

A-Level Chemistry

Day 1 – 10

Physical, Inorganic and Organic Chemistry

**All mark schemes can be found at the end of this
document**

SPEND 1 HOUR PER DAY ON EACH SECTION/DAY

REFER TO NOTES IN FOLDERS OR MY FAVOURITE ELIOT RINTOUL'S VIDEOS!!!

ALLOCATE MARKING TIME

ANSWER QUESTIONS IN PENCIL OR ON LINED PAPER, THIS GIVES YOU THE OPPORTUNITY, ONCE MARKED, TO RE-DO THE QUESTIONS. THIS IS AN EXTREMELY GOOD AND USEFUL METHOD TO REVISE AND ENSURE WHAT YOU ARE LEARNING IS COMMITTED TO YOUR LONG TERM MEMORY.

ENJOY!

Q4. Tetradecane ($C_{14}H_{30}$) is an alkane found in crude oil. When tetradecane is heated to a high temperature, 1 molecule of tetradecane decomposes to form 1 molecule of hexane and 3 more molecules. Which of the following could represent this reaction?

- A $C_{14}H_{30} \rightarrow C_6H_{14} + C_4H_8 + 2C_2H_4$
- B $C_{14}H_{30} \rightarrow C_6H_{14} + C_6H_{12} + C_2H_4$
- C $C_{14}H_{30} \rightarrow C_5H_{12} + 3C_3H_6$
- D $C_{14}H_{30} \rightarrow C_6H_{14} + C_2H_6 + 2C_3H_6$

(Total 1 mark)

Q5. Sulphur dioxide (SO_2) is produced when some fossil fuels are burned. Which of the following statements is true?

- A Sulphur dioxide can be removed from waste gases in a power station by an acid-base reaction with calcium oxide.
- B Sulphur dioxide is insoluble in water.
- C Sulphur dioxide is a basic oxide.
- D Sulphur dioxide is an ionic compound.

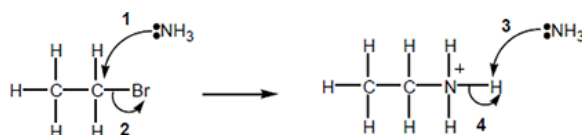
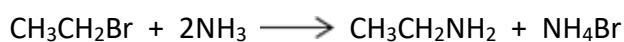
(Total 1 mark)

Q6. Which one of the following is least likely to occur in the reaction between methane and chlorine?

- A $CH_4 + Cl\cdot \rightarrow CH_3\cdot + HCl$
- B $CH_3\cdot + HCl \rightarrow CH_3Cl + H\cdot$
- C $CH_3\cdot + Cl_2 \rightarrow CH_3Cl + Cl\cdot$
- D $CH_3Cl + Cl\cdot \rightarrow CH_2Cl\cdot + HCl$

(Total 1 mark)

Q7. This question is about a method that can be used to prepare ethylamine.

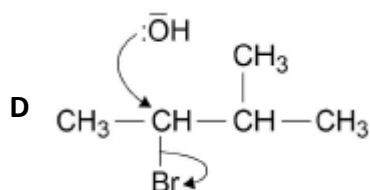
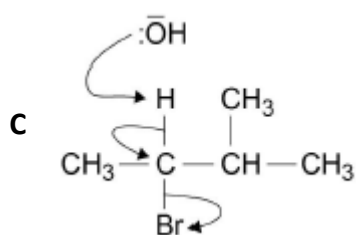
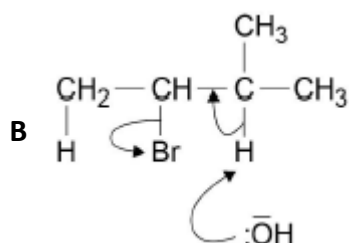
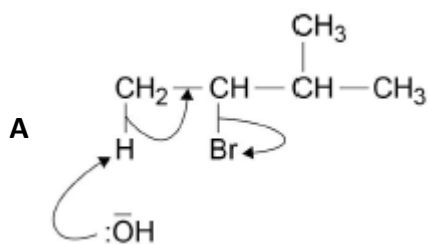


Which of the curly arrows in the mechanism is **not** correct?

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

(Total 1 mark)

Q8. Which of the following is a correct mechanism for the formation of 2-methylbut-2-ene from 2-bromo-3-methylbutane?



(Total 1 mark)

Q9. Which statement about ethene is correct?

- A** It has no geometric isomers because there is free rotation around the C=C bond.
- B** It reacts with HBr in a nucleophilic addition reaction.
- C** It burns in excess oxygen to produce carbon dioxide and water.
- D** The C=C bond is twice as strong as the C-C bond in ethane.

(Total 1 mark)

Q10. Propene reacts with hydrogen bromide to form a mixture of saturated organic products. The proton n.m.r. spectrum of the major organic product has

- A** 3 peaks with relative intensities 3:2:2
- B** 2 peaks with relative intensities 3:4
- C** 3 peaks with relative intensities 3:1:3
- D** 2 peaks with relative intensities 6:1

(Total 1 mark)

DAY 2 – PHYSICAL MCQ's

Q1. The relative molecular mass (M_r) of benzene-1,4-dicarboxylic acid is

- A 164
- B 166
- C 168
- C 170

(Total 1 mark)

Q2. Which of the following contains the most chloride ions?

- A 10 cm³ of 3.30×10^{-2} mol dm⁻³ aluminium chloride solution
- B 20 cm³ of 5.00×10^{-2} mol dm⁻³ calcium chloride solution
- C 30 cm³ of 3.30×10^{-2} mol dm⁻³ hydrochloric acid
- D 40 cm³ of 2.50×10^{-2} mol dm⁻³ sodium chloride solution

(Total 1 mark)

Q3. A sample of 2.18g of oxygen gas has a volume of 1870cm³ at a pressure of 101kPa. What is the temperature of the gas? The gas constant is $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$.

- A 167K
- B 334K
- C 668K
- D 334,000K

(Total 1 mark)

Q4. CH₂O is the empirical formula of

- A methanol
- B methyl methanoate
- C ethane-1,2-diol
- D butanal

(Total 1 mark)

Q5. An organic compound is found to contain 40.0% carbon, 6.7% hydrogen and 53.3% oxygen. Which of the following compounds could this be?

- A Ethanol
- B Ethanoic acid
- C Methanol
- D Methanoic acid

(Total 1 mark)

Q6. Hydrolysis of the ester, $\text{CH}_3\text{COOCH}_2\text{CH}_2\text{CH}_3$, produces ethanoic acid. In an experiment, 2.04g of the ester was used and 0.90g of ethanoic acid was produced. The percentage yield of ethanoic acid was:

- A 44
- B 59
- C 75
- D 90

(Total 1 mark)

Q7. What is the formula of calcium nitrate(V)?

- A CaNO_3
- B $\text{Ca}(\text{NO}_3)_2$
- C Ca_2NO_2
- D $\text{Ca}(\text{NO}_2)_2$

(Total 1 mark)

Q8. Which type of bond is formed between N and B when a molecule of NH_3 reacts with a molecule of BF_3 ?

- A Ionic.
- B Covalent.
- C Co-ordinate.
- D Van der Waals.

(Total 1 mark)

Q9. Which substance exists as a macromolecule?

- A Cu
- B SiO_2
- C P_4O_{10}
- D MgO

(Total 1 mark)

Q10. Which one of the following molecules or ions is pyramidal in shape?

- A BF_3
- B CH_3^+
- C CH_3^-
- D SF_3^-

(Total 1 mark)

DAY 3 – INORGANIC CHEMISTRY: TRANSITION METALS

1. (a) State the origin of the colour of transition-metal complexes.

