

**OXFORD CAMBRIDGE AND RSA EXAMINATIONS**  
**A2 GCE**  
**F335/01**  
**CHEMISTRY B (SALTERS)**  
**Chemistry by Design**

**WEDNESDAY 12 JUNE 2013: Afternoon**

**DURATION: 2 hours**  
**plus your additional time allowance**

**MODIFIED ENLARGED**

<b>Candidate forename</b>						<b>Candidate surname</b>				
<b>Centre number</b>						<b>Candidate number</b>				

**Candidates answer on the Question Paper.**

**OCR SUPPLIED MATERIALS:**

*Data Sheet for Chemistry B (Salters) (inserted)*

**OTHER MATERIALS REQUIRED:**

**Scientific calculator**

**READ INSTRUCTIONS OVERLEAF**

## **INSTRUCTIONS TO CANDIDATES**

- The Insert will be found in the centre of this document.
- Write your name, centre number and candidate number in the boxes on the first page. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **ALL** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.

## **INFORMATION FOR CANDIDATES**

- The number of marks is given in brackets [ ] at the end of each question or part question.
-  Where you see this icon you will be awarded marks for the quality of written communication in your answer.

This means for example you should:

- ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
- organise information clearly and coherently, using specialist vocabulary when appropriate.
- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry B (Salters)* is provided as an insert with this question paper.
- You are advised to show all the steps in any calculations.
- The total number of marks for this paper is 120.
- Any blank pages are indicated.

**Answer ALL the questions.**

- 1 There is concern over the way the oceans are becoming more acidic as more carbon dioxide dissolves in them.
- (a) (i) Draw a ‘dot-and-cross’ diagram for carbon dioxide.

Show outer electron shells only.

[1]

- (ii) Use your diagram to state and explain the shape of a carbon dioxide molecule.

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[4]

- (iii) A bond between carbon and oxygen is polar but the molecule of carbon dioxide has no overall dipole.

**Describe and explain the polarity of a carbon–oxygen bond.**

**Explain why the molecule of carbon dioxide has no overall dipole.**



**In your answer you should use appropriate technical terms, spelled correctly.**

[3]

[3]

- (iv) Carbon dioxide forms hydrogen bonds with water.**

**Draw a diagram to illustrate this.**

**Include relevant partial charges and lone pairs.**

**[3]**

- (v) Carbon dioxide is not very soluble in water.**

**Suggest an explanation for this in terms of hydrogen bonding.**

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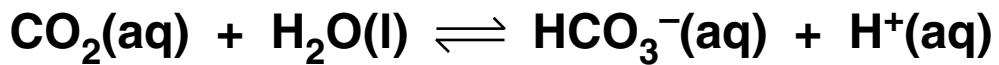
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**[2]**

**(b) An equilibrium occurring in the oceans is:**

**EQUATION 1.1**



- (i) Explain why an increase in the concentration of dissolved carbon dioxide leads to an increase in the acidity of the water.**

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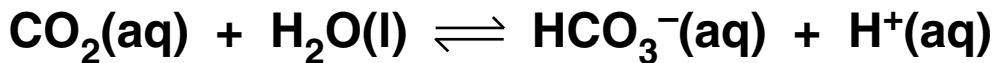
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**[2]**

## **EQUATION 1.1**



- (ii) The pH of the oceans is buffered by the reaction in EQUATION 1.1.

**Explain the meaning of buffered and give the important condition necessary for this equilibrium to result in buffering.**

[4]

- (c) Give the conjugate base of  $\text{HCO}_3^-$ .

[1]

[1]

- (d) Reference books say that the pH of the oceans has changed from 8.179 in pre-industrial times to 8.069 today.

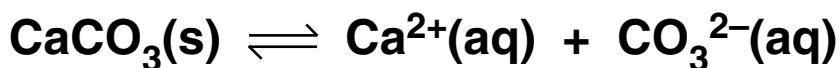
Calculate the percentage increase in  $[H^+]$ .

percentage increase in  $[H^+]$  = \_\_\_\_\_ % [2]

- (e) (i) The shells of some sea creatures are made of calcium carbonate.

