TEMASEK
JUNIOR COLLEGE

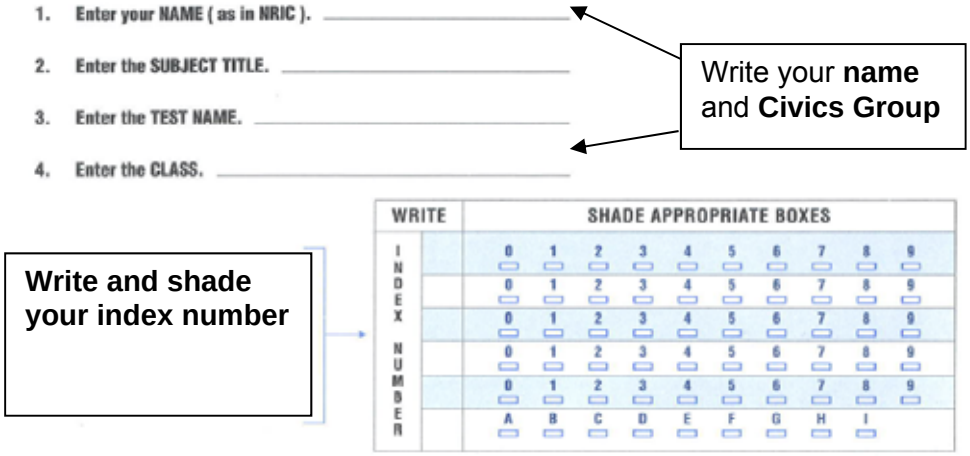
CHEMISTRY 8872/01

Paper 1 Multiple Choice **15th September 2017**
50 minutes

Additional materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.



There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **13** printed pages.

Section A

Part 1

For each question there are four possible answers, **A**, **B**, **C** and **D**. Choose the **one** you consider to be correct.

1 The reaction between aluminium powder and anhydrous barium nitrate is used as the propellant in some fireworks. Nitrogen gas is one of the products formed.

Which volume of nitrogen, measured under room conditions, is produced when 1 g of anhydrous barium nitrate reacts with an excess of aluminium?

A 86.9 cm^3 **B** 91.8 cm^3 **C** 174 cm^3 **D** 184 cm^3

2 Which statements about relative molecular mass are correct?

A It is the mass of one mole of the molecule.

B It is the ratio of the average mass of a molecule to the mass of a ^{12}C atom.

C It is the sum of the relative atomic masses of all the atoms within the molecule.

D It is the mass of one mole of molecules on a scale where one atom of ^{12}C has a mass of 12 units.

3 The first stage in the manufacturing of nitric acid is the oxidation of ammonia by oxygen.

$$\mathbf{w}NH_3(g) + \mathbf{x}O_2(g) \rightarrow \mathbf{y}NO(g) + \mathbf{z}H_2O(g)$$

Which values of **w**, **x**, **y** and **z** are needed to balance the equation?

	w	**x**	**y**	**z**
A	4	5	4	6
B	4	6	4	5
C	5	6	5	4
D	6	5	6	4

4 When beams of charged particles are pass through an electric field, they are deflected.

A stream of gaseous protons was passed between two oppositely charged plates and it deflected at an angle of 20.0°.

Under identical conditions, what angles and direction will He^{2+} be deflected?

	Angle of deflection	Deflected towards
A	5	Positive plate
B	10	Negative plate
C	20	Positive plate
D	40	Negative plate

5 In the reaction shown, M represents a Group 2 element.

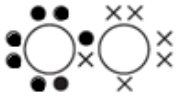
$$MO_2 \rightarrow MO + ½\ O_2$$

Which statement about this reaction is correct?

A It is a redox reaction.

B The anion in MO_2 contains 8 electrons.

C The lattice energy of MO_2 is greater in magnitude than the lattice energy of MO.

D The dot and cross diagram of the anion is  .

6 Which of the following species do not have all atoms that lie on the same plane?

A CH_2CH_2 **B** I_3^- **C** XeF_4 **D** $BeCl_4^{2-}$

7 In which pair of compounds does the first compound have higher boiling point than the second compound?

A HI, HF

B MgO, NaCl

C CH_4, SiH_4

D *trans*-$C_2H_2Cl_2$, *cis*-$C_2H_2Cl_2$

8 A slow stream of water from a tap can be deflected by an electrostatically charged plastic rod because water is a polar molecule.

Why is a water molecule polar?

A Water is able to dissociate into ions.

B The oxygen atom has 2 lone pairs of electrons

C Molecules are bonded together by hydrogen bonds.

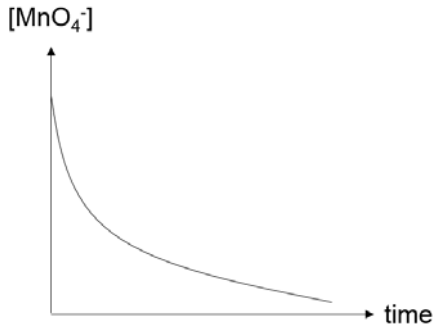
D The oxygen and hydrogen atoms have different electronegativities.

9 An autocatalytic reaction is one whereby the products catalyses the reaction. One such reaction is the reaction between ethanedioate and manganate(VII) anions.

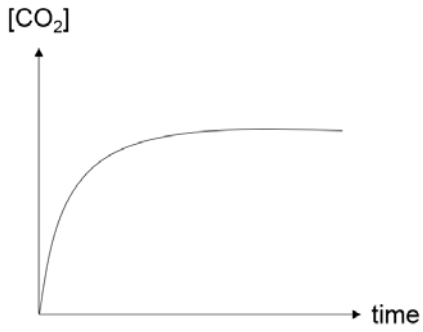
$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

Which of the following graphs would be obtained for an autocatalytic reaction?

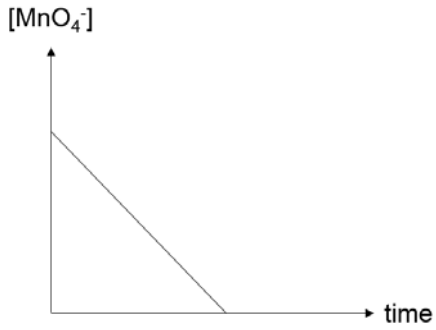
A



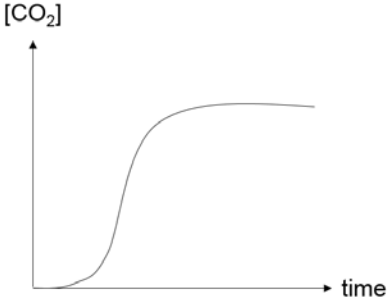
B



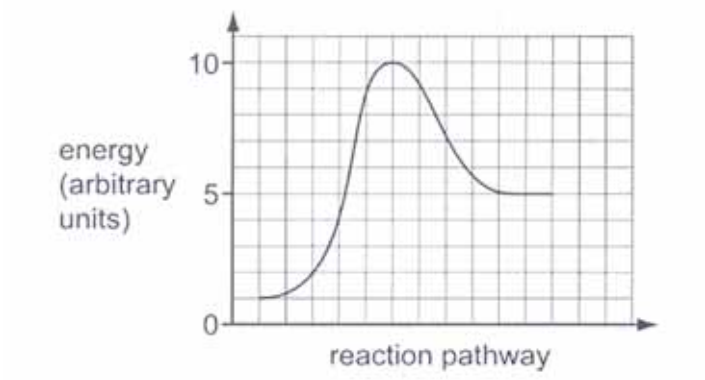
C



D

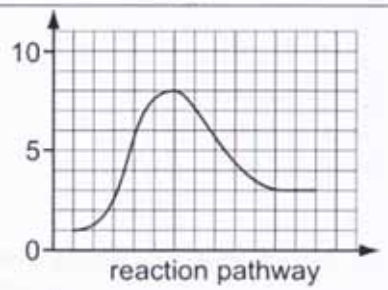
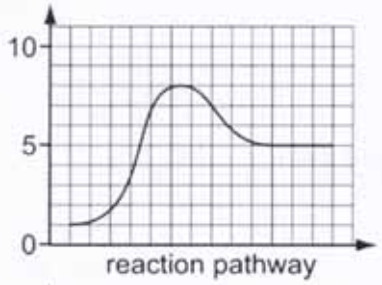
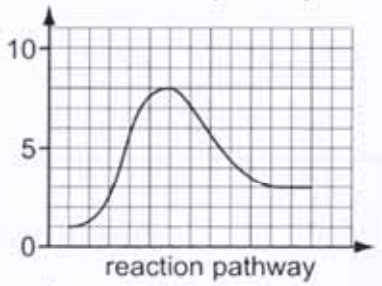
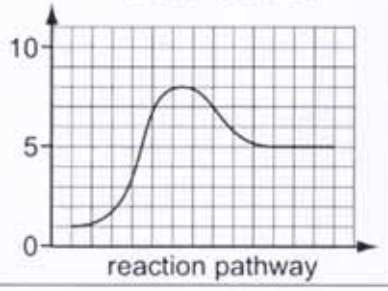


10 The diagram shows the reaction pathway diagram for an uncatalysed reaction.



The reaction is then catalysed.

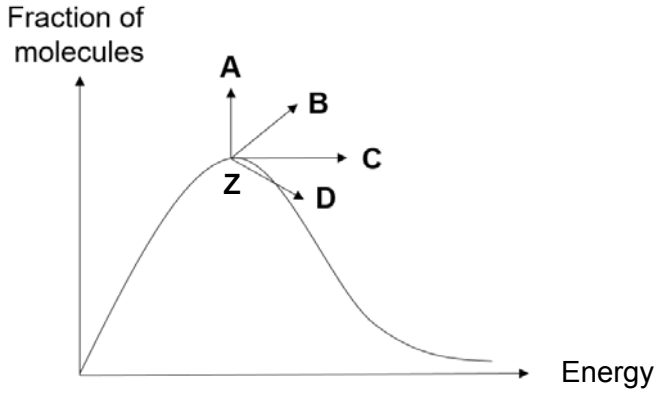
What are the changes in the rate constant and the reaction pathway diagram?

	rate constant	energy profile
A	decrease	
B	decrease	
C	increase	
D	increase	

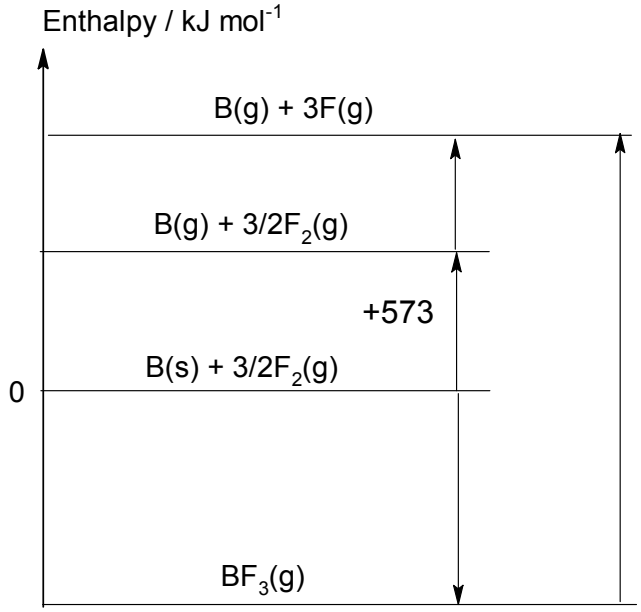
11 The following Maxwell-Boltzmann distribution curve shows the reaction when excess sodium carbonate reacts with 1 mol dm^{-3} hydrochloric acid at room temperature.

Point **Z** on the curve shows the most probable energy attained by the reactant molecules.

In which direction will point **Z** move when the same experiment is repeated with 2 mol dm^{-3} hydrochloric acid at 50 ^{o}C?



