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9701/21

May/June 2011

1 hour 15 minutes

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

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Write in dark blue or black pen.
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For Examiner's Use	
1	
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Total	

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

For
Examiner's
Use

- 1 Some intercontinental jet airliners use kerosene as fuel. The formula of kerosene may be taken as $C_{14}H_{30}$.

(a) To which homologous series of compounds does kerosene belong?

.....

[1]

(b) When kerosene burns in an excess of air, carbon dioxide and water form. Balance the following equation for the complete combustion of kerosene.



[1]

(c) In this section, give your answers to one decimal place.

The flight path from Beijing to Paris is approximately 8195 km.

A typical intercontinental jet airliner burns 10.8 kg of kerosene for each kilometre covered.

(i) Calculate the mass, in tonnes, of $C_{14}H_{30}$ burnt on a flight from Beijing to Paris.
[1 tonne = 1 000 kg]

(ii) Use your equation in (b) to calculate the mass, in tonnes, of CO_2 produced during this flight.

[4]

Bicycles may be carried on commercial airliners. When carried on airliners, bicycles are placed in the luggage hold. This is a part of the aircraft which, in flight, will have different temperatures and air pressures from those at sea level.

This question concerns the change in pressure in an inflated bicycle tyre from when it is at sea level to when it is in the hold of an airliner in flight.

- (d)** At sea level and a temperature of 20°C an inflated bicycle tyre contains 710 cm^3 of air at an internal pressure of $6 \times 10^5\text{ Pa}$.

Use the general gas equation $PV = nRT$ to calculate the amount, in moles, of air in the tyre at sea level.

[2]

The same bicycle, with its tyres inflated at sea level as described in **(d)** above, is placed in the luggage hold of an airliner. At a height of $10\,000\text{ m}$, the temperature in the luggage hold is 5°C and the air pressure is $2.8 \times 10^4\text{ Pa}$.

- (e)** Assuming the volume of the tyre does not change, use your answer to **(d)** to calculate the pressure inside the tyre at a height of $10\,000\text{ m}$.

[2]

[Total: 10]

- 2 Crude oil contains a mixture of hydrocarbons together with other organic compounds which may contain nitrogen, oxygen or sulfur in their molecules.

For
Examiner's
Use

At an oil refinery, after the fractional distillation of crude oil, a number of other processes may be used including 'cracking', 'isomerisation', and 'reforming'.

- (a) (i) What is meant by the term '*cracking*' and why is it carried out?

.....

.....

.....

.....

- (ii) Outline briefly how the cracking of hydrocarbons would be carried out.

.....

.....

- (iii) Construct a balanced equation for the formation of heptane, C_7H_{16} , by cracking tetradecane, $C_{14}H_{30}$.

.....

[4]

One of the sulfur-containing compounds present in crude oil is ethanethiol, C_2H_5SH , the sulfur-containing equivalent of ethanol. Ethanethiol is toxic and is regarded as one of the smelliest compounds in existence.

- (b) The boiling point of ethanol, C_2H_5OH , is higher than that of C_2H_5SH . Suggest a reason for this difference.

.....

.....[1]

When ethanethiol is burned in an excess of air, three oxides of different elements are formed.

For
Examiner's
Use

- (c) (i) Construct a balanced equation for this reaction.

.....

- (ii) **Two** of the oxides formed cause serious environmental damage.

For **each** of these oxides, identify the type of pollution caused and describe one consequence of this pollution.

.....

.....

.....

.....

.....

[6]

- (d) A small amount of ethanethiol is added to liquefied gases such as butane that are widely used in portable cooking stoves.

Suggest a reason for this.

..... [1]

Sulfur-containing compounds are removed from oil products at the refinery. The sulfur is recovered and converted into SO_2 , which is then used in the Contact process.

- (e) State the main operating details of the formation of SO_3 in the Contact process.

.....

.....

.....

.....

