

Please write clearly in block capitals.

Centre number

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Candidate number

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Surname

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Forename(s)

Candidate signature

I declare this is my own work.

A-level CHEMISTRY

Paper 3

Time allowed: 2 hours

Materials

For this paper you must have:

- the Periodic Table/Data Booklet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do **not** write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 90.

Advice

- You are advised to spend 70 minutes on **Section A** and 50 minutes on **Section B**.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
Section B	
TOTAL	



J U N 2 1 7 4 0 5 3 0 1

Section A

Answer **all** questions in this section.

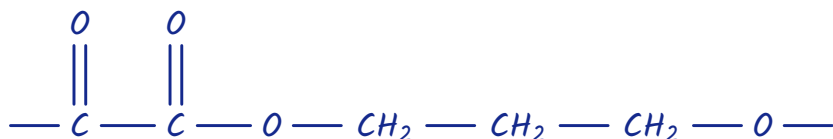
0 1

This question is about ethanedioic acid (HO₂CCOOH) and the ethanedioate ion (⁻O₂CCO⁻).

0 1 . 1

Ethanedioic acid reacts with propane-1,3-diol (HOCH₂CH₂CH₂OH) to form a polyester.

Draw the repeating unit of this polyester.

[2 marks]

0 1 . 2

Explain why polyesters are biodegradable but polyalkenes are not biodegradable.

[2 marks]

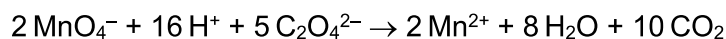
Polyesters have polar C=O and C–O bonds in the chain, so the δ+ carbon of the ester link is susceptible to nucleophilic attack and the chain can be hydrolysed.

Polyalkenes only have non-polar C–C (and C–H) bonds in the chain, so they are not attacked.



0 1 3

Sodium ethanedioate is used to find the concentration of solutions of potassium manganate(VII) by titration. The equation for this reaction is



A standard solution is made by dissolving 162 mg of $\text{Na}_2\text{C}_2\text{O}_4$ ($M_r = 134.0$) in water and making up to 250 cm^3 in a volumetric flask.

25.0 cm^3 of this solution and an excess of sulfuric acid are added to a conical flask. The mixture is warmed and titrated with potassium manganate(VII) solution. The titration is repeated until concordant results are obtained. The mean titre is 23.85 cm^3

Calculate the concentration, in mol dm^{-3} , of the potassium manganate(VII) solution.

[4 marks]

$$\text{amount of } \text{Na}_2\text{C}_2\text{O}_4 = 0.162 / 134.0 = 1.21 \times 10^{-3} \text{ mol (in } 250 \text{ cm}^3\text{)}$$

$$\text{in } 25.0 \text{ cm}^3: 1.21 \times 10^{-3} \div 10 = 1.21 \times 10^{-4} \text{ mol}$$

$$\text{amount of } \text{MnO}_4^- = 1.21 \times 10^{-4} \times 2/5 = 4.84 \times 10^{-5} \text{ mol}$$

$$\text{concentration} = 4.84 \times 10^{-5} \times 1000 / 23.85$$

$$= 2.03 \times 10^{-3} \text{ mol dm}^{-3}$$

Concentration 0.00203 mol dm^{-3}

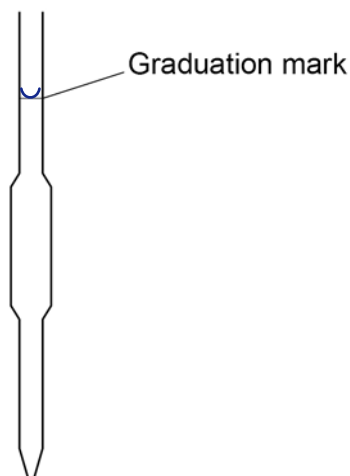
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0 1 . 4

Figure 1 shows the 25.0 cm³ pipette used to measure the sodium ethanedioate solution.

Figure 1



On **Figure 1**, draw the meniscus of the solution when the pipette is ready to transfer 25.0 cm³ of the sodium ethanedioate solution.

[1 mark]

0 1 . 5

Potassium manganate(VII) is oxidising and harmful.
Sodium ethanedioate is toxic.