12 Reaction of boron hydride with fluorine is a vigorous process and is used as rocket propellant. The reaction yields gaseous boron fluoride, BF_3, as one of the products. An energy level diagram involving BF_3 is shown below.



Given that the standard enthalpy change of formation of boron fluoride = -1137 kJ mol^{-1}

Use the above information and appropriate data from the Data Booklet, calculate the bond energy of B-F bond.

A 623 **B** 649 **C** 1869 **D** 1947

13 When 0.47 g of pentene was completely burnt in air, the heat produced raised the temperature of 200 g of water by 26.4 °C.

What is the enthalpy change of the reaction?

A - 22 kJ mol^{-1}

B - 3290 kJ mol^{-1}

C - 3296 kJ mol^{-1}

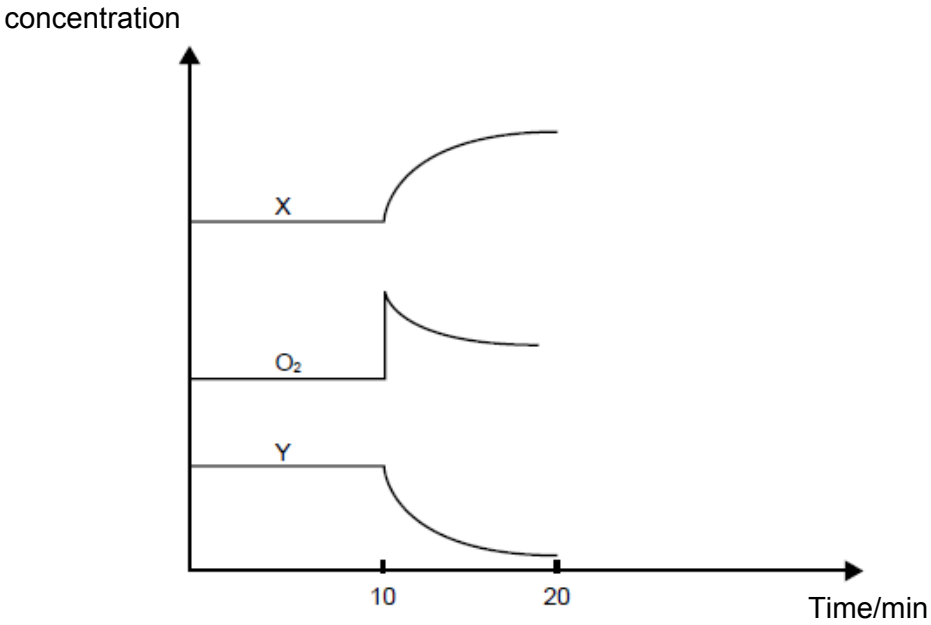
D - 3380kJ mol^{-1}

14 Sulfur dioxide can be converted to sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -192 \text{ kJ mol}^{-1}$$

A container was filled with an equilibrium mixture of sulfur dioxide, sulfur trioxide and oxygen in the presence of a catalyst. The container was initially at 450°C.

Concentrations during an experiment are shown on the diagram below.



Which of the following correctly shows the change at the 10 minute point and the identities of **X** and **Y**?

	X	**Y**	Change at the 10 min point
A	SO_2	SO_3	Temperature increases
B	SO_3	SO_2	Temperature increases
C	SO_3	SO_2	Oxygen was added
D	SO_2	SO_3	Oxygen was added

15 Which of the following could act as buffer solutions?

A sodium hydrogen carbonate + sodium carbonate

B nitric acid + sodium nitrate

C sodium hydroxide + sodium chloride

D ethanoic acid + methylethanoate

16 Element **Y** is in Period 13 of the Periodic Table. The following four statements were made about the properties of element **Y** or its compounds.

Three statements are correct descriptions and one is false.

Which statement does **not** fit with the other three?

A Element **Y** is a solid at room temperature.

B Element **Y** forms only one chloride when reacted with chlorine.

C The oxide of **Y** reacts with water to give an acidic solution.

D Adding NaOH(aq) to the solution resulting from the reaction of the chloride with water produces a white precipitate which is insoluble in excess of NaOH(aq).

17 For the elements in the third period of the Periodic Table, which property increases consistently from sodium to chlorine?

A electronegativity

B electrical conductivity

C melting point

D first ionisation energy

18 The equations for the complete combustion of the first four members of the alcohol homologous series are shown below.

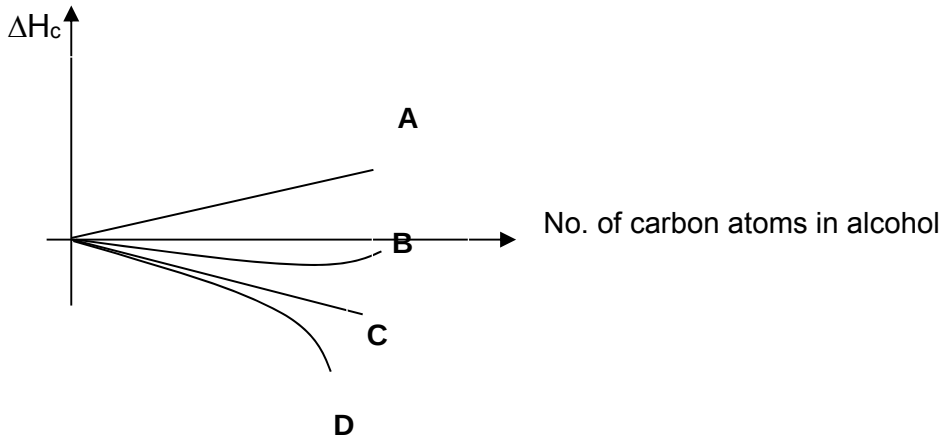
Methanol: $CH_3OH(l) + 1\frac{1}{2}O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

Ethanol: $CH_3CH_2OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$

Propan-1-ol: $CH_3CH_2CH_2OH(l) + 4\frac{1}{2}O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$

Butan-1-ol : $CH_3CH_2CH_2CH_2OH(l) + 6O_2(g) \rightarrow 4CO_2(g) + 5H_2O(l)$

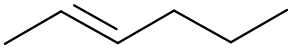
Which line on the graph shows the relationship between the number of carbon atoms in the alcohol and enthalpy change of combustion of the alcohol?



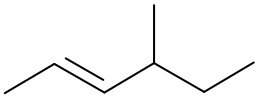
19 Use of the *Data Booklet* is relevant to this question.

Which compound has a M_r of 84 and will react with HBr to give a product with an M_r of 164.9?

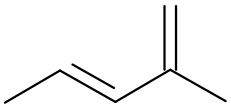
A



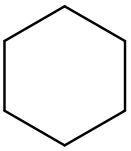
B



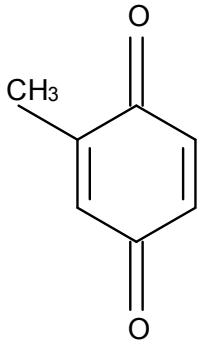
C



D

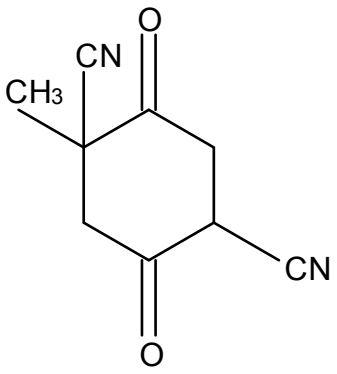


20 The unsaturated diketone shown is excreted by the bombardier beetle.

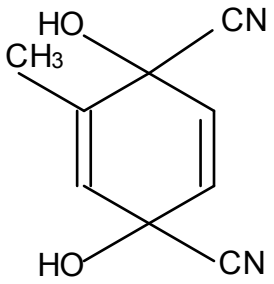


What is the compound formed when this compound reacts with hydrogen cyanide at 10-20°C?

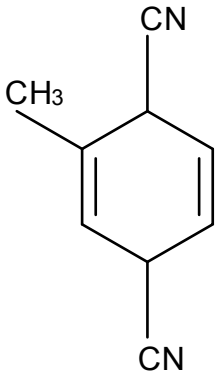
A



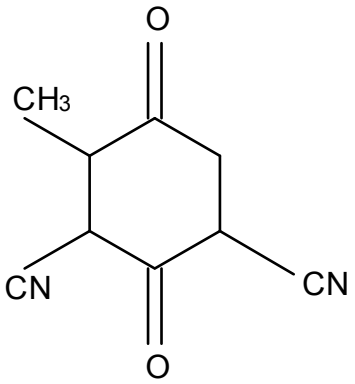
B



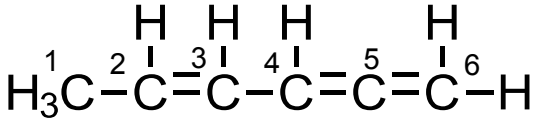
C



D



21



Which bond is present in the compound above?

A a σ bond formed by sp^3 - sp^3 overlap between C3 and C4

B a σ bond formed by sp^2 - sp overlap between C4 and C5

C a σ bond formed by sp^2 - sp^2 overlap between C5 and C6

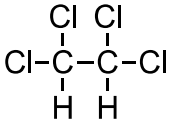
D a π bond formed by sp^2 – sp^2 overlap between C2 and C3

22 How many different alkenes are formed when 2-bromo-3-methylbutane reacts with ethanolic potassium hydroxide?

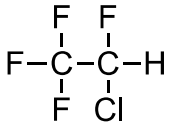
A 2 **B** 3 **C** 4 **D** 5

23 Which of the following will not damage the ozone layer through a radical chain reaction?

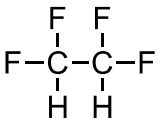
A



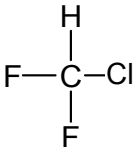
B



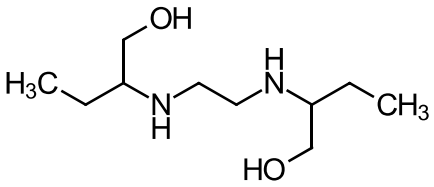
C



D



24 Ethambutol (EMB) is commonly used as first line drugs in tuberculosis treating regimes.

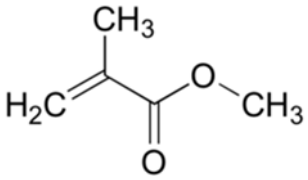


EMB

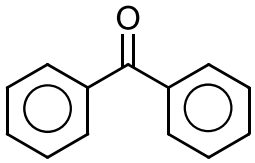
How many moles of hydrogen gas will be produced when one mole of EMB reacts with sodium?

A 1.0 **B** 2.0 **C** 3.0 **D** 4.0

25 Methyl methacrylate and benzophenone are common ingredients found in nail polishes.



Methyl methacrylate



Which of the following reagents cannot be used to distinguish between these two compounds?

A Acidified $K_2Cr_2O_7$ **B** 2,4-dinitrophenylhydrazine

C Tollens' Reagent **D** Bromine water

SECTION B

For each of the questions in this section, one or more of the 3 numbered statements **1** to **3** may be correct.

Decide whether each of the statements is or is not correct. (You may find it helpful to put a tick against the statements which you consider to be correct.)

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1,**2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

26 The Claus process recovers sulfur from the gaseous hydrogen sulfide found in raw natural gas and from the crude oil refinery by-product gases.

reaction I $2H_2S(g) + 3O_2(g) \rightarrow 2H_2O(l) + 2SO_2(g)$

reaction II $2H_2S(g) + SO_2(g) \rightarrow 2H_2O(l) + 3S(s)$

Which statement about the Claus process is correct?

1 H_2S is oxidised in the reaction.

2 SO_2 is a reducing agent.

3 Reaction II is a disproportionation reaction.

27 Which of the following have a solid lattice structure?

1 Ice

2 Iodine

3 Graphite

28 The following represents the electronic configuration of both a Group 2 cation and a Group 17 anion.

$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$

The radius of the anion is approximately twice that of the cation.

