Anglo-Chinese Junior College

JC2 Preliminary Examination
Higher 2

A Methodist Institution
(Founded 1886)

CHEMISTRY **9729/01**

Paper 1 Multiple Choice

9 September 2024
1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.

Do not use staples, paper clips, glue or correction fluid.

Write your name, Centre number and index number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in this booklet.

The use of an approved scientific calculator is expected, where appropriate.

Solutions

1	**D**	6	**B**	11	**C**	16	**A**	21	**D**	26	**B**
2	**B**	7	**A**	12	**C**	17	**D**	22	**C**	27	**B**
3	**B**	8	**D**	13	**D**	18	**D**	23	**B**	28	**B**
4	**C**	9	**A**	14	**A**	19	**C**	24	**C**	29	**B**
5	**D**	10	**B**	15	**D**	20	**A**	25	**B**	30	**D**

1 The incomplete combustion of a gaseous hydrocarbon produced 80 cm^3 of carbon dioxide, 40 cm^3 of carbon monoxide and 160 cm^3 of water vapour.

What volume of oxygen was used for combustion of the hydrocarbon?

A	40 cm^3
B	80 cm^3
C	160 cm^3
D	180 cm^3

$$C_xH_y + \frac{9}{2}O_2 \rightarrow 2CO_2 + CO + 4H_2O$$

40 80 40 160

Comparing volume ratio of gases,

$$40 \times \frac{9}{2} = 180 \text{ cm}^3$$

2 0.01 mol of an unknown ion $\mathbf{G}^{2+}$ required 17.25 cm^3 of 0.23 mol dm^{-3} acidified $KMnO_4$ to reach the end-point.

What is the final oxidation state of element **G**?

A	+3	**B**	+4	**C**	+5	**D**	+6

$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$

Amt of MnO_4^- = 0.01725 x 0.23
= 3.968×10^{-3} mol

Amt of e^- = $3.968 \times 10^{-3} \times 5$
= 1.984×10^{-2} mol

$1.984 \times 10^{-2} / 0.01 = 1.98 \approx 2$

1 mol of X^{2+} loses 2 mol of e^-, so final O.S of X is +4.

3 Which ion will be deflected the most in an applied electric field?

A	$^{79}Br^{+}$	**B**	$^{81}Br^{2+}$	**C**	$^{81}Br^{+}$	**D**	$^{82}Br^{2+}$

Angle of deflection is directly proportional to charge/mass ratio.

$^{81}Br^{2+}$ has the largest charge/mass ratio, so it will be deflected the most in an electric field.

4 An unstable ion has

- a nucleon number of 219,
- 51 more neutrons than electrons
- an atomic number of 84, 85, 86, or 87.

What could this ion be?

A	Po^{2+}	**B**	At^{3+}	**C**	Rn^{4+}	**D**	Fr^{5+}

	Po^{2+}	At^{3+}	Rn^{4+}	Fr^{5+}
number of protons	84	85	86	87
number of electrons	82	82	82	82
number of neutrons	133	133	133	133
nucleon number	217	218	219	220

5 Which species contains two π bonds?

1 BF_3NH_3
2 $CH_2CHCH_2CH_3$
3 CH_2CHCHO
4 $HCO_2CH_2COCH_3$

A	1 and 4 only
B	2 and 3 only
C	2 and 4 only
D	3 and 4 only

1 contains a dative bond between the boron atom and nitrogen atom.

2 contains only one π bond in the alkene.

3 contains two π bonds, one in the alkene and one in the aldehyde.

4 contains two π bonds, one in ester and one in ketone.

6 What is the strongest intermolecular force in ethanal, ethylamine and decan-1-ol?

	ethanal	ethylamine	decan-1-ol
A	hydrogen bonds	hydrogen bonds	induced dipoles
B	permanent dipoles	hydrogen bonds	induced dipoles
C	permanent dipoles	permanent dipoles	hydrogen bonds
D	hydrogen bonds	permanent dipoles	hydrogen bonds

Ethanal has permanent dipoles between its molecules as it is a polar molecule.

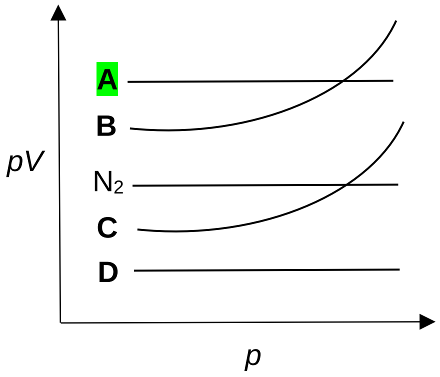
Ethylamine has hydrogen bonding between its molecules due to the lone pair of electrons on oxygen and the hydrogen bonded to oxygen in its molecules.

