Past-paper walk-through

Isomerism: optical ▪ 29.4

eXercise

Questions in this set

- 9701/42 N25 Q8 ▪ 16 marks
- 9701/44 N25 Q8 ▪ 11 marks

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 8

9701/42 N25 ▪ Q8 ▪ 16 marks

8 Asparagine and aspartic acid are two naturally occurring amino acids. Their structures and isoelectric points are shown in Table 8.1.

Table 8.1

amino acid	structure	isoelectric point
asparagine	$HOOCCH(NH_2)CH_2CONH_2$	5.41
aspartic acid	$HOOCCH(NH_2)CH_2COOH$	2.77

(a) Define isoelectric point.

Question 8

(b) Draw the structures of asparagine and aspartic acid at pH 2.

asparagine at pH 2	aspartic acid at pH 2

Question 8

[2]

(c) Asparagine and aspartic acid are treated separately with an excess of $LiAlH_4$.

Draw the structures of the organic products of these reactions.

product of asparagine treated with an excess of $LiAlH_4$	product of aspartic acid treated with an excess of $LiAlH_4$

Question 8

[2]

(d) Propanedioic acid, $HOOCCH_2COOH$, is treated with an excess of thionyl chloride, $SOCl_2$. Propanedioyl chloride, $ClOCCH_2COCl$, is formed.

(i) Write an equation for this reaction.

Question 8

(ii) Propanedioyl chloride reacts with an excess of asparagine to form compound **G** with molecular formula $C_{11}H_{16}N_4O_8$.

Each molecule of compound **G** has four amide groups.

Draw the structure of compound **G**.

Compound **G**, $C_{11}H_{16}N_4O_8$

Question 8

[2]

(e) Asparagine is hydrolysed with an excess of hot NaOH(aq).

Draw the structure of the organic product of this reaction.

Question 8

[2]

(f) A polymer can form from asparagine, $HOOCCH(NH_2)CH_2CONH_2$, as the only monomer.

Draw a length of the polymer chain containing **three** monomer residues.

Clearly label the repeat unit of the polymer on your diagram.

Question 8

[3]

(g) Aspartic acid exists in two optically active forms.

(i) Plane polarised light is passed through pure samples of these two optically active forms in solutions of the same concentration.

Describe **two** similarities and **one** difference in their effect on the plane polarised light.

Question 8

Question 8

Question 8

Question 8

[2]

(ii) Give the term used to describe a mixture of equal amounts of the two optically active forms.

Question 8

[Total: 16]

Question 8

Question 9 starts on page 20.

Solution 8

(a)

Mark scheme

- the pH at which an amino acid exists as a zwitterion
- 1

Solution 8

(b)

Mark scheme

- M1: [HOOCCH(NH3)CH2CONH2]+
- M2: [HOOCCH(NH3)CH2COOH]+
- 2
- 9701/42
- October/November 2025

Solution 8

(c)

Mark scheme

- M1: HOCH2CH(NH2)CH2CH2NH2
- M2: HOCH2CH(NH2)CH2CH2OH
- 2

Solution 8

(d)(i)

Mark scheme

- HOOCCH2COOH + 2SOCl2 → ClOCCH2COCl + 2SO2 + 2HCl

1

- 1

Solution 8

(d)(ii)

Mark scheme

- HOOCCH(CH2CONH2)NHCOCH2CONHCH(CH2CONH2)COOH
- M1: three molecules joined, with four correct amide groups only
- M2: whole structure correct as above, displayed formula accepted, skeletal formula as below accepted
- 2

Solution 8

(e)

Mark scheme

- M1: hydrolysis of amide to carboxylate ion
- M2: hydrolysis of –COOH to carboxylate ion and rest of molecule
- –OOCCH(NH2)CH2COO–
- 2
- 9701/42
- October/November 2025

Solution 8

(f) Mark scheme

- ▪
- three monomer residues
- ▪
- all linkages correct
- ▪
- correct trailing bonds
- ▪
- repeat unit marked contains correct atoms

Solution 8

- Any two [1], any three [2], all four [3]
- CH2CONH2 CH2CONH2
- | |
- –COCHNH–[–COCHNH–]–COCHNH–
- |
- CH2CONH2
- 3

Solution 8

(g)(i) Mark scheme

- ▪
- rotate the plane of the plane polarised light
- ▪
- by the same angle
- ▪
- in opposite directions
- Any two [1], all three [2]
- 2

Solution 8

(g)(ii)

Mark scheme

- racemic mixture
- 1

Question 8

9701/44 N25 ▪ Q8 ▪ 11 marks

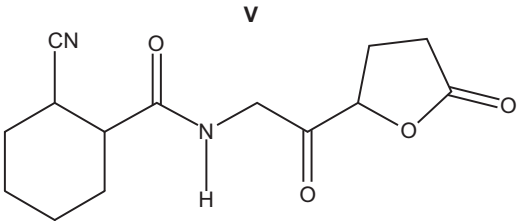
8 **(a)** Describe the difference in reactivity between ethanoyl chloride and chlorobenzene with water.

Explain your answer.

Question 8

(b) The structure of compound **V** is shown.

V



(i) Name all the functional groups in **V**.

Question 8

(ii) Deduce the number of possible optical isomers for **V**.

Question 8

(iii) Suggest **one** reason, other than better biological activity and lower dosage required, why it is beneficial to synthesise a single optical isomer of **V** for use as a drug.

