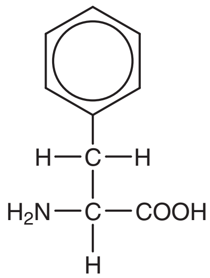
'ENGINEERING PROTEINS' TEST

60 marks (1 hour)

*A copy of the **EP Information Sheet** is required for this test, together with the spectroscopic data (n.m.r.) from Table 23 in the **Data Sheets**.*

1 Phenylketonuria (PKU) is a potentially lethal inherited disease. Babies suffering from PKU lack the ability to break down the surplus phenylalanine that is present in their diet. Excess phenylalanine is toxic and causes mental retardation.

Phenylalanine is a 2-amino acid (α-amino acid), and its structural formula is given below.



phenylalanine

a What feature of the structure of phenylalanine indicates that it could be one of the building blocks of our proteins? *(1 mark)*

b **i** Draw the structural formula of the *zwitterion* present in an aqueous solution of phenylalanine. *(2 marks)*

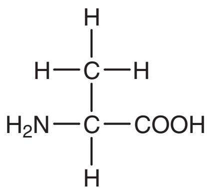
ii A small quantity of acid is added to an aqueous solution of phenylalanine. Draw the structural formula of the ion that is formed, and explain why the pH of the solution does not change very much on addition of the acid. *(3 marks)*

c Phenylalanine has two *stereoisomers*.

i What **type** of stereoisomerism is shown by phenylalanine? *(1 mark)*

ii Draw three-dimensional representations of the two isomers, showing clearly how they are related. *(2 marks)*

d Another amino acid, alanine, has the following structural formula.



alanine

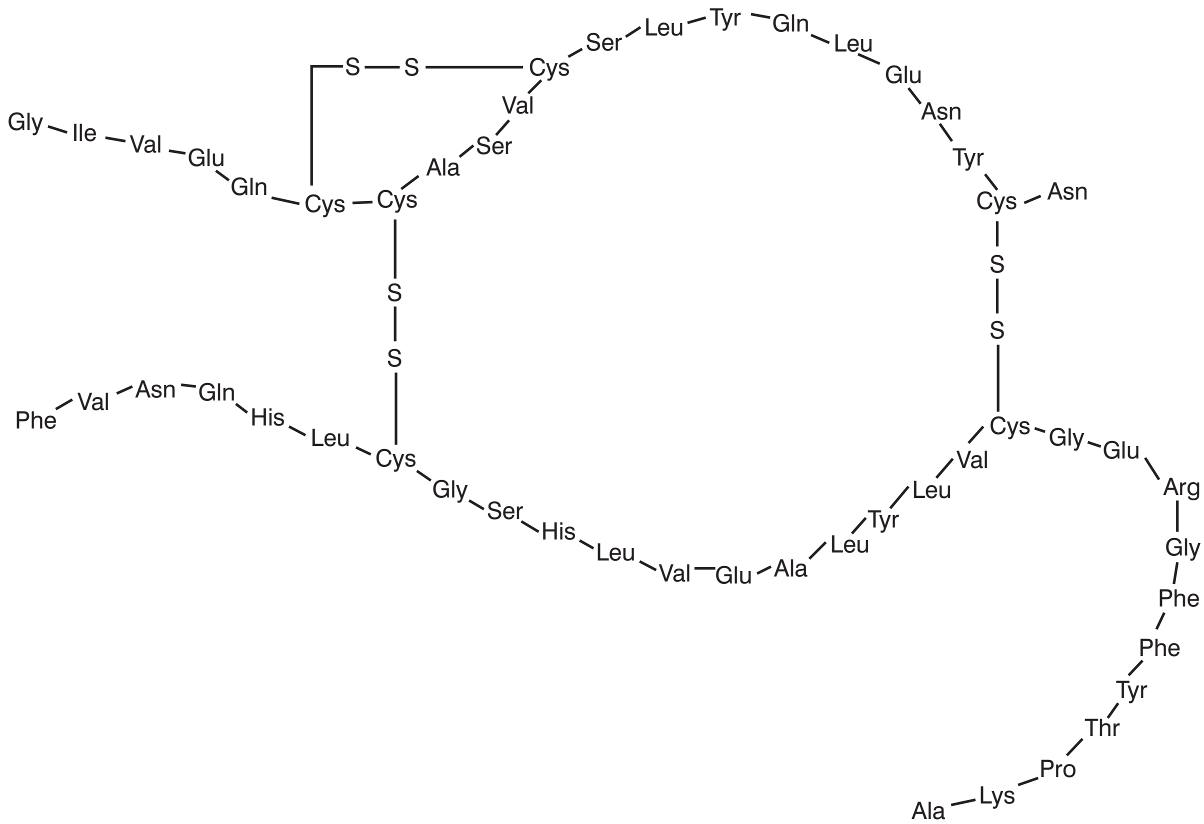
i Draw structural formulae for the **two** different *peptides* that can be formed when phenylalanine and alanine join to each other. *(2 marks)*