Suggest safety precautions, other than eye protection, that should be taken when:

- filling the burette with potassium manganate(VII) solution
- dissolving the solid sodium ethanedioate in water.

[2 marks]

Filling the burette Fill it below eye level (take it off the stand or put it on the floor).

Dissolving the solid Wear gloves (and wash hands after any spillage).

0 1 . 6

State the colour change seen at the end point of each titration.

[1 mark]

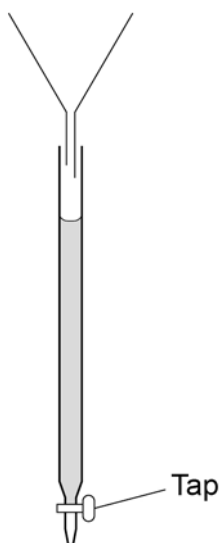
From colourless to (permanent) pale pink.



0 1 . 7

Figure 2 shows the burette containing potassium manganate(VII) solution.

Figure 2



Give **two** practical steps needed before recording the initial burette reading.

[2 marks]

- 1 *Remove the funnel from the top of the burette.*
- 2 *Open the tap to fill the jet below the tap so there are no air bubbles.*

Question 1 continues on the next page

Turn over ►



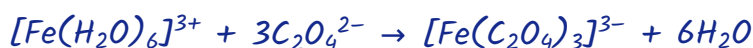
0 1 . 8

When $\text{Na}_2\text{C}_2\text{O}_4(\text{aq})$ is added to a solution containing $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ ions, a reaction occurs in which all six water ligands are replaced by ethanedioate ions.

Explain why the replacement of the water ligands by ethanedioate ions is favourable. In your answer refer to:

- the enthalpy and entropy changes for the reaction
- how the enthalpy and entropy changes influence the free-energy change for the reaction.

[6 marks]



Enthalpy: the enthalpy change, ΔH , for this reaction is negligible (approximately zero). The same number of bonds are broken and made: six Fe–O co-ordinate bonds to water ligands are broken and six Fe–O co-ordinate bonds to the ethanedioate ligands are formed. These are the same type of bond with similar bond enthalpies.

Entropy: ethanedioate is a bidentate ligand, so three ethanedioate ions replace six water molecules. The number of particles in solution increases from 4 to 7, so the disorder increases and there is an increase in entropy (ΔS is positive).

Free energy: $\Delta G = \Delta H - T\Delta S$. As ΔH is approximately zero and ΔS is positive, the $-T\Delta S$ term is negative, so ΔG is negative for the forward reaction (at any temperature).

A negative ΔG means the reaction is feasible, so the replacement of water by ethanedioate is favourable. This is the chelate effect, and it is driven by the entropy increase.



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20

Turn over ►



0 2

The protein fibroin can be broken down into amino acids using an enzyme.

0 2. 1

A student uses thin-layer chromatography (TLC) to identify these amino acids.

The student identifies two of the amino acids as alanine and serine.

Use **Figure 3** to calculate the R_f value of the unknown amino acid.
Show your working.

Use your R_f value and **Table 1** to identify the unknown amino acid.

[2 marks]