.....
.....

(2)

(b) Give **three** changes to a transition-metal complex which result in a change in colour.

Change 1

Change 2

Change 3

(3)

(c) You are provided with a 1.00mol dm⁻³ solution of iron (III) ions and a visible-light spectrophotometer (colorimeter). Outline a plan for experiments using this solution and this apparatus which would enable you to determine the concentration of iron (III) ions in a solution of unknown concentration.

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(5)

2. (a) Complete the electronic configuration of a cobalt (II) ion

Co²⁺ [Ar].....

(1)

(b) When cobalt (II) chloride is treated, under certain conditions, with the bidentate ligand, NH₂CH₂CH₂NH₂, (which can be represented by the symbol “en”), the compound [CoCl₂(en)₂]Cl is formed.

(i) What is the oxidation state of cobalt in the compound formed?

.....

(ii) What is meant by the term *bidentate* as applied to a ligand?

.....

(iii) What is the co-ordination number of cobalt in this compound?

.....

(iv) When this compound is treated with aqueous silver nitrate, only one mole of silver chloride is produced per mole of compound. Explain this observation.

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(5)

3. (a) The compound $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$ contains both chloride ions and ammonia molecules as ligands.

(i) State why chloride ions and ammonia molecules can behave as ligands.

.....

(ii) What is the oxidation state and the co-ordination number of cobalt in this complex compound?

Oxidation state of cobalt

Co-ordination number of cobalt

(iii) Suggest why the compound $[\text{Co}(\text{NH}_3)_6]\text{Cl}_3$ has a different colour from that of $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$.

.....

(4)

(b) Name and give the formula of an ammonia complex used to distinguish between aldehydes and ketones.

Name

Formula

(2)

(c) Deduce the formulae of the following complexes which contain only chloride ions as ligands.

(i) a tetrahedral complex ion of nickel(II)

.....

(ii) an octahedral complex ion of titanium(IV)

.....

(iii) a linear complex ion of copper(I)

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(3)

(d) Chloride ions form the tetrahedral complex ion $[\text{AlCl}_4]^-$ but fluoride ions form the octahedral complex ion $[\text{AlF}_6]^{3-}$. Suggest a reason for this difference.

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(1)

(e) When added to liquid ammonia in the absence of water, aluminium chloride forms a complex compound in which ammonia is the only ligand. Suggest the likely co-ordination number of aluminium in this compound and give a reason for your answer.

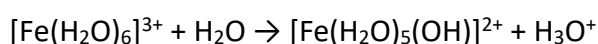
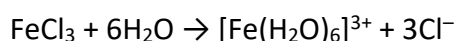
Co-ordination number

Reason

(2)

CATALYSIS EXAM QUESTIONS

Q1. When anhydrous iron(III) chloride is added to water the following reactions occur.



(a) State the type of acidity shown by FeCl_3 and by $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ in these reactions. Explain your answers.

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(4)

(b) Explain why the pH of a solution of iron(II) chloride is higher than that of a solution of iron(III) chloride of the same concentration.

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(3)

(c) Transition metals have variable oxidation states. This is an important factor in their ability to act as heterogeneous and homogeneous catalysts.

(i) Vanadium(V) oxide acts as a heterogeneous catalyst in the Contact Process. Write equations to show the role of vanadium(V) oxide in this process.

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(3)

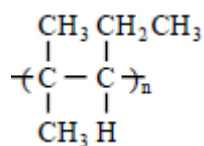
(ii) In aqueous solution, Fe^{2+} ions act as a homogeneous catalyst in the reaction between I^- and $\text{S}_2\text{O}_8^{2-}$ ions. Give one reason why the reaction is slow in the absence of a catalyst. Write equations to show how Fe^{2+} ions act as a catalyst for this reaction.

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(5)

DAY 4 – ORGANIC MCQ'S

Q11. The correct name for the alkene monomer which forms the polymer shown below is



- A 2-methyl-3-ethylpropene
- B 2-methylpent-2-ene
- C 2-methylpent-3-ene
- D 4-methylpent-2-ene

(Total 1 mark)

Q12. Which one of the following is **not** a suitable method for the preparation of ethanol?

- A oxidation of ethane
- B hydration of ethene
- C reduction of ethanal
- D hydrolysis of bromoethane

(Total 1 mark)

Q13. Which one of the following isomers is not oxidised under mild reaction conditions?

- A $(\text{CH}_3)_2\text{CHCH}(\text{OH})\text{COCH}_3$
- B $(\text{CH}_3)_2\text{C}(\text{OH})\text{CH}_2\text{COCH}_3$
- C $(\text{CH}_3)_2\text{CHCH}(\text{OH})\text{CH}_2\text{CHO}$
- D $(\text{CH}_3)_2\text{C}(\text{OH})\text{CH}_2\text{CH}_2\text{CHO}$

(Total 1 mark)

Q14. Which one of the following alcohols forms a mixture of alkenes when dehydrated?

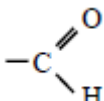
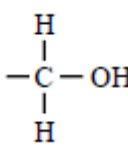
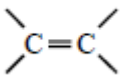
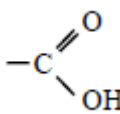
- A propan-1-ol
- B propan-2-ol
- C pentan-1-ol
- D pentan-2-ol

(Total 1 mark)

Q15. Certain chemical tests were performed on the pain-relief drug ibuprofen. The results of these tests are given in the table.

Test	Result
Aqueous sodium carbonate	Effervescence
Bromine water	Remained orange
Acidified potassium dichromate(VI) and heat	Remained orange
Fehling's solution and heat	Remained blue

Which one of the following functional groups do these results suggest that ibuprofen contains?

- A** 
- B** 
- C** 
- D** 

(Total 1 mark)

Q16. Which one of the following statements about but-2-enal, $\text{CH}_3\text{CH}=\text{CHCHO}$, is **not** true?

- A** It has stereoisomers.
- B** It shows a strong absorption in the infra-red at about 1700 cm^{-1} .
- C** It will turn an acidified solution of potassium dichromate(VI) green.
- D** It can be dehydrated by concentrated sulphuric acid.

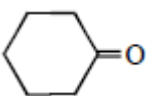
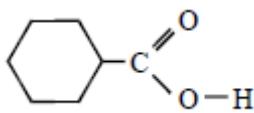
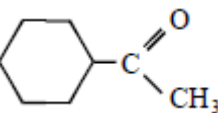
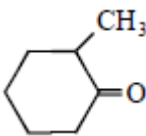
(Total 1 mark)

Q17. Which one of the following reactions will produce an organic compound that has optical isomers?

- A** dehydration of butan-2-ol by heating with concentrated sulphuric acid
- B** reduction of pentan-3-one by warming with NaBH_4
- C** addition of Br_2 to 3-bromopropene
- D** reduction of 2,3-dimethylpent-2-ene with H_2 in the presence of a nickel catalyst

(Total 1 mark)

Q18. The compound lithium tetrahydridoaluminate(III), LiAlH_4 , is a useful reducing agent. It behaves in a similar fashion to NaBH_4 . Carbonyl compounds and carboxylic acids are reduced to alcohols. However, LiAlH_4 also reduces water in a violent reaction so that it must be used in an organic solvent. Which one of the following can be reduced by LiAlH_4 to a primary alcohol?

- A** 
- B** 
- C** 
- D** 

(Total 1 mark)

Q19. Propanoic acid reacts with methanol in the presence of a small amount of concentrated sulphuric acid. The empirical formula of the ester formed is

- A** CH_2O
- B** $\text{C}_2\text{H}_6\text{O}_2$
- C** $\text{C}_2\text{H}_4\text{O}_2$
- D** $\text{C}_2\text{H}_4\text{O}$

(Total 1 mark)

Q20. Which one of the following does **not** contain any delocalised electrons?

