Bonding, Polarity & Intermolecular Forces

Question Paper 2

Level	International A Level
Subject	Chemistry
Exam Board	Edexcel
Topic	Application of Core Principles of Chemistry
Sub Topic	Bonding, Polarity & Intermolecular Forces
Booklet	Question Paper 2

Time Allowed: **80 minutes**

Score: **/66**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 This question is about some aspects of the chemistry of iodine and its compounds.

In industry, the main source of iodine is sodium iodate(V), $NaIO_3$, which occurs in deposits found in Chile.

In the human body, iodide ions, I^-, are needed for the thyroid gland to function properly. In many countries, potassium iodide, KI, is added to table salt as a source of iodide ions.

(a) In the production of iodine, the final stage involves the reaction between sodium iodate(V) and sodium iodide in acidic solution.

The ionic half-equations for the redox processes are as follows.

$IO_3^- + 6H^+ + 5e^- \rightarrow \frac{1}{2}I_2 + 3H_2O$

$I^- \rightarrow \frac{1}{2}I_2 + e^-$

(i) Use these half-equations to deduce the full ionic equation for the production of iodine by this process. State symbols are not required.

(2)

(ii) Identify, by its **formula**, the oxidizing agent in the reaction in (a)(i). Justify your answer in terms of electron transfer.

(1)

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(b) On addition of concentrated sulfuric acid to crystals of potassium iodide, solid sulfur and a black solid are observed amongst the products formed.

(i) Identify, by name or formula, the black solid.

(1)

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(ii) Construct the ionic half-equation for the formation of sulfur from concentrated sulfuric acid.

State symbols are not required.

(2)

(iii) When iodide ions react with concentrated sulfuric acid, another product, **X**, can also be detected. **X** is a toxic gas with a smell of rotten eggs.

Identify **X**, by name or formula, and give the oxidation numbers of sulfur when **X** is formed from concentrated sulfuric acid.

(3)

Identity of gas **X**:

Oxidation number of S in sulfuric acid is .....

Oxidation number of S in **X** is .....

(c) The Recommended Dietary Allowance, RDA, of iodide ions in a balanced diet is 140 μg per day.

($1\ \mu g = 1 \times 10^{-6}\ g$).

(i) Calculate the mass, in μg, of potassium iodide, KI, needed to supply the RDA of iodide ions.

Give your answer to **three** significant figures.

(2)

Mass of KI = ... μg

(ii) Suggest a reason, other than cost, why some countries do **not** add potassium iodide to table salt.

(1)

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(d) (i) When chlorine is passed over iodine crystals, iodine monochloride, ICl, is formed.

Iodine monochloride, ICl, is a liquid at room temperature whereas chlorine, Cl_2, is a gas.

Explain, in terms of intermolecular forces, why this is so.

(4)

(ii) When excess chlorine is passed over iodine monochloride, iodine trichloride, ICl_3, is formed. Draw the dot and cross diagram of ICl_3, showing only the outer electrons.

(2)

(e) When chlorine gas is bubbled into aqueous potassium iodide solution, a redox reaction occurs.

(i) Give the **ionic** equation for this reaction. State symbols are **not** required.

(1)

(ii) In a further experiment, 0.50 mol of chlorine gas was bubbled into an aqueous solution containing a mixture of 0.66 mol of sodium iodide and 0.66 mol of sodium bromide.

Assuming that **all the chlorine gas reacted**, calculate the number of moles of iodine and bromine produced. Justify your answer in terms of the relative reducing power of bromide and iodide ions.

(3)

The number of moles of iodine produced:

The number of moles of bromine produced:

Justification

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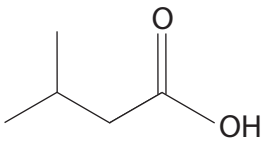
(Total for Question 1 = 22 marks)

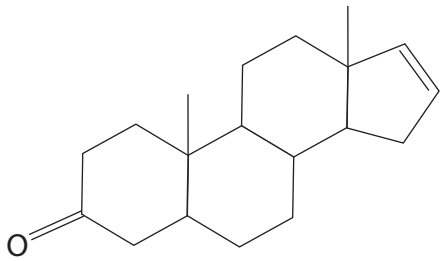
2 Some organic molecules, either on their own or as part of a mixture, contribute to some very unpleasant odours.

