Cambridge International **A Level**

Cambridge International Examinations
Cambridge International Advanced Level

CANDIDATE NAME

CENTRE NUMBER | | | | | |

CANDIDATE NUMBER | | | | |

5621213267

CHEMISTRY **9701/41**

Paper 4 Structured Questions **May/June 2015**

2 hours

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 an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Section A
Answer **all** questions.

Section B
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.

For Examiner's Use	
1	
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Total	

This document consists of **19** printed pages and **1** blank page.

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CAMBRIDGE International Examinations

Section A

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

1 **(a)** Complete the electronic configurations of the following atoms.

oxygen: $1s^2$.....

fluorine: $1s^2$.....

[1]

(b) A compound of fluorine and oxygen contains three atoms in each molecule.

(i) Predict its formula.

..... [1]

(ii) Draw a 'dot-and-cross' diagram to show its bonding.

[1]

(iii) Suggest the shape of this molecule.

..... [1]

(c) **(i)** Use $E^\ominus$ values from the *Data Booklet* to predict the relative oxidising abilities of fluorine and chlorine.

.....

.....

..... [2]

(ii) Predict the *type of reaction* that would occur between the interhalogen compound chlorine fluoride, C*l*F, and potassium bromide solution.

..... [1]

(iii) Construct an equation for this reaction.

..... [1]

[Total: 8]

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2 **(a)** Both chloroalkanes and acyl chlorides react with water, but only acyl chlorides fume in moist air.

(i) State which product causes the fumes in this reaction.

..... [1]

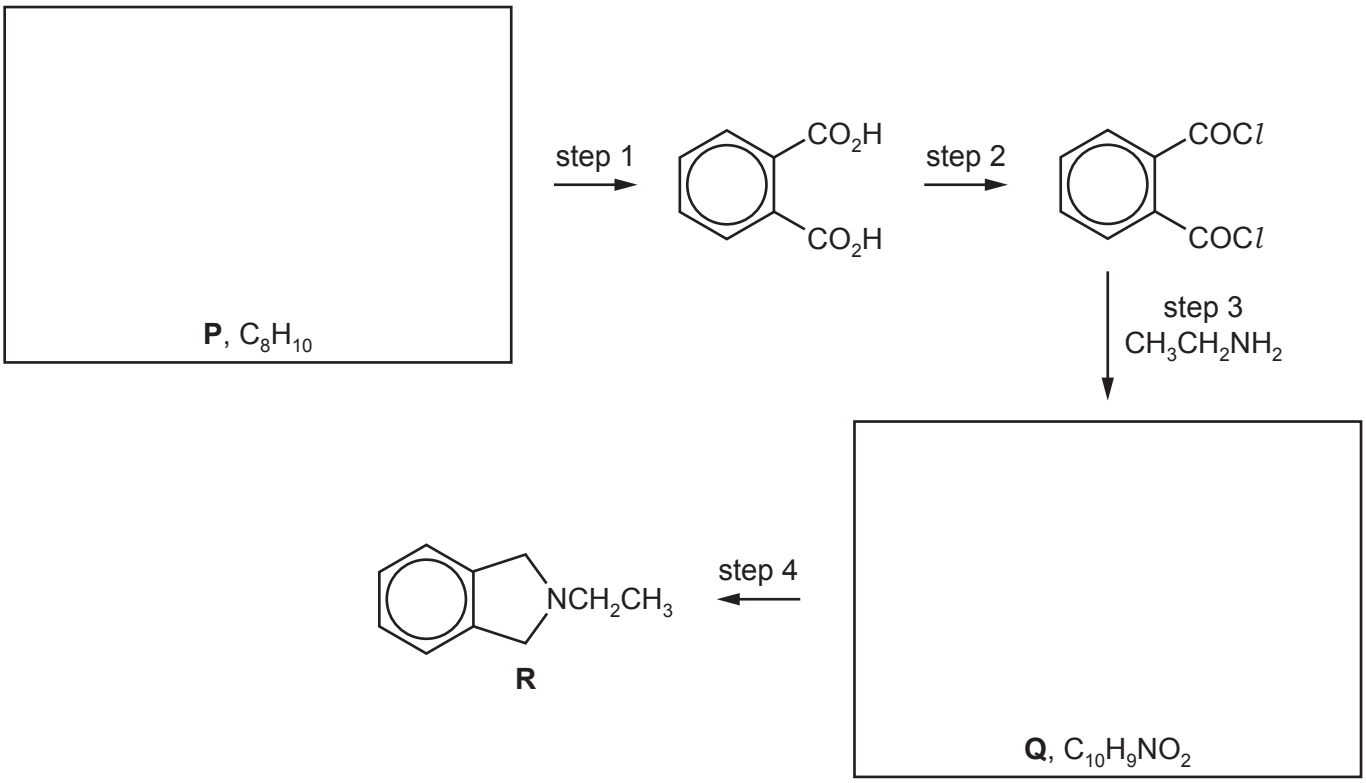
(ii) Explain why the reactivities of chloroalkanes and acyl chlorides differ.