ii On one of your formulae, draw a circle around the *peptide link*. *(1 mark)*

iii What reagent and conditions are usually used in the laboratory to break down the peptide link? *(3 marks)*

[TOTAL: 15 MARKS]

2 Ox insulin consists of two peptide chains with 21 and 30 amino acids respectively. The diagram below shows the primary structure of ox insulin. The disulphide bridges which are important in determining the tertiary structure of the protein are also displayed. The secondary structure of the insulin is determined by hydrogen bonding between the carbonyl and amino groups.



a What is meant by the following terms used in the above passage?

i 'the *primary structure* of ox insulin'; *(1 mark)*

ii 'the *secondary structure* of the insulin'. *(2 marks)*

b Draw a diagram to represent the hydrogen bonding between the carbonyl groups, C=O, and the amino groups, N—H, in the peptide chains. On your diagram show the polarity of the different atoms. *(3 marks)*

c Enzymes, like all proteins, have a precise *tertiary structure*.

i Explain why the tertiary structure of a protein is important in determining how the enzyme works. *(2 marks)*

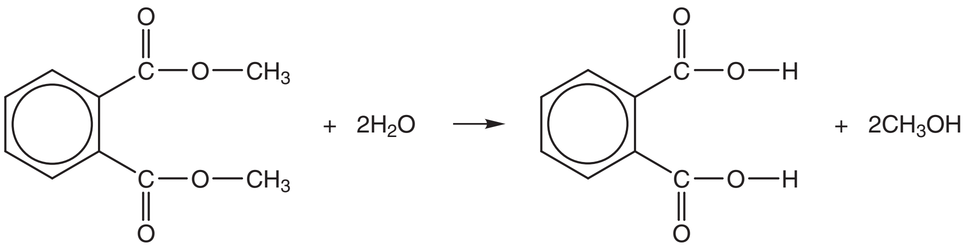
ii Enzymes lose their activity when heated. Explain this in terms of their shape and the intermolecular forces present. *(2 marks)*

iii The action of some enzymes is sensitive to pH. Explain how enzymes might be deactivated by small changes of pH that do not affect the tertiary structure. *(2 marks)*

[TOTAL: 12 MARKS]

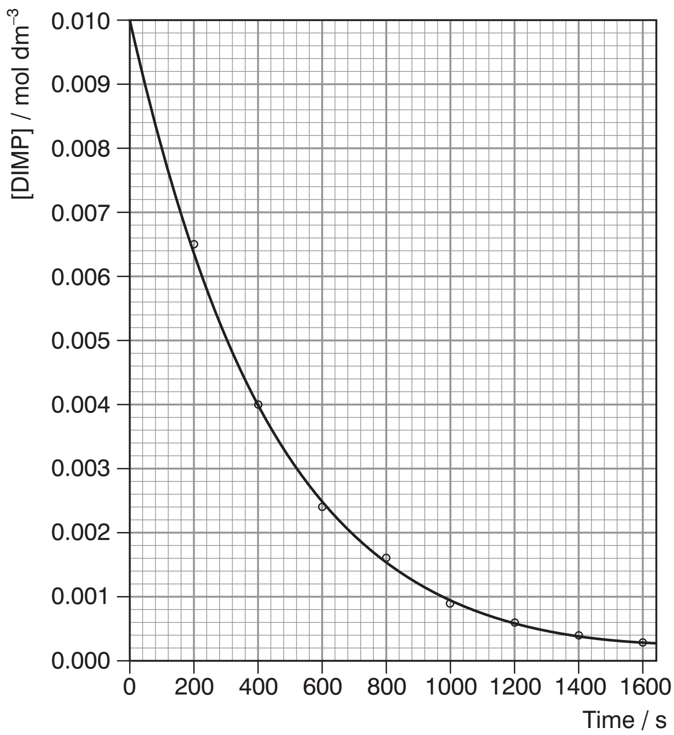
3 Forestry workers suffer badly from the bites of insects such as midges. The liquid DIMP was developed as an effective insect repellent. This is an ester called dimethylphthalate.