**Use the equations below to explain a possible effect of increased acidity on the shells of these sea creatures.**

## **EQUATION 1.2**



## EQUATION 1.3



13

[3]

- (ii) Explain ONE reason why it may be beneficial for the human race if more carbon dioxide dissolves in the oceans.

[1]

[1]

(f) The concentration of a saturated solution of carbon dioxide in water is  $3.3 \times 10^{-3}$  mol per 100 g at room temperature and pressure.

1.0 kg of this saturated solution is boiled, releasing all the CO<sub>2</sub>.

Calculate the volume (in cm<sup>3</sup>) that this CO<sub>2</sub> would occupy at room temperature and pressure.

One mole of gas at room temperature and pressure occupies 24 dm<sup>3</sup>.

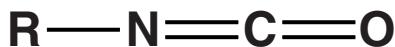
Give your answer to an APPROPRIATE number of significant figures.

volume = \_\_\_\_\_ cm<sup>3</sup> [3]

[TOTAL: 29]

- 2 Isocyanates are useful organic intermediates as they can be used to make pesticides and polymers.**

### **AN ISOCYANATE**



- (a) Isocyanates can be formed by reacting compound A with bromine and alkali.**

**Opposite a textbook shows the steps in the reaction as:**

- (i) Name the functional group in compound A.**

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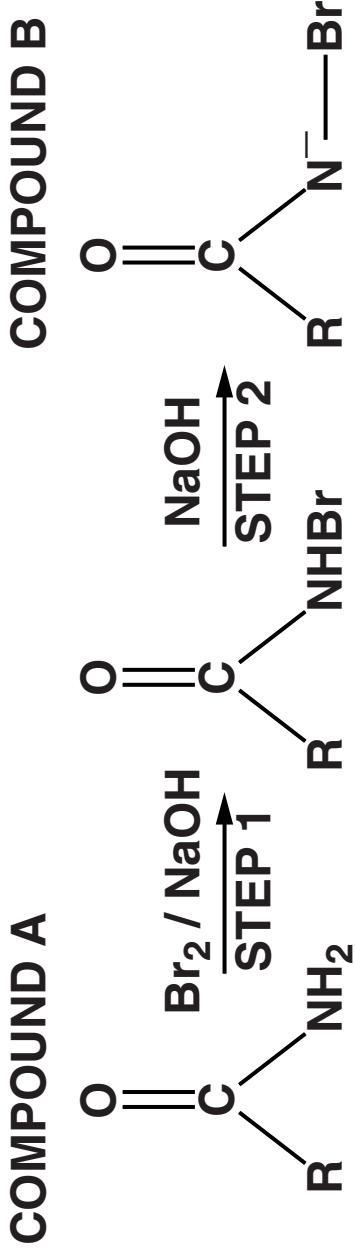
**[1]**

- (ii) Name the TYPE of reaction occurring in STEP 2.**

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**[1]**

- (iii) Draw ‘curly arrows’ on compound B to suggest the movement of electrons in STEP 3. [3]**



**(b) Isocyanates ( $R-N=C=O$ ) form carbamates by reacting with compounds with an  $-OH$  group.**

**One example of a carbamate, called ‘carbaryl’, is an insecticide. The structure of carbaryl is shown below.**

- (i) Complete the equation below for the formation of carbaryl by drawing structural formulae in the boxes. [2]**
- (ii) Explain, in terms of atom economy, why reactions such as that shown in the equation in (b)(i) could be regarded as ‘environmentally friendly’.**

