Name:		Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination 2014
Year 6

H1 CHEMISTRY 8872/02

Paper 2 Section A (Structured Questions) **16 September 2014**

Paper 2 Section B (Free–Response Questions) **2 hours**

Additional Materials: Data Booklet, Writing Paper

INSTRUCTIONS TO CANDIDATES

1 Answer **all** questions in Section A, and any **two** questions in Section B.

2 Write your **name** and **class** on this cover page.

Section A

3 Write your answers in the spaces provided on this question paper.

Section B

4 Write your **name** and **class** on the Cover Sheet provided.

5 Write your answers on the separate writing papers provided.

6 Answer any two questions.

7 At the end of the examination, fasten all your work securely together with the Cover Sheet on top.

INFORMATION FOR CANDIDATES

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

You are advised to show all workings in calculations.

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

For Examiner's Use	
Question No.	Section A Marks
1	/10
2	/8
3	/12
4	/5
5	/5
Total	/40

This question paper consists of **16** printed pages and **0** blank page.

Section A

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

1 Elements **A**, **B**, **C**, **D** and **E** are five consecutive elements from Period 3 and 4 of the Periodic Table. The table below shows the 1st eight ionisation energies for element **C**.

No. of electrons removed	1	2	3	4	5	6	7	8
Ionisation energy / kJ mol^{-1}	1260	2300	3850	5150	6542	9362	11018	33604

(a) **(i)** Deduce and explain which group element **C** comes from.

(ii) Hence deduce the identity of element **C** and write down its electronic configuration.

[4]

(b) Explain the following observations.

(i) The first ionisation energy of element **B** is lower than the first ionisation energy of element **A** even though the effective nuclear charge of element **B** is higher than the effective nuclear charge of element **A**.

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(ii) The atomic radius of element **D** is smaller than the atomic radius of element **E**.

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(iii) The ionic radius of the ion formed by the element **C** is larger than the ionic radius of the ion formed by the element **E** even though both of the ions are isoelectronic.

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[6]

[Total: 10]

2 Chlorine and its compounds are applied in a variety of chemical reactions.

(a) Chlorine reacts with benzene, cyclohexene and cyclohexane under different conditions.

(i) State the respective reaction conditions for chlorine to react with each of the organic compounds.

With benzene .....

With cyclohexene .....

With cyclohexane .....

(ii) Hence, deduce the order of reactivity for benzene, cyclohexene and cyclohexane.

In order of increasing reactivity:

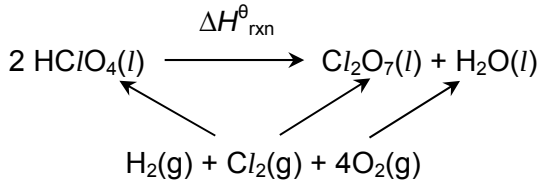
.....

[3]

(b) The most stable oxide of chlorine is dichlorine heptoxide. It has the formula Cl_2O_7 and contains a C*l*–O–C*l* linkage. Draw the dot–and–cross diagram for dichlorine heptoxide, stating the shape with respect to each central atom.

[2]

(c) Dichlorine heptoxide is formed from the dehydration of perchloric acid, $HClO_4$. As both reactants and products are unstable, the standard enthalpy change of reaction, ΔH^{θ}_{rxn}, can only be obtained through theoretical calculations.



$\Delta H^{\theta}_{f}(HClO_4) = -6.3$ kJ mol^{-1}

$\Delta H^{\theta}_{f}(Cl_2O_7) = -135$ kJ mol^{-1}

$\Delta H^{\theta}_{c}(H_2) = -286$ kJ mol^{-1}

(i) Define the term standard enthalpy change of formation of dichlorine heptoxide.

.....

.....

(ii) With reference to the energy cycle and data provided, calculate the standard enthalpy change of reaction, ΔH^{θ}_{rxn}.

[3]

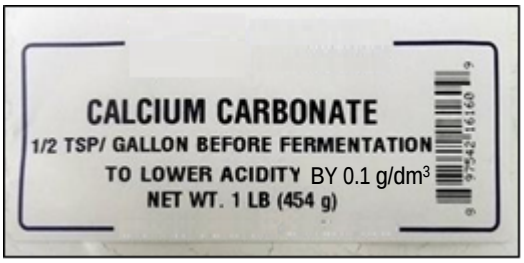
[Total: 8]

3 Wine is a complex mixture of chemicals which contribute to the acidity, taste, colour and texture of the wine. During the making of wine, the acidity of wine, which is also measured in terms of pH, is carefully controlled as it affects both the fermentation process and the wine's final taste.

