Section A

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

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

What is the number of atoms in 500 cm^3 of oxygen under room conditions?

A 1.25×10^{22} **B** 1.34×10^{22} **C** 2.50×10^{22} **D** 2.68×10^{22}

2 A pure hydrocarbon is used in bottled gas for cooking and heating.

When 10 cm^3 of the hydrocarbon is burned in 70 cm^3 of excess oxygen, the final gaseous mixture contains 30 cm^3 of carbon dioxide and 20 cm^3 of unreacted oxygen. All gaseous volumes were measured under identical conditions.

What is the formula of the hydrocarbon?

A C_2H_6 **B** C_3H_6 **C** C_3H_8 **D** C_4H_{10}

3 Oxygen difluoride, OF_2, will react with sulfur dioxide, SO_2, according to the following equation:

$$OF_2 + SO_2 \rightarrow SO_3 + F_2$$

What is oxidised and what is reduced in this reaction?

	fluorine	oxygen in OF_2	sulfur
A	oxidised	oxidised	reduced
B	oxidised	reduced	oxidised
C	reduced	oxidised	reduced
D	reduced	reduced	oxidised

4 A radioactive isotope of thallium, $^{81}_{201}Tl$, is used to assess damage in heart muscles after a heart attack.

Which one of the following statements about $^{81}_{201}Tl$ is correct?

A $^{82}_{201}Tl$ is an isotope of $^{81}_{201}Tl$.

B This isotope has a nucleon number of 120.

C The number of neutrons in one atom of this isotope is 201.

D The number of electrons in one atom of this isotope is 81.

5 Gallium nitride, GaN, could revolutionise the design of electric light bulbs because only a small length used as a filament gives excellent light at low cost.

GaN is an ionic compound containing the Ga^{3+} ion.

Which one of the following statements about GaN is **not** correct?

A The outer electronic configuration of Ga atom is $4s^2 4p^1$ since Ga is a Group 13 element.

B The electron arrangement of the nitrogen ion in GaN is $1s^2 2s^2 2p^3$.

C The electron arrangement of the nitrogen ion in GaN is $1s^2 2s^2 2p^6$.

D Ga^{3+} ion deflects less than Al^{3+} ion in an electric field.

6 Sodium borohydride, $NaBH_4$, and boron trifluoride, BF_3, are compounds of boron.

What are the shapes around boron in the borohydride ion and in boron trifluoride?

	borohydride ion	boron trifluoride
A	square pyramidal	trigonal pyramidal
B	square pyramidal	trigonal planar
C	tetrahedral	trigonal pyramidal
D	tetrahedral	trigonal planar

7 Why does aluminium chloride, Al_2Cl_6, sublime at a relatively low temperature of 180 °C?

A The intermolecular forces between Al_2Cl_6 molecules are weak.

B The co-ordinate bonds between Al and Cl atoms are weak.

C The covalent bonds between Al and Cl atoms are weak.

D The ionic bonds between Al^{3+} and Cl^- ions are strong.

8 The standard enthalpy changes of formation of iron(II) oxide, FeO(s), and aluminium oxide, $Al_2O_3(s)$, are -266 kJ mol^{-1} and -1676 kJ mol^{-1} respectively.

What is the enthalpy change under standard conditions for the following reaction?

$$3FeO(s) + 2Al(s) \rightarrow 3Fe(s) + Al_2O_3(s)$$

A $+878$ kJ mol^{-1}

B -878 kJ mol^{-1}

C -1410 kJ mol^{-1}

D -2474 kJ mol^{-1}

9 Some bond energy values are listed below.

bond	bond energy / kJ mol^{-1}
C–H	410
C–C*l*	340
C*l*–C*l*	244
Br–Br	193

These bond energy values relate to the following four reactions.

P $Br_2 \rightarrow 2Br$

Q $2Cl \rightarrow Cl_2$

R $CH_3 + Cl \rightarrow CH_3Cl$

S $CH_4 \rightarrow CH_3 + H$

What is the order of enthalpy changes of these reactions from most negative to most positive?

A **P → Q → R → S**

B **Q → R → S → P**

C **R → Q → P → S**

D **S → P → Q → R**

10 One mole of phosphorus(V) chloride, PCl_5, is heated to 600 K in a sealed flask of volume 1 dm^3.

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

Equilibrium is established and measurements are taken.

The experiment is repeated with one mole of PCl_5 heated to 600 K in a sealed flask of volume 2 dm^3.

How will the measurements vary?

A The equilibrium concentration of $PCl_5(g)$ is lower in the second experiment.

B The equilibrium concentrations of all three gases are the same in both experiments.

C The equilibrium concentrations of $PCl_3(g)$ and $Cl_2(g)$ are higher in the second experiment.

D The value of the equilibrium constant is higher in the second experiment.

11 Nitrogen reacts with hydrogen to produce ammonia.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

A mixture of 2.00 mol of nitrogen, 6.00 mol of hydrogen, and 2.40 mol of ammonia is allowed to reach equilibrium in a sealed vessel of volume 1 dm^3 under certain conditions. It was found that 2.32 mol of nitrogen were present in the equilibrium mixture.

What is the value of K_c under these conditions?

A $\dfrac{(2.40)^2}{(2.32)(6.00)^3}$

B $\dfrac{(2.08)^2}{(2.32)(6.32)^3}$

C $\dfrac{(1.76)^2}{(2.32)(6.96)^3}$

D $\dfrac{(1.76)^2}{(2.32)(6.32)^3}$

12 A buffer solution is composed of HCO_3^- and CO_3^{2-}.

What is the overall ionic equation that represents the reaction of hydrochloric acid with this buffer?

A $HCl(aq) + HCO_3^-(aq) \rightarrow Cl^-(aq) + H_2CO_3(aq)$

B $H_3O^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + HCO_3^-(aq)$

C $H_3O^+(aq) + HCO_3^-(aq) \rightarrow H_2O(l) + H_2CO_3(aq)$

D $HCl(aq) + CO_3^{2-}(aq) \rightarrow Cl^-(aq) + HCO_3^-(aq)$

13 Magnesium hydroxide dissolves in aqueous ammonium chloride, but not in aqueous sodium chloride.

Which one of the following statements explains this observation?

A The NH_4^+ ion acts as an acid.

B NH_4Cl dissociates less fully than $NaCl$.

C Na^+ and Mg^{2+} ions are isoelectronic (have the same number of electrons).

D The ionic radius of the NH_4^+ ion is similar to that of Mg^{2+}, but not that of Na^+.

14 An experiment was carried out to investigate the initial rate of reaction between ammonium peroxodisulphate, $(NH_4)_2S_2O_8$, an oxidising agent, and potassium iodide, KI.

The initial concentrations of the $(NH_4)_2S_2O_8$ and KI solutions in the mixture together with the time taken for the mixture to darken for the various experimental runs are given below.

initial concentration of $(NH_4)_2S_2O_8$ / mol dm^{-3}	initial concentration of KI / mol dm^{-3}	time taken to darken / s
0.10	0.20	35
0.05	0.20	70
0.10	0.067	105
0.02	0.75	?

What is the expected time taken (in s) to darken when the experiment is repeated using initial concentrations of $(NH_4)_2S_2O_8$ and KI to be 0.02 mol dm^{-3} and 0.75 mol dm^{-3} respectively?

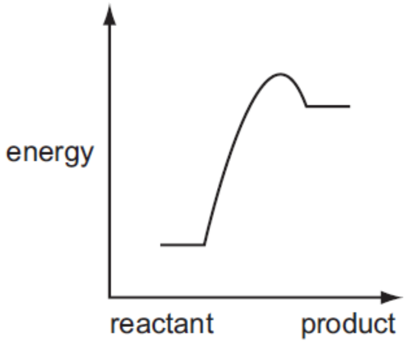
A 40 **B** 47 **C** 60 **D** 72

15 Four reactions of the type shown below are studied at the same temperature:

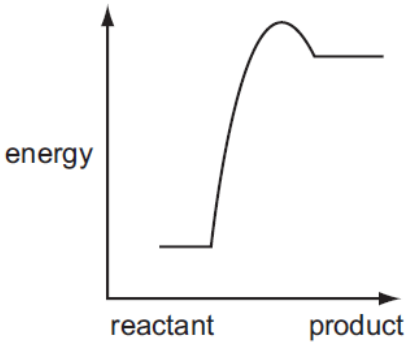
$$X(g) + Y(g) \rightarrow Z(g)$$

Which one of the following is the correct reaction pathway diagram for the reaction that would proceed most rapidly and with good yield?

