Name : _____ Class: _____ Reg Number: _____

Meridian Junior College
2009 JC2 Preliminary Examination
H1 Chemistry 8872

14 September 2009 2 hours

Paper 2

Candidates to answer Section **A** on the Question Paper and Section **B** on separate writing paper.

Additional Materials:
Data Booklet
Writing paper

INSTRUCTION TO CANDIDATES
Write your name, class and register number in the spaces provided at the top of this page.

Section A
Answer **all** questions.

Section B
Answer any **two** questions.

At the end of the examination, fasten your answers for Section **B** behind Section **A**.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets **[ ]** at the end of each question or part question.

You are reminded of the need for good English and clear presentation in your answers.

Examiner's Use		
Paper 1	**MCQ**	**/ 30**
Paper 2 Section A	**Q1**	**/ 7**
	Q2	**/ 8**
	Q3	**/ 10**
	Q4	**/ 15**
Paper 2 Section B	**Q5**	**/ 20**
	Q6	**/ 20**
	Q7	**/ 20**
Total		**/ 110**

This question paper consists of *Page 1 to 19.*

[Turn over

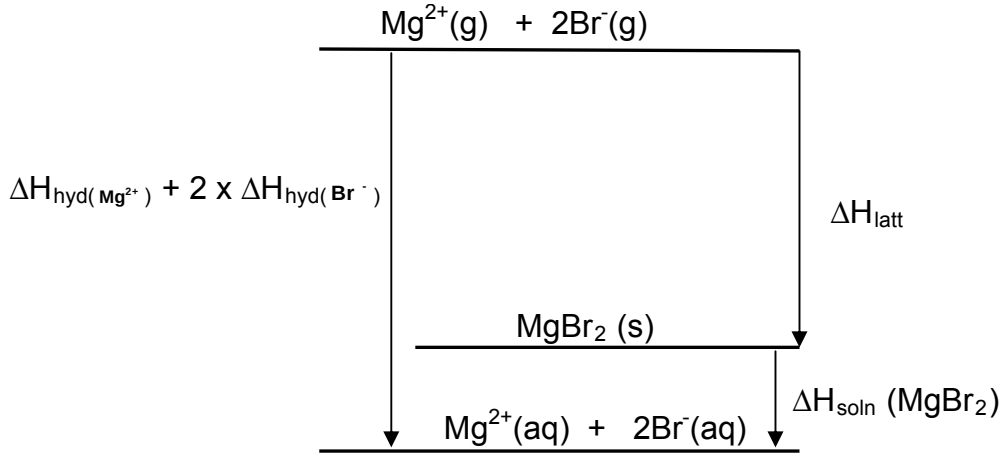
Section A

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

1(a) Magnesium bromide, $MgBr_2$, is a white solid that readily absorbs moisture from the atmosphere. It is often used as a mild sedative.

(i) Using magnesium bromide as an example, explain what is meant by the term *lattice energy*.

(ii) Use the energy level diagram, together with the given data to determine the lattice energy of magnesium bromide.



Enthalpy change of hydration of magnesium ion, $\Delta H_{hyd(Mg^{2+})}$	-1921 kJ mol^{-1}
Enthalpy change of hydration of bromide ion, $\Delta H_{hyd(Br^-)}$	-336 kJ mol^{-1}
Enthalpy change of solution of magnesium bromide, $\Delta H_{soln}(MgBr_2)$	-186 kJ mol^{-1}

(iii) Explain how you would expect the numerical magnitude of the lattice energy of $MgBr_2$ to compare with that of sodium fluoride, NaF.

[4]

(b) **(i)** With the aid of an equation, define the first ionisation energy of iodine.

(ii) State and explain how you would expect the first ionisation energy of iodine to compare with that of fluorine.

[3]

[Total : 7]

2 Early Periodic Tables, such as that devised by Mendeleev, listed the then known elements in order of their relative atomic mass.