Each type of wine has a different level of acidity. In order to obtain a fermentation mixture with the appropriate pH, home winemakers often need to refer to recommended levels of "*titratable acidity (TA)*", which calculates the mass of acid in a fixed volume of wine by assuming that tartaric acid is the only acid present in wine. The following table shows the recommended TA for two types of wine.

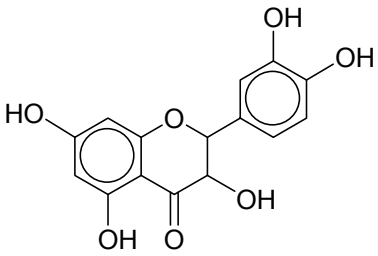
wine style	recommended titratable acidity (g dm^{-3})	pH range
dry white wine	6.5 – 7.5	2.11 – 2.16
sherry	5.0 – 6.0	2.16 – 2.20

One reliable method to determine the TA of wine is to perform titration of a small wine sample with aqueous sodium hydroxide. If the TA is found to be above the recommended range for a desired wine type, calcium carbonate can be added as an additive. The label below shows the calcium carbonate sold online by wine making websites.

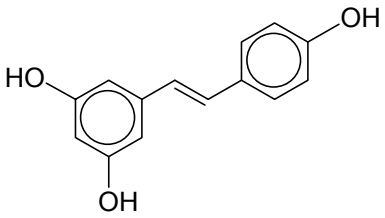


(½ tsp contains 2.85 g of calcium carbonate; 1 gallon = 3.8 dm^3)

Some of the chemicals in wine also act as buffers and thus regulate acidity. Examples include resveratrol and quercetin, whose structures are shown below. As many of such chemicals are found in the skins of red grapes, red wine is found to have a "*larger buffering capacity*" compared to white wine.



quercetin



resveratrol

(a) (i) Define pH.

.....

.....

(ii) By using H_2T as the symbol for tartaric acid, write the equilibrium which represents the dissociation of the first proton. Write an expression for the acid dissociation constant, K_a, for your chosen equilibrium.

(iii) With reference to the table on page 6, calculate the minimum concentration, in mol dm^{-3}, of tartaric acid and hydrogen ions recommended in sherry.

M_r of tartaric acid = 150.0

(iv) Hence, deduce the acid dissociation constant, K_a, of tartaric acid.

[5]

(b) Suggest with explanations, a suitable indicator for the titration between wine and sodium hydroxide.

---

[2]

(c) A home wine maker prepared 20 dm^3 of fermentation mixture for dry white wine and found that the TA was 7.8. Using the data on page 6, calculate the minimum mass of online purchased calcium carbonate required to obtain a suitable mixture for dry white wine.

[2]

(d) **(i)** On the structure of quercetin on page 6, name and circle two different functional groups.

(ii) Given that resveratrol is weakly acidic, write equations to illustrate how a buffer solution of resveratrol (represented as HA) and its sodium salt (represented as Na^+A^-) regulates acidity.

When H^+ ions are added .....

When OH^- ions are added .....

(iii) Suggest what it means for red wine to have a "larger buffering capacity".

.....

.....

[3]

[Total: 12]

4 Magnesium, the fourth most abundant element on Earth, has diverse applications such as in building or medicine.

(a) **(i)** Write equations, with state symbols, for the reactions of the oxides of magnesium and phosphorous with cold water.

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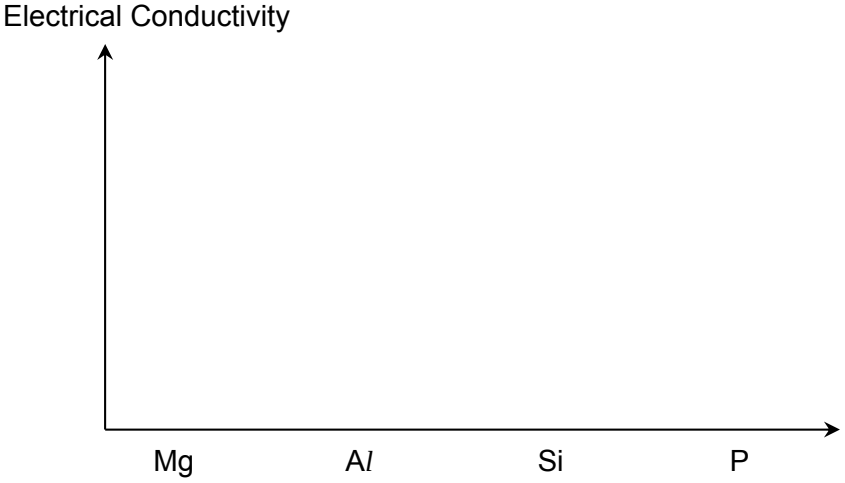
.....

