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9701/21

May/June 2013

1 hour 15 minutes

Additional Materials: Data Booklet

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DO **NOT** WRITE IN ANY BARCODES.

A Data Booklet is provided.

The number of marks is given in brackets [] at the end of each question or part question.

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This document consists of **10** printed pages and **2** blank pages.

Answer **all** the questions in the spaces provided.

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- 1** A sample of a fertiliser was known to contain ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4$, and sand only.

A 2.96 g sample of the solid fertiliser was heated with 40.0 cm^3 of $\text{NaOH}(\text{aq})$, an excess, and all of the ammonia produced was boiled away.

After cooling, the remaining $\text{NaOH}(\text{aq})$ was exactly neutralised by 29.5 cm^3 of 2.00 mol dm^{-3} HCl .

In a separate experiment, 40.0 cm^3 of the original $\text{NaOH}(\text{aq})$ was exactly neutralised by 39.2 cm^3 of the 2.00 mol dm^{-3} HCl .

- (a) (i)** Write balanced equations for the following reactions.

NaOH with HCl

.....

$(\text{NH}_4)_2\text{SO}_4$ with NaOH

.....

- (ii)** Calculate the amount, in moles, of NaOH present in the 40.0 cm^3 of the original $\text{NaOH}(\text{aq})$ that was neutralised by 39.2 cm^3 of 2.00 mol dm^{-3} HCl .

- (iii)** Calculate the amount, in moles, of NaOH present in the 40.0 cm^3 of $\text{NaOH}(\text{aq})$ that remained after boiling the $(\text{NH}_4)_2\text{SO}_4$.

- (iv)** Use your answers to **(ii)** and **(iii)** to calculate the amount, in moles, of NaOH that reacted with the $(\text{NH}_4)_2\text{SO}_4$.

- (v) Use your answers to (i) and (iv) to calculate the amount, in moles, of $(\text{NH}_4)_2\text{SO}_4$ that reacted with the NaOH.

- (vi) Hence calculate the mass of $(\text{NH}_4)_2\text{SO}_4$ that reacted.

- (vii) Use your answer to (vi) to calculate the percentage, by mass, of $(\text{NH}_4)_2\text{SO}_4$ present in the fertiliser.
Write your answer to a suitable number of significant figures.

[9]

- (b) The uncontrolled use of nitrogenous fertilisers can cause environmental damage to lakes and streams. This is known as *eutrophication*.

What are the processes that occur when excessive amounts of nitrogenous fertilisers get into lakes and streams?

.....

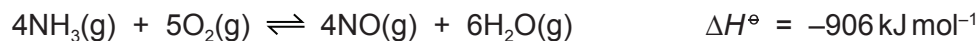
 [2]

- (c) Large quantities of ammonia are manufactured by the Haber process.
Not all of this ammonia is used to make fertilisers.
State **one** large-scale use for ammonia, **other than** in the production of nitrogenous fertilisers.

..... [1]

[Total: 12]

- 2 Ammonium nitrate fertiliser is manufactured from ammonia. The first reaction in the manufacture of the fertiliser is the catalytic oxidation of ammonia to form nitrogen monoxide, NO. This is carried out at about 1×10^3 kPa (10 atmospheres) pressure and a temperature of 700 to 850 °C.



- (a) Write the expression for the equilibrium constant, K_p , stating the units.

$K_p =$

units

[2]

- (b) What will be the effect on the yield of NO of **each** of the following?
In each case, explain your answer.

- (i) increasing the temperature

.....
.....
.....

- (ii) decreasing the applied pressure

.....
.....
.....

[4]

(c) The standard enthalpy changes of formation of $\text{NH}_3(\text{g})$ and $\text{H}_2\text{O}(\text{g})$ are as follows.

$$\text{NH}_3(\text{g}), \Delta H_f^\circ = -46.0 \text{ kJ mol}^{-1}$$

$$\text{H}_2\text{O}(\text{g}), \Delta H_f^\circ = -242 \text{ kJ mol}^{-1}$$

Use these data and the value of $\Delta H_{\text{reaction}}^\circ$ given below to calculate the standard enthalpy change of formation of $\text{NO}(\text{g})$.

