# FOUNDATION YEAR IN SCIENCE – CHEMISTRY (SX3003)

This assignment contains four sections, SECTION A to SECTION D.

## Instructions:

• Answer all questions in SECTION A to SECTION D.

The section that is being answered needs to be indicated and the answers must be correctly numbered.

- In calculations, show and explain your working.
- Chemical equations must be balanced, physical states included.
- Where relevant, in explanations and descriptions, your answer must contain appropriate technical terms, spelt correctly.
- It may be essential to read and or/ research relevant chemical topics, in order to answer some of the questions in this assignment.
- Answers to Section D MUST be word-processed. Only word-processed answers (Section D) will be MARKED. Your answers to Section D MUST be submitted to Plagiarism Checker (Turnitin). A copy of the Originality Report MUST be included with your word processed answers for SECTION D. SECTION D must be placed together with SECTIONS A to C in the drop box.
- The assignment must have a completed cover sheet. The coversheet and assignment answers must be placed in the drop-box on or before the deadline.

# Deadline for coursework submission: 13:30h on Wednesday, 28<sup>th</sup> March 2018.

Turn to Page 2 for SECTION A.

# **SECTION A**

## **ELECTRONIC STRUCTURE & IONIZATION ENERGY**

1. (i) Zinc metal reacts with a solution of iron(III) sulfate to give a solution of zinc sulfate and solid iron metal. Write the **full** electronic configuration in **spd notation** of the zinc ion in zinc sulfate.

(ii) Manganese(IV) oxide reacts with an aqueous solution of hydrochloric acid to produce manganese(II) chloride, water and chlorine gas. Write the **full** electronic configuration in **spd notation** of the manganese(II) ion and the chloride ion.

### (Total 3 Marks)

2. Write in the **abbreviated form** of the electronic configuration, **in box notation** of chromium and copper. Describe the reason(s) for the apparently anomalous arrangement of electrons in their atoms.

#### (Total 4 Marks)

3. The following table shows the first three ionization energies (in kJ mol<sup>-1</sup>) of elements in the SAME group of the Periodic Table.

Element	$\Delta H_{i1}$	$\Delta H_{i2}$	$\Delta H_{i3}$
А	383	437	3376
В	409	667	4881
С	425	765	5438
D	502	868	9929
Е	527	914	13820

- (a) In which group of the Periodic Table should the above elements be placed?
   Explain your answer in terms of the first three ionization energies. (2 Marks)
- (b) Which of the above elements has the smallest atomic number? Give reasons for your choice.

(3 Marks)

(Total 5 Marks)

#### Turn to Page 3 for SECTION A – Question 4.

Element	$\Delta H_{i1}$	$\Delta H_{i2}$	$\Delta H_{i3}$	$\Delta H_{i4}$
А	800	2400	3700	25000
В	740	1500	7700	10500
С	900	1757	14850	21000
D	418	3069	4439	5876
Е	577	1816	2745	11575

4. The following table shows the first four ionization energies of the elements A to E in kJ mol<sup>-1</sup>.

- (a) In which group of the Periodic Table should each element be placed? (5 Marks)
- (b) Calculate the energy needed to convert one mole of gaseous atoms of elementB into 1 mole of dipositive ions? Show your working. (2 Marks)

(Total 7 Marks)

#### **MOLARITY CALCULATIONS**

5. 5.00 g of lawn sand (a mixture of sand and ammonium sulfate) was weighed into a conical flask and 25 cm<sup>3</sup> of 2.0 mol dm<sup>-3</sup> sodium hydroxide solution was pipetted into the same flask. The conical flask was boiled for 20 minutes which ensured that all the ammonia had been driven off, because:

$$(NH_4)_2SO_{4(s)} + 2NaOH_{(aq)} \rightarrow 2NH_{3(q)} + Na_2SO_{4(aq)} + 2H_2O_{(1)}$$

The residue in the flask was cooled and filtered to remove the sand. The filtrate containing unreacted NaOH was made up to 250 cm<sup>3</sup> in a volumetric flask. 25 cm<sup>3</sup> samples of this solution were titrated against 0.1 mol dm<sup>-3</sup> hydrochloric acid using bromothymol blue as an indicator.

$$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$$

The mean titre was  $15.65 \text{ cm}^3$ .

Calculate the percentage of ammonium sulfate by mass in the lawn sand. Show and explain your working.