While there is hydrogen bonding between molecules of decan-1-ol, strongest intermolecular force in decan-1-ol is instantaneous dipole-induced dipoles due to the large electron cloud of the molecule.

7 The volumes and pressures of equal masses of two gases, N_2 and NH_3, are separately investigated, at constant temperature.

The results are plotted on a graph of *pV* against *p*. Both gases behave as ideal gases under the conditions chosen. The result for N_2 is given.

Which plot shows the result for NH_3?



Since both gases behave ideally, the *pV* against *p* plot for NH_3 is also a constant.

NH_3 has a lower molar mass than N_2. Since equal mass of gas is used, there are more NH_3 and given $pV = nRT$, its *pV* value will be higher.

8 What can be added to a mixture of MgO and Al_2O_3 to separate them by filtration?

	1	water
	2	HC*l*(aq)
	3	NaOH(aq)

	A	1, 2 and 3
	B	1 and 2 only
	C	2 and 3 only
	D	3 only
	MgO and Al_2O_3 are both insoluble in water, thus cannot be separated with water and then filtration. Both Al_2O_3 and MgO are soluble in aqueous HC*l* as they react with HC*l* to give soluble products. Hence, they cannot be separated by HCl(aq) and then filtration. Al_2O_3 is soluble in aqueous NaOH to form $NaAl(OH)_4$ while MgO is insoluble. Hence, NaOH(aq) and then filtration can separate the two oxides.	

9 The following table shows the results of two experiments involving Group 17 halides, X^- and Y^-.

experiment	deduction
halogen Z_2 added to X^-	X_2 formed
halogen Z_2 added to Y^-	Y_2 not formed

Which row shows the halogens in decreasing order of oxidising strengths?

	A	Y_2, Z_2, X_2
	B	Y_2, X_2, Z_2
	C	X_2, Z_2, Y_2
	D	X_2, Y_2, Z_2

Z_2 can oxidise X^-. Thus, Z_2 is a stronger oxidising agent than X_2.

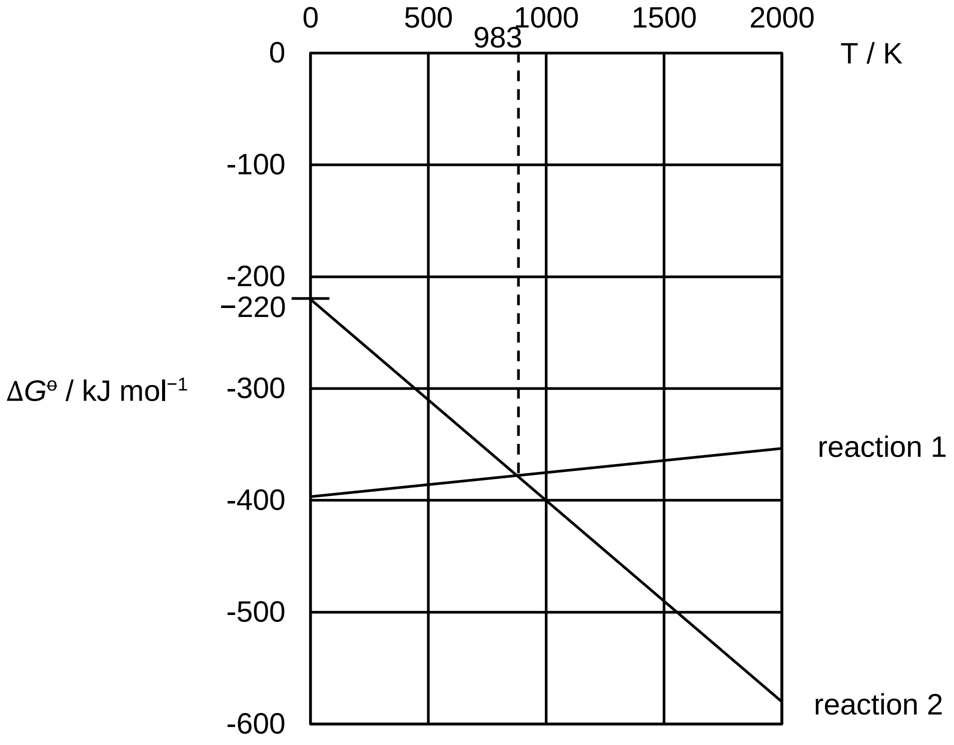
There is no visible reaction between Z_2 and Y^-, Z_2 cannot oxidise Y^-.
Hence Y_2 is a stronger oxidising agent than Z_2

Thus, the strongest oxidising agent is Y_2, followed by Z_2, then X_2.