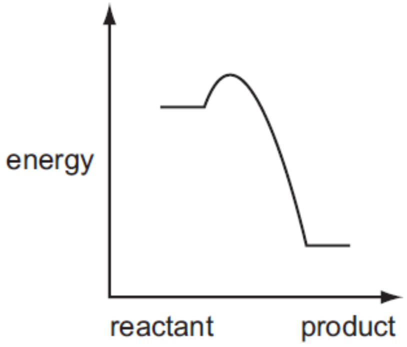
A


energy
reactant
product

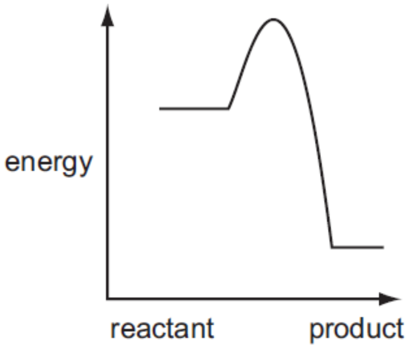
B


energy
reactant
product

C


energy
reactant
product

D


energy
reactant
product

16 Elements **W**, **X**, **Y** and **Z** have proton numbers less than 18. They occupy the following Groups in the Periodic Table.

Element	**W**	**X**	**Y**	**Z**
Group	12	14	15	16

Which two elements could combine to form a compound with giant molecular structure?

A **W** and **X**

B **W** and **Z**

C **X** and **Y**

D **X** and **Z**

17 Element **A** does not react with cold water but reacts vigorously when burnt in chlorine gas to give its chloride. The chloride dissolves in water to give a solution with pH of approximately 3.

What is element **A**?

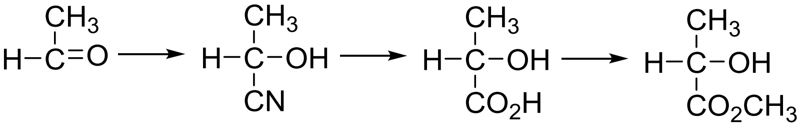
A Mg

B A*l*

C Si

D P

18 A reaction sequence is shown below:



$CH_3CHO \longrightarrow CH_3CH(OH)CN \longrightarrow CH_3CH(OH)CO_2H \longrightarrow CH_3CH(OH)CO_2CH_3$

Which one of the following reactions is **not** shown in the reaction sequence?

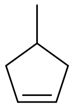
A addition

B condensation

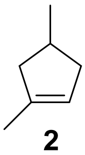
C hydrolysis

D oxidation

19 The diagram shows two different compounds



1



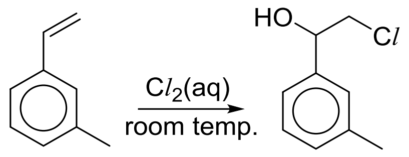
2

What is the total number of constitutional (structural) isomers, including **compound 2** that could be formed by adding a second methyl group to the ring of **compound 1**?

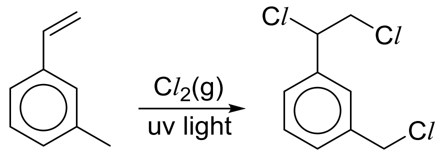
A 2 **B** 3 **C** 4 **D** 5

20 Which one of the following products is **unlikely** to form based on the given reagents and conditions?

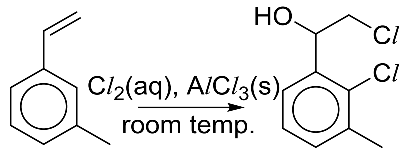
A


HO
Cl
Cl_2(aq)
room temp.

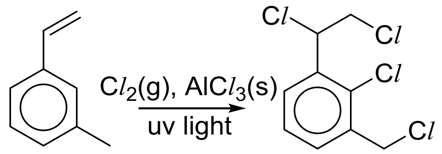
B


Cl
Cl
Cl_2(g)
uv light
Cl

C

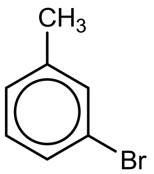

HO
Cl
Cl
Cl_2(aq), $AlCl_3$(s)
room temp.

D

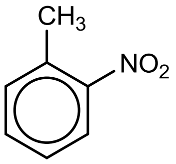

Cl
Cl
Cl
Cl_2(g), $AlCl_3$(s)
uv light
Cl

21 Which one of the following compounds **cannot** be made directly from methylbenzene?

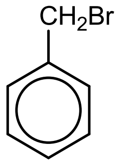
A



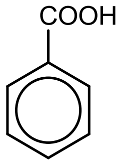
B



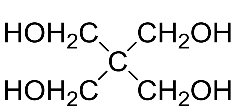
C



D



22 The structure of *pentaerythritol* is shown below. It is used in the manufacture of paint.


HOH_2C
CH_2OH
C
HOH_2C
CH_2OH

pentaerythritol

Which one of the following statements best describes a single molecule of *pentaerythritol*?

A It has an empirical formula of CH_3O.

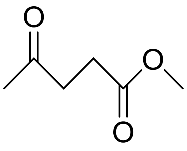
B It has a planar arrangement about the five carbon atoms.

C It reacts with hot excess concentrated sulfuric acid to form alkenes.

D It reacts with carboxylic acid in the presence of hot concentrated sulfuric acid to form esters.

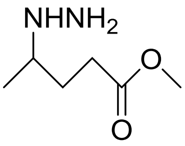
23 Hydrazine, NH_2NH_2, undergoes condensation reaction with carbonyl compounds, similar to 2,4–dinitrophenylhydrazine.

Which one of the following is likely to be the product when compound **Y** reacts with hydrazine?

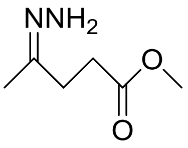


compound **Y**

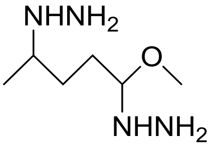
A



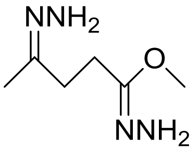
C



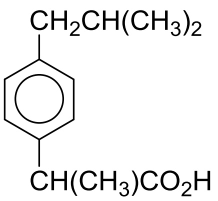
B


NHNH2
O
NHNH2

D



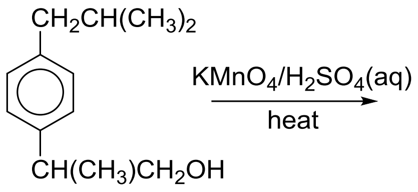
24 *Ibuprofen* is an anti-inflammatory drug.


$CH_2CH(CH_3)_2$
$CH(CH_3)CO_2H$

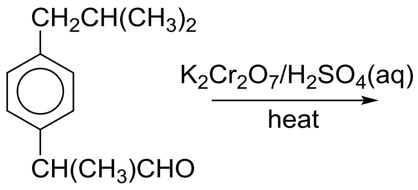
ibuprofen

Which one of the following reactions is **unlikely** to lead to its formation?

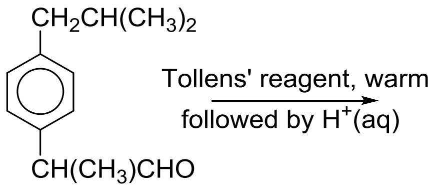
A


$CH_2CH(CH_3)_2$
$KMnO_4/H_2SO_4(aq)$
heat
$CH(CH_3)CH_2OH$

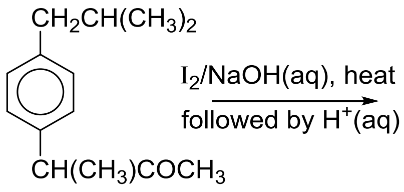
B


$CH_2CH(CH_3)_2$
$K_2Cr_2O_7/H_2SO_4(aq)$
heat
$CH(CH_3)CHO$

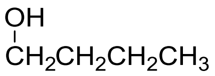
C

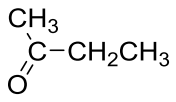

$CH_2CH(CH_3)_2$
Tollens' reagent, warm
followed by $H^+(aq)$
$CH(CH_3)CHO$

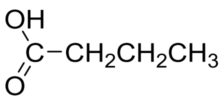
D

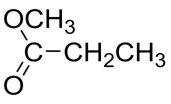

$CH_2CH(CH_3)_2$
I_2/NaOH(aq), heat
followed by $H^+(aq)$
$CH(CH_3)COCH_3$

25 How many of the following compounds can react with hot aqueous sodium hydroxide to form a sodium salt?


OH
$CH_2CH_2CH_2CH_3$


CH_3
$C-CH_2CH_3$
O


OH
$C-CH_2CH_2CH_3$
O


OCH_3
$C-CH_2CH_3$
O

A 1 **B** 2 **C** 3 **D** 4

Section B

For each of the questions in this section, one or more of the three 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 that 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 In which of the following pairs do **A** have a higher boiling point than **B**?