(Total 8 Marks)

#### **BONDING & ENERGY**

6. (a) Lithium amide is mainly used as a strong base in organic chemistry, often in liquid ammonia solution. Draw a dot & cross diagram to show the bonding in the amide ion. State and explain the shape of amide using the VSEPR theory. Estimate the H-N-H bond angle. (5 Marks)

Question 6 continued.

- (b) (i) Draw a dot & cross diagram to show the bonding in methanal, HCHO.
   State and explain the shape of HCHO using the VSEPR theory. Estimate the H-C-H bond angle. (4 Marks)
  - (ii) Methanal (HCHO) is a gas at room temperature whereas methanol (CH<sub>3</sub>OH) is a liquid. Suggest an explanation for this. (3 Marks)

#### (Total 12 Marks)

- 7. A coffee-cup calorimeter contains 65.0 cm<sup>3</sup> of a dilute solution of copper(II) sulfate at a temperature of 22.8 °C. A small amount of magnesium powder also at 22.8 °C is added to the solution. Copper metal is formed, and the temperature of the solution rises to 35.3 °C. The copper is collected, dried and weighted, when it is found to have a mass of 0.424 g.
  - (i) Calculate the total amount of energy released in this reaction, ignoring the heat capacity of the magnesium and the calorimeter. Take the specific heat capacity of the **solution** as  $4.18 \text{ J g}^{-1} \text{ K}^{-1}$ . Show and explain your working.
  - (ii) Calculate the enthalpy change for this reaction per mole of the copper formed. Show and explain your working.

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(Total 4 Marks)
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8. Use the values for average bond enthalpies (E) from the table below to calculate the enthalpy changes in each of the reactions (a) and (b)

Bond	C-C	C=C	С-Н	C=O	C-Cl	H-Cl	О-Н	0=0
E/kJ mol <sup>-1</sup>	346	611	412	743	339	431	463	497

(a) 
$$\operatorname{CH}_{4(g)} + 2\operatorname{O}_{2(g)} \rightarrow \operatorname{CO}_{2(g)} + 2\operatorname{H}_{2}\operatorname{O}_{(g)}$$
 (3 Marks)

(b)  $CH_3CH=CHCH_{3(g)} + HCl_{(g)} \rightarrow CH_3CH_2CH(Cl)CH_{3(l)}$ 

(c) Research and record the data book value for the standard enthalpy of combustion of methane. How would your answer to (a) compare to the data book value for the standard enthalpy of combustion of methane? Give a (2 Marks) reason or explain.

#### (Total 8 Marks)

(3 Marks)

- 9. (a) Draw a diagram of the energy distribution of gas particles in a system, at temperature, T<sup>1</sup>. On the same diagram, show the shape the distribution at a higher temperature T<sup>2</sup>. Note: temperature T<sup>2</sup> is higher than temperature T<sup>1</sup>. (3 Marks)
  - (b) Relate the two curves in (a) to the change in the rate of a gas phase reaction with increased temperature. (2 Marks)

Question 9 continued.

(c) Draw a labelled energy profile showing the energy changes during an exothermic reaction. Use this and the diagram drawn in (a) to explain how catalysts increase the rate of reactions. (4 Marks)

(Total 9 Marks)

Given the following data, construct a Hess's Law cycle and calculate the 10. (a) standard enthalpy of formation of ethane,  $\Delta H_{f}^{\Theta}$  [C<sub>2</sub>H<sub>6</sub>].

$$\begin{array}{rcl} 2C_{(s)} + 3H_{2(g)} \rightarrow C_{2}H_{6\,(g)} \\ \\ \Delta H^{\Theta}c \ carbon &= & -394 \ kJ \ mol^{-1} \\ \\ \Delta H^{\Theta}c \ hydrogen &= & -286 \ kJ \ mol^{-1} \\ \\ \Delta H^{\Theta}c \ ethane &= & -1560 \ kJ \ mol^{-1} \end{array}$$

$$\begin{array}{rcl} (4 \ Marks) \end{array}$$

 $\Delta H_{at}^{\Theta} [C] = 717 \text{ kJ mol}^{-1}$ 

Use the values for average bond enthalpies (E) from the table below along (b) with the standard enthalpy of atomisation of carbon to calculate the standard enthalpy of formation of ethane,  $\Delta H_{f}^{\Theta}$  [C<sub>2</sub>H<sub>6</sub>] using the equation given in (a).