10 An Ellingham diagram is a plot of Δ*G* versus temperature and it can be used to show the stability of compounds at various temperatures.

The following Ellingham diagram is for reactions 1 and 2.

Reaction 1: W + X → Y
Reaction 2: 2W + X → 2Z



Which statement is **incorrect**?

A	Reaction 1 is favoured at lower temperatures.
B	The entropy change of reaction 2 is negative.
C	The enthalpy change of reaction 2 is –220 kJ mol^{-1}
D	At 983 K, Δ*G* of the reaction 2Z → W + Y is zero.

A is correct. As temperature decreases, Δ*G* becomes more negative.

B is incorrect. Δ*G* = Δ*H*–TΔ*S*. The gradient of the graph is –Δ*S*. Since gradient of reaction 2 is negative, Δ*S* (entropy change) of reaction 2 is positive.

C: Since Δ*G* = Δ*H*–TΔ*S*, the y-intercept is Δ*H*, hence is –220 kJ mol^{-1}.

D: The lines for reaction 1 and 2 intersect at 983 K, the Δ*G* for both reactions have the same value, approximately –370 kJ mol^{-1}.

Reaction 1: W + X → Y –370 kJ mol^{-1}

	Reaction 2: 2W + X → 2Z –370 kJ mol^{-1} The reaction: 2Z → W + Y is Reaction 1 – Reaction 2 Hence, ΔG of the reaction is –370 –(–370) = 0

11	When an instant cold pack is used, a vigorous reaction occurs, and the temperature falls from 25 °C to 5 °C. What are the correct signs of ΔG and ΔS for this reaction?			
		ΔG	ΔS	
	A	+	+	
	B	+	–	
	C	–	+	
	D	–	–	
	A spontaneous reaction occurred (indicated by the drop in temperature) so ΔG is negative. The reaction is endothermic as the temperature fell. ΔS must be positive for negative $-T\Delta S$ term to outweigh the positive ΔH term so that overall ΔG is negative.			

12	The Dushman reaction is represented by the following equation. $IO_3^-(aq) + 5I^-(aq) + 6H^+(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$ The rate equation for this reaction is as follows. rate = $k[IO_3^-][I^-]^2[H^+]^2$ When the concentration of each reactant is *a* mol dm^{-3}, the initial rate was found to be *y* mol dm^{-3} s^{-1}. What will be the initial rate of the reaction if $[IO_3^-]$ is $2a$, $[I^-]$ is $\frac{1}{2}a$, and $[H^+]$ is $4a$?							
	A	$2y$	**B**	$4y$	**C**	$8y$	**D**	$16y$
	Initial rate = $k[a][a]^2[a]^2$ $y = ka^5$ new initial rate = $k[2a][\frac{1}{2}a]^2[4a]^2 = 8ka^5 = 8y$							

13 3.0 mol of Q, 1.5 mol of R and 0.2 mol of S were mixed in a 2.0 dm^3 flask and allowed to reach equilibrium.

$$4Q(g) + R(g) \rightleftharpoons S(g)$$

The equilibrium mixture contained 0.8 mol of S.

What is the equilibrium concentration of Q in the flask?

A	2.4 mol dm^{-3}
B	1.2 mol dm^{-3}
C	0.6 mol dm^{-3}
D	0.3 mol dm^{-3}

	$4Q(g)$ +	$R(g)$ $\rightleftharpoons$	$S(g)$
I / mol	3.0	1.5	0.2
C / mol	-2.4	-0.6	+0.6
E / mol	0.6	0.9	0.8

eqm concentration of Q = 0.6/2 = 0.3 mol dm^{-3}

14 Water dissociates according to the equation

$$H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$$

The pH of water at different temperatures are shown below.

temperature / K	pH
298	7.0
333	6.5

Which statements are true?

1	The dissociation of water is endothermic.
2	The pK_a of water increases when temperature increases.
3	Water becomes more acidic when temperature increases.

A	1 only
B	1 and 2 only
C	2 and 3 only
D	1, 2 and 3

Option 1: When temperature increases, pH deceases, thus $[H^+]$ increases. The POE shifts right when temperature increases to absorb the additional heat present favouring an endothermic process, thus the dissociation of water is endothermic.

Option 2: Since POE shifts right, K_a value ($K_a = \frac{[H^+][OH^-]}{[H_2O]}$)increases. Thus, p$K_a$ decreases.

Option 3: Water is always neutral as $[H^+] = [OH^-]$.