Include a sign in your answer.



For
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Use

[4]

[Total: 10]

- 3 This question refers to the elements in the section of the Periodic Table shown below.

For
Examiner's
Use

		H						He		
Li	Be			B	C	N	O	F	Ne	
Na	Mg			Al	Si	P	S	Cl	Ar	
K	Ca		transition elements		Ga	Ge	As	Se	Br	Kr

- (a) From this list of elements, identify in **each** case **one** element that has the property described. Give the **symbol** of the element.

- (i) An element that floats on cold water and reacts readily with it.

.....

- (ii) An element that forms an oxide that is a reducing agent.

.....

- (iii) The element that has the smallest first ionisation energy.

.....

- (iv) The element which has a giant molecular structure **and** forms an oxide which has a simple molecular structure.

.....

- (v) The element in Period 3 (Na to Ar) that has the smallest anion.

.....

- (vi) The element in Period 3 (Na to Ar) which forms a chloride with a low melting point and an oxide with a very high melting point.

.....

[6]

- (b) Use the elements in Period 3 (Na to Ar) in the section of the Periodic Table opposite to identify the oxide(s) referred to below.
In **each** case, give the **formula** of the oxide(s).

(i) An oxide which when placed in water for a long time has no reaction with it.

.....

(ii) An oxide which dissolves readily in water to give a strongly alkaline solution.

.....

(iii) Two acidic oxides formed by the same element.

..... and

(iv) An oxide which is amphoteric.

.....

[5]

- (c) Fluorine reacts with other elements in Group VII to form a number of different compounds.
Two such compounds and their boiling points are given in the table.

compound	ClF_3	BrF_3
boiling point / °C	12	127

- (i) The two molecules have similar electronic configurations.
Showing outer electrons only, draw a 'dot-and-cross' diagram of the bonding in ClF_3 .

- (ii) The two molecules have the same shape.
Suggest why the boiling points are significantly different.

.....
.....
.....
.....

[4]

[Total: 15]

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- 4 Organic chemistry is the chemistry of carbon compounds. The types of organic reactions that you have studied are listed below.

For
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Use

addition	elimination	hydrolysis
oxidation	reduction	substitution

Addition and substitution reactions are further described as follows.

electrophilic	nucleophilic	free radical
---------------	--------------	--------------

Complete the table below.

Fill in the central column by using **only** the types of reaction given in the lists above.

Use **both** lists when appropriate.

In the right hand column give the formula(e) of the reagent(s) you would use to carry out the reaction given.

organic reaction	type of reaction	reagent(s)
$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} \rightarrow$ $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2$		
$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} \rightarrow$ $\text{BrCH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$		
$\text{CH}_3\text{COCH}_3 \rightarrow$ $\text{CH}_3\text{C}(\text{OH})(\text{CN})\text{CH}_3$		
$\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3 \rightarrow$ $\text{CH}_3\text{CH}=\text{CHCH}_3$		

[Total: 11]

5 Crotonaldehyde, $\text{CH}_3\text{CH}=\text{CHCHO}$, occurs in soybean oils.

- (a) In the boxes below, write the **structural formula** of the organic compound formed when crotonaldehyde is reacted separately with each reagent under suitable conditions. If you think no reaction occurs, write 'NO REACTION' in the box.

reaction	reagent	product
A	Br_2 in an inert organic solvent	
B	PCl_3	
C	H_2 and Ni catalyst	
D	NaBH_4	
E	$\text{K}_2\text{Cr}_2\text{O}_7/\text{H}^+$	

[5]

- (b) Crotonaldehyde exists in more than one stereoisomeric form. Draw the **displayed formulae** of the **stereoisomers** of crotonaldehyde. Label **each** isomer.

[3]

(c) Draw the **skeletal formula** of crotonaldehyde.

