UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

CANDIDATE NAME									
CENTRE NUMBER						CANDIDATE NUMBER				

5533648812

CHEMISTRY **9701/41**

Paper 4 Structured Questions **May/June 2012**

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 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.

Section A
Answer **all** questions.

Section B
Answer **all** questions.

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	
2	
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4	
5	
6	
7	
8	
Total	

This document consists of **17** printed pages and **3** blank pages.

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For Examiner's Use

Section A

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

1 (a) (i) What is meant by the term *lattice energy*?

.....

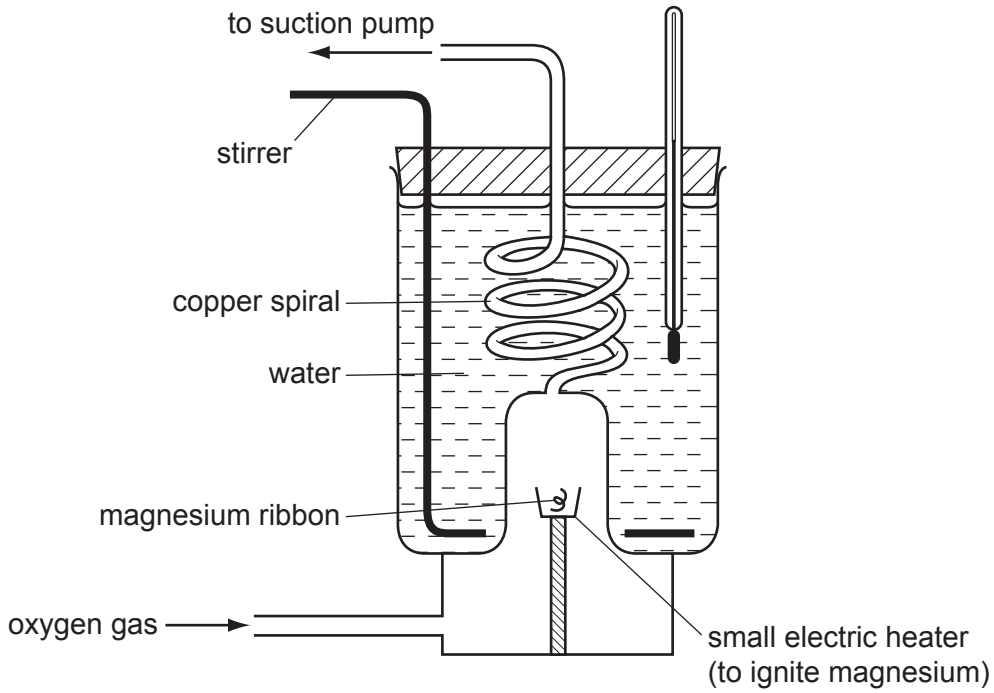
.....

(ii) Write an equation to represent the lattice energy of MgO.

.....

[3]

(b) The apparatus shown in the diagram can be used to measure the enthalpy change of formation of magnesium oxide, $\Delta H_f^{\ominus}$(MgO).



List the measurements you would need to make using this apparatus in order to calculate $\Delta H_f^{\ominus}$(MgO).

.....

.....

.....

..... [3]

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(c) Use the following data, together with appropriate data from the *Data Booklet*, to calculate a value of $\Delta H_f^{\ominus}$(MgO).

lattice energy of MgO(s)	=	–3791 kJ mol^{-1}
enthalpy change of atomisation of Mg	=	+148 kJ mol^{-1}
electron affinity of the oxygen atom	=	–141 kJ mol^{-1}
electron affinity of the oxygen anion, O^-	=	+798 kJ mol^{-1}

$\Delta H_f^{\ominus}$(MgO) = ... kJ mol^{-1}
[3]

(d) Write equations, including state symbols, for the reactions, if any, of the following two oxides with water. Suggest values for the pH of the resulting solutions.

oxide	equation	pH of resulting solution
Na_2O		
MgO		

[3]

[Total: 12]

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2 Nitrogen monoxide, NO, is formed in a reversible reaction when air is heated to the temperature of a car engine.

(a) (i) Suggest a 'dot-and-cross' electronic structure for nitrogen monoxide.

(ii) The enthalpy change of formation of nitrogen monoxide is +90 kJ mol^{-1}. What is the enthalpy change for the following reaction?

$$2NO(g) \rightarrow N_2(g) + O_2(g) \qquad \Delta H_r = \text{.....} \text{ kJ mol}^{-1}$$

(iii) Explain why nitrogen monoxide is formed in the car engine.