15 The table below describes some indicators.

indicator	colour in acid	colour in alkali	pK_a	range of pH for colour change
methyl orange	red	yellow	3.7	3.2 – 4.4
thymol blue	yellow	blue	8.9	8.0 – 9.6

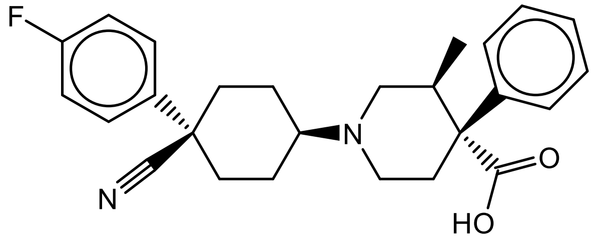
For the titration of NaOH(aq) against HCOOH(aq), which row shows the most suitable indicator and the corresponding colour change?

	indicator	colour change
A	methyl orange	red to orange
B	methyl orange	yellow to orange
C	thymol blue	yellow to green
D	thymol blue	blue to green

The titration is between a strong base and weak acid. Hence the equivalence point pH > 7 as a basic salt is produced. Thymol blue will be a suitable indicator.

Since NaOH is in the conical flask, thymol blue will turn from blue to green.

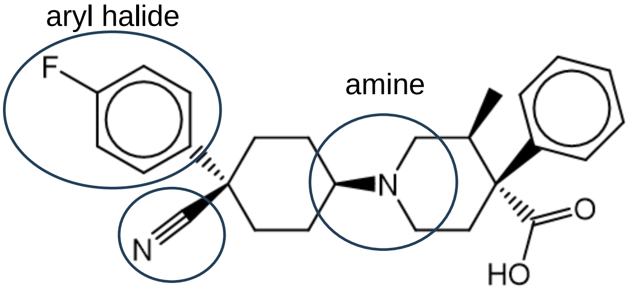
16 Levocabastine is an antihistamine used in the treatment of sore eyes.



Levocabastine

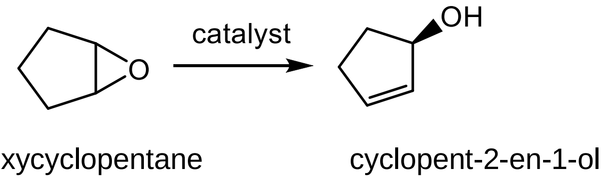
Which functional group is **not** present in Levocabastine?

A	alcohol
B	amine
C	aryl halide
D	nitrile



Levocabastine

17 1,2-epoxycyclopentane can be converted to cyclopent-2-en-1-ol in a single reaction.



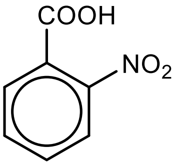
Which statement about the reaction is correct?

A	1,2-epoxycyclopentane rotates plane-polarised light.
B	A reducing agent is used for this reaction.
C	Cyclopent-2-en-1-ol is more volatile than the 1,2-epoxycyclopentane.
D	An isomerisation reaction has occurred.

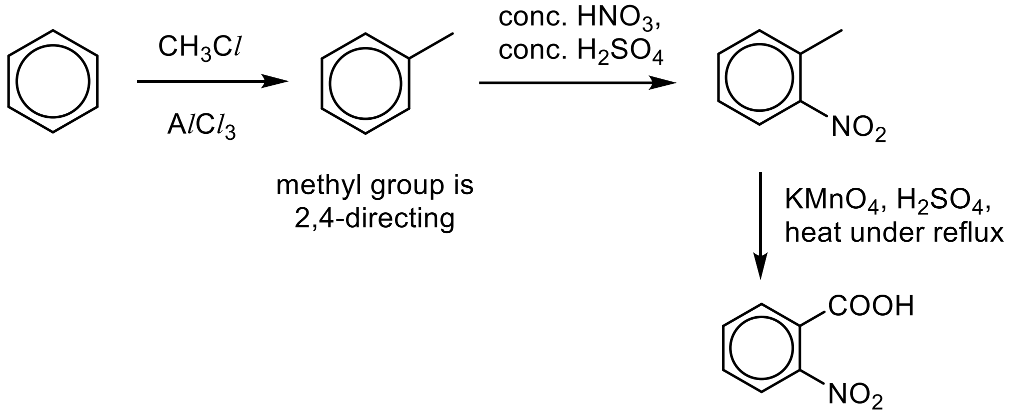
A: 1,2-epoxycyclopentane contains an internal plane of symmetry and does not rotate plane-polarised light.