			Ti = 50	Zr = 90	? = 180
			V = 51	Nb = 94	Ta = 182
			Cr = 52	Mo = 96	W = 186
			Mn = 55	Rh = 104.4	Pt = 197.4
			Fe = 56	Ru = 104.4	Ir = 198
			Ni = Co = 59	Pd = 106.6	Os = 199
H = 1			Cu = 63.4	Ag = 108	Hg = 200
	Be = 9.4	Mg = 24	Zn = 65.2	Cd = 112	
	B = 11	Al = 27.4	? = 68	Ur = 116	Au = 197?
	C = 12	Si = 28	? = 70	Sn = 118	
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210?
	O = 16	S = 32	Se = 79.4	**Te = 128?**	
	F = 19	Cl = 35.5	Br = 80	**I = 127**	
Li = 7	Na = 23	K = 39	Rb = 85.4	Cs = 133	Ti = 204
		Ca = 40	Sr = 87.6	Ba = 137	Pb = 207
		? = 45	Ce = 92		
		?Er = 56	La = 94		
		?Yt = 60	Di = 95		
		?In = 75.6	Th = 118?		

(a) When Mendeleev created the table, there were uncertainties regarding the relative atomic mass of tellurium. It is now known that there are eight isotopes of tellurium. Complete the following table. Give your answers to **four** significant figures.

isotope	**percentage abundance**	**isotopic mass x percentage abundance**
tellurium-120	0.09	11
tellurium-122	2.46	300
tellurium-123	0.87	107
tellurium-124	4.61	572
tellurium-125	6.99	874
tellurium-126	18.71	2357
tellurium-128	31.79	
tellurium-130		

Hence, calculate the relative atomic mass of tellurium to 1 decimal place.

[3]

(b) Tellurium (IV) chloride, $TeCl_4$, is a pale yellow solid at room temperature with a melting point and boiling point of 224°C and 380°C respectively. In the molten state, $TeCl_4$ dissociates into $TeCl_3^+$ and $Te_2Cl_{10}^{2-}$. Gaseous tellurium (IV) chloride, $TeCl_4$, has a structure similar to sulphur tetrafluoride, SF_4.

Explain in terms of structure and bonding, the relative electrical conductivity of $TeCl_4$ in the molten and gaseous state.

[2]

(c) Tellurium resembles silicon in many aspects. For example, both are metalloids and are used as semiconductors. Tellurium (IV) oxide, TeO_2, reacts with concentrated strong bases in the same way as silicon (IV) oxide, SiO_2.

(i) Write a balanced equation for the reaction between TeO_2 and NaOH.

(ii) Predict the pH of the solution formed when gaseous tellurium tetrachloride, $TeCl_4$, is bubbled into water. Suggest an equation for this reaction.

