Class	Reg Number
17	

Name _____

Calculator Model / No.

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examination
Higher 1

Chemistry 8873/01

Paper 1 **21 September 2018**
1 hour

Additional Material: *Data Booklet*
OMS

READ THESE INSTRUCTIONS FIRST

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

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

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This document consists of **12** printed pages (including this cover page)

Answer all questions.

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

1 Zinc ethanoate, $(CH_3CO_2)_2Zn$ (M_r = 183.4) may be taken as a dietary supplement to prevent zinc deficiency.

What is the total number of ions present in a 5 cm^3 solution of aqueous zinc ethanoate given that the solution has a concentration of 10.64 g dm^{-3}?

A 1.7×10^{19} **B** 5.2×10^{20} **C** 3.5×10^{22} **D** 1.0×10^{23}

2 Gases given off during volcanic eruptions include H_2S and CS_2.

A 40 cm^3 gaseous sample of H_2S and CS_2, present in a 3 : 1 ratio respectively, was analysed by combustion using 100 cm^3 of oxygen. After measuring the volume of gas remaining, the product was treated with an excess of aqueous sodium hydroxide and the volume of gas measured again.

Any sulfur present is converted to SO_2 after combustion.

Given that all volume measurements were made under room conditions, what were the measured volumes?

	volume of gaseous mixture after burning / cm^3	volume of gaseous mixture after adding NaOH (aq) / cm^3
A	60	0
B	60	50
C	85	25
D	85	75

3 Na_3NO_4 is very sensitive to water vapour and carbon dioxide in the air and it reacts with both of them to produce equimolar amounts of $NaNO_3$, $NaHCO_3$ and compound **E**.

What is compound **E**?

A NaH **B** Na_2O

C NaOH **D** $NaNO_2$

4 Which of the following contains more than one type of chemical bond?

1 barium carbonate

2 graphene

3 water

A **1**, **2** and **3**

B **1** and **2** only

C **1** and **3** only

D **1** only

5 Consider the following reactions:

Reaction 1 $F_2 + Cl_2 \longrightarrow 2\,ClF$

Reaction 2 $3\,F_2 + 4\,NH_3 \longrightarrow 3\,NH_4F + NF_3$

Reaction 3 $3\,Cl_2 + 8\,NH_3 \longrightarrow 6\,NH_4Cl + N_2$

Which of the following correctly shows the increasing order of reducing strength of the three species, Cl_2, F_2 and NH_3?

A $F_2 < Cl_2 < NH_3$

B $Cl_2 < F_2 < NH_3$

C $NH_3 < F_2 < Cl_2$

D $NH_3 < Cl_2 < F_2$

6 Which of the following statements about Al is correct?

1 It has high electrical conductivity due to the ability of its ions to carry the current.

2 It has high melting point due to strong attraction between the delocalised electrons and residual cations.

3 It has stronger metallic bonding than Na.

A **1**, **2** and **3**

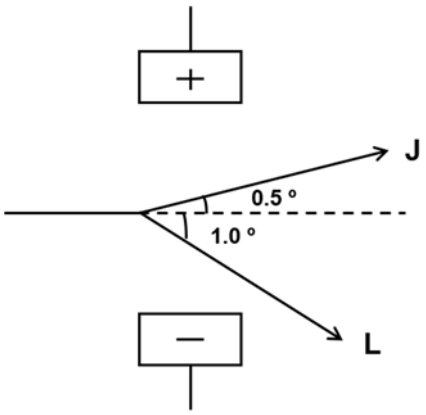
B **1** and **2** only

C **1** only

D **2** and **3** only

7 In the presence of an electric field, which of the following pair of ions will demonstrate deflection pathways as shown in the diagram below?

In this particular experimental setup, protons are deflected through an angle of 7.0º.



	J	L
A	$^{14}N^{-}$	$^{7}Li^{+}$
B	$^{18}O^{-}$	$^{27}Al^{3+}$
C	$^{16}O^{+}$	$^{32}S^{2-}$
D	$^{28}Si^{2+}$	$^{28}Si^{4-}$

8 A comparison is made of four different organic compounds with the same molar mass.

$CH_3CH_2CH_2CH_2CH_3$	$CH_3C(CH_3)_3$	$CH_3CH_2CH_2CHO$	$CH_2{=}CHCOOH$
W	**X**	**Y**	**Z**

Which of the following shows the boiling points of these compounds in the correct sequence?

	highest			lowest
A	**W**	**X**	**Y**	**Z**
B	**Y**	**Z**	**W**	**X**
C	**Z**	**Y**	**W**	**X**
D	**Z**	**Y**	**X**	**W**

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

Bismuth–212 is an unstable isotope of bismuth with a half–life of around 60 min.

The radioactive decay of bismuth–212 follows the following scheme, giving rise to two particles, **R** and **T**:

$$^{212}_{83}\text{Bi} \longrightarrow {}^{\mathbf{a}}_{\mathbf{b}}\mathbf{R} + {}^{4}_{2}\text{He}$$

$${}^{\mathbf{a}}_{\mathbf{b}}\mathbf{R} \longrightarrow {}^{\mathbf{c}}_{\mathbf{d}}\mathbf{T} + {}^{0}_{-1}\text{e}$$

Which are the likely formulae of the chlorides formed by particles, **R** and **T**?

	chloride of **R**	chloride of **T**
A	**R**Cl_2	**T**Cl_2
B	**R**Cl_2	**T**Cl_3
C	**R**Cl_3	**T**Cl_2
D	**R**Cl_3	**T**Cl_3

10 A 25 cm^3 of solution containing 0.010 mol dm^{-3} of an ion $\mathbf{G}^{4+}$ (aq) was reduced by excess zinc. After the unreacted zinc was removed, the resultant solution required 20.0 cm^3 of 0.0050 mol dm^{-3} potassium manganate(VII) to oxidise **G** back to its original +4 oxidation state.

MnO_4^- is reduced according to the equation:

$$MnO_4^- + 8H^+ + 5e \longrightarrow Mn^{2+} + 4H_2O$$

To what oxidation state was $\mathbf{G}^{4+}$ reduced by zinc?

A +3 **B** +2 **C** +1 **D** 0

11 The hydrolysis of the anticancer drug *cis–platin* in water follows a first–order kinetics with a rate constant of 0.09 h^{-1} at 25 °C.

How long will it take for the concentration of a freshly prepared aqueous solution of *cis–platin* to decrease to 18% of its original concentration?

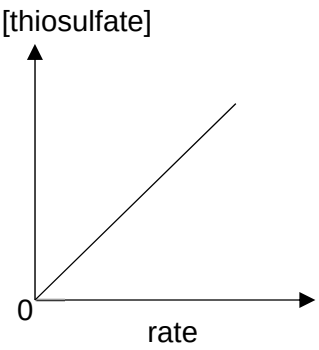
A 7.7 h **B** 15.4 h

C 19.0 h **D** 42.8 h

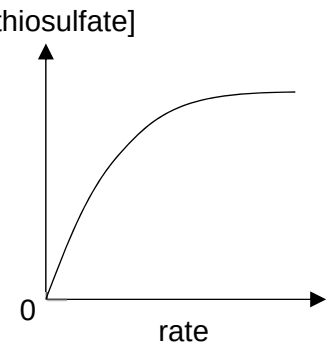
12 In the reaction between aqueous sodium thiosulfate and dilute acid, the reaction is found to be first order with respect to thiosulfate.

Which graph represents the experimental results?

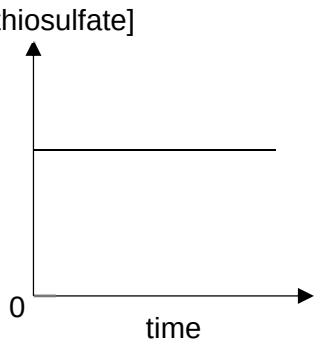
A



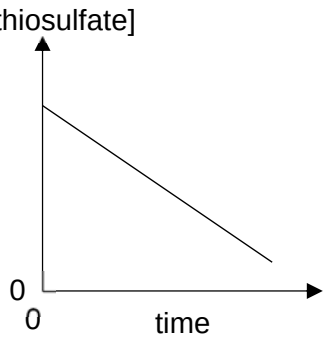
B



C



D



13 Which statement **best** defines the term *bond energy* for HF?

A Energy released when one mole of HF is formed from its gaseous ions.

B Energy released when one mole of HF is formed from its gaseous atoms.

C Energy required when one molecule of HF is broken into its gaseous atoms.

D Energy required when one mole of HF is broken into its gaseous atoms.

14 The values for 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.

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

What is the standard enthalpy change for the above reaction?

A +878 kJ mol^{-1}

B –878 kJ mol^{-1}

C +1410 kJ mol^{-1}

D –1410 kJ mol^{-1}

15 Which of the following enthalpy changes is always exothermic?

1 standard enthalpy change of formation

2 standard enthalpy change of combustion

3 standard enthalpy change of neutralisation

4 standard enthalpy change of reaction

A **1**, **2**, **3** and **4**

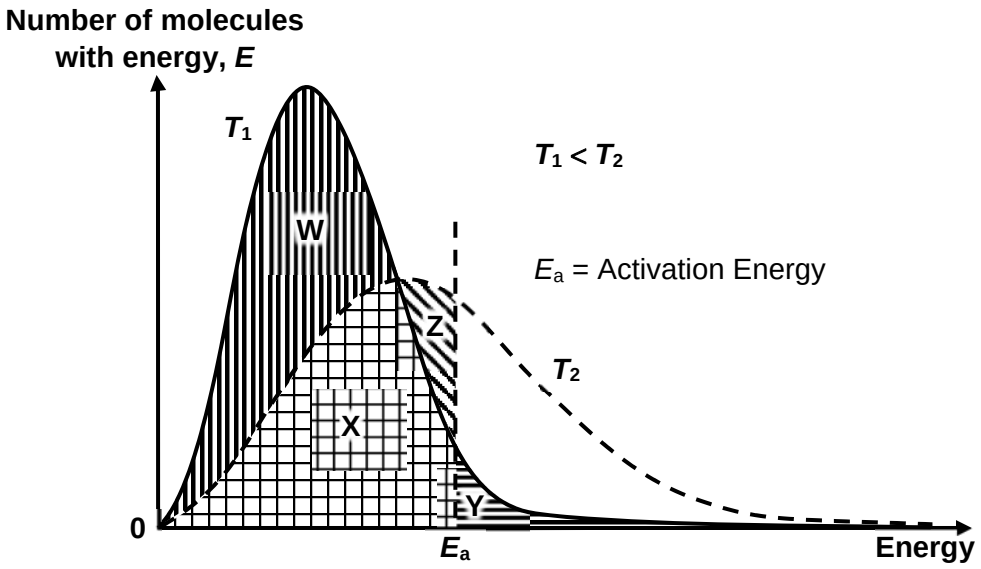
B **1** and **2** only

C **2** and **4** only

D **2** and **3** only

16 The distribution of the fraction of molecules with energy for two temperatures, T_1 and T_2 are shown in the diagram below.