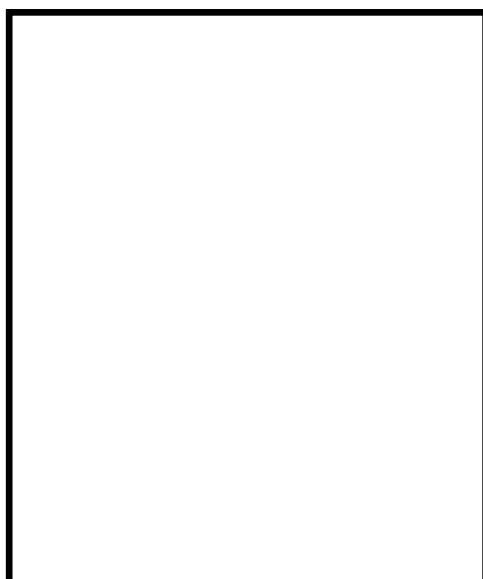
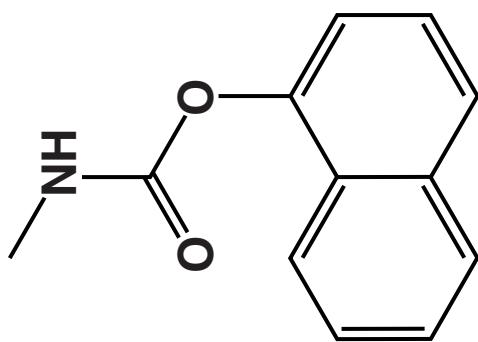
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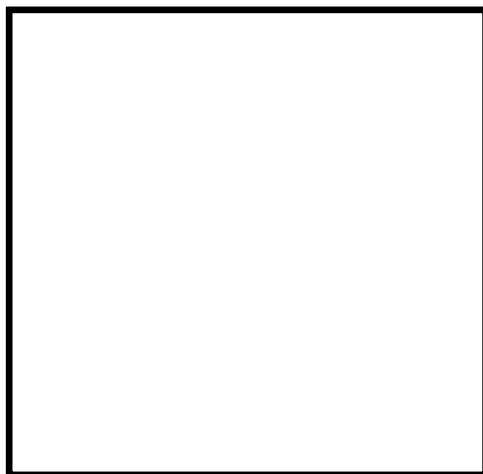
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**[2]**

ISOCYANATE COMPOUND WITH AN -OH GROUP CARBARYL



+



**(c) Carbaryl is an effective insecticide that works by reversibly inhibiting an enzyme vital to insect and mammalian metabolism. The use of carbaryl is now forbidden in the UK.**

**(i) Suggest ONE reason why the use of carbaryl is forbidden.**

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[1]

**(ii) Suggest how carbaryl inhibits the enzyme.**

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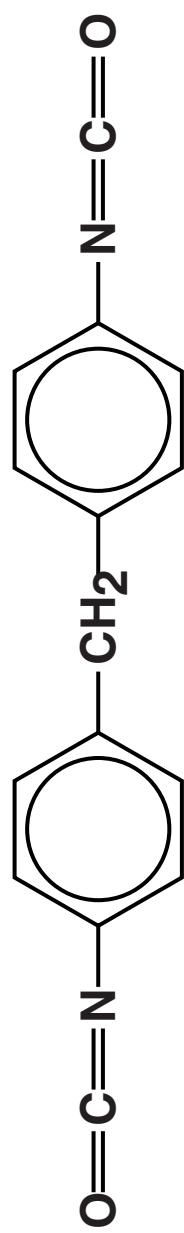
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[3]

