Name:		Class:	

ST ANDREW'S JUNIOR COLLEGE

JC2 Preliminary Examination (suggested solutions)

Chemistry **8872/2**
Higher 1 **31st August 2016**
Paper 2 **1400 – 1600**
Candidates answer on separate paper.
Additional Materials: Writing paper, Data Booklet

READ THESE INSTRUCTIONS FIRST
Write your name and civics group 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.

Section A:
Answer **all** the questions in this section in the spaces provided.

Section B:
Answer **two** questions from this section on separate answer paper.

You are reminded of the need for good English and clear presentation in your answers. The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiners use only:

Section A

Question 1	8	Question 3	8
Question 2	8	Question 4	16
Total for Section A			40

Section B

20	20
Total for Section B	40
Total	80

This document consists of **17** pages including a blank page.

[BLANK]

Section A

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

1 (a) Magnesium and sulfur are elements of period 3. The chemistry of these two elements and their oxides is discussed in this question.

Write equations to show the reaction of each of the elements magnesium and sulfur with oxygen. State what would be observed for the reaction of sulfur with oxygen.

magesnium: $Mg(s) + \frac{1}{2} O_2(g) \rightarrow MgO(s)$
sulfur: $S(s) + O_2(g) \rightarrow SO_2(g)$

observation: Burns with blue flame to form colourless, pungent SO_2 gas.

[3]

(b) Write equations to show the reaction of the oxides formed in **(a)** with water and state the pH of the resultant solution.

$MgO(s) + H_2O(l) \rightleftharpoons Mg(OH)_2(s)$ pH = 9

$SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$ pH = 2-3

[3]

1 (c) Magnesium oxide is used extensively as a refractory material. A refractory material is one that is physically and chemically stable at high temperatures.

Explain in terms of structure and bonding, why magnesium oxide is used as a refractory material.

Magnesium oxide has a giant ionic lattice structure with strong electrostatic attraction b/w oppositely charged ions.

Hence, large amount of energy is required to overcome the strong ionic bonds and thus it has a high melting point.

[Total: 8 marks]

2 Compound **X** is non-cyclic and has the molecular formula $C_8H_{11}NO_2$. It contains an ester and **two** other functional groups.

Data about the reactions of compound **X** are given in the table below.

Reaction	Reagent	Result
1	MnO_4^-/H^+	MnO_4^- is decolouried; Colourless gas forms a white precipitate with calcium hydroxide
2	Br_2 in CCl_4	Orange solution is decolourised; one organic product, $C_8H_{11}NO_2Br_2$, is formed
3	Na	No colourless gas evolved
4	NaOH(aq), heat	Ammonia gas is evolved; 2 organic products: Compound **Y**, $C_4H_2O_4Na_2$, and alcohol **Z**, $C_4H_{10}O$, are formed

(a) (i) What is the gas that is formed in reaction **1**?

CO_2

(ii) What type of reaction takes place in reaction **1**?

Oxidation

(iii) Name the functional group that reaction **1** shows to be present in compound **X**.

Alkene

(iv) Which other reaction confirms the functional group you have named in **(iii)**. Explain your answer.

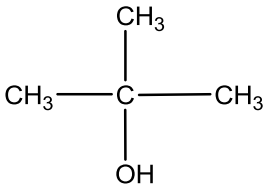
Reaction 2.

Alkene undergoes addition with Br_2. / The molecular formula shows that Br_2 is added/ refer to observations in the table.

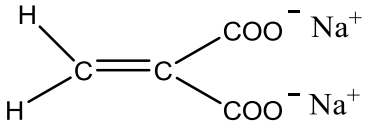
[2]

(b) Based on reaction **4,**

(i) Suggest the structure of alcohol **Z**, given that **Z** does not react with acidified potassium dichromate.



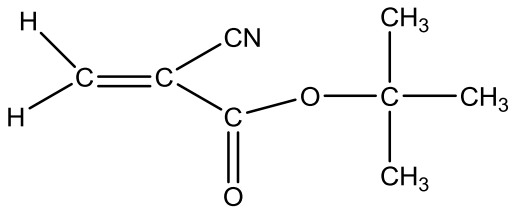
2 **(b)** **(ii)** Given the structure of compound **Y** below, explain why it does not exhibit geometric isomerism.



