2013 H2 Chemistry Prelim Examinations Paper 3 Suggested Solutions

1	Pho som vers	sphorus is the thirteenth element in the world to be discovered and due to this is netimes referred to as the Devil's element. The reference is also made due to its satility in forming chemical species with explosive of toxic natures.							
	(a)	One	One example of a highly reactive phosphorus-containing ion is phosphonium, PH_4^+ .						
		(i)	(i) Write a balanced chemical equation for the reaction between phosphonium iodide and potassium hydroxide to form phosphine, PH_3 .						
			$PH_4I + KOH \rightarrow PH_3 + KI + H_2O$						
		(ii)	Hence, suggest a suitable method of measuring the rate of reaction.						
			Volume of gas produced / Pressure increase						
		(iii)	Draw a 'dot-and-cross' diagram showing the electrons (outer shells only) in the phosphonium ion, and use the VSEPR (valence shell electron pair repulsion) theory to predict its shape. You may find both a written description and a 3-dimensional sketch useful in your answer.						
			$ \begin{pmatrix} H \\ H \\ H \end{pmatrix}^{+} \begin{pmatrix} H \\ H \end{pmatrix}^{+} \end{pmatrix}^{+} $ There are <u>4 bond pairs</u> of electrons around the P atom. To minimise repulsion, the <u>4 electron pairs</u> are <u>directed to the corners of a tetrahedron</u> . Shape of PH ₄ ⁺ : <u>tetrahedral</u>						
		(iv)	The bond angle in ammonia is 107.8°.						
			Predict the $H - P - H$ bond angle in phosphine and justify your answer. [7]						
			H–P–H bond angle: any specific angle between 90° and 107.8°						
			<u>N atom is more electronegative</u> than P atom. The bond pair is pulled closer towards the N atom. <u>Bond pair-bond pair repulsion is greater</u> in NH ₃ . Hence, the <u>bond angle in PH₃ is smaller</u> than that in NH ₃ . FYI: Because PH ₃ is trigonal pyramidal in shape, the bond angle should also be larger than that in a molecule with a trigonal bipyramidal shape. Hence, bond angle in PH ₃ is larger than 90°.						



(c)	Two I	resonance structures exist to stabilise the ylide used in step ${f III}$ above.					
	$ \begin{array}{c} & & \\ & & $						
	In this acidio	s step, tetrahydrofuran, THF, is used as an aprotic solvent – one that lacks an c hydrogen.					
	(i)	Explain why, unlike phosphorus, nitrogen cannot form organic compounds similar to ylides.					
		Nitrogen is a <u>period 2</u> element and does not have <u>available, low-lying d</u> orbitals in its valence shell to accommodate electrons.					
		Hence, it <u>cannot expand beyond the octet structure</u> .					
	(ii)	Explain why THF is a suitable solvent to employ in step III whereas water is not. [4]					
		Water is a protic solvent that <u>can release H⁺ ions to protonate the negatively-</u> charged C atom of the ylide, thus curbing the Wittig reaction.					
		An aprotic solvent like THF prevents neutralisation of the ylide.					
(d)	β -carotene is a food colouring that can be extracted from the pigmentation found in red-orange plants and fruits such as carrots. It can be synthesised using excess of an aldehyde and a diylide , a compound with two equivalents of phosphorus in its structure.						
		β-carotene					
	Sugg 6 stei	est the structures of the aldehyde and a symmetrical diylide with reoisomers that can be used to produce β -carotene. [2]					

	o
	The 6 possible stereoismers C-C-C T-T-T T-C-C (Same as C-C-T) T-T-C (Same as C-T-T) T-C-T C-T-C
(e)	Compounds X and Y are isomers that can undergo the Wittig reaction with the following ylide. $ \begin{array}{c} & & \\ $
	The products formed have the same molecular formula, C_7H_{14} , but only the product formed from X displays stereoisomerism. X and Y both do not react with ammonical silver nitrate.
	Draw the structures of X and Y. [2]
	X:
	Y:



2	(a)	Deuterium (symbol D or ${}^{2}_{1}$ H) was discovered in 1931. Deuterium accounts for approximately 0.0156% of all the naturally occurring hydrogen in the oceans, while the most common isotope (hydrogen-1) accounts for more than 99.98%. Chemically, deuterium behaves similarly to ordinary hydrogen.							
		(1)	On the same diagram, sketch how a beam of singly positively-charged deuterium ions and a beam of hydrogen ions will behave in an electric field.						
			In your diagram, indicate clearly the angle of deflection for each beam.						
			Diagram should show charged deuterium ion deflecting less than hydrogen						
			Deuterium ion and hydrogen ion must deflect in the same direction.						
			Since angle of deflection \propto e/m ratio: \angle of Deuterium ion is half of \angle of hydrogen ion						
		(ii)	Suggest the difference in the melting point and thermal stability of DC <i>l</i> , DBr and DI.						
			For melting point:						
			Number of electrons: DC <i>l</i> < DBr < DI						
			Extent of van der Waals' forces of attraction: DC <i>l</i> < DBr < DI Energy required to over come the VDW: DC <i>l</i> < DBr < DI Melting point: DC <i>l</i> < DBr < DI						
			For thermal stability: Bond length: DC <i>l</i> < DBr < DI Energy required to overcome the covalent bond: DC <i>l</i> > DBr > DI Thermal stability: DC <i>l</i> > DBr > DI						
		(11)							
		(111)	Chloride and iodide ions are known to react differently with concentrated deuterium sulfate, D_2SO_4 .						
			For the reaction involving iodide, it was observed that the yield of DI was significantly lower as compared to the yield of DC l for the reaction using chloride. It was also noted that a foul rotten egg smell was detected for the reaction involving the iodide.						
1			With reference to the Data Booklet and with the aid of equations, explain						
			the above mentioned observations.						
1									

		From the Data Booklet			
		$Cl_2 + 2e \rightleftharpoons 2Cl^- +1.36V$			
		$I_2 + 2e \rightleftharpoons 2I^- +0.54V$			
		E [•] value of I ⁻ is less pos	itive, it is a stroi	nger reducing ager	it as
		compared to Cl thus I has	s the ability <u>to redu</u>	ice the sulfur to a lo	ower
		oxidation state			
		For chloride:			
		$Cl^{-} + D_2SO_4 -$	$\rightarrow DSO_4^- + DCl$		
		For indida.			
		Foi louide.			
		(1) $T + D_{2}$		T	
		(1) $1 + D_{2}$ (2) $8DI + I$	$0.504 \rightarrow 4I_0 + D_0$	$S + 4D_0O$	
				0 1 1020	
		The foul rotten egg smell w	as due to the relea	se of D ₂ S.	
		Reason for low yield of DI			
		The yield for DI is lower due	e to further reaction	n with concentrated E	0 ₂ SO ₄
		Or The second second sector is the	C h - h		
		I here are by-products in th	e reaction betweer	1 and $D_2 SO_4$ nence	
		allected the yield of DI.			
(b)	Deut	erium can replace the norm	al hydrogen in wa	ter molecules to forr	n heavy
()	wate	r, D_2O . This difference incre	ases the strength	of water's hydrogen	-oxygen
	bond	s which make it more difficul	t to undergo electro	olysis.	
	•				
	Som	e data between light water ar	nd heavy water are	given below.	
		Property	D-O	H.O	
		Topony	(Heavy water)	(Light water)	
		Freezing point (°C)	3.82	0.00	
		Boiling point (°C)	101.4	100.0	
		Density at standard	1.1056	0.9982	
		condition (g/mL)			
	Heav	y water and light water can	be tested using the	eir freezing points and	d boiling
	point	ა.			
	Suac	est with reasoning, how a se	cientist can deplov	another physical m	ethod to
	differ	entiate the two types of wat	er without the use	of a temperature me	asuring
	devid	e.		·	0
					[2]
	Free	ze the heavy water and ligh	nt water separatel	<u>y.</u>	
	Dron	the heavy water ice cube	and light water ic	e cube into a glass	of light
	wate	r. Heavy water having a hi	aher density than	light water will sin	k in the
	alas	s of light water.	gner denoity than		
	<u></u>				