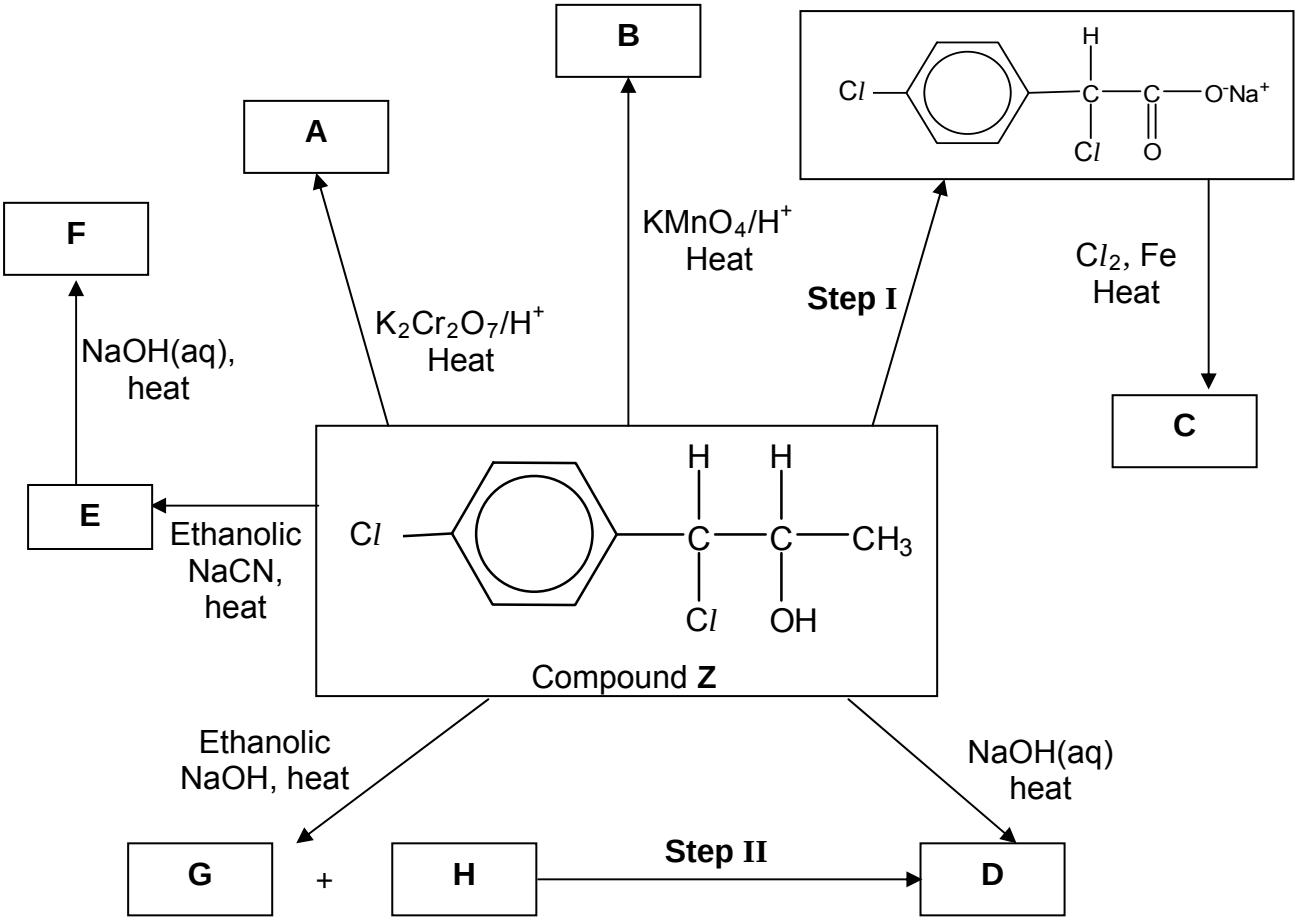
pH of solution : …….....

Equation: .....

[3]

[Total : 8]

3 The following shows a series of reactions that compound **Z** can undergo.



(a) Draw the structures of compounds **A** to **F** in the boxes provided below.

A	**B**	**C**
D	**E**	**F**

[6]

(b) When treated with NaOH in ethanol, compound **Z** produces a mixture of isomers, **G** and **H**.

Draw the full structural formulae of **G** and **H**.

G

H

[2]

(c) State the reagents and conditions required in Steps **I** and **II**.

Step **I**

Reagents: ……..

Conditions: ……..

Step **II**

Reagents: ……

Conditions: ……..

[2]

[Total: 10]

4 Sulphur compounds occur naturally in petrol. The presence of such compounds gives rise to the emission of toxic oxides of sulphur from car exhausts. One such pollutant produced from car emissions is the gas sulphur dioxide, SO_2. Sulphur dioxide reacts with water and oxygen in the atmosphere to produce 'acid rain', a dilute solution of sulphuric acid, resulting in further damage to urban architecture.

One process used to remove sulphur compounds from petroleum and diesel is called "hydroprocessing". This process uses catalysts consisting of metals deposited as thin layers on porous aluminium supports.

Hydroprocessing converts the sulphur compounds in the fuel to the gas hydrogen sulphide, H_2S. Some of the hydrogen sulphide produced is oxidised to sulphur dioxide and water as shown in equation **1**.

$$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(g) \qquad \textbf{(1)}$$

The sulphur dioxide produced is then reacted with the remaining hydrogen sulphide to produce solid sulphur as follows.

$$2H_2S(g) + SO_2(g) \rightarrow 3S(s) + 2H_2O(l) \qquad \textbf{(2)}$$

Sulphur dioxide also dissolves in water to form sulphurous acid, H_2SO_3. Unlike sulphuric acid, sulphurous acid is a weak acid and dissociates partially to form hydrogensulphites and protons, as shown in equation **3.**

$$H_2SO_3(aq) \rightleftharpoons H^+(aq) + HSO_3^-(aq) \qquad \textbf{(3)}$$

While sulphuric acid in the environment is harmful, a mixture of hydrogen sulphites and sulphurous acid is widely used in the food industry as an "acidity regulator".

