Please write clearly in block capitals.

Centre number		Candidate number	

Surname ______________________

Forename(s) ______________________

Candidate signature ______________________

I declare this is my own work.

A-level
CHEMISTRY

Paper 3

Friday 23 June 2023 Morning 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	

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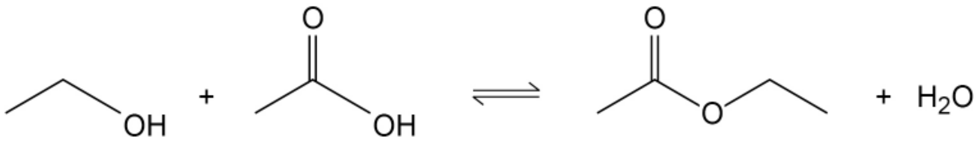
Section A

Answer **all** questions in this section.

0 1 Ethyl ethanoate can be made by reacting ethanol with ethanoic acid in the presence of concentrated sulfuric acid.



Method

1. A mixture of ethanol, ethanoic acid, and concentrated sulfuric acid, with anti-bumping granules, is heated under reflux for 10 minutes.
2. The apparatus is rearranged for distillation.
3. The mixture is heated to collect the liquid that distils between 70 and 85 °C
4. The distillate is placed in a separating funnel. Aqueous sodium carbonate is added, and a stopper is placed in the funnel. The mixture is shaken, releasing pressure as necessary.
5. The lower aqueous layer is removed and the upper organic layer is placed in a small conical flask.
6. Anhydrous calcium chloride is added to the sample in the conical flask. The flask is shaken well and left for a few minutes.
7. The liquid from the flask is redistilled and the distillate is collected between 74 and 79 °C

0 1 . 1 State the role of concentrated sulfuric acid in this reaction.

[1 mark]

0 1 . 2 The reaction mixture is flammable.

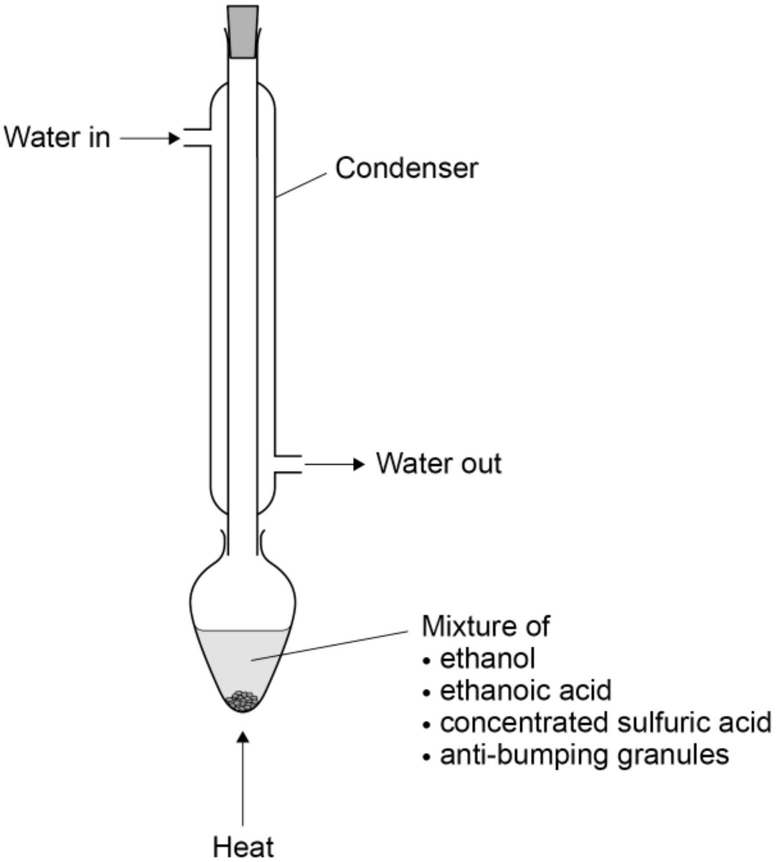
Suggest how the reaction mixture should be heated in step 1.