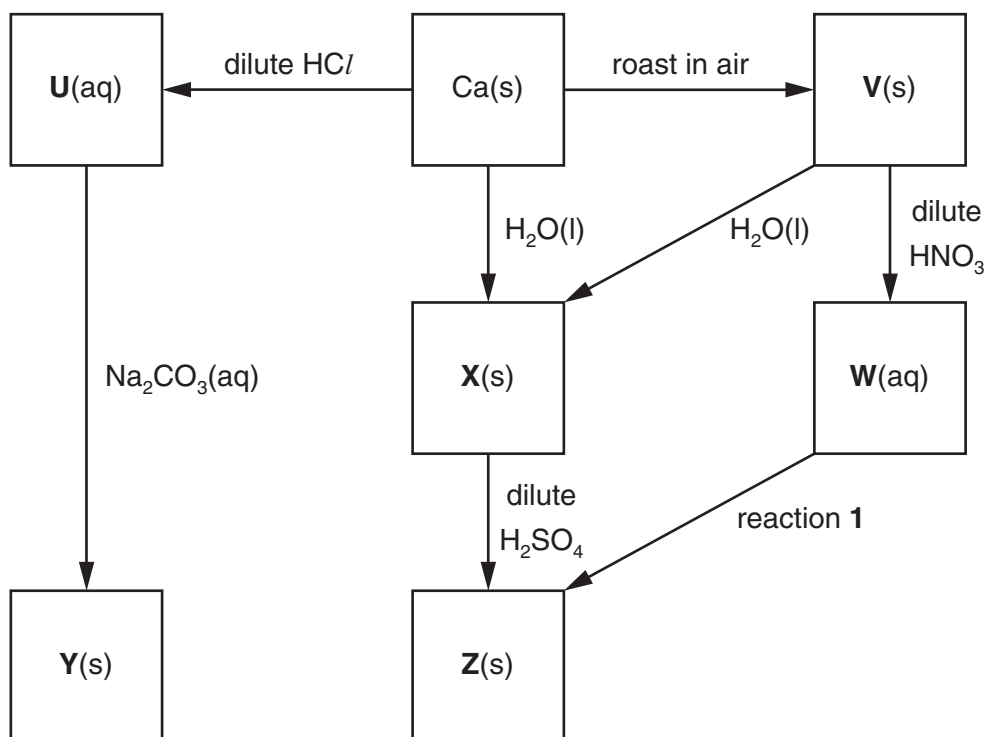
..... [3]

[Total: 15]

- 3 Calcium is the fifth most common element in the Earth's crust.
Calcium compounds occur in bones and teeth and also in many minerals.

For
Examiner's
Use

Some reactions of calcium and its compounds are shown in the reaction scheme below.



- (a) State the formula of **each** of the calcium compounds **U** to **Y**.

U

V

W

X

Y

[5]

- (b) Compound **Y** may be converted into compound **V**.
Outline how this reaction would be carried out in a school or college laboratory using a small sample of **Y**.

.....

..... [1]

- (c) (i) Construct balanced equations for the following reactions.

calcium to compound **U**

.....

compound **V** to compound **W**

.....

compound **U** to compound **Y**

.....

- (ii) Construct a balanced equation for the effect of heat on solid compound **W**.

.....

[4]

- (d) Suggest the formula of an aqueous reagent, other than an acid, for reaction 1.

.....

[1]

- (e) What would be observed when **each** of the following reactions is carried out in a test-tube?

the formation of **X** from Ca(s)

.....

the formation of **X** from **V**

.....

[2]

[Total: 13]

- 4 Ketones are widely used as solvents and as intermediates in the chemical industry.

Ketones contain the reactive keto group,  C=O.

- (a) Propanone, CH_3COCH_3 , undergoes a reaction with hydrogen cyanide, HCN .

- (i) What type of reaction is this?

.....

- (ii) What reagents are used?

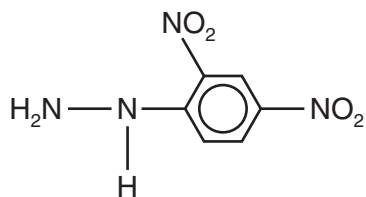
.....

- (iii) Draw a diagram to show the dipole present in the propanone molecule.

[3]

For
Examiner's
Use

(b) Propanone reacts with 2,4-dinitrophenylhydrazine reagent.

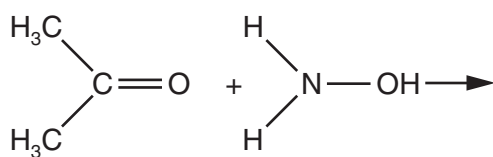


2,4-dinitrophenylhydrazine

- (i) Construct a balanced equation for the reaction between propanone and 2,4-dinitrophenylhydrazine.

- (ii) A similar type of reaction occurs between propanone and hydroxylamine, NH_2OH .

Draw the displayed formula of the organic product of this reaction.