(a) **(i)** Draw the dot-and-cross diagram as well as the displayed formula showing the shape of a molecule of sulphurous acid.

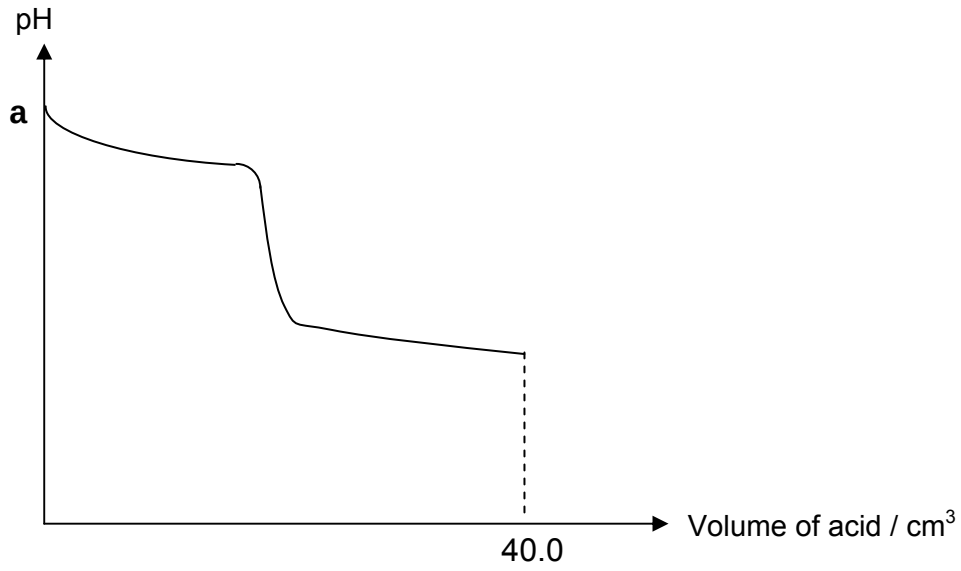
(ii) Using the Valence Shell Electron Pair Repulsion Theory, explain the shape around the sulphur atom in a molecule of sulphurous acid.

[4]

(b) A student titrated a 25.0 cm^3 solution of 0.0125 mol dm^{-3} potassium hydroxide with 0.010 mol dm^{-3} sulphurous acid solution. The reaction occurring in this titration is

$$KOH(aq) + H_2SO_3(aq) \rightarrow KHSO_3(aq) + H_2O(l)$$

A total of 40.0 cm^3 of acid was added. The following graph shows the variation of pH against the volume of acid added.



(i) Determine the pH at point **a** on the curve.

(ii) Calculate the equivalence volume of H_2SO_3 required in this titration.

(iii) The student is provided with some acid-base indicators.

Indicator	pH range at which colour change occurs
Methyl violet	0.5 – 1.5
Chlorophenol red	4.8 – 6.4
Alizarin Yellow	10.1 – 12.0

His classmate suggested that they could use chlorophenol red to detect the end-point of this titration.

Explain whether chlorophenol red is a suitable indicator for this titration.

(iv) A mixture of sulphurous acid and hydrogen sulphite based on equation **3** works as an "acidity regulator" in foodstuff.

$$H_2SO_3(aq) \rightleftharpoons H^+(aq) + HSO_3^-(aq) \qquad \textbf{(3)}$$

In this titration, such a mixture is produced.

Mark with a cross (**x**) on the titration curve where you would expect this mixture to be formed.

(v) Explain, with the aid of equations, how the mixture in **b(iv)** as an "acidity regulator".

[7]

(c) During hydroprocessing, the reaction in equation **(1)** is carried out in the presence of metal catalysts.

$$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(g) \qquad \textbf{(1)}$$

On the grid below, sketch and label a Maxwell-Boltzmann distribution curve to show how the presence of a catalyst increases the rate of reaction.

[2]

(d) **(i)** The enthalpy change for the reaction in equation **(1)** is -486 kJ mol^{-1}.

With the aid of the *Data Booklet*, calculate an average value for the S=O bond in SO_2. Give your answer to **three** significant figures.

(ii) The enthalpy change given in **d(i)** is not identical to the standard enthalpy change for the same reaction.

Suggest one reason for the difference in values.