- A** poly(propene)
- B** benzene
- C** graphite
- D** sodium

(Total 1 mark)

DAY 5 – PHYSICAL CHEMISTRY: ACIDS AND BASES

Q1. This question is about sulfuric acid and its salts.

(a) Draw the displayed formula of a molecule of H_2SO_4

(1)

(b) In aqueous solution, sulfuric acid acts as a strong acid. The H_2SO_4 dissociates to form HSO_4^- ions and H^+ ions.

The HSO_4^- ions act as a weak acid and dissociate to form SO_4^{2-} ions and H^+ ions.

Give an equation to show each stage in the dissociation of sulfuric acid in aqueous solution.

Include appropriate arrows in your equations.

Equation 1

Equation 2

(2)

(c) A student is required to make 250 cm^3 of an aqueous solution that contains an accurately measured mass of sodium hydrogensulfate (NaHSO_4).

Describe the method that the student should use to make this solution.

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(4)

(d) A solution that contains 605 mg of NaHSO_4 in 100 cm^3 of solution has a pH of 1.72

Calculate the value of K_a for the hydrogensulfate ion (HSO_4^-) that is behaving as a weak acid.

Give your answer to three significant figures.

State the units of K_a

K_a _____ Units _____

(6)

(e) Some sodium sulfate is dissolved in a sample of the solution from part **(d)**.

Explain why this increases the pH of the solution.

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(2)

(Total 15 marks)

Q2. A solution of 4-chlorobutanoic acid was titrated with sodium hydroxide solution. The pH was measured after each addition. Small volumes of sodium hydroxide solution were added. The titration data is shown in the table.

Volume of NaOH / cm³	0.0	5.0	10.0	15.0	18.0	19.0	20.0	21.0	22.0	25.0	30.0
pH	3.81	4.28	4.50	4.52	4.70	4.96	12.05	12.54	13.32	13.02	13.00

(a) Plot the values of the pH of the solution (y-axis) against the volume of NaOH.

(2)

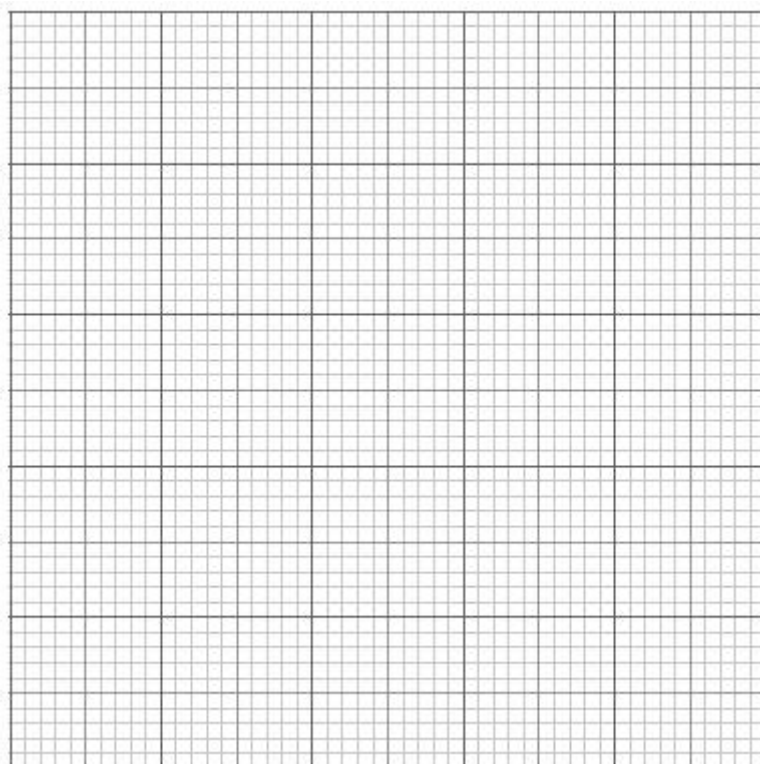
(b) Draw a curve of best fit for these points.

(2)

(c) The pK_a of a weak acid is equal to the pH of the solution in which half of the weak acid has been neutralised.

Use your graph to calculate a value of K_a for 4-chlorobutanoic acid.

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(3)

(d) Before this titration can take place, the pH probe needs to be calibrated.

Outline a simple method for calibrating a pH probe, including any measurements made and how they should be used.

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(3)

(e) Explain how you would use the curve you have plotted in part (a) to choose a suitable indicator for this titration.

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(2)

(f) Suggest an improvement a student could make to increase the accuracy of the end point when using an indicator in this experiment instead of a pH probe.

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(1)

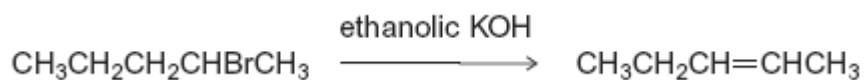
(Total 13 marks)

DAY 6 – ORGANIC CHEMISTRY – AS MECHANISMS

Q1. Organic reaction mechanisms help chemists to understand how the reactions of organic compounds occur. The following conversions illustrate several different types of reaction mechanism.

(a) When 2-bromopentane reacts with ethanolic KOH, two structurally isomeric alkenes are formed.

(i) Name and outline a mechanism for the conversion of 2-bromopentane into pent-2-ene as shown.

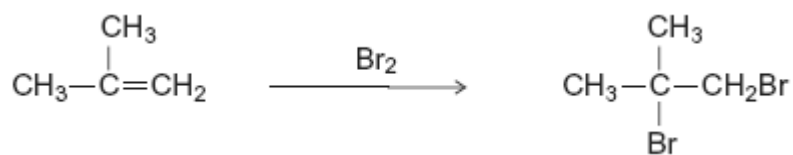


(4)

(ii) Draw the structure of the other structurally isomeric alkene produced when 2-bromopentane reacts with ethanolic KOH.

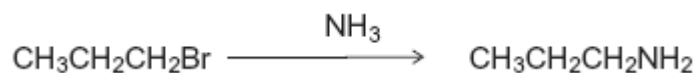
(1)

(b) Name and outline a mechanism for the following conversion.



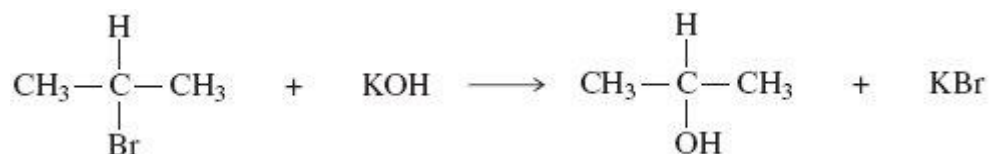
(5)

(c) Name and outline a mechanism for the following conversion.



(5)

Q2. (a) Consider the following reaction.



(i) Name and outline a mechanism for this reaction.

Name of mechanism _____

Mechanism

(3)

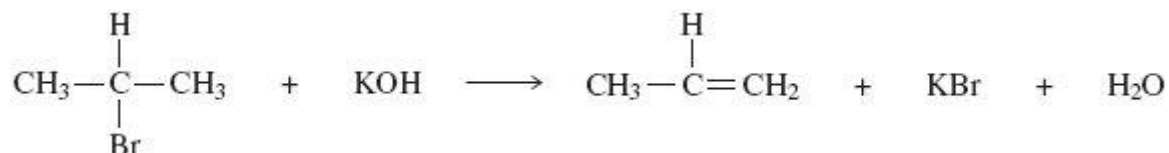
(ii) Name the haloalkane in this reaction.