[3]

[Total: 6]

- 5 The gas ethyne, C_2H_2 , more commonly known as acetylene, is manufactured for use in the synthesis of organic compounds. It is also used, in combination with oxygen, in 'oxy-acetylene' torches for the cutting and welding of metals.

For
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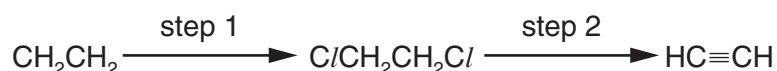
Industrially, ethyne is made from calcium carbide, CaC_2 , or by cracking liquid hydrocarbons.

- (a) When calcium carbide is reacted with water, ethyne and calcium hydroxide are formed.

Construct a balanced equation for this reaction.

.....[1]

Ethyne can also be obtained from ethene by using the following sequence of reactions.



- (b) (i) What types of reaction are step 1 and step 2?

step 1

step 2

- (ii) Suggest what reagent and conditions would be used in a laboratory in step 2.

reagent

conditions

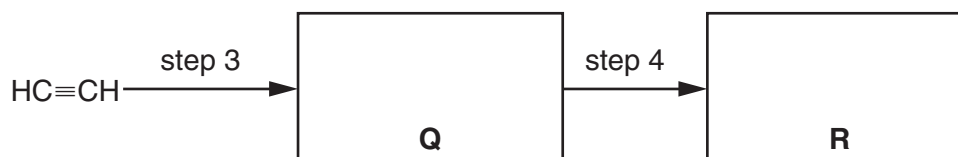
[5]

When ethyne is passed into water at $60^\circ C$, in the presence of a little H_2SO_4 and Hg^{2+} ions, a pungent, colourless organic liquid, **Q**, with M_r of 44 is obtained. This is step 3.

When **Q** is warmed with Tollens' reagent in a test-tube, a silver mirror is formed.

On acidification, the solution remaining in the test-tube is found to contain the organic compound **R** which has M_r of 60. This is step 4.

- (c) (i) Give the structural formulae of **Q** and **R**.



- (ii) What type of reaction is step 3 and step 4?

step 3

step 4

[4]

- (d) The standard enthalpy change of combustion of C_2H_2 , $\Delta H_{\text{c}}^{\ominus}$, is $-1300 \text{ kJ mol}^{-1}$ at 298 K.

Values of relevant standard enthalpy changes of formation, $\Delta H_{\text{f}}^{\ominus}$, measured at 298 K, are given in the table.

substance	$\Delta H_{\text{f}}^{\ominus} / \text{kJ mol}^{-1}$
$\text{CO}_2(\text{g})$	-394
$\text{H}_2\text{O}(\text{l})$	-286

- (i) Write balanced equations, with state symbols, that represent

the standard enthalpy change of combustion, $\Delta H_{\text{c}}^{\ominus}$, of C_2H_2 , and

.....

the standard enthalpy change of formation, $\Delta H_{\text{f}}^{\ominus}$, of C_2H_2 .

.....

- (ii) Use the data above and your answer to (i) to calculate the standard enthalpy change of formation, $\Delta H_{\text{f}}^{\ominus}$, of C_2H_2 .
Show clearly whether the standard enthalpy change of formation of C_2H_2 has a positive or negative value.

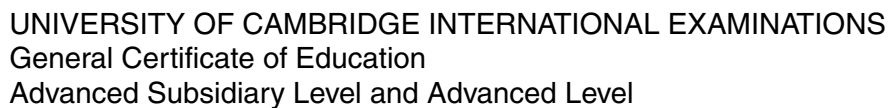
[6]

[Total: 16]

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9701/22

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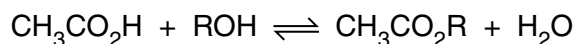
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Examiner's
Use

- 1 Ethanoic acid can be reacted with alcohols to form esters, an equilibrium mixture being formed.



The reaction is usually carried out in the presence of an acid catalyst.

- (a) Write an expression for the equilibrium constant, K_c , for this reaction, clearly stating the units.

$$K_c =$$

units [2]

In an experiment to determine K_c a student placed together in a conical flask 0.10 mol of ethanoic acid, 0.10 mol of an alcohol ROH, and 0.005 mol of hydrogen chloride catalyst.

The flask was sealed and kept at 25 °C for seven days.

After this time, the student titrated all of the contents of the flask with 2.00 mol dm⁻³ NaOH using phenolphthalein indicator.