Y

There are identical atoms/groups attached to the same carbon in the C=C bond

(c) You now have enough information to determine the structural formula of compound **X.** Suggest the structure of compound **X.**



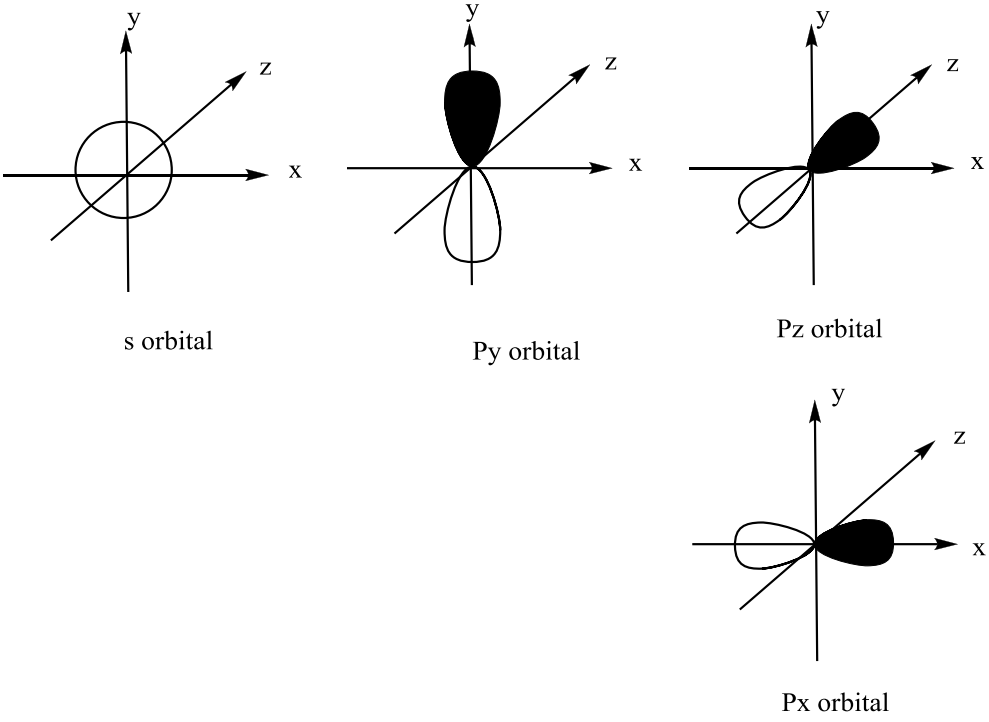
[Total: 8 marks]

3 Potassium manganate (VII) is a strong oxidising agent and can dissolve in water to give purple solution. It is often used in titration to determine the amount of Fe^{2+} ion in aqueous sample.

(a) (i) State the full electronic configuration of Fe^{2+}

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$

(ii) Sketch the shapes of the valence p and s orbitals in Fe^{2+}.



[2]

3 (a) (ii) Use the *Data Booklet* to construct an ionic equation for the reaction between acidified Fe^{2+} and manganate (VII) ions, MnO_4^-. Show your working clearly.

$Fe^{2+} \rightarrow Fe^{3+} + e$ ----- (1) x 5

$MnO_4^- + 8\ H^+ + 5\ e \rightarrow Mn^{2+} + 4H_2O$ ----- (2)

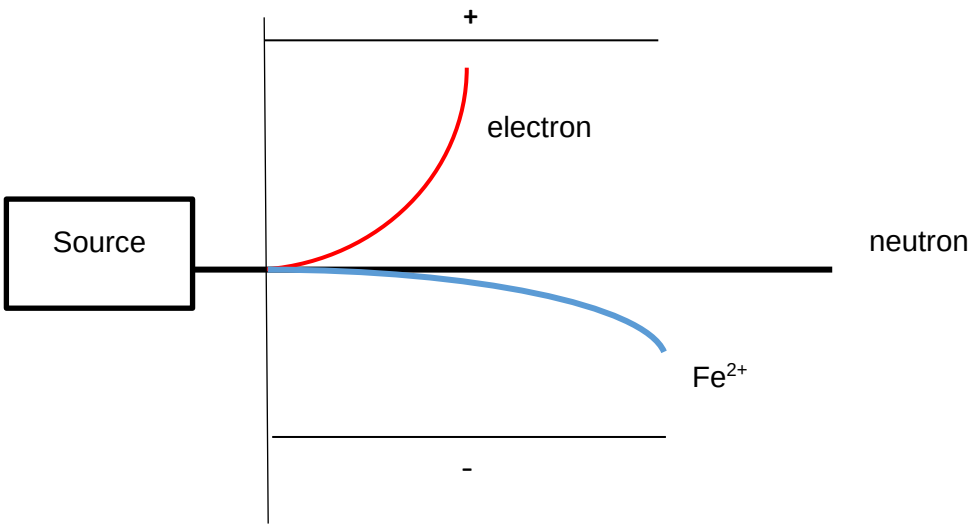
Equation 1 x 5 + Equation 2

$5\ Fe^{2+} + MnO_4^- + 8\ H^+ \rightarrow 5\ Fe^{3+} + Mn^{2+} + 4H_2O$

(iii) State what type of reaction this is.