**(d) Di-isocyanates are used to make polyurethane polymers.**

**For example, the di-isocyanate MDI can react with ethane-1,2-diol to form the polyurethane shown below.**

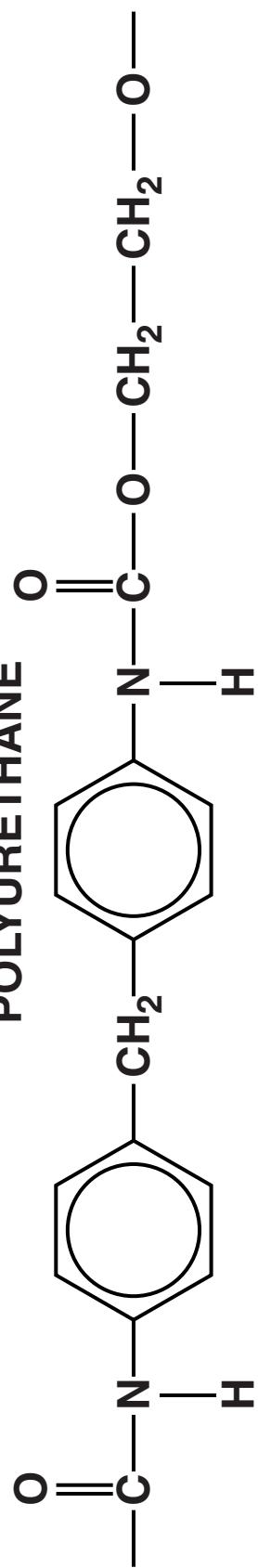
MDI



ETHANE-1,2-DIOL



POLYURETHANE



**Name the TYPE of polymerisation that is described above and explain your answer.**

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**[1]**

- (e) Polyurethane polymers can be ‘blown’ to produce foams.**

**Water vapour can be used to produce a blowing agent as it reacts with unreacted isocyanate groups to form carbon dioxide.**

**Suggest an equation for the reaction, representing the isocyanate as RNCO.**

**[1]**

- (f) A chemist wishes to substitute methyl groups on to the benzene rings in MDI to vary the properties of the polymer.

**Give the reagents and conditions needed to substitute a methyl group on to benzene.**

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[3]

**[TOTAL: 18]**

**3 Methanoic acid,  $\text{CH}_2\text{O}_2$ , is used in solution as a limescale remover.**

**(a) Draw the FULL structural formula for methanoic acid.**

[1]

**(b) (i) Complete the equation for the ionisation of methanoic acid in aqueous solution.**



[1]

**(ii) Write the expression for  $K_a$  for methanoic acid.**

$$K_a =$$

[1]

**(iii) The  $\text{p}K_a$  of methanoic acid is 3.77.**

**Show that  $K_a = 1.70 \times 10^{-4} \text{ mol dm}^{-3}$ .**

[1]

- (iv) Calculate the pH of a  $0.0040\text{ mol dm}^{-3}$  solution of methanoic acid.

Give your answer to TWO decimal places.

pH = \_\_\_\_\_ [2]

- (v) You used two approximations in (iv). One of these is not a very good approximation when used for acids as strong as methanoic acid.

Give the approximation.

Explain, with reference to numbers in your calculation, why it is not a very good approximation.

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[2]

- (c) Limescale is mainly calcium carbonate. Write an equation for the reaction of methanoic acid with calcium carbonate.

[2]

**(d) Methanoic acid and methanoates together form buffer solutions.**

**(i) Calculate the pH of a solution containing equal amounts of methanoic acid and sodium methanoate.**

$$K_a = 1.70 \times 10^{-4} \text{ mol dm}^{-3}.$$

pH = \_\_\_\_\_ [1]

**(ii) Enough sodium hydroxide is added to react with half the methanoic acid in the mixture of methanoic acid and sodium methanoate in (i).**

**Calculate the pH of the resulting solution.**

pH = \_\_\_\_\_ [2]

- (e) Methanoic acid can be made in the laboratory by the oxidation of methanol. A chemist attempts to oxidise methanol and purifies an organic product from this reaction.
- (i) The product has just one peak in its proton NMR spectrum.

Identify the product and explain why it gives the NMR spectrum described.

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[2]

- (ii) The chemist runs an infrared spectrum of this product.

Give the wavenumber ranges of the peaks (above  $1500\text{ cm}^{-1}$ ) and the bonds responsible for these peaks that you would expect to find in the infrared spectrum.

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[2]

(f) Methanoic acid vapour ( $\text{CH}_2\text{O}_2$ ) decomposes in the presence of certain catalysts to give carbon dioxide and hydrogen.

(i) Suggest an industrial use for the hydrogen produced by this reaction.

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[1]

(ii) Write the equation for the equilibrium reaction for the decomposition of methanoic acid.

Complete the expression for  $K_c$  for this equilibrium.

equation:

$$K_c =$$

[1]

(iii) Give the SIGN of the  $\Delta S_{\text{sys}}$  for the forward reaction in (ii) and give your reasons.

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[2]

- (iv) The value of  $K_c$  at 298 K for the reaction in (f)(ii) is  $4.8 \times 10^6 \text{ mol dm}^{-3}$ .  
Methanoic acid vapour is allowed to reach equilibrium at 298 K.  
The concentration of methanoic acid vapour in the equilibrium mixture is found to be  $2.5 \times 10^{-9} \text{ mol dm}^{-3}$ .