At the end-point, 22.5 cm³ of NaOH had been used.

- (b) (i) Calculate the amount, in moles, of NaOH used in the titration.
- (ii) What amount, in moles, of this NaOH reacted with the hydrogen chloride?
- (iii) Write a balanced equation for the reaction between ethanoic acid and NaOH.
- (iv) Hence calculate the amount, in moles, of NaOH that reacted with the ethanoic acid.

[4]

- (c) (i) Use your results from (b) to calculate the amount, in moles, of ethanoic acid present at equilibrium. Hence complete the table below.

For
Examiner's
Use

	$\text{CH}_3\text{CO}_2\text{H}$	ROH	$\text{CH}_3\text{CO}_2\text{R}$	H_2O
initial amount/mol	0.10	0.10	0	0
equilibrium amount/mol				

- (ii) Use your results to calculate a value for K_c for this reaction.

[3]

- (d) Esters are hydrolysed by sodium hydroxide. During the titration, sodium hydroxide reacts with ethanoic acid and the hydrogen chloride, but not with the ester.

Suggest a reason for this.

.....

..... [1]

- (e) What would be the effect, if any, on the amount of ester present if all of the water were removed from the flask and the flask kept for a further week at 25 °C?

Explain your answer.

.....

.....

..... [2]

[Total: 12]

- 2 Halogenoalkanes have been widely used as aerosol propellants, refrigerants and solvents for many years.

For
Examiner's
Use

Fluoroethane, $\text{CH}_3\text{CH}_2\text{F}$, has been used as a refrigerant. It may be made by reacting ethene with hydrogen fluoride.

You are to calculate a value for the C–F bond energy in fluoroethane.

- (a) Use relevant bond energies from the *Data Booklet*, and the equation below to calculate a value for the bond energy of the C–F bond.



C–F bond energy = ... kJ mol^{-1} [4]

- (b) Another halogenoalkane which was used as a refrigerant, and also as an aerosol propellant, is dichlorodifluoromethane, CCl_2F_2 .

State **two** reasons why compounds such as $\text{CH}_3\text{CH}_2\text{F}$ and CCl_2F_2 have been used as aerosol propellants and refrigerants.

.....
 [2]

CCl_2F_2 is one of many chlorofluorocarbon compounds responsible for damage to the ozone layer in the stratosphere.

For
Examiner's
Use

- (c) By using relevant data from the *Data Booklet*, and your answer to (a) suggest why CCl_2F_2 is responsible for damage to the ozone layer in the stratosphere whereas $\text{CH}_3\text{CH}_2\text{F}$ is not.

.....

 [2]

Both $\text{CH}_3\text{CH}_2\text{F}$ and CCl_2F_2 are greenhouse gases.

The 'enhanced greenhouse effect' is of great concern to the international community.

- (d) (i) What is meant by the term *enhanced greenhouse effect*?

.....

- (ii) Water vapour is the most abundant greenhouse gas.

What is the second most abundant greenhouse gas?

..... [3]

A greenhouse gas which is present in very small amounts in the atmosphere is sulfur hexafluoride, SF_6 , which is used in high voltage electrical switchgear.

- (e) What shape is the SF_6 molecule?

..... [1]