#### **Displayed formula of ethane:**

Bond	C-C	С-Н	H-H
E/kJ mol <sup>-1</sup>	346	412	436

(c) Comment on the discrepancy between the two calculated values for the standard enthalpy of formation of ethane in (a) and (b). Stating with a reason, which of the two values is likely to be more accurate.

(3 Marks)

(Total 10 Marks)

## **END OF SECTION A**

## TOTAL FOR SECTION A

#### **Turn to Page 6 for SECTION B**

70 MARKS



#### **SECTION B**

### **RATES OF REACTION**

1. 1-bromobutane was hydrolysed by aqueous sodium hydroxide solution.

 $C_4H_9Br + NaOH \rightarrow C_4H_9OH + NaBr$ 1-bromobutane butan-1-ol

During the reaction the sodium hydroxide is used up. Samples of the reaction mixture were drawn off at regular time intervals and analysed by titration with standard hydrochloric acid to find out the concentration of sodium hydroxide. The results are given in the table below:

Time / secs	Concentration of hydroxide ion / mol dm <sup>-3</sup>
0	0.500
100	0.350
200	0.250
300	0.180
400	0.125
500	0.090
600	0.063
700	0.040
800	0.030

(a) From the above information, identify the independent variable and dependent variable.
 Plot a suitable graph. The graph MUST be a hand drawn, plotted on graph paper.
 Note: NO marks are awarded for identifying the independent and dependent variable.

(3 Marks)

(b) Select 4 suitable points along your graph [see part (a)] and draw tangents to find the rates. Construct a table of "Rate" against "Concentration". Note: The rates need to be calculated and the calculations shown.

(4 Marks)

- (c) Plot a graph of Rate against Concentration. (3 Marks)
- (d) From your graph in part (c) deduce the Order of Reaction. (1 Mark)
- (e) Write a rate equation with respect to the concentration of hydroxide ions. (2 Marks)
- (f) Calculate the rate constant k from the gradient of the graph, drawn in part (c). Show your working.

(2 Marks)

(Total 15 Marks)

#### **ORGANIC CHEMISTRY**

(a)

(d)

2.

- $Na_2Cr_2O_7(aq) + C_3H_8O$ water condenser water  $H_2SO_4$  (aq) ice/water mixture receiver
- A student was given the following instructions for the preparation and identification of a carbonyl 3. compound:

Which of the above compounds exhibits stereoisomerism? Draw the

displayed 3D (three dimensional) formulae the isomers. Suggest how these

To  $40 \text{ cm}^3$  of water in a flask, carefully add 6 cm<sup>3</sup> of concentrated sulfuric acid and set up the apparatus as shown below.

Make up a solution of 28 g of sodium dichromate  $Na_2Cr_2O_7$  in 15 cm<sup>3</sup> of water, add 20 cm<sup>3</sup> of the alcohol  $C_3H_8O$  and pour the solution into the dropping funnel.

Boil the acid in the flask and add the mixture containing the alcohol at such a rate that the product is slowly collected in the receiver in the ice-water bath.

- (c) Which of the above compounds exhibits geometrical isomerism? Draw skeletal formulae of the isomers. Name the isomers.

(Total 5 Marks)

(Total 5 Marks)

(Total 16 Marks)

(Total 4 Marks)

(Total 2 Marks)

- (b) Draw **displayed formulae** of **two** other isomers of compound (ii)
- Write the **condensed formulae** of the following compounds:
- (i) 2,3-Dichlorohex-2-ene
- (ii) 2-Methylbutane
- Butan-1,3-diol (iii)
- 2,2-Dihydroxy-1-phenyl-pentan-3-one (iv)

isomers could be distinguished from one another.

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Question 3 continued.

3.	Redistil the crude product and collect the fraction that boils between 48 and 50 °C.
	The equation for the reaction is:

 $3C_{3}H_{8}O + Na_{2}Cr_{2}O_{7} + 4H_{2}SO_{4} \rightarrow 3C_{3}H_{6}O + Na_{2}SO_{4} + Cr_{2}(SO_{4})_{3} + 7H_{2}O$ 