[1]

(d) The product of reaction E in the table opposite will react with a solution containing acidified manganate(VII) ions.

Draw the **structural formulae** of the organic products when the reagent is

(i) cold, dilute;

(ii) hot, concentrated.

[3]

[Total: 12]

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CHEMISTRY

9701/22

Paper 2 Structured Questions AS Core

May/June 2013

1 hour 15 minutes

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.

Write in dark blue or black pen.

You may use a soft pencil for any diagrams, graphs or rough working.

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

DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.

You may lose marks if you do not show your working or if you do not use appropriate units.

A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [] at the end of each question or part question.

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Answer **all** the questions in the spaces provided.

For
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Use

- 1 Ammonium sulfate is a fertiliser which is manufactured by the reaction between ammonia and sulfuric acid.

- (a) Ammonia is described as a weak base and sulfuric acid as a strong acid.

By using an equation, explain clearly what is meant by the term *weak base*.

.....

.....

.....

.....

..... [3]

- (b) Ammonia and sulfuric acid are both manufactured by processes which involve chemical equilibria.

- (i) Sulfuric acid is produced from sulfur trioxide which is made by the Contact process.

State **three** important operating conditions for the Contact process for the manufacture of sulfur trioxide.

For **each** of your conditions, you should avoid the use of vague phrases such as 'high temperature'.

condition 1

.....

condition 2

.....

condition 3

.....

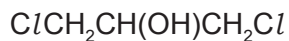
- (ii) How is the sulfur trioxide produced converted into sulfuric acid?

.....

.....

[4]

- (c) Chloropropanols such as 1,3-dichloropropan-2-ol (1,3-DCP) are present in some foods.



1,3-DCP

- (i) What will be produced when 1,3-DCP is reacted separately with the following reagents under suitable conditions?

In each case give the **structural** formula.

concentrated sulfuric acid

an excess of ammonia

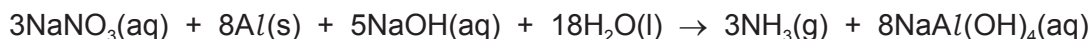
- (ii) Describe as fully as you can what type of reaction occurs with ammonia.

.....
[4]

[Total: 11]

- 2 Chile saltpetre is a mineral found in Chile and Peru, and which mainly consists of sodium nitrate, NaNO_3 . The mineral is purified to concentrate the NaNO_3 which is used as a fertiliser and in some fireworks.

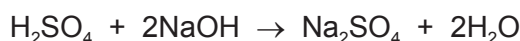
In order to find the purity of a sample of sodium nitrate, the compound is heated in NaOH(aq) with Devarda's alloy which contains aluminium. This reduces the sodium nitrate to ammonia which is boiled off and then dissolved in acid.



The ammonia gas produced is dissolved in an excess of H_2SO_4 of known concentration.



The amount of unreacted H_2SO_4 is then determined by back-titration with NaOH of known concentration.



- (a) A 1.64 g sample of impure NaNO_3 was reacted with an excess of Devarda's alloy. The NH_3 produced was dissolved in 25.0 cm^3 of $1.00 \text{ mol dm}^{-3} \text{ H}_2\text{SO}_4$. When all of the NH_3 had dissolved, the resulting solution was titrated with NaOH(aq) . For neutralisation, 16.2 cm^3 of $2.00 \text{ mol dm}^{-3} \text{ NaOH}$ were required.
- (i) Calculate the amount, in moles, of H_2SO_4 present in the 25.0 cm^3 of $1.00 \text{ mol dm}^{-3} \text{ H}_2\text{SO}_4$.
- (ii) Calculate the amount, in moles, of NaOH present in 16.2 cm^3 of $2.00 \text{ mol dm}^{-3} \text{ NaOH}$.
- (iii) Use your answer to (ii) to calculate the amount, in moles, of H_2SO_4 that reacted with 16.2 cm^3 of $2.00 \text{ mol dm}^{-3} \text{ NaOH}$.
- (iv) Use your answers to (i) and (iii) to calculate the amount, in moles, of H_2SO_4 that reacted with the NH_3 .