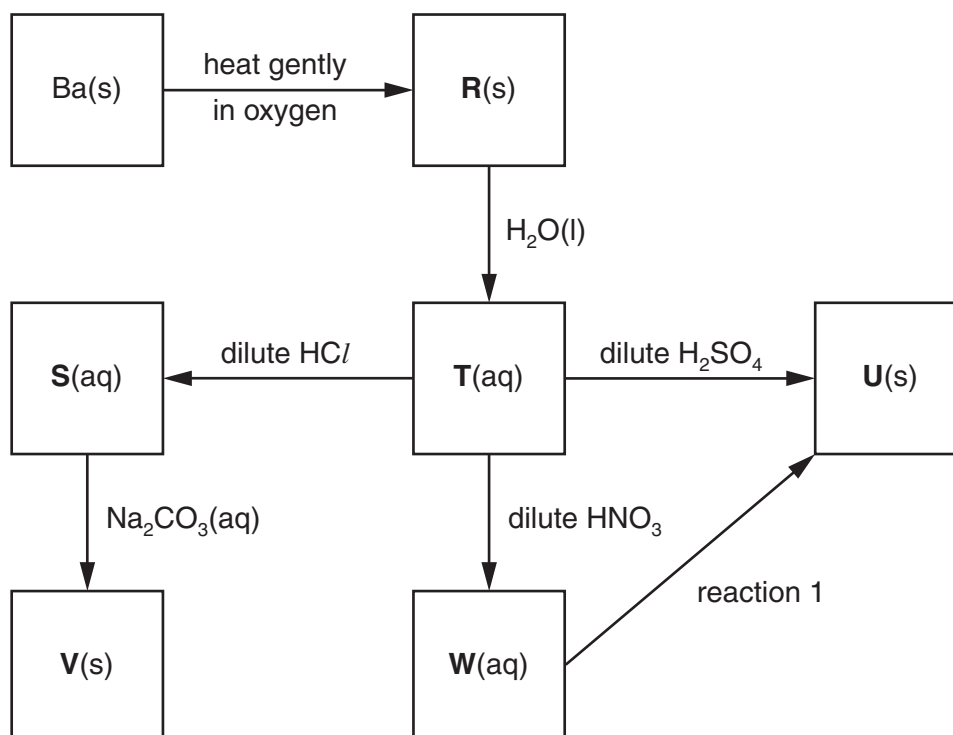
[Total: 12]

- 3 Barium, proton number 56, is a Group II element which occurs in nature as the carbonate or sulfate.

The element was first isolated by Sir Humphry Davy in 1808.

Some reactions of barium and its compounds are shown in the reaction scheme below.

For
Examiner's
Use



- (a) State the formula of **each** of the barium compounds **R** to **W**.

R

S

T

U

V

W

[6]

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

compound **T** to compound **W**

.....

the roasting of **V** in air

.....

- (ii) Suggest a gaseous reagent for the conversion of **T** into **V** and write a balanced equation for the reaction.

reagent

equation [4]

- (c) Suggest the formula of an aqueous reagent, other than an acid, for reaction 1.

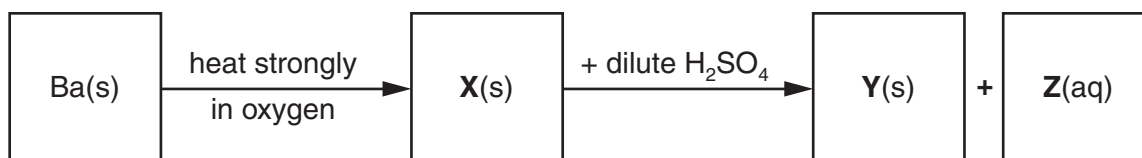
..... [1]

When barium is heated strongly in oxygen, an oxide **X** is formed.

The oxide **X** contains 18.9% of oxygen by mass.

The oxide **X** reacts with dilute sulfuric acid in a 1:1 ratio.

Two products, one insoluble and one soluble, are formed.



- (d) (i) Calculate the empirical formula of **X**.

- (ii) Suggest the identity of the solid **Y**.

.....

- (iii) Use your answers to (i) and (ii) to construct an equation for the reaction of **X** with H_2SO_4 .

..... [4]

[Total: 15]

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4 Chlorine is manufactured by electrolysis from brine, concentrated aqueous sodium chloride.

For
Examiner's
Use

- (a) (i) Describe, with the aid of a fully labelled diagram, the industrial electrolysis of brine in a diaphragm cell. State what each electrode is made of and show clearly the inlet for the brine and the outlets for the products.

- (ii) Write a half-equation, with state symbols, for the reaction at **each** electrode.

anode

cathode

- (iii) Name the chemical that is produced in solution in this electrolytic process.

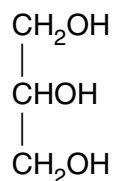
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[7]

[Total: 7]

- 5 Although there are many different types of food eaten around the world, animal fats and/or vegetable oils are commonly used in cooking.

Animal fats and vegetable oils are usually glyceryl esters, that is esters of glycerol, propane-1,2,3-triol.



Many animal fats contain esters of stearic acid, $\text{CH}_3(\text{CH}_2)_{16}\text{CO}_2\text{H}$.

Vegetable oils often contain esters of oleic acid, $\text{CH}_3(\text{CH}_2)_7\text{CH}=\text{CH}(\text{CH}_2)_7\text{CO}_2\text{H}$.

- (a) Draw the structural formula of the glyceryl ester formed when one molecule of glycerol is completely esterified with stearic acid.