.....

.....

..... [1]

(b) Compound **R** is a useful intermediate in the synthesis of pharmaceutical compounds. It can be made from compound **P** by the following route.



(i) Suggest structures for the starting material **P** and the intermediate **Q**. [2]

(ii) Suggest reagents and conditions for the following steps in the above scheme.

step 1 .....

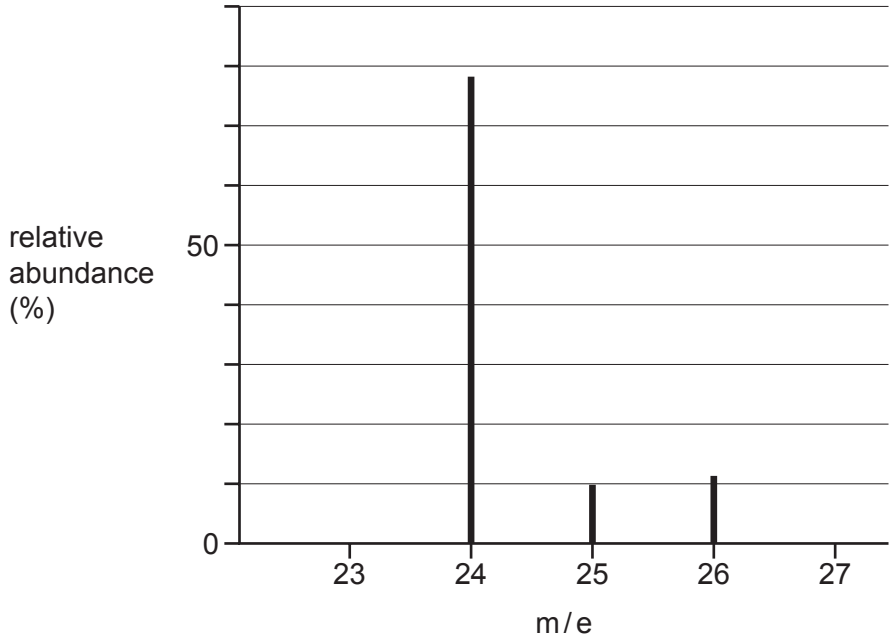
step 2 .....

step 4 .....

[3]

[Total: 7]

3 **(a)** The mass spectrum of the element magnesium is shown below.



(i) From the mass spectrum, complete the table with the relative abundances of the three isotopes.

isotope	relative abundance
^{24}Mg	
^{25}Mg	
^{26}Mg	

[1]

(ii) Use your values in **(i)** to calculate the relative atomic mass, A_r, of magnesium to **two** decimal places.

A_r (Mg) = ... [1]

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(b) (i) Describe and explain the trend in the thermal stabilities of the nitrates of the Group II elements down the group.

.....

.....

.....

.....

..... [3]

When lithium nitrate, $LiNO_3$, is heated, it readily decomposes giving off a brown gas. This reaction is similar to that which occurs when magnesium nitrate is heated, but it does not occur with other Group I nitrates.

(ii) Suggest an equation for the action of heat on $LiNO_3$.

