1		Planning	
		The benzenediazonium ion, $C_6H_5N_2^+$ , reacts with water as shown in the equation.	
		$C_6H_5N_2^+$ (aq) + $H_2O$ ( <i>l</i> ) ® $C_6H_5OH$ (aq) + $N_2$ (g) + $H^+$ (aq)	
		At temperatures below 10 °C, the reaction is very slow. However, nitrogen gas is evolved	
		at a measureable rate at temperatures of 20 °C and above.	
		In this experiment, you are provided with an aqueous solution containing 0.100 mol dm <sup>-3</sup> of	
		the benzenediazonium ion at a temperature below 10 °C.	
		You are required to design an experiment to deduce the order of reaction with respect to	
		$C_6H_5N_2{}^{\scriptscriptstyle +}$ of an aqueous solution at 20 $^{o}C$ and an atmospheric pressure of 101 kPa.	
	(a)	Define the term order of reaction.	[1]
		Order of reaction with respect to a reactant is the power of the concentration of that	,
		reactant in the experimentally determined rate equation.	
	(b)	Outline the steps you would take to determine the order of reaction with respect to	
		$C_6H_5N_2^+$ (aq) at 20 °C. In your plan, include the following details:	
		- a suitable volume of $C_6H_5N_2^+$ (aq) used,	
		- measurements to be taken,	
		- plotting of a suitable graph, if any.	[5]
		Assume <u>50 cm<sup>3</sup></u> of nitrogen gas to be collected. (Volume chosen has to be large enough	
		for sufficient volume of $C_6H_5N_2^+$ solution used)	;
		Using $pV = nRT$ ,	
		Amount of nitrogen gas to be collected = 0.002074 mol	
		= Amount of $C_6H_5N_2^+$ required	
		Thus, minimum volume of $C_6H_5N_2^+$ needed = 0.002074 / 0.1 = 20.7 cm <sup>3</sup>	;
		(To use 25 cm <sup>3</sup> of $C_6H_5N_2^+$ )	
		Use a water bath (no naked flame) to maintain a temperature of 20 °C for the reaction	;
		mixture.	
		Record the volume of nitrogen produced over regular time intervals of 5 minutes.	;
		A graph of volume of nitrogen produced against time is plotted.	;
		A graph of volume of nitrogen produced against time is plotted.	•

(c)	Draw a labelled diagram of the experimental set-up.	
	[You may assume that you are given common apparatus found in a school laboratory.]	[2]
	1 mark for suitable apparatus (use of well-greased gas syringe to collect nitrogen gas),	
	well-labeled.	
	1 mark for feasibility of set-up	
(d)	Describe how you will use the results obtained to determine the order of reaction with	
	respect to $C_6H_5N_2^+$ (aq).	[2]
	From the graph of volume of nitrogen produced against time plotted, determine the time	
	taken for nitrogen to be produced. (time taken for 1/2 of total volume, then 3/4 of total	;
	volume, then all of nitrogen produced)	
	If the time taken is constant, order of reaction with respect to $C_6H_5N_2^+$ (aq) is one.	;
(e)	Identify one potential hazard in this experiment and suggest the safety precaution you	
	would take to overcome this.	[2]
	The organic compounds are toxic and may cause irritation when in contact with the skin.	
	Gloves should be worn during the experiment.	;
	OR	
	Conduct the experiment in a fume cupboard to present inhaling of toxic fumes.	;
	[Total: 12 marks]	