(ii) On the axes below, sketch the electrical conductivity of the period 3 elements from magnesium to phosphorous.



[3]

(b) Constipation medicine, containing magnesium, is available in tablet or powder containing capsule forms as shown below.

Tablet

Powder Containing Capsule

Suggest, with explanations, which form would faster relieve the symptoms of constipation.

---

[2]

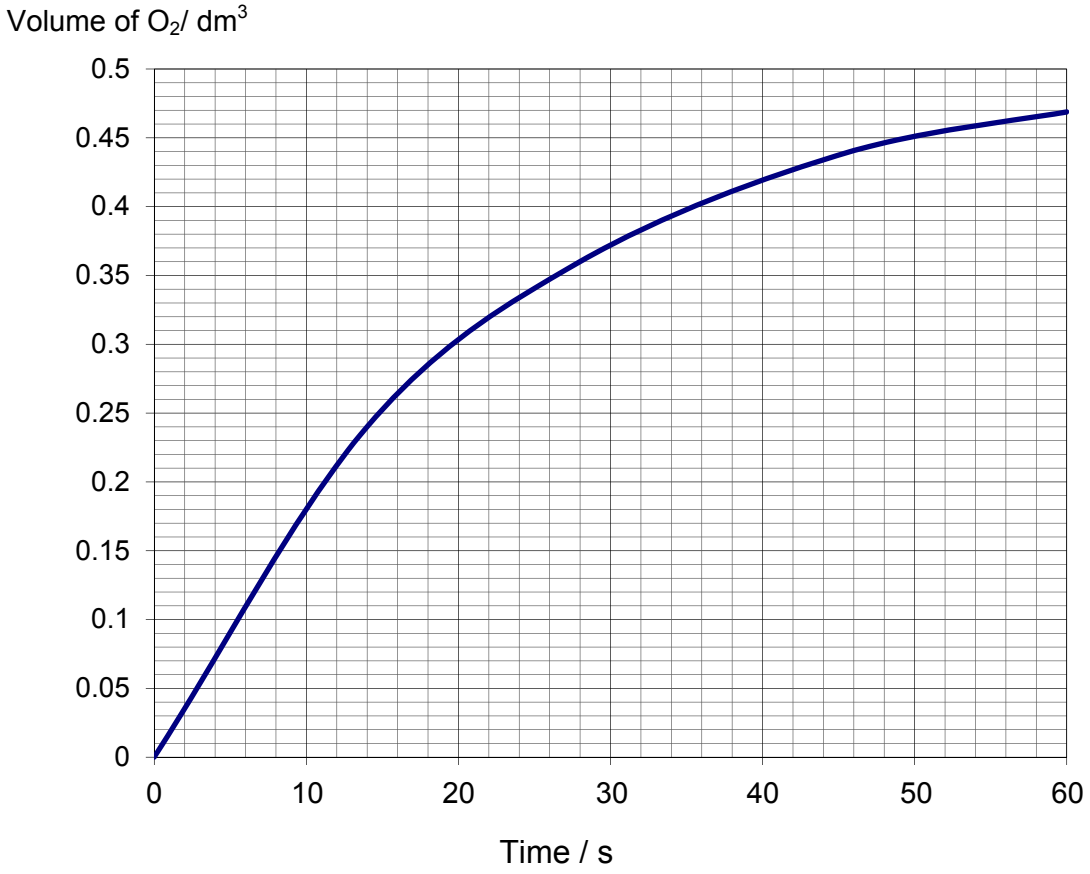
[Total: 5]

5 Hydrogen peroxide solution can be used to bleach hair.

A solution of hydrogen peroxide slowly in aqueous solution according to the following equation.

$$H_2O_2(aq) \rightarrow H_2O(l) + \frac{1}{2} O_2(g)$$

A 50 cm^3 solution with the original concentration of 0.8 mol dm^{-3} was placed in a bottle contaminated with transition metal ions, which act as catalysts for the decomposition. The volume of oxygen produced was collected over time, and the following graph was obtained at room conditions.