	A	**B**
1	CH_3CH_2CN	$CH_3CH_2CH_2CH_3$
2	$H_2C{=}CHCH_2OH$	CH_3CH_2CHO
3	$CH_3CH_2CH_2I$	$CH_3CH_2CH_2Cl$

27 Carboxylic acids react with alcohols to form esters in an equilibrium reaction as shown:

$$CH_3COOH(l) + CH_3CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_3(l) + H_2O(l) \qquad \Delta H > 0$$

Which of the following will lead to an increase in the yield of the ester?

1 Heating the mixture

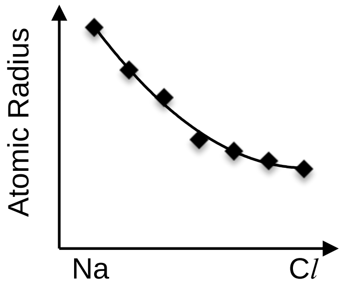
2 Adding water into the mixture

3 Adding excess sodium hydroxide into the mixture

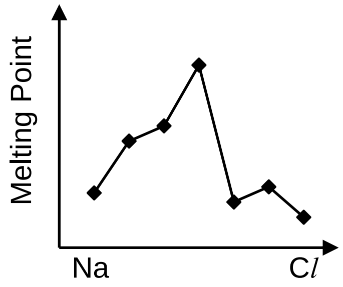
A	B	C	D
1, 2 and **3** are correct	**1** and **2** only are correct	**2** and **3** only are correct	**1** only is correct

28 Which of the following graphs show the correct trend of the respective physical properties of elements across the third period (Na to C*l*)?

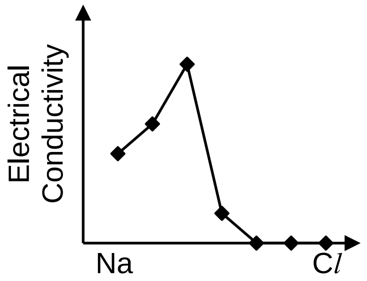
1



2



3



29 Hep–4–enal is present in cow’s milk.

$CH_3CH_2CH{=}CHCH_2CH_2CHO$

hep–4–enal

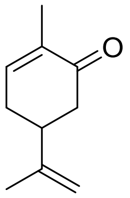
Which of the following options show the correct product for the indicated reducing agent?

1 with H_2/Ni $CH_3CH_2CH_2CH_2CH_2CH_2CHO$

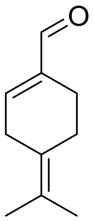
2 with $NaBH_4$ $CH_3CH_2CH{=}CHCH_2CH_2CH_2OH$

3 with $LiAlH_4$ $CH_3CH_2CH{=}CHCH_2CH_2CH_2OH$

30 The structures of two carbonyl derivatives of cyclohexene are shown below.



compound **W**



compound **X**

Which of the following statements about the two molecules are likely to be correct?

1 **W** and **X** cannot exhibit cis–trans isomerism.

2 **W** and **X** can be distinguished using Fehling’s solution.

3 **W** and **X** can undergo addition reaction with hot alcoholic NaCN.

VICTORIA JUNIOR COLLEGE
2017 JC2 PRELIM EXAMINATIONS
H1 CHEMISTRY PAPER 1 ANSWERS

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

Section A

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

1 An experiment was conducted to determine the amount of ascorbic acid (vitamin C, $C_6H_8O_6$) in one supplement tablet.

A supplement tablet was dissolved in water and made up to 250 cm^3. 25.0 cm^3 of the solution was pipetted into a conical flask containing 5.0 cm^3 of 0.400 mol dm^{-3} KI and 5.0 cm^3 of 1 mol dm^{-3} HC*l*. A few drops of starch indicator were then added. This resulting solution was titrated against 4.00×10^{-3} mol dm^{-3} KIO_3. 23.90 cm^3 of KIO_3 was required for complete reaction.

When IO_3^- ions are added to an acidic solution containing I^- ions, a redox reaction occurs.

$$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O \text{ -------- } \mathbf{(1)}$$

The I_2 formed by this reaction then reacts with ascorbic acid to form dehydroascorbic acid ($C_6H_6O_6$).

$$C_6H_8O_6 + I_2 \rightarrow 2I^- + C_6H_6O_6 + 2H^+ \text{ -------- } \mathbf{(2)}$$

Due to reaction **(2)**, the I_2 formed in **(1)** will immediately react away as long as there is any ascorbic acid present. Once all the ascorbic acid has been reacted, the excess I_2 is free to react with the starch indicator, forming the blue-black starch-iodine complex, indicating the end-point of the reaction.

(a) Suggest a reason why the concentration of KI used was much higher than that of KIO_3.

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[1]

(b) Explain in terms of the change in oxidation number which species have been reduced in **(1)**. Write a half equation for this reduction.

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[2]

(c) **(i)** Calculate the amount, in moles, of ascorbic acid present in the original 250 cm^3 solution.

[3]

(ii) Hence, calculate the mass of ascorbic acid in one tablet.

[2]

(d) Ascorbic acid is susceptible to oxidation by atmospheric oxygen over time. A student used a sample of ascorbic acid that was prepared several hours prior to titration.

State, with reasoning, what effect this will have on the volume of KIO_3 required for complete reaction and hence the calculated mass of ascorbic acid.

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[2]

[Total: 10]

2 **(a)** The compound whose bonding most resembles pure ionic bonding is a Group 1 fluoride, **M**F.

(i) When the Group 1 cation is passed through an electric field, it is deflected through an angle of +5.0°.

Given that the same electric field deflected $^{92}Sr^{3+}$ through an angle of +22°, calculate the relative atomic mass (A_r) of **M**. Hence suggest a possible identity of the **M**.

[2]

(ii) Explain why the second ionisation energy of **M** is more endothermic than its first ionisation energy.

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[1]

(iii) Suggest a reason why the bonding in **M**F resembles pure ionic the most.

....

....

....

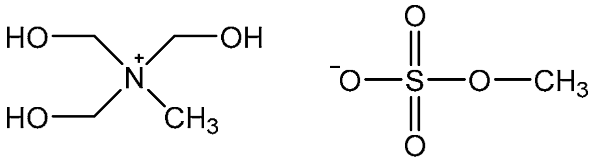
[1]

(iv) Draw a dot-cross diagram to show the bonding in **M**F. Show outer electrons only.

[1]

(b) Most ionic compounds are solids at room temperature and pressure. However, researchers have designed ionic compounds whose ionic bonding is so weak that they exist as liquids under these conditions.

An example of an ionic liquid is shown below.



Suggest two features of these ions that account for the compound having a low melting point.

1. ....

2. .... [2]

(c) Hydrogen bonds are weaker than ionic or covalent bonds, but accounts for many important intermolecular attractions.

State an anomalous property of water that is the result of hydrogen bonding.

.... [1]

(d) Draw and label the hydrogen bond between two water molecules. Indicate the bond angle around the hydrogen atom involved in the hydrogen bond. Include all relevant lone pairs and dipoles.

[2]

[Total: 10]

3 **(a)** Sodium and sulfur are elements in Period 3 in the Periodic Table.

Describe what you would observe when these two elements are separately burned in oxygen. Write equations for the reactions that occur.

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[4]

(b) The oxides, MgO, Al_2O_3 and P_4O_{10}, exist as white powdered solids with high melting points.

(i) Arrange the oxides in decreasing melting points and explain their relative melting points in terms of their structure and bonding.

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[4]

(ii) Describe two chemical reactions you could carry out on a sample of white powder to determine the identity of the oxide.

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[2]

[Total: 10]

4 **(a)** *Cracking* is a process used in the petroleum industry that converts large hydrocarbon molecules into smaller, more useful ones**.**

(i) In one particular reaction, a 16–carbon alkane undergoes cracking to form C_3H_6, C_4H_8 and C_6H_{14} as the **only** products.

Write a balanced equation to represent this reaction.

……………………………………………………………………………………………..

[1]

(ii) The hydrocarbon, C_4H_8, formed from the above reaction is found to display *cis–trans isomerism*.

State the structural requirements for *cis–trans isomerism* to be displayed in an organic molecule.