W, **X**, **Y** and **Z** refer to the different shaded areas under the two graphs.



Which of the following expressions gives the **increase** in fraction of molecules having at least the activation energy at higher temperature, T_2?

A $\frac{Y}{X+Y+Z}$

B $\frac{Z}{X+Y+Z}$

C $\frac{X-Z}{W+X+Y}$

D $\frac{W-Z}{W+X+Y}$

17 Which of the following statements about a catalyst is correct?

1 A catalyst increases both the rate of the forward and backward reaction.

2 A catalyst increases the rate of reaction through affecting the rate constant.

3 A catalyst increases the rate of reaction through decreasing the enthalpy change of the reaction, ΔH.

4 A catalyst increases the rate of reaction through increasing the average kinetic energy of the reactant particles.

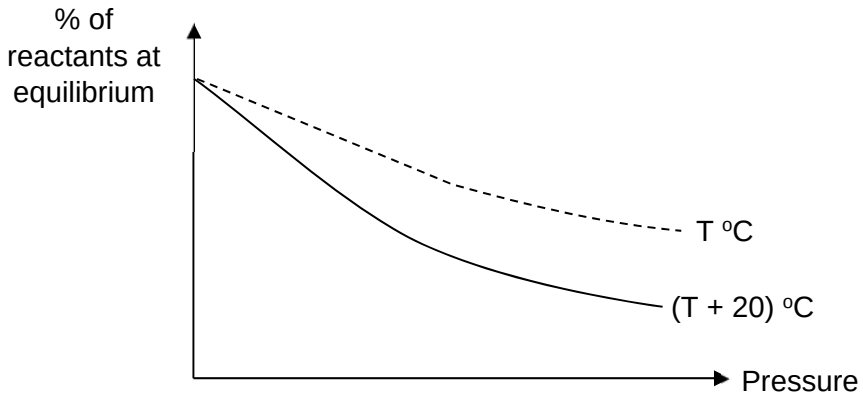
A **1**, **2** and **4** only

B **1** and **2** only

C **2** and **3** only

D **2** and **4** only

18 The graphs below show the variation of the percentage of gaseous reactants present at equilibrium, with temperature and pressure.



Which of the following systems could the graphs represent?

A $2N_2(g) + O_2(g) \rightleftharpoons 2N_2O(g)$ $\Delta H = +82$ kJ mol^{-1}

B $CO_2(g) + C(s) \rightleftharpoons 2CO(g)$ $\Delta H = +173$ kJ mol^{-1}

C $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H = -92$ kJ mol^{-1}

D $3O_2(g) + 4NH_3(g) \rightleftharpoons 2N_2(g) + 6H_2O(g)$ $\Delta H = -1248$ kJ mol^{-1}

19 Platinum and rhodium nanoparticles are used in catalytic converters of motor cars.

Which reaction in the catalytic converter does **not** remove hazardous and polluting gases from the exhaust fumes?

These equations are qualitative and unbalanced.
[HC = unburnt hydrocarbon; NO_x = oxides of nitrogen]

A $HC + NO_x \longrightarrow H_2O + CO + N_2$

B $CO + NO_x \longrightarrow CO_2 + N_2$

C $HC + NO_x \longrightarrow H_2O + CO_2 + N_2$

D $CO + O_2 \longrightarrow CO_2$

20 What is the volume of deionised water that needs to be added to a 10 cm^3 of 0.0100 mol dm^{-3} calcium hydroxide to have a resultant solution with pH of 11.5?

A 21.6 cm^3 **B** 31.6 cm^3

C 53.2 cm^3 **D** 63.2 cm^3

21 The table shows some data of two acid–base indicators.

indicator	**approximate pH range of colour change**	**colour change**	
		acid	**alkali**
bromophenol–blue	3.0 – 4.6	yellow	purple
phenol–red	6.8 – 8.5	yellow	red

Which conclusion can be drawn about a solution when it turns bromophenol–blue purple and phenol–red yellow?

A The solution is strongly acidic.

B The solution is weakly acidic.

C The solution is strongly alkaline.

D The solution is weakly alkaline.

22 Which of the following is correctly arranged in order of **decreasing** values?

A atomic radius of P, S, C*l*

B melting point of P, S, C*l*

C first ionisation energy of Na, Mg, A*l*

D electrical conductivity of Na, Mg, A*l*

23 The properties of the oxides of four elements in Period 3, **E, F, G** and **H** are given below.

1	The oxide of **E** is amphoteric.
2	The oxide of **F** dissolves in water to form a strongly alkaline solution.
3	The oxide of **G** reacts with dilute sodium hydroxide at room temperature.
4	The oxide of **H** is insoluble in water but is soluble in concentrated sodium hydroxide.

Which of the following shows the correct sequence of the four elements in order of increasing proton number?

A **F**, **E**, **G**, **H**

B **F**, **E**, **H**, **G**

C **G**, **F**, **E**, **H**

D **G**, **F**, **H**, **E**

24 Which of the following statements explains the trend in thermal stability of hydrogen halides down the group?

A Hydrogen halide bond becomes less polar down the group.

B Electron cloud size of hydrogen halide molecules increases down the group.

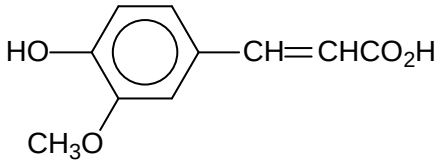
C Bond energy of hydrogen halide decreases more than the bond energy of the halogens.

D Less energy is required to break the permanent dipole – permanent dipole attractive forces in the hydrogen halides down the group.

25 How many isomers (including both constitutional and cis–trans isomers) are possible for C_4H_7Cl?

A 9 **B** 10 **C** 11 **D** 12

26 Ferulic acid is an antioxidant that occurs widely in plants.

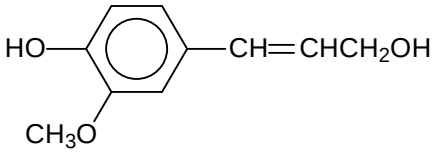


ferulic acid

Which of the following statements is true about ferulic acid?

1 It decolourises aqueous bromine.

2 It is not very soluble in water but dissolves in aqueous NaOH.

3 It can be prepared from 

using hot acidified $K_2Cr_2O_7$.

A **1**, **2** and **3**

B **1** and **2** only

C **1** only

D **2** and **3** only

27 Compound **T** can be converted to a compound **U** as shown below.

$$CH_3COCH_2COOH \xrightarrow{\textbf{I}} CH_3CH(OH)CH_2COOH \xrightarrow{\textbf{II}} CH_3CH(OH)CH_2CONHCH_3$$

T **U**

Which of the following statements is **incorrect** with regards to the given reaction scheme?

A Stage **I** may involve the use of sodium borohydride.

B Stage **I** may involve the use of lithium aluminium hydride.

C Stage **II** may involve the use of DCC and methylamine.

D Stage **II** may involve the use of $CH_3CH(OH)CH_2COCl$ and methylamine.

28 Which of the following compounds are formed when $CH_3CO_2CH_2NHCOCH_3$ is heated under reflux with excess aqueous sodium hydroxide?

A $CH_3CO_2CH_2NH_2$ and CH_3COOH

B $CH_3CO_2CH_2NH_2$ and CH_3COONa

C CH_3COOH and $HOCH_2NH_2$

D CH_3COONa and $HOCH_2NH_2$

29 A section of nylon–6,6 is shown below.

$$–CO(CH_2)_4CONH(CH_2)_6NHCO(CH_2)_4CONH(CH_2)_6NH–$$

Which monomers could form this polymer?

A $NH_2(CH_2)_6NH_2$ and $CH_3(CH_2)_3CO_2H$

B $NH_2(CH_2)_6NHCO_2H$ and $CH_3(CH_2)_3CO_2H$

C $NH_2(CH_2)_6NH_2$ and $HO_2C(CH_2)_4CO_2H$

D $CH_3(CH_2)_5NH_2$ and $HO_2C(CH_2)_4CONH_2$

30 LDPE is used to make plastic bags while and HDPE is used to make milk jug.

Which of the following statements is true about these substances?

1 LDPE is flexible and HPDE is rigid.

2 LDPE comprises of shorter branched polymer chains while HPDE comprises of longer linear polymer chains.

3 LDPE and HDPE can be generated from propene using appropriate catalysts and reaction conditions.

A **1**, **2** and **3**

B **1** and **2** only

C **1** only

D **1** and **3** only

END OF PAPER

Name **Suggested Solutions**

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Qn	Ans
1	B
2	C
3	C
4	D
5	A
6	D
7	A
8	C
9	C
10	B

Qn	Ans
11	C
12	A
13	D
14	B
15	D
16	D
17	B
18	A
19	A
20	C

Qn	Ans
21	B
22	A
23	B
24	C
25	C
26	A
27	B
28	D
29	C
30	B

1 **Answer: B**

Explanation:

$[(CH_3CO_2)_2Zn] = \frac{10.64}{183.4} = 0.0580$ mol dm^{-3}

Amount of $(CH_3CO_2)_2Zn = \frac{5}{1000} \times 0.0580 = 2.90 \times 10^{-4}$ mol

$(CH_3CO_2)_2Zn \equiv 2CH_3CO_2^- \equiv Zn^{2+}$

Total amount of ions = $3 \times 2.90 \times 10^{-4} = 8.70 \times 10^{-4}$ mol

Total number of ions = $8.70 \times 10^{-4} \times 6.02 \times 10^{23} =$ 5.2×10^{20} ions

2 **Answer: C**

Volume of H_2S = $\frac{3}{4} \times 40$ **= 30 cm^3 and volume of CS_2 =** $\frac{1}{4} \times 40$ **= 10 cm^3**

Combustion equations:

H_2S (g) + $\frac{3}{2}$ **O_2 (g)** → **SO_2 (g)** + **H_2O (*l*)** and

30 cm^3 **45 cm^3** **30 cm^3**

CS_2 (g) + **$3O_2$ (g)** → **CO_2 (g)** + **$2SO_2$**
10 cm^3 **30 cm^3** **10 cm^3** **20 cm^3**

Total volume of SO_2 formed = 30 + 20 = **50 cm^3**

Volume of CO_2 formed = **10 cm^3**

volume of O_2 remaining = 100 – (45 + 30) = **25 cm^3**

Volume of gaseous mixture after burning = 50 + 10 + 25 = **85 cm^3**

Since CO_2 and SO_2 are acidic gases, they will be removed by NaOH (aq)

therefore, **Volume of gaseous mixture after adding NaOH (aq)** = 85 – 60 = **25 cm^3**

3 **Answer: C**

By conservation of mass,

$Na_3NO_4 + H_2O + CO_2 \longrightarrow NaNO_3 + NaHCO_3 + NaOH$

4 **Answer: D**

Option 1 Bonding in barium carbonate: ionic between Ba^{2+} and CO_3^{2-}, covalent within CO_3^{2-}

Option 2 Bonding in graphene: covalent only between C atoms

Option 3 Bonding in water: covalent only between H and O atoms

5 **Answer: A**

By considering change in oxidation number of element:

Reaction 1 $F_2 + Cl_2 \longrightarrow 2ClF$

0 0 +1 –1

Cl_2 acts as reducing agent hence it is a stronger reducing agent than F_2.