		5	
		strength of metallic bond ↑	;
		\ m.p. ↑	
		Si	
		giant covalent structure	
		large amount of energy required to break strong covalent bonds between Si atoms.	
		\ high m.p.	
		P to Ar	
		Simple molecular structure	
		weak temporary dipole – induced dipole forces of attraction between molecules	
		low m n	
		( low m.p.	
		size of electron cloud of molecules varies, $S_8 > P_4 > Cl_2 > Ar$	
		size of electron cloud of molecules ↑, strength of temporary dipole – induced dipole forces	
		of attraction ↑.	
		$\ m.p.: S_8 > P_4 > Cl_2 > Ar$	,
	(c)	Silicon reacts with oxygen to form silicon dioxide as a possible product.	
		In dentistry, a composite material based on SiO <sub>2</sub> has been developed to be used as dental	
		fillings.	
	(i)	State one property of SiO <sub>2</sub> that makes it suitable for use as dental fillings.	
		SiO <sub>2</sub> is hard and resistant to chemical attack (Unreactive towards acids in food or saliva)	•
	(ii)	Draw a diagram to illustrate the type of bonding involved in SiO <sub>2</sub> .	[2]
		Tetrahedral, similar to diamond.	;
		Each Si is bonded to 4 O atoms, and each O is bonded to 2 Si atoms	
		[Total: 9 marks]	
3		Ammonia gas decomposes into nitrogen and hydrogen when passed over a platinum	
		gauze. The rate of decomposition is found to be independent of the partial pressure of	
		ammonia at very high pressures, but the rate was directly proportional to the partial	
		pressure of ammonia at low pressures.	
	(a)	Explain this observation as far as you can.	[2]
		$2NH_3 \leftrightarrow N_2 + 3H_2$	
		When the pressure is high enough, the catalyst surface would be saturated with adsorbed	
		ammonia molecules (By LCP, equilibrium shifts left at high pressure). Any decomposition	
		products that are desorbed from the surface would immediately be replaced by incoming	:
			,

	6		
	adsorbed ammonia. Hence, rate of decor	nposition is constant.	
	At low pressure, the catalyst surface is	not saturated with adsorbed ammonia molecules.	
	Hence, rate of decomposition depends o	n the partial pressure of ammonia.	•
(b)	Given that 45% of ammonia dissociated	d into nitrogen and hydrogen at moderately high	
	temperatures, and a total pressure of 1 a	tm, calculate the value of $K_p$ , stating its units.	[3]
	2NF	$_{3} \leftrightarrow N_{2} + 3H_{2}$	
	l / mol 2	0 0	
	C/ mol -0.9	+0.45 +1.35	
	E / mol 1.1	0.45 1.35	;
	Total amount at eqm = 2.90		
	$P_{NH3} = 1.1 / 2.9 = 0.3793 atm$		
	P <sub>N2</sub> = 0.1552 atm		
	P <sub>H2</sub> = 0.4655 atm		;
	$K_p = (0.1552) (0.4655)^3 / 0.3793^2 = 0.109$	atm <sup>-2</sup> (3s.f.) (with units stated)	;

(c)	Ammonia, nitrogen and hydrogen are non-ideal gases.	
(i)	State two assumptions of the kinetic theory as applied to an ideal gas.	
	Gas particles have negligible volume as compared to the volume of the whole gas.	;
	Gas particles have negligible intermolecular forces of attraction.	;
 (ii)	Which of these three gases deviates the most from an ideal gas? Explain your answer.	
	Ammonia, due to formation of hydrogen bonding (strongest intermolecular force) between	
	its molecules. Thus, the intermolecular forces of attraction are significant.	;
(iii)	For a given fixed mass of an ideal gas, sketch graphs of:	
	I: P against V at constant T (where P represents pressure)	
	II: V against $pV$ at constant T (where $p$ represents density)	[5]
	P V V pV	,
	[Total: 10 marks]	