(v) Use your answer to (iv) to calculate the amount, in moles, of NH_3 that reacted with the H_2SO_4 .

(vi) Use your answer to (v) to calculate the amount, in moles, of NaNO_3 that reacted with the Devarda's alloy.

(vii) Hence calculate the mass of NaNO_3 that reacted.

(viii) Use your answer to (vii) to calculate the percentage by mass of NaNO_3 present in the impure sample.
Write your answer to a suitable number of significant figures.

[9]

(b) The above reaction is an example of a redox reaction.
What are the oxidation numbers of nitrogen in NaNO_3 and in NH_3 ?

 NaNO_3 NH_3

[1]

[Total: 10]

- 3 This question refers to the elements in the section of the Periodic Table shown below.

		H						He	
Li	Be			B	C	N	O	F	Ne
Na	Mg			Al	Si	P	S	Cl	Ar
K	Ca	 transition elements	Ga	Ge	As	Se	Br	Kr	

- (a) From this list of elements, identify in **each** case **one** element that has the property described. Give the **symbol** of the element.

- (i) An element that when placed in cold water sinks and reacts readily.

.....

- (ii) An element whose molecules contain π bonding.

.....

- (iii) An element that forms a gaseous toxic oxide.

.....

- (iv) The element which has a giant molecular structure **and** forms an oxide which also has a giant molecular structure.

.....

- (v) An element that forms a covalent chloride which dissolves in water to give a conducting solution.

.....

- (vi) The element in Period 3 (Na to Ar) with the greatest electrical conductivity.

.....

[6]

(b) Some of the elements in Period 3 (Na to Ar) burn with a coloured flame when heated in oxygen or chlorine.

- (i) Give the symbol of **one** such element, the formula of the **oxide** formed, and state the flame colour that would be seen.

symbol of element

formula of oxide

flame colour

- (ii) For the element you have used in (i), give the formula of the chloride formed, and state the pH of the solution produced when this chloride is shaken with water.

formula of chloride

pH of solution

[4]

(c) Chlorine reacts with both bromine and iodine to form BrCl and ICl respectively. The melting points of chlorine and the two chlorides are shown in the table.

substance	Cl_2	BrCl	ICl
m.p. / °C	-101	-66	24

- (i) Showing outer electrons only draw a 'dot-and-cross' diagram of the bonding in ICl .

- (ii) Suggest why the melting points increase from Cl_2 to ICl .

.....

- (iii) Suggest which of these three molecules has the largest permanent dipole. Explain your answer.

.....

[5]

[Total: 15]

4 Crotyl alcohol, $\text{CH}_3\text{CH}=\text{CHCH}_2\text{OH}$, is a colourless liquid which is used as a solvent.

- (a) In the boxes below, write the **structural formula** of the organic compound formed when crotyl alcohol is reacted separately with each reagent under suitable conditions. If you think no reaction occurs, write 'NO REACTION' in the box.

A	Br_2 in an inert organic solvent	
B	PCl_5	
C	H_2 and Ni catalyst	
D	NaBH_4	
E	$\text{K}_2\text{Cr}_2\text{O}_7/\text{H}^+$ heat under reflux	

[5]

- (b) Draw the **displayed formula** of the organic compound formed when crotyl alcohol is reacted with cold, dilute acidified potassium manganate(VII).

[1]

- (c) Draw the **skeletal formula** of the compound formed in reaction E.

[2]

(d) Crotyl alcohol is obtained from crotonaldehyde, $\text{CH}_3\text{CH}=\text{CHCHO}$.

- (i) Describe one test that would confirm the presence of a small amount of unreacted crotonaldehyde in the crotyl alcohol.

Give the name of the reagent used and state what you would see.

reagent

observation

- (ii) What *type of reaction* is the conversion of crotonaldehyde into crotyl alcohol?

.....

[3]

- (e) Compound **P**, another unsaturated compound, is found in some blue cheeses.
The percentage composition by mass of compound **P** is C: 73.7%; H: 12.3%; O: 14.0%.