(a)	In the conde	(1 Mark)	
(b)	Why	(1 Mark)	
(c)	(i)	Calculate how many moles of Na <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> were used?	(1 Mark)
	(ii)	Use the density of the alcohol $(0.79 \text{ g cm}^{-3})$ to calculate the mass and hence the number of moles of alcohol used in the preparation. Explain which reagent is in excess.	(3 Marks)
	(iii)	The student obtained 7.2 g of the carbonyl compound. Calculate the percentage yield obtained.	(2 Marks)
	(iv)	Suggest why the percentage yield is well below 100%.	(2 Marks)
(d) (e)	Identi releva What	fy the possible isomers of $C_3H_8O$ . Note: Your answer/s <b>MUST</b> be ant to the reaction described in question 3. type of isomerism do the above isomers of $C_3H_8O$ display? earbonyl compound gave a yellow precipitate on addition of 2,4-	(3 Marks)
	dinitr Fehlii	ophenylhydrazine but did not reduce ammoniacal silver nitrate or ngs solution.	
	(i)	Identify (Name) the carbonyl compound $C_3H_6O$ .	(1 Mark)
	(ii)	Draw the displayed formula of the 2,4-dinitrophenylyhydrazine product, the yellow precipitate.	(1 Mark)
	(iii)	Which isomer of C <sub>3</sub> H <sub>8</sub> O was used in the preparation?	(1 Mark)
(f)	The y is a d	ellow precipitate formed on addition of 2,4-dinitrophenylhydrazine erivative that can be used to identify the carbonyl compound	
	(i)	Name the method that you would use to purify the derivative.	(1 Mark)
	(ii)	Describe what must be done with the purified derivative to characterise the carbonyl compound?	(2 Marks)
			(Total 19 Marks)

# Turn to Page 9 for SECTION B - Question 4.

4. Alkenes react with hydrogen bromide at room temperature.

		TOTAL FOR SECTION B	70 MARKS
		END OF SECTION B	
		Pare (0).	(Total 11 Marks)
	(d)	Compare and contrast the reaction mechanisms of part (a) and part (b).	(4 Marks)
	(c)	Draw the reaction mechanism for the reaction in part (b) [5(b)] /above reaction]. Explain the mechanism. Mechanism must contain curly arrows.	(4 Marks)
	(b)	2-Bromo-2-methylpentane is heated under reflux with ethanol and concentrated sodium hydroxide. Draw the skeletal formulae of the organic products formed.	(2 Marks)
5.	(a)	1-Chloro-3-ethylcyclopentane is heated under reflux with aqueous sodium hydroxide. Draw the skeletal formula of the organic product formed.	(1 Mark)
			(Total 9 Marks)
	(c)	(b) above) why products are formed.	(3 Marks)
	(b)	Draw the reaction mechanism for the reaction in part (a) (above reaction). Explain the mechanism. Mechanism must contain curly arrows.	(4 Marks)
	(a)	Draw displayed formulae of the products formed in the reaction between 2-methylpent-1-ene and hydrogen chloride at room temperature.	(2 Marks)

# Turn to Page 10 for SECTION C

# **SECTION C**

In following equations, calculate the numbers of moles of substances denoted by letters a - d:

1.		$CO_{(g)}$ + $Cl_{2(g)}$	$\rightleftharpoons$ COCl <sub>2(g)</sub>	
	At start	2 mole 4 moles	0 moles	
	At equilm	1.5 moles <b>a</b>	b	
				(Total 1 Mark)
2.		$NH_2COONH_{4(s)} \rightleftharpoons$	$2NH_{3(g)} + CO_{2(g)}$	
	At start	C	0 moles 0 moles	
	At equilm	3 moles	4 moles <b>d</b>	
	_			(Total 1 Mark)

3. An important reaction in the manufacture of sulfuric acid is:

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)} \qquad \Delta H = -197 \text{ kJ mol}^{-1}$$

This reaction was intensively investigated by Bodenstein in 1905. In one of his experiments he found that, at 1000K, equilibrium occurred when the partial pressures of the gasses in the mixture were as follows:

$$P_{SO_2} = 0.557$$
 atmospheres  $P_{O_2} = 0.170$  atmospheres  $P_{SO_3} = 0.464$  atmospheres

- (a) Write an expression for the equilibrium constant, Kp, for this reaction in terms of partial pressures (1 Mark)
- (b) Use the partial pressures given above to calculate the value of Kp at 1000K, including its units (3 Marks)
- (c) What would be the effects on the value of Kp, if the following changes were made to the system:
  - (i) the partial pressure of oxygen is increased by 0.500 atmosphere (1 Mark)
  - (ii) the temperature was lowered to 400K (1 Mark)

(Total 6 Marks)

4. Benzoic acid is a weak monobasic acid. Representing benzoic acid as HBen and its conjugate base as Ben<sup>-</sup> explain how a solution containing benzoic acid and its sodium salt can function as a buffer solution. Your answer **MUST** contain chemical equations.