Figure 3

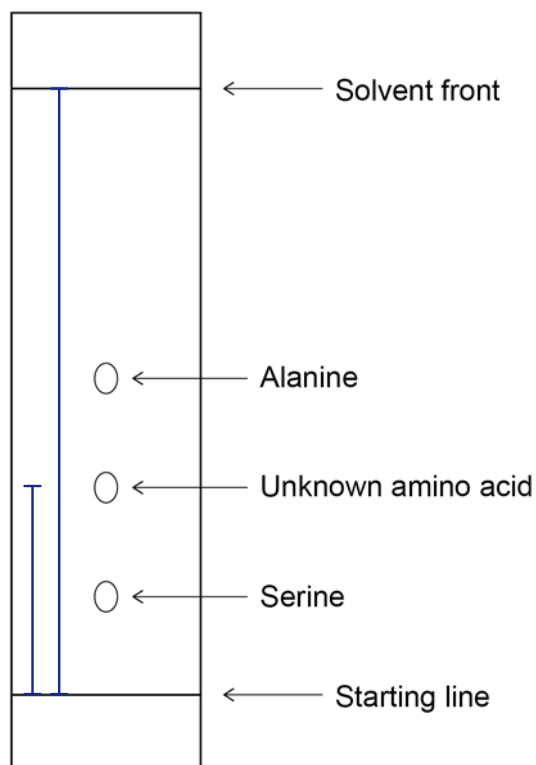


Table 1

Amino acid	R_f value
tyrosine	0.25
glycine	0.34
valine	0.64
leucine	0.73

$$R_f = \text{distance moved by amino acid} / \text{distance moved by solvent}$$

$$= 2.7 \text{ cm} / 8.0 \text{ cm} = 0.34$$

R_f value 0.34

Identity glycine



0 2 . 2

The amino acids cannot be seen as they move during the experiment.

State how the amino acids can be made visible at the end of the experiment.

[1 mark]

Spray with ninhydrin (a developing agent) and warm, or shine a UV lamp on the plate.

0 2 . 3

State why each amino acid has a different R_f value.

[1 mark]

Each amino acid has a different relative affinity for (attraction to) the stationary phase and a different solubility in the mobile phase (solvent).

4

Turn over for the next question

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0	3
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This question is about ketones.

0	3	.	1
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Solution **X** reacts with liquid ketones to form a crystalline solid.

This reaction can be used to identify a ketone if the crystalline solid is separated, purified by recrystallisation, and the melting point determined.

Describe how the crystalline solid is separated and purified.

[5 marks]

Filter off the crystalline solid from the reaction mixture (under reduced pressure, using a Buchner funnel and flask).

Dissolve the solid in the minimum volume of hot solvent (e.g. ethanol), to make a saturated solution.

Leave the solution to cool so that crystals form, then filter off the crystals under reduced pressure using a Buchner funnel.

Wash the crystals with a small amount of cold solvent, then dry them, e.g. by leaving them in a desiccator or pressing them between filter papers.



0 3 . 2 Propanone (CH_3COCH_3) reacts with the weak acid HCN to form a hydroxynitrile.

This hydroxynitrile is usually made by reaction of propanone with KCN followed by dilute acid, instead of with HCN

State the hazard associated with the use of KCN

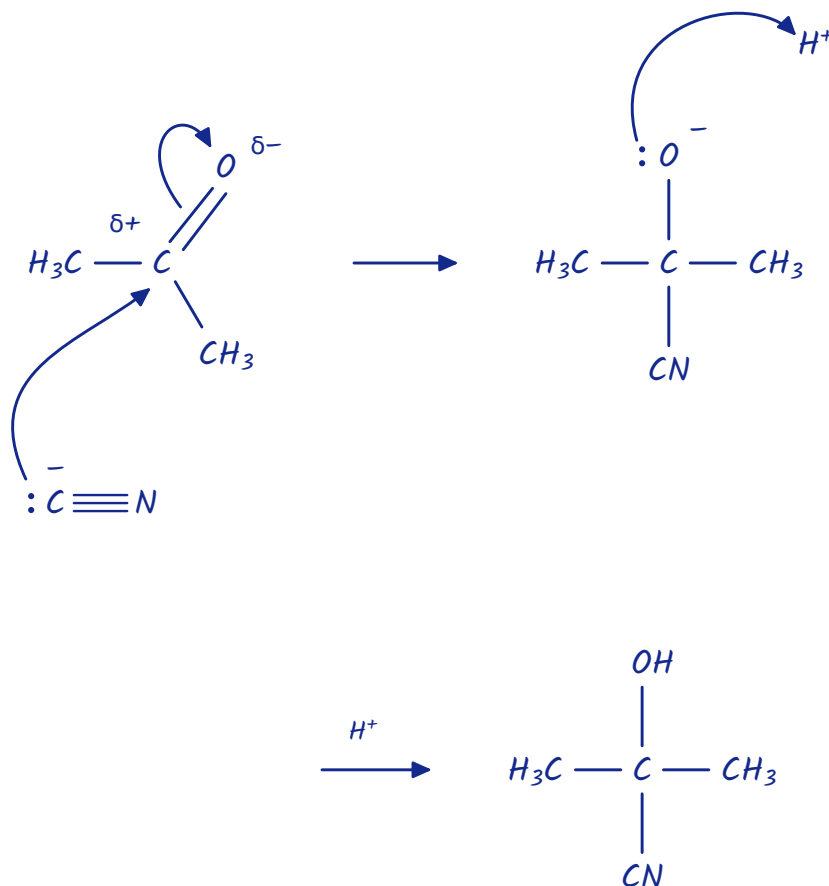
Suggest a reason, other than safety, why KCN is used instead of HCN.