(c)	Durir	ng World War II, German scientists were known to conduct experiments						
	usinę	g heavy water.						
	(i)	With reference to the bond length data below, determine why it is more difficult for heavy water, D_2O , to undergo electrolysis process as compared to light water, H_2O .						
		Bond type Bond length (m) $Cl-Cl$ 1.76×10^{-10} $D-Cl$ 1.27×10^{-10} $H-Cl$ 1.29×10^{-10}						
		Using C <i>l</i> -C <i>l</i> , the atomic radius of $Cl = (1.76 \times 10^{-10}) \div 2 = 8.8 \times 10^{-11} \text{ m}$						
		Using the atomic radius of C <i>l</i> and the bond length of D-C <i>l</i> Atomic radius of D = $(1.27 \times 10^{-10}) - (8.8 \times 10^{-11}) = 3.9 \times 10^{-11}$ m						
		Using the atomic radius of Cl and the bond length of D-Cl Atomic radius of H = $(1.27 \times 10^{-10}) - (8.8 \times 10^{-11}) = 4.11 \times 10^{-11}$ m						
		Since the atomic radius of oxygen in D ₂ O and H ₂ O is constant, The bond length of D-O in heavy water will be shorter than that of H-O						
		OR OR <u>More energy will be required to overcome the stronger D-O bonds</u> and this it will be <u>more difficult for heavy water to undergo electrolysis.</u>						
	(ii)	Heavy water is processed via electrolysis with a concentrated potassium hydroxide-light water mixture.						
		During the process, oxygen gas is produced at the anode and hydrogen gas is produced at the cathode.						
		Write chemical equations for the reactions happening at the anode and cathode and suggest how heavy water can be obtained from the mixture of concentrated potassium hydroxide and light water.						
		Anode reactions: Due to high concentration of OH^{-} , selective discharge will occur. $4OH^{-} \rightarrow O_{2} + 2H_{2}O + 4e^{-}$						
		When all OH ⁻ ions have completely reacted the light water molecules will then react as follows:						
		2H ₂ O → 4H ⁺ + 4e + O ₂ At the <u>cathode</u> , reduction of light water will occur: 2H ₂ O + 2e → H ₂ + 2OH ⁻						
		Ultimately due to the cathode and anode reactions, <u>all light water will be</u> transformed to H_2 gas and O_2 gas which can be easily removed from the solution. Heavy water can then be separated from the potassium ions by distillation.						

) Suggest why distillation is not effective as the initial stage of in separating heavy water from the potassium hydroxide-light water mixture.	(iii)	
The boiling point of light water and heavy water is too close for distillation to take place effectively.		
8]		
[Total : 20		

3	Chlorine is often used as a disinfectant in swimming pools to remove organic molecules and pathogens. The disinfecting action is due to the presence of hypochlorous acid, $HClO$, and chlorate(I) ion, OCl^{-} formed by the reaction of chlorine with water.								
		$Cl_2(aq) + H_2O(l) \rightleftharpoons HClO(aq) + H^+(aq) + Cl^-(aq) (1)$							
	Ну	pochlo	prous acid ionises as a weak acid with dissociation constant of 3 x 10^{-8} moldm ⁻³ .						
			$HClO(aq) \rightleftharpoons H^{+}(aq) + OCl^{-}(aq) (2)$						
	The hypochlorous acid and chlorate(I) ions make up 'free available chlorine' (FAC). When chlorine is added, FAC combines with the contaminants in the pool, called combined available chlorine (CAC). The total available chlorine (TAC) is the sum of free available chlorine (FAC) and combined available chlorine (CAC).								
	It is of am	s unde chlorc ount c	esirable when CAC exceeds 0.2 ppm as chloroamines are produced. The removal bamines, known as breakpoint chlorination, is achieved by adding appropriate of sodium hypochlorite, NaOC <i>I</i> , as follows:						
		Gallo	ns of sodium hypochlorite needed to reach breakpoint chlorination						
		_ <u>po</u>	ol volume (in gallons) x 8.3 x combined available chlorine(ppm) x 1.0 x 10						
			1 000 000						
	(a) Sodium hypochlorite (NaOC <i>l</i>) is a compound that can be effectively used for water purification. It can be readily made with the use of caustic soda, NaOH and chlorine, at cold temperatures.								
		(i)	With the aid of a chemical equation, suggest what complication can be avoided when this process is carried out in cold temperature						
			In hot conditions, <u>further disproportionation</u> occurs where oxidation number of Cl increases from +1 to +5 in ClO_3^- and decreases from + 1 to -1 in Cl , which is undesirable. 6NaOH (aq) + $3Cl_2$ (g) $\rightarrow 5NaCl$ (aq) + $NaClO_3$ (aq) + $3H_2O$ (<i>I</i>)						
		(ii)	 (ii) Using the data above, calculate the number of gallons of sodium hypochlorite needed to reach breakpoint chlorination for a 120, 000 gallon pool given that TAC = 1.5 ppm and FAC = 0.7 ppm respectively. 						
			Leave your answer in <u>2</u> significant figures.						
			TAC = FAC + CAC						
			CAC = 0.8 ppm						