.....

(iv) Using bond enthalpy values from the *Data Booklet* and your answer in **(ii)** above, calculate a value for the bond energy of nitrogen monoxide.

bond energy = ... kJ mol^{-1}

[5]

(b) At 800 K, nitrogen monoxide reacts with hydrogen according to the following equation.

equation **I** $\quad 2H_2(g) + 2NO(g) \rightarrow 2H_2O(g) + N_2(g)$

The following table shows how the initial rate of this reaction depends on the partial pressures of the reagents.

experiment	p(H_2) / atm	p(NO) / atm	initial rate / atm s^{-1}
1	0.64	1.60	1.50×10^{-7}
2	0.64	0.80	3.75×10^{-8}
3	0.32	1.60	7.50×10^{-8}

(i) Find the order of the reaction with respect to each reactant, explaining how you arrive at your answer.

.....

.....

.....

.....

.....

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(ii) Write down the rate equation and the units of the rate constant.

.....

The following mechanism has been put forward for this reaction.

step 1 $NO + NO \rightarrow N_2O + O$

step 2 $H_2 + O \rightarrow H_2O$

step 3 $H_2 + N_2O \rightarrow N_2 + H_2O$

(iii) Show how the overall stoichiometric equation **I** can be derived from the three equations for the individual steps given above.

(iv) Suggest which of the three reactions in the mechanism is the rate determining step. Explain your answer.

.....

.....

[8]

(c) The following information on half-reactions relates to the reaction between HNO_3 and an excess of $FeSO_4$.

$Fe^{3+} + e^- \rightarrow Fe^{2+}$ $\quad E^\ominus = +0.77\,V$

$3H^+ + NO_3^- + 2e^- \rightarrow HNO_2 + H_2O$ $\quad E^\ominus = +0.94\,V$

$HNO_2 + H^+ + e^- \rightarrow NO + H_2O$ $\quad E^\ominus = +0.99\,V$

(i) Suggest the formula of the nitrogen-containing final product of this reaction.

.....

(ii) Write an equation for the formation of this nitrogen-containing product.

(iii) Nitrogen monoxide forms a dark brown complex with an excess of $FeSO_4(aq)$. What kind of bonding is involved in the complex formation?

.....

(iv) Suggest a formula for this complex.

.....

[4]

[Total: 17]

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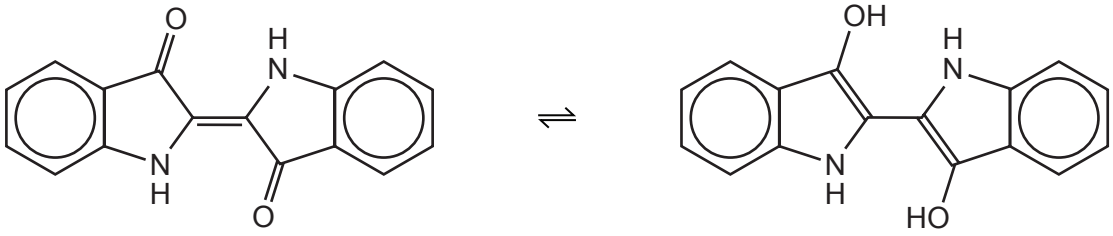
3 Indigo is the dye used in blue jeans. Although originally extracted from plants of the type *indigofera*, it is now almost entirely made artificially.

Indigo is insoluble in water but this disadvantage can be overcome by converting it into the water-soluble colourless leuco-indigo. If cloth soaked in a solution of leuco-indigo is left to dry in the air, the leuco-indigo is converted into the insoluble blue indigo, which is precipitated out onto the fibres of the cloth.



indigo leuco-indigo

(a) (i) Give the molecular formula of indigo.

.....

(ii) Name **three** functional groups in indigo.

.....

[3]

(b) (i) What *type of reaction* is the conversion of indigo into leuco-indigo?

.....

(ii) Suggest a laboratory reagent for this reaction.

.....

[2]

(c) Suggest **two** chemical tests that could be used to distinguish between indigo and leuco-indigo. Write your answers in the following table.

test	reagents and conditions	observation with indigo	observation with leuco-indigo
1			
2			

[5]

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(d) When indigo is heated with hydrogen and a nickel catalyst, compound **A**, $C_{16}H_{28}N_2O_2$, is formed.

(i) Suggest a structure for **A**.