Redox

(b) An electric field is used to separate a stream of particles emitting from a source containing Fe^{2+}, electrons and neutrons particles. Sketch in the space below, how the particles will behave in the electric field.



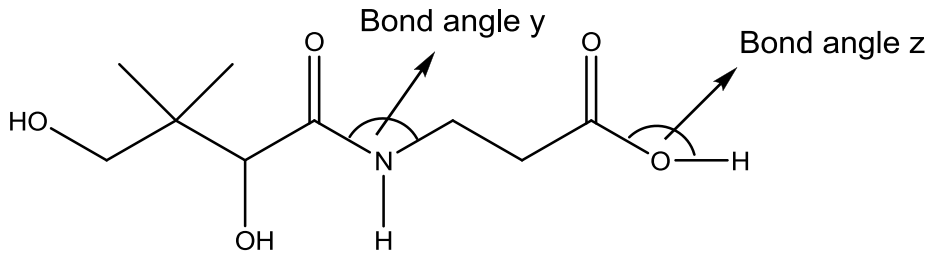
[2]

[Total: 7 marks]

4 (a) A Berocca Performance® supplement tablet contains the following ingredients. It is a multi-vitamin supplement that can be found in major supermarkets.

	Each tablet contains
Vitamin B1	15 mg
Vitamin B5	25 mg
Vitamin B6	10 mg
Vitamin C	500 mg
Nicotinamide	50 mg
Folic acid	10 mg
Calcium	100 mg
Magnesium	100 mg
Total mass	**810 mg**

The structure of the vitamin B5 molecule is shown below.



(a) State any of the 3 functional groups present in the vitamin B5 molecule above.

Primary alcohol

Secondary alcohol

Carboxylic acid

Amide

Any 3

[3]

(b) **(i)** State the bond angles, y and z. **[1]**

Bond angle y: 107^0

Bond angle z: $104.5^0/105^0$

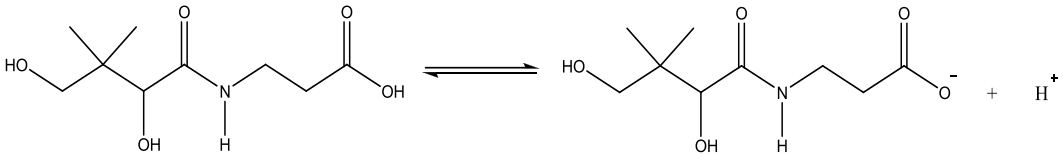
(ii) Using the VSEPR theory, explain the difference in bond angles, y and z. **[2]**

With respect to N atom, there is 1 lone pair and 3 bond pairs.
Whereas with respect to O atom, there are 2 lone pairs and 2 bond pairs.

Lone pair-lone pair repulsion> lone pair-bond pair repulsion > bond pair-bond pair repulsion.

Thus y is a larger bond angle.

(c) The acid dissociation of Vitamin B5 molecule is as shown below.



(i) The pH of stomach is 1 and the pH of blood is 6.5. Explain qualitatively how the extent of dissociation of Vitamin B5 changes as it moves from the stomach into the blood.

Less [H+] present in bloodstream (or show by calculation), position of equilibrium shifts right to replenish [H+].

Hence, the extent of dissociation of vitamin B5 increases.

(ii) The pH of Vitamin B5 is 4.4 while the pH of ethanol is 6.8. Explain.

The conjugate base of ethanol has an electron-donating alkyl group which will intensify the negative charge on O of the anion, making it less stable.

Whereas the conjugate base of vitamin B5 has its negative charge is dispersed over the 2 highly electronegative oxygen atoms (or over the O-C-O bond), making it more stable

Vitamin B5 is more acidic than ethanol.

[2]

(d) Given that blood contains 70% of water, suggest why calcium and magnesium is present as the salt form in the supplement tablet in order for it to be better absorbed into the blood stream.

The salt can form ion-dipole interaction with water hence easily absorbed in blood. [1]

4 (e) To investigate the percentage by mass of vitamin B5 in a Berocca tablet, a student dissolved the tablet and then made up to 250 cm^3 of solution in a volumetric flask. She titrated a 25.0 cm^3 portion of the solution with 2.5 x 10^{-3} mol dm^{-3} sodium hydroxide and required 10.20 cm^3 of sodium hydroxide for complete neutralisation.