Calculate the empirical formula of compound **P**.

[2]

[Total: 13]

- 5 A student reacted together an alcohol and a carboxylic acid under appropriate conditions to produce an ester.
A sweet smelling organic liquid, **Q**, with the empirical formula C_2H_4O was produced.
The M_r of **Q** was found by experiment to be 87.5.

(a) What is the molecular formula of **Q**?

..... [1]

- (b) In the boxes below, draw the structural formulae of **four** isomers with this formula that are esters.

W	X
Y	Z

[4]

A sample of **Q** was hydrolysed by heating with aqueous sulfuric acid.
The resulting mixture was heated under reflux with acidified potassium dichromate(VI) to give a **single** organic product, **R**.
The product, **R**, was collected and subjected to the following tests.

A sample of **R** gave no reaction with Tollens' reagent.

A second sample of **R** gave no reaction with 2,4-dinitrophenylhydrazine reagent.

A third sample of **R** gave an effervescence with sodium carbonate.

(c) (i) What does the result of the test with Tollens' reagent show about **R**?

.....

(ii) What does the result of the test with 2,4-dinitrophenylhydrazine reagent show about **R**?

.....

(iii) What functional group does the result of the test with sodium carbonate show to be present in **R**?

.....

[3]

(d) (i) What is the identity of the single organic compound, **R**?

.....

(ii) Which of your structures, **W**, **X**, **Y** or **Z**, represents the ester, **Q**?

.....

[2]

(e) Which, if any, of your esters, **W**, **X**, **Y** or **Z**, is chiral?

.....

..... [1]

[Total: 11]

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CHEMISTRY

9701/23

Paper 2 Structured Questions AS Core

May/June 2013

1 hour 15 minutes

Candidates answer on the Question Paper.

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For
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- 1 Carbon disulfide, CS_2 , is a volatile, flammable liquid which is produced in small quantities in volcanoes.

(a) The sequence of atoms in the CS_2 molecule is sulfur to carbon to sulfur.

- (i) Draw a 'dot-and-cross' diagram of the carbon disulfide molecule.
Show outer electrons only.

- (ii) Suggest the shape of the molecule and state the bond angle.

shape

bond angle

[3]

(b) Carbon disulfide is readily combusted to give CO_2 and SO_2 .

- (i) Construct a balanced equation for the complete combustion of CS_2 .

.....

- (ii) Define the term *standard enthalpy change of combustion*, $\Delta H_c^\ominus$.

.....

.....

.....

[3]

- (c) Calculate the standard enthalpy change of formation of CS_2 from the following data. Include a sign in your answer.

standard enthalpy change of combustion of $\text{CS}_2 = -1110 \text{ kJ mol}^{-1}$

standard enthalpy change of formation of $\text{CO}_2 = -395 \text{ kJ mol}^{-1}$

standard enthalpy change of formation of $\text{SO}_2 = -298 \text{ kJ mol}^{-1}$

[3]

- (d) Carbon disulfide reacts with nitrogen monoxide, NO , in a 1:2 molar ratio. A yellow solid and two colourless gases are produced.

- (i) Construct a balanced equation for the reaction.

.....

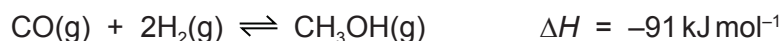
- (ii) What is the change in the oxidation number of sulfur in this reaction?

from to

[3]

[Total: 12]

- 2 Methanol, CH_3OH , can be produced industrially by reacting carbon monoxide, CO , with hydrogen, H_2 .



The process is carried out at $4 \times 10^3 \text{ kPa}$ (40 atmospheres) and 1150 K.

- (a) (i) State Le Chatelier's Principle.

.....