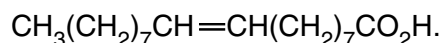
[1]

- (b) What reagent(s) would you use, in a school or college laboratory, to obtain a small sample of oleic acid, $\text{C}_{17}\text{H}_{33}\text{CO}_2\text{H}$, from the glyceryl ester present in a vegetable oil?

.....

[1]

Oleic acid is the *cis* isomer and elaidic acid the *trans* isomer of



- (c) By using this formula, draw the structural formula of elaidic acid, clearly showing the stereochemistry.

[1]

Oleic and elaidic acids are examples of mono-unsaturated acids.

Many vegetable oils contain esters of polyunsaturated fatty acids. Such oils are often hydrogenated to form esters containing saturated or mono-unsaturated fatty acids.

For
Examiner's
Use

(d) (i) Suggest the meaning of the term *polyunsaturated fatty acid*.

.....
.....

(ii) What reagent and condition(s) are used for the hydrogenation of an unsaturated fatty acid?

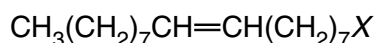
reagent

condition(s) [3]

In cooking, unsaturated fats are often oxidised to give aldehydes or ketones.

(e) (i) Give the structural formulae of the two aldehydes formed by the partial oxidation of the unsaturated fat below.

In the structure, X, represents the rest of the fat molecule.



(ii) Name the reagent you would use to show that the product contained **either** an aldehyde **or** a ketone. What change would be seen?

reagent

observation

(iii) What reagent would you use to **confirm** the presence of an aldehyde? What change would be seen?

reagent

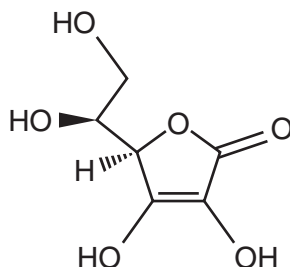
observation [6]

Animal fats and vegetable oils can become rancid because of oxidation. The rancid fat or oil has an unpleasant smell and taste.

For
Examiner's
Use

Antioxidants are used to prevent the spoilage of many foodstuffs by oxidation.

One antioxidant that is widely used is vitamin C, ascorbic acid.



ascorbic acid

- (f) (i) How many chiral carbon atoms are present in one molecule of ascorbic acid?
If none, write 'none'.

.....

- (ii) The ascorbic acid molecule contains three functional groups.

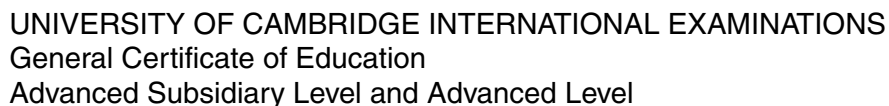
Two of these are alcohol (primary and secondary) and alkene.

What is the name of the third functional group?

.....

[2]

[Total: 14]



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- 1 Methanoic acid, HCO_2H , was formerly known as formic acid because it is present in the sting of ants and the Latin name for ant is *formica*. It was first isolated in 1671 by John Ray who collected a large number of dead ants and extracted the acid from them by distillation.

In this question, you should give all numerical answers to two significant figures.

At room temperature, pure methanoic acid is a liquid which is completely soluble in water.

When we are stung by a 'typical' ant a solution of methanoic acid, **A**, is injected into our skin.

Solution **A** contains 50% by volume of pure methanoic acid.

A 'typical' ant contains $7.5 \times 10^{-6} \text{ dm}^3$ of solution **A**.

- (a) (i) Calculate the volume, in cm^3 , of solution **A** in one ant.

volume = ... cm^3

- (ii) Use your answer to (i) to calculate the volume, in cm^3 , of pure methanoic acid in one ant.

volume = ... cm^3

- (iii) Use your answer to (ii) to calculate how many ants would have to be distilled to produce 1 dm^3 of pure methanoic acid.

number = ...
[3]

When we are stung by an ant, the amount of solution **A** injected is 80% of the total amount of solution **A** present in one ant.

For
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Use

The density of pure methanoic acid is 1.2 g cm^{-3} .

(b) (i) Calculate the volume, in cm^3 , of **pure** methanoic acid injected in one ant sting.

volume = ... cm^3

(ii) Use your answer to **(i)** to calculate the mass of methanoic acid present in one ant sting.

mass = ... g
[3]

Bees also sting us by using methanoic acid. One simple treatment for ant or bee stings is to use sodium hydrogencarbonate, NaHCO_3 .