(a) Complete the following table to determine the volume of oxygen produced when the concentration of hydrogen peroxide has been reduced to 50% and to 25% of original concentration.

percentage of original $[H_2O_2]$ left	no. of moles of H_2O_2 reacted	volume of oxygen produced / dm^3
50%		
25%		

[2]

(b) Using the graph and information from **(a)**, deduce the order with respect to hydrogen peroxide.

[2]

(c) Given that the gradient at 0 seconds is 0.0125 mol dm^{-3} s^{-1}, calculate a value for the rate constant.

[1]

[Total: 5]

Section B

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

6 (a) The ExxonMobil's Singapore Refinery, its largest refinery in the world, owns and operates a 605,000–barrel–per–day refinery in Jurong and on Jurong Island. The refinery operating on the Jurong Island converts crude oil into finished products such as liquefied petroleum gas and motor gasoline among many other products.

Gasoline, commonly known as petrol in Singapore, is a complex mixture of hydrocarbon that may contain 500 hydrocarbons between 5–12 carbons. A typical composition of gasoline is as follows:

type of hydrocarbon	*Percentage in mixture*
Straight chain alkanes	30%
Branched chain alkanes	30%
Cyclic alkanes	20%
Benzenes	20%

(i) For each of the four types of hydrocarbon, draw the structural formula of a representative 6–carbon hydrocarbon.

(ii) What would be the mass of a gasoline mixture containing 500 6–carbon hydrocarbons?

[4]

(b) A Japanese company claimed to have created a nanotechnology powered fuel–saving catalyst called "Nanoballs". This catalyst is said to enable gasoline to burn more efficiently and cleanly. One main component of Nanoballs is aluminium silicate which is essentially aluminium oxide and silicon dioxide.

(i) Describe the structure and bonding in aluminium oxide and silicon dioxide.

(ii) With the use of a balanced chemical equation, identify one reagent that can be used to distinguish between aluminium oxide and silicon dioxide.

[3]

(c) The Jurong Aromatics Plant on Jurong Island produces cyclohexane used in making nylon and to manufacture end products such as textile, carpets and auto parts. A sample of cyclohexane and its reaction with bromine is studied.

Bromine is added to an excess of cyclohexane (C_6H_{12}) and water. A shot of ultraviolet light is then given to this mixture. When the reaction is complete, the resultant aqueous layer contains hydrobromic acid (HBr).

It is found that 25 cm^3 of 0.100 mol dm^{-3} solution of aqueous sodium hydroxide is required to neutralise all the acid in the aqueous layer.

(i) Identify the type of reaction that has occurred between cyclohexane and bromine.

(ii) How can you tell that the reaction is complete?

(iii) Determine the number of moles of HBr present.

(iv) Assuming that the main organic product of this reaction is bromocyclohexane, write a balanced equation for the reaction and determine the number of moles of cyclohexane that has reacted.

[6]

(d) To test for the presence of bromocyclohexane, aqueous sodium hydroxide is added to bromocyclohexane and heated. Reagent **F** followed by reagent **G** is then added to the resulting solution. A large amount of precipitate is observed.

(i) Identify the type of reaction that has occurred between bromocyclohexane and aqueous sodium hydroxide.

(ii) Identify reagents **F**, **G** and the precipitate.

(iii) The reaction in **(i)** is found to be overall second order, involving both reactants in a one–step reaction. Write the rate equation for this reaction.

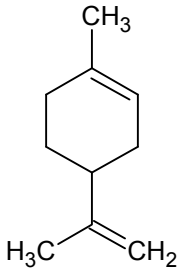
(iv) Predict with reasoning how the rate would be affected if the concentration of both reactants is doubled.

(v) When chlorocyclohexane is used instead of bromocyclohexane in the reaction with aqueous sodium hydroxide under similar conditions, it is found that the precipitate appears more slowly. Explain this difference.

