Week 55

A-Level Chemistry

Homework bundle for this week

本周作业合集

exercises.lol

Contents 目录

A-Level Chemistry Name: ____________ Score: ______

1. In TLC, the stationary and mobile phases are:
   - ☐ the plate coating (stationary) and the solvent moving up it (mobile)
   - ☐ two gases
   - ☐ two solids
   - ☐ a carrier gas and a liquid
2. In GLC, the mobile phase is:
   - ☐ an unreactive carrier gas
   - ☐ a solid plate
   - ☐ a polar solvent
   - ☐ water
3. In carbon-13 NMR, the number of peaks tells you:
   - ☐ how many different carbon environments there are
   - ☐ the number of hydrogen atoms
   - ☐ the molar mass
   - ☐ the boiling point
4. In proton NMR, the number of groups of peaks tells you:
   - ☐ the number of different proton (hydrogen) environments
   - ☐ the molar mass
   - ☐ the number of carbons
   - ☐ the boiling point
5. The Rf value is:
   - ☐ distance moved by the spot ÷ distance moved by the solvent front
   - ☐ distance moved by the solvent ÷ distance moved by the spot
   - ☐ the retention time
   - ☐ the peak area
6. Equivalent carbons (in the same environment) give a single shared peak.

   ☐ True ☐ False

7. In thin-layer chromatography, the ratio of distances moved by a spot and the solvent is the _________ value.

   ____

8. In gas chromatography, the time a component takes to pass through the column is its _________ time.

   ____

9. The number of peaks in a carbon-13 NMR spectrum shows the number of different carbon _________.

   ____

10. A more soluble component travels further up a TLC plate.

    ☐ True ☐ False

1. **the plate coating (stationary) and the solvent moving up it (mobile)**

   The plate coating stays still; the solvent (mobile phase) travels up, carrying the spots.

2. **an unreactive carrier gas**

   A carrier gas moves the components past the liquid stationary phase.

3. **how many different carbon environments there are**

   Each distinct carbon environment gives one peak; equivalent carbons share a peak.

4. **the number of different proton (hydrogen) environments**

   Protons in different environments give peaks at different chemical shifts.

5. **distance moved by the spot ÷ distance moved by the solvent front**

   Rf = spot distance / solvent-front distance; it lies between 0 and 1.

6. **True**

   Carbons in identical environments are not distinguished, so they appear as one peak.

7. **Rf**

   Always between 0 and 1.

8. **retention**

   Used to identify components.

9. **environments**

   Equivalent carbons give one peak.

10. **True**

    It spends more time in the moving solvent.

37.1 Thin-layer chromatography

Name: ____________ Class: ________ Date: __________ **Total: 9 marks**

KEY WORDS stationary phase 固定相 • mobile phase 流动相 • solvent front 溶剂前沿 • thin-layer chromatography • chromatography 色谱

Objective

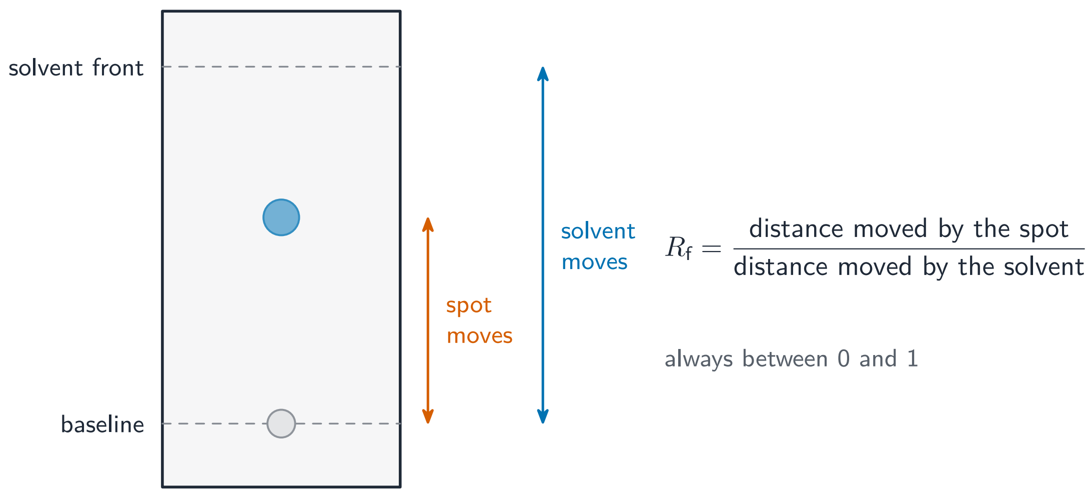
Build the skills to answer exam questions on **thin-layer chromatography** 薄层色谱 (TLC) — the two phases, the R_f **value**, and what it tells you.