Calculate the equilibrium concentrations of  $\text{CO}_2$  and  $\text{H}_2$ .

concentration of  $\text{CO}_2$  = \_\_\_\_\_  $\text{mol dm}^{-3}$

concentration of  $\text{H}_2$  = \_\_\_\_\_  $\text{mol dm}^{-3}$  [2]

- (v) A student suggests that the reaction in (f)(ii) should be carried out at low pressure.

Give the chemical reasoning behind this suggestion.

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[2]

- (vi) The enthalpy change for the forward reaction in (f)(ii) is  $+6 \text{ kJ mol}^{-1}$ . The student suggests that the reaction should be carried out at high temperature because of the effect of temperature on the equilibrium yield of products.

# Give the chemical reasoning behind this suggestion.

**Suggest why it might not be economical to use a high temperature in this case.**



**In your answer, you should make it clear how your points link together.**

[4]

[4]

[TOTAL: 29]

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**4 In 2014, it is hoped that a European spacecraft called Rosetta will send a landing craft to a distant comet. One of the many measuring instruments on the landing craft will be a gas–liquid chromatograph linked to a mass spectrometer.**

**(a) A gas–liquid chromatograph uses a carrier gas moving through a column.**

**(i) Give an important feature of the carrier gas.**

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[1]

**(ii) What is inside the column?**

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[1]

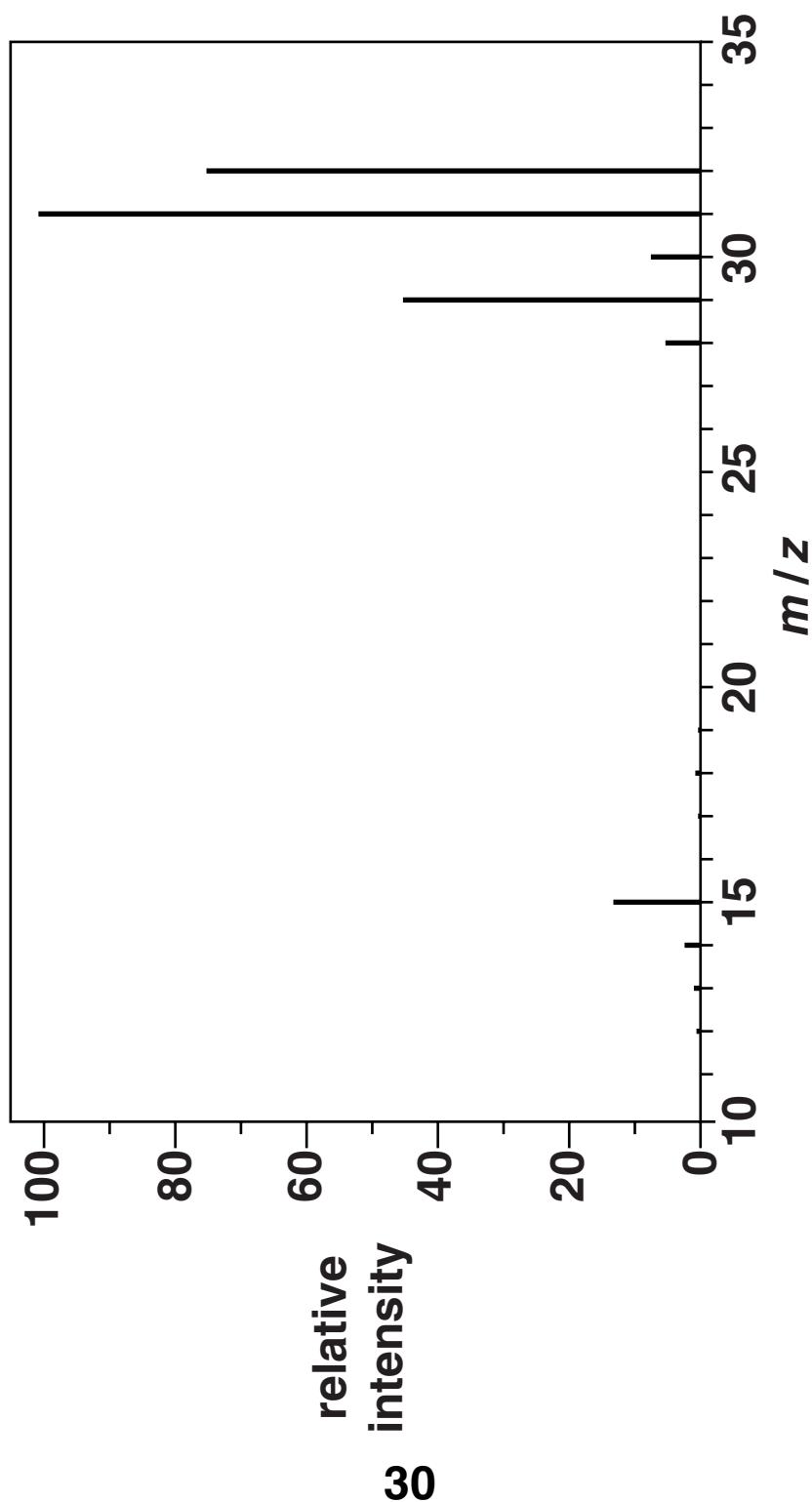
**(iii) What measurement is used to distinguish the compounds separated by the gas–liquid chromatograph?**