(1)

(iii) Identify the characteristic of the haloalkane molecule that enables it to undergo this type of reaction.

(1)

(b) An alternative reaction can occur between this haloalkane and potassium hydroxide as shown by the following equation.



Name and outline a mechanism for this reaction.

Name of mechanism _____

Mechanism

(c) Give **1** condition needed to favour the reaction shown in part (b) rather than that shown in part (a).

(4)

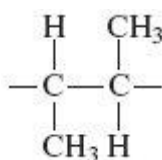
(1)

(d) Alkenes can be polymerised to produce poly(alkenes).

(i) State the type of polymerisation that alkenes undergo.

(1)

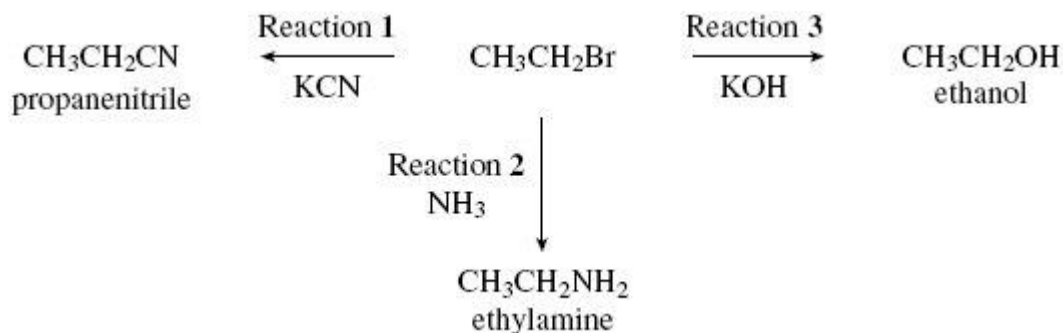
(ii) Name the alkene that gives a polymer with the repeating unit shown below.



Name of alkene _____

(1)

Q3. Nucleophiles react with bromoethane in substitution reactions. This type of reaction is illustrated in the following scheme.



(a) State what is meant by the term *nucleophile*.

(1)

(b) Outline a mechanism for the reaction of potassium cyanide with bromoethane (Reaction 1).

(2)

(c) Explain why an excess of ammonia is needed in Reaction 2 to produce a high yield of ethylamine.

(1)

(d) When potassium hydroxide reacts with bromoethane, ethene can also be formed. Name and outline a mechanism for this reaction.

Name of mechanism _____

Mechanism

(4)

Q4. 2-Methyl but-2-ene reacts with concentrated sulfuric acid to form two different products.

(a) Outline a mechanism for this reaction to show the formation of the major product.

(4)

(b) Draw the structure of the minor product of this reaction.

(1)

(c) Explain why the two products are formed in different amounts.

(2)

DAY 7 – PHYSICAL MCQ's

Q11. Which molecule has the largest dipole?

- A ClF_3
- B BF_3
- C SF_6
- D CF_4

(Total 1 mark)

Q12. Use your understanding of intermolecular forces to predict which of these compounds has the highest boiling point.

- A HF
- B HCl
- C HBr
- D HI

(Total 1 mark)

Q13. In which one of the following reactions is the standard enthalpy change equal to the standard enthalpy of formation of lithium fluoride?

- A $\text{Li(g)} + \text{F(g)} \rightarrow \text{LiF(s)}$
- B $\text{Li}^+(\text{g}) + \text{F}^-(\text{g}) \rightarrow \text{LiF(s)}$
- C $\text{Li}^+(\text{aq}) + \text{F}^-(\text{g}) \rightarrow \text{LiF(s)}$
- D $\text{Li(s)} + \frac{1}{2}\text{F}_2(\text{g}) \rightarrow \text{LiF(s)}$

(Total 1 mark)

Q14. When ethanamide (CH_3CONH_2) burns in oxygen the carbon is converted into carbon dioxide, the hydrogen is converted into water and the nitrogen forms nitrogen gas.

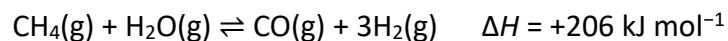
Substance	ethanamide	carbon dioxide	water
Enthalpy of formation (ΔH_f^\ominus) / kJ mol^{-1}	-320	-394	-286

Using the data above, which one of the following is a correct value for the enthalpy of combustion of ethanamide?

- A $-1823 \text{ kJ mol}^{-1}$
- B $-1183 \text{ kJ mol}^{-1}$
- C $-1000 \text{ kJ mol}^{-1}$
- D -360 kJ mol^{-1}

(Total 1 mark)

Q15. Hydrogen is produced by the reaction of methane with steam. The reaction mixture reaches a state of dynamic equilibrium.



Some enthalpy data is given in the table.

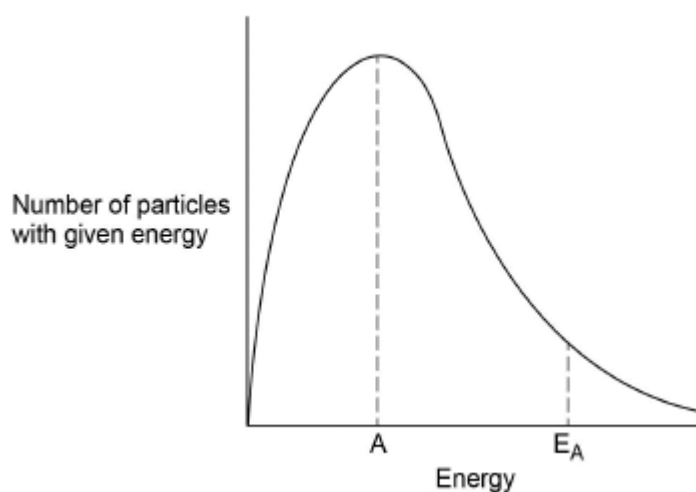
Bond	C–H	O–H	H–H	C=O
Bond enthalpy / kJ mol^{-1}	413	463	436	To be calculated

Use the information in the table and the stated enthalpy change to calculate the missing bond enthalpy.

- A 234
- B 1064
- C 1476
- D 1936

(Total 1 mark)

Q16. The graph shows a typical energy distribution for particles of an ideal gas in a sealed container at a fixed temperature.

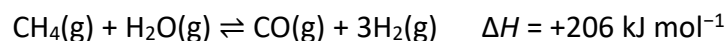


Which of the following statements is true?

- A Position A represents the mean energy of a molecule in the container.
- B Addition of a catalyst moves the position of E_A to the right.
- C The area under the curve to the right of E_A represents the number of molecules with enough energy to react.
- D The position of the peak of the curve at a higher temperature is further away from both axes.

(Total 1 mark)

Q17.Hydrogen is produced by the reaction of methane with steam. The reaction mixture reaches a state of dynamic equilibrium.

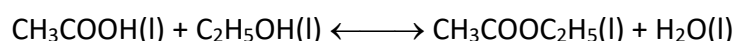


Which of the following shows how the equilibrium yield of hydrogen and the value of the equilibrium constant are affected by the changes shown?

Change	Effect on equilibrium yield of H ₂ (g)	Effect on value of K _c
A Increase pressure	decrease	decrease
B Add a catalyst	increase	no effect
C Increase temperature	increase	increase
D Remove CO(g) as formed	increase	increase

(Total 1 mark)

Q18. Ethanoic acid reacts with ethanol in a reversible reaction represented by the equation. In an experiment 3.0 mol of ethanoic acid were mixed with 1.0 mol of ethanol and when the reaction had reached equilibrium 0.9 mol of water had been formed.