..... [1]

(iii) Suggest why the Group I nitrates other than $LiNO_3$ do **not** decompose in this way when heated.

.....

..... [1]

[Total: 7]

4 **(a)** Silver sulfate, Ag_2SO_4, is sparingly soluble in water. The concentration of its saturated solution is 2.5×10^{-2} mol dm^{-3} at 298 K.

(i) Write an expression for the solubility product, K_{sp}, of Ag_2SO_4, and state its units.

K_{sp} = units: ..... [1]

(ii) Calculate the value for $K_{sp}(Ag_2SO_4)$ at 298 K.

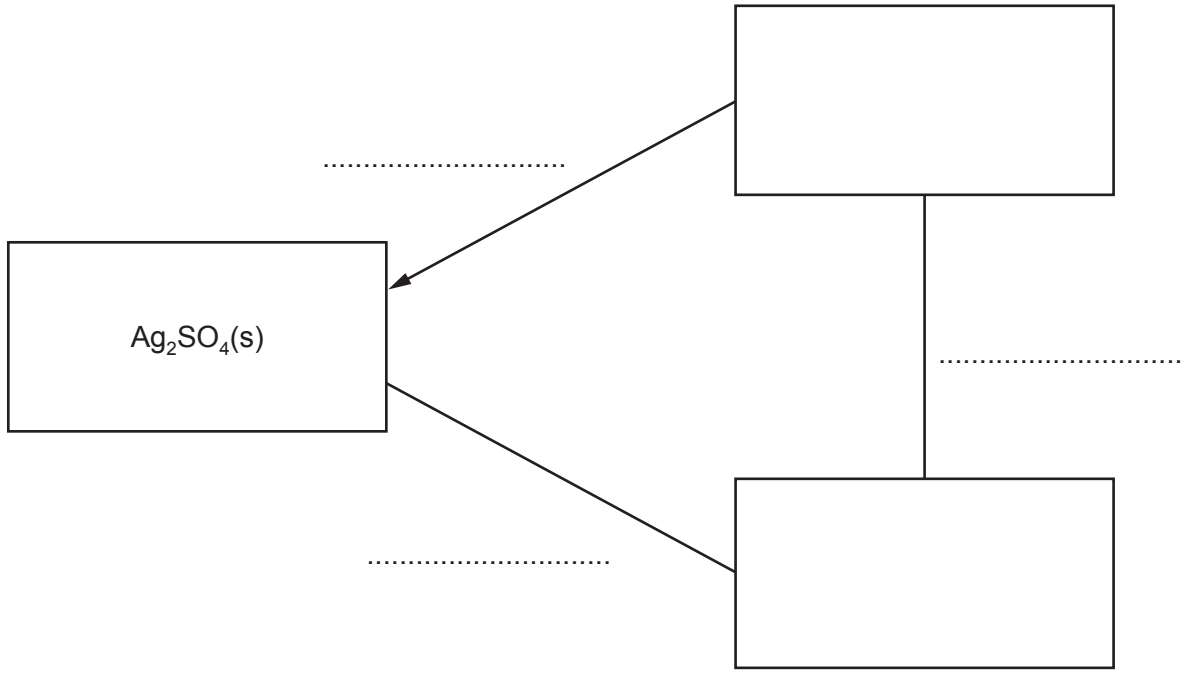
K_{sp} = ... [1]

(b) Using Ag_2SO_4 as an example, complete the following Hess' Law energy cycle relating the

- lattice energy, $\Delta H^{\ominus}_{latt}$,
- enthalpy change of solution, $\Delta H^{\ominus}_{sol}$, and
- enthalpy change of hydration, $\Delta H^{\ominus}_{hyd}$.