You must be able to:

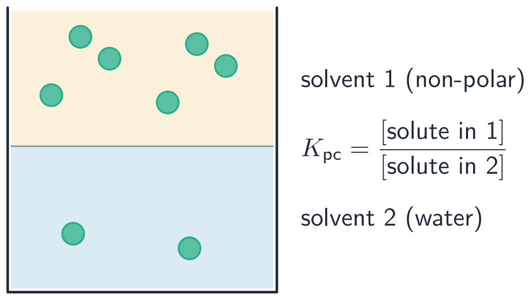
- identify the stationary and mobile phases in TLC
- calculate an R_f value
- explain why one component has a smaller R_f than another

1 Worked examples

■ The R_f value



The R_f value is how far the spot moved divided by how far the solvent front moved



TLC separates by partition between phases

$$R_f = \frac{\text{distance moved by the spot}}{\text{distance moved by the solvent front}}$$

- **stationary phase** stays still (e.g. aluminium oxide on a plate); **mobile phase** is the solvent that moves up.
- R_f is always between 0 and 1.
- a substance that sticks more strongly to the stationary phase (or is less soluble in the mobile phase) moves **less** → **smaller** R_f.

2 Practice

2.1 Name the stationary phase commonly used in TLC. [1]

2.2 A spot moves 3.6 cm; the solvent front moves 4.8 cm. Calculate its R_f. [1]

3 Exam-style questions

3.1 An R_f value can never be: [1]

- **A** 0.2
- **B** 0.85
- **C** 1.4
- **D** 0.5

3.2 A component with a **smaller** R_f value: [1]

- **A** is more soluble in the mobile phase
- **B** sticks more strongly to the stationary phase

- **C** moves further up the plate
- **D** has no interaction with the plate

3.3 On a TLC plate, a spot travels 2.1 cm while the solvent front travels 6.0 cm.

(a) Calculate the R_f value. [2]

(b) State what a low R_f suggests about how strongly the component binds to the stationary phase. [1]

3.4 Explain why two components of a mixture separate on a TLC plate. [2]

Solutions

2.1 aluminium oxide (alumina) / silica on a plate.

2.2 $R_\mathrm{f} = 3.6/4.8 = 0.75$.

3.1 C. R_f is always between 0 and 1, so 1.4 is impossible.

3.2 B. A smaller R_f means it sticks more strongly to the stationary phase and moves less.

3.3 (a) $R_\mathrm{f} = \dfrac{2.1}{6.0} = 0.35$.
(b) it binds (adsorbs) strongly to the stationary phase.

3.4 the components have different affinities for the stationary and mobile phases; so they travel up the plate at different rates and end at different heights, giving different R_f values.

A-LEVEL CHEMISTRY • EXERCISE SHEET

37.2 Gas/liquid chromatography

Name: ____________ Class: ________ Date: __________ **Total: 9 marks**

KEY WORDS retention time 保留时间 • stationary phase 固定相 • mobile phase 流动相 • gas/liquid chromatograph
• chromatography 色谱