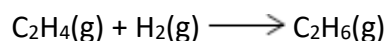


The equilibrium constant for the reaction under these conditions is

- A** 0.20
- B** 0.23
- C** 3.9
- C** 4.3

(Total 1 mark)

Q19.The rate equation for the hydrogenation of ethene



is $\text{Rate} = k[\text{C}_2\text{H}_4][\text{H}_2]$

At a fixed temperature, the reaction mixture is compressed to triple the original pressure.

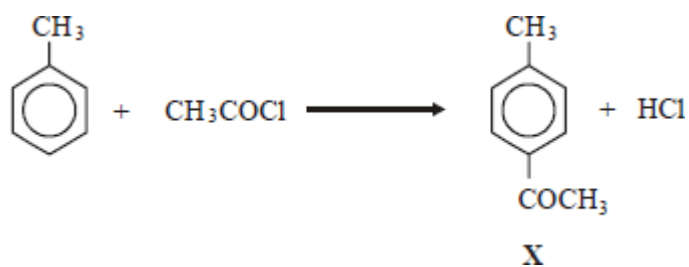
What is the factor by which the rate of reaction changes?

- A** 6
- B** 9
- C** 12
- D** 27

(Total 1 mark)

DAY 8 – ORGANIC MCQ's

Q21. Ethanoyl chloride reacts with methylbenzene forming compound **X** according to the equation.

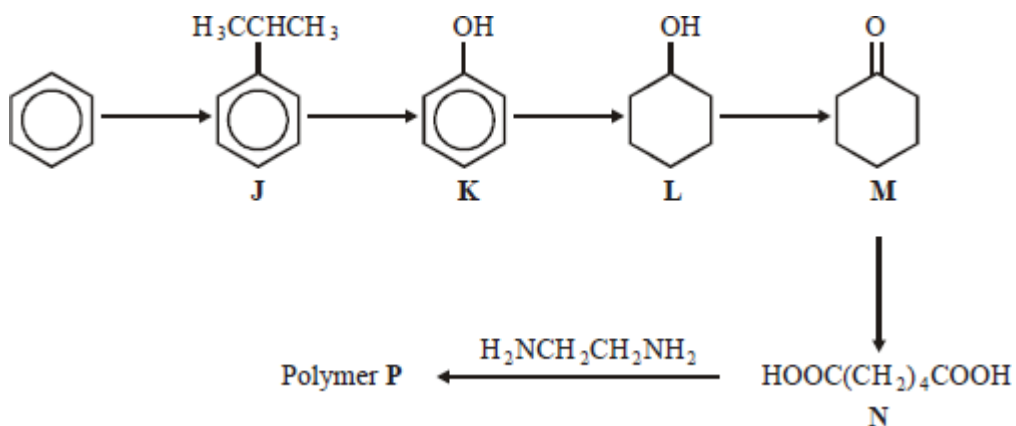


If the experimental yield is 40.0%, the mass in g of **X** ($M_r = 134.0$) formed from 18.4g of methylbenzene ($M_r = 92.0$) is

- A 26.8
- B 16.1
- C 10.7
- D 7.4

(Total 1 mark)

Q22. This question is about the following reaction scheme which shows the preparation of polymer **P**.



Polymer **P** is formed in a 2-step reaction from **N**. The 1st stage is a neutralisation reaction. The volume, in cm^3 , of a 0.20mol dm^{-3} solution of $\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$ required to neutralise $6.8 \times 10^{-3}\text{mol}$ of the acid **N** is

- A 17
- B 34
- C 68
- D 136

(Total 1 mark)

Q23. Terylene is made by reacting benzene-1,4-dicarboxylic acid and ethane-1,2-diol. Terylene is

- A an addition polymer.
- B a polyamide.
- C a polyester.
- D a nylon.

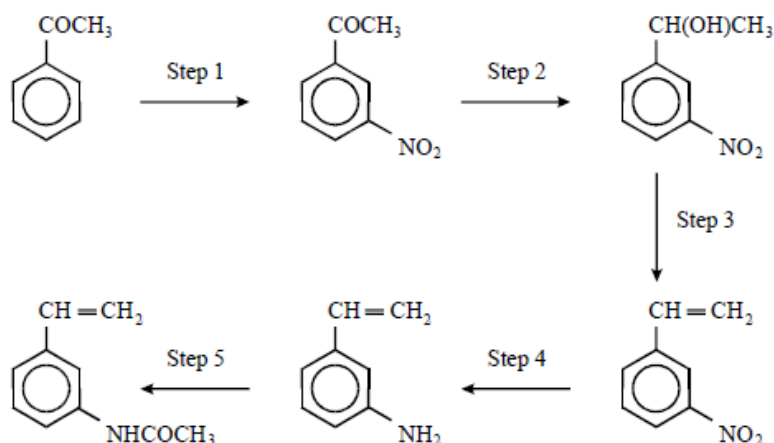
(Total 1 mark)

Q24. A drug is designed to simulate one of the following molecules that adsorbs onto the active site of an enzyme. Which molecule requires the design of an optically active drug?

- A $\begin{array}{c} \text{H}-\text{CH}-\text{COOH} \\ | \\ \text{OH} \end{array}$
- B $\begin{array}{c} \text{CH}_3-\text{C}-\text{COOH} \\ || \\ \text{O} \end{array}$
- C $\begin{array}{c} \text{CH}_3-\text{CH}-\text{COOH} \\ | \\ \text{OH} \end{array}$
- D $\begin{array}{c} \text{CH}_2-\text{CH}_2-\text{COOH} \\ | \\ \text{OH} \end{array}$

(Total 1 mark)

Q25. Refer to the following reaction sequence:



Which one of the following types of reaction is **not** involved in the above sequence?

- A acylation
- B oxidation
- C reduction
- D dehydration

(Total 1 mark)

Q26. Which amine has only **three** peaks in its proton NMR spectrum?

- A** Methylamine
- B** Trimethylamine
- C** Diethylamine
- D** Propylamine

(Total 1 mark)

MARK SCHEMES

ORGANIC MCQ's

M1.B
M2.C
M3.C
M4.A
M5.A
M6.B
M7.D
M8.B
M9.C
M10.D
M11.B
M12.A
M13.B
M14.D
M15.D
M16.D
M17.D
M18.B
M19.D
M20.A
M21.C
M22.B
M23.C
M24.C
M25.B
M26.C

PHYSICAL MCQ's

M1.B
M2.B
M3.B
M4.B
M5.B
M6.C
M7.B
M8.C
M9.B
M10.C
M11.A
M12.A
M13.D
M14.B
M15.B
M16.C
M17.C
M18.C
M19.B

TRANSITION METALS MARK SCHEME

Q1. (a) Electron transitions/electrons excited in d shell (1) or d-d transition
 Do NOT allow charge transfer
 (Energy in) visible range (1)
 (NOT emits in visible region)

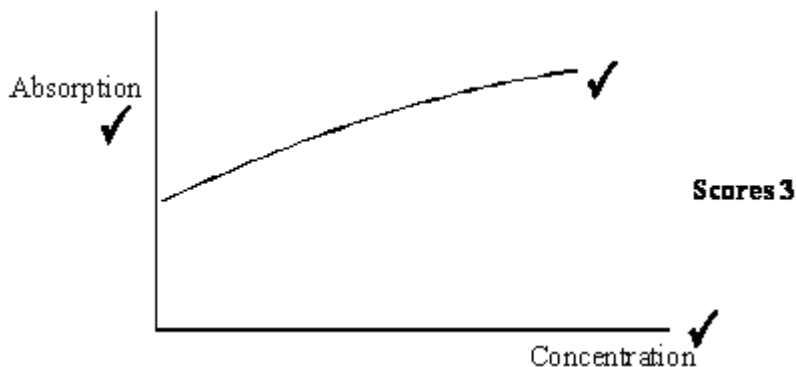
2

(b) Change 1: (Different) oxidation states (1)
 Change 2 : (Different) ligands (1)
 Change 3: (Different) co-ordination number (1)
 Do not allow shape as an answer