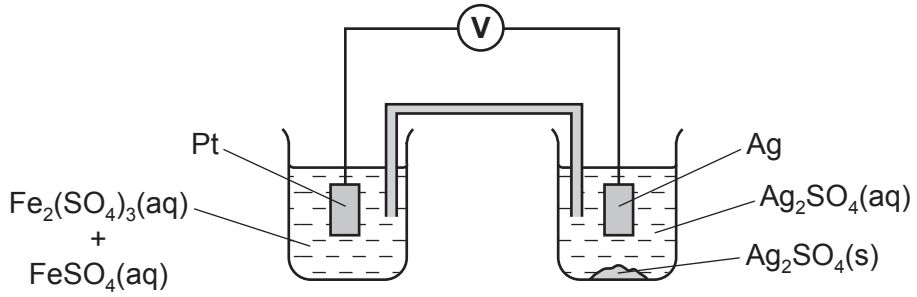
On your diagram:

- include the relevant species in the two empty boxes,
- label each enthalpy change with its appropriate symbol,
- complete the remaining two arrows showing the correct direction of enthalpy change.



[4]

(c) An electrochemical cell is set up as follows.



(i) Use the *Data Booklet* to calculate the value of $E^{\ominus}_{cell}$ under standard conditions, stating which electrode is the positive one.

$E^{\ominus}_{cell}$ = ... positive electrode: ..... [1]

(ii) How would the actual E_{cell} of the above cell compare to the $E^{\ominus}_{cell}$ under standard conditions? Explain your answer.

.....

..... [1]

(iii) How would the E_{cell} of the above cell change, if at all, if a few cm^3 of concentrated Na_2SO_4(aq) were added to

- the beaker containing Fe^{3+}(aq) + Fe^{2+}(aq),

.....

- the beaker containing Ag_2SO_4(aq)?

.....
[2]

(iv) Explain any changes in E_{cell} you have stated in **(iii)**.

.....

..... [1]

(d) Solutions of iron(III) sulfate are acidic due to the following equilibrium.

$$[Fe(H_2O)_6]^{3+}(aq) \rightleftharpoons [Fe(H_2O)_5(OH)]^{2+}(aq) + H^+(aq) \qquad K_a = 8.9 \times 10^{-4}\,mol\,dm^{-3}$$

Calculate the pH of a $0.1\,mol\,dm^{-3}$ solution of iron(III) sulfate, $Fe_2(SO_4)_3$.

pH = ...
[2]

[Total: 13]

5 **(a)** Atoms and ions of elements are made up from the three subatomic particles, protons, electrons and neutrons, in varying amounts.

Complete the following table to show the number of each particle in $^{14}C^{2-}$.

	protons	electrons	neutrons
$^{14}C^{2-}$			

[2]

(b) Describe the observations you would make during the reactions, if any, of the following chlorides with water.
Write equations for any reactions that occur.

CCl_4 observation .....

.....

equation .....

$GeCl_4$ observation .....

.....

equation .....

$SnCl_4$ observation .....

.....

equation .....

[4]

(c) Suggest a reason for any difference in the reactivities of the chlorides given in **(b)**.

.....

..... [1]

(d) Use data from the *Data Booklet* to explain why an aqueous solution of $SnCl_2$ reacts with Cl_2(g) but an aqueous solution of $PbCl_2$ does not.

Write an equation for the reaction.

.....

.....

.....

.....

..... [3]

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(e) (i) State the relationship between the Faraday constant and the Avogadro constant.

..... [1]

(ii) When a current of 1.2A was passed through dilute sulfuric acid for 30 minutes, it was found that 130 cm^3 of oxygen, measured at 25 °C and 1 atm, was collected at the anode. The following reaction takes place.

$$2H_2O(l) \rightarrow 4H^+(aq) + O_2(g) + 4e^-$$

Use these data and data from the *Data Booklet* to calculate a value for the Avogadro constant, *L*, by calculating

- the number of moles of oxygen produced,
- the number of moles of electrons needed for this,
- the number of coulombs passed,
- the number of electrons passed,
- the number of electrons in one mole of electrons (*L*).