Objective

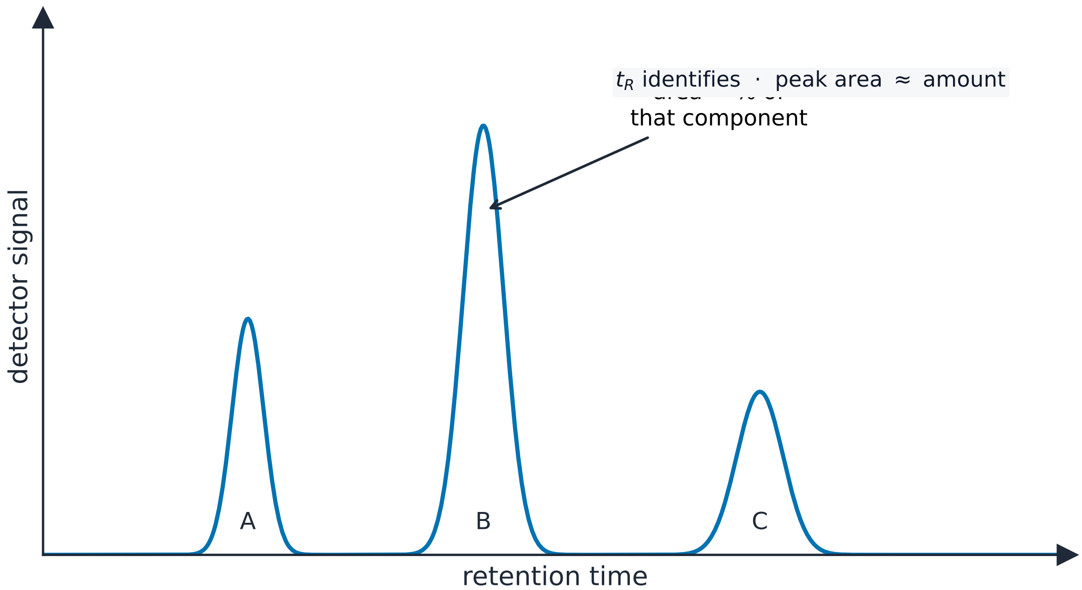
Build the skills to answer exam questions on **gas/liquid chromatography** 气液色谱 (GLC) — the phases, **retention time** 保留时间, and reading peak areas.

You must be able to:

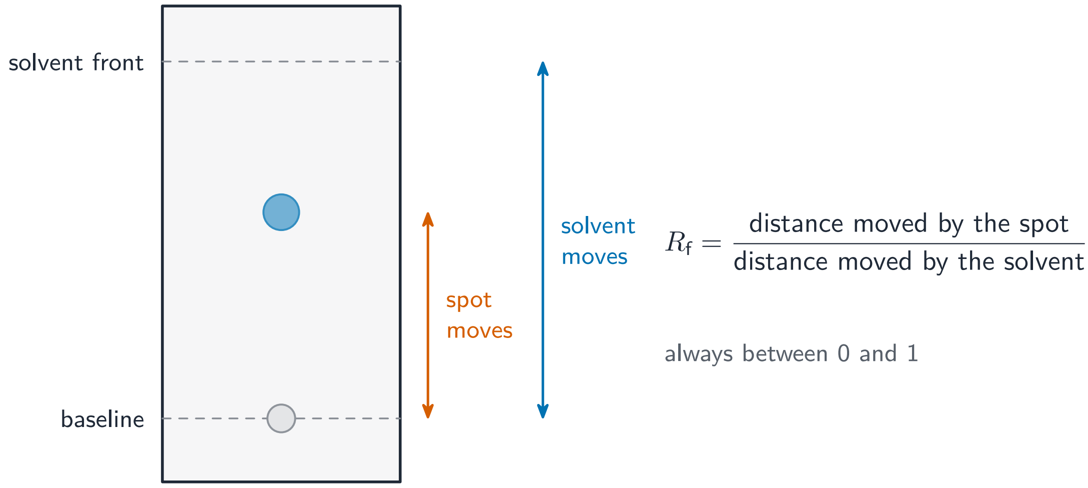
- identify the stationary and mobile phases in GLC
- explain what retention time depends on
- use peak areas to find the composition of a mixture

1 Worked examples

■ Reading a chromatogram



Each component gives a peak at its own retention time; the peak area is its percentage in the mixture



GLC alongside TLC as a chromatographic method

- **stationary phase:** a high-boiling non-polar liquid on a solid support; **mobile phase:** an unreactive carrier gas.
- **retention time** = how long a component takes to pass through; more interaction with the stationary phase → **longer** retention time.
- **peak area** = the proportion (percentage) of that component.