[2 marks]

Hazard Toxic (poisonous)

Why KCN is used HCN is a weak acid so $[\text{CN}^-]$ is too low; KCN fully dissociates to give more of the CN^- nucleophile.

0 3 . 3 Outline the mechanism for the reaction of propanone with KCN followed by dilute acid. **[4 marks]**



Turn over for the next question



0 4

This question is about Group 7 chemistry.

0 4 . 1

Give an equation for the reaction of solid sodium bromide with concentrated sulfuric acid to form bromine.

State **one** observation made during this reaction.

[2 marks]

Equation



Observation *Orange / brown fumes (of bromine) are seen.*

0 4 . 2

A solution that is thought to contain chloride ions and iodide ions is tested.

1. Dilute nitric acid is added to the solution.
2. Aqueous silver nitrate is added to the solution.
3. A pale yellow precipitate forms.
4. Excess dilute aqueous ammonia is added to the mixture.
5. Some of the precipitate dissolves and a darker yellow precipitate remains.

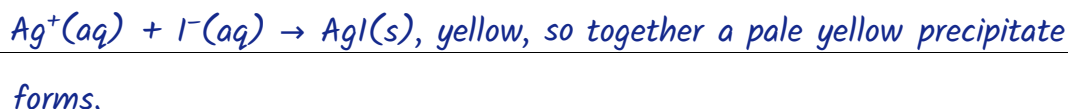
Give a reason for the use of each reagent.

Explain the observations.

Give ionic equations for any reactions.

[5 marks]

Dilute nitric acid reacts with and removes carbonate (and hydroxide) ions, which would otherwise form other precipitates with silver nitrate. Silver nitrate is added because the Ag^+ ions form precipitates with the halide (chloride and iodide) ions:



Excess dilute ammonia dissolves the AgCl but not the AgI , so the darker yellow precipitate left is AgI :



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7

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0 5

A mixture of methanoic acid and sodium methanoate in aqueous solution acts as an acidic buffer solution.

The equation shows the dissociation of methanoic acid.



Calculate the mass, in g, of sodium methanoate (HCOONa) that must be added to 25.0 cm^3 of $0.100 \text{ mol dm}^{-3}$ methanoic acid to produce a buffer solution with $\text{pH} = 4.05$ at 298 K

For methanoic acid, $\text{p}K_{\text{a}} = 3.75$ at 298 K

Assume that the volume of the solution remains constant.

[5 marks]

$$K_{\text{a}} = 10^{-3.75} = 1.78 \times 10^{-4} \text{ mol dm}^{-3}$$

$$[\text{H}^+] = 10^{-4.05} = 8.91 \times 10^{-5} \text{ mol dm}^{-3}$$

$$K_{\text{a}} = [\text{H}^+][\text{HCOO}^-] / [\text{HCOOH}]$$

$$\begin{aligned} [\text{HCOO}^-] &= K_{\text{a}}[\text{HCOOH}] / [\text{H}^+] = (1.78 \times 10^{-4} \times 0.100) / 8.91 \times 10^{-5} \\ &= 0.200 \text{ mol dm}^{-3} \end{aligned}$$

$$\text{amount of HCOONa} = 0.200 \times 25.0 / 1000 = 5.00 \times 10^{-3} \text{ mol}$$

$$M_{\text{r}} \text{ of HCOONa} = 68.0$$

$$\text{mass} = 5.00 \times 10^{-3} \times 68.0 = 0.339 \text{ g}$$

Mass 0.339 g

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5



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ANSWER IN THE SPACES PROVIDED**