		Gallons of sodium hypocrite needed to reach breakpoint chlorination								
		= $\frac{\text{pool volume}(\text{in gallons}) \times 8.3 x \text{ combined available chlorine } \times 1.0 x 10}{100}$								
		- 1000000								
		$=\frac{120,000 \times 8.3 \times 0.8 \times 1.0 \times 10}{1000 \times 1000 \times 1000}$								
		1,000,000								
		= 8.0 gallons								
(h)		entrol is acceptial in the maintenance of the peak water and it was found that it								
(u)	shou	Id be maintained at an optimum pH of 7.4. When sodium hypochlorite is added to								
	swim	ming pool, it increases the pH and often, acid is added to regulate it to the								
	optin	num pH.								
	(i)	Using the equations and any relevant information from the question, comment								
		on why the pool waters have to be maintained at a pri of 7.4.								
		[You may consider the use of Le Chatelier's Principle in your explanation.]								
		The pool water needs to maintain the ratio of [HCIO] and [OCI] for buffering								
		capacity at pH of 7.4.								
		By Le Chatelier's Principle,								
		When pH is too alkaline, [H ⁺] decreases and the position of equilibrium in (2) will shift to right to produce more H ⁺ , [HCIO] decreases and [OCI] increases								
		When pH is too acidic, [H ⁺] increases and the position of equilibrium in (2) will shift								
		TO LETT TO LEGACE THE H , THOUS INCREASES and TOOL I decreases								
		A compromise of pH 7.4 is used.								
	(ii)	Calculate that the ratio of the concentration of OCl^{-} to HClO when the pH of the pool is at pH 8.0								
		$Ka = \frac{[H^+][ClO^-]}{[ClO^-]}$								
		[HClO]								
		$(10^{-8})[OCl^{-1}]$								
		$3 \times 10^{-\circ} = \frac{1}{[HOCl]}$								
		$\frac{[OCl^{-}]}{[HOCl]} = 3.00$								

(iii) Using your ratio in (c)(ii) and taking the concentration of HOCl to be x mol dm⁻³, what is the mass of HC*l* that should be added to 1 dm³ of swimming pool water so that the pH can be brought back down to the optimum pH of 7.4. Leaving your answer in term of *x*. [7] When acid is added: $H^+ + OCl^- \rightarrow HClO$ From (c)(ii) [HOCl] = x,[OCl] = 3xLet the [HCl] added be y When H⁺ is added to the buffer solution, H⁺ + OC $l \rightarrow$ HClO $7.4 = -\lg 3 \times 10^{-8} + \lg \frac{[salt]_{new}}{[HOCl]_{new}}$ $7.4 - 7.5229 = \lg \frac{3x - y}{x + y}$ $0.7535 = \frac{3x - y}{x + y}$ $y = 1.281x \text{ mol dm}^{-3}$ y = 1.281x (36.5) = 46.8 x g dm⁻³ (C) Disinfection by chlorination can be detrimental to health as chlorine can react with naturally occurring organic compounds found in the pool to produce disinfection byproducts (DBPs). The most common DBPs are trihalomethanes (THMs). (i) State the type of reaction and the condition that optimises the formation of THMs. Free radical substitution and uv light (ii) Outline **only** the propagation step in the formation of trichloromethane, a type of THM. **Propagation:** $\begin{array}{rcl} \mathsf{CH}_2 \, \mathsf{Cl}_2 & + & \mathsf{Cl} \bullet & \rightarrow & \mathsf{CH} \, \mathsf{Cl}_2 \bullet & + & \mathsf{HCl} \\ \mathsf{CH} \, \mathsf{Cl}_2 \bullet & + & \mathsf{Cl}_2 & \rightarrow & \mathsf{CH} \, \mathsf{Cl}_3 & + & \mathsf{Cl} \bullet \end{array}$