2 Practice

2.1 Name the mobile phase in GLC. [1]

2.2 State what the **area** of a GLC peak tells you. [1]

3 Exam-style questions

3.1 In GLC, a component that interacts **more** with the stationary phase has a: [1]

- **A** shorter retention time
- **B** longer retention time
- **C** larger R_f
- **D** smaller peak area

3.2 The **percentage** of each component in a mixture is found from the: [1]

- **A** retention time
- **B** number of peaks
- **C** area under each peak
- **D** height of the baseline

3.3 A GLC trace of a three-component mixture has peak areas 5, 3 and 2 units.

(a) Calculate the percentage of the first component. [2]

(b) State which component left the column **last**, given it interacted most with the stationary phase. [1]

3.4 Explain why different components of a mixture have different retention times. [2]

Solutions

2.1 an unreactive carrier gas.

2.2 the percentage (proportion) of that component in the mixture.

3.1 B. More interaction with the stationary phase $\rightarrow$ longer retention time.

3.2 C. The area under each peak gives the percentage.

3.3 (a) total area $= 5 + 3 + 2 = 10$; first component $= \dfrac{5}{10} \times 100 = 50\%$.
(b) the component with the **longest** retention time / smallest R_f-type behaviour — the one that interacts most strongly.

3.4 each component interacts to a different extent with the stationary phase; the more it interacts, the more it is held back, so it takes longer to pass through.

6 **(a)** Thin-layer and gas/liquid chromatography can be used to separate mixtures into their individual components.

(i) Define the following terms used in chromatography.

R_f value ....

....

retention time ....

.... [2]

(ii) Each type of chromatography makes use of a stationary phase and a mobile phase.

Complete Table 6.1 with a description of each of these.

Table 6.1

	stationary phase	mobile phase
thin-layer chromatography		
gas/liquid chromatography		

[1]

(b) A mixture of two substances **A** and **B** is analysed by thin-layer chromatography.

The R_f value of substance **A** is larger than that of substance **B**.

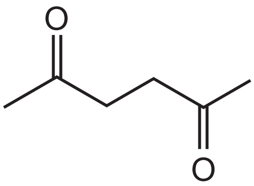
Suggest why substance **A** has a larger R_f value.

....

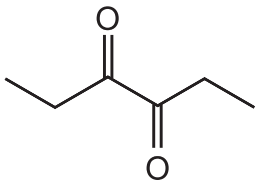
.... [1]

(c) The two isomeric compounds **Y** and **Z** are analysed by proton (^1H) NMR spectroscopy.

Y



Z



(i) Complete Table 6.2 to predict the number of peaks observed in the proton (^1H) NMR spectra for **Y** and **Z**.

Table 6.2

compound	number of peaks observed
Y	
Z	

[1]

(ii) Name **all** the different splitting patterns observed in the proton (^1H) NMR spectra for **Y** and **Z**.

Y ....

Z ....

[2]

[Total: 7]

37.3 Carbon-13 NMR spectroscopy

Name: ____________ Class: ________ Date: __________ **Total: 9 marks**

KEY WORDS carbon-13 nmr 碳 • nmr 核磁共振 • chemical shift 化学位移 • chemical environment 化学环境

Objective

Build the skills to answer exam questions on **carbon-13 NMR** 碳-13 核磁共振 — using the number and position of peaks to count carbon **chemical environments** 化学环境 and suggest structures.