Reaction 2 $3F_2 + 4NH_3 \longrightarrow 3NH_4F + NF_3$

0 –3 –1 +3

NH_3 acts as reducing agent hence it is a stronger reducing agent than F_2.

Reaction 3 $3Cl_2 + 8NH_3 \longrightarrow 6NH_4Cl + N_2$

0 –3 –1 0

NH_3 acts as reducing agent hence it is a stronger reducing agent than Cl_2.

NH_3 is the **strongest reducing agent** whereas **F_2** is the **weakest reducing agent**.

6 **Answer: D**

Statement **1** is incorrect as electrical conductivity in metals is due to the delocalised electrons, not mobile ions.

Statement **2** is correct as melting involves overcoming of the strong metallic bonds arising from the strong electrostatic forces attraction between the delocalised electrons and the residual metallic cations.

Statement **3** is correct as *Al* contribute more delocalised electrons than Na and this contributes to stronger metallic bonds.

7 **Answer: A**

J must be an **anion** (deflected towards positive terminal) while **L** is a **cation** (deflected towards negative plate). Options **C** and **D** are incorrect.

$\frac{q}{m}$ ratio for proton ($^{1}H^{+}$ nuclei) = $\frac{1}{1}$ ➔ **7.0°** **(deflected towards negative plate)**

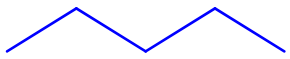
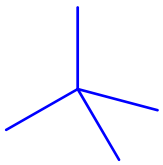
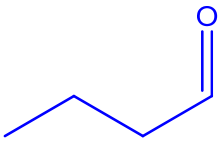
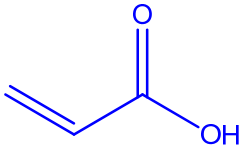
$\frac{q}{m}$ ratio for $^{14}N^{-}$ = $-\frac{1}{14}$ hence angle of deflection of $^{14}N^{-}$ = $-\frac{1}{14} \times 7.0° = -0.5°$ **(deflected towards positive plate)**

$\frac{q}{m}$ ratio for $^{7}Li^{+}$ = $+\frac{1}{7}$ hence angle of deflection of $^{7}Li^{+}$ = $+\frac{1}{7} \times 7.0° = +1.0°$ **(deflected towards negative plate)**

$\frac{q}{m}$ ratio for $^{18}O^{-}$ = $-\frac{1}{18}$ hence angle of deflection of $^{18}O^{-}$ = $-\frac{1}{18} \times 7.0° = -0.4°$ (deflected towards positive plate)

$\frac{q}{m}$ ratio for $^{27}Al^{3+}$ = $+\frac{3}{27}$ hence angle of deflection of $^{27}Al^{3+}$ = $+\frac{3}{27} \times 7.0° = +0.8°$ (deflected towards negative plate)

8 **Answer: C**

W	X	Y	Z
$CH_3CH_2CH_2CH_2CH_3$	$CH_3C(CH_3)_3$	$CH_3CH_2CH_2CHO$	$CH_2=CHCOOH$
 non–polar, straight chain	 non–polar, spherical	 polar (no hydrogen bonding between molecules)	 polar (hydrogen bonding present between molecules)
id–id	id–id (less extensive)	pd–pd	Hydrogen bonds
b.p. 36.1 °C	b.p. 10 °C	b.p. 74.8 °C	b.p. 141 °C

9 **Answer: C**

$^{212}_{83}Bi \rightarrow {}^{208}_{81}\mathbf{Tl} + {}^{4}_{2}He$

$^{208}_{81}\mathbf{Tl} \rightarrow {}^{208}_{82}\mathbf{Pb} + {}^{0}_{-1}e$

R is T*l* and **T** is Pb. Since T*l* and Pb belong to Group 13 and 14 respectively, the likely formulae of chlorides formed with T*l* and Pb in this context are $TlCl_3$ (**RCl_3**) and $PbCl_2$ (**TCl_2**) respectively.

10 **Answer: B**

Initial amount of $\mathbf{G^{4+}} = \frac{25}{1000} \times 0.010 = 2.50 \times 10^{-4}$ mol

Let the product formed be G^{n+}

Amount of G^{n+} in resultant solution = 2.50×10^{-4} mol

Amount of MnO_4^- reacted = $\frac{20}{1000} \times 0.0050 = 1.00 \times 10^{-4}$ mol

$MnO_4^- + 8H+ \longrightarrow Mn^{2+} + 4H_2O + 5e$

$MnO_4^- \equiv 5e$

Amount of electrons lost = 5.00×10^{-4} mol

2.50×10^{-4} mol of G^{n+} gained 5.00×10^{-4} mol of electrons.

$G^{n+} \equiv 2e$

Hence the oxidation state of G in G^{n+} increases by 2 to +4 in G^{4+}

Therefore, G^n is G^{2+}.

11 **Answer: C**

Half–life, $t_{\frac{1}{2}} = \frac{\ln 2}{k} = \frac{\ln 2}{0.09} = 7.7$ h

$$\frac{C_t}{C_o} = \left(\frac{1}{2}\right)^n$$

$$\frac{18}{100} = \left(\frac{1}{2}\right)^n \Rightarrow n = 2.47$$

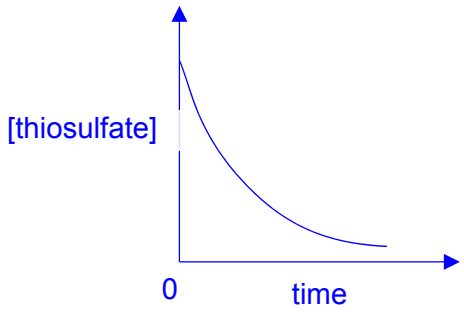
Time taken = half–life × n = 7.7 × n = **19.0 h**

12 **Answer: A**

Since order of reaction w.r.t. thiosulfate is 1 ⇒ Rate = k'[thiosulfate], where k' = k[acid]^n

Graph **A** shows the relationship where [thiosulfate] ∝ rate, while graph **B** shows a second order relationship.

Graph **C** and **D** are both incorrect as the graph of concentration against time should be



13 **Answer: D**

Bond energy of X–Y bond is the average energy ***absorbed*** to **break one mole of covalent bond in the gas phase** into **constituent gaseous atoms under standard conditions.**

Equation: X–Y (g) → X (g) + Y (g)

Option **A** is incorrect because one mole of HF is broken into gaseous atoms and not formed from its gaseous ions.

Option **B** is incorrect because energy is not released, but absorbed when one mole of HF is broken into its gaseous atoms.

Option **C** is incorrect because the quantity in the definition of bond energy is stated as one mole of covalent bond and not one molecule.

Hence, only Option **D** best defines the term *bond energy* for a diatomic gaseous molecule.

14 **Answer: B**

$\Delta H^{\ominus}_{rxn} = \sum \Delta H^{\theta}_{f}(\text{products}) - \sum \Delta H^{\theta}_{f}(\text{reactants})$

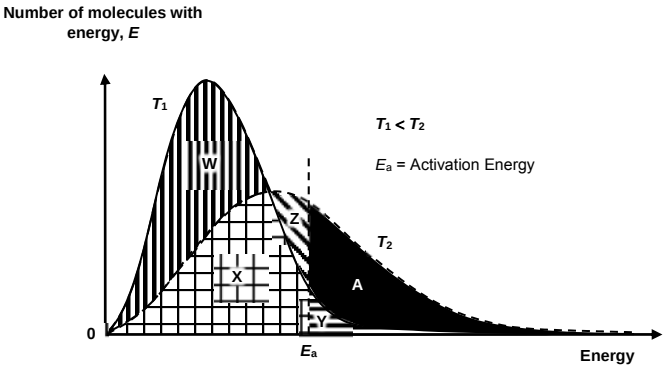
$= 3\ \Delta H^{\ominus}_{f}(\text{Fe (s)}) + \Delta H^{\ominus}_{f}(Al_2O_3\ \text{(s)}) - 3\ \Delta H^{\ominus}_{f}(\text{FeO (s)}) - 2\ \Delta H^{\ominus}_{f}(Al\ \text{(s)})$

$= (-1676) - 3(-266) =$ **$-$ 878 kJ mol^{-1}**

15 **Answer: D**

Enthalpy change of combustion / neutralisation are always exothermic as heat is released with these reactions.

16 **Answer: D**



Explanation:

The black area (**A**) gives the **increase** in *number of molecules* with energy ≥ E_a

The *total number of molecules* is given by the area under each graph:

Total area under the graph
= W + X + Y = X + Y + Z + A

So, **W = Z + A** or **A = W – Z**

$$\text{Fraction of molecules} = \frac{\mathbf{A}}{\mathbf{W}+\mathbf{X}+\mathbf{Y}} = \frac{\mathbf{W}-\mathbf{Z}}{\mathbf{W}+\mathbf{X}+\mathbf{Y}}$$

17 **Answer: B**

Option 1 is correct.
A catalyst provides an alternative reaction pathway with lower activation energy. Hence, a catalyst increases the both the rate of the forward and reverse reaction.

Option 2 is correct.
A catalyst provides an alternative reaction pathway with lower activation energy. Hence, a catalyst increases the rate of reaction through affecting the rate constant, *k*. (Arrhenius Equation).

Option 3 is wrong.
A catalyst does not alter the ΔH of the reaction.

Option 4 is wrong.
A catalyst does not increase the average kinetic energy of the reactant particles. Temperature does.

18 **Answer: A**

From the graph, the % gaseous reactants present at equilibrium decreases with an increase in pressure and temperature.
➔ % product present at equilibrium increases with an increase in pressure and temperature.

This shows that equilibrium position shifts right with an increase in temperature and pressure. This implies that forward reaction is endothermic and there are more moles of gaseous reactants than products.

19 **Answer: A**

Toxic CO gas is produced in A.

20 **Answer: C**

pH = 11.5 ➔ pOH = 14 – 11.5 = 2.5
$[OH^-] = 10^{-2.5} = 3.16 \times 10^{-3}$ mol dm^{-3}

$Ca(OH)_2 \equiv 2\ OH^-$
$[Ca(OH)_2]_{diluted} = ½ \times 3.16 \times 10^{-3} = 1.08 \times 10^{-3}$ mol dm^{-3}

Let x be the final volume of the diluted solution in cm^3
Apply $c_1v_1 = c_2v_2$ ➔ $(0.0100)\left(\frac{10}{1000}\right) = (1.08 \times 10^{-3})\left(\frac{x}{1000}\right)$
x = 63.24 cm^3

Volume of deionised water required = 63.24 – 10.0 = 53.2 cm^3

21 **Answer: B**

Bromophenol–blue appears purple (**pH > 4.6)** ⇒ Option **A** is **incorrect**

Phenol–red appears yellow (**pH < 6.8)** ⇒ Options **C and D** are **incorrect**.