3

(c) Add an appropriate (or a given correct) ligand to intensify colour (1)
 e.g. thiocyanate (CNS)⁻ or bipyridyl
 Make up solutions of known concentration (1)
 Measure absorption or transmission (1)
 Plot graph of results or calibration curve (1)
 Measure absorption of unknown and (1)
 compare

N.B.: Allow concentration statement if included in graph statement
 Allow adsorption but circle the d
 Also



5

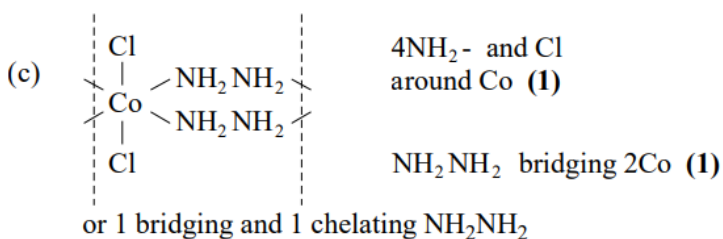
[10]

Q2.

(a) Co^{2+} [AR] $3d^7$ (1) 1

(b) (i) 3 (1)
 (ii) two donor atoms or 2 lone pairs bond (1)
 (iii) 6 (1)

(iv) 1 Cl^- available or ionic structure (1)
 2 Cl are covalently bonded (1)
 or strongly bonded or complex ion stable 5



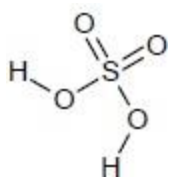
[8]

Q3.

- (a) (i) have lone pair (1)
 (ii) +3 (1)
 6 (1)
 (iii) different ligands (1) 4
- (b) Tollen's or diammine silver(I) (1)
 $[\text{Ag}(\text{NH}_3)_2]^+$ (1) 2
- (c) (i) $[\text{NiCl}_4]^{2-}$ (1)
 (ii) $[\text{TiCl}_6]^{2-}$ (1)
 (iii) $[\text{CuCl}_2]^-$ (1) 3
- (d) F^- smaller than Cl^- (1) 1

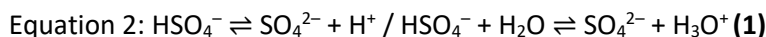
[10]**CATALYSIS EXAM Q****Q1.**

- (a) FeCl_3 accepts electron pairs from water (1)
 Hence acts as a Lewis acid (1)
 $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ donates protons (1)
 Hence acts as a Bronsted-Lowry acid (1)
- (b) The Fe^{2+} ion has a smaller charge to size ratio (1)
 Hence less polarising than Fe^{3+} or less weakening effect on O-H bonds (1)
- (c) (i) $\text{V}_2\text{O}_5 + \text{SO}_2 \rightarrow \text{V}_2\text{O}_4 + \text{SO}_3$ (1)
 $\text{V}_2\text{O}_4 + \text{O}_2 \rightarrow \text{V}_2\text{O}_5$ (1)
- (ii) Both ions are negative or ions repel (1)
- $2\text{Fe}^{2+} + \text{S}_2\text{O}_8^{2-} \rightarrow 2\text{Fe}^{3+} + 2\text{SO}_4^{2-}$ Species (1) Balanced (1)
- $2\text{Fe}^{3+} + 2\text{I}^- \rightarrow 2\text{Fe}^{2+} + \text{I}_2$ Species (1) Balanced (1)

[13]**ACIDS AND BASES MARK SCHEME****Q1. (a)****(1)**

Ignore shape / bond angles
Ignore lone pair(s) on O atoms
NOT lone pair(s) on S atom

- (b) Equation 1: $\text{H}_2\text{SO}_4 \rightarrow \text{HSO}_4^- + \text{H}^+$ / $\text{H}_2\text{SO}_4 + \text{H}_2\text{O} \rightarrow \text{HSO}_4^- + \text{H}_3\text{O}^+$ (1)
 Equation 1: NOT \rightleftharpoons



Equation 2: NOT \rightarrow or \leftrightarrow

Allow \rightleftharpoons or \rightleftharpoons or \rightleftharpoons

Ignore state symbols in both equations

Allow multiples in both equations

- (c) **M1** weigh solid and transfer using a method that Allows exact mass to be known (there should be two weighings, one of which could be zeroing, and method could be by difference or with washings or directly weighed into container)

M1 Ignore any mass quoted

NOT if any other solid added

- M2** dissolve in water in suitable container (NOT in 250 cm³ of water)

M2 NOT if any other solution added

- M3** transfer with washings into 250 cm³ volumetric/graduated flask

M3 Reference to 250 cm³ can appear anywhere

- M4** make up to mark / 250 cm³ AND THEN shake / invert / mix

M4 Allow if conical flask used

NOT if beaker used

Alternative method (M2-4)

M2 in 250 cm³ volumetric/graduated flask

M3 dissolve (NOT in 250 cm³ of water)

M4 make up to mark / 250 cm³ AND THEN shake/invert/mix

- (d) **M1** $[\text{H}^+] = 10^{-1.72}$ (= 0.0191 (mol dm⁻³))

M2 amount NaHSO₄ = 0.605/120.1 (= 5.04 x 10⁻³ (mol))

M3 initial [NaHSO₄] = [HSO₄⁻] = **M2** x 10 (= 5.04 x 10⁻² (mol dm⁻³))

$$K_a = \frac{[\text{H}^+][\text{SO}_4^{2-}]}{[\text{HSO}_4^-]} \quad \text{or} \quad K_a = \frac{[\text{H}^+]^2}{[\text{HSO}_4^-]}$$

M4
$$K_a = \frac{0.0191^2}{0.0504 - 0.0191}$$

M5 $K_a = 1.17 \times 10^{-2}$ (1.15 – 1.18 x 10⁻²) must be 3sf

M6 mol dm⁻³

Correct answer scores **M1-5** (must be 3sf)

Alternative method that does not subtract 0.0191:

7.21×10^{-3} (7.15 – 7.26 x 10⁻³) scores **M1-5**

(where **M4** $K_a = \frac{0.0191^2}{0.0504}$)

If not correct answer:

For **M1-3**, if answer is shown, it must be correct (Ignore sf)

Allow ECF from **M1/2/3** to **M4/5** (but not from **M3** to **M5**)

if omission of **M3** gives negative **M5**)

NOT ECF from incorrect K_a expression in **M4** to **M5**

M6 If not mol dm⁻³, Allow ECF for units from incorrect K_a expression in **M4**

7.21×10^{-2} (7.15 – 7.26 x 10⁻²) gives **M1,2,4,5** (by alternative method omitting **M3**)

- (e) **M1** ($\text{HSO}_4^- \rightleftharpoons \text{SO}_4^{2-} + \text{H}^+$) equilibrium moves/shifts left (to counteract / remove increased [SO₄²⁻])

M1 Allow H^+ reacts with SO₄²⁻/sulfate

Ignore favours the reverse / left / backwards reaction

NOT base / A⁻ / sodium sulfate in place of SO₄²⁻/sulfate

M2 so [H⁺] decreases

M2 Allow fewer H⁺ (ions) or amount of H⁺ lower or removes H⁺

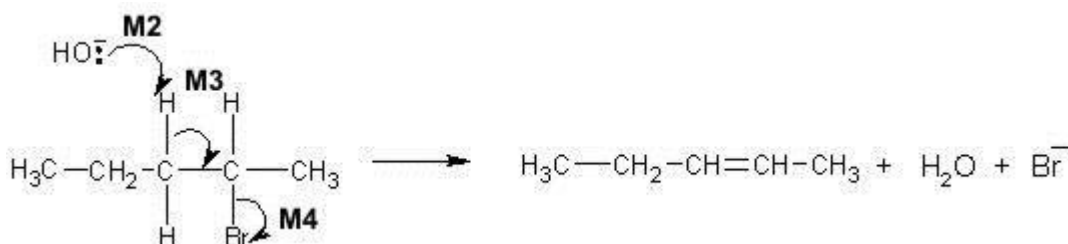
M2 independent of **M1**

Q2.