[1 mark]

Do not write outside the box

0 1 . 3 **Figure 1** shows how a student set up the apparatus for reflux in step 1.
You should assume that the apparatus is clamped correctly.

Figure 1



Identify **two** mistakes the student made in setting up the apparatus.

State the problem caused by each mistake.

[4 marks]

Mistake 1 ____

____

Problem caused ____

____

____

Mistake 2 ____

____

Problem caused ____

____

____

Turn over ►

Do not write outside the box

0 1 . 4 State why sodium carbonate is added to the distillate in step 4.

Explain why there is a build-up of pressure in the separating funnel.

[2 marks]

0 1 . 5 Give a reason why two layers form in the separating funnel.

Suggest why ethyl ethanoate forms the upper layer.

[2 marks]

Reason

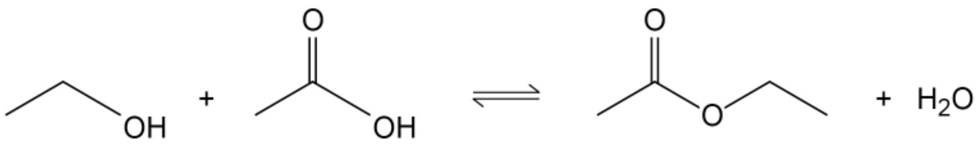
Suggestion

0 1 . 6 State why anhydrous calcium chloride is added in step 6.

[1 mark]

Do not write outside the box

0 1 . 7 A student uses the method to prepare some ethyl ethanoate.



The student adds 10.0 cm^3 of ethanol (M_r = 46.0) to 5.25 g of ethanoic acid (M_r = 60.0) and obtains 5.47 g of ethyl ethanoate (M_r = 88.0).

For ethanol, density = 0.790 g cm^{-3}

Determine the limiting reagent.

Calculate the percentage yield of ethyl ethanoate.

[5 marks]

Limiting reagent ________________________

Percentage yield ________________________

0 1 . 8 Suggest a reason why the percentage yield is **not** 100%.

[1 mark]

____

____

17

Do not write outside the box

0 2 This question is about isomerism and the dehydration of alcohols.

Pentan-2-ol has the molecular formula $C_5H_{12}O$

0 2 . 1 Draw the **displayed** formula of an unbranched position isomer of pentan-2-ol that can be dehydrated to form a single alkene.

[1 mark]

0 2 . 2 Draw the **skeletal** formula of a chain isomer of pentan-2-ol that can be dehydrated to form a mixture of alkenes.

[1 mark]

0 2 . 3 Draw the structure of an unbranched functional group isomer of pentan-2-ol.

[1 mark]

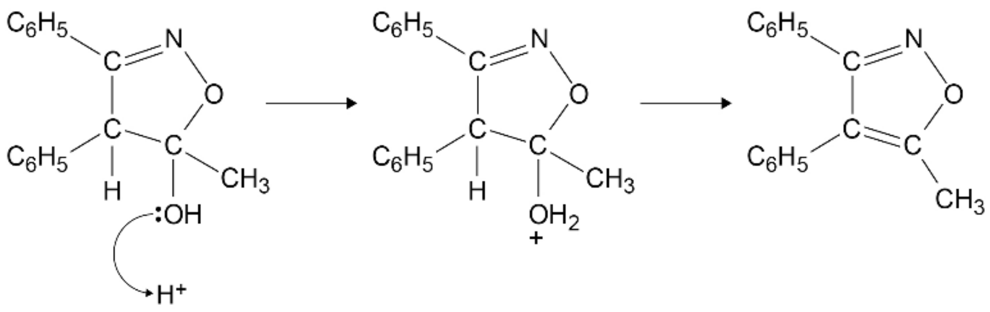
0 2 . 4 Another isomer of pentan-2-ol is an alcohol that is **not** dehydrated when heated with concentrated sulfuric acid.