Which reasons explain the difference in size?

1 The cation has more protons than the anion.

2 There is more electron shielding in the anion than in the cation.

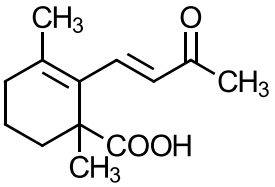
3 The anion is more electronegative than the cation.

The responses **A** to **D** should be selected on the basis of

A	B	C	D
1,**2** and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

No other combination of statements is used as a correct response.

29 Compound **Y** is a derivative of β-ionone, which is an important contributor of the aroma of roses.

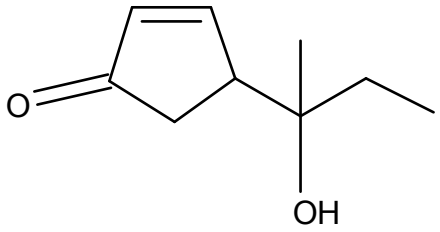


Compound **Y**

What is the correct number of H atoms incorporated per molecule of Compound **Y** when Compound **Y** is reacted with each of the following reducing agents?

	Reducing agent	Number of hydrogen atoms incorporated per molecule of **Y**
1	$NaBH_4$ in ethanol	2
2	H_2 / Ni	6
3	LiA/H_4 in dry ether	8

30 Compound **Z** has the following structure:



Compound **Z**

Which of the following statements about compound **Z** is ***incorrect***?

1 It will give orange crystals with Brady's reagent.

2 It is able to exhibit *cis trans* isomerism.

3 It turns acidified potassium dichromate orange to green.

A: 8 B: 8
C: 7 D: 7

2017 JC2 Prelim H1 CHEMISTRY MCQ Worked Solution

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
B	C	A	B	A	D	B	D	D	D	D	B	B	C	A
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
C	A	C	A	B	B	A	C	A	C	D	A	D	B	C

1 Answer: B

Since $Ba(NO_3)_2 \equiv N_2$, M_r of $Ba(NO_3)_2$ = 261.3
No. of moles of N_2 = No. of moles of $Ba(NO_3)_2$ = $\frac{1}{261.3}$ = 3.83×10^{-3} mol
Volume of N_2 = $3.83 \times 10^{-3} \times 24000$ = 91.8 cm^3

2 Answer: C

Definition – Relative molecular mass is the average mass of one molecule of an element or compound on a scale on which one atom of the ^{12}C isotope of carbon has a mass of 12 units.

A is incorrect. Relative molecular mass is a ratio.
B is incorrect. It should be the ratio of the average mass of a molecule to 1/12 the mass of a ^{12}C atom.
C is correct.
D is incorrect. It is the mass of one mole of molecules on a scale where one mole of ^{12}C atoms has a mass of 12 units.

3 Answer: A

$NH_3 + H_2O \rightarrow NO + 5H^+ + 5e$ x4
$4e + 4H^+ + O_2 \rightarrow 2H_2O$ x5
$4NH_3 + 4H_2O + 5O_2 \rightarrow 4NO + 10H_2O$
$4NH_3 + + 5O_2 \rightarrow 4NO + 6H_2O$

4 Answer: B

Positively charged particles deflected towards negative electrode

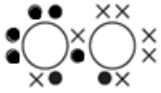
Angle of deflection α $\frac{Charge}{Mass}$

$$\frac{20}{Angle\ of\ deflection\ of\ He^{2+}} = \frac{\frac{+1}{1}}{\frac{+2}{4}}$$

Angle of deflection He^{2+} = +10

5 Answer: A

A. Disproportionation (self-redox) reaction.
Oxidation state of O changes from -1 in MO_2 to -2 in MO and 0 in O_2,
B. O_2^{2-} contains 8+8+2 = 18e
C. lattice energy ∝ $(q+q^-/r^+ + r^-)$ In this case, only r^- is different. Since peroxide ion, O_2^{2-} is bigger than oxide ion, O^{2-} the lattice energy of MO_2 is smaller than MO.
D: The dot-and-cross diagram of the anion should be



6 Answer: D

A: Ethene is a planar molecule which has all atoms on the plane

B: Tri-iodide has 3 lone pairs and 2 bond pairs, hence the ion is linear and all atoms lie on the same plane

C: XeF_4 has 4 bond pairs and 2 lone pairs, hence shape is square planar and all atoms lie on the same plane

D: $BeCl_4^{2-}$ has a total of 4 bond pairs (2 covalent bonds and 2 dative bonds) around Be atom. The shape is tetrahedral.

7 Answer: B

A: HF has hydrogen bonding between its molecules and hence require a larger energy to overcome compared to pd-pd between HI molecules.

B: MgO has a higher boiling point. MgO has a higher lattice energy than NaCl due to larger charge and smaller ionic radii of Mg^{2+} and O^{2-} ion compared to Na^+ and Cl^-.

C: SiH_4 has a higher boiling point as its M_r is larger than CCl_4 and thus the id-id interactions are stronger and more extensive than CH_4.

D: *trans*-$C_2H_2Cl_2$ has a lower boiling point as it has no net dipole moment so the molecule is non-polar and only has id-id interactions between the molecules. *cis*-$C_2H_2Cl_2$ has pd-pd interaction between the molecules and more energy is needed to overcome the stronger pd-pd interactions.

8 Answer D

Dipoles are present due to the difference in electronegativity between oxygen and hydrogen atoms. There are is a net dipole hence water is polar.

9 Answer: D

A & C: Wrong as the concentration of manganate would decrease slowly at the start of the reaction before decreasing more quickly as more Mn^{2+} catalyst is generated.

B: Wrong as the volume of CO_2 cannot be increasing rapidly at the start of the reaction due to slow rate of reaction.

10 Answer D

Rate constant is affected by temperature and catalyst.

Rate = k[reactant]

Catalyst increases the rate when concentration is constant hence catalyst increases rate constant.

Energy profile will show NO CHANGE in the ΔH however will lower the E_a of the graph.

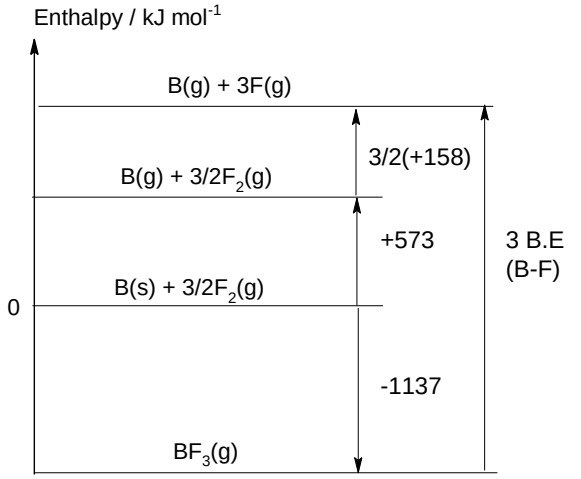
11 Answer: D

When temperature increases, Z will drop below the original point.

When concentration increases, the number of molecules with higher energy increases. The total number of molecules will also increase. Thus, the fraction of molecules remained unchanged.

As the y-axis is the fraction of molecules, shape of the graph is independent of concentration changes.

12 Answer: B



By Hess' Law,

-1137 + 3 B.E (B-F) = +573 + 3/2 (+158)
B.E (B-F) = +649 kJ mol^{-1}

13 Answer B

Heat released when pentene is burnt
= 200 x 4.18 x 26.4
= 22070 J

M_r of pentene = 5(12) + 10(10) = 70

No. of moles of pentene = 0.47/70 = 0.00671 mol

Enthalpy change of combustion = 22070/00671
= -3290 kJ mol^{-1}

Possible errors
A: did not divide by number of moles
C: Added mass of hydrocarbon in mass
D: M_r of pentene is 72

14 Answer: C

When the change was introduced, only the concentration of oxygen increased. This implies that oxygen was added. By Le Chatelier's Principle, the position of equilibrium will shift to the right resulting in an increase in concentration of SO_3 and decrease in concentration of SO_2.

If temperature was increased, there will not be any change in concentration of oxygen.

15 Answer A

A buffer must contain the weak acid and its conjugate base (or weak base and its conjugate acid)
A:Weak Acid (HCO_3^-) + Conjugate base (CO_3^{2-}) → Buffer
B: Strong Acid + Salt → Not a Buffer
C: Strong base + Salt → Not a Buffer
D: Weak Acid + Ester → Not a Buffer

16 Answer C

Option **A** implies **Y** can be Na, Mg, A*l*, Si, P or S.
Option **B** implies **Y** can be Na, Mg, A*l* or Si.
Option **C** implies **Y** can be P or S.
Option **D** implies **Y** must be Mg.

17 Answer A

B: electrical conductivity increase across the metals befor dropping to zero for the non metals.
C: melting point increase from sodium to silicon before dropping.
D: 1st IE generally increase across the period.

18 Answer: C

Enthalpy change of combustion is exothermic thus values are negative. The homologous series defer by a CH_2 hence enthalpy change varies linearly.

Reference table of values for alcohols.

name	alcohol	ΔH_{comb}
methanol	CH_3OH	–726
ethanol	CH_3CH_2OH	–1367
propan–1–ol	$CH_3(CH_2)_2OH$	–2021
butan–1–ol	$CH_3(CH_2)_3OH$	–2676
pentan–1–ol	$CH_3(CH_2)_4OH$	–3329
hexan–1–ol	$CH_3(CH_2)_5OH$	–3984
heptan–1–ol	$CH_3(CH_2)_6OH$	–4638
octan–1–ol	$CH_3(CH_2)_7OH$	–5294

19 Answer A

B has an M_r of 98.
C will react with 2 HBr to give a compound with M_r = 243.8.
D does not react with HBr.

20 Answer: B

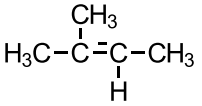
Nucleophilic addition reaction of the C=O.

21 Answer; B

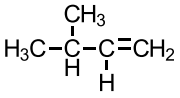
A: a σ bond formed by $sp^2 – sp^2$ overlap between C3 and C4
C: a σ bond formed by $sp – sp^2$ overlap between C5 and C6
D: a π bond formed by p – p overlap between C2 and C3

22 Answer: A

Elimination of HBr results in 2 alkenes,



and



23 Answer C

In presence of u.v light, the C-C*l* bond cleaves homolytically to produce Cl radical which can damage the ozone layer through a chain reaction. C-H and C-F bonds are stronger and will not break under u.v. light.

24 Answer A

2 –OH groups in 1 mol of EMB react with Na to give 1 mol of H_2 gas.

2 R-OH + 2Na → 2 RO^-Na^+ + H_2

25 Answer C

A: Orange dichromate turns green for methyl methacrylate as ester bond cleave and the primary alcohol part of the ester gets oxidised. Orange dichromate remains orange for benzophenone.

B: orange ppt formed for benzophenone and no orange ppt formed for methyl methacrylate.

C: Tollen's reagent is negative for both compounds as both compounds do not have an aldehyde functional group.

D: reddish-brown bromine water decolourise for methyl methacrylate due to C=C. Reddish brown bromine remain for benzophenone.

26 Answer: D (1 only)

1 is correct as H_2S (oxidation state of sulfur is -2) is oxidized to S (oxidation state 0).
2 is incorrect as SO_2 is an oxidizing agent and oxidises H_2S in reaction.
3 is incorrect as reaction II is a comproportionation reaction.

27 Answer A (1, 2, 3)

All three have solid lattice structure.

28 Answer D (1 only)

Option **1** – cation has more protons mean nuclear charge larger hence the ion is smaller in size.
Option **2** – the shielding is the same since both have the same number of quantum shells
Option **3** – does not explain the size of ions.