	(iii)	The selectivity of the radical reactions can be predicted mathematically based on a combination of an experimentally determined reactivity factor, R _i , and a statistical factor, nH _i . In order to use the equation shown below, we need to look at our original alkane and look at each H in turn to see what product it would give if it were to be substituted. The following formula and data can be used effectively to determine the percentage yield of substituted halogenoalkanes for methane.						
		$\%P_i = -$	20				Reactivity	
			viold of product ("				Br	Cl
		where $\%P_i = \%$	imber of H of type	<i>'i</i> '	Methyl /	1°	1	1
		$R_i = re$	activity factor for type	vpe 'i'		2° 30	82	3.9
						3	1040	5.2
		Using the inform methane underg	ation provided, de oes free radical su	educe w Ibstitutio	which is the	predo ess ch	minant sp Iorine gas	ecies when
		Туре	Organic Cpd	nH _i		R _i		_
		methyl	H	4		1		
			H-C-H H					
		1 ⁰	H	3		1		
			H-C-C <i>l</i> H					
		2 ⁰	H	2		3.9		
			H-C-Cl Cl					
		3 ⁰	H	1		5.2		
			$Cl - \dot{C} - Cl$					
			Cl					
		For monosubstitut For disubstitututed For tri-substituted For tetra-substituted	ed methane = $(4/20)$ d methane= $(3/20)$ methane = $(7.8/20)$ ed methane = $(5.2/2)$) x 100 = x 100 = x 100 = 0) x 100	= 20% 15% 39%) = 26%			
		Trichloromethan	<u>e is the pred</u> ominant	species	s as it forms	<u>the mo</u>	<u>st stab</u> le ra	dical.
	(iv)	Suggest a propert	y of chlorine that allo	ows it to	act as a disi	nfectar	nt in swimm	ing pools.
		As a <u>strong oxi</u> [Chlorine and its therefore easily pe	dising agent, chlor hydrolysis product enetrate the negative	rine kills t hypoc ely charg	s via the ox hlorous acio ged surface o	idation d are of patho	of organic neutrally c ogens.]	c molecules. harged and
								[6]



[Total : 20]



(c)	In re heat resid	In reaction I , an exothermic reaction is initiated when ammonium dichromate(VI) is heated. Two colourless and odourless gases are evolved leaving only solid residue X , a grey-green powder.					
	By using oxidation numbers, and showing all your working, identify the two gases evolved and construct a balanced equation for the decomposition. [3]						
	N₂(g) and H ₂ O(g)					
		$(NH_4)_2Cr_2O_7 \rightarrow Cr_2O_3 + N_2 + 4H_2O$					
	[Oxio	d no: N(-3)Cr(+6) Cr(+3) N(0)]					
	(Gases formed are colourless and odourless, so they cannot be NH_3 or NO_2 . Since oxidation state of Cr decreased from +6 to +3, oxidation state of the other element must have increased. In the reactant, H has O.S. of +1 and cannot be oxidised further. Hence, N could have been oxidised from -3 to 0 oxidation state, forming N_2 . The other gas formed is H_2O .)						
(d)	In reaction II , sulfur is added to the reaction. X and a sulfur-containing product with the oxidation state +6 is formed.						
	(i) Suggest the role of sulfur.						
		Reducing agent					
	(ii)	Write a balanced ionic equation, including state symbols, to illustrate					
		[2]					
		$Cr_2O_7^{2-}(aq) + S(s) \rightarrow SO_4^{2-}(aq) + Cr_2O_3(s)$					
(e)	In re alum	eaction III, the extraction of chromium involves a thermite reaction of X with inium, which is a displacement reaction.					
	(i)	Write a thermochemical equation for the Thermite reaction.					
		$Cr_2O_3(s) + 2Al(s) \rightarrow 2Cr(s) + Al_2O_3(s) \Delta H < 0$					
	 (ii) By quoting and using relevant E[⊕] values from the <i>Data Booklet</i>, explain why the extracted chromium metal dissolves in dilute sulfuric acid to give a blue solution but turns green slowly even in the absence of air. [5] 						
	$Cr^{2+} + e \qquad \qquad$						