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[1]

- (b) The compounds emerging from the gas–liquid chromatograph are passed through a mass spectrometer. This is used to determine the  $M_r$  of the substances and to give more detailed information about their structure.

The mass spectrum of a simple ORGANIC compound, containing C, H and O only, is shown below.



**(i) What is the  $M_r$  of the compound?**

**Explain how you arrived at your answer.**

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**[2]**

**(ii) Suggest the formula of the ion that gives rise to the peak at  $m/z$  15.**

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**[2]**

**(iii) Suggest a formula for the compound.**

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**[1]**

(c) The gas chromatograph on the Rosetta landing craft will be able to distinguish between chiral compounds. Scientists will be looking for evidence of amino acids in the comet's tail.

(i) Draw below the structures of the two enantiomers of the amino acid serine,  $\text{HOOC}-\text{CH}(\text{CH}_2\text{OH})-\text{NH}_2$ , to show how they are related.



[2]

(ii) Suggest why scientists are looking for the presence of amino acids in the comet.

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[1]

(d) In 2005, a spacecraft landed on Titan, a moon of Saturn. By gas chromatography, scientists discovered that the atmosphere of Titan contained, among other things, methane, traces of ethane and traces of cyanogen,  $(CN)_2$ .

- (i) High-energy ultraviolet radiation from the Sun breaks down the methane to produce radicals which start a chain reaction. Some of the radicals combine to form ethane.

**Write two equations that illustrate the formation of ethane from methane by this method.**

**Classify each of these equations in terms of the TYPE of radical reaction involved.**

[4]

- (ii) Cyanogen,  $(CN)_2$ , reacts with ethene in an electrophilic addition where two CN groups are added across the double bond, producing compound C.

**Compound C can be hydrolysed in acid solution to form compound D.**

**Predict the structural formulae of compounds C and D.**

**You may need to refer to your Data Sheet.**

**COMPOUND C**

**COMPOUND D**

**[2]**

**[TOTAL: 17]**

- 5 ‘Titanium yellow’ is a pigment with formula  $\text{NiO} \bullet \text{Sb}_2\text{O}_5 \bullet 20\text{TiO}_2$  that is used for oil painting.
- (a) Complete the electron configurations for a titanium atom and for the titanium ion with the oxidation state that titanium shows in  $\text{TiO}_2$ .

atom       $1\text{s}^2 \ 2\text{s}^2 \ 2\text{p}^6 \ 3\text{s}^2$  \_\_\_\_\_

ion       $1\text{s}^2 \ 2\text{s}^2 \ 2\text{p}^6 \ 3\text{s}^2$  \_\_\_\_\_ [2]

- (b) Give the oxidation state of antimony in  $\text{Sb}_2\text{O}_5$  and the systematic name of  $\text{Sb}_2\text{O}_5$ .