- (a) Sensible scales **(1)**
If pH not on y-axis lose M1
Both axes must have labels (does not have to have units)
 All points plotted accurately **(1)**
Plotted points must cover at least half of the grid
Allow ± 1 small square
- (b) Line is smooth **(1)**
Penalise very thick or doubled lines but make some allowance for drawing a complex curve for M1
 Avoids the anomalous point **(1)**
Line must pass within ± 1 small square of all points (except the anomalous)
- (c) Reads the volume off at the equivalence point and divides by 2 to find volume at half-equivalence **(1)**
Volume at equivalence should be between $19 - 20 \text{ cm}^3$
Consequential to their plotted points.
Half-equivalence = $9.5 - 10 \text{ cm}^3$
If candidate has used incorrect volume, CE loses M1 and M2 but can score M3 as a process mark.
 Reads off pH at half-equivalence **(1)**
If candidate has misread volume from their graph, lose M1
4.40 - 4.50
 (pH = pK_a)
 K_a = 10^{-pK_a} **(1)**
Range of values for K_a = $3.16 \times 10^{-5} - 3.98 \times 10^{-5}$
Mark M3 independently
- (d) Use of a buffer solution **(1)**
 Rinses probe (with distilled/deionised water) between measurements **(1)**
 Measures pH of more than one buffer solutions **(1)**
 Plots a graph of pH of buffer against pH on probe **OR** adjusts meter / probe **OR** draws a calibration curve **(1)**
Max 3 of 4 points
Allow "solution of known pH" for "buffer"
- (e) pH range of steep section of curve **OR** between 5 – 12 (or any values both within this range) **(1)**
 Indicator's colour change must fall within this range **(1)**
Allow pK indicator approx. equal to pH of centre of range
- (f) Adding the solution dropwise (near the end point) **(1)**

[13]**AS MECHANISMS MARK SCHEME****Q1.**

- (a) (i)
- M1 Elimination**

**M2** must show an arrow from the lone pair on the oxygen

of a negatively charged hydroxide ion to a correct H atom
M3 must show an arrow from a C-H bond adjacent to the C-Br bond towards the appropriate C-C bond.
 Only award if a reasonable attempt has been made at the attack on the H atom of the appropriate adjacent C-H
M4 is independent provided it is from their original molecule
 Award full marks for an E1 mechanism in which **M3** is on the correct carbocation.

N.B. These are double-headed arrows

For M1, accept "Base elimination" but no other prefix.

*Penalise **M2** if covalent KOH*

*Penalise **M4** for formal charge on C of C-Br or incorrect partial charges on C-Br*

Ignore other partial charges

Penalise once only in any part of the mechanism for a line and two dots to show a bond.

*Max any 2 of 3 marks **for the mechanism** for wrong reactant (or wrong product if shown).*

Accept the correct use of "sticks" for the molecule except for the C-H being attacked

4

(ii) **Structure for pent-1-ene**

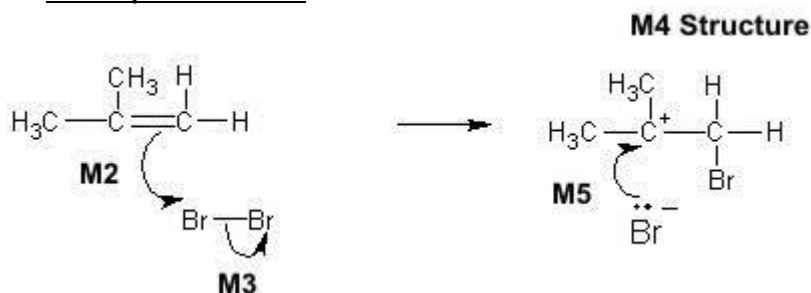


Penalise C_3H_7

Accept correct "sticks"

1

(b) **M1 Electrophilic addition**



M2 must show an arrow from the double bond towards the Br atom of the Br-Br molecule

M3 must show the breaking of the Br-Br bond.

M4 is for the structure of the tertiary carbocation with Br on the correct carbon atom.

M5 must show an arrow from the lone pair of electrons on the negatively charged bromide ion towards the positively charged carbon atom.

N.B. These are double-headed arrows

For M1, both words required.

For the mechanism

***M2** Ignore partial negative charge on the double bond.*

***M3** Penalise partial charges on Br-Br bond if wrong way and penalise formal charges*

Penalise once only in any part of the mechanism for a line and two dots to show a bond

*Max any 3 of 4 marks **for the mechanism** for*

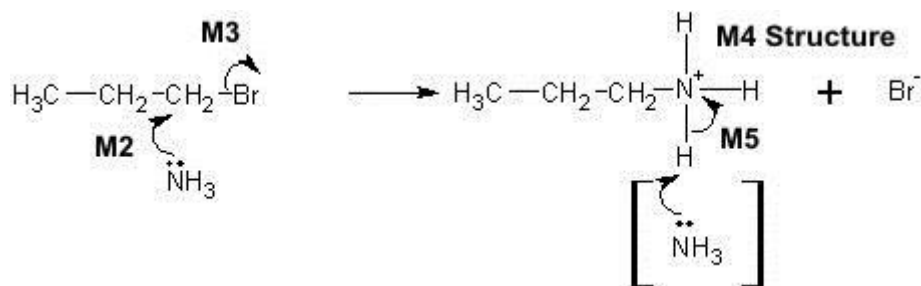
wrong organic reactant or wrong organic product (if shown) or primary carbocation.

*If HBr is used, max 2 marks **for their mechanism***

Accept the correct use of "sticks"

5

(c) **M1 Nucleophilic substitution**



M2 must show an arrow from the lone pair of electrons on the nitrogen atom of an ammonia molecule to the C atom.

M3 must show the movement of a pair of electrons from the C-Br bond to the Br atom. **M3** is independent provided it is from their original molecule

M4 is for the structure of the alkylammonium ion, which could be a condensed formula. A positive charge must be shown on/or close to, the N atom.

M5 is for an arrow from the N-H bond to the N atom.

Award full marks for an S_N1 mechanism in which M2 is the attack of the ammonia on the intermediate carbocation.

N.B. These are double-headed arrows

For M1, both words required.

Penalise M2 if NH₃ is negatively charged.

Penalise M3 for formal charge on C or incorrect partial charges

The second mole of ammonia is not essential for M5; therefore ignore any species here.

Penalise once only for a line and two dots to show a bond.