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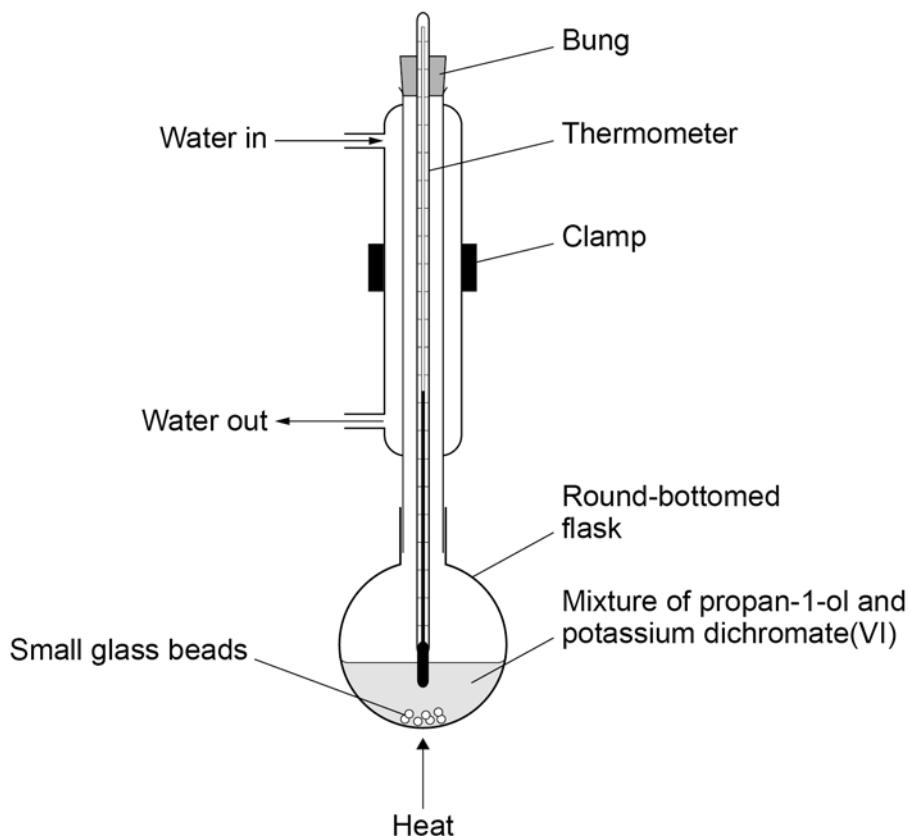
0 6

A student plans an experiment to investigate the yield of propanoic acid when a sample of propan-1-ol is oxidised.

Figure 4 shows the apparatus that the student plans to use for the experiment.

The student's teacher says that the apparatus is not safe.

Figure 4



0 6 . 1

Give **two** reasons why the apparatus shown in **Figure 4** is not safe.

[2 marks]

- 1 *The flask is not clamped (only the condenser is clamped).*
- 2 *There is a bung in the top of the condenser, so it is a sealed system and pressure would build up on heating.*



0 6 . 2

Give **one** additional reagent that is needed to form any propanoic acid.

[1 mark]

Sulfuric acid (dilute H_2SO_4) to acidify the dichromate.

0 6 . 3

State **two** more mistakes in the way the apparatus is set up in **Figure 4**.

[2 marks]

1 *The water flows the wrong way through the condenser: it should go in at the bottom and out at the top.*

2 *The thermometer is not needed for heating under reflux.*

0 6 . 4

State the purpose of the small glass beads in the flask in **Figure 4**.

[1 mark]

To prevent bumping (it makes small bubbles form so the mixture boils smoothly).

Question 6 continues on the next page

Turn over ►



0 6 . 5

After correcting the mistakes, the student heats a reaction mixture containing 6.50 g of propan-1-ol with an excess of the oxidising agent.

The propanoic acid separated from the reaction mixture has a mass of 3.25 g

State the name of the technique used to separate the propanoic acid from the reaction mixture.

Calculate the percentage yield of propanoic acid.