(i) Suggest with explanation, a suitable indicator for the above titration.

Phenolphthalein is a suitable indicator.

The pH range of phenolphthalein lies within the rapid pH change over the equivalence point of this titration.

[2]

(ii) Assuming that only Vitamin B5 reacts sodium hydroxide, calculate the percentage by mass of Vitamin B5 in a Berocca tablet and hence state if the percentage by mass of Vitamin B5 follows the ingredient guideline.

M_r of vitamin B5 is 219

No. of moles of NaOH = $\frac{10.2}{1000} \text{ x } 2.5 \text{ x } 10 - 3 = 2.55 \text{ x } 10^{-5}$ mol

No. of moles of Vitamin B5 in (25 cm^3) = 2.55 x 10^{-5} mol

No. of moles of Vitamin B5 in (250cm^3) = 2.55 x 10^{-5} x 10

= 2.55 x 10^{-4}

Mass of vitamin B5 in a tablet = 2.55 x 10^{-4} x 219

= 55.8 mg

% mass = 55.8/810 x 100 %

= 6.89 %

The % by mass of vitamin B5 does not follow the ingredient guideline (25/810 x 100 % = 3.09%). **[3]**

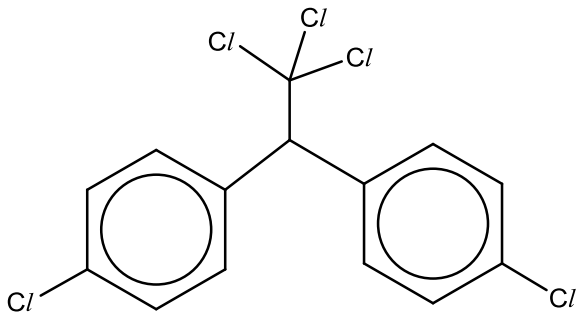
[Total: 16 marks]

-- END OF SECTION A---

Section B

Answer **two** questions from this section on separate answer paper.

1(a) Chlorobenzene is used to make an insecticide known as DDT.



DDT

(i) Calculate the percentage by mass of chlorine in DDT.

Molecular formula of DDT = $C_{14}H_9Cl_5$

Molecular mass of DDT = 354.5

% by mass of Chlorine = 5(35.5) / 354.5 x 100% = 50.1%

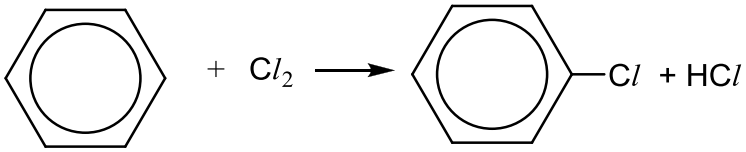
(ii) Using your knowledge of halogenoalkanes, explain why chlorobenzene cannot undergo hydrolysis by heating it under reflux with dilute aqueous KOH but chlorohexane can.

Chlorobenzene is inert to hydrolysis as the lone pair of electrons on chlorine delocalised the benzene ring.

Hence, the C-Cl bond in chlorobenzene exhibits partial double bond character/strengthen and is resistant to hydrolysis.

(iii) Benzene can react with chlorine to form chlorobenzene. State the conditions required for this reaction to occur and write an equation for this reaction.

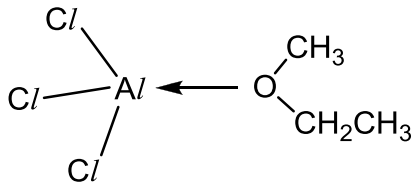
Conditions: $AlCl_3$ / $FeCl_3$



[6]

(b) Natural samples of chlorine consist of mixtures of isotopes.

Isotope	Relative abundance / %
^{35}Cl	75.6
^{36}Cl	24.2
^{37}Cl	0.186
^{38}Cl	0.014