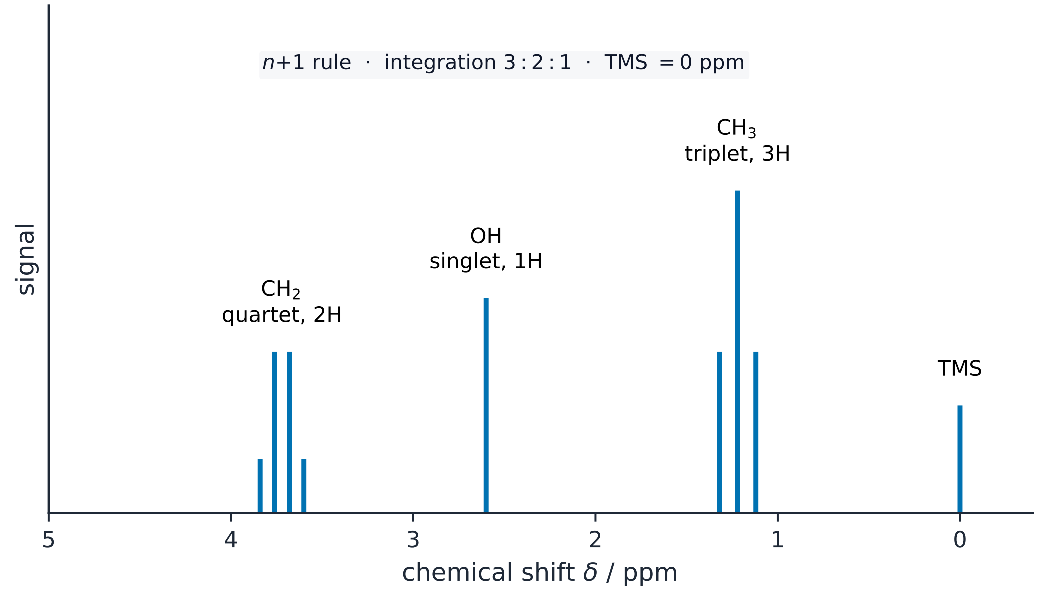
You must be able to:

- state what the number of peaks in a ^{13}C NMR spectrum tells you
- use chemical shift to suggest the type of carbon
- deduce possible structures from a ^{13}C spectrum

1 Worked examples

■ Counting carbon environments

NMR uses a very strong magnetic field (from a superconducting magnet) to study how nuclei behave



An NMR spectrum from a carbon environment count

- in ^{13}C NMR, each different **carbon environment** gives **one peak** (equivalent carbons share a peak).
- **number of peaks** = number of different carbon environments.
- **chemical shift** (peak position) suggests the type of carbon (e.g. C=O is far downfield).

Example: ethanol CH_3CH_2OH has 2 carbon environments → **2 peaks**.

2 Practice

2.1 State what the number of peaks in a ^{13}C NMR spectrum tells you. [1]

2.2 State how many peaks propanone, CH_3COCH_3, gives in its ^{13}C spectrum. [1]

3 Exam-style questions

3.1 In ^{13}C NMR, two carbon atoms in the **same** environment give: [1]

- **A** two separate peaks
- **B** a single peak
- **C** no peak
- **D** a split peak

3.2 How many peaks does propan-1-ol, $CH_3CH_2CH_2OH$, give in its ^{13}C spectrum? [1]

- **A** 1
- **B** 2
- **C** 3
- **D** 4

3.3 A compound C_3H_6O gives **two** peaks in its ^{13}C NMR spectrum, one far downfield (a C=O).

(a) Deduce a possible structure. [2]

(b) Explain how the number of peaks supports your structure. [1]

3.4 Explain why ethanoic acid, CH_3COOH, gives **two** peaks in its ^{13}C NMR spectrum. [2]

Solutions

2.1 the number of different carbon (chemical) environments in the molecule.

2.2 2 peaks (the two CH_3 carbons are equivalent; the C=O is the second).

3.1 B. Equivalent carbons in the same environment give a single peak.

3.2 C. Propan-1-ol has three different carbon environments → 3 peaks.

3.3 (a) propanone, CH_3COCH_3 — the C=O gives the downfield peak and the two equivalent CH_3 give the other.
(b) the two equivalent methyl carbons share one peak and the C=O gives the second, so two peaks fit.

3.4 ethanoic acid has two different carbon environments — the CH_3 carbon and the COOH carbon; each gives one peak, so there are two peaks.