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……………………………………………………………………………………………..

[2]

(iii) Hence, draw the displayed formulae of the cis–trans isomers of C_4H_8. Label each isomer clearly.

[2]

(b) Another important process in the petroleum industry is *reforming*, which increases the proportion of aromatic, cyclic and branched–chain hydrocarbons in petrol. This enables petrol to burn more smoothly in car engines.

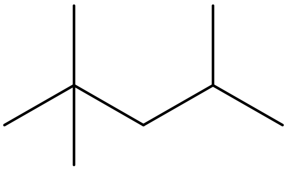
(i) One of the main products formed from the reforming process is methylbenzene, which undergoes two different reactions with bromine, depending on the conditions used.

For each reaction, state the conditions required and write a balanced equation, showing clearly the structure of **any one mono–brominated** organic product formed.

Conditions	**Equation**

[2]

(ii) Another product of the reforming process has the structure below:



State the name of the compound above.

…………………………………………………………………………………………..
[1]

(c) Compound **C** has a symmetrical structure with the molecular formula $C_6H_{12}Br_2$. In the presence of alcoholic NaOH, **C** produces **D**, C_6H_{10}.

When **D** is oxidised by hot acidified $KMnO_4$, three compounds, CO_2, CH_3CO_2H and CH_3COCO_2H, are formed in equimolar amounts.

Deduce the structures of **C** and **D**.

C	**D**

[2]

[Total: 10]

Section B

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

5 **(a)** Nitrogen is an element that is essential to life on earth. In spite of nitrogen's abundance in the atmosphere, the quantity of nitrogen containing compounds that were available for human use was limited. The Haber process for the manufacture of ammonia and the Ostwald process for the conversion of ammonia to nitric acid were developed in the early 20th century.

Ammonia is manufactured from nitrogen and hydrogen by the Haber process as shown in the equation:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H_{rxn} = -45.9 \text{ kJ mol}^{-1}$$

(i) Write an expression for the equilibrium constant, K_c, for the Haber process. [1]

(ii) Calculate the value of K_c given the following equilibrium concentrations at 1000 K. State the units of K_c.

gas	**Concentration / mol dm^{-3}**
nitrogen	1.36
hydrogen	1.84
ammonia	0.142

[2]

(iii) Explain why the activation energy of the process is high. [1]

(iv) Hence describe and explain the conditions required for the favourable production of ammonia in the Haber process. [3]

(b) A large proportion of the ammonia manufactured is then used to manufacture nitric acid which is another industrially important compound. In Ostwald process, nitric acid is produced industrially from ammonia, air and water using the following sequence of reactions:

Step 1 $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$ **ΔH_{rxn} (step 1)**

Step 2 $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ **ΔH_{rxn} (step 2)**

Step 3 $4NO_2(g) + O_2(g) + 2H_2O(l) \rightarrow 4HNO_3(aq)$ **ΔH_{rxn} (step 3)**

Overall reaction $NH_3(g) + 2O_2(g) \rightarrow HNO_3(aq) + 2H_2O(l)$

(i) Using relevant bond energy data from the *Data Booklet* and the following value, calculate the enthalpy change, **ΔH_{rxn} (step 1)**, for the reaction between ammonia and oxygen gas.

Bond energy for NO(g) = 607 kJ mol^{-1}

[2]

(ii) Using the following enthalpy changes, calculate the enthalpy changes, **ΔH_{rxn} (step 2)** and **ΔH_{rxn} (step 3)**.

$\Delta H_f(NO_2)$ = +33.2 kJ mol^{-1}
$\Delta H_f(NO)$ = +90.3 kJ mol^{-1}
$\Delta H_f(HNO_3)$ = –207.4 kJ mol^{-1}
$\Delta H_c(H_2)$ = –285.8 kJ mol^{-1}

[3]

(iii) Hence, or otherwise, calculate the enthalpy change for the **overall reaction**.

[2]

(c) A monobasic acid **HA,** extracted from a fruit has a pH of 3.5.

(i) Calculate the concentration, in mol dm^{-3}, of hydrogen ions in the acid **HA**.

[1]

(ii) 25.0 cm^3 of a sample of the acid **HA** was titrated with 0.25 mol dm^{-3} aqueous NaOH. 21.25 cm^3 of the aqueous NaOH was required to reach equivalence point.

Calculate the concentration, in mol dm^{-3}, of the acid **HA**.

[2]

(iii) Based on your answers to **(c)(i)** and **(c)(ii)** above, what can you deduce about the strength of the acid **HA**? Give a reason for your deduction.

[1]

(iv) Hence predict the volume of carbon dioxide evolved when 25.0 cm^3 of 0.40 mol dm^{-3} of HC*l* and **HA** reacts with excess Na_2CO_3 under standard conditions.

[2]

[Total: 20]

6 **(a)** Potassium reacts with ammonia to give a compound of KNH_2 as shown in the given equation:

$$2K + 2NH_3 \rightarrow 2KNH_2 + H_2$$

The rate of the reaction was investigated by using a freshly cut piece of potassium which was weighed and added to a large excess of ammonia. The experiment was conducted at room temperature and pressure.

The total volume of gas evolved at every minute was recorded and shown below.

Time/ min	0	1	2	3	4	5	6	7	8
Total volume of gas/ cm^3	0	23.0	36.5	46.0	51.0	55	58.0	60	60

(i) Plot the experimental results on graph paper.

[2]

(ii) Hence deduce the order of reaction with respect to potassium.

[1]

(iii) Write a rate equation for the reaction and calculate the rate constant, stating its units.

[2]

(iv) In this experiment, the kinetics appear to be zero order with respect to ammonia. Suggest a reason for this.

[1]

(v) Calculate the mass of potassium used in the experiment.

[2]

(b) Ammonia is an important starting material in the manufacture of fertilisers as well as explosives and plastics. The Haber process is used to form ammonia as shown in the equation below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

(i) Draw a Maxwell Boltzmann distribution curve for the reactants at temperature $\mathbf{T_1}$. Label this curve **X**. Mark the position of the activation energy with a line. Label this as $\boldsymbol{E}_\mathbf{a}$.

[2]

(ii) On the axes that you have drawn, draw a **second** distribution curve that represents the reaction at a higher temperature $\mathbf{T_2}$. Label this curve **Y**.

Use curves **X** and **Y** to describe and explain the effects of an increase in temperature on the rate of a reaction.

[3]

(iii) Name a catalyst that can be used for the Haber Process.

[1]

(c) **(i)** Draw a dot-and-cross diagram to show the bonding in an ammonia molecule.

[1]

(ii) By using the Valence Shell Electron Pair Repulsion theory, state the shape and bond angle in the ammonia molecule and explain in details how it arises.

[2]

(iii) When ammonia is mixed with aluminium chloride in a 1:1 ratio, a new single compound is formed.

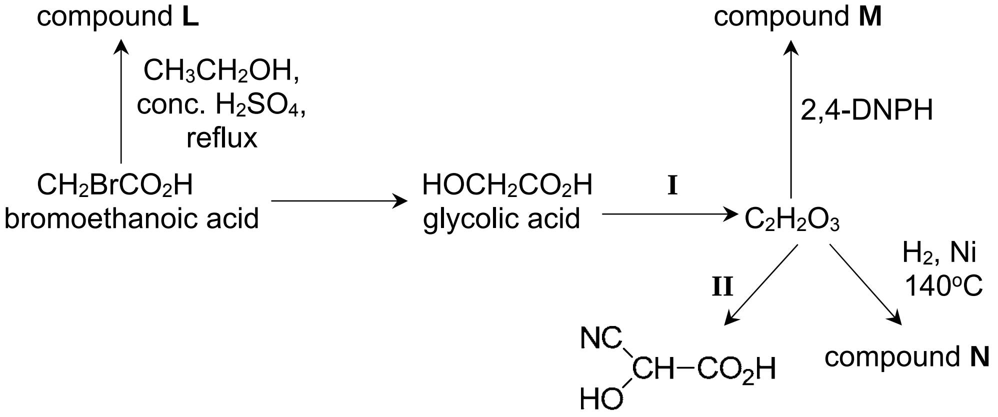
Suggest the type of bond that is formed between ammonia and aluminium chloride, explaining your answer clearly. Draw a ***displayed*** structure of the product formed, indicating the bond angle with respect to nitrogen and aluminium.

[3]

[Total: 20]

7 **(a)** Glycolic acid, $HOCH_2CO_2H$, is a colourless, odourless and hygroscopic crystalline solid which is used in various skin-care products.