The solution must be **weakly acidic and with 4.6 < pH < 6.8**.

22 **Answer: A**

- Atomic radius decreases from P to S to Cl.
- Melting point of S_8 is the highest among the 3 elements.
- First ionisation energy increases across the period. However 1st I.E of Mg > 1st I.E of Al as 3p valence electron of Al is further away from nucleus than 3s valence electron of Mg.
- Electrical conductivity increases with more valence electrons available for metals.

23 **Answer: B**

1 The oxide of **E** is amphoteric.	**E** is **aluminum**.
2 The oxide of **F** dissolves in water to form a strongly alkaline solution.	**F** is **sodium**.
3 The oxide of **G** reacts with dilute sodium hydroxide at room temperature.	**G** could either be **phosphorus or sulfur**.
4 The oxide of **H** is insoluble in water but is soluble in concentrated sodium hydroxide.	**H** is **silicon**.

In **increasing proton number**,
sodium, aluminium, silicon, phosphorus/sulfur

Option **B**: **F, E, H, G**

24 **Answer: C**

Thermal decomposition: $H–X \longrightarrow H_2 + X_2$

A is incorrect as polarity of the H–X bond does not affect thermal stability.

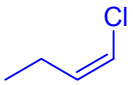
B is incorrect as the size of the H–X molecules relates to the extent of electron cloud distortion and intermolecular forces of attraction; this does not affect the H – X bond strength.

C is correct as thermal decomposition of H–X is more predominantly affected by energy required to break the H – X bond in the reactant compared with the energy released in forming the X–X bond in the product.

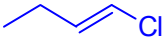
D is incorrect as thermal decomposition involves breaking the H–X bond, not the intermolecular forces of attraction between the H–X molecules.

25 **Answer: C**

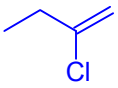
C_4H_7Cl



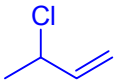
cis–1–chlorobut–1–ene



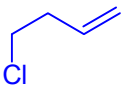
trans–1–chlorobut–1–ene



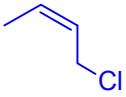
2–chlorobut–1–ene



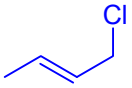
3–chlorobut–1–ene



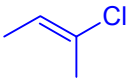
4–chlorobut–1–ene



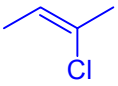
cis–1–chlorobut–2–ene



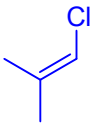
trans–1–chlorobut–2–ene



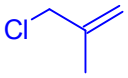
cis–2–chlorobut–2–ene



trans–2–chlorobut–2–ene



1–chloro–2–
methylpropene



3–chloro–2–
methylpropene

26 **Answer: A**

1 The alkene functional group in ferulic acid undergoes addition with aqueous bromine.

2 It is insoluble in water due to the hydrophobic benzene ring.
It undergoes neutralisation with NaOH(aq) to form sodium carboxylate salt (ionic compound) which is then soluble in water due to the formation of more favourable ion–dipole interactions.

3 Primary alcohol in ferulic acid undergoes oxidation with hot acidified $K_2Cr_2O_7$ to form carboxylic acid.

27 **Answer: B**

Lithium aluminium hydride will reduce both ketone and carboxylic acid to alcohols, which is **not** what happened in stage **I** (reduction of ketone to form secondary alcohol)

28 **Answer: D**

Ester and amide undergo basic hydrolysis simultaneously to form CH_3COONa and $HOCH_2NH_2$.

29 **Answer: C**

The repeat unit of nylon–6,6 is $–CO(CH_2)_4CONH(CH_2)_6NH–$
and the 3 amide linkages undergo hydrolysis to form two monomers $HO_2C(CH_2)_4CO_2H$ and $NH_2(CH_2)_6NH_2$.

30 **Answer: B**

Statement **1** is correct. (infer from the given products).

Statement **2** is correct.
HDPE is a linear chain polymer and has little branching as the polymer chains lie close to each other and are packed regularly. The better packing in HDPE means a decrease in distance between HDPE polymer chains and hence a higher density is observed. On the other hand, LDPE has a lot of branching and this increases the distance between polymer chain molecules due to irregular packing.

Statement **3** is incorrect as the monomer is ethene not propene.

END OF PAPER

Class	Reg Number
17	

Name _____

Calculator Model / No.

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examination
Higher 1

Chemistry 8873/02

Paper 2

13 September 2018
2 hours

Additional Material: *Data Booklet*

READ THESE INSTRUCTIONS FIRST

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

This booklet contains Section **A** and Section **B**.

Section A (60 marks): Page 2 to 15
Answer **all** questions in the spaces provided. You are advised to spend about **1 h 30 min** on Section **A**.

Section B (20 marks): Page 16 to 24
Answer **one** question in Section **B** in the spaces provided You are advised to spend about **30 min** on Section **B**.

INFORMATION FOR CANDIDATES

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

Examiner's Use		
Paper 1	MCQ	/ 30
		/ 33 %
Paper 2 Section A	Q1	/ 15
	Q2	/ 17
	Q3	/ 16
	Q4	/ 12
Paper 2 Section B		/ 20
Paper 2 Total		/ 80
		/ 67 %
Grand Total		/ 100 %
Grade		

This document consists of **24** printed pages. (inclusive of this cover page)

Section A

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

1 Chemists have long studied the trend of elements, and the Periodic Table was celebrated as an effective way to arrange the elements while reflecting some of the most well-known trends in their physical and chemical properties.

(a) Using structure and bonding, describe and explain the variation in melting points for elements aluminium to phosphorous.

[4]

(b) **(i)** The ionisation energies of Period 3 elements from sodium to argon generally increases, with the exception of two decreases: from Mg to A*l*, and from P to S.

Explain these two anomalies in the trend.

[2]

From Mg to A*l*

From P to S

(ii) An element from Period 3 was found to have the following successive ionisation energy values. Deduce the identity of this element.

Ionisation Energy	1st	2nd	3rd	4th	5th	6th	7th	8th
Value / kJ mol^{-1}	790	1600	3200	4400	16000	20000	24000	29000

[1]

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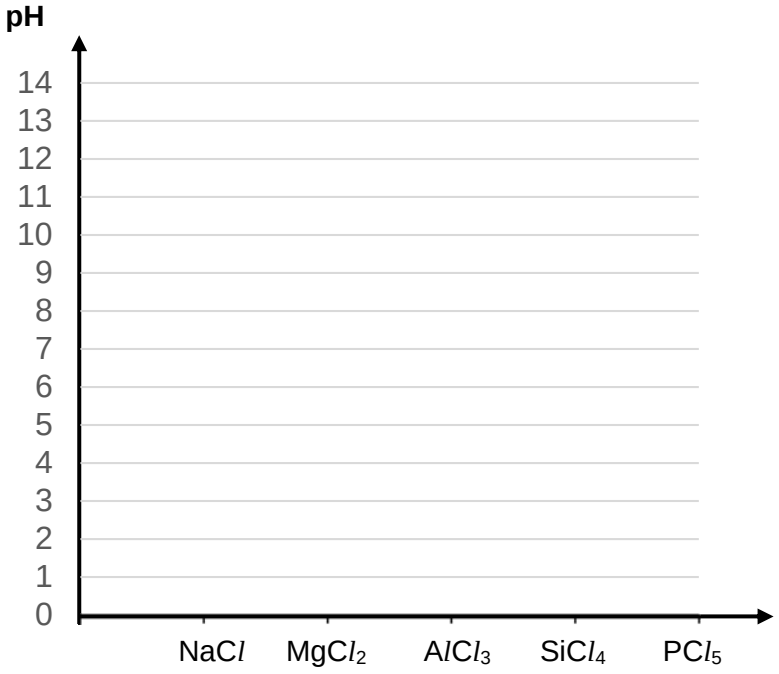
(c) Chlorides of Period 3 elements display a wide range of properties.

(i) The pH of the resultant solution when Period 3 chlorides dissolves in or react with water shows a periodic trend. Sketch the pH trend from NaC*l* to PCl_5.

[1]



(ii) Write an equation for the reaction of PCl_5 with water.

[1]

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(iii) One of the Period 3 chlorides and $BeCl_2$ have similar reaction with water. Identify this Period 3 chloride and explain why these two chlorides have similar chemical reactivity.

[1]

(d) Describe and explain the relative reactivity of elements of Group 17 as oxidising agents.

[2]

(e) At the nanoscale, new properties may emerge in certain compounds.

For example, graphene is known to have very high tensile strength and high electrical conductivity. Describe the structure of graphene and explain how its structure relates to these two properties.

[3]

[Total: 15]

2(a) Nearly all petrol and diesel vehicles have some kind of catalytic converter fitted to the exhaust to reduce the amount of pollutants emitted into the environment. The catalytic converter usually contains palladium nanoparticles which act as catalyst.

(i) Define the term nanoparticles.

[1]

(ii) Explain why palladium used is in the form of nanoparticles instead of its bulk form.

[2]

(iii) The palladium catalyst helps to remove carbon monoxide from the exhaust. For example,

$$CO + \frac{1}{2} O_2 \longrightarrow CO_2$$

State the **type** of catalyst and outline the mode of action of catalyst in this reaction.

[2]

(b) Carbon monoxide, water and propene can be used to produce butanoic acid according to the following equation:

$$CO + H_2O + CH_3CH{=}CH_2 \xrightarrow{\text{metal catalyst}} CH_3CH_2CH_2CO_2H$$

Draw the structure of the product formed when 2-methylpropene is used in the above reaction.

[1]

(c) Propene can be converted to propanone by the following route.

$$CH_3CH{=}CH_2 \xrightarrow{\mathbf{I}} CH_3CHCl\!CH_3 \xrightarrow{\mathbf{II}} CH_3CH(OH)CH_3 \xrightarrow{\mathbf{III}} CH_3COCH_3$$

(i) Suggest the types of reaction for steps **I** and **III**.

[2]

	step **I**	step **III**
type of reaction		

(ii) State the reagent and conditions for step **II**.

[1]

.....

(iii) State and explain how the rate of reaction for step **II** changes when 2-chloropropane is replaced by 2-iodopropane

[2]

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(d) The kinetics of the acid-catalysed reaction of propanone with iodine

$$CH_3COCH_3(aq) + I_2(aq) \xrightarrow{H^+(aq)} CH_2ICOCH_3(aq) + HI(aq)$$

can be investigated experimentally by varying the concentrations of the three substances involved and determining the time for the colour of the iodine to disappear.

In this method the rate of the reaction is measured in terms of the rate at which the iodine changes, i.e.

$$\text{rate} \propto \frac{\text{volume of aqueous iodine used}}{\text{time for the colour of iodine to disappear}}$$

The following results were obtained in such an investigation.

Expt	Volume of CH_3COCH_3 / cm^3	Volume of I_2 / cm^3	Volume of H^+ / cm^3	Volume of H_2O / cm^3	Relative time for the colour of iodine to disappear
1	8	4	8	0	1
2	8	4	4	4	2
3	4	4	8	4	2
4	8	2	8	2	0.5

(i) Deduce the order of reaction with respect to propanone, iodine and hydrogen ions.