Draw the structure of this isomer.

[1 mark]

Do not write outside the box

0 2 . 5 An incomplete mechanism for the dehydration of a compound is shown.



Complete the mechanism for this reaction by drawing two curly arrows on the intermediate.

Name the mechanism for this reaction.

[3 marks]

---

0 2 . 6 An isomer of the final product can also form in the reaction in Question **02.5**.

Draw the structure of this isomer.

[1 mark]

8

Turn over ►

Do not write outside the box

0 3 Endomorphin-2 is a peptide with the amino acid sequence shown.

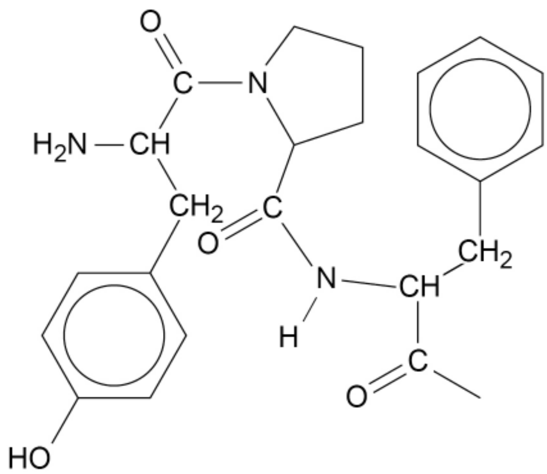
Tyr–Pro–Phe–Phe–NH_2

Each amino acid is represented by a three-letter abbreviation.

Tyr = tyrosine Pro = proline Phe = phenylalanine

Figure 2 shows part of the structure of endomorphin-2, showing the Tyr–Pro–Phe– part of the molecule.

Figure 2



0 3 . 1 The $–NH_2$ at the end of the amino acid sequence of endomorphin-2 shows that the terminal functional group is an amide, not an acid.

Complete the structure of endomorphin-2 in **Figure 2**.

[2 marks]

0 3 . 2 Use the structure in **Figure 2** to draw the skeletal formula of proline, Pro.

[1 mark]

Do not write outside the box

A student hydrolyses a sample of endomorphin-2 to break it down into its constituent amino acids.

The student analyses the resulting mixture by thin-layer chromatography, TLC.

0 3 . 3 State a reagent and the conditions needed for the hydrolysis.

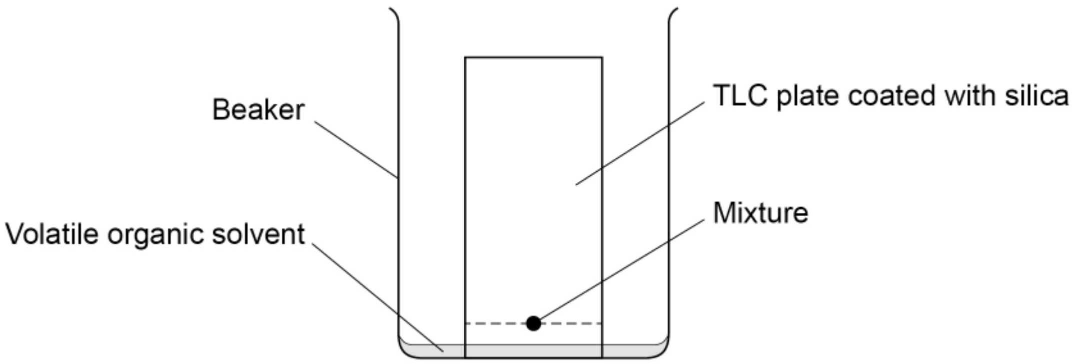
[2 marks]

Reagent ____________________

Conditions ____________________

0 3 . 4 **Figure 3** shows the apparatus used for the TLC.