 [2]

- (ii) From your understanding of Le Chatelier's Principle, state the conditions of temperature and pressure that could be used in order to produce an increased yield of methanol in this process.
 In **each** case, explain why the yield would increase.

temperature

explanation

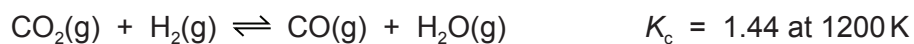
.....

pressure

explanation

..... [4]

- (b) The carbon monoxide for use in the production of methanol may be formed by reacting carbon dioxide with hydrogen.



A mixture containing 0.70 mol of CO_2 , 0.70 mol of H_2 , 0.30 mol of CO and 0.30 mol of H_2O was placed in a 1 dm^3 flask and allowed to come to equilibrium at 1200 K.

Calculate the amount, in moles, of each substance present in the equilibrium mixture at 1200 K.

	CO_2	+	H_2	$\rightleftharpoons$	CO	+	H_2O
initial moles	0.70		0.70		0.30		0.30

[4]

[Total: 10]

- 3 This question refers to the elements in the section of the Periodic Table shown below.

		H						He	
Li	Be			B	C	N	O	F	Ne
Na	Mg			Al	Si	P	S	Cl	Ar
K	Ca	 transition elements		Ga	Ge	As	Se	Br	Kr

- (a) From this list of elements, identify in **each** case **one** element that has the property described. Give the **symbol** of the element.

- (i) An element that has molecules which consist of single atoms.

.....

- (ii) An element that has a molecule which contains exactly four atoms.

.....

- (iii) The element that is a liquid at room temperature and pressure.

.....

- (iv) The element in Period 3 (Na to Ar) that has the largest atomic radius.

.....

- (v) The element in Period 3 (Na to Ar) that has the highest melting point.

.....

- (vi) The element in Period 3 (Na to Ar) that forms the largest anion.

.....

- (vii) An element that reacts with water to give a solution that can behave as an oxidising agent.

.....

[7]

- (b) The formulae and melting points of some of the oxides of the elements in Period 3, Na to Cl, are given in the table.

formula of oxide	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₄ O ₆	SO ₂	Cl ₂ O ₇
m.p./°C	1132	2830	2054	1710	24	-73	-92

- (i) Give the formulae of **two** of these oxides that have simple molecular structures.

..... and

- (ii) Give the formula of one of these oxides that will give no reaction with water when placed in it for a long time.

.....

- (iii) Give the formula of the product formed when MgO is reacted with SO₂.

.....

[4]

- (c) The melting points of the elements Si to Cl are given in the table.

element	Si	P	S	Cl
m.p./°C	1414	44	115	-102

- (i) Explain why the melting point of Si is very much greater than those of the other three elements.

.....

.....

- (ii) Suggest why the melting points of the other three elements are in the order S > P > Cl.

.....

.....

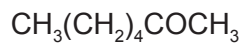
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[4]

[Total: 15]

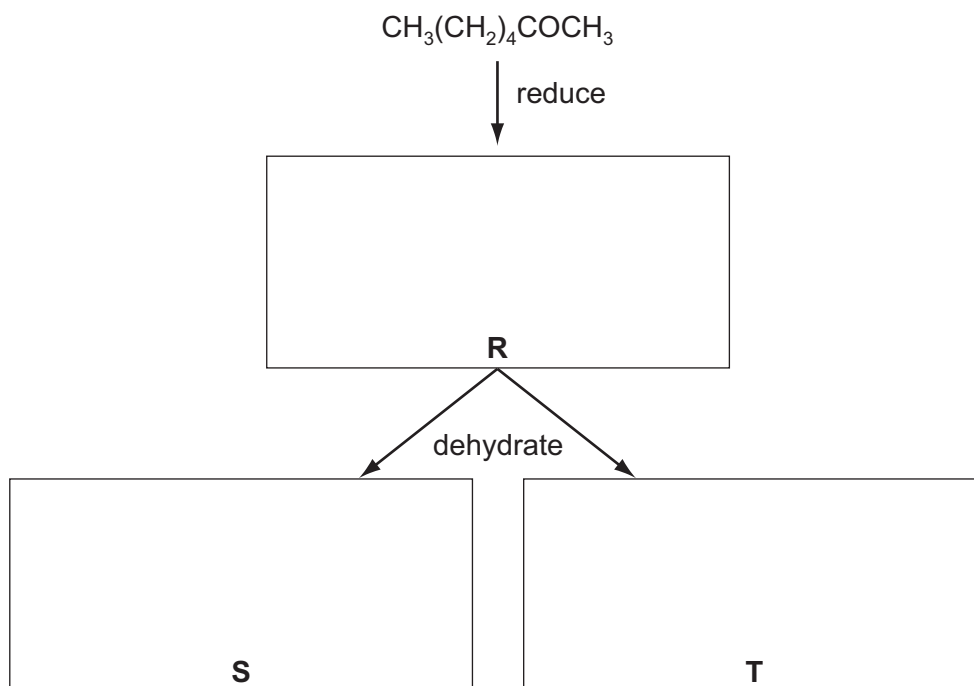
- 4 Compound **Q**, heptan-2-one, is found in some blue cheeses.