Question 8

(c) A sample of **V** is hydrolysed with an excess of hot aqueous alkali.

The products are isolated from the reaction mixture at pH 12.

Draw the structures of the **two** organic products of the **complete** alkaline hydrolysis of **V** in Fig. 8.1.

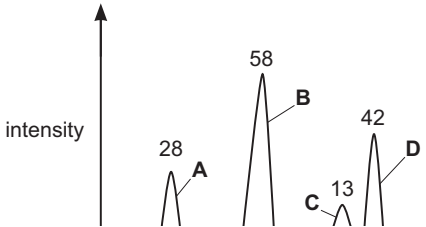
Question 8

Fig. 8.1

[3]

(d) A polypeptide formed from four amino acids, **A**, **B**, **C** and **D**, is completely hydrolysed and then analysed by gas–liquid chromatography.

The chromatogram produced is shown in Fig. 8.2.



Question 8

Question 8

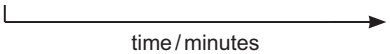


Fig. 8.2

The number above each peak represents the area under the peak.

The area under each peak is proportional to the mass of the respective amino acid in the mixture.

(i) Calculate the percentage by mass of amino acid **A** in the original mixture.

Question 8

(ii) The retention time for amino acid **D** is the longest.

Explain why **D** has a longer retention time than the **other** amino acids **A**, **B** and **C**.

Question 8

[Total: 11]

Important values, constants and standards

molar gas constant	$R = 8.31\,\text{J K}^{-1}\,\text{mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^{4}\,\text{C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23}\,\text{mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19}\,\text{C}$
molar volume of gas	$V_m = 22.4\,\text{dm}^3\,\text{mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0\,\text{dm}^3\,\text{mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14}\,\text{mol}^2\,\text{dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18\,\text{kJ kg}^{-1}\,\text{K}^{-1}$ ($4.18\,\text{J g}^{-1}\,\text{K}^{-1}$)

Question 8

	13	14	15	16	17	18
						2 He helium 4.0
	5 B boron 10.8	6 C carbon 12.0	7 N nitrogen 14.0	8 O oxygen 16.0	9 F fluorine 19.0	10 Ne neon 20.2
12	13 Al aluminium 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9
30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8
48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3
80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium –	85 At astatine –	86 Rn radon –
112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

Question 8

The Periodic Table of Elements

Group

1
H hydrogen 1.0

Key

…mic number …ic symbol name …e atomic mass

5	6	7	8	9	10	11
23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5
41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium –	44 Ru ruthenium 101.1	45 Rh rhodium 102.9	46 Pd palladium 106.4	47 Ag silver 107.9
73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0
105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –

59 Pr …aseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium –	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9
91 Pa …rotactinium 231.0	92 U uranium 238.0	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –

1	2			
3 **Li** lithium 6.9	4 **Be** beryllium 9.0		ato atom relativ	
11 **Na** sodium 23.0	12 **Mg** magnesium 24.3	3	4	
19 **K** potassium 39.1	20 **Ca** calcium 40.1	21 **Sc** scandium 45.0	22 **Ti** titanium 47.9	
37 **Rb** rubidium 85.5	38 **Sr** strontium 87.6	39 **Y** yttrium 88.9	40 **Zr** zirconium 91.2	
55 **Cs** caesium 132.9	56 **Ba** barium 137.3	57–71 lanthanoids	72 **Hf** hafnium 178.5	
87 **Fr** francium –	88 **Ra** radium –	89–103 actinoids	104 **Rf** rutherfordium –	

lanthanoids	57 **La** lanthanum 138.9	58 **Ce** cerium 140.1	pr
actinoids	89 **Ac** actinium –	90 **Th** thorium 232.0	p

Solution 8

(a) Mark scheme

- ▪
- chlorobenzene is less reactive than ethanoyl chloride
- ▪
- p orbital / lone pair on Cl / –Cl will overlap / delocalise into the ring
- OR C of COCl has most electron deficient OR has an electronegative oxygen atom / two electronegative atoms / electron
- withdrawing C=O group
- ▪

Solution 8

- due to partial double C–Cl bond
- OR C–Cl bond strengthened (more) / stronger bond between Cl and benzene / ring
- OR C–Cl weakened in ROCl
- any two [1], all three [2]
- 2

Solution 8

(b)(i) Mark scheme

- ▪
- nitrile
- ▪
- amide
- ▪
- ketone / carbonyl
- ▪
- ester

Solution 8

- any two [1], all four [2]
- 2

Solution 8

(b)(ii)

Mark scheme

- 8 / eight
- 1

Solution 8

(b)(iii)

Mark scheme

- no need to separate optical isomers
- 1
- 9701/44
- October/November 2025

Solution 8

(c)

Mark scheme

- M1: amide bond hydrolysed and COO– and NH2 formed
- M2: nitrile bond hydrolysed and COO– formed
- M3: ester bond hydrolysed and COO– and OH formed
- 3

Solution 8

(d)(i)

Mark scheme

- percentage $= 100 \times 28 / (28 + 58 + 13 + 42) = 19.9$ (%) min 2sf
- 1

(d)(ii)

Mark scheme

- D is attracted more strongly to the stationary phase / forms stronger intermolecular forces with the stationary phase
- 1