Figure 3



There is a piece of the apparatus missing from **Figure 3**. This omission will result in an inaccurate chromatogram.

Identify the missing piece of the apparatus.

State and explain why this piece of the apparatus is needed.

[3 marks]

Missing piece ____________________

Explanation ____________________

____

____

____

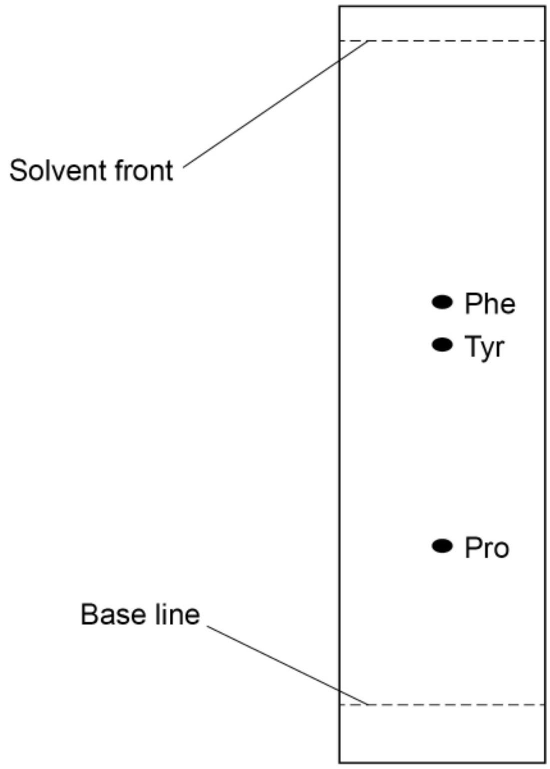
0 3 . 5 State why the amino acids separate on the TLC plate.

[1 mark]

When the solvent has risen up the TLC plate, the student removes the plate from the beaker and sprays it with a developing agent.

Figure 4 shows the result.

Figure 4



0 3 . 6 Name a suitable developing agent.

State why the developing agent is needed.

[2 marks]

Name

Why needed

Do not write outside the box

0 3 . 7 Determine the R_f value for Tyr.

[1 mark]

R_f ____________

12

Turn over for the next question

Do not write outside the box

0 4 A student is given two aqueous solutions, **L** and **M**, that both contain iron salts.

The student does a series of tests on the solutions.

Table 1 shows these tests and the observations.

Table 1

Test	Observations with L	Observations with M
Add ammonia solution slowly until in excess.	A red-brown precipitate forms that is insoluble in excess.	A green precipitate forms that is insoluble in excess.
Add sodium carbonate solution.	A red-brown precipitate forms. Effervescence is seen.	A green precipitate forms.
Add dilute nitric acid and then divide into two portions. Add barium chloride solution to the first portion. Add silver nitrate solution to the second portion.	No change is seen. No change is seen. A white precipitate forms.	No change is seen. A white precipitate forms. No change is seen.

Identify **L** and **M** using the results in **Table 1**.

In your answer:
- identify all precipitates
- explain why effervescence is seen in the reaction of sodium carbonate with **L** but **not** with **M**
- give ionic equations for all reactions.

[6 marks]

Do not write outside the box

6

Do not write outside the box

0 5 The molar enthalpy of vaporisation (ΔH_{vap}) of a liquid is the enthalpy change when one mole of liquid is converted to vapour at the boiling point of the liquid.

A student does an experiment to determine ΔH_{vap} for water.

The student:

- places a large beaker on a balance
- pours 500 cm^3 of water into the beaker
- uses a 2.4 kW heater to raise the temperature of the water to 100 °C
- records the mass of the beaker and hot water
- uses the 2.4 kW heater to boil the water for 100 s
- records the mass of the beaker and remaining water.

The loss in mass is 103 g

0 5 . 1 Calculate ΔH_{vap} for water.