(ii) Calculate the volume of hydrogen, measured at room temperature and pressure, that would have been absorbed if 2.50 g of indigo had undergone this reaction.

volume = ...dm^3
[3]

(e) Suggest the structure of the product formed when indigo reacts with an excess of $Br_2(aq)$.

[3]

[Total: 16]

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[Turn over

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4 (a) (i) Describe and explain the trend in the volatilities of the Group IV chlorides CCl_4, $GeCl_4$ and $PbCl_4$.

.....

.....

.....

.....

.....

.....

(ii) Describe and explain the reactions, if any, of these chlorides with water. Write equations for any reactions that occur.

.....

.....

.....

.....

.....

.....

.....

[7]

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(b) SnO_2 and PbO_2 react with acids in different ways.

- SnO_2 reacts with concentrated sulfuric acid to form a colourless solution with no evolution of gas.
- PbO_2 reacts with concentrated sulfuric acid to give a white solid, **B**, and oxygen gas.
- PbO_2 reacts with cold concentrated hydrochloric acid to give a yellow solution containing the $[PbCl_6]^{2-}$ ion, with no evolution of gas.
- Warming this yellow solution causes the evolution of Cl_2 gas, leaving a colourless solution which on cooling in ice precipitates a white solid, **C**.

(i) Identify the two white solids, **B** and **C**, mentioned above.

B .....

C .....

(ii) Suggest an equation for **each** of the four reactions described above.

.....

.....

.....

.....

.....

.....

[4]

[Total: 11]

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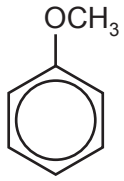
5 **(a)** Methoxybenzene reacts with $Br_2(aq)$ in a similar manner to phenol.



methoxybenzene

(i) Draw the structural formula of the product of the reaction between methoxybenzene and an excess of bromine.

(ii) Suggest a chemical reaction you could use to distinguish between methoxybenzene and phenol. State the reagent, describe the observations you would make, and give an equation for the reaction.

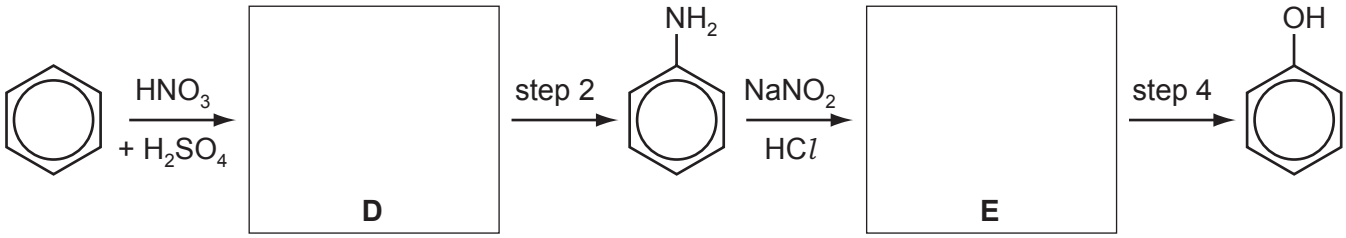
reagent .....

observation .....

equation

[4]

(b) Phenol can be synthesised from benzene by the following route.



(i) Suggest structures for compounds **D** and **E** and draw them in the boxes above.

(ii) Suggest reagents and conditions for

step 2, ...

step 4. .....