29 Answer: B (1 and 2 only)

Compound **Y** has 2 C=C, 1 COOH and 1 ketone functional group. Every functional group in Compound **Y** that gets reduced would have 2 H-atoms incorporated per molecule of Compound **Y**.

	Reducing agent	No. of hydrogen atoms incorporated per molecule of Compound **Y**	Functional group reduced
1	$NaBH_4$ in ethanol	2	1 ketone group
2	H_2 / Ni	6	2C=C + 1 ketone
3	LiA/H_4 in dry ether	**4**	1 ketone and 1 – COOH group

30 Answer C (2 and 3)

1 is correct. Ketone will form orange crystals with Brady's reagent (2,4 DNPH).

2 is wrong. C=C in a ring cannot exhibit cis-trans isomerism.

3 is wrong. Compound Z contains tertiary alcohol which cannot be oxidised hence it does not turn potassium dichromate orange to green.

TEMASEK JUNIOR COLLEGE

PRELIMINARY EXAMINATIONS

HIGHER 1

CANDIDATE NAME									
CIVICS GROUP			/						
CENTER NUMBER	S					INDEX NUMBER			

CHEMISTRY **8872/02**

Paper 2 **11 September 2017**

2 hours

Candidates answer section **A** on the Question Paper.

Additional Materials: Answer Paper

Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Civics Group, centre number, index number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer **two** questions on separate answer paper.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
A1	/ 15
A2	/ 13
A3	/ 12
Section B	/ 40
Paper 1	/ 30
Total	

This document consists of **17** printed pages.

Section A

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

1 This question is on the elements in period 3 of the Periodic Table.

(a) Describe what you see when phosphorus and sulfur are separately burned in air or oxygen. [2]

(b) The oxides MgO, Al_2O_3 and SiO_2 are all used as refractory materials due to their high melting points. The last two are major constituents of gemstones, such as rubies, sapphires and amethysts.

If a sample of one of the oxides was provided as a white powder, describe the reactions you could carry out on the powder to determine which of the three oxides it was. Write balanced equations where appropriate. [3]

(c) When dry chlorine is passed over heated aluminium foil in a hard glass tube, a vapour is produced which condenses to a yellow-white solid on the cooler parts of the tube. At low temperatures, the vapour has the empirical formula $AlCl_3$ and a M_r of 267.

(i) Suggest the molecular formula of the vapour, and draw a dot-and-cross diagram to describe its bonding. [2]

(ii) When a large amount of water is added to the yellow-white solid, a clear, weakly acidic solution results.

Write equations to explain the observation. [2]

Chlorine also reacts with phosphorus under suitable condition to give phosphorus pentachloride.

(iii) When phosphorus pentachioride is added to water, the resulting solution has a pH of 1. Explain with the aid of an equation. [2]

(d) Silver chloride is an important photosensitive inorganic material widely used in photographic applications. It is industrially produced by mixing solutions of silver nitrate and sodium chloride.

$$Ag^+(aq) + Cl^-(aq) \rightleftharpoons AgCl(s) \qquad \Delta H^\ominus = -65.7 \text{ kJ mol}^{-1}$$

(i) Use the data in the table to calculate *x*, the standard enthalpy change of formation of $Ag^+(aq)$.

Species	$\Delta H_f^\ominus$
$Ag^+(aq)$	*x*
$Cl^-(aq)$	-167
AgCl(s)	-127

[2]

(ii) Suggest whether a lower or higher temperature should be used to increase the yield of silver chloride. Explain your answer.

[2]

[Total: 15]

2 **(a)** In 1887, a Swedish scientist Svante Arrhenius postulated that acids and bases dissociate in water to form hydrogen ions, H^+, and hydroxide ions, OH^-, respectively.

(i) Suggest a limitation of the Arrhenius concept of acids and bases.

[1]

A theory proposed by Danish chemist J.N. Brønsted and British chemist T.M. Lowry overcame the shortcomings of the Arrhenius theory.

(ii) Using the Brønsted–Lowry model, explain the roles of nitric acid in the two reactions below.

$HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$ *Reaction 1*

$HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$ *Reaction 2*

[2]

(b) Propanoic acid inhibits the growth of mold and some bacteria. Most propanoic acid produced is consumed as a preservative for both animal feed and food for human consumption.

The K_a values of propanol, propanoic acid and malonic acid are given below.

Compound	Formula	K_{a1}	K_{a2}
Propanol	$CH_3CH_2CH_2OH$	7.94×10^{-17}	—
Propanoic acid	$CH_3CH_2CO_2H$	1.35×10^{-5}	—
Malonic acid	$HO_2CCH_2CO_2H$	1.41×10^{-3}	2.00×10^{-6}

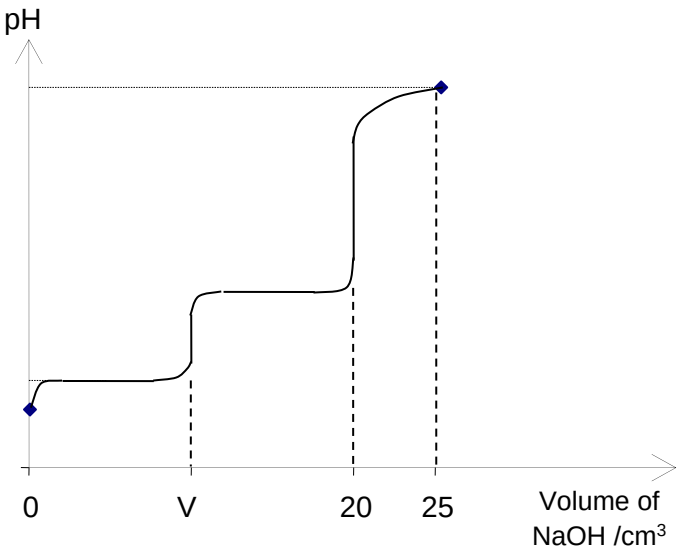
Suggest reason(s) why

(i) K_a of propanoic acid is higher than that of propanol. [2]

(ii) K_{a1} of malonic acid is higher than K_a of propanoic acid. [1]

(iii) K_{a1} of malonic acid is higher than K_{a2} of malonic acid. [1]

(c) 25 cm^3 of 0.10 mol dm^{-3} of NaOH is gradually added to 10 cm^3 of 0.10 mol dm^{-3} malonic acid.



(i) State the value for V.

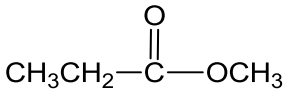
[1]

V = _____

(ii) Calculate the pH of the mixture when 25 cm^3 of NaOH has been added.

[2]

(d) Compound **A** can be directly synthesised from propanoic acid.

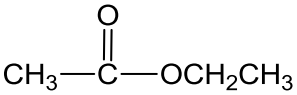


Compound **A**

(i) Suggest reagents and conditions to form compound **A** from propanoic acid.

[1]

Compound **B** is an isomer of compound **A**.



Compound **B**

(ii) Suggest methods by which compounds **A** and **B** could be distinguished from each other by chemical tests.

[2]

[Total: 13]

3 **(a)** Glucose is a reducing sugar and can be identified using Benedict's reagent or Fehling's solution as shown by the following equation.

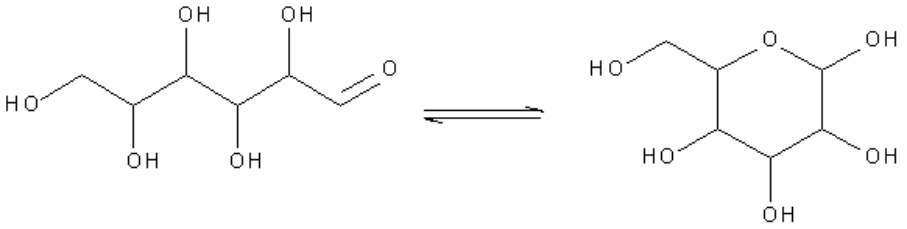
$$C_6H_{12}O_6 + 2Cu^{2+}(aq) \rightarrow Cu_2O(s) + \text{products}$$

A 5.00 g sample of food was treated with an excess copper(II) ions and 0.286 g of copper(I) oxide precipitated was collected.

Calculate the percentage of glucose in the food sample assuming that all the sugar present in the food is in the form of glucose.

[2]

(b) Most of the energy our bodies need comes from carbohydrates and fat. Starch is broken down into glucose,$C_6H_{12}O_6$. Glucose exist mainly in cyclic forms with a small percentage in open chains.



open-chain cyclic

Glucose is transported to the cells to react with oxygen via a series of steps to form carbon dioxide, water and energy.

(i) Write a balanced equation for the reaction of glucose with oxygen.

[1]

(ii) Using data from the *Data Booklet*, calculate the amount of energy released per mole of glucose using the **cyclic** structure.

[2]

(iii) The literature value for the amount of energy released per mole of glucose is – 2800 kJ.

Apart from bond energies being average values, suggest another reason for the difference between this value and that calculated in **(b)(ii)**.

[1]

Like carbohydrates, fats are metabolised into carbon dioxide and water and when subjected to combustion in a bomb calorimeter. The reaction of tristearin, $C_{57}H_{110}O_6$, a typical fat is as follows:

$$C_{57}H_{110}O_6 + \frac{163}{2} O_2 \rightarrow 57\ CO_2 + 55\ H_2O \quad \Delta H^{\ominus} = -37760\ kJ\ mol^{-1}$$

The fuel value is the energy when one gram of the material undergoes combustion. The table below shows the fuel value of carbohydrates and protein and the food label of a cup noodle:

	Fuel value / kJ g^{-1}
Carbohydrate	17
Fat (Tristearin)	To be calculated
Protein	17

Nutrition Facts
Serving Size 1 container (70g)

Amount Per Serving	
Calories 310	Calories from Fat 100
	% Daily Value*
Total Fat 12g	18%
Saturated Fat	25%
Trans Fat	
Cholesterol 0mg	0%
Sodium 1010mg	42%
Total Carbohydrate 44g	15%
Dietary Fiber 4g	16%
Sugars 4g	
Protein 8g	

(iv) Determine the fuel value of tristearin. (M_r of tristearin = 890)

Hence deduce if tristearin or carbohydrate is a better source of energy. [2]

(v) During reading or watching television, the average adult uses about 7 kJ min^{-1}.

By considering only the total fat, carbohydrate and protein content, calculate the duration in minutes of such activity that can be sustained by one serving of cup noodle. [1]

(c) In the body, glucose is also converted to energy via alcoholic fermentation. This process has been used in making beer and the side products such as esters contribute greatly to the taste and aroma of the beer.

Ethyl acetate can be formed as follows

$$CH_3CO_2H + CH_3CH_2OH \rightleftharpoons CH_3CO_2CH_2CH_3 + H_2O$$

1.51 mol of CH_3CO_2H and 1.66 mol of CH_3CH_2OH was allowed to reach equilibrium in a 100 cm^3 solution. 10 cm^3 of the equilibrium mixture was extracted and large amounts of cold water was added to quench the reaction. The mixture was then titrated with 22.40 cm^3 of 2 mol dm^{-3} NaOH.

Calculate the K_c for the formation of ethyl acetate.

[3]

[Total: 12]

Section B

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

4 **(a)** **(i)** Define the term *empirical formula*. [1]

(ii) Hydrocarbon **P** with M_r = 70 contains 85.7% by mass of carbon.
Determine the empirical formula and hence the molecular formula of **P**. [2]

(iii) Hydrocarbon **P** exhibits stereoisomerism. Draw and label the stereoisomers of **P**. [2]

(b) Organic compound **Q,** with molecular formula $C_6H_8O_4$, can be found in most leather products and is used as a mould inhibitor.

Q decolourises aqueous bromine. On heating one mole of **Q** with dilute acid, two organic products **R**, $C_4H_4O_4$, and methanol are obtained. Vigorous effervescence was observed when **R** reacted completely with sodium carbonate in equimolar proportions.