The reaction scheme below shows some reactions involving glycolic acid.



(i) State the reagents and conditions for reactions **I** and **II**.

[2]

(ii) Draw the structural formulae for compounds **L**, **M** and **N**.

[3]

(iii) The K_a of bromoethanoic acid is 1.38×10^{-3} mol dm^{-3}.

Predict, with reasons, whether the K_a of chloroethanoic acid would be greater or less than that of bromoethanoic acid.

[3]

(b) Bromoethane is used as a solvent, an anaesthetic in medicine and a refrigerant. It is also a useful intermediate for making other organic compounds, such as carboxylic acid.

(i) Bromoethane reacts with aqueous NaOH under heating condition.

How would you expect the rate of this reaction to compare to that of the reaction of iodoethane with aqueous NaOH? Explain your answer.

[3]

(ii) Bromoethane can be used to prepare propanal under laboratory conditions, using propanoic acid as an intermediate.

Suggest a synthesis involving not more than 4 steps for this conversion. Include reagents and conditions for each step, as well as the structures of the intermediate compounds formed.

[5]

(c) Propose appropriate test-tube reactions which would enable you to distinguish between the following compounds. Include expected observations for each compound in your answer.

I. bromoethane and iodoethane

[2]

II. $CH_3CH_2CO_2CH_3$ and $CH_3CH_2CO_2CH_2CH_3$

[2]

[Total : 20]

Victoria Junior College
2017 VJC H1 Chemistry Prelim Exam 8872/2
Suggested Answers

Section A

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

S1 An experiment was conducted to determine the amount of ascorbic acid (vitamin C, $C_6H_8O_6$) in a supplement tablet.

A supplement tablet was dissolved in water and made up to 250 cm^3. 25.0 cm^3 of the solution was pipetted into a conical flask containing 5.0 cm^3 of 0.400 mol dm^{-3} KI and 5.0 cm^3 of 1 mol dm^{-3} HC*l*. A few drops of starch indicator were then added. This resulting solution was titrated against 4.00×10^{-3} mol dm^{-3} KIO_3. 23.90 cm^3 of KIO_3 was required for complete reaction.

When IO_3^- ions are added to an acidic solution containing I^- ions, a redox reaction occurs.

$$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O \text{ -------- } \mathbf{(1)}$$

The I_2 formed by this reaction then reacts with ascorbic acid to form dehydroascorbic acid ($C_6H_6O_6$).

$$C_6H_8O_6 + I_2 \rightarrow 2I^- + C_6H_6O_6 + 2H^+ \text{ -------- } \mathbf{(2)}$$

Due to reaction **(2)**, the I_2 formed in **(1)** will immediately react away as long as there is any ascorbic acid present. Once all the ascorbic acid has been reacted, the excess I_2 is free to react with the starch indicator, forming the blue-black starch-iodine complex, indicating the end-point of the reaction.

(a) Suggest a reason why the concentration of KI used was much higher than that of KIO_3.

IO_3^- needs to be added in excess, to ensure that there will be sufficient I_2 produced to react with $C_6H_8O_6$.

[1]

(b) Explain in terms of the change in oxidation number which species have been reduced in **(1)**. Write a half equation for this reduction.

Oxidation number of I changed from +5 in IO_3^- to 0 in I_2. Hence IO_3^- is reduced.
$IO_3^- + 6H^+ + 5e^- \rightarrow \frac{1}{2} I_2 + 3H_2O$

[2]

(c) **(i)** Calculate the amount, in moles, of ascorbic acid present in the original 250 cm^3 solution.

No. of moles of IO_3^- = $23.90 \times 10^{-3} \times 4.00 \times 10^{-3} = 9.56 \times 10^{-5}$ mol
No. of moles of I_2 = $9.56 \times 10^{-5} \times 3 = 2.87 \times 10^{-4}$ mol
No. of moles of $C_6H_8O_6$ in 25.0 cm^3 = 2.87×10^{-4} mol
No. of moles of $C_6H_8O_6$ in 250 cm^3 = 2.87×10^{-4} mol x 250/25.0
= 2.87×10^{-3} mol

[3]

(ii) Hence, calculate the mass of ascorbic acid in one tablet.

M_r of $C_6H_8O_6$ = 12.0 × 6 + 1.0 × 8 + 16.0 × 6 = 176.0
Mass of $C_6H_8O_6$ in one tablet = $2.87 \times 10^{-3} \times 176.0$ = 0.505 g

[2]

(d) Ascorbic acid is susceptible to oxidation by atmospheric oxygen over time. A student used a sample of ascorbic acid that was prepared several hours prior to titration.

State, with reasoning, what effect this will have on the volume of KIO_3 required for complete reaction and hence the calculated mass of ascorbic acid.

Amount of ascorbic acid in the sample would be lower, less I_2 and hence less KIO_3 would be required for complete reaction. Since mass is proportional to mole, the calculated mass of ascorbic acid would be lower.

[2]

[Total: 10]

2 **(a)** The compound whose bonding most resembles pure ionic bonding is a Group 1 fluoride, **M**F.

(i) When the Group 1 cation is passed through an electric field, it is deflected through an angle of +5.0 °.

Given that the same electric field deflected $^{92}\text{Sr}^{3+}$ through an angle of +22 °, calculate the relative atomic mass (A_r) of **M**. Hence suggest a possible identity of the **M**.

deflection angle = k |charge/mass|

For proton,
22 = k |3/92|
k = 675

For unknown Group 1 cation,
5.0 = 675 |1/A_r|
A_r = 135.0
Hence the Group 1 metal is likely to be caesium.

[2]

(ii) Explain why the second ionisation energy of **M** is more endothermic than its first ionisation energy.

The second electron is removed from an inner shell, which is closer and more strongly attracted to the nucleus. More energy is needed to remove the second electron, and second ionisation energy is more endothermic.

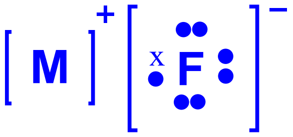
[1]

(iii) Suggest a reason why the bonding in **M**F resembles pure ionic the most.

Largest possible electronegativity difference between the 2 elements.
[OR Lowest polarising power of cation and lowest polarisability of anion.]

[1]

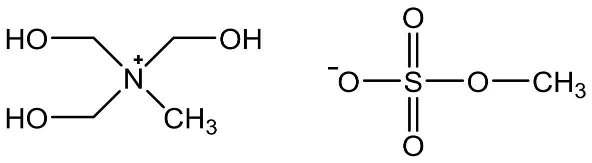
(iv) Draw a dot-cross diagram to show the bonding in **M**F. Show outer electrons only.



[1]

(b) Most ionic compounds are solids at room temperature and pressure. However, researchers have designed ionic compounds whose ionic bonding is so weak that they exist as liquids under these conditions.

An example of an ionic liquid is shown below.



Suggest two features of these ions that account for the compound having a low melting point.

1. **Small cationic and anionic charges**
2. **Large cationic and anionic radii**

[2]

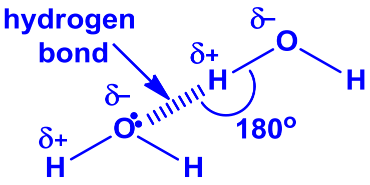
(c) Hydrogen bonds are weaker than ionic or covalent bonds, but accounts for many important intermolecular attractions.

State an anomalous property of water that is the result of hydrogen bonding.

Ice is less dense than liquid water.
[OR H_2O has a higher boiling point than H_2S.]

[1]

(d) Draw and label the hydrogen bond between two water molecules. Indicate the bond angle around the hydrogen atom involved in the hydrogen bond. Include all relevant lone pairs and dipoles.



Correct attractive forces between lone pair of O & δ+H on adjacent molecules
Correct label of hydrogen bond
Correct label of dipoles
Correct bond angle

[2]

[Total: 10]

Q3 **(a)** Sodium and sulfur are elements in Period 3 in the Periodic Table.

Describe what you would observe when these two elements are separately burned in oxygen. Write equations for the reactions that occur.

Sodium burns vigorously with a bright yellow / orange flame to form a white solid of Na_2O.

$4Na + O_2 \rightarrow 2Na_2O$

Sulfur burns slowly with a pale blue flame to form a colourless gas of SO_2 in limited oxygen and a colourless gas of SO_3 in excess oxygen.

$S + O_2 \rightarrow SO_2$

[OR $2SO_2 + O_2 \rightarrow 2SO_3$]

[4]

(b) The oxides, MgO, Al_2O_3 and P_4O_{10}, exist as white powdered solids with high melting points.