37.4 Proton (1H) NMR spectroscopy

Name: ____________ Class: ________ Date: __________ **Total: 10 marks**

KEY WORDS splitting 裂分 • chemical environment 化学环境 • proton 质子 • singlet 单峰 • triplet 三峰

Objective

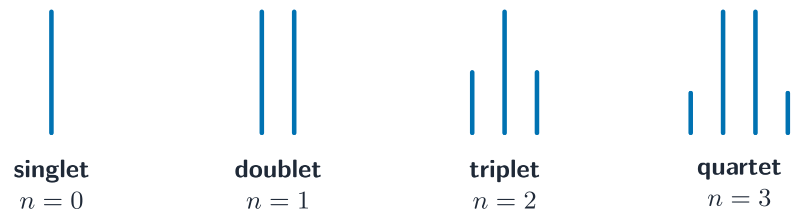
Build the skills to answer exam questions on **proton (^{1}H) NMR 质子核磁共振** — chemical environments, peak **area** ratios, **splitting 裂分** by the $n+1$ rule, and the use of TMS and D_2O.

You must be able to:

- count proton environments and use area ratios
- apply the $n+1$ rule to predict splitting patterns
- explain the roles of TMS, a deuterated solvent and D_2O

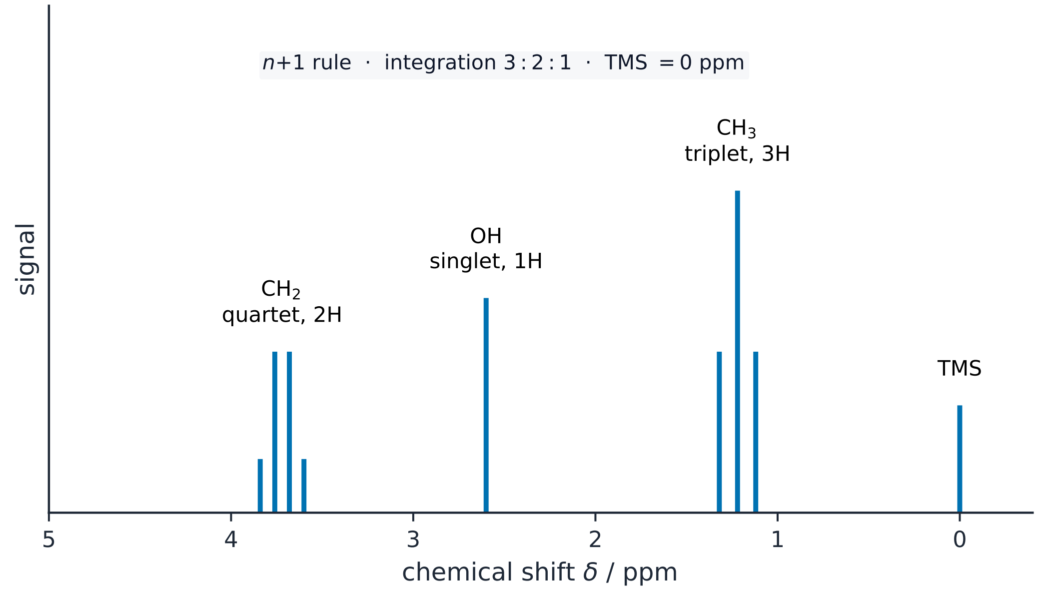
1 Worked examples

■ Splitting and areas



n equivalent neighbours split a peak into $n+1$ lines

The $n+1$ rule: n equivalent neighbouring protons split a peak into $n+1$ lines



Ethanol: three environments give a CH_3 triplet, a CH_2 quartet and an OH singlet, areas in ratio 3:2:1

- **number of peaks** = number of proton environments; **area ratio** = ratio of protons.
- $n + 1$ **rule:** n equivalent neighbours $\rightarrow$ $n + 1$ lines (0→singlet, 1→doublet, 2→triplet, 3→quartet).
- **TMS** sets the shift = 0; a **deuterated solvent** ($CDCl_3$) gives no signal; shaking with $\mathbf{D_2O}$ removes O–H/N–H peaks.