4		The reaction	between phenol and benzoyl	chloride produces an e	ster with	the formula	
		C <sub>6</sub> H₅COOC <sub>6</sub>	$H_5$ . Hydrogen chloride is also for	med in this reaction.			
			Name of Compound	Chemical formula	Mr		
			Phenol	C <sub>6</sub> H₅OH	94.0		
			Benzoyl chloride	C <sub>6</sub> H <sub>5</sub> COC <i>l</i>	140.5		
			?	C <sub>6</sub> H <sub>5</sub> COOC <sub>6</sub> H <sub>5</sub>	198.0		
					11		
		The crude (	impure) ester produced in the r	eaction can be purified	by recryst	tallisation in	
		<i>ethanol</i> . A ty	pical yield, based on benzoyl ch	loride is 70%.			
		[Additional ir	nfo:				
		Melting poin	t of ester: 68- 70 °C				
		Boiling point	of ester: 298- 299 °C]				
		-					
	(a)	State the na	me of the ester that is produced	in the reaction.			[1]
		Phenyl Benz	coate				
	(b)	Explain why	this reaction will not occur if	benzoic acid was use	d instead	of benzoyl	
		chloride.					[1]
		Phenol is we	eakly acidic. In the presence of a	a stronger acid (benzoyl	acid), phe	enol can act	,
		as a base to	react with benzoyl chloride to fo	rm esters.			
		1 4 1				0 1 1 1	
	(C)	in this exper	riment, only 70% of benzoyi chi	oride is converted into t	o the este	r. Calculate	
	(1)	the minimum	mass of benzoyl chloride neede	ed to form 5 g of the este	er.		
		Amount of e	ster = 5 / 198 = $0.02525$ mol = a	mount of benzoyl chlorid	e 		
		Minimum ma	ass of benzoyl chloride required :	= 100/70 x 0.02525 x 140	0.5 = <u>5.07</u>	<u>g (3s.f)</u>	,
	(!!)		de la cherra de la companya de la co				[0]
	(11)	Hence, calcu	ulate the minimum mass of phen-	or needed in the reaction	1.		[2]
		Mass of phe	noi required = $100/70 \times 0.02525$	x 94.0 = <u>3.39 g (3s.f)</u>			;
	/ P		ч. н. <i>н. н. н. н.</i> х				
	(d)	Brietly descr	be how the crude (impure) este	er produced can be purifi	ed by recr	ystallisation	
	(i)	ın ethanol.					

	8		1
	Dissolve the crude ester in hot ethanol, i	until a saturated solution is obtained. ;	
	Filter and allow the hot solution to cool	. Crystals will form upon cooling. Dry the crystals	
	using filter paper. ;		
(ii)	Suggest and explain a method that can	be used to check the purity of the ester produced.	
			[4]
	Use of melting point to check purity of th	e ester.	;
	If a pure ester is obtained, a sharp and o	distinct melting point will be obtained. If the ester is	
	impure, the ester will melt over a range of	of temperatures.	;
 (e)	Another ester, $\mathbf{P}$ (M <sub>r</sub> = 116) used in synt	hetic fruit flavors, is subjected to hydrolysis to give	
	a monoprotic acid, <b>Q</b> and an alcohol, <b>R</b> .		
	When 1.00 g of <b>Q</b> is titrated with 0.500	mol dm <sup>-3</sup> NaOH, 33.0 cm <sup>3</sup> of NaOH is required for	
	neutralization. <b>R</b> reacts with alkaline aq	ueous iodine to give a precipitate <b>S</b> . Compound <b>R</b>	
	exists as a pair of isomers, both of wh	ich are oxidized to give <b>T</b> which also reacts with	
	alkaline aqueous iodine to give the same	e precipitate <b>S</b> , and a solution <b>U</b> .	
	Identify the structures <b>P</b> , <b>Q</b> , <b>R</b> , <b>S</b> , <b>T</b> and	<b>U</b> , explaining your deductions clearly.	[8]
	Observations	Deductions	
	Mol of acid = mol of NaOH = 0.0165	Q is CH <sub>3</sub> CO <sub>2</sub> H	
	$M_r$ of $Q = 1 / 0.0165 = 60.6$		
	Calculating M <sub>r</sub> :	<b>R</b> is an alcohol with 4 carbon atoms.	
	116 + 18.0 = R + 60.0.6		
	M <sub>r</sub> of R = 73.4		
	<b>R</b> oxidizes to give <b>T</b> , and both react	<b>S</b> is CHI <sub>2</sub> (vellow ppt) and solution <b>U</b>	
	with alkaline aqueous jodine to give a	contains a sodium salt with 3 carbon	
	vellow ppt <b>S</b> and a solution <b>U</b>	atoms	
	yonow ppro and a control of	R contains a 2 <sup>0</sup> alcohol and T	
		contains a kotono	
	Provinte as a pair of isomore	P contains a chiral contor (optical	
	R exists as a pair of isomers		
		15011615)	
1			1