(c) (i) Construct a balanced equation for the reaction between methanoic acid and sodium hydrogencarbonate.

.....

(ii) In a typical bee sting, the mass of methanoic acid injected is $5.4 \times 10^{-3} \text{ g}$. Calculate the mass of NaHCO_3 needed to neutralise one bee sting.

mass = ... g
[3]

[Total: 9]

- 2 The kinetic theory of gases is used to explain the large scale (macroscopic) properties of gases by considering how individual molecules behave.

(a) State **two** basic assumptions of the kinetic theory as applied to an ideal gas.

- (i)
.....
- (ii)
.....
- [2]

(b) State **two** conditions under which the behaviour of a real gas approaches that of an ideal gas.

- (i)
(ii)
- [2]

(c) Place the following gases in decreasing order of ideal behaviour.

ammonia, neon, nitrogen

most ideal **least ideal**

Explain your answer.

-
.....
- [3]

(d) By using the kinetic-molecular model, explain why a liquid eventually becomes a gas as the temperature is increased.

-
.....
.....
.....
- [2]

- (e) Ethane, CH_3CH_3 , and fluoromethane, CH_3F are *iso*-electronic, that is they have the same total number of electrons in their molecules.

For
Examiner's
Use

Calculate the **total** number of electrons in one molecule of CH_3F .

[1]

- (f) The boiling points of these two compounds are given below.

compound	bp/K
CH_3CH_3	184.5
CH_3F	194.7

Suggest explanations for the following.

- (i) the close similarity of the boiling points of the two compounds

.....

- (ii) the slightly higher boiling point of CH_3F

.....

[2]

[Total: 12]

- 3 Elements in the same period of the Periodic Table show trends in physical and chemical properties. The grids on this page and on the opposite page refer to the elements of the third period, Na to Cl.

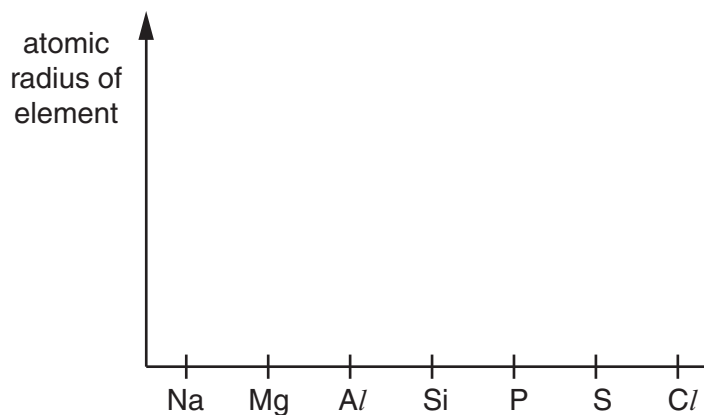
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On **each** of these grids, draw a clear sketch to show the variation of the stated property.

Below **each** grid, briefly explain the variation you have described in your sketch.

For each explanation you should refer to the important factors that cause the differences in the property you are describing.

(a)



explanation

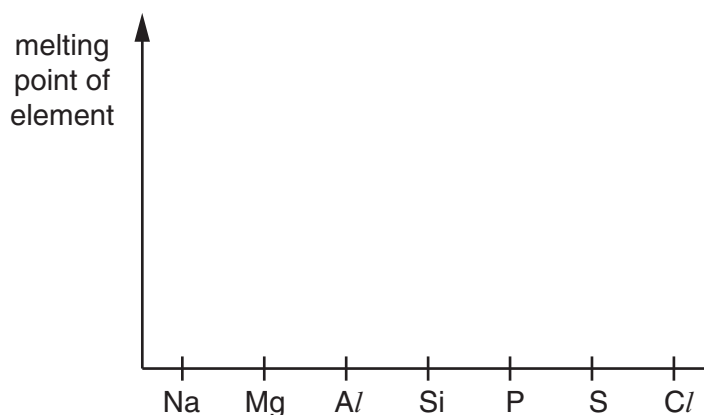
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[3]