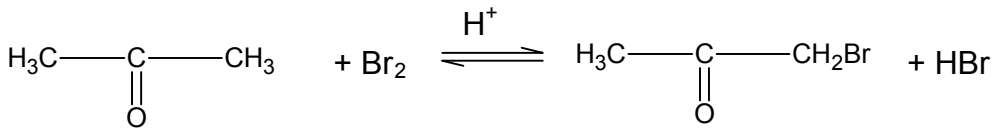
[2]

[Total: 15]

Section B

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

5 When aqueous solutions of bromine and propanone are mixed, the following reaction occurs.



propanone Compound **A**

When the pH of the solution is between 4 to 7, the reaction occurs very slowly. However, at pH values less than 3, the reaction occurs rapidly.

A student performed several experiments where different initial concentrations of propanone, bromine and acid solutions are mixed. The change in concentration of bromine was followed with appropriate methods. The following data was obtained.

Experiment	[Propanone] (mol dm^{-3})	[H^+] (mol dm^{-3})	[Br_2] (mol dm^{-3})	Rate of reaction (mol dm^{-3} s^{-1})
1	1.60	0.403	4.14×10^{-3}	2.80×10^{-5}
2	0.80	0.101	3.69×10^{-3}	2.85×10^{-6}
3	0.40	0.202	3.72×10^{-3}	2.94×10^{-6}
4	1.60	0.202	4.38×10^{-3}	1.27×10^{-5}
5	1.61	0.200	8.81×10^{-3}	1.30×10^{-5}

(a) **(i)** What do you understand by the term *rate equation* ?

(ii) Suggest one method in which the rate of reaction may be measured.

(iii) Using the data in the table, determine the orders of reaction with respect to

1 Propanone

2 Bromine

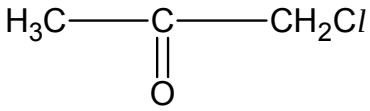
3 H^+

(iv) Deduce, with reasoning, the role of H^+ ions in this reaction.

(v) Write the rate equation for this reaction. Calculate a value for the rate constant, *k*, for this reaction, stating its units.

[8]

(b) Compound **B** can be synthesized from propanone under suitable conditions, but in the absence of H^+ ions.



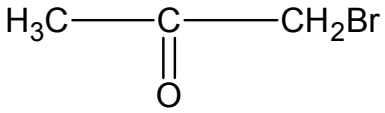
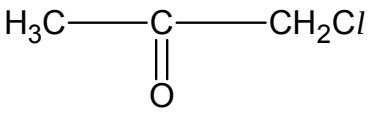
Compound **B**

(i) Suggest suitable reagents and conditions to carry out this reaction.

(ii) State the type of reaction.

(iii) Equimolar samples of **A** and **B** were added separately to test-tubes containing aqueous sodium hydroxide in a hot-water bath and left to stand for several minutes. Acidified silver nitrate was subsequently added to each mixture.

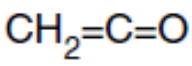
The time, **t**, taken for the appearance of a precipitate was estimated.

Compound	t / min
 **A**	5
 **B**	40

Account for the difference in **t**, with the aid of relevant data from the *Data Booklet*.

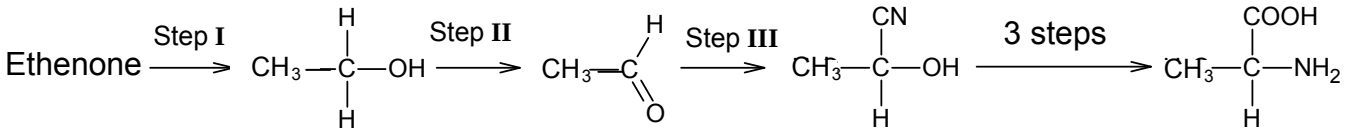
[4]

(c) Ethenone belongs to a class of organic compounds, known as ketenes. Ketenes are widely used in pharmaceutical research for the synthesis of organic compounds. Ethenone resembles propanone in many of its chemical properties.



Ethenone

Ethenone is the starting reagent for the synthesis of *alanine*, an amino acid. *Alanine* is a building block for protein molecules present in living organisms.



D **E** **F** *Alanine*

(i) With reference to the structure of ethenone, suggest why the name ketene is used.