[4 marks]

Technique (Fractional) distillation

$$\text{amount of propan-1-ol} = 6.50 / 60.0 = 0.108 \text{ mol}$$

$$= \text{maximum amount of propanoic acid (1 : 1)}$$

$$\text{maximum mass of propanoic acid} = 0.108 \times 74.0 = 8.02 \text{ g}$$

$$\text{percentage yield} = 3.25 / 8.02 \times 100 = 40.5\%$$

Percentage yield 40.5%

0 6 . 6

State a simple chemical test that distinguishes the propanoic acid from the propan-1-ol.

Give **one** observation for the test with each substance.

[3 marks]

Test Add sodium carbonate (or sodium hydrogencarbonate)

Propanoic acid Effervescence (bubbles)

Propan-1-ol No visible change (no reaction)

13



Section B

Answer **all** questions in this section.Only **one** answer per question is allowed.

For each answer completely fill in the circle alongside the appropriate answer.

CORRECT METHOD



WRONG METHODS



If you want to change your answer you must cross out your original answer as shown.



If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown.

You may do your working in the blank space around each question but this will not be marked.
Do **not** use additional sheets for this working.

0 7

Which does **not** involve the absorption of ultraviolet radiation or visible light?

[1 mark]

A The blue appearance of copper(II) sulfate solution in daylight.

☐

B The breakdown of ozone in the upper atmosphere.

☐

C The ionisation of a molecule in a mass spectrometer.

☒

D The reaction between chlorine and methane at room temperature.

☐

0 8

Which statement about chloride ions is **not** correct?

[1 mark]

A They form a white precipitate with silver nitrate solution that is soluble in dilute aqueous ammonia.

☐

B They form an octahedral cobalt(II) complex when aqueous cobalt(II) ions are reacted with an excess of chloride ions.

☒

C They form when chlorine reacts with potassium bromide solution.

☐D They have the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6$ ☐

Turn over ►



0 9

What is the mole fraction of 1.0 g of a compound of relative molecular mass 100.0 dissolved in 30.0 g of a solvent of relative molecular mass 50.0?

[1 mark]

A 6.0×10^{-3} ☐B 1.6×10^{-2} ☒C 1.7×10^{-2} ☐D 3.0×10^{-2} ☐

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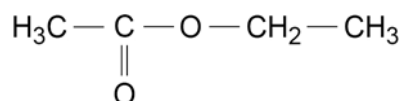
Which has the electron configuration of a noble gas?

[1 mark]

A H^+ ☐B O^- ☐C Se^{2-} ☒D Zn^{2+} ☐

1 1

Which statement does **not** support the suggestion that an unknown organic compound is



[1 mark]

A Its ^1H NMR spectrum has 3 peaks with an integration ratio of 2:3:3☐B Its ^{13}C NMR spectrum has 3 peaks.☒C Its infrared spectrum has an absorption at 1735 cm^{-1} ☐

D It has 36.36% by mass of oxygen and 9.09% by mass of hydrogen.

☐

1 2

Which statement about inorganic ionic compounds is **always** correct?

[1 mark]

A They dissolve in water to give neutral solutions.

☐

B They release energy when they melt.

☐

C They contain metal cations.

☐

D They form giant structures.

☒

1 3

Which species has a lone pair of electrons on the central atom?

[1 mark]

A CO₂☐B SO₂☒C PCl₆⁻☐D SO₄²⁻☐

1 4

In which substance do covalent bonds break when it melts?

[1 mark]

A hexane

☐

B ice

☐

C iodine

☐

D silicon dioxide

☒

1 5

In which molecule are all the atoms in the same plane?

[1 mark]

A CH₃CHO☐B CH₃NH₂☐C C₆H₅Cl☒D C₆H₅CH₃☐

Turn over ►



1 6

Which molecule has a permanent dipole?

[1 mark]**A** BF_3 ☐**B** NH_3 ☒**C** SiCl_4 ☐**D** SO_3 ☐**1 7**Which statement about $(\text{CH}_3)_2\text{CHCH}_2\text{COOH}$ is correct?**[1 mark]****A** In aqueous solution it reacts with magnesium to form carbon dioxide.☐**B** It can form hydrogen bonds.☒**C** It has optical isomers.☐**D** It has the IUPAC name 2-methylbutanoic acid.☐**1 8**A mixture of 2 dm^3 of hydrogen and 1 dm^3 of oxygen is at room temperature.

Which statement is correct?