Use all of the above information to determine the functional groups present in **Q** and **R**. For each functional group you identify, explain how you came to your decision. Hence determine the identity of **Q** and **R**. [6]

(c) Many chemical reactions such as the Contact Process between sulfur dioxide and oxygen occur very slowly at room conditions. One way to speed up the rate of reaction is to use a catalyst.

(i) Explain what is meant by *rate of reaction*. [1]

(ii) Explain with the aid of a Boltzmann distribution curve, how a catalyst speeds up the rate of the reaction. [3]

(d) A kinetics study was conducted on the reaction of $S_2O_8^{2-}$ and I^- to determine the rate equation. Varying volumes of $S_2O_8^{2-}$ and I^- were added to a mixture containing sodium thiosulfate and starch indicator, followed by topping up with suitable volume of water.

As the reaction of $S_2O_8^{2-}$ and I^- proceeds, the iodine produced will be consumed by the $Na_2S_2O_3$. When all $Na_2S_2O_3$ has reacted, the remaining iodine will react with the starch indicator, forming a blue-black complex. The rate of reaction is determined by the time taken for the blue-black colouration to appear.

Experiment	Volume of KI / cm^3	Volume of $Na_2S_2O_8$ / cm^3	Volume of $Na_2S_2O_3$ / cm^3	Volume of water / cm^3	Time for blue-black colour / s
1	10	20	10	10	50
2	5	20	10	15	100
3	30	10	10	0	33
4	20	40	20	20	***x***

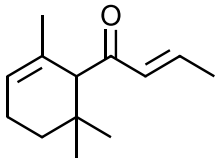
(i) Determine the order of reaction with respect to iodide and peroxodisulfate. [2]

(ii) Hence, construct a rate equation for the above reaction, and determine the units of the rate constant. [2]

(iii) Deduce the time taken, x, for the blue-black colouration to appear for experiment 4. [1]

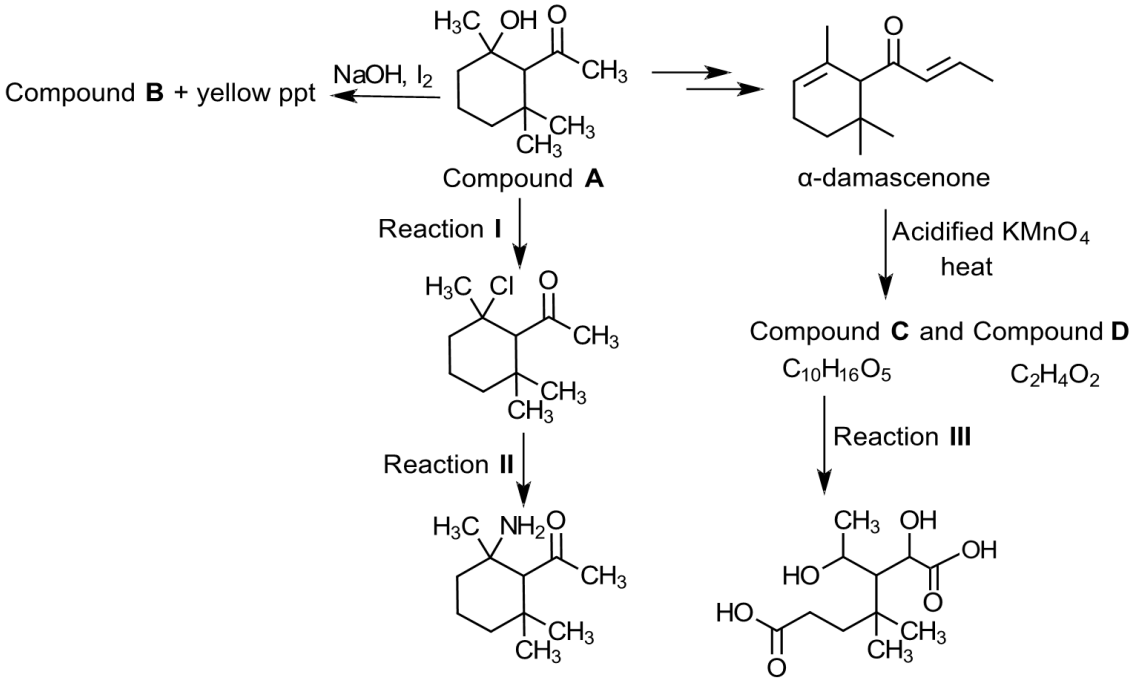
[Total: 20]

5 In the synthesis of damascenones, which are active ingredients in the characteristic smell of Bulgarian rose oil, it was found that compound **B** is a possible pre-cursor.



α-damascenone

Compound **A** and α-damascenone can undergo a series of chemical reactions as shown in the flow chart below:



(a) **(i)** State the reagents and conditions for Reaction **I**, **II** and **III**. [3]

(ii) Draw the structural formulae of Compound **B**, **C** and **D**. [3]

(b) Methanol reacts with acidified potassium dichromate(VI) to form methanoic acid.

Relevant half-equation for this equation is given below:

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

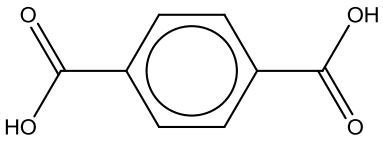
(i) Explain, in terms of the change in oxidation number**,** the role of potassium dichromate(VI) in the reaction with methanol. [2]

(ii) Write the half-equation for the oxidation reaction of methanol to methanoic acid. Hence using the half-equation given above, construct an ionic equation for the reaction between $Cr_2O_7^{2-}$ and CH_3OH in acid solution. [2]

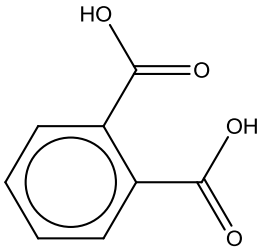
(c) **(i)** Define second ionisation energy of aluminium. [1]

(ii) Explain why the second ionisation energy of aluminium is greater than that of silicon. [1]

(d) Terephthalic acid (TPA) and phthalic acid (PA) both have the molecular formula $C_6H_4(COOH)_2$. While TPA is used principally to make clothing and plastic bottles, PA has limited commercial application. The structures of TPA and PA are shown below.



TPA



PA

(i) TPA and PA melts at 300 °C and 207 °C, respectively.
With reference to intermolecular interactions, explain why TPA has a higher melting point than PA. [2]

(ii) TPA can be reduced to a diol for the synthesis of a renewable polymer.
Draw the structure of this diol. Illustrate with a diagram, the interaction of this diol with water. [3]

(iii) Hence, explain why the diol in **(d)(ii)** is soluble in water. [1]

(e) In selecting a suitable material for the manufacture of bulletproof armour, it is necessary to ensure that the material does not shatter upon high impact force from a bullet.

With reference to the structures of gold and fluorite, CaF_2, explain why gold is more suitable for the lining of bulletproof armour. [2]

[Total: 20]

6 High octane fuels that are free from lead additives often contain aromatic hydrocarbons such as benzene, which can be obtained from hexane by the process of "reforming".

$$C_6H_{14} \longrightarrow C_6H_6 + 4H_2$$

(a) **(i)** Suggest reasons for the following statements

- Alkane is generally unreactive.
- Benzene undergoes substitution reaction rather than addition reaction. [3]

(ii) State the reagents and conditions required for the formation of benzoic acid from benzene. [2]

(b) Chlorine-37 is an isotope of chlorine.
Benzene can react with the electrophile $^{37}Cl^+$ to form dichlorobenzene

(i) Define the term *isotope*. [1]

(ii) Write the electronic configuration for $^{37}Cl^+$. [1]

(iii) State the number, charge and location of the sub-atomic particles in $^{37}Cl^+$. [3]

(iv) Draw the non-polar isomer of dichlorobenzene. [1]

(c) Hexane and benzene undergoes combustion to form carbon dioxide.

(i) For each of the three compounds, hexane, benzene and carbon dioxide, state the

- hybridisation
- shape and
- bond angle about carbon. [3]

(ii) Describe the bonding that occurs in hexane and carbon dioxide in terms of the overlap of the orbitals. Draw diagrams to illustrate your answer. [3]

(d) In the stratosphere, chloroflurocarbons (CFC) such as CCl_3F can form radicals such as $\bullet CCl_2F$, which deplete the ozone layer.

(i) Explain what is meant by the term *radical.* [1]

(ii) Draw the dot-and-cross diagram of the $\bullet CCl_2F$ free radical. [1]

(iii) Hydrofluorocarbons (HFC) such as CH_2FCF_3, does not deplete the ozone layer compared to CFCs. Suggest why this is so. [1]

[Total: 20]

TEMASEK JUNIOR COLLEGE

PRELIMINARY EXAMINATIONS

HIGHER 1

CANDIDATE NAME										
CIVICS GROUP			/							
CENTER NUMBER	S					INDEX NUMBER				

CHEMISTRY **8872/02**

Paper 2 **11 September 2017**

2 hours

Candidates answer section **A** on the Question Paper.

Additional Materials: Answer Paper

Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Civics Group, centre number, index number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer **two** questions on separate answer paper.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
A1	/ 15
A2	/ 13
A3	/ 12
Section B	/ 40
Paper 1	/ 30
Total	

This document consists of **18** printed pages.

Section A

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

1 This question is on the elements in period 3 of the Periodic Table.

(a) Describe what you see when phosphorus and sulfur are separately burned in air or oxygen.

[2]

- **For phosphorus, it burns with a white flame on heating in air or oxygen to form white phosphorus(V) oxide, P_4O_{10}.**

($P_4(s) + 5O_2(g) \rightarrow P_4O_{10}(s)$)

- **For sulfur, it burns slowly with a blue flame on heating in air or oxygen to form colourless sulfur dioxide, SO_2.**

($S(s) + O_2(g) \rightarrow SO_2(g)$)

[Equations not necessary]

Note : need to describe clearly what is observed.

(b) The oxides MgO, Al_2O_3 and SiO_2 are all used as refractory materials due to their high melting points. The last two are major constituents of gemstones, such as rubies, sapphires and amethysts.

If a sample of one of the oxides was provided as a white powder, describe the reactions you could carry out on the powder to determine which of the three oxides it was. Write balanced equations where appropriate.

[3]

- **Step 1**

Add NaOH(aq) to the solid. If the solid dissolves, it is Al_2O_3, otherwise it is either MgO or SiO_2

$Al_2O_3 + 2NaOH + H_2O \rightarrow 2Na[Al(OH)_4]$

If solid does not dissolve in NaOH,

- **Step 2**

Add HCl(aq) to the solid. If the solid dissolves, it is MgO otherwise it is SiO_2.

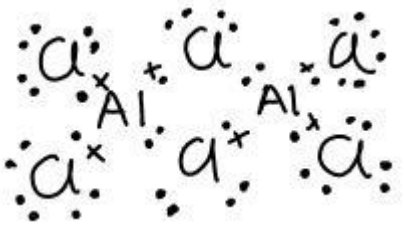
$MgO + 2HCl \rightarrow MgCl_2 + H_2O$

2 equations : 1m

Note : MgO is basic, Al_2O_3 is amphoteric. SiO_2 is acidic but can only react with conc. NaOH.

(c) When dry chlorine is passed over heated aluminium foil in a hard glass tube, a vapour is produced which condenses to a yellow-white solid in the cooler parts of the tube. At low temperatures the vapour has the empirical formula $AlCl_3$ and a M_r of 267.

(i) Suggest the molecular formula of the vapour, and draw a dot-and-cross diagram to describe its bonding.

- **Al_2Cl_6**
- 

[2]

Note : Do not draw arrows to show dative bonds for dot-cross diagram. Non-bonding valence electrons must be shown for all atoms.

(ii) When a large amount of water is added to the yellow-white solid, a clear, weakly acidic solution results.

Write equations to explain the observation.