*Max any 3 of 4 marks **for the mechanism** for wrong organic reactant (or wrong organic product if shown)*

Accept the correct use of "sticks"

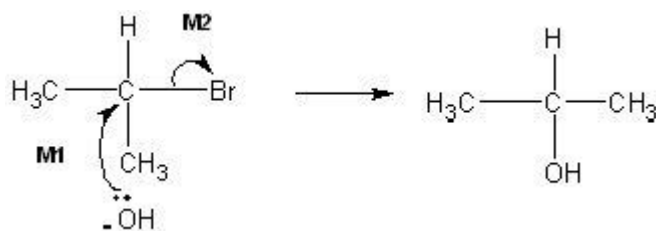
5

[15]

Q2.

(a) (i) Nucleophilic substitution

1



2

M1 must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the central C atom.

M2 must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently.

Penalise M1 if covalent KOH is used

Penalise M2 for formal charge on C or incorrect partial charges

Penalise once only for a line and two dots to show a bond.

*Max 1 mark **for the mechanism** for the wrong reactant and/or "sticks"*

Ignore product

Award full marks for an S_N1 mechanism in which M1 is the attack of the hydroxide ion on the intermediate carbocation.

(ii) 2-bromopropane ONLY

1

- (iii) Polar C–Br OR polar carbon–bromine bond OR dipole on C–Br
OR δ^+ (δ^-)
 C atom of carbon–bromine bond is δ^+ /electron deficient **OR** C–Br
 (Credit carbon–halogen bond as an alternative to
 carbon–bromine bond)

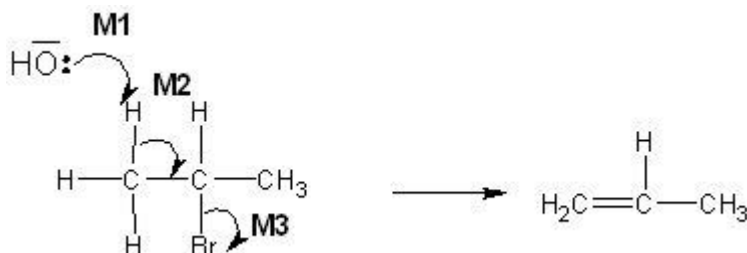
*It must be clear that the discussion is about the carbon atom of the C–Br
 bond. NOT just reference to a polar molecule.
 Ignore X for halogen*

1

- (b) Elimination

*Credit “base elimination” but NOT “nucleophilic elimination”
 No other prefix.*

1



3

M1 must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom

M2 must show an arrow from the correct C-H bond to the C-C bond and should only be awarded if an attempt has been made at M1

M3 is independent.

Mechanism

Penalise M1 if covalent KOH

Penalise M3 for formal charge on C or incorrect partial charges

Penalise once only for a line and two dots to show a bond.

*Max 2 marks **for the mechanism** for wrong reactant and/or “sticks”*

Ignore product

Award full marks for an E1 mechanism in which M2 is on the correct carbocation.

- (c) Any one condition from this list to favour elimination;

Apply the list principle

- alcohol(ic)/ethanol(ic) (solvent)
- high concentration of KOH/alkali/hydroxide **OR** concentrated KOH/hydroxide
Ignore “aqueous”
- high temperature or hot or heat under reflux or T = 78 to 100°C
Ignore “excess”

1

- (d) (i) Addition (polymerisation) ONLY

Penalise “additional”

1

- (ii) But-2-ene ONLY (hyphens not essential)

Ignore references to cis and trans or

E/Z

Ignore butane

1

Q3.

- (a) Electron pair donor

[12]

OR

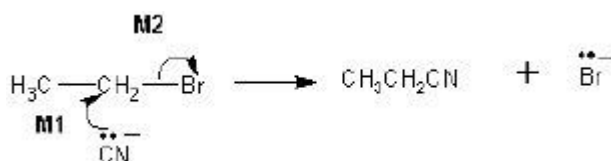
Species which uses a pair of electrons to form a co-ordinate / covalent bond.

QoL

Credit "lone pair" as alternative wording

1

(b)



M1 Must show an arrow from the lone pair of electrons on the carbon atom of the negatively charged cyanide ion to the central C atom.

M2 Must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently.

Award full marks for an S_N1 mechanism in which M1 is the attack of the cyanide ion on the intermediate carbocation.

Penalise M1 if covalent KCN is used

Penalise M2 for formal charge on C or incorrect partial charges

Penalise once only for a line and two dots to show a bond.

Max 1 mark for the wrong reactant or "sticks"

2

(c) Ethylamine / $\text{CH}_3\text{CH}_2\text{NH}_2$ is a nucleophile

OR

Ethylamine could react further

OR

Ethylamine could make secondary / tertiary amines

OR

To make reaction with ammonia more likely

OR

To minimise further substitution

OR

The idea of releasing free amine from the salt

OR

The idea of removing a proton from the intermediate alkylammonium ion

OR

The idea that ammonia acts both initially as a nucleophile and then as a base

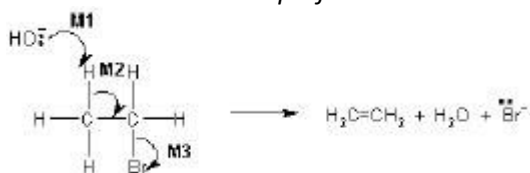
Do not credit a simple reference to the equation or the mechanism requiring two moles of ammonia.

1

(d) **Elimination**

Credit "base elimination" but NOT "nucleophilic elimination"

No other prefix.



M1 Must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom

1

M2 Must show an arrow from the correct C-H bond to the C-C bond and should only be awarded if an attempt has been made at M1

M3 Is independent.

Award full marks for an E1 mechanism in which M2 is on the correct carbocation.

Mechanism

Penalise M1 if covalent KOH

Penalise M3 for formal charge on C or incorrect partial charges

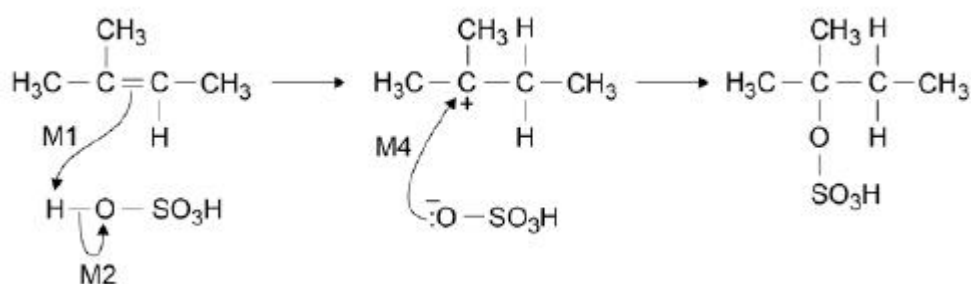
Penalise once only for a line and two dots to show a bond.

Max 2 marks **for the mechanism** for wrong reactant or "sticks"

3

[8]

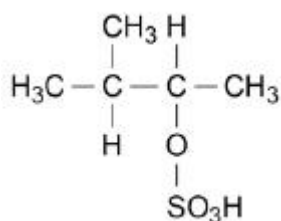
Q4.



M1, M2 and M4 are awarded for the three curly arrows shown on the mechanism (1 mark for each correct)

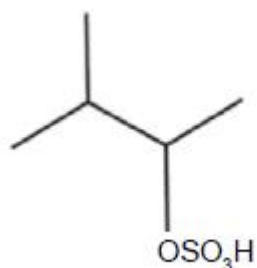
M3 is for the structure of the carbocation intermediate

4



Correct answers include:

- the displayed formula
- structural formulae such as $\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}(\text{OSO}_3\text{H})\text{CH}_3$
- skeletal formulae such as



(c) The major product is formed via a tertiary carbocation intermediate and the minor product is formed via a secondary carbocation intermediate

The tertiary carbocation is more stable than the secondary carbocation

1

1

1

[7]