[1 mark]**A** There is no reaction to form water because the molecules do not collide with sufficient energy.☒**B** There is no reaction to form water because the molecules do not collide with sufficient frequency.☐**C** The mean velocity of the hydrogen molecules is less than that of the oxygen molecules.☐**D** The partial pressure of each gas is the same.☐

1 9

Which statement about the distribution curve of molecular energies in an ideal gas at a given temperature is correct?

[1 mark]

- A There are no molecules with zero energy.
- B The curve is symmetrical about the maximum.
- C Changing the temperature has no effect on the position of the maximum.
- D Most molecules have the mean energy.



2 0

Which statement about the addition of a catalyst to an equilibrium mixture is correct?

[1 mark]

- A The activation energy for the reverse reaction increases.
- B The equilibrium constant for the forward reaction increases.
- C The rate of the reverse reaction increases.
- D The enthalpy change for the forward reaction decreases.



2 1

Which equation does **not** show the reduction of a transition metal?

[1 mark]

- A $\text{TiCl}_4 + 2\text{Mg} \rightarrow \text{Ti} + 2\text{MgCl}_2$
- B $2\text{FeCl}_3 + 2\text{KI} \rightarrow 2\text{FeCl}_2 + 2\text{KCl} + \text{I}_2$
- C $\text{MnO}_2 + 4\text{HCl} \rightarrow \text{MnCl}_2 + \text{Cl}_2 + 2\text{H}_2\text{O}$
- D $\text{CoO} + 4\text{HCl} \rightarrow [\text{CoCl}_4]^{2-} + \text{H}_2\text{O} + 2\text{H}^+$



Turn over for the next question

Turn over ►



2 2

Which substance contains delocalised electrons?

[1 mark]**A** cyclohexane☐**B** graphite☒**C** iodine☐**D** sodium chloride☐**2 3**Which compound has *E*–*Z* isomers?**[1 mark]****A** $\text{CH}_2=\text{CHBr}$ ☐**B** $\text{CH}_2=\text{CBr}_2$ ☐**C** $\text{CHBr}=\text{CHBr}$ ☒**D** $\text{CBr}_2=\text{CHBr}$ ☐**2 4**

Which polymer has hydrogen bonding between the polymer chains?

[1 mark]**A** Kevlar☒**B** PVC☐**C** poly(phenylethene)☐**D** Terylene☐

2 5

Which compound needs the greatest amount of oxygen for the complete combustion of 1 mol of the compound?

[1 mark]**A** ethanal☐**B** ethanol☒**C** ethane-1,2-diol☐**D** methanol☐**2 6**

Which compound is produced when 1-phenylethanol reacts with acidified potassium dichromate(VI)?

[1 mark]**A** $\text{C}_6\text{H}_5\text{CH}_2\text{CH}_2\text{OH}$ ☐**B** $\text{C}_6\text{H}_5\text{CH}_2\text{CHO}$ ☐**C** $\text{C}_6\text{H}_5\text{COCH}_3$ ☒**D** $\text{C}_6\text{H}_5\text{CH}(\text{OH})\text{CH}_3$ ☐**2 7**

Which is the correct general formula for non-cyclic compounds in the homologous series?

[1 mark]**A** alcohols $\text{C}_n\text{H}_{2n+2}\text{O}$ ☒**B** aldehydes $\text{C}_n\text{H}_{2n+1}\text{O}$ ☐**C** esters $\text{C}_n\text{H}_{2n+1}\text{O}_2$ ☐**D** primary amines $\text{C}_n\text{H}_{2n+2}\text{N}$ ☐

Turn over for the next question

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2 8

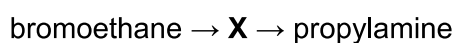
Which compound forms a white precipitate when added to aqueous silver nitrate?

[1 mark]**A** bromoethane☐**B** ethanal☐**C** ethanoic anhydride☐**D** ethanoyl chloride☒**2 9**Nitration of 1.70 g of methyl benzoate ($M_r = 136.0$) produces methyl 3-nitrobenzoate ($M_r = 181.0$). The percentage yield is 65.0%

What mass, in g, of methyl 3-nitrobenzoate is produced?