- **$AlCl_3 + 6H_2O \rightarrow [Al(H_2O)_6]^{3+} + 3Cl^-$** [2]
- **$[Al(H_2O)_6]^{3+} \rightarrow [Al(H_2O)_5(OH)]^{2+} + H^+$**

Chlorine also reacts with phosphorus under suitable condition to give phosphorus pentachloride.

(iii) When phosphorus pentachioride is added to water, the resulting solution has a pH of 1. Explain with the aid of an equation. [2]

- **It undergoes hydrolysis with water because it has energetically accessible 3d orbitals.**
- **$2PCl_5 + 8H_2O \rightarrow 2H_3PO_4 + 10HCl$**

Silver chloride is an important photosensitive inorganic material widely used in photographic applications. It is industrially produced by mixing solutions of silver nitrate and sodium chloride.

$$Ag^+(aq) + Cl^-(aq) \rightleftharpoons AgCl(s) \qquad \Delta H^\ominus = -65.7 \text{ kJ mol}^{-1}$$

(d) (i) Use the data in the table to calculate *x*, the standard enthalpy change of formation of $Ag^+(aq)$.

Species	$\Delta H_f^\ominus$
$Ag^+(aq)$	*x*
$Cl^-(aq)$	-167
$AgCl(s)$	-127

[2]

$\Delta H_r^\ominus = \Sigma n\Delta H_f^\ominus(\text{products}) - \Sigma n\Delta H_f^\ominus(\text{reactants})$
• $-65.7 = -127 - (x + (-167))$
$x =$ • + 106 kJ mol^{-1}

Note : Must indicate sign for endothermic enthalpy change.

(ii) Suggest whether a lower or higher temperature should be used to increase the yield of silver chloride. Explain your answer.

[2]

• A lower temperature should be used.
• By Le Chatelier's Principle, the system will favour the forward exothermic reaction when temperature is lowered. Hence, the position of equilibrium shifts to the right increasing the yield of silver chloride.

Note : [AgCl(s)] is always a constant but yield increases when position of equilibrium shifts right.

[Total: 15]

2 **(a)** In 1887, a Swedish scientist Svante Arrhenius postulated that acids and bases dissociate in water to form hydrogen ions, H^+, and hydroxide ions, OH^-, respectively.

(i) Suggest a limitation of the Arrhenius concept of acids and bases. [1]

Accept any of the answers below
- **It applies only to aqueous solutions.**
- **It does not adequately explain why such compounds as ammonia are bases.**
- **The hydrogen ion, H^+, exists as hydronium ion, H_3O^+, in water.**

A theory proposed by Danish chemist J.N. Brønsted and British chemist T.M. Lowry overcame the shortcomings of the Arrhenius theory.

(ii) Using the Brønsted–Lowry model, explain the roles of nitric acid in the two reactions below. [2]

$$HNO_3 + NaOH \rightarrow NaNO_3 + H_2O \qquad \textit{Reaction 1}$$
$$HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^- \qquad \textit{Reaction 2}$$

- **In reaction 1, HNO_3 is acting as an acid as it donated a proton, H^+, to OH^-.**
- **In reaction 2, HNO_3 is acting as a base as it accepted a proton, H^+, from H_2SO_4.**

(b) Propanoic acid inhibits the growth of mold and some bacteria. Most propanoic acid produced is consumed as a preservative for both animal feed and food for human consumption.

The K_a values of propanol, propanoic acid and malonic acid are given below.

Compound	Formula	K_{a1}	K_{a2}
Propanol	$CH_3CH_2CH_2OH$	7.94×10^{-17}	—
Propanoic acid	$CH_3CH_2CO_2H$	1.35×10^{-5}	—
Malonic acid	$HO_2CCH_2CO_2H$	1.41×10^{-3}	2.00×10^{-6}

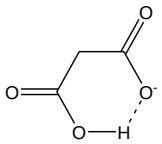
Suggest reason(s) why

(i) K_a of propanoic acid is higher than that of propanol. [2]

- **Delocalisation of negative charge over two oxygen atoms in $CH_3CH_2CO_2^-$ results in a more stable anion while the negative charge is localised on the O atom in $CH_3CH_2CH_2O^-$.**
- **The electron-releasing $-CH_2CH_2CH_3$ group intensifies the negative charge on the O atom, thus destabilising the $CH_3CH_2CH_2O^-$ anion.**

(ii) K_{a1} of malonic acid is higher than K_a of propanoic acid. [1]

- **This is due to the stabilisation of the monoanion by hydrogen bonding with the unionised $-CO_2H$ group in malonic acid.**



or

- **The electron withdrawing $-CO_2H$ group in $HOOC-CH_2-CO_2^-$ helps to disperse the negative charge on oxygen, stabilising the anion.**

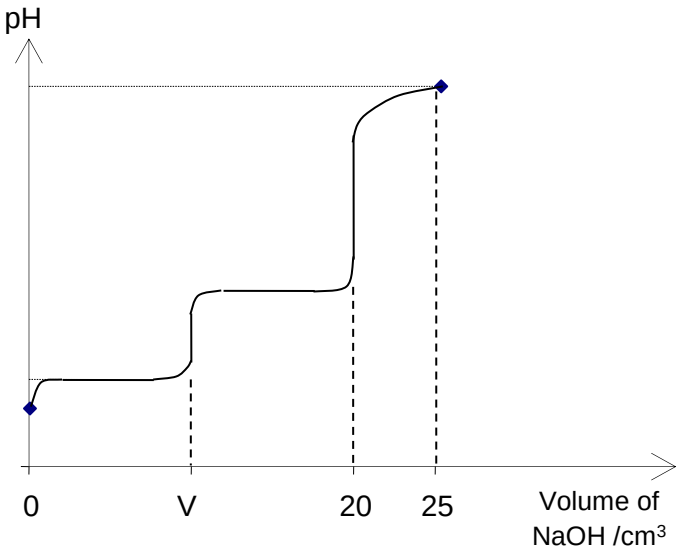
(iii) K_{a1} of malonic acid is higher than K_{a2} of malonic acid. [1]

- **The stabilising hydrogen bonding in the monoanion of malonic acid would be destroyed by the ionisation of the second $-CO_2H$ group.**

or

- **The removal of an H^+ from $HO_2CCH_2CO_2^-$ that already carries a negative charge would be electrostatically unfavourable.**

(c) 25 cm^3 of 0.10 mol dm^{-3} of NaOH is gradually added to 10 cm^3 of 0.10 mol dm^{-3} malonic acid.



(i) State the value for V. [1]

- **V = 10 cm^3**

(ii) Calculate the pH of the mixture when 25 cm^3 of NaOH has been added. [2]

Volume of excess NaOH added = 25 -20 = 5 cm^3

- **No. of moles of excess NaOH = $\frac{5}{1000}$ x 0.10 = 5.00 x 10^{-4} mol**

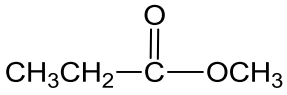
Total volume of solution = 10 + 25 = 35 cm^3

$[OH^-] = \frac{5.00\times10^{-4}}{\frac{35}{1000}}$ = 0.0143 mol dm^{-3}

pOH = -log $[OH^-]$ = 1.85

- **pH = 14 – pOH = 12.2**

(d) Compound **A** can be directly synthesised from propanoic acid.

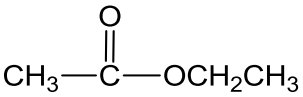


Compound **A**

(i) Suggest reagents and conditions to form compound **A** from propanoic acid. [1]

- **CH_3OH, conc H_2SO_4, heat**

Compound **B** is an isomer of compound **A**.



Compound **B**

(ii) Suggest methods by which compounds **A** and **B** could be distinguished from each other by chemical tests. [2]

- **Heat each compound with aqueous sodium hydroxide. Add aqueous alkaline iodine with warming to the reaction products.**
- **Yellow precipitate of CHI_3 is observed for hydrolysed products of compound B but not A.**

or

- **Heat each compound with aqueous sodium hydroxide, followed by heating the reaction products with acidified $KMnO_4$.**
- **CO_2 observed for hydrolysed product (CH_3OH) of compound A but not B.**

[Total: 13]

3 (a) Glucose is a reducing sugar and can be identified using Benedict's reagent or Fehling's solution as shown by the following equation.

$$C_6H_{12}O_6 + 2Cu^{2+}(aq) \rightarrow Cu_2O(s) + \text{products}$$

A 5.00 g sample of food was treated with an excess copper(II) ions and 0.286 g of copper(I) oxide precipitated was collected.

Calculate the percentage of glucose in the food sample assuming that all the sugar present in the food is in the form of glucose.

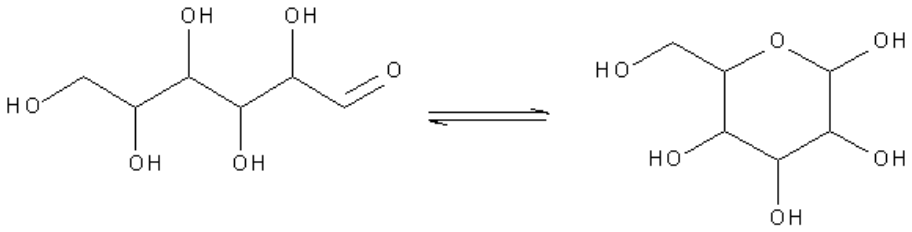
[2]

Number of moles of Cu_2O = 0.286 / ((2 x 63.5) + 16) = 0.286 / 143 = 0.002 mol
• Number of moles of glucose = 0.002 mol

M_r of glucose = 6(12) + 12(1) + 6(16) = 180
Mass of glucose = 180 x 0.002 = 0.360g

• Percentage of glucose = 0.360 / 5 x 100% = 7.20%

(b) Most of the energy our bodies need comes from carbohydrates and fat. Starch is broken down into glucose,$C_6H_{12}O_6$. Glucose exist mainly in cyclic forms with a small percentage in open chains.



open-chain cyclic

Glucose is transported to the cells to react with oxygen via a series of steps to form carbon dioxide, water and energy.

(i) Write a balanced equation for the reaction of glucose with oxygen. [1]

• $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

(ii) Using data from the Data Booklet, calculate the amount of energy released per mole of glucose using the cyclic structure.

[2]

Using the cyclic structure of glucose,

Bond-breaking	**Bond-Forming**
5 x C – C	**12 x C = O**
5 x O – H	**12 x O – H**
7 x C – H	
7 x C – O	
6 x O = O	

• Energy released
= +(5 x 350 + 5 x 460 + 7 x 410 + 7 x 360 + 6 x 496) – (12 x 740 + 12 x 460)
= • - 1980 kJ mol^{-1}

Note: O=O and C-H bonds often missed out.

(iii) The literature value for the amount of energy released per mole of glucose is – 2800 kJ.

Apart from bond energies being average values, suggest another reason for the difference between this value and that calculated in **(b)(ii)**.

[1]

• The ΔH calculated using bond energies applies for the reactants and products in the gaseous phase but the reaction involves solid glucose and liquid H_2O rather than gaseous H_2O.

Like carbohydrates, fats are metabolised into carbon dioxide and water and when subjected to combustion in a bomb calorimeter. The reaction of tristearin, $C_{57}H_{110}O_6$, a typical fat is as follows:

$$C_{57}H_{110}O_6 + \frac{163}{2} O_2 \rightarrow 57\ CO_2 + 55\ H_2O \quad \Delta H^{\ominus} = -37760\ kJ\ mol^{-1}$$

The fuel value is the energy when one gram of the material undergoes combustion. The table below shows the fuel value of carbohydrates and protein and the food label of a cup noodle:

	Fuel Value / kJ g^{-1}
Carbohydrate	17
Fat (Tristearin)	To be calculated
Protein	17

(iv) Determine the fuel value of tristearin. (M_r of tristearin = 890)

No. of moles of tristearin in 1 g = 1/890 = 1.12 x 10^{-3} mol
• Fuel value of tristearin = 1.12 x 10^{-3} x 37760 = 42.4 kJ/g

Hence deduce if tristearin or carbohydrate is a better source of energy. [2]

• Since more energy is produced per gram, tristearin is a better source of energy than carbohydrate.