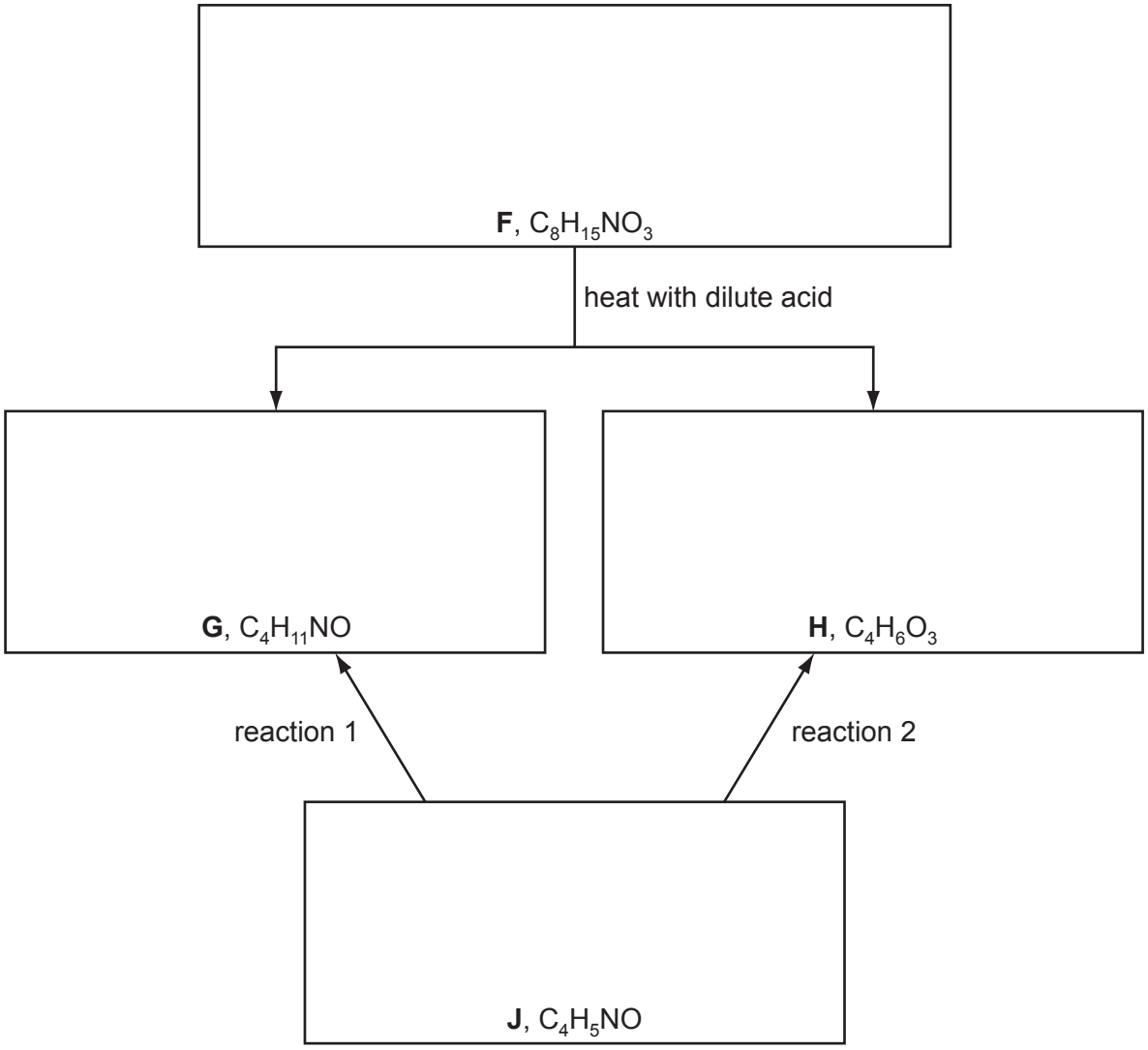
[4]

(c) The following chart shows some reactions of compound **F** which is a neutral compound.

G forms a salt with dilute H_2SO_4, whereas **H** forms a salt with NaOH(aq).

Both **G** and **H** can be obtained from compound **J** by separate one-step reactions (reaction 1 and reaction 2 below).

All four compounds **F**, **G**, **H** and **J** form a yellow precipitate with alkaline aqueous iodine.



(i) Suggest structures for **F**, **G**, **H** and **J**, and draw them in the boxes above.

(ii) Suggest reactants and conditions for

reaction 1, ...

reaction 2. .....

[6]

[Total: 14]

Section B

For Examiner's Use

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

6 In key reactions responsible for growth and repair in the human body, amino acids react together to form polymers known as proteins.

(a) (i) What *type of reaction* is this polymerisation?

.....

(ii) From stocks of glycine and alanine, it is possible to make the dipeptide gly-ala.
Using the same three-letter abbreviations for the amino acids, give the structures of all other possible dipeptides that can be made from these stocks of amino acids.

[3]

(b) (i) DNA consists of a double helix formed by two strands held together by hydrogen bonds between base pairs.
Sketch a section of DNA showing **two** base pairs, using blocks for the various components. You should label all of the components.

(ii) Suggest what the effect on DNA replication would be if the hydrogen bonds between the strands were replaced by stronger bonds, e.g. covalent bonds.

.....

.....

[4]

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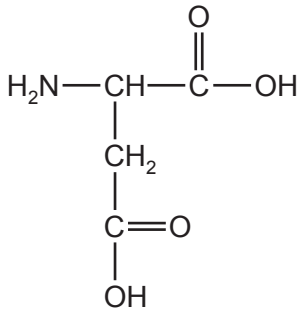
(c) Some diseases, such as sickle-cell anaemia, are caused by mutation resulting in a change in the triplet code.