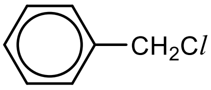
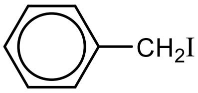
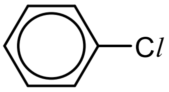
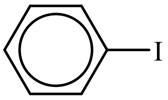
	B: The average oxidation number of carbon in both compounds remains the same so it is not reduction. C: Cyclopent-2-en-1-ol contains hydrogen bonding between its molecules which are stronger than the permanent dipole – permanent dipole interactions between 1,2-epoxycyclopentane. Cyclopent-2-en-1-ol has a higher boiling point and is less volatile than 1,2-epoxycyclopentane. D: The number of atoms in 1,2-epoxycyclopentane and cyclopent-2-en-1-ol are the same.

18	Both benzene and propene react with bromine. Which statement best explains the difference in the reactivity between these compounds?	
	A	Benzene is a planar molecule which allows ease of attack by bromine whereas propene is a non-planar molecule.
	B	The carbocation intermediate produced in the reaction of benzene with bromine is stabilised by resonance.
	C	The sideway overlap of p orbitals in benzene means the C−C bonds alternate between long, single bonds and short, double bonds.
	D	The delocalisation of electrons in benzene causes it to be more stable.
	The difference in reactivity towards electrophiles stems from the stability of benzene, requiring a strong electrophile with a full positive charge for reaction. This stability comes from the delocalisation of electrons in benzene.	

19	Benzene reacts in a three-stage process to produce 2-nitrobenzoic acid?  2-nitrobenzoic acid Which reagents could be used for the three-stage process?

			first stage	second stage	third stage	
	A		CH_3Cl, $AlCl_3$	HNO_3(aq)	$KMnO_4$, dilute H_2SO_4, heat under reflux	
	B		conc HNO_3, conc H_2SO_4	CH_3Cl, $AlCl_3$	$KMnO_4$, dilute H_2SO_4, heat under reflux	
	C		CH_3Cl, $AlCl_3$	conc HNO_3, conc H_2SO_4	$KMnO_4$, dilute H_2SO_4, heat under reflux	
	D		CH_3Cl, $AlCl_3$	$KMnO_4$, dilute H_2SO_4, heat under reflux	conc HNO_3, conc H_2SO_4	

20	Compound **X** is boiled with aqueous sodium hydroxide, cooled and then acidified with dilute nitric acid. Aqueous silver nitrate was subsequently added to the mixture. It was observed that a precipitate, which formed when aqueous silver nitrate was added, dissolved upon the addition of aqueous ammonia to the mixture. What could be the structure of **X**?			
	A		**C**	
	B		**D**	
	Only alkyl halides will undergo nucleophilic substitution with NaOH(aq) to liberate the halide ion, giving a positive test with $AgNO_3$(aq). Only AgCl will dissolve with the addition of NH_3(aq), so the compound contains an alkyl chloride.			

21	The mechanism for the reaction between ethanal and hydrogen cyanide is given below. step 1: $CH_3CHO + CN^- \rightarrow CH_3CHOCN^-$ step 2: $CH_3CHOCN^- + HCN \rightarrow CH_3CH(OH)(CN) + CN^-$ Which statement regarding the mechanism and the reaction is correct?	
	A	The negative charge is on the nitrogen atom in the intermediate.
	B	There is one sp^2 hybridised carbon atom in the intermediate.
	C	The ethanal behaves as the nucleophile in step 1.
	D	The mixture does not rotate plane-polarised light after the reaction.

A: The negative charge is on the oxygen atom in the intermediate.

B: There is no sp^2 hybridised carbon atom in the intermediate.

C: Ethanal behaves as the electrophile in step 1.

D: As CN^- attacks both sides of the plane of the sp^2 carbon in ethanal, the resulting mixture will contain equal amounts of both enantiomers.

22 An unknown organic compound has the molecular formula $C_5H_{12}O$. It was subjected to the following chemical test.

test	observations
alkaline aqueous iodine, warm	yellow precipitate is seen
hot acidified $KMnO_4$	purple solution decolourises

Two students saw the test~~s~~ and each made a comment.

student E The compound is a secondary alcohol.

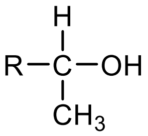
student F The compound is definitely pentan-2-ol.

Which students are correct?

	student E	student F	
A	✓	✓	key
B	✗	✓	✓ = correct
C	✓	✗	✗ = not correct
D	✗	✗	

There is no degree of unsaturation in the molecular formula $C_5H_{12}O$. This means the compound does not contain a ketone nor alkene.

The positive test with alkaline aqueous iodine means the compound has the structural formula

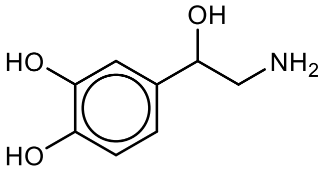


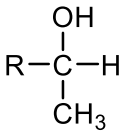
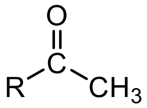
$$R-\overset{\displaystyle H}{\underset{\displaystyle CH_3}{C}}-OH$$

.