(i) Arrange the oxides in decreasing melting points and explain their relative melting points in terms of their structure and bonding.

Melting points decrease in the order: MgO > Al_2O_3 > P_4O_{10}

Both MgO and Al_2O_3 have giant ionic structure with strong electrostatic attraction between the cations and anions.

As Al^{3+} has a higher charge density and hence higher polarising power than Mg^{2+}, the O^{2-} electron cloud experiences distortion by the highly polarising Al^{3+}. This results in a decrease in ionic character and a lower lattice energy in Al_2O_3 and hence a lower melting point.

P_4O_{10} has a simple molecular structure with weak instantaneous dipole-induced dipole interactions between the molecules. A small amount of energy is needed to break these weak interactions, hence lowest melting point.

[4]

(ii) Describe two chemical reactions you could carry out on a sample of white powder to determine the identity of the oxide.

Add HC*l*(aq) and NaOH(aq)

	MgO	**Al_2O_3**	**P_4O_{10}**
Add HC*l*(aq)	**Dissolves to form a colourless solution [of $MgCl_2$(aq)].**	**Dissolves to form a colourless solution [of $AlCl_3$(aq)].**	**Does not dissolve (negligible dissolution of solid due to solubility of P_4O_{10} in H_2O to give H_3PO_4 is considered).**

Add NaOH(aq)	**Does not dissolve (negligible dissolution of solid due to some solubility of MgO in H_2O to form $Mg(OH)_2$ is considered).**	**Dissolves to form a colourless solution [of $NaAl(OH)_4(aq)$].**	**Dissolves to form a colourless solution [of $Na_3PO_4(aq)$].**

React with both NaOH and HCl, Al_2O_3 identified
React with both NaOH only, P_4O_{10} identified
React with HCl only, MgO identified

[2]

[Total: 10]

4 **(a)** *Cracking* is a process used in the petroleum industry that converts large hydrocarbon molecules into smaller, more useful ones**.**

(i) In one particular reaction, a 16–carbon alkane undergoes cracking to form C_3H_6, C_4H_8 and C_6H_{14} as the **only** products.

Write a balanced equation to represent this reaction.

$\mathbf{C_{16}H_{34} \rightarrow C_6H_{14} + C_4H_8 + 2C_3H_6}$

[1]

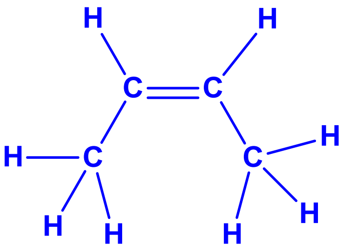
(ii) The hydrocarbon, C_4H_8, formed from the above reaction is found to display *cis–trans isomerism*.

State the structural requirements for *cis–trans isomerism* to be displayed in an organic molecule.

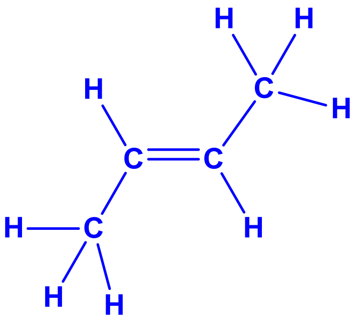
The molecule must have a C=C bond which cannot be rotated.
To each alkene carbon, 2 different groups are attached.

[2]

(iii) Hence, draw the displayed formulae of the cis–trans isomers of C_4H_8. Label each isomer clearly.



cis



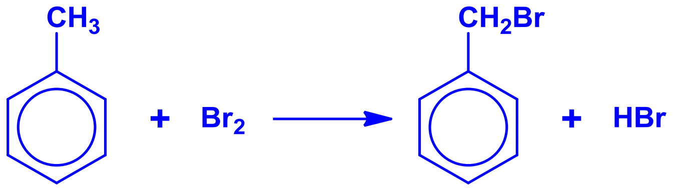
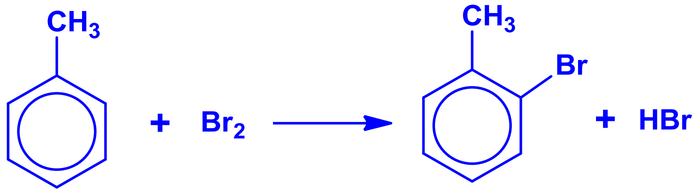
trans

[2]

(b) Another important process in the petroleum industry is *reforming*, which increases the proportion of aromatic, cyclic and branched–chain hydrocarbons in petrol. This enables petrol to burn more smoothly in car engines.

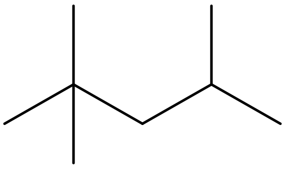
(i) One of the main products formed from the reforming process is methylbenzene, which undergoes two different reactions with bromine, depending on the conditions used.

For each reaction, state the conditions required and write a balanced equation, showing clearly the structure of **any one mono–brominated** organic product formed.

Conditions	**Equation**
UV light, excess $C_6H_5CH_3$	
Presence of anhydrous $FeBr_3$ catalyst	 **[OR show Br at position 4]**

[2]

(ii) Another product of the reforming process has the structure below:



State the name of the compound above.

2, 2, 4–trimethylpentane

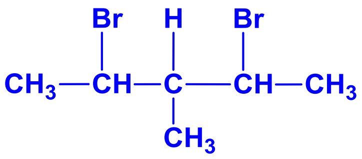
[1]

(c) Compound **C** has a symmetrical structure with the molecular formula $C_6H_{12}Br_2$. In the presence of alcoholic NaOH, **C** produces **D**, C_6H_{10}.

When **D** is oxidised by hot acidified $KMnO_4$, three compounds, CO_2, CH_3CO_2H and CH_3COCO_2H, are formed in equimolar amounts.

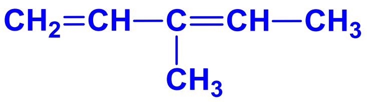
Deduce the structures of **C** and **D**.

C



$$CH_3-\overset{\overset{\textstyle Br}{|}}{C}H-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle CH_3}{|}}{C}}-\overset{\overset{\textstyle Br}{|}}{C}H-CH_3$$

D



$$CH_2{=}CH-\underset{\underset{\textstyle CH_3}{|}}{C}{=}CH-CH_3$$

[2]

[Total: 10]

Section B

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

5 **(a)** Nitrogen is an element that is essential to life on earth. In spite of nitrogen's abundance in the atmosphere, the quantity of nitrogen containing compounds that were available for human use was limited. The Haber process for the manufacture of ammonia and the Ostwald process for the conversion of ammonia to nitric acid were developed in the early 20th century.

Ammonia is manufactured from nitrogen and hydrogen by the Haber process as shown in the equation:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H_{rxn} = -45.9 \text{ kJ mol}^{-1}$$

(i) Write an expression for the equilibrium constant, K_c, for the Haber process.

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

[1]

(ii) Calculate the value of K_c given the following equilibrium concentrations at 1000 K. State the units of K_c.

gas	**concentration/ mol dm^{-3}**
nitrogen	1.36
hydrogen	1.84
ammonia	0.142

$$K_c = \frac{(0.142)^2}{(0.136)(1.84)^3}$$

$$= 2.38 \times 10^{-3} \text{ mol}^{-2} \text{ dm}^{6}$$

[2]

(iii) Explain why the activation energy of the process is high.

The activation energy of the process is high due to the high bond energy of the N≡N bond.

[1]

(iv) Hence describe and explain the conditions required for the favourable production of ammonia in Haber process.

High pressure (200 atm) favors the production of ammonia. By Le Chatelier's Principle, the equilibrium position will shift right to reduce the increase in pressure leading to greater amount of ammonia.

Low temperature favors the production of ammonia. By Le Chatelier's Principle, the equilibrium position will shift right to produce more heat leading to greater amount of ammonia. However low temperature will mean slower rate of reaction. Hence temperature is kept high (450 °C) for faster rate of reaction.

Addition of catalyst (finely divided iron) is used to increase the rate of reaction but not the yield of ammonia.

[3]

(b) A large proportion of the ammonia manufactured is then used to manufacture nitric acid which is another industrially important compound. In Ostwald process, nitric acid is produced industrially from ammonia, air and water using the following sequence of reactions:

Step 1 $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$ **ΔH_{rxn} (step 1)**

Step 2 $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ **ΔH_{rxn} (step 2)**

Step 3 $4NO_2(g) + O_2(g) + 2H_2O(l) \rightarrow 4HNO_3(aq)$ **ΔH_{rxn} (step 3)**

Overall reaction $NH_3(g) + 2O_2(g) \rightarrow HNO_3(aq) + 2H_2O(l)$

(i) Using relevant bond energy data from the *Data Booklet* and the following value, calculate the enthalpy change, **ΔH_{rxn} (step 1)**, for the reaction between ammonia and oxygen gas.