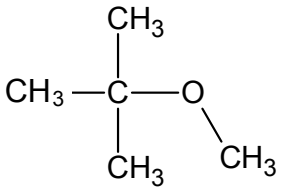
(ii) Compound **F** may be converted to *alanine* in a 3-step process. State the reagents and conditions for the sequence and draw the displayed formula of all the intermediates.

(iii) Suggest reagents and conditions for Step **I**, **II** and **III**.

[8]

[Total: 20]

6 Oxygenated organic compounds contain oxygen as part of their chemical structure. One such example is methyl-tertiary-butyl ether, or *MTBE*. Liquid *MTBE i*s added as a solvent to petroleum to reduce pollution.

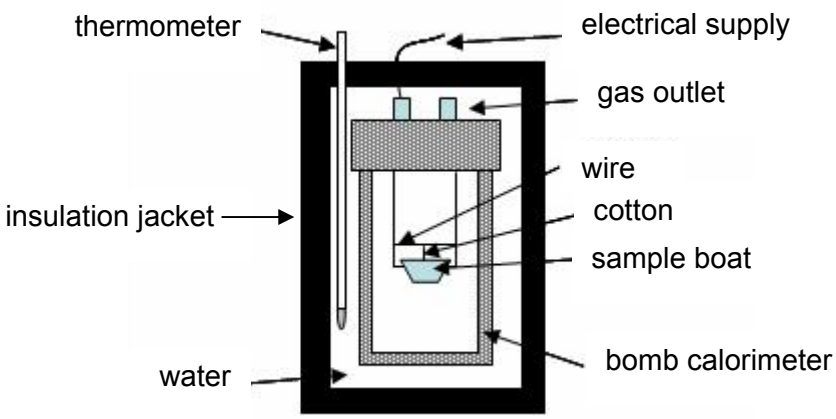


methyl-tertiary-butyl ether (*MTBE*)

(a) What is meant by the *standard enthalpy change of formation of MTBE*? Support your answer with the aid of an appropriate equation.

[2]

(b) While the enthalpy change of formation of *MTBE* cannot be determined experimentally, the enthalpy change of combustion of *MTBE* can be determined using a bomb calorimeter. The experimental set-up is as shown.



A known volume of water was added and *MTBE* was introduced into the sample boat. A spark was produced when the electrical supply was switched on. The temperature was recorded at every 1 minute interval for 20 minutes. At the end of the experiment, the apparatus was allowed to cool.

The following results were recorded:

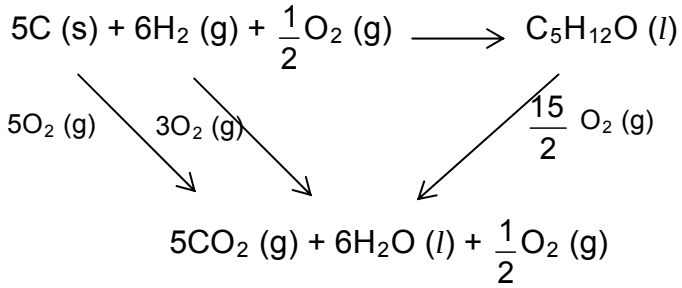
Mass of sample boat + *MTBE* (start of experiment) / g	106.01
Mass of sample boat + *MTBE* (after leaving to cool) / g	100.51
Volume of water heated / cm^3	500
Initial temperature / °C	28.0
Final maximum temperature / °C	95.5

The instrumentation manual of the calorimeter states that the efficiency factor is 70%.

Calculate the enthalpy change of combustion of *MTBE*. Assume that the specific heat capacity of water is 4.18 J g^{-1} K^{-1}.

[4]

(c) Using your answer to part **(b)**, the energy cycle below and the data provided, calculate the enthalpy change of formation of *MTBE.*



Data provided: $\Delta H_f(CO_2)$ = -393 kJ mol^{-1}, $\Delta H_f(H_2O)$ = -286 kJ mol^{-1}

[1]

(d) Compound **K** is a structural isomer of *MTBE*. **K** decolourises warm alkaline iodine solution and produces effervescence with sodium metal. When **K** is refluxed with concentrated sulphuric acid, two isomeric compounds **L** and **M** are obtained. Upon reaction with hot acidified potassium manganate (VII), **L** produces **N,** C_3H_6O. **N** gives a precipitate when treated with 2,4-dinitrophenylhydrazine but not with Tollen's reagent.