		$2Cr^{2+}(aq) + 2 H^{+}(aq) \rightarrow 2Cr^{3+}(aq) + H_2(g)$ $E^{\ominus}_{cell} = +0.41 V > 0$, feasible T <u>he H⁺ acts as oxidising agen</u> t, oxidising the metal Cr to blue Cr ²⁺ to the green Cr ³⁺ (or eqn). Reaction is <u>slow</u> because of <u>2 positively-charged ions reacting</u> .						
(f)	In reaction IV, describe and explain what happens when warm aqueous sodium hydroxide is added to aqueous ammonium dichromate(VI) solution. You should include suitable observations and balanced equations for any reactions that occur.							
		L ·						
	NH₃ solut NH₄ ⁺ Cr₂O	gas evolved turns moist red litmus blue and orange dichromate(VI), $Cr_2O_7^{2-}$, ion turns yellow as chromate(VI), $CrO_4^{2^-}$ is formed. + $OH^- \rightarrow NH_3 + H_2O_7^{2^-} + 2OH^- \rightarrow 2CrO_4^{2^-} + H_2O_7^{2^-}$						
		Total 20 marks						

5	5 Haemoglobin in the blood carries oxygen from the respiratory organs to the rest of the body (i.e. the tissues) where it releases the oxygen to burn nutrients to provide energy to power the functions of the organism, and collects the resultant carbon dioxide to bring it back to the respiratory organs to be dispensed from the organism.									
	(a)	With quat	Nith reference to the haemoglobin (Hb) molecule, describe what is meant by the term quaternary structure of proteins.							
		Qua com are r Hae each	aternary structure of proteins consists of <u>more than one polypeptide chain</u> ming together to form the <u>complete protein</u> maintained by the same forces that e responsible for tertiary structure. aemoglobin consists of 4 polypeptide chains: 2 α-sub-units and 2 β-sub-units, with ch sub-unit being non-covalently bonded to a baem (iron) group							
	(b)	One the f	molecule of haemoglobin can bind up to four molecules of oxygen, according to ollowing equation. Hb (aq) + 4O₂ (aq) □ Hb(O₂)₄ (aq)(1) bon monoxide reacts with haemoglobin in the same way as oxygen. Hb (aq) + CO (aq) □ HbCO (aq)(2)							
		(i)	Briefly explain how a haemoglobin molecule carries oxygen and why carbon monoxide is toxic to the human body.							
			Iron found in haem group <u>binds reversibly with oxygen</u> to form oxyhaemoglobin, which supplies oxygen to cells in the rest of the body. <u>Stronger ligands like CO</u> bond <u>irreversibly</u> with haemoglobin and this prevents the haemoglobin from carrying oxygen.							
		(ii)	Write an expression for K_c for reaction 1, stating its units.							
			$K_{C} = \frac{[Hb(O_{2})_{4}]}{[Hb][O_{2}]^{4}}$ Units: mol ⁻⁴ dm ¹²							
		(iii)	Experiments have shown that when the concentration of O_2 (aq) is 7.6 x 10 ⁻⁶ mol dm ⁻³ , the concentrations of Hb and Hb(O_2) ₄ are equal. Use this information to calculate a value of K _c .							
			Since [Hb] = [Hb(O ₂) ₄] $K_{c} = \frac{1}{[O_{2}]^{4}}$ $K_{c} = \frac{1}{(7.6 \times 10^{-6})^{4}} = 3.00 \times 10^{20} mol^{-4} dm^{12}$							
		(iv)	Use your value of K _c in (b)(iii) to calculate the percentage of Hb converted to							