(v) During reading or watching television, the average adult uses about 7 kJ/min. By considering only the total fat, carbohydrate and protein content, calculate the duration in minutes of such activity that can be sustained by one serving of cup noodle.

[1]

Total energy provided by cup noodle = 12 x 42.4 + 44 x 17 + 8 x 17 = 1390 kJ
• No. of minutes that can be sustained by energy = 1390/7 = 199 min

(c) In the body, glucose is also converted to energy via alcoholic fermentation. This process has been used in making beer and the side products such as esters contribute greatly to the taste and aroma of the beer.

Ethyl acetate can be formed as follows

$$CH_3CO_2H + CH_3CH_2OH \rightleftharpoons CH_3CO_2CH_2CH_3 + H_2O$$

1.51 mol of CH_3CO_2H and 1.66 mol of CH_3CH_2OH was allowed to reach equilibrium in a 100 cm^3 solution. 10 cm^3 of the equilibrium mixture was extracted and large amounts of cold water was added to quench the reaction. The mixture was then titrated with 22.40 cm^3 of 2 mol dm^{-3} NaOH.

Calculate the K_c for the formation of ethyl acetate.

[3]

NaOH ≡ CH_3CO_2H

No. of moles of CH_3CO_2H in 10 cm^3 = (22.40/1000) x 2 = 0.0448 mol
• No. of moles of CH_3CO_2H in 100 cm^3 = 0.0448 x 10 = 0.448 mol

•	CH_3CO_2H +	CH_3CH_2OH ⇌	$CH_3CO_2CH_2CH_3$ +	H_2O
Initial amount/mol	**1.51**	**1.66**	**0**	**0**
Change in amount/mol	**-1.06**	**-1.06**	**+1.06**	**+1.06**
Eqm amount/mol	**0.448**	**0.600**	**1.06**	**1.06**

• $K_c = \frac{[CH3CO2CH2CH3][H2O]}{[CH3CO2H][CH3CH2OH]} = \frac{(\frac{1.06}{0.1})(\frac{1.06}{0.1})}{(\frac{0.448}{0.1})(\frac{0.6}{0.1})} = 4.18$

[Total: 12]

Section B

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

4 **(a)** **(i)** Define the term *empirical formula*.

[1]

Empirical formula is the simplest formula that shows the relative number of atoms of each element in the compound.

(ii) Hydrocarbon **P** with M_r = 70 contains 85.7% by mass of carbon.
Determine the empirical formula and hence the molecular formula of **P**.
[2]

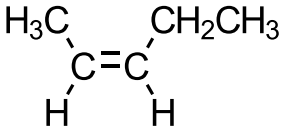
	C	H
Mole ratio	**85.7/12**	**14.3/1**
	7.14	**14.3**
Simplest ratio	**1**	**2**

- **Empirical formula : CH_2**

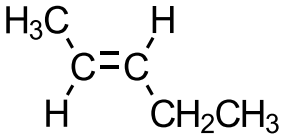
$(CH_2)_n$ = 70
14n = 70
n = 5

- **Molecular formula : C_5H_{10}**

(iii) Hydrocarbon P exhibits stereoisomerism. Draw and label the stereoisomers of P.
[2]

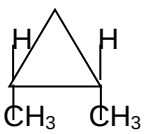


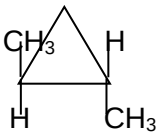
cis



trans

or





(b) Organic compound **Q,** with molecular formula $C_6H_8O_4$, can be found in most leather products and is used as a mould inhibitor.

Q decolourises aqueous bromine. On heating one mole of **Q** with dilute acid, two organic products **R**, $C_4H_4O_4$, and methanol are obtained. Vigorous effervescence was observed when **R** reacted completely with sodium carbonate in equimolar proportions.

Use all of the above information to determine the functional groups present in **Q** and **R**. For each functional group you identify, explain how you came to your decision. Hence determine the identity of **Q** and **R**.

•Q undergoes electrophilic addition reaction with aqueous bromine. Q has C=C.
•Vigorous effervescence observed when R reacts with sodium carbonate
R has carboxylic acid functional group as it liberates CO_2 with carbonate.
• Q reacted with sodium carbonate in equimolar proportions. Q has two carboxylic acid functional groups since 2 moles of $–CO_2H$ will react with 1 mole of sodium carbonate.
•Heating Q with dilute acid gives R, a carboxylic acid and CH_3OH. Q has an ester functional group as it undergoes acid hydrolysis.
•Since Q has 6C and R has 4C and there are only 2 organic products after hydrolysis, 2 moles of CH_3OH must be produced. R is a dicarboxylic acid so Q is a diester.

•R : $HO_2C-CH=CH-CO_2H$ $H_2C=C(CO_2H)_2$

or

•Q : $CH_3O-CO-CH=CH-CO_2CH_3$ $H_2C=C(CO_2CH_3)_2$

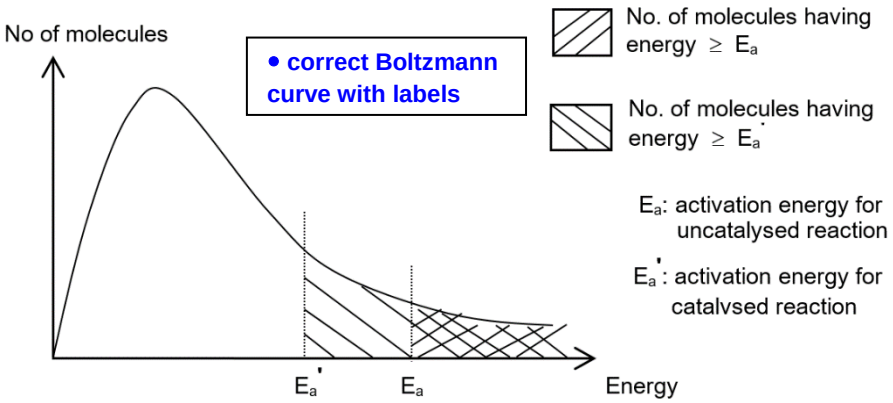
[6]

(c) Many chemical reactions such as the Contact Process between sulfur dioxide and oxygen occur very slowly at room conditions. One way to speed up the rate of reaction is to use a catalyst.

(i) Explain what is meant by *rate of reaction*. [1]

Rate of reaction is defined as the • change in the concentration of reactant or product per unit time.

(ii) Explain with the aid of a Boltzmann distribution curve, how a catalyst speeds up the rate of the reaction. [3]



A catalyst provides • an alternative pathway for the reaction to take place, which has a lower activation energy than the uncatalysed reaction.

• The number of reactant molecules having energy greater than or equal to the lower activation energy, E_a' increases significantly.

Hence the frequency of effective collisions increases and the rate increases.

(d) A kinetics study was conducted on the reaction of $S_2O_8^{2-}$ and I^- to determine the rate equation. Varying volumes of $S_2O_8^{2-}$ and I^- were added to a mixture containing sodium thiosulfate and starch indicator, followed by topping up with suitable volume of water.

As the reaction of $S_2O_8^{2-}$ and I^- proceeds, the iodine produced will be consumed by the $Na_2S_2O_3$. When all $Na_2S_2O_3$ has reacted, the remaining iodine will react with the starch indicator, forming a blue-black complex. The rate of reaction is determined by the time taken for the blue-black colouration to appear.

Experiment	Volume of KI / cm^3	Volume of $Na_2S_2O_8$ / cm^3	Volume of $Na_2S_2O_3$ / cm^3	Volume of water / cm^3	Time for blue-black colour / s	**rate ∝ 1/t**
1	10	20	10	10	50	**0.02**
2	5	20	10	15	100	**0.01**
3	30	10	10	0	33	**0.03**
4	20	40	20	20	*x*	

(i) Determine the order of reaction with respect to iodide and peroxodisulfate. [2]

For expt 1 to 3, total volume is kept constant, so volume of reactant ∝ concentration.

Since thiosulfate is the limiting reagent and volume is constant, relative rate ∝ 1/t, so relative rates for expt 1, 2 and 3 are 0.02, 0.01 and 0.03.

- **Comparing expt 1 and 2, when conc of KI decreases by 2 times, rate decreases by 2 times → 1st order with respect to I^-.**
- **Comparing expt 1 and 3,**

$$\frac{\text{Rate}_{expt1}}{\text{Rate}_{expt3}} = \frac{k[KI][S_2O_8^{2-}]^n}{k[KI][S_2O_8^{2-}]^n}$$

$$\frac{0.02}{0.03} = \frac{k[10][20]^n}{k[30][10]^n}$$

Solving, n = 1

(ii) Hence, construct a rate equation for the above reaction, and determine the units of the rate constant. [2]

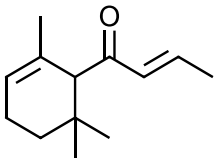
- **Rate = $k[I^-][S_2O_8^{2-}]$**
- **Units of k is $mol^{-1}\ dm^3\ s^{-1}$**

(iii) Deduce the time taken, x, for the blue-black colouration to appear for experiment 4. [1]

Since volume of all reactants double and total volume of mixture doubles, concentration of KI, $Na_2S_2O_8$ and $Na_2S_2O_3$ remain the same. Rate of reaction remains constant, so x = 50 s.

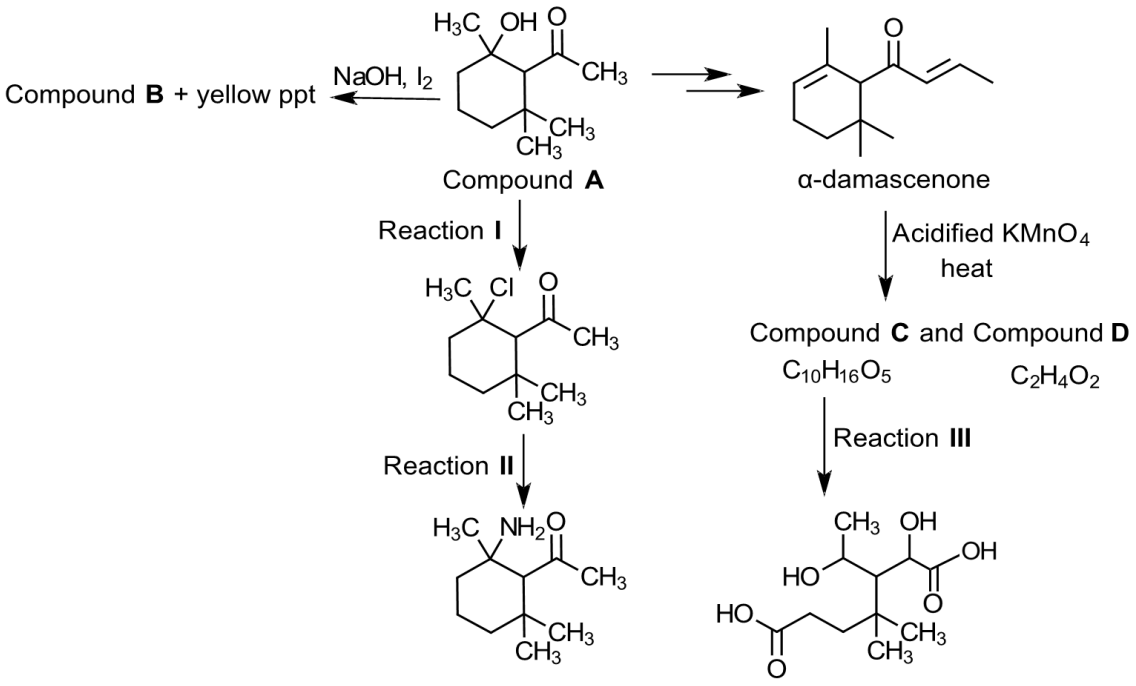
[Total: 20]

5 In the synthesis of damascenones, which are active ingredients in the characteristic smell of Bulgarian rose oil, it was found that compound **B** is a possible pre-cursor.