[1 kW = 1 kJ s^{-1}]

[3 marks]

ΔH_{vap} ____________________ kJ mol^{-1}

Do not write outside the box

Table 2 shows some data about three compounds that all contain the same number of electrons.

Table 2

Compound	CH_3CH_2OH	$CH_3CH_2NH_2$	CH_3OCH_3
Boiling point / K	352	290	248

0 5 . 2 All three compounds in **Table 2** are polar.
Ethanol is the most polar and ethylamine is the least polar.

Explain why all three molecules are polar and why ethylamine is the least polar.
In your answer refer to the shapes around, and relative electronegativities of, the most electronegative atoms.

[4 marks]

0 5 . 3 Explain the trend in the boiling points of the three compounds.
Refer to the intermolecular forces in all three compounds in your answer.

[3 marks]

10

Do not write outside the box

0 6 Calcium hydroxide is almost insoluble in water, but it reacts with dilute hydrochloric acid.

$$Ca(OH)_2(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(l)$$

A student adds 100 cm^3 of 0.100 mol dm^{-3} hydrochloric acid to 0.600 g of solid calcium hydroxide.

0 6 . 1 Show, by calculation, that the calcium hydroxide is in excess.

[2 marks]

0 6 . 2 The final mixture contains a saturated solution of $Ca(OH)_2$ at 293 K

At 293 K

- the solubility of $Ca(OH)_2$ in this solution is 0.400 g dm^{-3}
- $K_w = 6.80 \times 10^{-15}$ mol^2 dm^{-6}

Calculate the pH of this solution.
Give your answer to two decimal places.

[5 marks]

pH ____________________

7

Do not write outside the box

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 row shows the number of each fundamental particle in one $^{25}Mg^{2+}$ ion?

[1 mark]

	protons	neutrons	electrons
A	12	12	10
B	14	11	12
C	12	13	10
D	12	13	12

0 8 What is the relative molecular mass (M_r) of benzene-1,4-dicarboxylic acid?

[1 mark]

A 164.0

B 166.0

C 168.0

D 170.0

Do not write outside the box

0 9 Which substance has significant electron delocalisation?

[1 mark]

A graphite ⬭

B iodine ⬭

C sodium chloride ⬭

D tetrachloromethane ⬭

1 0 Which reaction has a standard enthalpy change equal to the standard enthalpy of formation for barium chloride?

[1 mark]

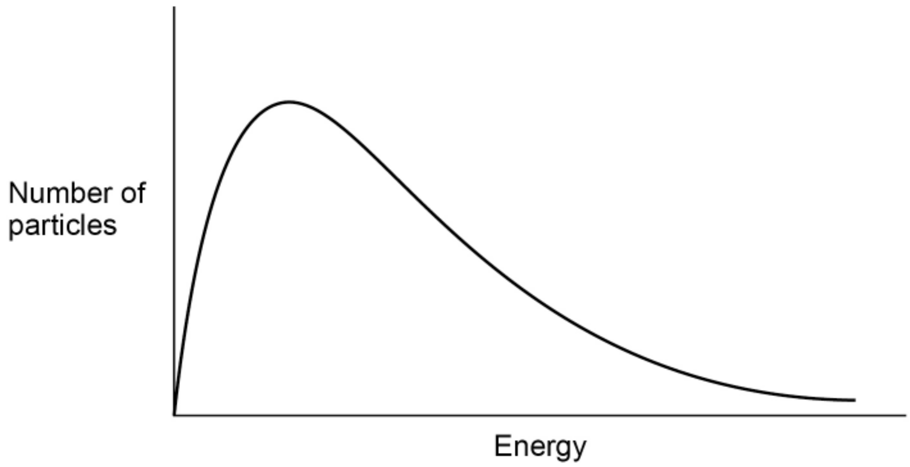
A $Ba(g) + Cl_2(g) \rightarrow BaCl_2(s)$ ⬭

B $Ba^{2+}(g) + 2Cl^-(g) \rightarrow BaCl_2(s)$ ⬭

C $Ba(s) + Cl_2(g) \rightarrow BaCl_2(s)$ ⬭

D $Ba^{2+}(s) + 2Cl^-(g) \rightarrow BaCl_2(s)$ ⬭

1 1 This is a Maxwell–Boltzmann distribution for a gaseous reactant.