(Total 4 Marks)

#### Turn to Page 11 for SECTION C - Question 5.

5. Aspirin is a weak monobasic acid. The acid dissociation constant Ka for aspirin is  $3.27 \times 10^{-4}$  mol dm<sup>-3</sup> at 25 °C. A chemist wishes to make a buffer solution with a pH of 4.10 using aspirin and its sodium salt. The chemist starts with a solution containing 0.04 mol dm<sup>-3</sup> aspirin.

- (a) Calculate the pH of the aspirin solution (2 *Marks*)
- (b) Calculate  $[H_3O^+]$  for a solution with pH = 4.10 (1 Mark)
- (c) Calculate the concentration of the sodium salt of aspirin required to produce a solution with a pH of 4.10 (2 Marks)

(Total 5 Marks)

6. Balance the following redox equations, using the oxidation number method: (a)  $SO_3^{2^-}{}_{(g)} + Ce^{4_+}{}_{(aq)} + H_2O_{(l)} \rightarrow SO_4^{2^-}{}_{(aq)} + Ce^{3_+}{}_{(aq)} + H^+{}_{(aq)}$  (2 Marks) (b)  $Cl_{2(aq)} + OH_{(aq)} \rightarrow C\Gamma_{(aq)} + ClO_3^-{}_{(aq)} + H_2O_{(l)}$  (2 Marks) (c) Explain what type of reaction is (b)? (1 Mark) (Total 5 Marks)

7. Cresolphthalein is a common acid – base indicator which changes colour over with the pH range 8.2 - 9.8.

Would cresolphthalein be a suitable indicator for the titration between 25.0 cm<sup>3</sup> of 0.2 mol dm<sup>-3</sup> hydrochloric acid and 0.2 mol dm<sup>-3</sup> ammonia? Explain your answer. What other **method** could be used to identify the end-point of the hydrochloric acid and ammonia titration?

(Total 4 Marks)

Turn to Page 12 for SECTION C - Question 8.

8. (a) Copy and complete the table below for the titration of 0.10 mol dm<sup>-3</sup> potassium hydroxide solution against a 0.10 mol dm<sup>-3</sup> hydrochloric acid solution

(3 Marks)

Volume of 0.10 mol dm <sup>-3</sup>	Total volume of solution /	$[H^{+}(aq)] / mol dm^{-3}$	pН
potassium hydroxide added / cm <sup>3</sup>	cm <sup>3</sup>	or	
		$[H_3O^+(aq)] / mol dm^{\cdot 3}$	
	Initial volume of 0.10 mol dm <sup>-3</sup> hydrochloric acid = 25.00 cm		
0	25.00		
10.00			
15.00			
20.00			
24.90			
24.99			
25.00			
25.01			
25.10			
30.00			
35.00			
40.00			
50.00			

(b) Plot a graph **on graph paper.** Clearly mark or indicate on the graph: the pH at the start of the titration, pH at equivalence point, volume of potassium hydroxide at equivalence point and pH when all of the potassium hydroxide has been added.

(6 Marks) (Total 9 Marks)

## END OF SECTION C

## TOTAL FOR SECTION C

35 MARKS

## **SECTION D**

IMPORTANT: Answers to Section D MUST be word-processed. Only word-processed answers (Section D) will be MARKED. A copy of your answers to Section D MUST be submitted to Plagiarism Checker (Turnitin) and a copy of the Originality Report MUST included with your answer script for SECTION D

#### AN INVESTIGATION OF THE PETROLEUM INDUSTRY

- 1. Describe the process of fractional distillation of crude oil. Your answer must also include:
  - A diagram of the fractional distillation tower;
  - Scientific principles underlying the distillation process;
  - A table containing the main/principal fractions obtained from fractional distillation of crude oil and the boiling point of each fraction.

All sources **MUST** be acknowledged using Harvard referencing.

#### (Total 10 Marks)

2. Explain the process, catalytic cracking <u>or</u> catalytic reforming: platforming. Your answer must also include why it is used in the petroleum refinery process. For the process include a chemical equation and examples of two products formed.

All sources **MUST** be acknowledged using Harvard referencing.

(Total 5 Marks)

# **END OF SECTION D**

# TOTAL FOR SECTION D

15 MARKS

#### **END OF ASSIGNMENT**