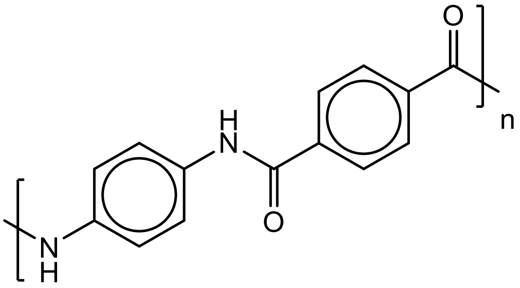
The positive test with hot acidified $KMnO_4$ indicates the compound can be oxidised and contains a primary or secondary alcohol. Student E is correct.

Student F is not correct as the alcohol may be 3-methylbutan-2-ol.

23	Noradrenaline functions in the brain as a neurotransmitter.  noradrenaline How many moles of sodium hydroxide will react with one mole of noradrenaline?	
	A	1
	B	2
	C	3
	D	4
	Only phenol is sufficiently acidic to react with NaOH. Alcohols do not react with NaOH.	

24	Which statement regarding ethanoic acid is true?	
	A	It reacts with hydrogen chloride to form ethanoyl chloride.
	B	It can be reduced to ethanol with hydrogen gas in the presence of Pt.
	C	It does not form a yellow precipitate when warmed with alkaline aqueous iodine.
	D	It reacts with phenol in the presence of concentrated sulfuric acid to form phenyl ethanoate.
	A: To form CH_3COCl, either $SOCl_2$ or PCl_5 must be used. HCl only reacts with alcohols. B: The unsaturated π bonds in the carboxylic acid can be reduced to give primary alcohol. C: Only alcohols with the structure  $R-\overset{\overset{OH}{\vert}}{\underset{\underset{CH_3}{\vert}}{C}}-H$ or carbonyl compounds with the structure  will give a positive test with alkaline aqueous iodine. D To form phenyl ethanoate, phenol needs to react with ethanoyl chloride, not ethanoic acid. Carboxylic acids only forms esters with alcohols, not phenols.	

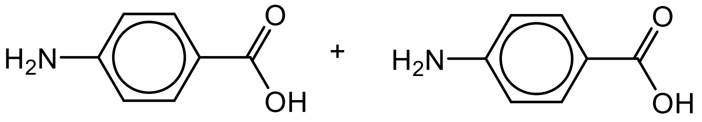
25 Kevlar is a light weight and strong material, used to make tyres and bulletproof vests. Its structure is given below.



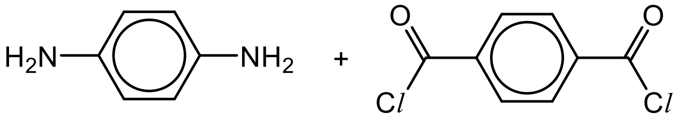
Kevlar

Which option produces Kevlar in the greatest yield?

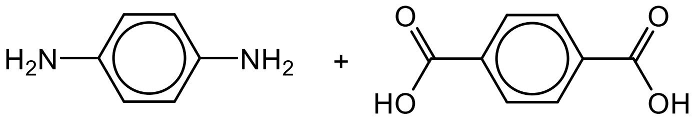
A



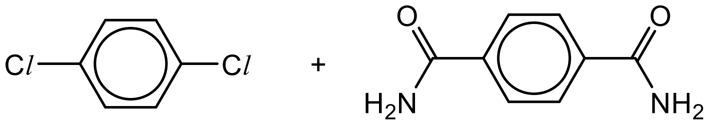
B



C



D



A: The structure of the reactant is incorrect as each benzene ring is bonded to one N atom and C atom. In Kevlar, one benzene ring is bonded to 2 N atoms, while another is bonded to 2 C atoms, in a repetitive fashion.

B: The amine reacts with the acyl chloride in a condensation reaction.

C: The amine reacts with the carboxylic acid in an acid-base reaction.

D: Amides do not react with aryl halides.

26 A peptide chain isolated from a protein in the medicinal mushroom *Lingzhi* is shown below.

ser-gly-arg-asn-leu-gly-val-lys-pro-ser

The enzyme trypsin will only hydrolyse a polypeptide chain at a peptide bond where the carboxyl group has been donated by either lysine (lys) or arginine (arg).

Which fragments could be made when trypsin acts on the peptide chain from *Lingzhi*?