	5	
	R: CH <sub>3</sub> CH <sub>2</sub> CH(OH)CH <sub>3</sub>	
	S: CHI <sub>3</sub>	
	T: CH <sub>3</sub> CH <sub>2</sub> COCH <sub>3</sub>	
	U: CH <sub>3</sub> CH <sub>2</sub> COO <sup>-</sup> Na <sup>+</sup>	
	(1 mark for each unknown, a maximum of two marks for each pair of correct observations	
	and deductions)	
	[Total: 16 marks]	

5		This question discusses metals in Group I and Group II of the Periodic table.		
	(a)	For a group I element, the ease with which the following reaction occurs is indicated by its		
		electrode potential, $E^{\theta}$ . <b>M</b> (s) <b>® M</b> <sup>+</sup> (aq) + e <sup>-</sup> Reaction (I)		
		Calculate the enthalpy change of reaction (I) for Li and Na, using values given below as		
		well as relevant data from the data booklet.		
		Element (M) $\Delta H_{at}$ (M) / kJ mol <sup>-1</sup> $\Delta H_{hydration}$ (M*) / kJ mol <sup>-1</sup>		
		Li 159 -957		
		Na 107 -841	[3]	
		$\Delta H$ M(s) ® M <sup>+</sup> (ag) + e <sup>-</sup>		
		$\Delta H_{at}$ $\Delta H_{hyd}$		
		$\mathbf{M} (g) \otimes \mathbf{M}^{+} (g) + \mathbf{e}^{-} ;$		
		1 <sup>st</sup> IE		
		By Hess' Law,		
		$\Delta H = \Delta H_{at} + 1^{st} IE - \Delta H_{hyd}$		
		For Li, $\Delta H = 159 + 519 - 957 = -279 \text{ kJ mol}^{-1}$ ;		
		For Na, $\Delta H = 107 + 494 - 841 = -240 \text{ kJ mol}^{-1}$ ;		
	(b)	Comment on the relationship between the enthalpy change of Reaction (I) obtained in (a)		
		and the E <sup>e</sup> values given in the data booklet for Li and Na.	[2]	
		$Li^+ (aq) + e^- \otimes Li (s) \qquad E^{\theta} = -3.04 V$		

			10			
		Na⁺ (aq) + e⁻ ® Na (s)	E° = -2.71 V			
		The E <sup>e</sup> values mirror the	calculated $\Delta H$ value	S.		;
		The more exothermic	$\Delta H$ value for Li ca	alculated in (a) show	ws that the reaction is	
		energetically more favou	rable to form Li+. The	e more negative E <sup>θ</sup> va	alue also indicates that Li	
		is readily oxidized to Li+.				;
	(c)	The melting points of Gr	oup II oxides are giv	en in the table below		
			Oxide	Melting point / °C	]	
			MgO	2852		
			CaO	2614		
			SrO	2430		
		-	BaO	1918	-	
		L		I		
		Explain the trend in the r	nelting points.			[2]
		The melting point of the	oxides decrease dow	n the group.		
		$I = \alpha q^+ q^-$				
		$r^{+} + r^{-}$				;
		Down the group, cationic	size increases, thus	a lattice energy decrea	ases.	
		This results in decreasin	g electrostatic forces	of attraction betweer	n the cation and O <sup>2-</sup> ,	
		hence melting point decr	eases.			;
	(d)	Describe the reactions, it	f any, for magnesium	and calcium with col	d water, writing	
		equations, with state syn	nbols, for any reactio	ons taking place.		[3]
		Mg does not react with c	old water.			;
		Calcium reacts vigorous	y with cold water to	give effervescence of	hydrogen gas and a	
		white ppt of Ca(OH) <sub>2</sub> .				;
		Ca (s) + H <sub>2</sub> O (aq) $\rightarrow$ Ca(	OH <sub>2</sub> ) (s) + H <sub>2</sub> (g)			;
					[Total: 10 marks]	
					-	
6		Synthetic detergents (an	ionic, cationic and r	non-ionic) consist of a	a hydrocarbon chain and	
		polar group. As a surfac	ctant, the synthetic of	detergent is more eff	ective than conventional	
		soap in hard water – wat	er that contains diss	olved minerals such a	as Ca <sup>2+</sup> and Mg <sup>2+</sup> .	
					-	
		Anionic detergents				
		<u></u>				