[3]

propanone

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iodine

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hydrogen ions

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(ii) Hence write the rate equation for this reaction.

[1]

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(iii) Another experiment, with 0.80 mol dm^{-3} propanone, 0.0010 mol dm^{-3} iodine and 0.20 mol dm^{-3} hydrochloric acid, is carried out at the same temperature.

Calculate the value of the rate constant if the rate is 4.2×10^{-6} mol dm^{-3} s^{-1}. Give the units of the rate constant.

[2]

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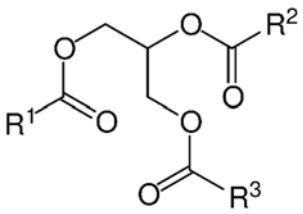
[Total: 17]

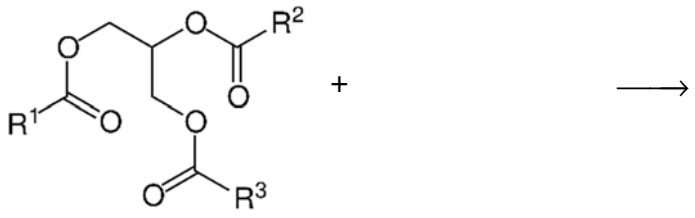
3(a) Limited scientific evidence suggests that eating two tablespoons of olive oil daily may reduce the risk of coronary heart disease. Olive oil comprises mainly of the mixed triglyceride esters of oleic acid, palmitic acid and other fatty acids. The general chemical structure of olive oil is shown below where R^1, R^2 and R^3 are alkyl groups or alkenyl groups.



Olive oil undergoes rancidification when exposed to moisture, resulting in an unpleasant taste and odour. The products formed in the reaction are propane-1,2,3-triol and fatty acids.

Complete the equation to illustrate the rancidification reaction of olive oil.

[1]



(b) Oleic acid has the structure shown.

$$CH_3(CH_2)_7CH=CH(CH_2)_7COOH$$

(i) Describe the bonding in C=C in terms of orbital overlap. Draw a diagram to illustrate your answer.

[2]

(ii) Oleic acid exists as a pair of isomers.

Draw and label the structural formulae of the two isomers.

[2]

(iii) Describe a chemical test that would distinguish oleic acid from ethanoic acid.

[2]

(c) **Fig. 3.1** shows a bomb calorimeter, inside a controlled temperature water jacket, which is used to find an accurate value of standard enthalpy change of combustion of oleic acid.

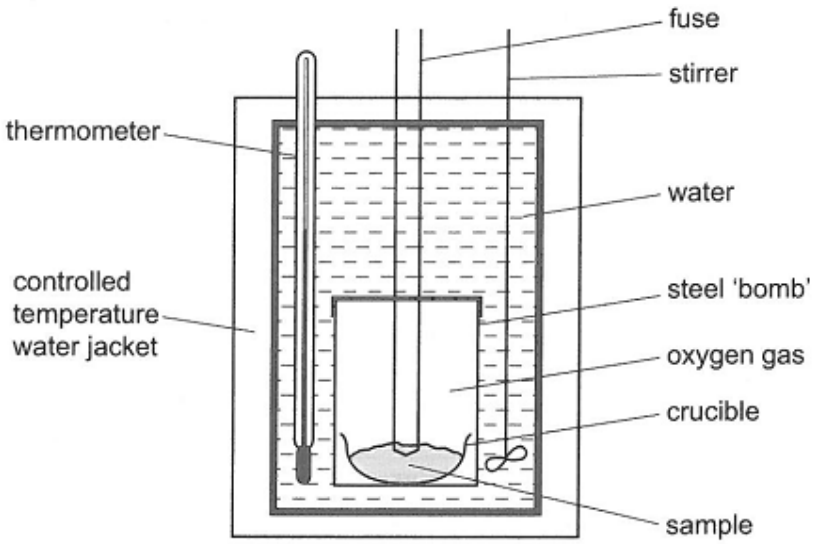


Fig. 3.1

(i) What is meant by the *standard enthalpy change of combustion* of oleic acid?

[1]

.....

(ii) Explain why the steel 'bomb' is flushed with a high pressure of oxygen at the start of the experiment.

[1]

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(iii) There is no heat lost from the calorimeter because of the controlled temperature water jacket.

Suggest how the controlled temperature water jacket achieves this.

[1]

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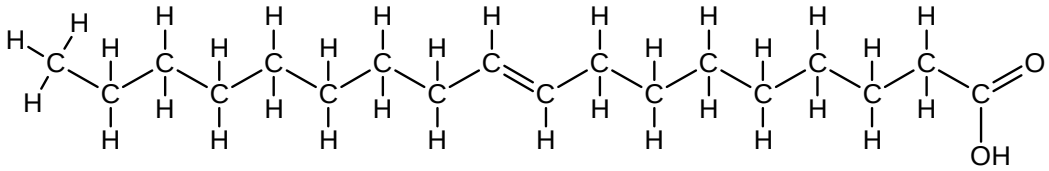
(iv) A 2.98 g sample of oleic acid ($C_{18}H_{34}O_2$) is burned in a bomb calorimeter with a heat capacity of 1.98 kJ K^{-1}. The temperature of the calorimeter increases by 59.3 ^{o}C.

Calculate the standard enthalpy change of combustion of oleic acid.

[2]

(v) Use the bond energies given in the *Data Booklet* to calculate another value for the standard enthalpy change of combustion of oleic acid.



oleic acid

You may find the following information useful in your calculation.
An oleic acid ($C_{18}H_{34}O_2$) molecule contains 33 C–H bonds,16 C–C bonds and other bonds.

[3]

(vi) Suggest a reason for the discrepancy between the value in **(c)(iv)** and that in **(c)(v).**

[1]

[Total: 16]

4(a) There are two types of polymerisation, addition and condensation

Account for the differences between these two types of polymerisation.

[2]

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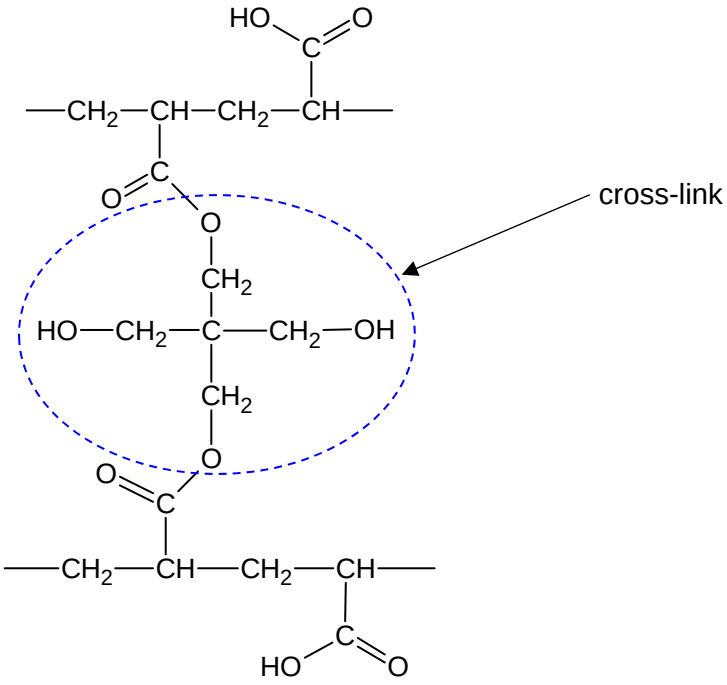
(b) Super-absorbent polymers have the ability to absorb 200 – 300 times their own mass of water. They are classified as hydrogels and are widely used in personal disposable hygiene products such as diapers. However, these synthetically made hydrogels are usually non-biodegradable.

The diagram below shows part of the structure of a hydrogel.



The hydrogel is formed from chains of one polymer which are then cross-linked using another molecule.

(i) State the type of polymerisation used to form these polymer chains.

[1]

.....

(ii) Draw the **displayed** structural formula of the monomer used.

[1]

(iii) Draw the structure of the molecule used to cross-link the polymer chains.

[1]

(iv) Once a hydrogel has absorbed water, it can be dried and re-used many times. Explain why this is possible, referring to the structure.

[1]

(v) The amount of cross-linking has little effect on the ability of the gel to absorb water. Suggest why this is the case.

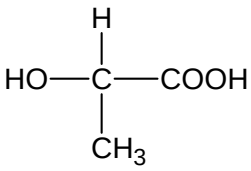
[1]

(vi) Suggest one property of the hydrogel that will change if more cross-linking takes place. Explain how the increased cross-linking brings about this change.

[2]

(c) Unlike hydrogel, the polymer, 'polyactide' or PLA is biodegradable. The monomer required to produce PLA is *lactic acid*, 2-hydroxypropanoic acid.

The structure of *lactic acid* is as shown.



(i) Draw the structure of the polymer PLA, showing **two** repeat units.

[1]

One of the reasons PLA has attracted so much attention is that it is biodegradable. This does, however restrict some potential uses. The polymer has a melting point of around 175 °C , but soften between 60 – 80°C. However, its properties enable it to have a range of uses in food packaging and in fibres.

(ii) Explain why PLA would not be a suitable packaging materials for food pickled in vinegar.

[1]

(iii) Suggest why PLA containers are not usually used to hold hot drinks.

[1]

.....

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.....

.....

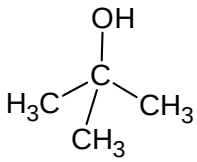
[Total: 12]

END OF SECTION A

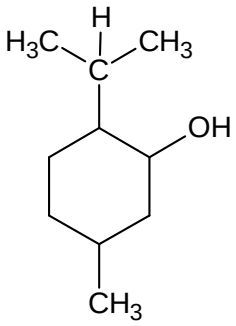
Section B

Answer **one** question from this section, in the spaces provided.

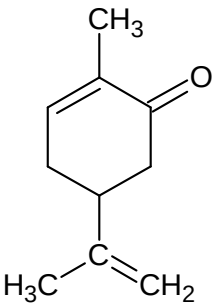
5(a) Three natural–occurring compounds used commercially are shown below:



2 methylpropan–2–ol



Menthol

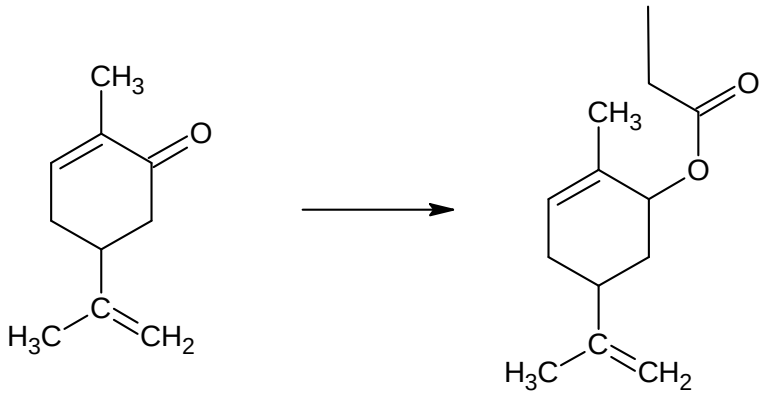


Carvone

(i) Describe a set of two chemical tests that can be used to distinguish the above three compounds. Write an equation for each reaction that takes place.