Hb(O ₂) ₄ when the concentration of O ₂ (aq) is increased to 2.40 x 10^{-5} mol dm ⁻³ . [8]						
$K_{c} = \frac{[Hb(O_{2})_{4}]}{[Hb][O_{2}]^{4}}$ $3.00x10^{20} = \frac{[Hb(O_{2})_{4}]}{[Hb](2.40x10^{-5})^{4}}$ $\frac{[Hb(O_{2})_{4}]}{[Hb]} = 99.53$ Hence, 99.5% of Hb is converted to Hb(O_{2})_{4}.						
In the formation of haemoglobin, the primary structures of the polypeptide chains of haemoglobin are first formed from their constituent amino acids, eg lysine, serine and alanine. $H_2N-CH-COOH H_2N-CH-COOH H_2N-CH-CH-COOH H_2N-CH-CH-COOH H_2N-CH-CH-COOH H_2N-CH-CH-COOH H_2N-CH-CH-COOH H_2N-CH-CH-COOH H_2N-CH-CH-COOH H_2N-CH-CH-COOH H_2N-CH-CH-CH-CH-CH-CH-CH-CH-CH-CH-CH-CH-CH-$						
In the presence of haem groups, these polypeptide chains spontaneously coalesce into a haemoglobin molecule. By considering the chemical interactions involved at each step, suggest what the signs of ΔG , ΔH and ΔS would be for the overall process. Explain your reasoning. [3]						
$\frac{\Delta H \text{ should be negative}}{\Delta S \text{ should be negative}} \text{ because } \frac{\text{bonds are being formed}}{\Delta S \text{ should be negative}} \text{ as the degree of disorder is decreased as the chain coil or come} \\ \frac{\Delta S \text{ should be negative}}{\Delta S \text{ should be negative}} \text{ as the degree of disorder is decreased as the chain coil or come} \\ \frac{\Delta G \text{ should be negative}}{\Delta G \text{ should be negative}} \text{ because the } \frac{\text{reaction is spontaneous}}{\Delta S \text{ should be negative}}.$						
Proteins can be denatured using heavy metals ions such as Fe ³⁺ (aq). Explain how this denaturation occurs. [1] Disrupt the original ionic bonds between charged R groups by forming new ionic bonds with these charged R groups. OR Disrupt the disulfide bonds by forming bonds with the -S group of cysteine						

(e)	The stability constant, K_{stab} , is an equilibrium constant for equilibrium that exists between a transition metal ion surrounded by water molecule ligands and the same transition metal ion surrounded by the ligands of another kind in a ligand displacement reaction. Some of the K_{stab} for iron-based complexes are listed in the table below.									
			Complex formed	K _{stab} of complex	Colour					
			[Fe(H ₂ O) ₅ (SCN)] ²⁺	9.17 x 10 ²	Deep Red					
			$[Fe(H_2O)_5(F)]^{2+}$	2.40 x 10 ⁵	Colourless					
			[FeC <i>I</i> ₄] ⁻	8.00 x 10 ⁻¹	Yellow					
			[Fe(CN) ₆] ³⁻	4.08 x 10 ⁵²	Orange					
	(i)	From the data above, suggest why the K_{stab} value for $[Fe(CN)_6]^{3-}$ is extremely large.								
		CN⁻is a '	very strong ligand, as a	a result forms very s	table complex.					
	(ii)	Use the data in the table to predict what will be observed when a solution of $[Fe(H_2O)_5(SCN)]^{2+}$ is treated with sodium fluoride.								
		Since the K_{stab} for $[Fe(H_2O)_5(F)]^{2+}$ is larger as compared to $[Fe(H_2O)_5(SCN)]^{2+}$, ligand exchange will happen and the <u>colour changes from deep red to</u> <u>colourless</u> .								
	(iii)	Explain why $[Fe(H_2O)_5(F)]^{2+}$ forms a colourless complex.								
		F ⁻ is a <u>weak field ligand</u> which caused <u>ΔE to be very small</u> . As a result the <u>energy required to cause the d-d transition falls outside the visible</u> <u>region</u> of the electromagnetic spectrum.								
	(iv)	In the presence of thiocyanate ions, $[Fe(H_2\Omega)_2]^{3+}$ is able to undergo ligand exchange								
	()	reaction a	as shown below:			,				
		$[Fe(H_2O)_6]^{3+} (aq) + SCN^{-} (aq) \longrightarrow [Fe(H_2O)_5(SCN)]^{2+} (aq) + H_2O (aq)$ Yellow Blood-red								
		Silver ions also react with thiocyanate ions to form a white precipitate, AgSCN.								
		State the observation when aqueous silver ions are added to the above equilibrium. Explain your answer.								
		The inten	sity of red colour of the s	olution will decrease /	solution changes	رم <u>ا</u> from blood-red				
		to yellow. Silver ions react with thiocyanate ions, causing the concentration of SCN ⁻ to decrease. By Le Chatelier's Principle, addition of aqueous silver ions will cause the <u>position of</u> <u>equilibrium</u> to shift to the <u>left</u> to <u>increase</u> the concentration of SCN ⁻ .								

Total 20 marks