α-damascenone

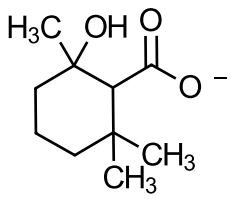
Compound **A** and α-damascenone can undergo a series of chemical reactions as shown in the flow chart below:



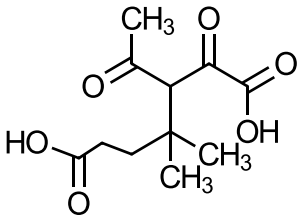
(a) (i) State the reagents and conditions for Reaction **I**, **II** and **III**. [3]

- **Reaction I: PCl_5 (s), room temp**
- **Reaction II: Excess concentrated NH_3, heat in a sealed tube**
- **Reaction III: $NaBH_4$, alcohol as solvent, room temp**

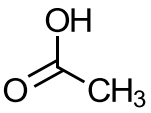
(ii) Draw the structural formulae of Compound **B**, **C** and **D**. [3]



●Compound **B**



●Compound **C**



● Compound **D**

(b) Methanol reacts with acidified potassium dichromate(VI) to form methanoic acid.

Relevant half-equation for this equation is given below:

$$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$$

(i) Explain in terms of the change in oxidation number**,** why potassium dichromate(VI) is an oxidising agent in the reaction with methanol.

[2]

● $Cr_2O_7^{2-}$ acts as an oxidising agent because it oxidises methanol and the oxidation number of C increases from –2 in CH_3OH to +2 in HCOOH, and ●itself is being reduced as oxidation number of Cr decreases from +6 in $Cr_2O_7^{2-}$ to +3 in Cr^{3+}.

(ii) Write the half-equation for the oxidation reaction of methanol to methanoic acid, and using the half-equation given above, construct an ionic equation for the reaction between $Cr_2O_7^{2-}$ and CH_3OH in acid solution.

[2]

● Oxidation: $CH_3OH + H_2O \rightarrow HCOOH + 4H^+ + 4e^-$

Overall:

$3CH_3OH + 2Cr_2O_7^{2-} + 28H^+ + 3H_2O \rightarrow 3HCOOH + 4Cr^{3+} + 14H_2O + 12H^+$

● $3CH_3OH + 2Cr_2O_7^{2-} + 16H^+ \rightarrow 3HCOOH + 4Cr^{3+} + 11H_2O$

(c) **(i)** Define second ionisation energy of aluminium. [1]

● 2nd IE of aluminium is the minimum amount of energy to completely remove 1 mole of valence electrons from 1 mole of ground state gaseous Al^+ ions to form 1 mole of gaseous Al^{2+} ions.

(ii) Explain why the second ionisation energy of aluminium is greater than that of silicon. [1]

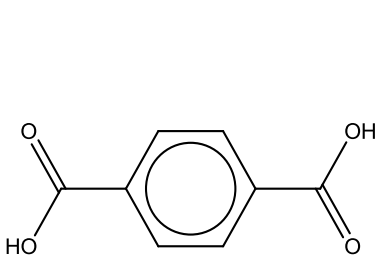
Al^+: [Ne] $3s^2$

Si^+: [Ne] $3s^2$ $3p^1$

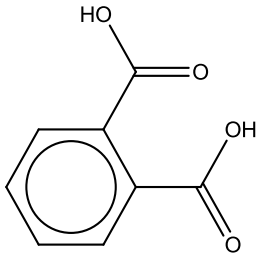
Si has a higher nuclear charge than Al. However, ● 2nd IE of Al involves the removal of 3s electron which is more strongly attracted and closer to the

nucleus than the removal of 3p electron for Si. Hence, more energy is needed to remove the 3s electron.

(d) Terephthalic acid (TPA) and phthalic acid (PA) both have the molecular formula $C_6H_4(COOH)_2$. While TPA is used principally to make clothing and plastic bottles, PA has limited commercial application. The structures of TPA and PA are shown below.



TPA



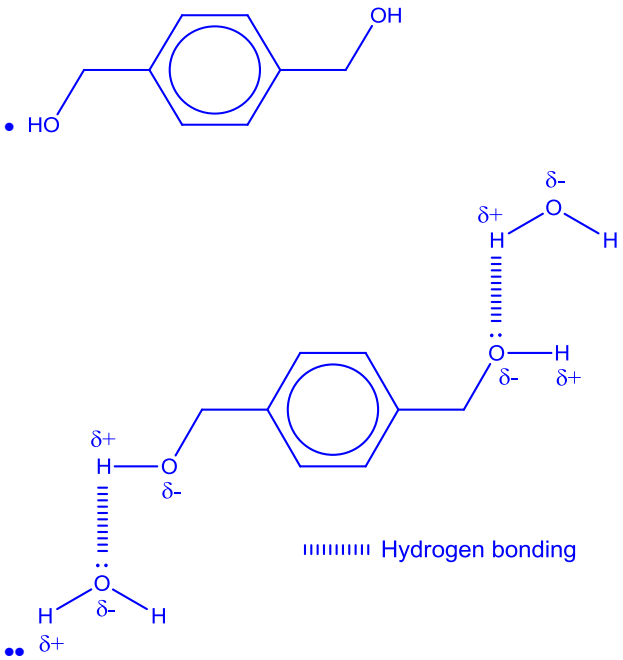
PA

(i) TPA and PA melts at 300 °C and 207 °C, respectively.
With reference to intermolecular interactions, explain why TPA has a higher melting point than PA. [2]

• Due to the close proximity of the 2 -COOH groups in PA, intramolecular hydrogen bonding occurs. This reduces the extent of intermolecular hydrogen bonding between PA molecules.

• In TPA, the 2 -COOH groups are further away hence only intermolecular hydrogen bonding occurs. Thus, more heat energy is needed to overcome the more extensive hydrogen bonding.

(ii) TPA can be reduced to a diol for the synthesis of a renewable polymer.
Draw the structure of this diol and illustrate with a diagram, its interaction with water. [3]



(iii) Hence, explain why the diol in **(d)(ii)** is soluble in water. [1]

• Formation of hydrogen bonds between the diol and water releases sufficient energy to overcome the hydrogen bonding between diol molecules and hydrogen bonding between water molecules.

(e) In selecting a suitable material for the manufacture of bulletproof armour, it is necessary to ensure that the material does not shatter upon high impact force from a bullet.
With reference to the structures of gold and fluorite, CaF_2, explain why gold is more suitable for the lining of bulletproof armour. [2]

• When hit with a high impact force, the layers of close-packed gold atoms can slide over one another without breaking the non-directional metallic bonds.

However, for an ionic compound CaF_2, a • high impact force would cause layers of ions to shift and causes ions to same charge to slide next to each other, forcing the layers to come apart and shatter.

[Total: 20]

6 High octane fuels that are free from lead additives often contain aromatic hydrocarbons such as benzene, which can be obtained from hexane by the process of "reforming".

$$C_6H_{14} \longrightarrow C_6H_6 + 4H_2$$

(a) (i) Suggest reasons for the following statements

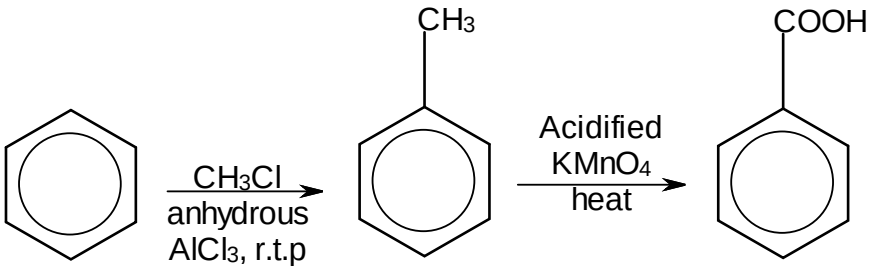
- Alkane is generally unreactive.
- Benzene undergoes substitution reaction rather than addition reaction. [3]

● Alkanes are saturated and contain only C–H and C–C bonds, which are relatively strong and difficult to break.

● In addition, alkane molecules are non-polar due to similar electronegativity of carbon and hydrogen atoms.

● Due to the extra stability of having a π electrons delocalised system, benzene undergoes substitution rather than addition reactions

(ii) State the reagents and conditions required for the formation of benzoic acid from benzene. [2]



● 1m for formation of methylbenzene with correct reagent and condition.
● 1m for formation of benzoic acid with correct reagent and condition.

(b) Chlorine-37 is an isotope of chlorine.
Benzene can react with the electrophile $^{37}Cl^+$ to form dichlorobenzene

(i) Define the term *isotope*.

● Atoms of the same element having same number of protons but different number of neutrons [1]

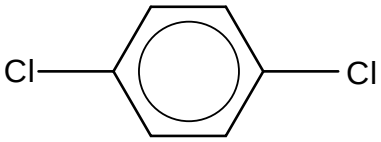
(ii) Write the electronic configuration for $^{37}Cl^+$. [1]

● $1s^2 2s^2 2p^6 3s^2 3p^5$

(iii) State the number, charge and location of the sub-atomic particles in $^{37}Cl^+$. [3]

● 17 positively charged protons and ● 20 neutrons (no charge) in the nucleus
● 16 negatively charged electrons surrounding the nucleus

(iv) Draw the non-polar isomer of dichlorobenzene. [1]



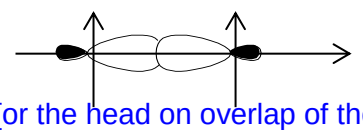
(d) Hexane and benzene undergoes combustion to form carbon dioxide.

(i) For each of the three compounds, hexane, benzene and carbon dioxide, state
- Hybridization state and
- Shape and bond angle about carbon. [3]

	Hexane	Benzene	Carbon dioxide
● Hybridisation	sp^3	sp^2	sp
● Bond angle	109.5^o	120^o	180^o
● Shape	Tetrahedral	Trigonal planar	Linear

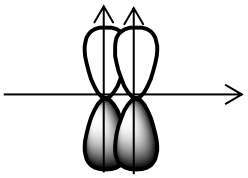
(ii) Describe the bonding that occurs in hexane and carbon dioxide in terms of the overlap of the orbitals. Draw diagrams to illustrate your answer. [3]

● In hexane, the type of covalent bond formed is σ-bond. It is formed by the head-on overlap of sp^3 orbitals to form C-C σ-bond.



[or the head on overlap of the C-H bond represented by overlap of sp^3 orbital with s orbital of H]

● In CO_2, the types of covalent bonds formed are σ-bond and π-bond. A π-bond is formed by the sideways overlap of p orbitals. (This occurs only after a σ-bond is formed)



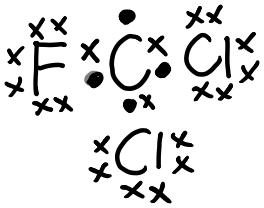
● 1m for diagrams

(e) In the stratosphere, chloroflurocarbons (CFC) such as CCl_3F can form radicals such as ●CCl_2F, which deplete the ozone layer.

(i) Explain what is meant by the term *radical.* [1]

● A radical is a species that contain an odd number of electrons and has a single unpaired electron in one of its orbital.

(ii) Draw the dot-and-cross diagram of the ●CCl_2F free radical. [1]



(iii) Hydrofluorocarbons (HFC) such as CH_2FCF_3, does not deplete the ozone layer compared to CFCs. Suggest why this is so. [1]

● Hydrofluorocarbons are inert. This is because C-F and C-H bonds are very strong and are unlikely to cleave to form free radicals hence they do not deplete the ozone layer.

[Total: 20]