[1 mark]**A** 0.830☐**B** 1.10☐**C** 1.47☒**D** 2.26☐**3 0**

A two-step preparation of propylamine is shown.

What is **X**?**[1 mark]****A** $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$ ☐**B** $\text{CH}_3\text{CH}_2\text{CN}$ ☒**C** $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$ ☐**D** $\text{CH}_3\text{CH}_2\text{NH}_2$ ☐

3	1
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Which compound reacts with warm dilute aqueous sodium hydroxide?

[1 mark]

A C_6H_6

☐

B $\text{CH}_3\text{CH}=\text{CH}_2$

☐

C $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$

☐

D $(\text{CH}_3\text{CO})_2\text{O}$

☒

3	2
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Methylamine reacts with bromoethane by nucleophilic substitution to produce a mixture of products.

Which is **not** a possible product of this reaction?

[1 mark]

A $\text{C}_2\text{H}_5\text{NHCH}_3$

☐

B $(\text{C}_2\text{H}_5)_2\text{NCH}_3$

☐

C $[(\text{C}_2\text{H}_5)_2\text{N}(\text{CH}_3)_2]^+ \text{Br}^-$

☒

D $[(\text{C}_2\text{H}_5)_3\text{NCH}_3]^+ \text{Br}^-$

☐

Turn over for the next question

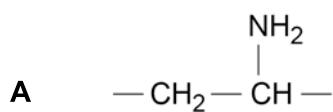
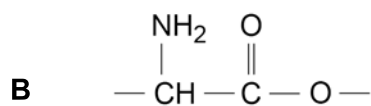
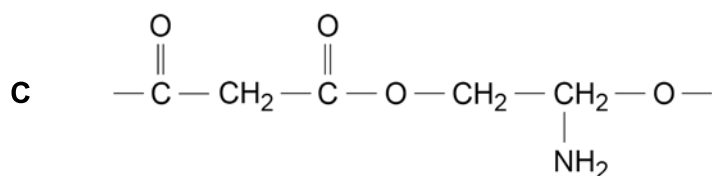
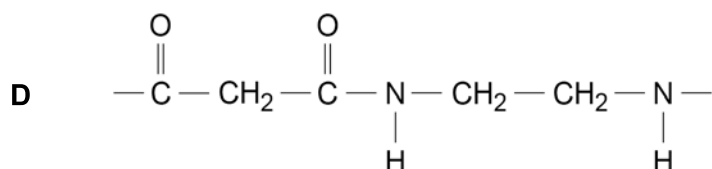
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3 3

Which is the repeating unit of a polyamide?

[1 mark]

☐☐☐☒

3 4

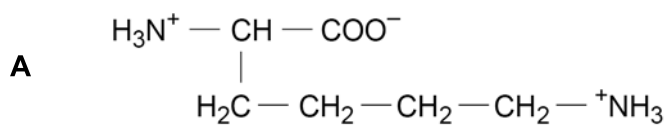
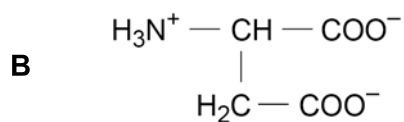
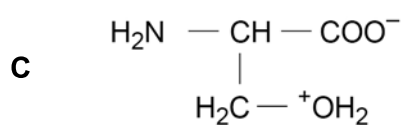
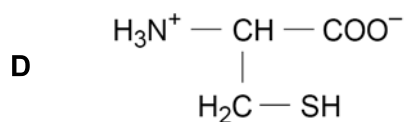
Which type of polymer is **not** hydrolysed by heating with concentrated aqueous sodium hydroxide?

[1 mark]

A poly(alkene)☒**B** poly(amide)☐**C** poly(ester)☐**D** protein☐

3 5

Which is the structure of a zwitterion of an amino acid?

[1 mark]☐☐☐☒**3 6**

Which row shows a pair of bases that can link two strands of DNA with three hydrogen bonds?

Use the Data Booklet to help you answer this question.

[1 mark]

	Base 1	Base 2	
A	adenine	guanine	☐
B	cytosine	thymine	☐
C	cytosine	guanine	☒
D	adenine	thymine	☐

30**END OF QUESTIONS**

There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**



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