[7]

[Total: 20]

7 Limonene, $C_{10}H_{16}$, is a cyclic terpene which possesses a strong smell of lemon.

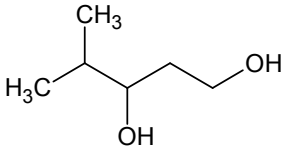


Limonene

(a) γ–Terpinene is an isomer of limonene. On treatment with an excess of hot concentrated manganate(VII) ions it forms two products **H** and **J**.

$$\gamma - \text{terpinene} \xrightarrow{MnO_4^-} \underset{C_4H_6O_3}{\mathbf{H}} + \underset{C_6H_{10}O_3}{\mathbf{J}}$$

Both compounds **H** and **J** evolve CO_2 with $Na_2CO_3(aq)$ and both give orange precipitates with 2,4–dinitrophenylhydrazine reagent, but neither reacts with Fehling's solution. Compound **H** gives a yellow precipitate with alkaline aqueous iodine, but **J** does not. Compound **J** can be obtained from compound **K** by reaction with hot acidified $Cr_2O_7^{2-}$ ions.



K

Use the information above to deduce a structure for γ–terpinene, compound **H** and **J,** explaining **all** the reactions involved.

[12]

(b) Because of its ready availability, surplus limonene has been used as a biofuel in diesel engines.

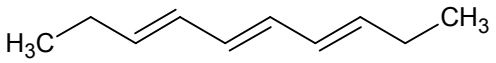
(i) Define the term *standard enthalpy change of combustion* of limonene.

(ii) Using the molecular formula of limonene, write a balanced equation for the complete combustion in air.

(iii) Use bond energy values from the *Data Booklet* to calculate the enthalpy change of combustion of limonene. [Rather than the C=O value given in the *Data Booklet*, use a value of 805 kJ mol^{-1} for the bond energy of each C=O bond in CO_2.]

(iv) The enthalpy change of combustion of conventional diesel fuel is about –45 kJ g^{-1}. How does the enthalpy change of combustion of limonene per gram compare to this value?

(v) Deca–3,5,7–triene is another isomer of limonene. Explain, in terms of bonding and structure of both limonene and deca–3,5,7–triene, which compound should have a higher boiling point.



deca–3,5,7–triene

[8]

[Total: 20]

8 Methanol, a highly toxic liquid, has a variety of applications in fuel cells and organic synthesis, among many others.

(a) When methanol is used as a fuel cell, it is oxidised to carbon dioxide. The oxidising agent, oxygen, is converted to water.

(i) By balancing half equations, write the overall equation for the reaction above.

(ii) In an experiment, 350 cm^3 of 1.5 mol dm^{-3} methanol is reacted. Given that the percentage of oxygen in air is 20%, calculate the minimum volume of air required, at room temperature and pressure, to completely react with the methanol present.

(iii) Suggest suitable reagents and conditions to convert methanol to carbon dioxide in an organic laboratory.

[5]

(b) Methanol can be converted into product **M** in the following three step synthesis.

$$CH_3OH \xrightarrow{\text{Step I}} CH_3Cl \xrightarrow[\text{heat}]{H_2N{-}CH_2{-}CN} \mathbf{L} \xrightarrow{\text{Step II}} \underset{\mathbf{M}}{HN(CH_3){-}CH_2{-}COOH}$$

(i) Deduce the identity of **L**, and suggest suitable reagents and conditions for Steps I and II.

(ii) In product **M**, the nitrogen atom is acting as a Bronsted base, and the carboxylic acid acts as a Bronsted acid. Suggest a possible product when product **M** undergoes an intramolecular neutralisation.

[4]

(c) Methanol and ethanoic acid react as shown in the following equilibrium.

$$CH_3OH + CH_3COOH \rightleftharpoons \mathbf{N} + H_2O \qquad \Delta H < 0$$

(i) A teacher mixed 0.5 mol of CH_3OH and 0.5 mol of ethanoic acid in 1 dm^3 of a suitable solvent and allowed the system to react. After some time, he found that the yield of **N** remained constant at 60%. Calculate a value of the K_c for this reaction, including units.

(ii) Hence, deduce the initial amount of methanol required to react with 1.5 mol of ethanoic acid, to produce the same amount of **N** in **(i)**.

(iii) Deduce if an increase or decrease in temperature will improve the yield of product **N**.

(iv) State and explain the relative acidity of methanol and ethanoic acid.

(v) Draw the displayed formula of product **N**.

(vi) Write a balanced equation for the reaction when **N** is heated with aqueous sodium hydroxide. State the type of reaction that has taken place.

[11]

[Total: 20]