2 Practice

2.1 State what the relative **areas** of ^{1}H NMR peaks tell you. [1]

2.2 Using the $n + 1$ rule, state the splitting of a CH_3 next to a CH_2. [1]

3 Exam-style questions

3.1 A proton with **two** equivalent neighbours appears as a: [1]

- **A** singlet
- **B** doublet
- **C** triplet
- **D** quartet

3.2 Shaking a sample with D_2O causes a peak to **disappear**. This peak is due to: [1]

- **A** a CH_3 group
- **B** an O–H or N–H proton
- **C** a CH_2 group
- **D** the TMS reference

3.3 The ^1H NMR spectrum of ethanol, CH_3CH_2OH, has three groups of peaks.

(a) Give the splitting pattern of the CH_3 and the CH_2 peaks, with reasons. [2]

(b) State the ratio of the peak areas. [1]

3.4 A compound has two ^1H environments with area ratio 3:2; the larger peak is a triplet and the smaller a quartet. Deduce the two groups present and explain the splitting. [3]

Solutions

2.1 the ratio of the numbers of protons in each environment.

2.2 a triplet ($n = 2$ neighbours $\rightarrow 2 + 1 = 3$ lines).

3.1 C. Two equivalent neighbours give $2 + 1 = 3$ lines — a triplet.

3.2 B. D_2O exchange removes the O–H / N–H peak.

3.3 (a) the CH_3 is a triplet (its 2 CH_2 neighbours give $2 + 1 = 3$); the CH_2 is a quartet (its 3 CH_3 neighbours give $3 + 1 = 4$).
(b) $CH_3 : CH_2 : OH = 3 : 2 : 1$.

3.4 the triplet (area 3) is a CH_3 with 2 neighbours, and the quartet (area 2) is a CH_2 with 3 neighbours; so the groups are CH_3 and CH_2 next to each other, i.e. an ethyl group; each splits the other by the $n + 1$ rule.

7 **P**, **Q**, **R**, **S**, **T**, **U**, and **V** are the seven structural isomers with molecular formula $C_5H_{10}O$ that have a carbonyl group.

P $CH_3(CH_2)_3CHO$ **Q** $CH_3CH_2CH(CH_3)CHO$ **R** $(CH_3)_2CHCH_2CHO$

S $(CH_3)_3CCHO$ **T** $CH_3CH_2CH_2COCH_3$ **U** $CH_3CH_2COCH_2CH_3$

V $(CH_3)_2CHCOCH_3$

(a) Only one of these seven compounds has stereoisomers.

Draw three-dimensional diagrams of the **two** stereoisomers of this compound.

[2]

(b) **P**, **Q**, **R**, **S**, **T**, **U**, and **V** are treated separately with alkaline I_2(aq) and the product mixture is acidified.

(i) Identify the **two** compounds that give a positive result with alkaline I_2(aq).

.... and .... [1]

(ii) Describe the observations when **one** of the compounds you have identified in **(b)(i)** is treated with alkaline I_2(aq) and give the structural formulae of the **two** carbon-containing products of this reaction.

observations ....

two carbon-containing products ....

and ....

[2]

P $CH_3(CH_2)_3CHO$ **Q** $CH_3CH_2CH(CH_3)CHO$ **R** $(CH_3)_2CHCH_2CHO$

S $(CH_3)_3CCHO$ **T** $CH_3CH_2CH_2COCH_3$ **U** $CH_3CH_2COCH_2CH_3$

V $(CH_3)_2CHCOCH_3$

(c) The proton (^{1}H) NMR spectra of **P**, **Q**, **R**, **S**, **T**, **U**, and **V** are compared.

(i) Identify the only compound that gives a spectrum with two singlets and no other peaks.

.... [1]

Fig. 7.1 shows the spectrum obtained from one of the compounds.