(b)



explanation

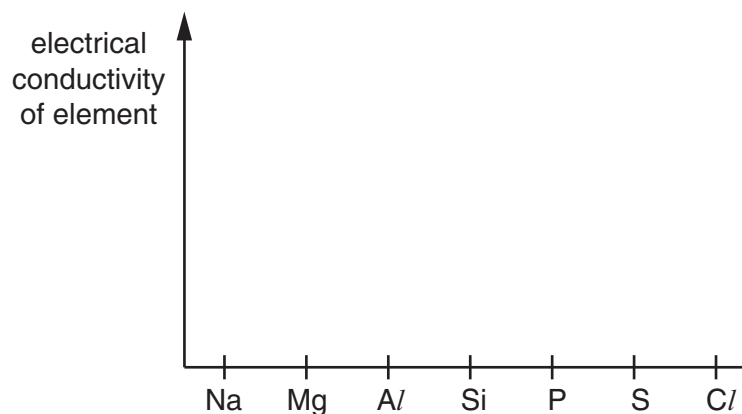
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[4]

(c)



explanation

.....

.....

.....

[4]

(d) The melting points of some of the oxides of the elements sodium to sulfur are given in the table below.

compound	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₄ O ₆	SO ₂
mp/K	1193	3173	2313	1883	297	198

(i) What type of bond is broken when **each** of the following compounds is melted?

Na₂O

SiO₂

P₄O₆

(ii) Identify **one** of these six oxides that has no reaction at all with water.

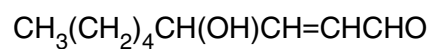
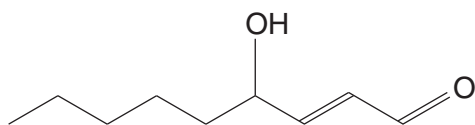
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[4]

[Total: 15]

- 4 The compound *trans*-4-hydroxy-2-nonenal (HNE) is thought to lead to infections of the lung when cigarettes are smoked.

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***trans*-4-hydroxy-2-nonenal**

- (a) What is the empirical formula of *trans*-4-hydroxy-2-nonenal?

.....

[1]

- (b) (i) HNE contains an alkene group. Name as fully as you can **two** other functional groups which are present in the HNE molecule.

.....

.....

- (ii) How would you confirm the presence of the alkene group in HNE?
State the reagent used and the observation you would make.

reagent

observation

[5]

HNE is a reactive compound.

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Use

(c) Give the structural formulae of all of the carbon-containing compounds formed in each case when HNE is reacted separately with the following reagents.

(i) hot concentrated manganate(VII) ions in acid solution

(ii) hot phosphorus trichloride, PCl_3

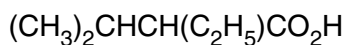
(iii) sodium tetrahydridoborate(III), NaBH_4

[4]

[Total: 10]

- 5 Fermentation of sugars by bacteria or moulds produces many different organic compounds.

One compound present in fermented molasses is 2-ethyl-3-methylbutanoic acid which gives a distinctive aroma to rum.



2-ethyl-3-methylbutanoic acid

- (a) (i) What is the molecular formula of 2-ethyl-3-methylbutanoic acid?

- (ii) How many chiral carbon atoms are present in a molecule of 2-ethyl-3-methylbutanoic acid? If none write 'none'.

.....

[2]

A sample of 2-ethyl-3-methylbutanoic acid may be prepared in a school or college laboratory by the oxidation of 2-ethyl-3-methylbutan-1-ol, $(\text{CH}_3)_2\text{CHCH}(\text{C}_2\text{H}_5)\text{CH}_2\text{OH}$.

- (b) (i) State the reagent(s) that would be used for this oxidation.
Describe what colour change would be seen.

reagent(s)

colour change from to

This reaction is carried out by heating the reacting chemicals together.

- (ii) What could be the main organic impurity present in the sample of the acid?

Explain your answer.

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

- (iii) State whether a distillation apparatus or a reflux apparatus should be used.

Explain your answer.

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

[6]

- (c) A structural isomer of 2-ethyl-3-methylbutan-1-ol is 2-ethyl-3-methylbutan-2-ol, $(\text{CH}_3)_2\text{CHC}(\text{OH})(\text{C}_2\text{H}_5)\text{CH}_3$.

What colour change would be seen if this were heated with the reagents you have given in (b)(i)?

Explain your answer as clearly as you can.

.....

 [3]

An isomer of 2-ethyl-3-methylbutanoic acid which is an ethyl ester is a very strong smelling compound which is found in some wines.

- (d) This ethyl ester contains a branched hydrocarbon chain and is chiral.

Draw the displayed formula of this ethyl ester.

Identify the chiral carbon atom with an asterisk (*).

[3]

[Total: 14]

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