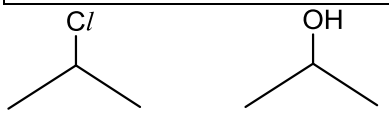
	Use the relative abundance data to calculate the relative atomic mass of chlorine to 4 significant figures.	
		[1]
	the relative atomic mass of chlorine = (0.756 x 35) + (0.242 x 36) + (0.00186 x 37) + (0.00014 x 38) = 35.25	
(c)	Chlorine can be used to form $SiCl_4$ and $AlCl_3$.	
	(i)	Write equations with state symbols to show the reaction of chlorine to form $SiCl_4$ and $AlCl_3$ respectively.
		$Si(s) + 2Cl_2(g) \rightarrow SiCl_4(l)$ $Al(s) + 3/2Cl_2(g) \rightarrow AlCl_3(s)$
	(ii)	Describe, with an equation, the reaction of $SiCl_4$ with water. What would be the effect of adding universal indicator to the product?
		$SiCl_4$ hydrolyses in water to form a strongly acidic solution. $SiCl_4 + 4H_2O \rightarrow SiO_2.2H_2O + 4HCl$ Colour in universal indicator: red
	(iii)	When $AlCl_3$ is mixed in a 1:1 ratio with ethoxymethane, $CH_3CH_2OCH_3$, a colourless liquid is formed. Suggest what type of bond and draw the structural formula of the product formed.
		Dative bonding is formed as ethoxymethane has a lone pair of electrons on O that can be donated to the empty orbital of Aluminium. 
		[6]
(d)	An organic compound **A** is a chloroalkane which has the following composition by mass: C, 45.8%; H, 8.9%; Cl, 45.3%. It has a relative molecular mass of 78.5. **B** reacts with PCl_5 to give **A**. Heating **B** with acidified $KMnO_4$ gives **C**. When 2,4-dinitrophenylhydrazine is added to **C**, an orange-yellow crystalline solid, **D**, is produced.	

B forms a yellow precipitate when reacted with warm alkaline aqueous iodine.

Using all the above information, identify the organic compounds **A**, **B**, **C** and **D**. Show all the deductions that you make from the information you have been given.

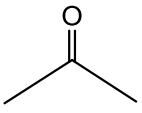
[7]

Information	**Deduction**
An organic compound **A** is a chloroalkane which has the following composition by mass: C, 45.8%; H, 8.9%; C*l*, 45.3%. It has a relative molecular mass of 78.5.	Empirical formula of A is C_3H_7Cl. Since, it has a relative molecular mass of 78.5, hence the molecular formula of A is C_3H_7Cl.
Heating **B** reacts with PCl_5 gives **A**.	B undergoes substitution. B is an alcohol.
Heating **B** with acidified $KMnO_4$ gives **C**.	B undergoes oxidation. B is a secondary (or primary) alcohol. to give C (ketone/ carboxylic acid)
When 2,4-dinitrophenylhydrazine is added to **C**, an orange-yellow crystalline solid, **D**, is produced	C undergoes condensation. C is a ketone.
B forms a yellow precipitate when reacted with warm alkaline aqueous iodine.	B undergoes oxidation. B has $CH_3CH(OH)$-R.

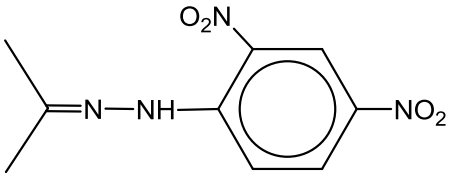


A

B

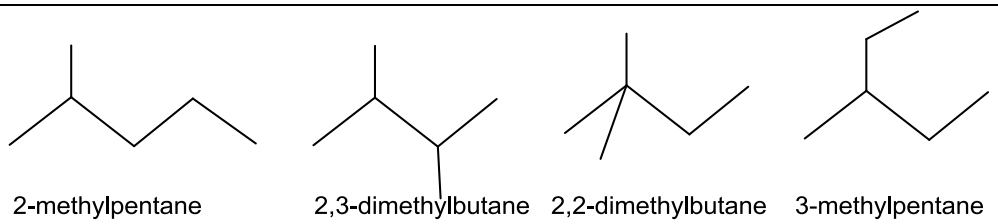
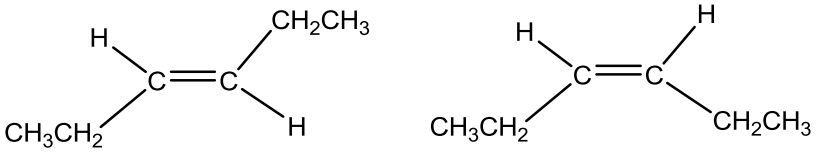