An experiment was set up to determine how quickly DIMP hydrolysed in acidic conditions at room temperature, according to the equation below. The concentration of DIMP in an acidic solution was determined at measured time intervals. The initial concentrations of the reactants were 0.010 mol dm^{-3} of DIMP and 0.100 mol dm^{-3} of H^{+}(aq).



a **i** Suggest a method by which the progress of the reaction could be followed (i.e. the concentration of DIMP measured at time intervals as the reaction proceeds). *(2 marks)*

ii Use the graph below to determine the **first three** half-lives of DIMP. *(3 marks)*



iii What is the order of reaction with respect to DIMP? Give a reason for your answer. *(2 marks)*

b Further experiments showed that the order of the reaction with respect to H^{+}(aq) concentration was first order. Use this information and your answer to part **a iii** to write the rate equation for the reaction. *(2 marks)*

[TOTAL: 9 MARKS]

4 Normal haemoglobin (HbA) is a protein made up of four subunits, two α chains and two β chains. People who suffer from the inherited disease *sickle-cell anaemia* make abnormal haemoglobin (HbS), in which the β chains have one amino acid in their sequence different from that in normal haemoglobin. The condition is caused by a single error in the DNA that codes for the β chain.

Messenger RNA (mRNA) molecules carry the instructions for making the protein chains from the DNA in the cell nucleus to the ribosomes, where protein synthesis takes place. Each mRNA molecule has a sequence of bases that codes for the amino acid units in the chain. Moving from the $-NH_2$ end of the β chain, these are:

	($-NH_2$ end)
mRNA for normal haemoglobin (HbA)	GUGCACCUGACUCCUGAGGAGAAG
mRNA for sickle-cell haemoglobin (HbS)	GUGCACCUGACUCCUGUGGAGAAG

a **i** Look at the sequence of bases in the mRNA for HbA and HbS and find the one that is different. Counting from the $-NH_2$ end, for which *codon* does this difference occur? (A codon is a sequence of three bases, or triplet, that codes for a particular amino acid.) *(1 mark)*

ii Use the **EP Information Sheet** provided to name the amino acid in HbA which has been replaced in HbS. *(1 mark)*

b The mRNA is made in the cell nucleus from DNA.

i Use the symbols base, sugar and phosphate to draw a diagram representing a double strand of DNA. *(3 marks)*

ii Which intermolecular forces hold the two chains of DNA together? Indicate their position on your diagram by dotted lines. *(2 marks)*

c **i** Briefly explain how genetic engineering might be used to attempt to cure sickle-cell anaemia. *(2 marks)*

ii Many people believe that the widespread use of genetic engineering is not justified. Give **one** advantage and **one** disadvantage of the technique. *(2 marks)*

[TOTAL: 11 MARKS]

5 Ethanol is widely used in the chemical industry as a solvent for organic compounds. It is manufactured by reacting ethene with steam over a phosphoric acid catalyst.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad \Delta H = -46\ \text{kJ mol}^{-1}$$

a **i** Write an expression for the equilibrium constant, K_c, for the reaction, in terms of the concentrations of reactants and products. *(2 marks)*

ii Use the information below to calculate the equilibrium concentration of ethanol vapour under these conditions. *(3 marks)*

Temperature	570 K
Pressure	60 atm
K_c	$24\ \text{dm}^3\ \text{mol}^{-1}$ at 570 K
$[H_2O(g)]$ (at equilibrium)	$0.050\ \text{mol dm}^{-3}$
$[C_2H_4(g)]$ (at equilibrium)	$0.45\ \text{mol dm}^{-3}$

b **i** Will the equilibrium constant be larger, smaller or the same at 670 K? Explain your answer. *(3 marks)*

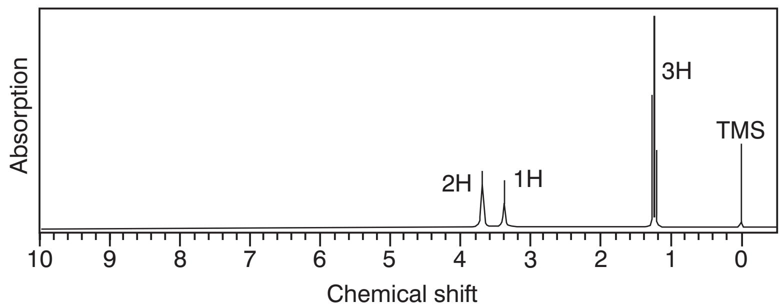
ii Describe and explain the effect of increasing the pressure in the reaction vessel on:

1 the equilibrium constant; *(1 mark)*

2 the composition of the equilibrium mixture. *(1 mark)*

iii Suggest why a higher pressure is not used for this process. *(1 mark)*

c A pure sample of one of the components of the equilibrium mixture has the low-resolution n.m.r. spectrum shown below. Use the spectrum and **Data Sheet (Table 23)** to identify the compound. Explain your reasoning.

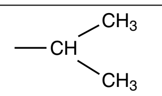
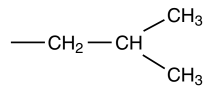
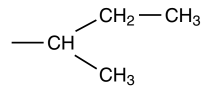
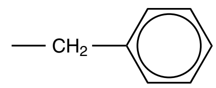
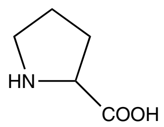
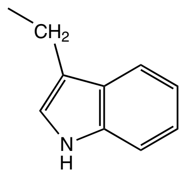
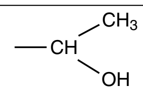


(2 marks)

[TOTAL: 13 MARKS]

(Adapted from OCR Chemistry (Salters), Paper 1, question 3, 1995)

EP INFORMATION SHEET

Amino acid	Abbreviation	R group
Glycine	Gly	—H
Alanine	Ala	$—CH_3$
Valine	Val	
Leucine	Leu	
Isoleucine	Ile	
Phenylalanine	Phe	
Proline	Pro	
Trytophan	Trp	
Serine	Ser	$—CH_2—OH$
Threonine	Thr	

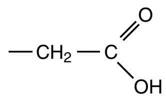
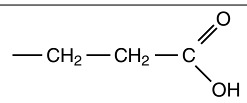
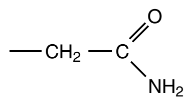
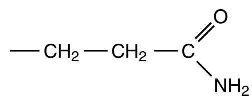
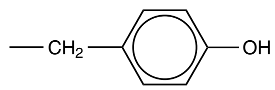
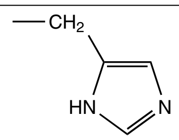
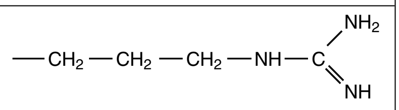
Amino acid	Abbreviation	R group
Cysteine	CysH	$—CH_2—SH$
Methionine	Met	$—CH_2—CH_2—S—CH_3$
Aspartic acid	Asp	
Glutamic acid	Glu	
Asparagine	Asn	
Glutamine	Gln	
Tyrosine	Tyr	
Histidine	His	
Lysine	Lys	$—CH_2—CH_2—CH_2—CH_2—NH_2$
Arginine	Arg	

Table 1 The twenty amino acids that make up proteins

First base	Second base U	Second base C	Second base A	Second base G	Third base
U	UUU Phe	UCU Ser	UAU Tyr	UGU Cys	U
	UUC Phe	UCC Ser	UAC Tyr	UGC Cys	C
	UUA Leu	UCA Ser	UAA Stop	UGA Stop	A
	UUG Leu	UCG Ser	UAG Stop	UGG Trp	G
C	CUU Leu	CCU Pro	CAU His	CGU Arg	U
	CUC Leu	CCC Pro	CAC His	CGC Arg	C
	CUA Leu	CCA Pro	CAA Gln	CGA Arg	A
	CUG Leu	CCG Pro	CAG Gln	CGG Arg	G
A	AUU Ile	ACU Thr	AAU Asn	AGU Ser	U
	AUC Ile	ACC Thr	AAC Asn	AGC Ser	C
	AUA Ile	ACA Thr	AAA Lys	AGA Arg	A
	AUG Met	ACG Thr	AAG Lys	AGG Arg	G
G	GUU Val	GCU Ala	GAU Asp	GGU Gly	U
	GUC Val	GCC Ala	GAC Asp	GGC Gly	C
	GUA Val	GCA Ala	GAA Glu	GGA Gly	A
	GUG Val	GCG Ala	GAG Glu	GGG Gly	G

Table 2 The triplet base codes (codons) for each amino acid used in messenger RNA