1 ser-gly-arg

2 lys-pro-ser

3 asn-leu-gly-val-lys

4 arg-asn-leu-gly-val

A 1, 2, 3 and 4

B 1 and 3 only

C 2 and 4 only

D 1 and 4 only

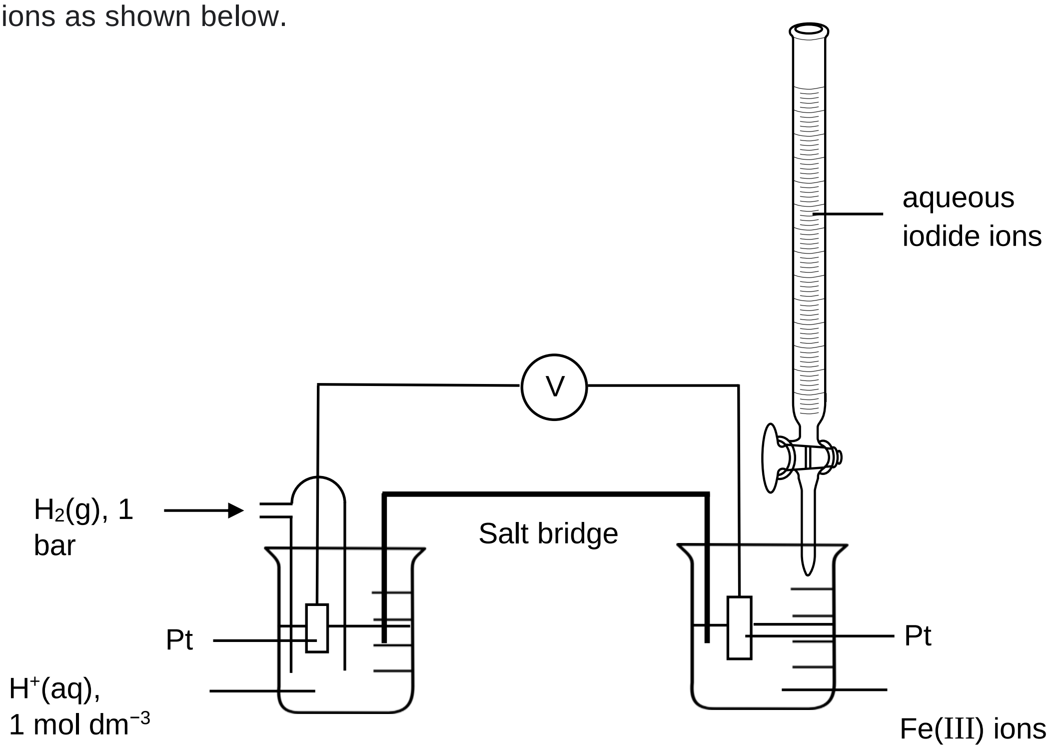
By convention, the carboxyl group is on the right hand side of the amino acid. Hence, we need to cut on the right hand side of arg and lys.

ser-gly-arg-|asn-leu-gly-val-lys-|pro-ser

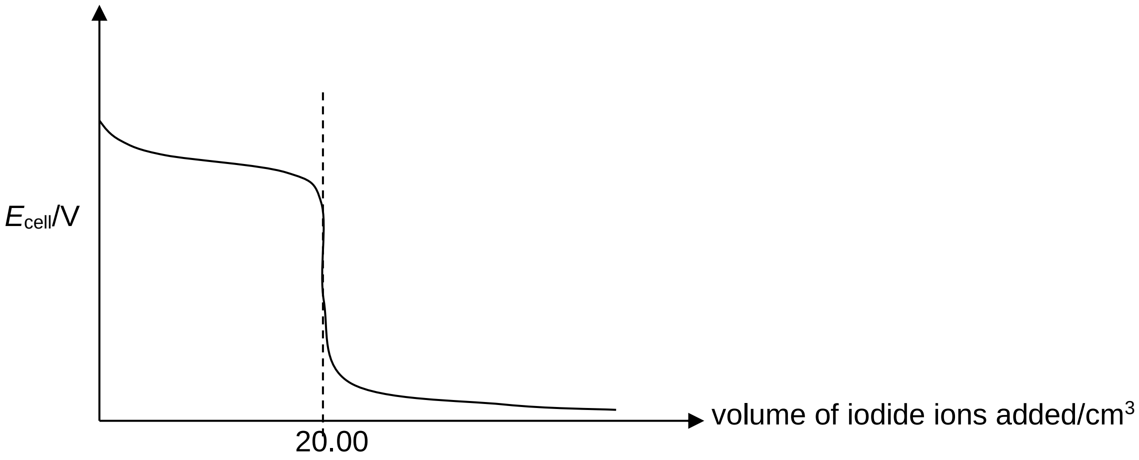
Hence, only 1 and 3 can be obtained.