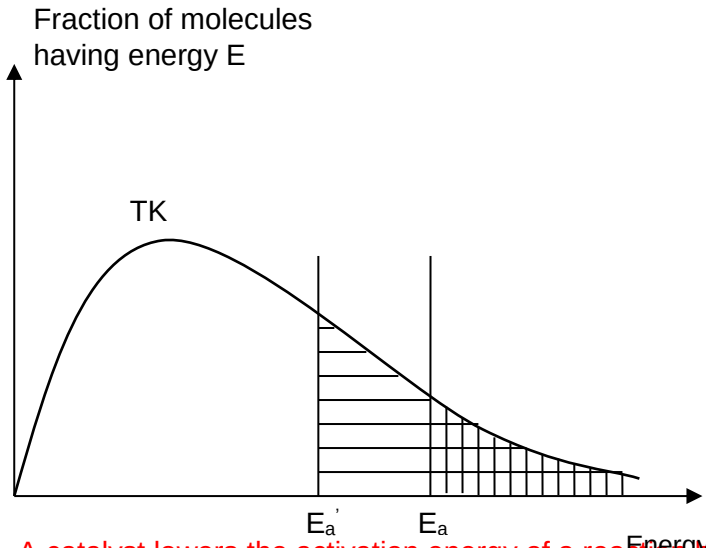
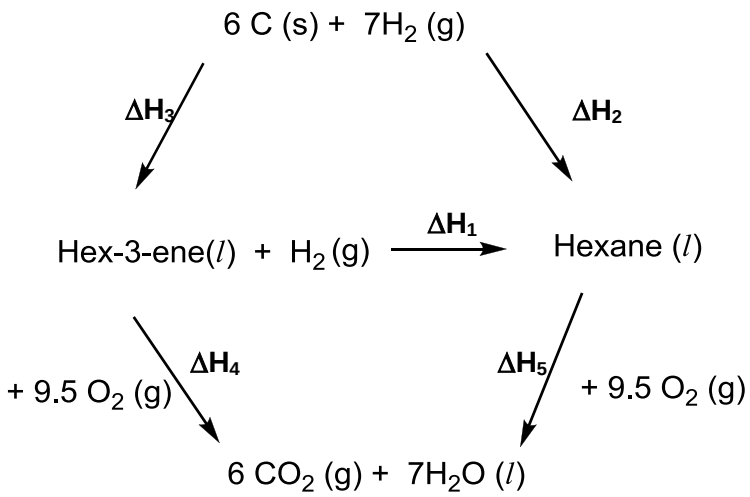
C

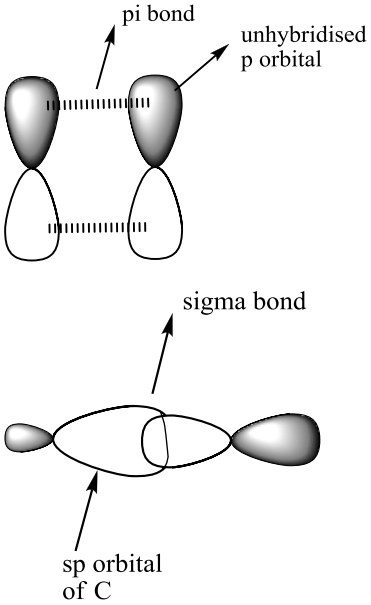


D

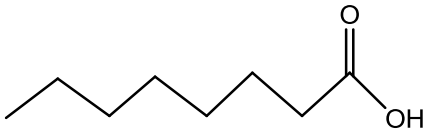
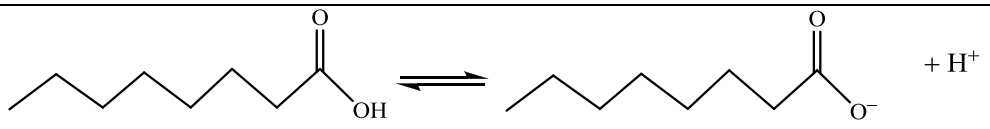
[Total: 20 marks]

2 (a)	Hexane, C_6H_{14} and hex-3-ene, C_6H_{12} are hydrocarbons that contain 6 carbon atoms.	
	(i)	Draw one structural isomer of hexane and name the compound.
		 2-methylpentane 2,3-dimethylbutane 2,2-dimethylbutane 3-methylpentane
	(ii)	Hex-3-ene can also exhibit geometrical isomerism. Explain how this type of isomerism arises and draw the isomers formed.
		 trans cis Geometrical isomerism (cis-trans isomerism) arises when there is restricted rotation about a double (pi) bond as each C of the double bond is connected to 2 different groups.
		[4]
(b)	(i)	Hex-3-ene can undergo hydrogenation to form hexane as shown below. **Hex-3-ene + Hydrogen gas → Hexane** Use relevant bond energy from the data booklet to determine a value for the enthalpy change of hydrogenation.
		[2]
		ΔH_r^θ = ∑ BE(reactants) - ∑ BE(products) = [4C-C + C=C + 12C-H + H-H] – [5C-C + 14C-H] = -C-C + C=C – 2C-H + H-H = -350 + 610 - 2(410) + 436 = **-124 kJ mol^{-1}**

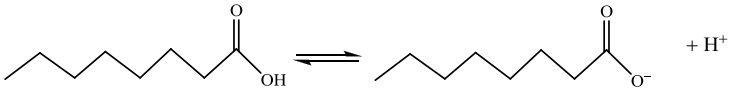
	(ii)	Sketch an energy distribution curve for the reactants and use it to explain the effect of nickel on the rate of the hydrogenation reaction.
		 • A catalyst lowers the activation energy of a reaction by providing an alternative reaction pathway. • Increase in the number of molecules having energy greater than or equal to the lowered activation energy/ E≥ Ea'. • Frequency of effective collisions increases. • Reaction rate thus increases.
		[3]
(c)	The diagram below shows an energy cycle involving hexane and hex-3-ene.	
		