(i) State the type of structural isomerism between *MTBE* and **K**.

(ii) Deduce the structures of **K**, **L**, **M** and **N**. Explain the chemistry of the reactions involved.

(iii) Draw the structural formula of two other isomers of **K**.

[7]

(e) Inorganic elements react with oxygen to form oxides. A 35.55 g sample of **X**, a group (VI) element, was burnt in excess oxygen to form 57.15 g of an oxide of molecular formula **X**O_3.

(i) Determine the identity of **X**.

(ii) Predict the pH of the solution formed when **X**O_3 is added to water.

(iii) Given that the oxide behaves in the same way as sulphur trioxide, write an equation for the reaction of the oxide with sodium hydroxide.

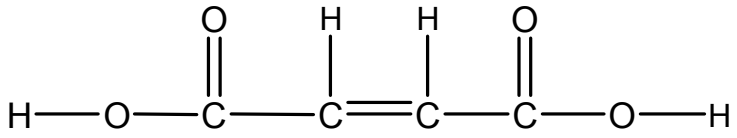
(iv) Another element, **Y**, is in the same period as **X**. The oxide of **Y** is able to dissolve in both acids and alkalis.

Suggest which oxide has a higher boiling point. Explain your answer in terms of the different chemical properties and structures of the compounds.

[6]

[Total: 20]

7(a) The structure of compound **A**, butenedioic acid, is given below:



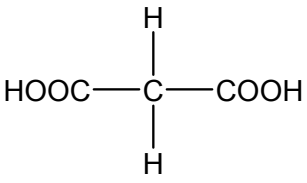
Compound **A**

Butenedioic acid exhibits *cis-trans isomerism*.

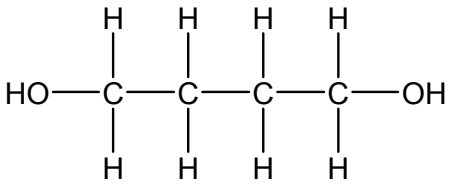
(i) With reference to butenediodic acid, explain what is meant by the terms in italics.

(ii) Explain, using diagrams, why the *trans*–isomer has a higher boiling point than the *cis*–isomer.

(iii) The structural formula of compounds **B** and **C** are given below.



Compound **B**



Compound **C**

By means of simple chemical tests, show how the **first compound** in each set could be positively identified. In your tests, describe clearly the reagents and conditions to be used and the expected observations for each compound. **No test is to be used more than once.**

1 **A** from **B**

2 **A** from **C**

[9]

(b) Mixing butenedioic acid and methanol under suitable conditions in a beaker will form an equilibrium mixture as shown by the equation.

$$HOOCCH{=}CHCOOH\ (l) + 2CH_3OH\ (l) \rightleftharpoons CH_3OCOCH{=}CHCOOCH_3\ (l) + 2H_2O\ (l)$$

(i) State the reagents and conditions needed for the above reaction.

(ii) In the beaker of organic mixture, a dynamic chemical equilibrium is established between the products and reactants. Explain what is meant by the term *dynamic chemical equilibrium*.

(iii) Explain the effect of increasing concentration of methanol on the composition of the equilibrium mixture.

(iv) If 1.0 mol of HOOCCH=CHCOOH and 1.0 mol of CH_3OH are allowed to reach equilibrium at 298K, 0.76 mol of H_2O is produced. Calculate the value of the equilibrium constant, K_c at 298K.

[7]

(c) The iodate (V) ion, IO_3^-, is a powerful oxidising agent and reacts with sulphite ions, SO_3^{2-}. In the reaction, iodine is produced.

In an experiment, 18.85 cm^3 of 0.200 mol dm^{-3} of iodate (V) ions required 31.40 cm^3 of 0.300 mol dm^{-3} of sodium sulphite for complete reaction.

(i) Determine the number of moles of sulphite ions that react with one mole of iodate (V) ions.

(ii) What change in oxidation number does the sulphur in SO_3^{2-} undergo?

(iii) Hence, calculate the oxidation state of sulphur in the sulphur - containing product of this reaction and suggest its chemical formula.

(iv) Hence, construct a balanced equation for the reaction between iodate (V) ions and sulphite ions.

[4]

[Total: 20]