11

	12	
	Reagents: Add excessCH3ClConditions: Heat; (without stating excess, no marks)	
	Mechanism: Electrophilic substitution ;	
	1 mark for correct intermediate	
	1 mark for clearly shown arrows	
	1 mark for indicating that the electrophile is $HSO_3^+$	
	(students need not know how to generate the electrophile)	
(b)	Suggest why non-ionic detergents are commonly used in dish-washing liquids.	[1]
	They do not possess charges and thus do not react with hard water. ;	
(c)	Describe a chemical test that can be used to distinguish between sodium-n-	
	dodecylbenzenesulfonate and pentaerythrityl palmitate.	
	You are to include all reagents, conditions and expected observations.	[2]
	Reagent: PCl <sub>5</sub>	
	Conditions: room temperature	;
	Observations: white fumes of HCl gas evolved for pentaerythrityl palmitate, absence of	
	white fumes for sodium-n-dodecylbenzenesulfonate	;
(d)	Apart from detergents or soap, cleaning products may also contain enzymes to degrade	
	protein-based stains. Enzymes are proteins with a specific biological activity that are	
	determined by their primary, secondary, tertiary and quaternary structures.	
(i)	Apart from its function as an enzyme, state one other function of proteins.	
	Transport and storage OR structure and shape OR regulation and defense OR Receptors	;
(ii)	Briefly describe with a well-labeled diagram, one example of a secondary structure of a	
	protein.	[3]
	Either a diagram of <i>b</i> -sheet or <i>a</i> -helix <u>with</u> a brief description.	
	<i>a-helix:</i> Helix is stabilized by hydrogen bonds which are arranged such that the O of the C=O	
	group of the n <sup>th</sup> residue points along the helix axis towards the N of the N-H group of the (n	
	+ 4) <sup>#</sup> residue Parallel b-sheet:	;
	Formed when segments of polypeptide chains lie adjacent to one another. Hydrogen	
	bonds are formed between the C=O and N-H groups of adjacent chains, and are perpendicular to the direction of the sheet. R groups of adjacent amino acid residues	
	points up or down of the sheet	

	13	
	$\begin{array}{c c} NH_{2} & NH_{2} & COOH \\ CH-R & CH-R & O= & N-H \\ R-CH & R-CH & R-CH & R-CH & R-CH \\ R-CH & R-CH & R-CH & R-CH & R-CH \\ H-N & C=O-H-N & C=O \\ CH-R & CH-R & C=O-H-N \\ R-CH & R-CH & R-CH & R-CH \\ R-CH \\ R-CH & R-CH \\ R-CH \\ R-CH \\ R-CH \\ R-$	;
(e)	The effectiveness of enzymes can be reduced by the addition of heavy metal ions such as	
	Hg <sup>+</sup> or Pb <sup>2+</sup> .	
 (i)	Explain this phenomenon.	
	Heavy metal ions disrupt salt bridges (in R groups) that are held together by opposite charges, thus causing the protein structure to unfold.	;
(ii)	Pb <sup>2+</sup> typically forms complexes that are coloured. Explain why this is so.	[4]
	Transition element complexes are coloured because of electron transition between d orbitals In a complex, the presence of ligands causes the 3d orbitals to split into 2 sets of different energies. Radiation from the visible region of the electromagnetic spectrum is absorbed when an electron moves from a d orbital of lower energy to another partially filled / unfilled d orbital of higher energy. Hence, transition element complexes are coloured.	- , , ,
	The colour seen is the complement of the colours absorbed.	
	[Total: 15 marks]	
	END OF PAPER	