	(i)	In the energy cycle above, what enthalpy change is represented by ΔH_3 and ΔH_5?
		ΔH_3 = standard enthalpy change of formation of hex-3-ene

		ΔH_5 = standard enthalpy change of combustion of hexane.
	(ii)	Write an equation that links ΔH_1, ΔH_2 and ΔH_3.
		$\Delta H_2 = \Delta H_1 + \Delta H_3$
	(iii)	Using your answer in **(b)(i)** and **(c)(ii)**; and given that ΔH_f of Hexane is -285.8 kJ mol^{-1}, calculate a value for ΔH_3.
		$\Delta H_3 = +124 - 285.8 =$ **$-$ 161.8 kJ mol^{-1}**
		[4]
(d)	Carbon reacts with oxygen and chlorine to form CO_2 and CCl_4.	
	(i)	Draw the dot-and-cross diagrams for CO_2.
		
	(ii)	Describe the bonding in CO_2 in terms of the overlap of orbitals. Draw diagrams to illustrate your answer.
		Sigma bond is a head on overlap between orbitals + label diagram but pi bond is a side on overlap between p orbitals.+ label diagram 
	(iii)	CO_2 is a gas whilst CCl_4 is a liquid at room temperature and pressure. Explain.
		Both CO_2 and CCl_4 are non polar simple covalent molecules held by weak intermolecular induced dipole - induced dipole forces of attraction. However, CCl_4 has a larger electron cloud than CO_2 hence exhibiting more significant

		induced dipole - induced dipole forces of attraction which requires more energy to overcome.
		[5]
(e)	Beryllium and boron are in the same period as carbon. Explain the difference between the values of the first ionisation energies between beryllium and boron.	
	• $_4$Be: $1s^2\ 2s^2$ $_5$B : $1s^2\ 2s^2\ 2p^1$ Or In Be, the first electron is removed from the 2s orbital, whereas for B, the first electron is removed from the 2p orbital. • The 2p orbital is further from the nucleus and also experiences additional screening effect by the two 2s electrons. • These factors outweigh the effect of increase in nuclear charge from Be to B, resulting in a lower effective nuclear charge • and less energy required to remove an electron from 2p than the 2s orbital first ionization energy of boron is lower.	
		[2]
		[Total: 20 marks]

3 (a)	Caprylic acid is found naturally in the milk of various mammals, and as a minor constituent of coconut oil and palm kernel oil. Caprylic acid is used commercially in the production of esters used in perfumery and also in the manufacture of dyes.  **Caprylic acid**	
	(i)	A bottle of perfume has been found to contain caprylic acid. Write an equilibrium equation to show the dissociation of caprylic acid. Hence, write the K_c expression, stating the units.
		 $K_c = \frac{[CH_3(CH_2)_6COO^-][H^+]}{[CH_3(CH_2)_6COOH]}$ Units: mol dm^{-3}
	(ii)	Given that the K_c value for the equilibrium in **(a)(i)** is 3.08 x 10^{-5}, calculate the concentration of caprylic acid when the pH of the perfume is found to be 4.2.

mol dm^{-3}

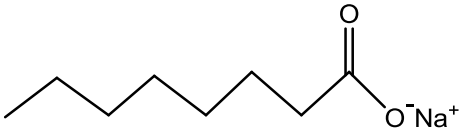


Initial	**X**	0	0
Change	- 6.31 x 10^{-5}	+ 6.31 x 10^{-5}	+ 6.31 x 10^{-5}
Equilibrium	X - 6.31 x 10^{-5}	6.31 x 10^{-5}	6.31 x 10^{-5}

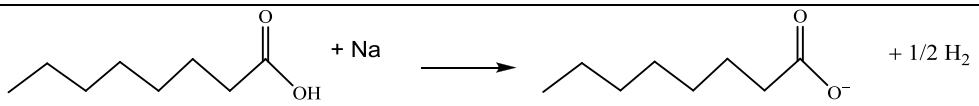
$$3.08 \times 10^{-5} = \frac{(6.31 \times 10^{-5})^2}{\mathbf{X} - 6.31 \times 10^{-5}}$$

X = 0.000192 mol dm^{-3}

(iii) Sodium caprylate can be made from 0.01 g of caprylic acid and excess sodium metal. Write an equation for the formation of sodium caprylate and calculate the volume of hydrogen gas that can be produced at standard temperature and pressure.