Bond energy for NO(g) = 607 kJ mol^{-1}

ΔH_{rxn} (step 1) = Σ(BE of reactants) – Σ(BE of products)
= [12(390) + 5(496)] – [4(607) + 12(460)]
= –788 kJ mol^{-1}

[2]

(ii) Using the following enthalpy changes, calculate the enthalpy change, **ΔH_{rxn} (step 2)** and **ΔH_{rxn} (step 3)**.

ΔH_f (NO_2) = +33.2 kJ mol^{-1}
ΔH_f (NO) = +90.3 kJ mol^{-1}
ΔH_f (HNO_3) = –207.4 kJ mol^{-1}
ΔH_c (H_2) = –285.8 kJ mol^{-1}

ΔH_{rxn} (step 2) = Σ(ΔH_f products) – Σ(ΔH_f reactants)
= (33.2) – 2(90.3)
= –114 kJ mol^{-1}
ΔH_{rxn} (step 3) = Σ(ΔH_f products) – Σ(ΔH_f reactants)
= [4(–207.4)] – [4(+33.2) + 1(0) + 2(–285.8)]
= –391 kJ mol^{-1}

[3]

(iii) Hence, or otherwise, calculate the enthalpy change for the **overall reaction**.

Adding Step 1, Step 2 x 2 and Step 3 gives
$4NH_3(g) + 8O_2(g) \rightarrow 4HNO_3(aq) + 8H_2O(l)$
Dividing by 4 will give:
$NH_3(g) + 2O_2(g) \rightarrow HNO_3(aq) + 2H_2O(l)$
4 x ΔH_{rxn}(overall) = –788 + 2(–114) + (–391)
ΔH_{rxn}(overall) = –352 kJ mol^{-1}

[2]

(c) A monobasic acid **HA,** extracted from a fruit has a pH of 3.5.

(i) Calculate the concentration, in mol dm^{-3}, of hydrogen ions in the acid **HA**.

$[H^+] = 10^{-3.5} = 3.16 \times 10^{-4}$ mol dm^{-3}

[1]

(ii) 25.0 cm^3 of a sample of the acid **HA** was titrated with 0.25 mol dm^{-3} aqueous NaOH. 21.25 cm^3 of the aqueous NaOH was required to reach equivalence point.

Calculate the concentration, in mol dm^{-3}, of the acid **HA**.

No. of mol of NaOH = $\frac{21.25}{1000} \times 0.25$ = 5.312×10^{-3}
= No. of mol of HA

$[HA] = \dfrac{5.312 \times 10^{-3}}{\frac{25}{1000}}$ = 0.2125 = 0.213 mol dm^{-3}

[2]

(iii) Based on your answers to **(c)(i)** and **(c)(ii)** above, what can you deduce about the strength of the acid **HA**? Give a reason for your deduction.

HA is a weak acid.
Since $[HA] >> [H^+]$, HA dissociates partially to form H^+.

[1]

(iv) Hence predict the volume of carbon dioxide evolved when 25.0 cm^3 of 0.40 mol dm^{-3} of HC*l* and **HA** reacts with excess Na_2CO_3 under standard conditions.

$2H^+ + CO_3^{2-} \rightarrow H_2O + CO_2$
Number of moles of CO_2 = ½ x number of moles of H^+
= ½ x (0.40 x 0.025)
= 5.00×10^{-3}
Volume of CO_2 evolved for HC*l* = $5.00 \times 10^{-3} \times 24000$
= 120 cm^3
Since volume and conc. used for HA is the same,
Volume of CO_2 evolved for HA = 120 cm^3

Alternative answer
HC*l* + HA + $CO_3^{2-} \rightarrow H_2O + CO_2$ + C*l*$^-$ + A^-
Number of moles of HC*l* = number of moles of HA
= number of moles of CO_2
= (0.40 x 0.025)
= 1.00×10^{-2}
Volume of CO_2 evolved (in total) = $1.00 \times 10^{-2} \times 24000$
= 240 cm^3

[2]

[Total: 20

6 **(a)** Potassium reacts with ammonia to give a compound of KNH_2 as shown in the given equation:

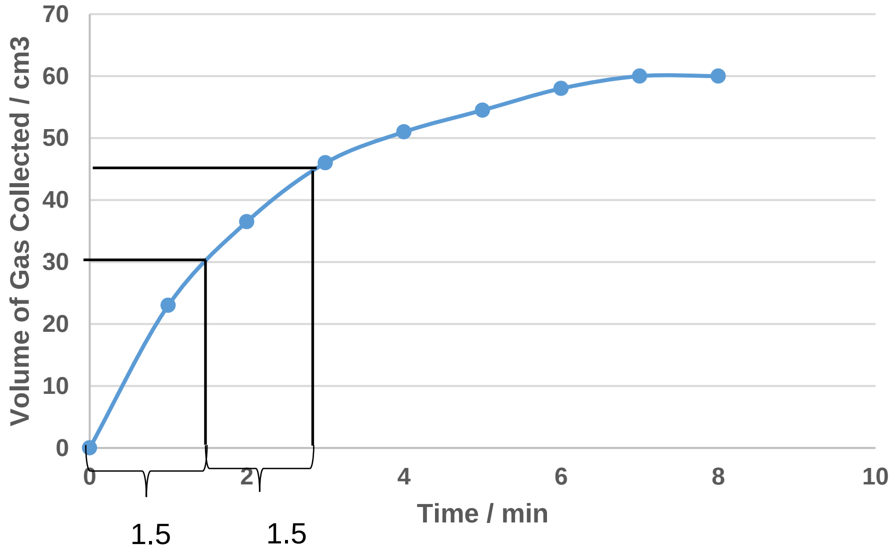
$$2K + 2NH_3 \rightarrow 2KNH_2 + H_2$$

The rate of the reaction was investigated by using a freshly cut piece of potassium which was weighed and added to a large excess of ammonia. The experiment was conducted at room temperature and pressure.

The total volume of gas evolved at every minute was recorded and shown below.

Time / min	0	1	2	3	4	5	6	7	8
Total volume of gas / cm^3	0	23.0	36.5	46.0	51.0	55	58.0	60	60

(i) Plot the experimental results on graph paper.



Axes and units
Smooth curve
Graph more than ½ page
Construction lines to show 2 constant half-lives

[2]

(ii) Hence deduce the order of reaction with respect to potassium.

Since half-life is constant at 1.5 min, it is first order wrt to potassium.

[1]

(iii) Write a rate equation for the reaction and calculate the rate constant, stating its units.

Rate = k[K]

$t_{1/2} = \frac{\ln 2}{k} = 1.5$ **hence** $k = \frac{\ln 2}{1.5} = \frac{0.693}{1.5} = \bullet\ 0.462\ \text{min}^{-1}$

[2]

(iv) In this experiment, the kinetics appear to be zero order with respect to ammonia. Suggest a reason for this.

The ammonia was in large excess hence its change in concentration will not be significant.

[1]

(v) Calculate the mass of potassium used in the experiment.

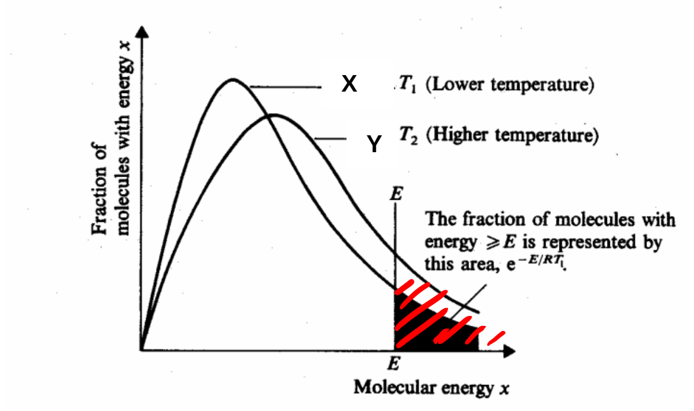
Amount of hydrogen evolved = 60 / 24000 = 2.50 x 10^{-5} mol
Amount of potassium used = 2 x 2.50 x 10^{-5} = 5.00 x 10^{-5} mol
Mass of potassium = 5.00 x 10^{-5} x 39.1 = 0.196 g

[2]

(b) Ammonia is an important starting material in the manufacture of fertilisers as well as explosives and plastics. The Haber process is used to form ammonia as shown in the equation below:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

(i) Draw a Maxwell Boltzmann distribution curve for the reactants at temperature **T_1**. Label this curve **X**. Mark the position of the activation energy with a line. Label this as **E_a**.