L = ... mol^{-1}
[4]

[Total: 15]

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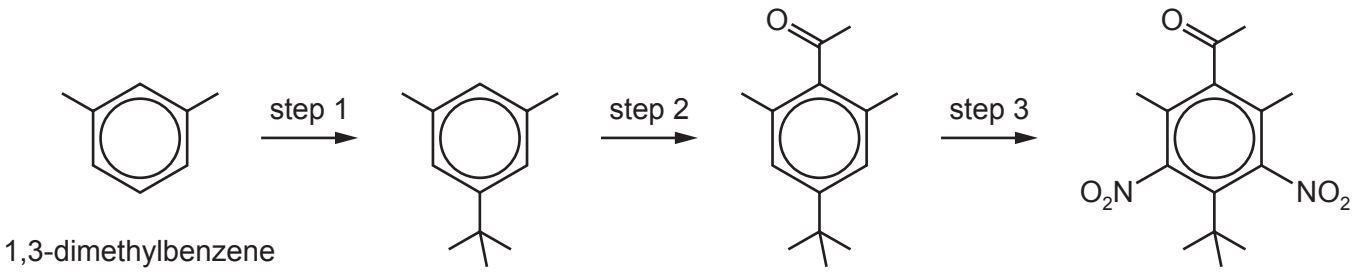
[Turn over

6 1,3-dimethylbenzene is a useful starting material for several commercially important compounds.

(a) The artificial 'musk ketone', **A**, is a perfume agent added to many cosmetics and detergents. It is made from 1,3-dimethylbenzene by the following route.



1,3-dimethylbenzene

'musk ketone' **A**

(i) The only by-product of step 2 is HC*l*.

Suggest the reagent that was used in this step.

..... [1]

(ii) Suggest the *type of reaction* that is occurring during both step 2 and step 3.

..... [1]

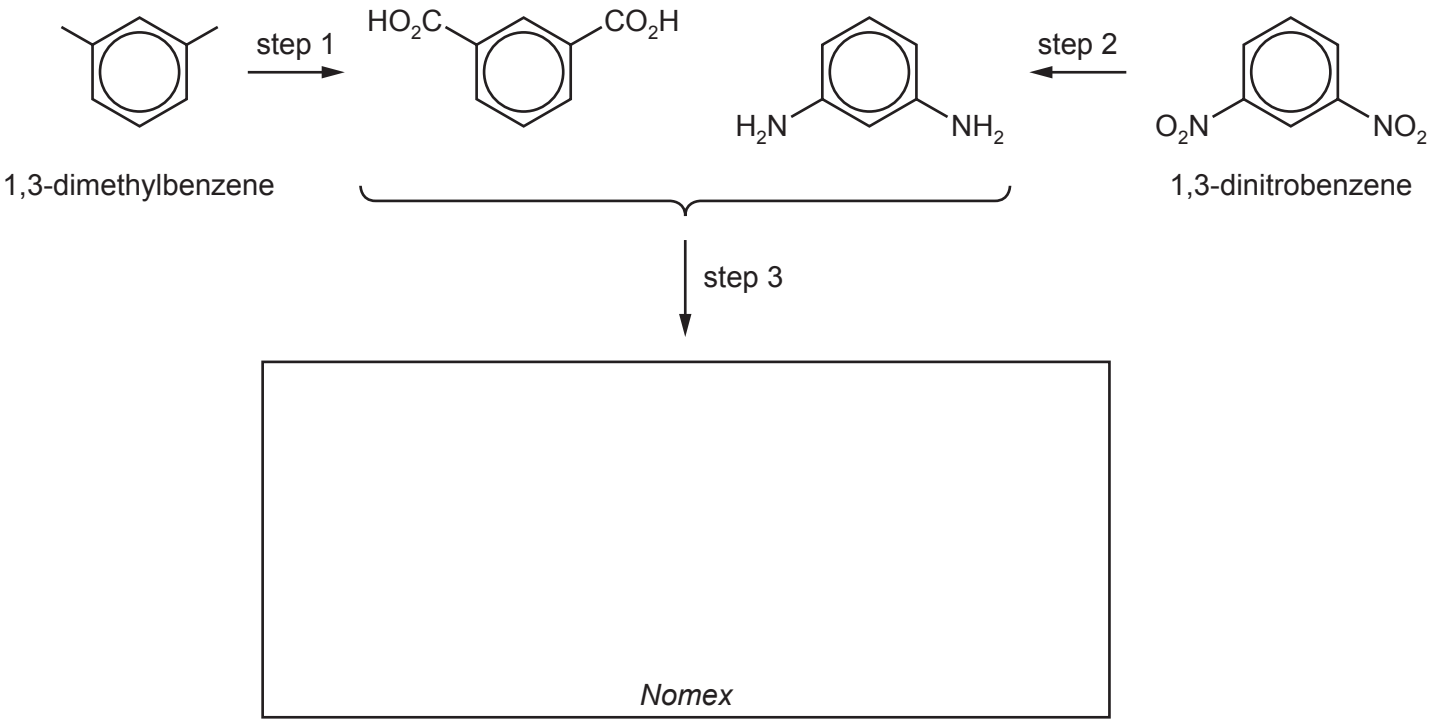
(iii) State the reagents and conditions needed for step 3.