[5]

(ii) Carvone can be converted to organic compound **D** in two steps.



Carvone Compound **D**

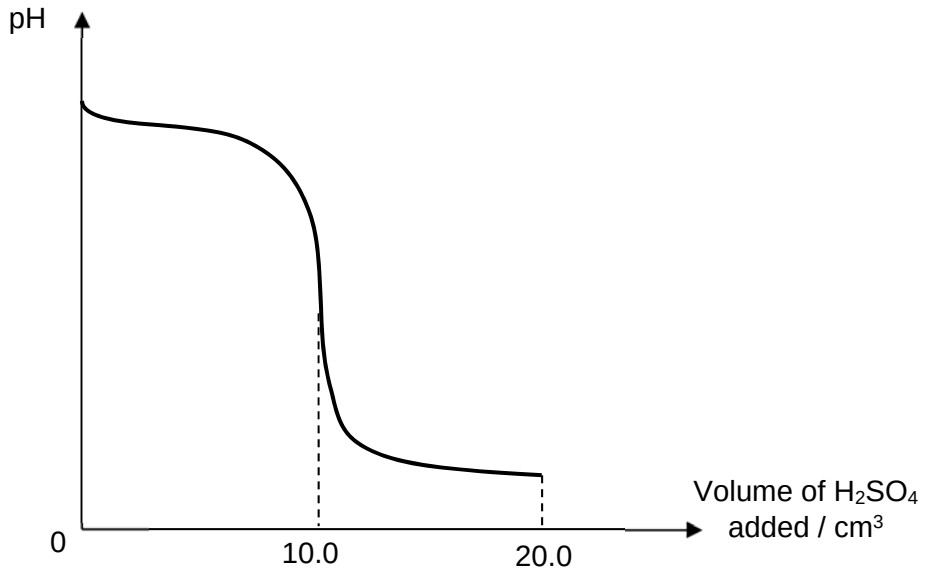
State the reagents and conditions necessary for each step. Give the structure of the intermediate involved in the conversion.

[3]

(b) Ammonia was used in smelling salts to treat fainting. Modern smelling salt solution may contain other products such as lavender oil to act in conjunction with aqueous ammonia.

When 40 cm^3 of aqueous ammonia was titrated against 0.200 mol dm^{-3} sulfuric acid, H_2SO_4 using a pH meter, the following graph was obtained.

$$2NH_3\ (aq) + H_2SO_4\ (aq) \longrightarrow (NH_4)_2SO_4\ (aq)$$



(i) Explain what is meant by the terms *Bronsted–Lowry base* and *conjugate acid–base pair*. Illustrate your explanation using ammonia in the above reaction with sulfuric acid.

Explain why the *Arrhenius* definition of base does not apply for ammonia in the above reaction.

[3]

(ii) Write an expression for the base dissociation constant, K_b, of ammonia.

[1]

(iii) Using the titration curve provided, state the volume of sulfuric acid needed for the exact neutralisation of 40 cm^3 of aqueous ammonia. Hence, calculate the initial concentration of aqueous ammonia.

[2]

(iv) The resultant solution at the end of the titration can be considered as a sulfuric acid solution of concentration 0.0333 mol dm^{-3}. Calculate the pH of this resultant solution to 2 decimal place.

[1]

(v) Suggest an appropriate indicator for the titration, giving a reason for your choice.

[1]

.....

.....

.....

(vi) Explain what do you understand by the term *buffer solution*.

[1]

(vii) The *Henderson–Hasselbalch* equation is useful for the estimation of the pH of a buffer solution. An alternative form of the equation is shown below which can be used to determine the pOH of a basic buffer solution.

$$pOH = pK_b + \log_{10} \frac{[BH^+]}{[B]}$$

Calculate the pH of a basic buffer solution, if the solution contains NH_4^+ and NH_3 in a 2 : 1 ratio, given that the base dissociation constant, K_b of ammonia, NH_3 is 1.78×10^{-5} mol dm^{-3}.

[2]

(viii) The enthalpy changes of neutralisation involving sulfuric acid with two bases are shown below.

sodium hydroxide, NaOH	– 57.3 kJ mol^{-1}
ethylamine, $CH_3CH_2NH_2$	– 51.5 kJ mol^{-1}

Comment and explain for the above observation as fully as you can.

[1]

[Total: 20]

6(a) Hydroxylamine, NH_2OH is commonly used in photography developing solution. Prolonged exposure to hydroxylamine by photography developers might cause irritation to their respiratory tract. To minimise the health hazard on these developers, the safety limit of the concentration of hydroxylamine is capped at below 0.00200 mol dm^{-3}.

A scientist performed the following experiment to determine if a sample of photography developing solution was within the safety limit.

100 cm^3 of NH_2OH solution was added to 40 cm^3 of 0.015 mol dm^{-3} acidified I_2 (aq) solution. In this reaction, iodine is used in excess and NH_2OH is oxidised to form dinitrogen monoxide, N_2O.

(i) Using half-equations, write a balanced equation for the reaction between NH_2OH (aq) and I_2 (aq) in an acidic medium.

[2]

Reduction: _____

Oxidation: _____

Overall: _____

A 25.0 cm^3 aliquot of the resultant reaction mixture was then titrated with a standard solution of 0.00500 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$ (aq).

$$I_2\ (aq) + 2\ S_2O_3^{2-}\ (aq) \longrightarrow 2I^-\ (aq) + S_4O_6^{2-}\ (aq)$$

Starch solution was added as indicator for this titration to enhance the contrast of the colour change at the end-point of the titration. 22.50 cm^3 of $Na_2S_2O_3$ (aq) was required.

(ii) State the expected colour change at the end-point of the titration.

[1]

_____

(iii) Calculate the amount of I_2 remaining in the reaction mixture.

[2]

(iv) Calculate the concentration of NH_2OH in 100 cm^3 sample of the photography developing solution. Hence conclude whether the solution is within the safety limit.

[2]

(v) Iodate(V) ion, IO_3^- was used to generate iodine required for the reaction with NH_2OH.

In this IO_3^- ion, the central iodine atom can expand its octet structure. Draw the dot-and-cross diagram of IO_3^- ion.

[1]

(vi) From your answer in **(a)(v)**, state the bond angle around the central iodine atom and account for the shape of IO_3^- ion.

[2]

(b) In an industrial process, 5 mol of dinitrogen tetroxide, N_2O_4 and 7 mol of nitrogen monoxide, NO was heated in a 2.0 dm^3 vessel. The temperature is kept at 500 °C. The two gases react slowly to form blue dinitrogen trioxide, N_2O_3 according to the following equation. It was found that the equilibrium mixture contains 2.3 mol of NO.

$$N_2O_4\,(g) + 2NO\,(g) \rightleftharpoons 2N_2O_3\,(g) \qquad \Delta H = -30.5\ kJmol^{-1}$$

(i) Write an expression for the equilibrium constant, K_c for the reaction, stating the units.

[1]

(ii) Determine the equilibrium concentrations of the three gases. Hence, calculate the value of K_c.

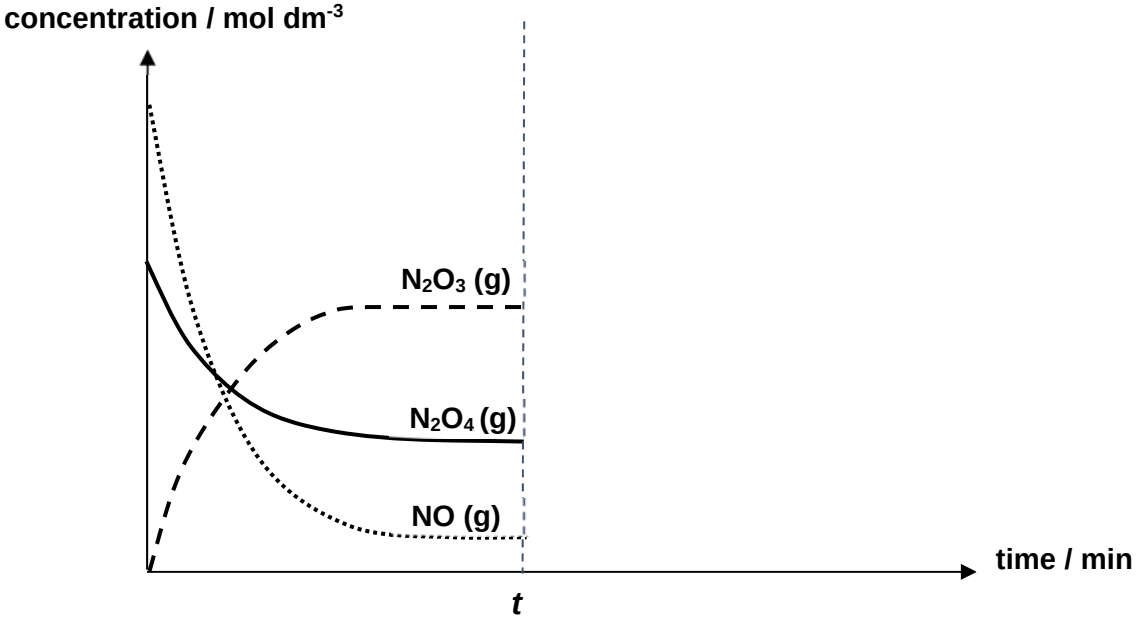
[2]

(iii) Predict and explain the effect of increasing temperature on the equilibrium position and equilibrium composition.

[2]

(iv) Sketch on the same axes, how the concentration of the three gases will change when temperature was increased at ***t***.

[2]



(v) State the operating pressure and temperature (high or low) required to obtain a high yield of N_2O_3. Explain your answer.

[2]

(vi) Hence, suggest why the operating temperature is fixed at a moderately high temperature of 500 °C.

[1]

[Total: 20]

END OF PAPER

Name SUGGESTED SOLUTIONS

Class	Reg Number
17	

Calculator Model / No.

MERIDIAN JUNIOR COLLEGE
JC2 Preliminary Examination
Higher 1

Chemistry 8873/02

Paper 2

13 September 2018
2 hours

Additional Material: *Data Booklet*

READ THESE INSTRUCTIONS FIRST

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

This booklet contains Section **A** and Section **B**.

Section A (60 marks) : Page 2 to 15
Answer **all** questions in the spaces provided. You are advised to spend about **1 h 30 min** on Section **A**.

Section B (20 marks): Page 16 to 24
Answer **one** question in Section **B** in the spaces provided. You are advised to spend about **30 min** on Section **B**.

