- 1680 cm^{-1} shows C=O; the low value indicates conjugation with the ring (aryl ketone). (1)
- ^{13}C peak at δ 197 confirms a carbonyl (ketone) carbon; no O–H, so not acid/alcohol. (1)

Q13 (b) [4]

- Structure: phenylethanone, $C_6H_5COCH_3$. (1)
- Name: phenylethanone (accept acetophenone). (1)
- δ 7.4–8.0 (5H, multiplet): monosubstituted benzene ring. (1)
- δ 2.60 (3H, singlet): CH_3 attached to C=O with no adjacent H; slightly deshielded by the carbonyl. (1)

Q13 (c) [3]

- *m/z* 105 = $C_6H_5CO^+$ (loss of CH_3, 15). (1)
- *m/z* 77 = $C_6H_5^+$. (1)
- *m/z* 43 = CH_3CO^+. (1)

Q14 [6] — Level of response

- **Level 3 (5–6 marks):** A logically sequenced plan that correctly identifies all four liquids, with correct reagents, conditions and observations throughout.
- **Level 2 (3–4 marks):** A plan that identifies at least two liquids with mostly correct chemistry; some observations missing or imprecise.
- **Level 1 (1–2 marks):** Some correct tests stated but poorly sequenced; observations incomplete or partly incorrect.
- **0 marks:** No creditworthy response.

Indicative content: *Test 1 — add Na_2CO_3(aq) (or $NaHCO_3$) to samples of each: effervescence (CO_2, turns limewater milky) identifies **propanoic acid**. Test 2 — warm the remaining three with Tollens' reagent: silver mirror identifies **propanal** (allow Fehling's: brick-red precipitate). Test 3 — warm the remaining two with acidified potassium dichromate(VI): orange → green identifies **propan-1-ol** (oxidised to propanal/propanoic acid); no change identifies **propanone**. Alternative: 2,4-DNPH distinguishes carbonyls (propanal, propanone give orange ppt) from the alcohol and acid; any coherent sequence that discriminates all four gains credit.*

END OF MARK SCHEME · 150 marks