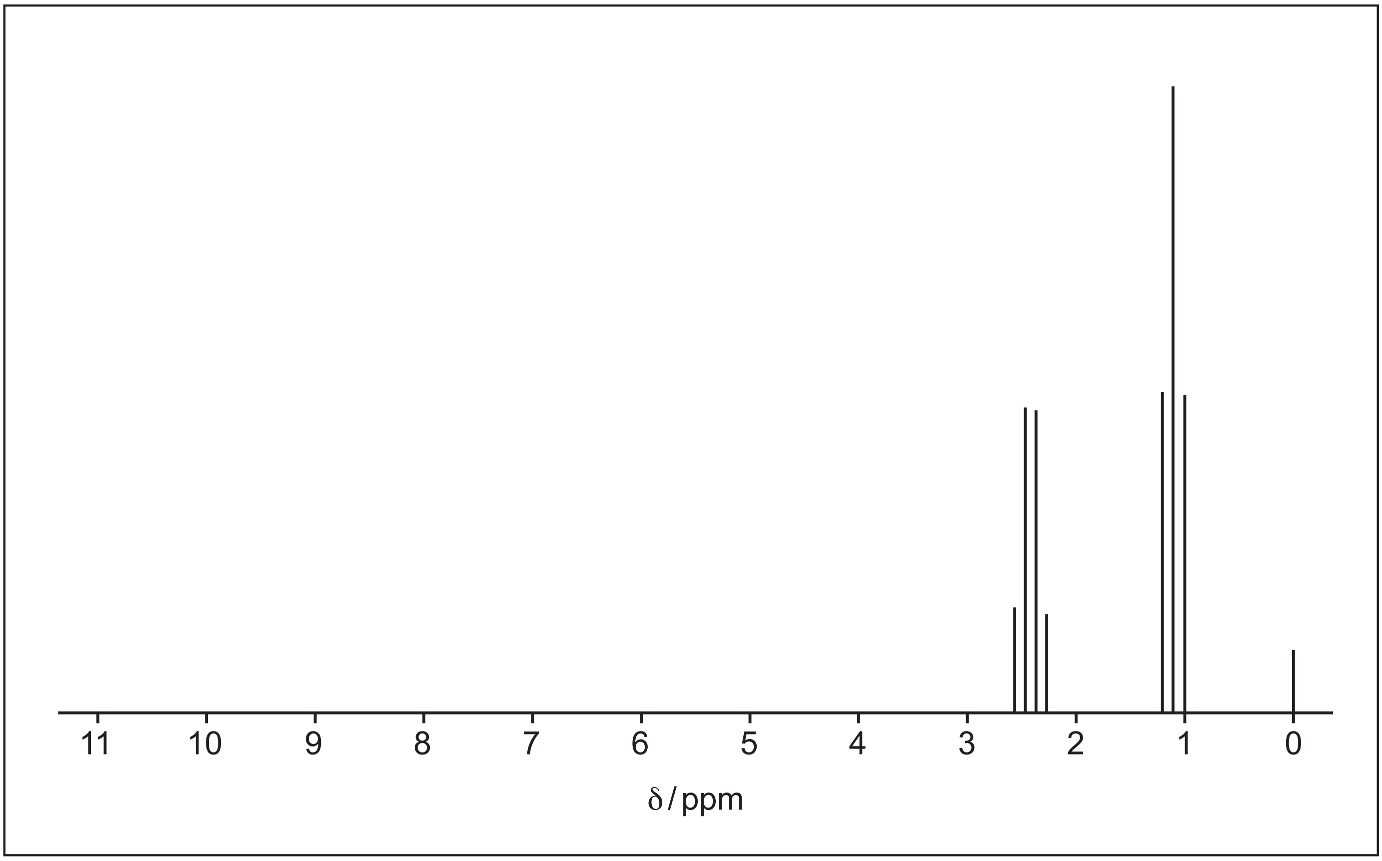


Fig. 7.1

(ii) Identify the compound that gives this spectrum.

.... [1]

(iii) Name the splitting pattern of the peak at δ = 1.1 in Fig. 7.1.

Give the reason for this splitting.

name ....

reason ....

[1]

(iv) Identify the substance that gives the small peak at δ = 0 in Fig. 7.1.

.... [1]

(d) The carbon-13 NMR spectra of **R**, **S**, **T** and **U** are compared.

Complete Table 7.1 to state the number of peaks in the spectrum of each compound.

Table 7.1

compound		number of peaks
R	$(CH_3)_2CHCH_2CHO$	
S	$(CH_3)_3CCHO$	
T	$CH_3CH_2CH_2COCH_3$	
U	$CH_3CH_2COCH_2CH_3$	

[2]

[Total: 11]