\_\_\_\_\_ [2]

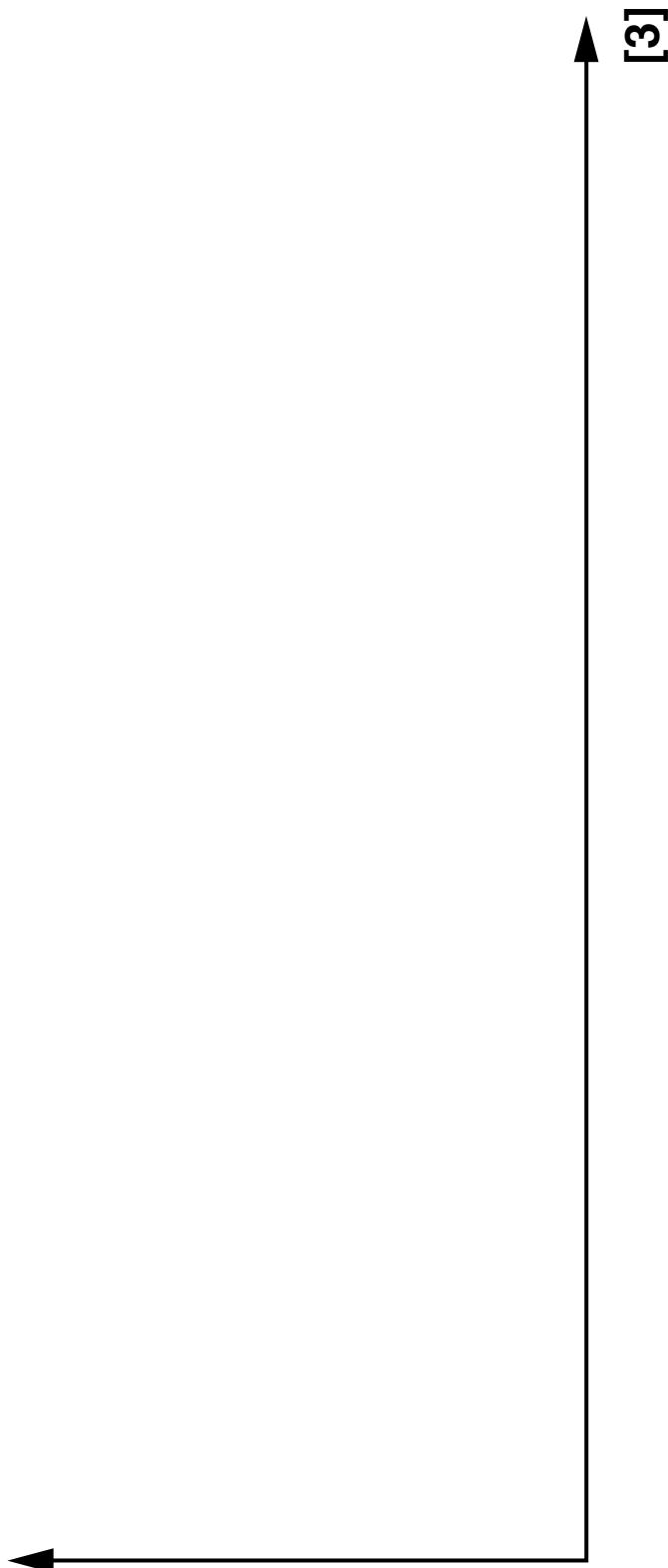
- (c) Calculate the percentage by mass of titanium in  $\text{NiO} \bullet \text{Sb}_2\text{O}_5 \bullet 20\text{TiO}_2$  ( $M_r$  1996).

percentage Ti = \_\_\_\_\_ % [2]

- (d) On a computer screen, the colour of titanium yellow can be represented by mixing 93% red, 90% green and 0% blue.

**Sketch the visible reflectance spectrum of titanium yellow on the axes below.**

**Label the axes. (No scales are necessary.)**



(e) Explain, in terms of electron energy levels, why compounds of transition metals are coloured.