Axes labelled correctly
Start from 0 and correct shape
Indicate E_a
Shade area under curve

[2]

(ii) On the axes that you have drawn, draw a **second** distribution curve that represents the reaction at a higher temperature **T_2**. Label this curve **Y**.

Use curves **X** and **Y** to describe and explain the effects of an increase in temperature on the rate of a reaction.

Correct shape and position of new curve.
When temperature increases, average kinetic energy of the molecules increases. Proportion of molecules with minimum E_a also increases. Hence frequency of effective collisions increases leading to an increase in rate.

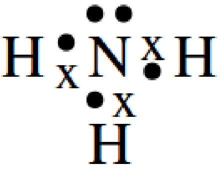
[3]

(iii) Name a catalyst that can be used for the Haber Process.

Iron [OR aluminium oxide]

[1]

(c) **(i)** Draw a dot-and-cross diagram to show the bonding in an ammonia molecule.



[1]

(ii) By using the Valence Shell Electron Pair Repulsion theory, state the shape and bond angle in the ammonia molecule and explain in details how it arises.

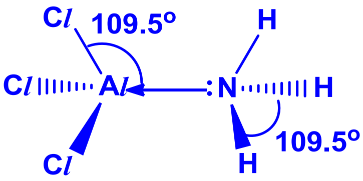
107° and trigonal pyramidal in shape
Presence of 3 bond pairs and 1 lone pair electrons
Degree of repulsion according to VSEPR theory is lone pair–lone pair > lone pair–bond pair > bond pair–bond pair
The electron pairs will maximise their distance apart in order to minimise repulsion hence lone pair pushes 3 bond pairs closer together.

[2]

(iii) When ammonia is mixed with aluminium chloride in a 1:1 ratio, a new single compound is formed.

Suggest the type of bond that is formed between ammonia and aluminium chloride, explaining your answer clearly. Draw a ***displayed*** structure of the product formed, indicating the bond angle with respect to nitrogen and aluminium.

Dative bond is formed when lone pair of electrons on nitrogen of ammonia is shared with the electron-deficient aluminium atom which has energetically accessible empty orbitals.

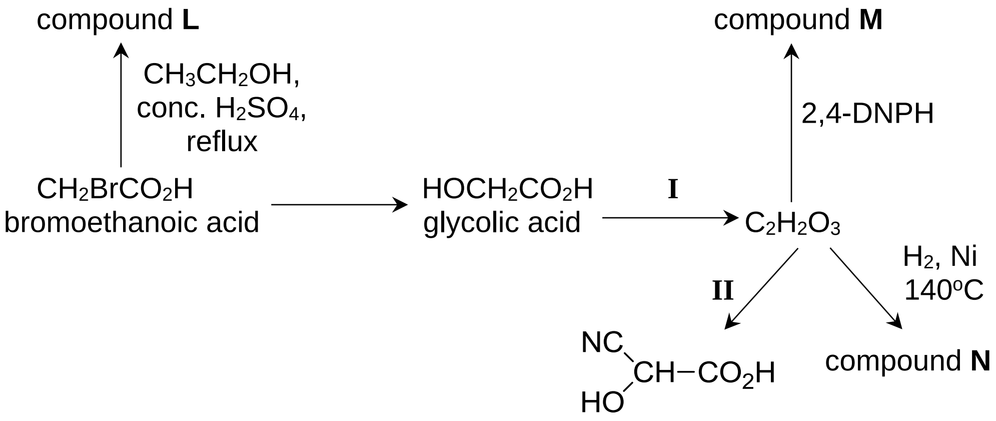


[3]

[Total: 20]

7 **(a)** Glycolic acid, $HOCH_2CO_2H$, is a colourless, odourless and hygroscopic crystalline solid which is used in various skin-care products.

The reaction scheme below shows some reactions involving glycolic acid.


compound **L**
CH_3CH_2OH, conc. H_2SO_4, reflux
compound **M**
2,4-DNPH
CH_2BrCO_2H
bromoethanoic acid
$HOCH_2CO_2H$
glycolic acid
I
$C_2H_2O_3$
II
H_2, Ni
140°C
NC
CH−CO_2H
HO
compound **N**

(i) State the reagents and conditions for reactions **I** and **II**.

Reaction I: $K_2Cr_2O_7$(aq), H_2SO_4(aq), distil

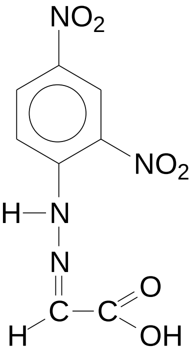
Reaction II: HCN, NaCN (catalyst), room temperature

[2]

(ii) Draw the structural formulae for compounds **L**, **M** and **N**.

L: $BrCH_2COOCH_2CH_3$

M:


NO2
NO2
H
N
N
C
C
O
OH
H

N: $HOCH_2CO_2H$

for each correct structure

[3]

(iii) The K_a of bromoethanoic acid is 1.38 x 10^{-3} mol dm^{-3}.

Predict, with reasons, whether the K_a of chloroethanoic acid would be greater or less than that of bromoethanoic acid.

The electron–withdrawing inductive effect of chlorine is greater than that of bromine due to its higher electronegativity. Hence, this leads to a greater extent of dispersal of negative charge in carboxylate ion, making the anion more stable.

Hence, chloroethanoic acid would be a stronger acid. Its K_a value will therefore be greater than 1.38 x 10^{-3} mol dm^{-3}.

[3]

(b) Bromoethane is used as a solvent, an anaesthetic in medicine and a refrigerant. It is also a useful intermediate for making other organic compounds, such as carboxylic acid.

(i) Bromoethane reacts with aqueous NaOH under heating condition.

How would you expect the rate of this reaction to compare to that of the reaction of iodoethane with aqueous NaOH? Explain your answer.

2-iodobutane will have a faster reaction with NaOH(aq). I has a larger atomic radius than C*l*, hence, C–I has a longer bond length / weaker bond strength. C–I bond will be broken more easily and 2-iodobutane will therefore undergo substitution more easily.

[3]

(ii) Bromoethane can be used to prepare propanal under laboratory conditions, using propanoic acid as an intermediate.

Suggest a synthesis involving not more than 4 steps for this conversion. Include reagents and conditions for each step, as well as the structures of the intermediate compounds formed.

$$\begin{tikzcd}
CH_3CH_2Br \arrow[r, "\text{alcoholic KCN, reflux}"] & CH_3CH_2CN \arrow[r, "H_2SO_4(aq)\text{, reflux}"] & CH_3CH_2CO_2H \arrow[d, "LiAlH_4\text{ in dry ether, room temp OR }NaBH_4\text{ in ethanol}"] \\
 & CH_3CH_2CHO & CH_3CH_2CH_2OH \arrow[l, "K_2Cr_2O_7(aq)\text{, }H_2SO_4(aq)\text{, distil}"']
\end{tikzcd}$$

[5]

(c) Propose appropriate test-tube reactions which would enable you to distinguish between the following compounds. Include expected observations for each compound in your answer.

I. bromoethane and iodoethane

Test: Add NaOH(aq), heat, followed by addition of excess HNO_3(aq) and $AgNO_3$(aq).

Observation: A cream ppt of AgBr is formed for bromoethane, while a yellow ppt of AgI is formed for iodoethane.

[2]

II. $CH_3CH_2CO_2CH_3$ and $CH_3CH_2CO_2CH_2CH_3$

Test: Add H_2SO_4 (aq), heat, followed by $KMnO_4$(aq)

Observation:
For $CH_3CH_2CO_2CH_3$, there is a decolourisation of purple $KMnO_4$ and an effervescence of CO_2 which forms white ppt with limewater.

For $CH_3CH_2CO_2CH_2CH_3$, there is a decolourisation of purple $KMnO_4$ without effervescence.

OR
Test: Add NaOH (aq), heat, followed by I_2(aq), NaOH (aq), warm < 70°C.

Observation:
For $CH_3CH_2CO_2CH_3$, there is no pale yellow ppt of CHI_3 formed.

For $CH_3CH_2CO_2CH_2CH_3$, there is pale yellow ppt CHI_3 formed.

[2]

[Total : 20]