What is represented by the total area under the curve?

[1 mark]

A total energy of the particles

B activation energy for the reaction

C total number of reacting particles

D total number of particles present

1 2 The rate of reaction is greater when a catalyst is used, without changing the temperature.

Which statement explains why the rate of reaction is greater with a catalyst?

[1 mark]

A The collision frequency increases because the catalysed reaction has a lower activation energy.

B The collision frequency increases because there is an increase in the average energy of the particles.

C The proportion of successful collisions increases because the catalysed reaction has a lower activation energy.

D The proportion of successful collisions increases because there is an increase in the average energy of the particles.

1 3 When HF is added to water at 298 K, this equilibrium is established.

$$HF(aq) \rightleftharpoons H^+(aq) + F^-(aq)$$

At equilibrium, $[HF] = 7.70 \times 10^{-3}$ mol dm^{-3} and $[F^-] = 2.30 \times 10^{-3}$ mol dm^{-3}

What is the value of the equilibrium constant, in mol dm^{-3}, at 298 K?

[1 mark]

A 1.45×10^3 ⬭

B 3.35 ⬭

C 2.99×10^{-1} ⬭

D 6.87×10^{-4} ⬭

1 4 In which oxide is the named element in its highest oxidation state?

[1 mark]

A chlorine in ClO_2 ⬭

B magnesium in MgO ⬭

C nitrogen in N_2O_4 ⬭

D sulfur in SO_2 ⬭

1 5 What happens when water is vaporised?

[1 mark]

A Covalent bonds break within molecules. ⬭

B Intermolecular forces are overcome. ⬭

C The enthalpy of the molecules decreases. ⬭

D The disorder of the molecules decreases. ⬭

Do not write outside the box

1 6 Which species can behave as a Brønsted–Lowry acid in aqueous solution?

[1 mark]

A SO_4^{2-} ⬭

B HCO_3^- ⬭

C BF_3 ⬭

D NH_3 ⬭

1 7 Which change causes the pH of 10 cm^3 of 1.0 mol dm^{-3} NaOH to be halved at 298 K?

$K_w = 1.0 \times 10^{-14}$ at 298 K

[1 mark]

A adding 10 cm^3 of water ⬭

B adding 10 dm^3 of water ⬭

C adding 5 cm^3 of 1.0 mol dm^{-3} HCl ⬭

D adding 10 cm^3 of 1.0 mol dm^{-3} HCl ⬭

1 8 A 0.100 mol dm^{-3} solution of a weak acid has pH = 2.50

What is the value of K_a for this acid, in mol dm^{-3}?

[1 mark]

A 3.16×10^{-2} ⬭

B 3.16×10^{-3} ⬭

C 1.00×10^{-4} ⬭

D 1.00×10^{-5} ⬭

Do not write outside the box

1 9 Which statement is **not** correct about the Period 3 elements sodium to chlorine?

[1 mark]

A Sodium has the largest atomic radius. ⬭

B Sodium has the lowest melting point. ⬭

C Silicon has the highest melting point. ⬭

D Chlorine has the highest first ionisation energy. ⬭

2 0 Equal volumes of pairs of solutions are mixed.

Which pair forms a buffer solution?

[1 mark]

A ammonia and ammonium chloride ⬭

B ammonia and methylamine ⬭

C ethanoic acid and methanoic acid ⬭

D hydrochloric acid and sodium hydroxide ⬭

2 1 Barium metal is added to a large excess of water.