..... [1]

(iv) Suggest the structures of the two products formed when **A** is reacted with alkaline aqueous iodine.

[2]

(b) 1,3-dimethylbenzene is also a starting material for the synthesis of the polymer *Nomex*, used in fireproof protective clothing worn by firefighters, military pilots and racing car drivers. The polymer is made from 1,3-dimethylbenzene and 1,3-dinitrobenzene by the following route.



(i) Draw the structure of one repeat unit of *Nomex* in the box above. [1]

(ii) What *type of polymer* is *Nomex*?

..... [1]

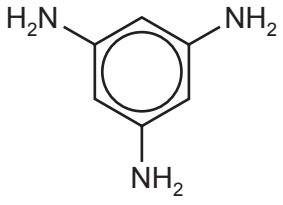
(iii) Suggest the by-product formed during step 3.

..... [1]

(iv) Suggest reagents and conditions for step 2.

..... [1]

(v) Suggest how and why the properties of the polymer might change if some of the diamine monomer were replaced with 1,3,5-triaminobenzene.



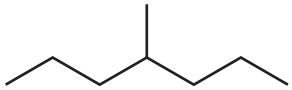
1,3,5-triaminobenzene

.....

..... [1]

[Total: 10]

7 **(a)** Long chain alkanes such as 4-methylheptane can be 'cracked' to produce shorter chain hydrocarbons.



4-methylheptane

$\longrightarrow$ **B** (C_3H_8) + a mixture of **C**, **D** and **E** (isomers of C_5H_{10})

(i) State the conditions necessary for this reaction to take place.

..... [1]

(ii) Suggest the structure of **B**.

B

[1]

(iii) Compounds **C**, **D** and **E** are isomers with the molecular formula C_5H_{10}.
On heating with concentrated acidified $KMnO_4$,

- compound **C** gives CO_2 and compound **F** ($C_4H_8O_2$),
- **D** and **E** each give a 1 : 1 mixture of compounds **G** ($C_2H_4O_2$) and **H** ($C_3H_6O_2$).

Suggest structures for compounds **C** - **H**.

C **D** **E**

F **G** **H**

[3]

(iv) Name the type of isomerism shown between **D** and **E**.

..... [1]

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(b) Propene, $CH_3CH=CH_2$, reacts with bromine to give 1,2-dibromopropane.

(i) How is this reaction usually carried out?

..... [1]

(ii) State the *type of reaction* that is occurring here.

..... [1]

(iii) Draw the mechanism of this reaction, including the structures of any intermediates, and any dipoles, lone pairs and curly arrows to show the movements of electrons.

[2]

[Total: 10]

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[Turn over

Section B

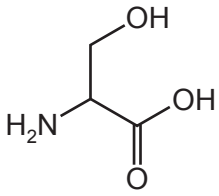
Answer **all** the questions in the spaces provided.

8 Proteins are formed by the polymerisation of amino acids.

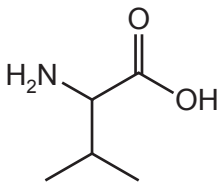
(a) (i) State the type of chemical reaction used to form these polymer chains.

..... [1]

(ii) The amino acids serine and valine can combine together to form a dipeptide.



serine, *ser*



valine, *val*

Draw the skeletal structure of the dipeptide '*val-ser*'.