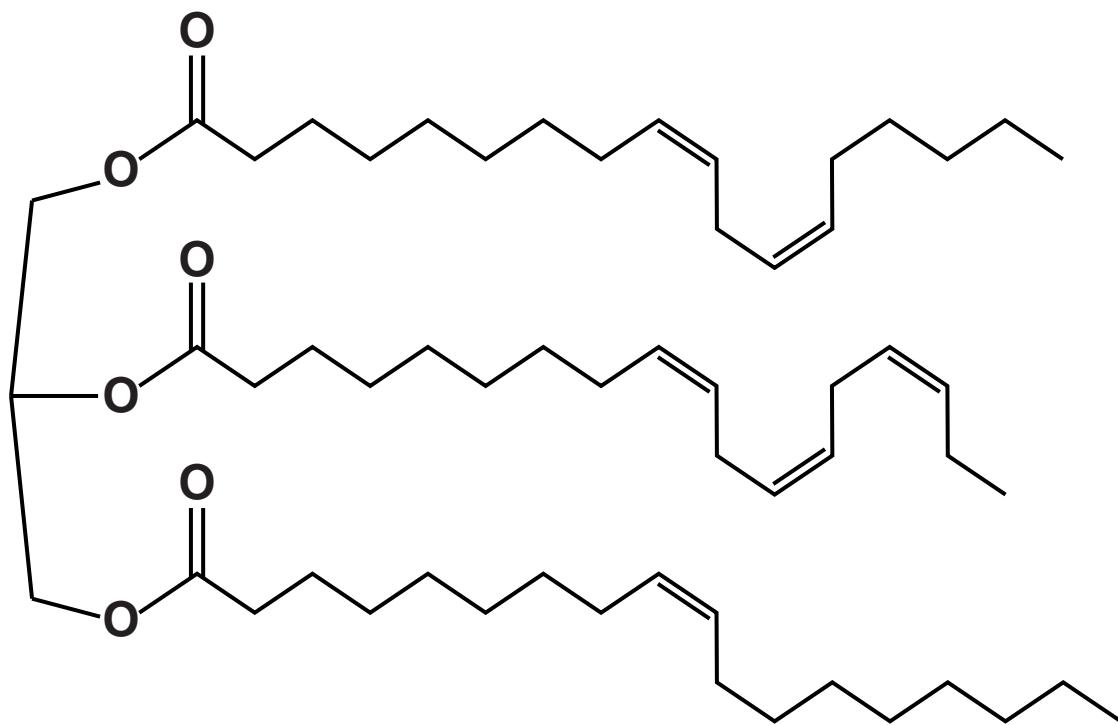


**In your answer, you should make it clear how your points link together.**

[5]

- (f) An oil is used to suspend the pigment for oil painting. A good oil for this purpose is linseed oil. One of the constituents of linseed oil, compound E, is shown below.

COMPOUND E



- (i) Name the functional group (apart from the C=C group) found in compound E.

[1]

- (ii) Classify the arrangements around the C=C double bonds in compound E as cis or trans, giving your reasoning.

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[1]

- (iii) Suggest why oils with trans groups have higher boiling points than those with cis groups.

[4]

[4]

**QUESTION 5 CONTINUES ON PAGE 40**

**(g) Unsaturated oils react with iodine.**

- (i) Complete the equation below to show the reaction of iodine with a carbon–carbon double bond in an oil.**



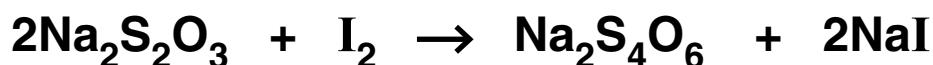
[2]

- (ii) The ‘iodine number’ of an oil is the number of grams of iodine that will react with 100 g of the oil.**

**0.200 g of a sample of linseed oil is reacted with a solution containing 0.00170 mol of  $I_2$  (an excess).**

**Some iodine remains unreacted.**

**28.0 cm<sup>3</sup> of 0.0200 mol dm<sup>-3</sup> sodium thiosulfate,  $Na_2S_2O_3$ , are needed to react with the iodine REMAINING.**



**Calculate the iodine number of the sample of linseed oil.**

**iodine number = \_\_\_\_\_ [5]**

**[TOTAL: 27]**

**END OF QUESTION PAPER**

## **ADDITIONAL ANSWER SPACE**

**If additional answer space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margins.**









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