Which observation is correct **and** complete?

[1 mark]

A a colourless solution ⬭

B a colourless solution with effervescence ⬭

C a dense white precipitate ⬭

D a dense white precipitate with effervescence ⬭

2 2 Which species is the strongest reducing agent?

[1 mark]

A F_2 ⬭

B I_2 ⬭

C F^- ⬭

D I^- ⬭

2 3 Which statement about the shapes of ions is **not** correct?

[1 mark]

A $[CoCl_4]^{2-}$ is square planar. ⬭

B NH_4^+ is tetrahedral. ⬭

C $[Co(H_2NCH_2CH_2NH_2)_3]^{2+}$ is octahedral. ⬭

D $[Co(H_2O)_6]^{2+}$ is octahedral. ⬭

2 4 Which compound can decolourise acidified potassium manganate(VII) solution?

[1 mark]

A $AgNO_3$ ⬭

B $CuSO_4$ ⬭

C $FeSO_4$ ⬭

D $Fe_2(SO_4)_3$ ⬭

Turn over for the next question

2 5 Which statement about catalysts used in reactions at equilibrium, at a constant temperature, is correct?

[1 mark]

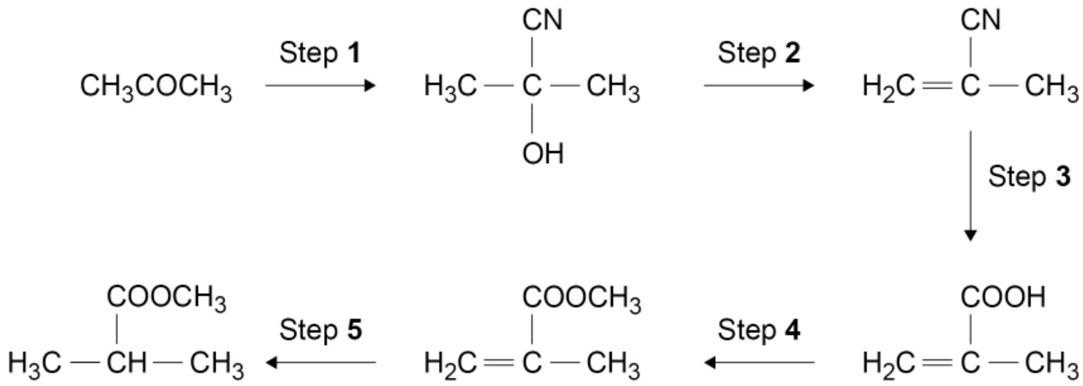
A They are always used in the solid state.

B They increase the rate of the forward reaction but decrease the rate of the reverse reaction.

C They have no effect on the value of the equilibrium constant.

D They make the forward reaction more exothermic.

2 6 Consider this reaction scheme.



Which step is shown with a correct reagent and a correct condition?

[1 mark]

A Step 1 HCN dissolved in water

B Step 2 KOH dissolved in warm water

C Step 4 CH_3OH with an alkaline catalyst

D Step 5 H_2 with a nickel catalyst

Do not write outside the box

2 7 Which process does **not** involve a heterogeneous catalyst?

[1 mark]

A catalytic cracking of alkanes ⬭

B Contact process ⬭

C decomposition of ozone ⬭

D Haber process ⬭

2 8 The equation for the complete combustion of butane is

$$C_4H_{10} + 6\frac{1}{2}\,O_2 \rightarrow 4\,CO_2 + 5\,H_2O$$

What is the mole fraction of butane in a mixture of butane and oxygen with the minimum amount of oxygen needed for complete combustion?