INFORMATION FOR CANDIDATES

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

Examiner's Use		
Paper 1	MCQ	/ 30
		/ 33 %
Paper 2 Section A	Q1	/ 15
	Q2	/ 17
	Q3	/ 16
	Q4	/ 12
Paper 2 Section B		/ 20
Paper 2 Total		/ 80
		/ 67 %
Grand Total		/ 100 %
Grade		

This document consists of **24** printed pages.

Section A

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

1 Chemists have long studied the trend of elements, and the Periodic Table was celebrated as an effective way to arrange the elements while reflecting some of the most well-known trends in their physical and chemical properties.

(a) Using structure and bonding, describe and explain the variation in melting points for elements aluminium to phosphorous.

[4]

The melting point increases from aluminium (A*l*) to silicon (Si), then decrease to phosphorous (P_4)

Aluminium: giant metallic lattice structure
Large amount of energy needed to overcome strong electrostatic forces of attraction between the cations and the sea of delocalised electrons.

Silicon: giant molecular structure
Larger amount of energy to overcome the strong and extensive covalent bonds between Si atoms in the giant 3–dimensional molecular structure.

Phosphorous: simple molecular structure
Small amount of energy to overcome the weak intermolecular instantaneous dipole–induced dipole forces of attraction between P_4 molecules.

(b) **(i)** The ionisation energies of Period 3 elements from sodium to argon generally increases, with the exception of two decreases: from Mg to A*l*, and from P to S.

Explain these two anomalies in the trend.

[2]

From Mg to A*l*
A*l* has a lower 1st I.E as compared to Mg. The 3p electron in A*l* is further away from the nucleus compared to 3s electron in Mg. Hence, the 3p electron in A*l* experience weaker electrostatic attraction with the nucleus and hence require less energy to remove.

From P to S.
S has a lower 1st I.E as compared to P. Inter–electron repulsion is present in the doubly–filled 3p orbital of S atom. Hence, it is easier to remove the valence electron in the doubly-filled 3p orbital of S atom.

(ii) An element from Period 3 was found to have the following successive ionisation energy values. Deduce the identity of this element.

Ionisation Energy	1st	2nd	3rd	4th	5th	6th	7th	8th
Value / kJ mol^{-1}	790	1600	3200	4400	16000	20000	24000	29000

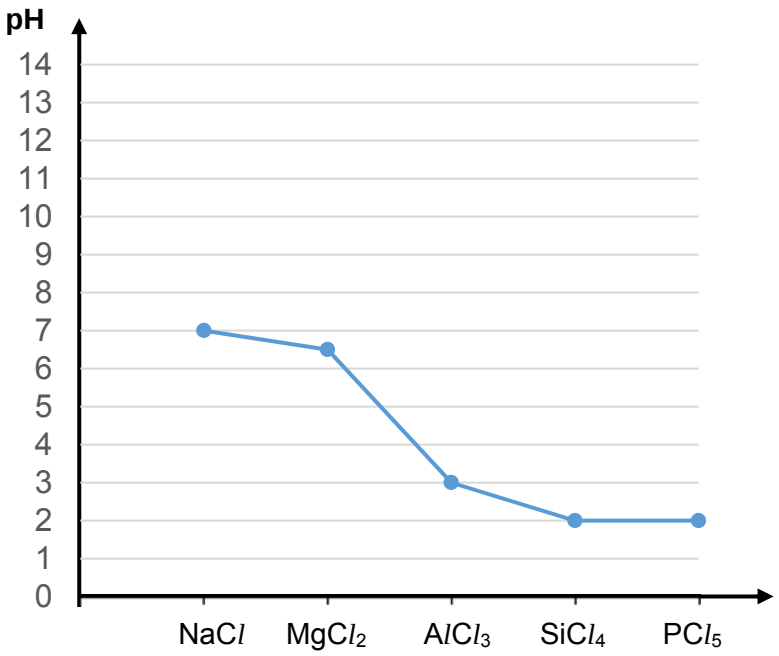
[1]

The element is silicon because there was a large increase from 4th to 5th ionisation energy. This indicates that the removal of the 5th electron was from the inner quantum shell and the element has 4 valence electrons.

(c) Chlorides of Period 3 elements display a wide range of properties.

(i) The pH of the resultant solution when Period 3 chlorides dissolves in or react with water shows a periodic trend. Sketch the pH trend from NaCl to PCl_5.

[1]



(ii) Write an equation for the reaction of PCl_5 with water.

[1]

$PCl_5 + 4H_2O \longrightarrow H_3PO_4 + 5HCl$

(iii) One of the Period 3 chlorides and $BeCl_2$ have similar reaction with water. Identify this Period 3 chloride and explain why these two chlorides have similar chemical reactivity.

[1]

Period 3 chloride: $AlCl_3$
Be^{2+} and Al^{3+} have similar charge density
OR Be and Al have same atomic radius and electronegativity.

(d) Describe and explain the relative reactivity of elements of Group 17 as oxidising agents.

[2]

Down the group,

- atomic radius increases.
- tendency for X_2 to accept electrons decreases.
- tendency for X_2 to be reduced to X^- decreases.
- oxidising power of X_2 decreases.

(e) At the nanoscale, new properties may emerge in certain compounds.

For example, graphene is known to have very high tensile strength and high electrical conductivity. Describe the structure of graphene and explain how its structure relates to these two properties.

[3]

Graphene is a single layer of carbon atoms arranged in hexagons as they are in graphite (or a single layer of graphite). Each carbon atom in the layer is covalently bonded with 3 other carbon atoms resulting in a hexagonal lattice structure. Graphene has high tensile strength because of the strong covalent bonds between carbon atoms.

Each carbon atom has a 2p orbital that has a single electron that is not involved in bonding. This p orbital overlap sideways with its neighbouring carbon atom, resulting in an extended π-electron cloud of delocalised electrons above and below the plane. Graphene is an excellent conductor of electricity because it has delocalised mobile electrons over the layer which serves as charge carriers and can carry an electric current.

[Total: 15]

2(a) Nearly all petrol and diesel vehicles have some kind of catalytic converter fitted to the exhaust to reduce the amount of pollutants emitted into the environment. The catalytic converter usually contains palladium nanoparticles which act as catalyst.

(i) Define the term nanoparticles.

[1]

Nanoparticles are defined as particles with all dimensions between 1–100 nm on the nanoscale.

(ii) Explain why palladium used is in the form of nanoparticles instead of its bulk form.

[2]

Nanoparticles has high surface area per unit volume, i.e. the proportion of atoms on the surface of the nanoparticles is larger. As reaction occur on the surface of materials, chemical reaction often proceed more quickly OR rate of reaction increases.

(iii) The palladium catalyst helps to remove carbon monoxide from the exhaust. For example,

$$CO + \frac{1}{2} O_2 \longrightarrow CO_2$$

State the **type** of catalyst and outline the mode of action of catalyst in this reaction.

[2]

Heterogeneous catalyst

Adsorption: Reactant molecules are adsorbed onto the nanoparticle catalyst surface through the formation of *temporary bonds*.

Activation: This adsorption increases the surface concentration of the reactants and weakens the covalent bonds within the reactant molecules, thereby lowering the activation energy. Reactant molecules are brought closer together and reaction can take place between the reactants molecules more easily.

Desorption: Products diffuse away formed from the surface of the catalyst

(b) Carbon monoxide, water and propene can be used to produce butanoic acid according to the following equation:

$$CO + H_2O + CH_3CH{=}CH_2 \xrightarrow{\text{metal catalyst}} CH_3CH_2CH_2CO_2H$$

Draw the structure of the product formed when 2-methylpropene is used in the above reaction.

[1]

$CO + H_2O + (CH_3)_2C{=}CH_2 \longrightarrow (CH_3)_2CHCH_2CO_2H$ **[1]**

(c) Propene can be converted to propanone by the following route.

$$CH_3CH{=}CH_2 \xrightarrow{\textbf{I}} CH_3CHClCH_3 \xrightarrow{\textbf{II}} CH_3CH(OH)CH_3 \xrightarrow{\textbf{III}} CH_3COCH_3$$

(i) Suggest the types of reaction for steps **I** and **III**.

[2]

	step **I**	step **III**
type of reaction	addition	oxidation

(ii) State the reagent and conditions for step **II**.

[1]

aqueous NaOH, heat

(iii) State and explain how the rate of reaction for step **II** changes when 2-chloropropane is replaced by 2-iodopropae.

[2]

Relative reactivity of halogenoalkanes depends on the C-X bond strength.
C–I covalent bond is weaker than C–Cl
Relative ease of breaking C–I bond is greater than C–Cl
Hence rate of reaction increases when 2-chloropropane is replaced by 2-iodopropane.

(d) The kinetics of the acid-catalysed reaction of propanone with iodine

$$CH_3COCH_3(aq) + I_2(aq) \xrightarrow{H^+(aq)} CH_2ICOCH_3(aq) + HI(aq)$$

can be investigated experimentally by varying the concentrations of the three substances involved and determining the time for the colour of the iodine to disappear.

In this method the rate of the reaction is measured in terms of the rate at which the iodine changes, i.e.

$$\text{rate} \propto \frac{\text{volume of aqueous iodine used}}{\text{time for the colour of iodine to disappear}}$$

The following results were obtained in such an investigation.

Expt	Volume of CH_3COCH_3 / cm^3	Volume of I_2 / cm^3	Volume of H^+ / cm^3	Volume of H_2O / cm^3	Relative time for the colour of iodine to disappear
1	8	4	8	0	1
2	8	4	4	4	2
3	4	4	8	4	2
4	8	2	8	2	0.5

(i) Deduce the order of reaction with respect to propanone, iodine and hydrogen ions.

[3]

propanone

Comparing experiment 1 and 3, when conc. of propanone is halved while keeping the conc. of other reactants constant, rate is halved. Hence order of reaction w.r.t. propanone is 1

iodine

Comparing experiment 1 and 4, when conc. of iodine is halved while keeping the conc. of other reactants constant, rate does not change. Hence order of reaction w.r.t. iodine is 0.

hydrogen ions

Comparing experiment 1 and 2, when conc. of H^+ is halved while keeping the conc. of other reactants constant, rate is halved. Hence order of reaction w.r.t. H^+ is 1.

(ii) Hence write the rate equation for this reaction.

[1]

rate = k $[CH_3COCH_3]$ $[H^+]$

(iii) Another experiment, with 0.80 mol dm^{-3} propanone, 0.0010 mol dm^{-3} iodine and 0.20 mol dm^{-3} hydrochloric acid, is carried out at the same temperature.

Calculate the value of the rate constant if the rate is 4.2×10^{-6} mol dm^{-3} s^{-1}. Give the units of the rate constant.

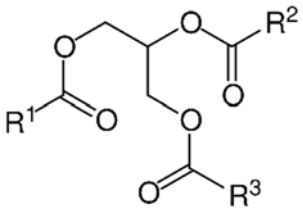
[2]

$4.2 \times 10^{-6} = k(0.80)(0.2)$

$k = 2.6 \times 10^{-5}$ units: mol^{-1} dm^3 s^{-1}

[Total: 17]

3(a) Limited scientific evidence suggests that eating two tablespoons of olive oil daily may reduce the risk of coronary heart disease. Olive oil comprises mainly of the mixed triglyceride esters of oleic acid, palmitic acid and other fatty acids. The general chemical structure of olive oil is shown below where R^1, R^2 and R^3 are alkyl groups or alkenyl groups.