27 *Use of the Data Booklet* is relevant to this question.

Aqueous iodide ions were added to an aqueous solution containing 50 cm^3 of iron(III) ions as shown below.



The titration curve obtained is shown below.



What is the volume of iodide ions added for the E_{cell} value to be +0.77 V?

A	0.00 cm^3	**C**	20.00 cm^3
B	10.00 cm^3	**D**	40.00 cm^3

At 0.0 cm^3, the solution only contains Fe^{3+} ions.

When I^- ions are added, it reduces the Fe^{3+} to Fe^{2+}. $2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$
This creates a half cell of Fe^{3+}/Fe^{2+} measured against H^+/H_2 between 0 to 20 cm^3, as there will be a mixture containing Fe^{3+} and Fe^{2+} in solution.

At 10.0 cm^3, the $[Fe^{3+}] = [Fe^{2+}]$, hence, $E^\ominus(Fe^{3+} / Fe^{2+})$ value for the half-cell is 0.77V.
$E_{cell} = 0.77 – 0.00 = +0.77$V.

At 20.0cm^3, the mixture only contains I_2 and Fe^{2+}. After 20.0 cm^3, the mixture contains I_2, I^- and Fe^{2+} and the half-cell measured against H^+/H_2 will become I_2/I^-.

28 *Use of the Data Booklet is relevant to this question.*

By considering $E^\ominus$ values, which aqueous species will oxidise Sn^{2+} to Sn^{4+}?

1	H_2O_2, H^+
2	I_2
3	V^{3+}

A	1, 2 and 3 only
B	1 and 2 only
C	2 and 3 only
D	1 only

$Sn^{4+} + 2e^- \rightleftharpoons Sn^{2+}$ $\quad E^\ominus = +0.15V$

Since Sn^{2+} is oxidised, it is at the oxidation half-cell. The species to be reduced is at the reduction half-cell.

Hence, the $E^\ominus$ of the aqueous species > +0.15V for the reaction to be feasible.

$E^\ominus(H_2O_2,H^+/H_2O) = +1.77V$ and $E^\ominus(I_2/I^-) = +0.54V$ hence can oxidise Sn^{2+}.

$E^\ominus(V^{3+}/V^{2+}) = –0.26V$, hence cannot oxidise Sn^{2+}.

29 A complex of chromium with the general formula $CrCl_3{\bullet}6H_2O$ forms an aqueous solution.

When 0.01 mol of an aqueous solution of this compound was treated with an excess of aqueous silver nitrate, 2.87 g of precipitate was obtained.

What is the formula of the chromium complex?

A	$[Cr(H_2O)_6]^{3+}$	**C**	$[Cr(H_2O)_4Cl_2]^+$

	B	$[Cr(H_2O)_5Cl]^{2+}$	**D**	$[Cr(H_2O)_3Cl_3]$

Amt of AgCl ppt = 2.87 ÷ 143.4
= 0.0200 mol

Ratio of Cl^- : $CrCl_3{\bullet}6H_2O$ = 0.02 ÷ 0.01
= 2

There are 2 anions Cl^- that are not in the complex ion. Hence the complex only contains 1 Cl^-.

30 A student carried out 2 experiments on separate samples of aqueous $CuSO_4$.

Experiment 1

When aqueous potassium iodide was added to a sample of aqueous $CuSO_4$, a white precipitate in a brown solution was formed.

Experiment 2

When aqueous ammonia is added to another sample aqueous of $CuSO_4$, a pale blue precipitate is formed. The precipitate dissolves when an excess of aqueous ammonia is added, forming a deep blue solution.

Which statement about experiments 1 and 2 is **incorrect**?

A	Ligand exchange occurred in Experiment 2.
B	The pale blue precipitate is $[Cu(OH)_2(H_2O)_4]$.
C	Reduction of copper(II) ions occurred in Experiment 1.
D	The complex ion in the deep blue solution has a tetrahedral shape.

Experiment 1:

$2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$

Reduction of Cu^{2+} to Cu^+ occurred in experiment 1.

The white ppt is CuI

Ligand exchange occurred in experiment 2

$[Cu(H_2O)_6]^{2+} + 2OH^- \rightleftharpoons [Cu(OH)_2(H_2O)_4] + 2H_2O$

The blue ppt is $[Cu(OH)_2(H_2O)_4]$

$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightleftharpoons [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$

The deep blue solution is due to $[Cu(NH_3)_4(H_2O)_2]^{2+}$. The ion has an octahedral shape as there are 6 ligands about the metal centre.