Sodium caprylate



Mole of caprylic acid = 0.01 / 144 = 6.94 x 10^{-5} mol

Mole of hydrogen gas = 3.47 x 10^{-5} mol

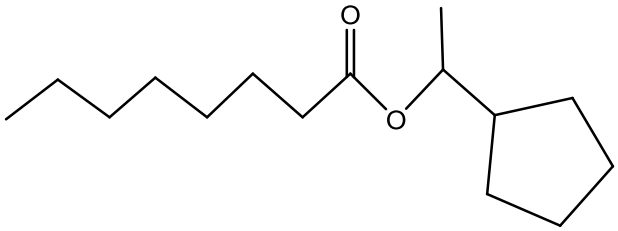
Volume of hydrogen gas at stp = 7.78 x 10^{-4} dm^3

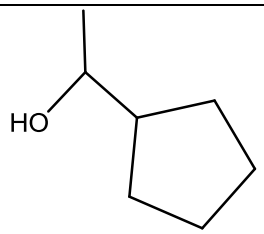
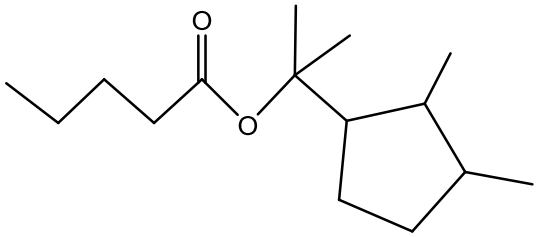
(iv) Sodium caprylate and caprylic acid are used as an acidic buffer in the ion-chromatography separation of amino acids in albumin protein. Explain with the aid of a relevant equation how the pH is regulated upon the addition of a small amount of HNO_3 (aq).

$CH_3(CH_2)_6COO^- + H^+ \rightarrow CH_3(CH_2)_6COOH$

A large reservoir of $CH_3(CH_2)_6COO^-$ will remove a small amount of acid to ensure that the pH remains almost unchanged.

[9]

(b)	(i)	Aqueous sodium chromate(VI) contains yellow CrO_4^{2-} ions. These chromate(VI) ions exist in equilibrium with dichromate(VI) ions as shown by the equilibrium below. $2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$ **yellow** **orange** Describe and explain what you would observe if dilute acid was added to a portion of the equilibrium mixture shown above.
		When dilute acid is added, the equilibrium will shift right to remove excess acid. Hence, an orange solution is observed.
	(ii)	When the equilibrium mixture in **b(i)** is cooled, the solution becomes more orange and less yellow. Deduce whether the equilibrium is exothermic or endothermic, explaining your answer.
		When the solution is cooled, the equilibrium will favour the exothermic reaction to produce more heat. When the solution becomes more orange and less yellow, the equilibrium has shifted right. Hence, the equilibrium is exothermic.
	(iii)	State the full electronic configuration of chromium in dichromate(VI) ion.
		$1s^2 2s^2 2p^6 3s^2 3p^6$
	(iv)	Caprylic acid can be formed from an alcohol using hot acidified potassium dichromate. Name the type of reaction and write an equation for the reaction.
		Type of reaction: Oxidation $CH_3(CH_2)_6CH_2OH + 2[O] \rightarrow CH_3(CH_2)_6COOH + H_2O$
		[7]
(c)	(i)	Caprylic acid can be used to form Ester **Q**. State the reagent and conditions required for this reaction.  **Ester Q**

		 Heat and concentrated sulfuric acid
	(ii)	Ester **R** is an isomer of Ester **Q**. Suggest a chemical test to distinguish between Ester **R** and Ester **Q**.  **Ester R**
		Add aqueous NaOH and heat / aqueous H_2SO_4 and heat to both Ester R and Ester Q. This is followed by aqueous H_2SO_4 $KMnO_4$ / $K_2Cr_2O_7$ and heat. OR Add aqueous H_2SO_4 $KMnO_4$ / $K_2Cr_2O_7$ and heat Ester Q will turn from purple to colourless whilst Ester R will remain as a purple solution / Ester Q will turn from orange to green whilst Ester R will remain as an orange solution.
		[4]
		[Total: 20 marks]