The molecule shown below, commonly called isovaleric acid, is responsible for the smell of sweaty feet.



Isovaleric acid can be used to produce esters that have important industrial uses in the pharmaceutical industry, as sedatives and tranquilizers, and in the food industry, as flavouring and fragrance additives.

The molecule with the systematic name (5α)-androst-16-en-3-one, labelled **X** in this question, is found in human sweat and urine.



X

However, in other situations, these molecules can induce a very different effect. For example, **X** is present in commercial products used by pig farmers to determine when sows are ready for mating.

(a) What is the systematic name for isovaleric acid?

(1)

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(b) What is the molecular formula of isovaleric acid?

(1)

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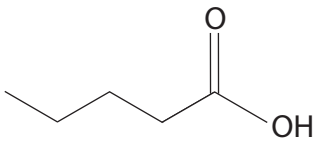
(c) Isovaleric acid has three structural isomers which are also carboxylic acids. One of these acids is drawn in the first box below.

In the empty boxes below, draw the structures, using **skeletal** formulae, of the other two carboxylic acid structural isomers of isovaleric acid.

(2)

 valeric acid		

*(d) At room temperature, valeric acid is a liquid. It is sparingly soluble in water and very soluble in ethanol.

Describe simple experiments you could carry out to show the different solubilities of valeric acid in these two solvents. No measurements are required, but you should state how you would make your experiments valid.

State the expected observations from your experiments.

(3)

(e) Isoamyl alcohol is the alcohol from which isovaleric acid can be produced directly. This alcohol forms intermolecular hydrogen bonding.

Using the simplified representation R—O—H, draw a hydrogen bond between two alcohol molecules and clearly indicate the bond angle about the hydrogen involved in the hydrogen bond.

(2)

(f) There are also London forces between molecules of isoamyl alcohol.

*(i) Describe how London forces are formed.

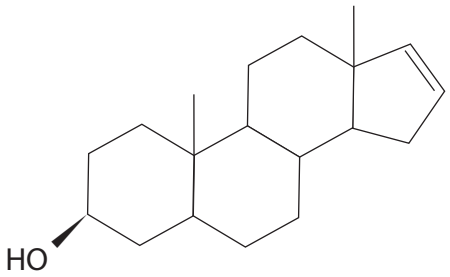
(2)

(ii) The straight-chain structural isomer of isoamyl alcohol has a boiling temperature of 138 °C.

Suggest whether the boiling temperature for isoamyl alcohol will be higher than, lower than or the same as the straight-chain isomer. Justify your choice.

(3)

(g) The molecule identified as **X** in the introduction to question 23, can be formed from the alcohol **Y** shown below.



Y

(i) The oxidation of an alcohol of this type with acidified sodium dichromate(VI) could involve either reflux or distillation.

Explain why either could be used in this case.

(1)

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(ii) An alternative reagent for the oxidation of an alcohol is acidified potassium manganate(VII), $KMnO_4$. However, this is likely to produce other products because **X** contains another functional group that could react with this reagent.

Name this other functional group in **X** and suggest the type of molecule formed in its reaction with acidified potassium manganate(VII), $KMnO_4$.

(2)

Functional group that reacts .....

Type of molecule formed .....

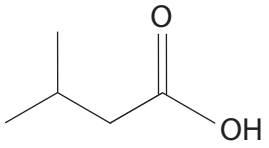
*(h) Isovaleric acid and alcohol **Y** could react together to produce a compound with a pleasant aroma, but this can be masked by even a small residue of the starting molecules.

Generally, spectroscopic methods are much more reliable than sense of smell in detecting the presence of molecules.

The infrared absorption ranges associated with some functional groups are given below.

O—H stretching in alcohols	3750 – 3200 cm^{-1}
O—H stretching in carboxylic acids	3300 – 2500 cm^{-1}
C=O stretching in aldehydes	1740 – 1720 cm^{-1}
C=O stretching in ketones	1700 – 1680 cm^{-1}
C=O stretching in carboxylic acids, alkyl	1725 – 1700 cm^{-1}
C—H stretching in alkane	2962 – 2853 cm^{-1}
C—H stretching in alkene	3095 – 3010 cm^{-1}

By quoting appropriate data, describe how both infrared spectroscopy and mass spectrometry could be used to determine the presence of **isovaleric acid**. The skeletal formula of isovaleric acid is shown below.