[2]

(iii) Suggest how the type of amino acids in a protein determines its three-dimensional structure.

.....

.....

.....

..... [2]

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(b) Using labelled diagrams or words as appropriate, explain

(i) why a particular enzyme may only catalyse a specific reaction on a specific substrate,

.....

.....

.....

..... [2]

(ii) how *non-competitive* inhibition of an enzyme-catalysed reaction can occur.

.....

.....

.....

..... [3]

[Total: 10]

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[Turn over

9 **(a)** DNA fingerprinting has become a very important technique for analysing samples from living or once-living organisms.

(i) After extraction and purification, what is the first step in **analysing** a sample of DNA?

.....

..... [1]

(ii) What can be done to increase the amount of DNA for analysis?

.....

..... [1]

(iii) During electrophoresis, it is observed that amino acids can move in **different** directions or not at all, whilst DNA fragments always move in the **same** direction.

Explain these two observations.

.....

.....

.....

..... [2]

(iv) DNA fingerprinting can also be useful in archaeology.

Which of the following would **not** be suitable for analysis by DNA fingerprinting?
Put a cross (x) in the appropriate box(es).

a piece of leather from an Egyptian tomb	☐
a sample of skin from a mummified body	☐
a fragment of ancient pottery	☐
a piece of wood from a Roman chariot	☐

[1]

(b) **(i)** X-ray crystallography can be used to help analyse the structure of macromolecules.

What does this technique tell us about a particular macromolecule?

.....

..... [1]

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(ii) Which element will show up most strongly in the X-ray crystallography of a biological polymer of general formula $C_vH_wP_xN_yO_z$?
Explain your answer.

.....

..... [1]

(c) (i) Explain what is meant by a *partition coefficient*.

.....

..... [1]

(ii) The partition coefficient of a particular pesticide between hexane and water is 6.0.
A solution contains 0.0042 g of the pesticide dissolved in 25 cm^3 of water. The solution is shaken with 25 cm^3 of hexane.

Calculate the mass of pesticide that will be dissolved in the hexane layer at equilibrium.

[2]

[Total: 10]

10 In recent years there has been worldwide interest in the possible extraction of 'shale gas' (a form of natural gas) as an important energy source.

(a) One of the problems associated with using shale gas is its variable composition.
Table 1 shows the percentage composition of shale gas from four different sources **J**, **K**, **L** and **M**.

source	CH_4	C_2H_x	C_3H_y	CO_2	N_2
J	80.3	8.1	2.3	1.4	7.9
K	82.1	14.0	3.5	0.1	0.3
L	88.0	0.8	0.7	10.4	0.1
M	77.5	4.0	0.9	3.3	14.3

In the formulae above, ***x*** and ***y*** are variables.

Table 1

(i) Draw the structures of **three** possible compounds with the formula C_3H_y.

[2]

(ii) Which source of shale gas, **J**, **K**, **L** or **M**, will provide the most energy when burned? Explain your answer.

.....

..... [1]

(iii) Suggest **two** methods by which carbon dioxide can be removed from shale gas.

1 .....

.....

2 .....

.....
[2]

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(b) **Table 2** shows a comparison of the relative amounts of pollutants produced when shale gas, fuel oil and coal are burned to produce **the same amount of energy**.

air pollutant	shale gas	fuel oil	coal
CO_2	117	164	208
CO	0.040	0.033	0.208
NO_2	0.092	0.548	0.457
SO_2	0.001	1.12	2.59
particulates	0.007	0.84	2.74

Table 2

(i) Suggest why shale gas produces the smallest amount of CO_2.

.....

..... [1]

(ii) Explain which of the three fuels, shale gas, fuel oil or coal, is the **largest** contributor to 'acid rain'.

fuel .....

.....

..... [1]

(iii) Suggest a reason why fuel oil and coal produce more NO_2 than shale gas.

.....

..... [1]

(iv) State **one** environmental consequence of raised levels of

- CO, ...
- CO_2. .....

[2]

[Total: 10]

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