(i) Explain why some changes in the triplet code do **not** result in a change in the primary structure of a protein.

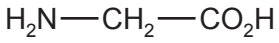
.....

.....

(ii) Suggest what change in the tertiary structure of a protein would result from a mutation that replaced aspartic acid with glycine.



aspartic acid



glycine

.....

.....

(iii) Sometimes a mutation can result in the *deletion* of a single base in DNA (or RNA). Explain why this is likely to have more serious consequences for the protein than the *replacement* of one base by another.

.....

.....

[3]

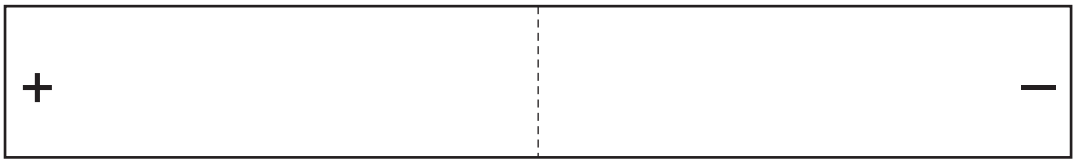
[Total: 10]

7 The analysis of a protein may be carried out by breaking it down into its amino acids. These can then be separated by a process called electrophoresis.

(a) The structures of glycine, lysine and glutamic acid at pH 7 are shown.

glycine	$H_3N^+CH_2CO_2^-$
lysine	$H_3N^+CH(CH_2CH_2CH_2CH_2NH_3^+)CO_2^-$
glutamic acid	$H_3N^+CH(CH_2CH_2CO_2^-)CO_2^-$

Draw and label three circles on the chart below to indicate the likely position of each of these amino acids after electrophoresis of a solution containing these amino acids in a buffer at pH 7.



start point

[3]

(b) Some organic compounds have very different solubilities in water and in organic solvents such as hexane. They may be extracted from an aqueous reaction mixture by shaking the mixture with portions of hexane and separating the two layers.
The process of distribution of a compound between two solvents is called *partition*.

(i) State what is meant by the term *partition coefficient*.

.....

.....

.....

(ii) One of the concerns about organic pollutants, such as pesticide residues, is that they can enter the food chain and become concentrated in human breast milk. Explain how this can happen.

.....

.....

.....

.....

[3]

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(c) Propene was treated with bromine in the presence of chloride ions and the product analysed using mass spectrometry.

A group of peaks was found in the range *m*/*e* 156–160 with the following relative heights.

m/*e*	relative height
156	3
158	4
160	1

(i) Identify the species responsible for each of these peaks.

156 .....

158 .....

160 .....

A large peak was present in the spectrum with a *m*/*e* value of less than 20.

(ii) Suggest the *m*/*e* value for the peak and the species that produced it.

m/*e* .....

species .....

[4]

[Total: 10]

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8 Some of the most commonly used polymers are formed by the polymerisation of ethene, C_2H_4. The presence of side-chains affects the bulk properties of an addition polymer. Unbranched polymers pack closer together than polymers with several side-chains.

Poly(ethene) exists in two different forms LDPE (low density poly(ethene)) which has lots of side-chains, and HDPE (high density poly(ethene)) in which there are fewer and shorter side-chains.

(a) Explain with the aid of sketches why the presence of side-chains causes a difference in density in poly(ethene).

.....

.....

..... [2]

(b) By reference to the type of bonding between the poly(ethene) chains, explain why LDPE has a lower melting point that HDPE.

.....

.....

..... [2]

(c) Polymerisation can take place by two different methods depending on the monomers involved. The two methods are addition and condensation.
Give **two** differences between the methods.

1. .....

.....

2. .....

.....
[2]

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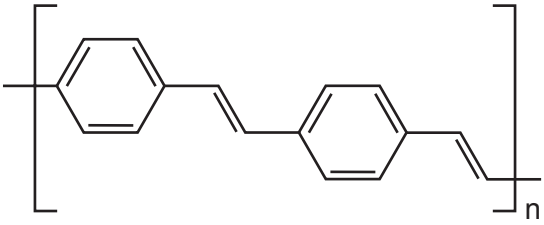
(d) There has been a great deal of commercial interest in the development of polymers that can conduct electricity and/or emit light. A length of one such polymer is shown.



(i) Suggest how this polymer conducts electricity.

.....

(ii) Suggest the molecular geometry required for this molecule to conduct.

Explain your answer.

.....

.....

(iii) What is the empirical formula of this polymer?

.....

[4]

[Total: 10]

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