[1 mark]

A 0.133 ⬭

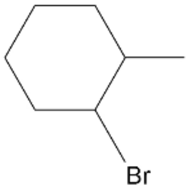
B 0.153 ⬭

C 0.167 ⬭

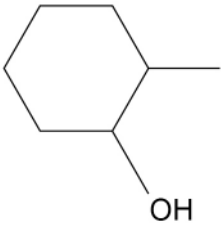
D 0.200 ⬭

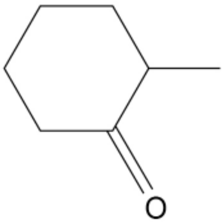
Turn over for the next question

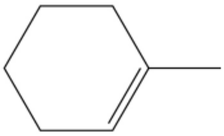
Do not write outside the box

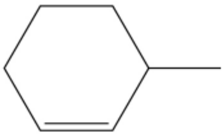
2 9 Which is **not** a possible product of a reaction between KOH and  ?

[1 mark]

A  ⬭

B  ⬭

C  ⬭

D  ⬭

3 0 Most scientists believe that the concentration of ozone in the upper atmosphere should not be allowed to decrease.

Which statement is a correct reason for this belief?

[1 mark]

A Ozone helps to prevent global warming. ⬭

B Ozone is an efficient disinfectant. ⬭

C Ozone helps to remove pollutants such as chloroalkanes. ⬭

D Ozone absorbs ultraviolet radiation. ⬭

3 1 Compound **X** can be converted into an alcohol in a two-stage process.

$$\text{Compound } \mathbf{X} \xrightarrow[\ ]{\text{Concentrated } H_2SO_4} \text{Intermediate} \xrightarrow[\ ]{\text{Excess } H_2O} \text{Alcohol}$$

What is the name of compound **X**?

[1 mark]

A propene

B propanal

C methylbenzene

D ethanamide

3 2 Which is a correct equation for the oxidation of 1-phenylethanol?
[O] represents oxygen from an oxidising agent.

[1 mark]

A $C_6H_5CH_2CH_2OH + 2[O] \rightarrow C_6H_5CH_2COOH + H_2O$

B $C_6H_5CH_2CH_2OH + [O] \rightarrow C_6H_5CH_2CHO + H_2O$

C $C_6H_5CH(OH)CH_3 + [O] \rightarrow C_6H_5CH_2CHO + H_2O$

D $C_6H_5CH(OH)CH_3 + [O] \rightarrow C_6H_5COCH_3 + H_2O$

Turn over for the next question

3 3 The skeletal formulas of two compounds are shown.

Which method would distinguish between samples of these compounds?

[1 mark]

A comparing fingerprint regions of their infrared spectra

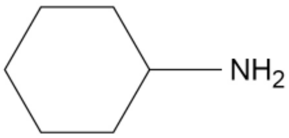
B obtaining molecular masses from their high resolution mass spectra

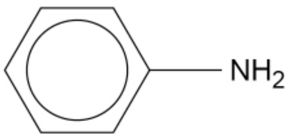
C warming with acidified potassium dichromate(VI) solution

D warming with Tollens' reagent

3 4 Which compound is the strongest base?

[1 mark]

A 

B 

C NH_3

D NH_4Cl

3 5 Which statement about enzymes is **not** correct?

[1 mark]

A The tertiary structure of an enzyme influences which molecules can bind to the active site.

B The action of enzymes can be inhibited by a molecule or ion that binds to the active site.

C Enzymes work equally well on both optical isomers of a substrate.

D Computers can be used to design drugs to block active sites on enzymes.

3 6 Cisplatin has the formula $[Pt(NH_3)_2Cl_2]$
Cisplatin is an anti-cancer drug that prevents replication of DNA.

When cisplatin bonds to DNA, which is the correct ligand replacement reaction?

[1 mark]

A replacement of one NH_3 ligand ⬭

B replacement of two NH_3 ligands ⬭

C replacement of one NH_3 ligand and one Cl^- ligand ⬭

D replacement of two Cl^- ligands ⬭

30

END OF QUESTIONS

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ANSWER IN THE SPACES PROVIDED

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Question number	**Additional page, if required.** **Write the question numbers in the left-hand margin.**