compound **Q**

- (a) Compound **Q** may be reduced to **R**.
Compound **R** may be dehydrated to give two different products, **S** and **T**.

- (i) In the boxes below, draw the **structural formulae** of **R**, **S**, and **T**.



- (ii) State the reagents that would be used for **each** of these reactions in a school or college laboratory.

reduction

dehydration

[5]

- (b) In the boxes below, write the **structural formula** of the organic compound formed when **Q** is reacted separately with each reagent under suitable conditions. If you think no reaction occurs, write 'NO REACTION' in the box.

Tollens' reagent	
HCN	
$K_2Cr_2O_7/H^+$	

[3]

- (c) The first stage of cheese making is to produce 2-hydroxypropanoic acid (lactic acid) from milk.



lactic acid

Other than the use of a pH indicator, what reagent could you use to confirm the presence of some lactic acid in a sample of heptan-2-one?
State what observation you would make.

reagent

observation [2]

[Total: 10]

- 5 Compounds containing the allyl group, $\text{CH}_2=\text{CHCH}_2-$, have pungent smells and are found in onions and garlic.
Allyl alcohol, $\text{CH}_2=\text{CHCH}_2\text{OH}$, is a colourless liquid which is soluble in water.

(a) Allyl alcohol behaves as a primary alcohol and as an alkene.

Give the structural formula of the organic compound formed when allyl alcohol is reacted separately with each of the following reagents.

(i) acidified potassium dichromate(VI), heating under reflux

(ii) bromine in an inert organic solvent

(iii) cold, dilute, acidified potassium manganate(VII)

(iv) hot, concentrated, acidified potassium manganate(VII)

[5]

(b) Allyl alcohol undergoes the following reactions.

(i) When reacted with concentrated HCl at 100°C , $\text{CH}_2=\text{CHCH}_2\text{Cl}$ is formed.

State as fully as you can what *type of reaction* this is.

.....

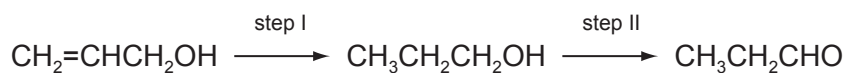
(ii) When reacted with MnO_2 at room temperature, $\text{CH}_2=\text{CHCHO}$ is formed.

What *type of reaction* is this?

.....

[2]

- (c) Allyl alcohol can be converted into propanal in two steps.



- (i) What reagents and conditions would be used for **each** step?

step I

reagent(s)

condition(s)

step II

reagent(s)

condition(s)

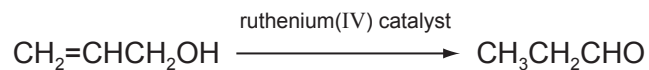
- (ii) Allyl alcohol and propanal are isomers.

What form of isomerism do they display?

.....

[5]

- (d) Allyl alcohol may also be converted into propanal by using a ruthenium(IV) catalyst in water.



Suggest what is unusual about this single step reaction.

.....

..... [1]

[Total: 13]

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