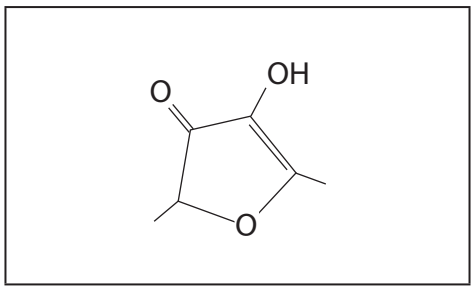
(4)

(Total for Question 2 = 21 marks)

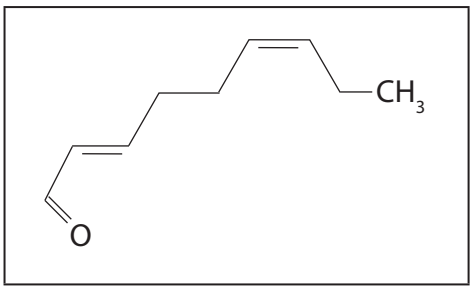
3 The sensation of flavour arises from a combination of both taste, detected by chemical receptors on the tongue, and smell, detected by chemical receptors in the nose.

Some chemicals are commonly called after one particular flavour or aroma, such as:

'strawberry furanone'



'cucumber aldehyde'



However, a flavour such as strawberry is not created from just one chemical but can be from a mixture containing many different chemicals, all of which can interact with various receptors in the mouth and the nose. For example, one strawberry milkshake product contains 59 different ingredients in order to achieve the required strawberry flavour.

In order to detect the different chemical components of a particular flavour, a number of chemical techniques can be employed. One such technique is GCMS, Gas Chromatography Mass Spectometry. The volatile chemicals are first separated by gas chromatography and then detected and analysed by mass spectrometry.

The flavour of various chemicals and their mixtures can be altered by the ways in which they are processed or cooked. For example, the Maillard reaction is promoted by heating and is responsible for the browning of bread and results in the formation of toast, which has a different flavour to the uncooked bread.

(a) Give the molecular formula of the 'strawberry furanone'.

(1)

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(b) Name **one** functional group, other than ketone, present in the 'strawberry furanone' molecule.

(1)

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(c) The presence of an OH group can be detected by the use of sodium or by the use of phosphorus(V) chloride, PCl_5.

Using the formula R-OH, complete the balanced equations for both of these reactions and give one observation for each of them. State symbols are not required.

(i) The reaction with sodium

(2)

Equation +

Observation .....

(ii) The reaction with phosphorus(V) chloride

(2)

Equation +

Observation .....

(iii) In each reaction a hazardous gas is produced. By considering the hazards associated with each of these gases, suggest which poses the greater risk. Justify your answer.

(2)

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(d) The 'cucumber aldehyde' can be formed from the oxidation of the corresponding alcohol.

(i) Identify by names or formulae, the two reagents that could be used together to oxidize an alcohol to an aldehyde. State the essential reaction condition.

(3)

Reagents for oxidation .....

Condition .....

*(ii) Infrared spectroscopy can be used to distinguish different functional groups, such as alcohols and aldehydes.

State how this analytical technique is used to do this and explain the effect of the radiation on the molecule.

Specific values and experimental details are not required.

(3)

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*(e) Differences in volatility can be exploited to achieve the separation of molecules. Alkanes have a higher volatility than the corresponding alcohol and so can be effectively separated on this basis.

Explain how the intermolecular forces present in alkanes arise and how the predominant intermolecular force in alcohols is formed, and then why alkanes have a higher volatility.

(7)

Intermolecular forces in alkanes .....

How they arise .....

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Predominant intermolecular forces in alcohols .....

How they arise .....

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Why alkanes have a higher volatility .....

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(f) Explain how it is possible to distinguish between individual chemicals using their mass spectra.

(1)

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(g) The browning of apples, which can occur when they are bruised, is due to the action of enzymes which create brown polymers. However, this does not affect the aroma of the apples. Suggest why this is so.

(1)

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(Total for Question 3 = 23 marks)