Olive oil undergoes rancidification when exposed to moisture, resulting in an unpleasant taste and odour. The products formed in the reaction are propane-1,2,3-triol and fatty acids.

Complete the equation to illustrate the rancidification reaction of olive oil.

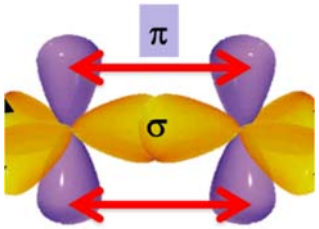
[2]

(b) Oleic acid has the structure shown.

$$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$$

(i) Describe the bonding in C=C in terms of orbital overlap. Draw a diagram to illustrate your answer.

[2]



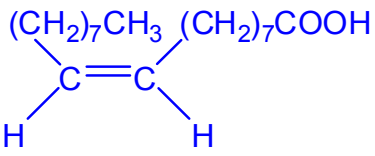
The C=C double bond consists of 1 σ bond and 1 π bond.
The C−C σ bond is formed by the head-on overlap between one orbital of the carbon atom and one orbital of another carbon atom.

The C−C π bond is formed by the sideway overlap between the 2*p* orbital of the carbon atom and 2*p* orbital of another carbon atom.

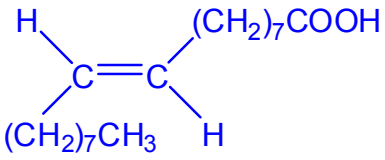
(ii) Oleic acid exists as a pair of isomers.

Draw and label the structural formulae of the two isomers.

[2]



cis isomer



trans isomer

(iii) Describe a chemical test that would distinguish oleic acid from ethanoic acid.

[2]

Add Br_2 in CCl_4 to each compound in the dark at r.t.p.
Oleic acid: Orange-red bromine solution is decolourised.
Ethanoic acid: Orange-red bromine solution is NOT decolourised.

(c) Fig. 3.1 shows a bomb calorimeter, inside a controlled temperature water jacket, which is used to find an accurate value of standard enthalpy change of combustion of oleic acid.

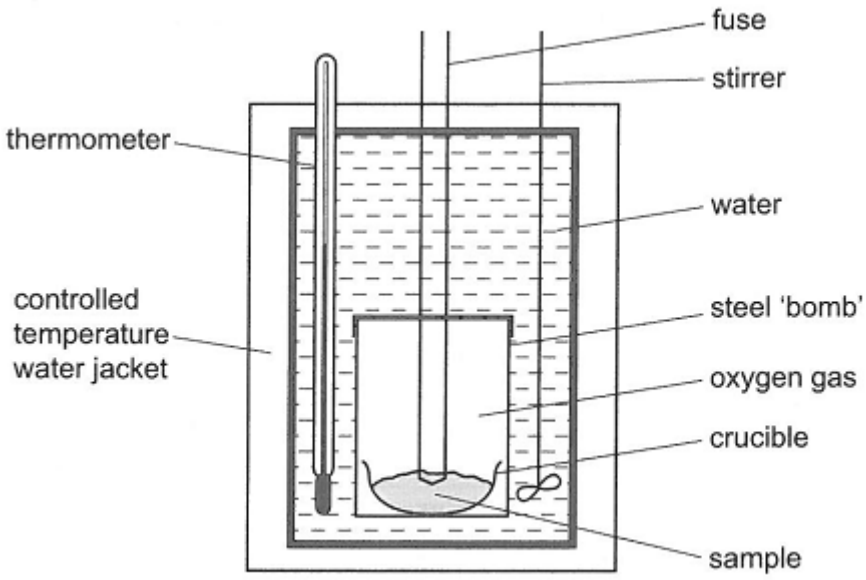


Fig. 3.1

(i) What is meant by the *standard enthalpy change of combustion* of oleic acid?

[1]

It is the energy released when 1 mole of oleic acid is completely burned in (excess) oxygen under standard conditions (298 k and 1 bar).

(ii) Explain why the steel 'bomb' is flushed with a high pressure of oxygen at the start of the experiment.

[1]

It is to ensure that there is sufficient O_2 present in the steel bomb for complete combustion.

(iii) There is no heat lost from the calorimeter because of the controlled temperature water jacket. Suggest how the controlled temperature water jacket achieves this.

[1]

The temperature of water in the jacket is raised with an electric heater so that it just matches the average temperature of the calorimeter.

(iv) A 2.98 g sample of oleic acid ($C_{18}H_{34}O_2$) is burned in a bomb calorimeter with a heat capacity of 1.98 kJ K^{-1}. The temperature of the calorimeter increases by 59.3 °C.

Calculate the standard enthalpy change of combustion of oleic acid.

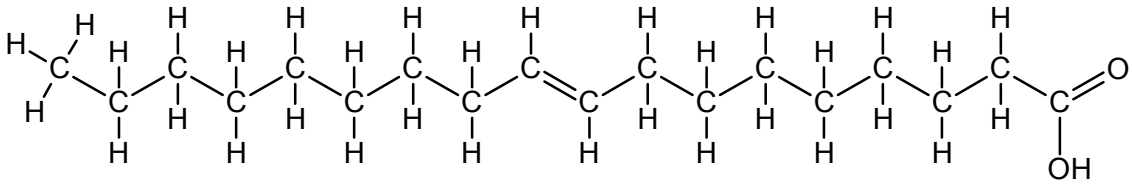
[2]

Heat absorbed by calorimeter = 1.98 × 59.3 = 117 kJ

Amount of oleic acid used = $\frac{2.98}{282.0}$ = 0.0106 mol

$\Delta H_c^{\ominus}$(oleic acid) = $-\frac{117}{0.0106}$ = – 11000 kJ mol^{-1}

(v) Use the bond energies given in the *Data Booklet* to calculate another value for the standard enthalpy change of combustion of oleic acid.



oleic acid

You may find the following information useful in your calculation.
An oleic acid ($C_{18}H_{34}O_2$) molecule contains 33 C–H bonds,16 C–C bonds and other bonds.

[3]

$$C_{18}H_{34}O_2\ (l) + \frac{51}{2} O_2\ (g) \rightarrow 18\ CO_2\ (g) + 17\ H_2O\ (l)$$

Bond breaking (endothermic) ➔ energy absorbed		Bonds forming (exothermic ➔ energy released	
33 C-H bonds	33 (410)	36 C=O bonds in CO_2	36 (805)
16 C-C bonds	16 (350)	34 O-H bonds	34 (460)
1 C=C bond	610		
1 C=O bond	740		
1 C-O bond	360		
1 O-H bond	460		
$\frac{51}{2}$ O=O bonds	$\frac{51}{2}$ (496)		
Total	33948 kJ mol^{-1}	Total	44620 kJ mol^{-1}

$\Delta H_c^{\ominus}$(oleic acid) = 33948 – 44620 = – 10672 = – 10700 kJ mol^{-1}

(vi) Suggest a reason for the discrepancy between the value in **(c)(iv)** and that in **(c)(v).**

[1]

Bond energy values of polyatomic molecules in the *Data Booklet* are average values.
OR
Oleic acid is not in gaseous state**.**

[Total: 16]

4(a) There are two types of polymerisation, addition and condensation

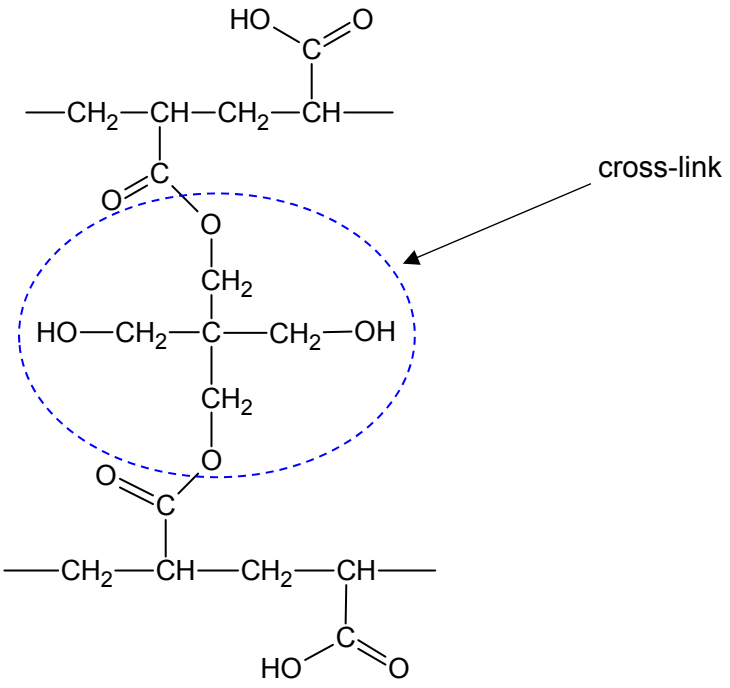
Account for the differences between these two types of polymerisation.

[2]

	Addition Polymerisation	**Condensation Polymerisation**
Type of monomers	Involves monomers containing double or triple bonds (unsaturated compounds)	Involves monomers containing alcohol, carboxylic acid or amino ($-NH_2$) functional groups.
By-products during polymerisation	No loss of molecules and the polymer is the only product.	Involves elimination of small molecules e.g. H_2O or HC*l*.
Empirical formula of polymer as compared to its monomers	Addition polymers have the same empirical formula as their monomers.	Empirical formula of the condensation polymer is not the same as that of the monomer.

(b) Super-absorbent polymers have the ability to absorb 200 – 300 times their own mass of water. They are classified as hydrogels and are widely used in personal disposable hygiene products such as diapers. However, these synthetically made hydrogels are usually non-biodegradable.

The diagram below shows part of the structure of a hydrogel.



The hydrogel is formed from chains of one polymer which are then cross-linked using another molecule.

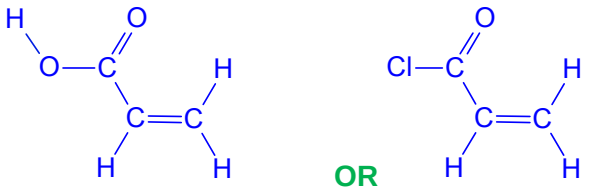
(i) State the type of polymerisation used to form these polymer chains.

[1]

Addition polymerisation

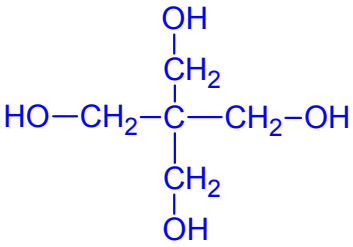
(ii) Draw the **displayed** structural formula of the monomer used.

[1]



(iii) Draw the structure of the molecule used to cross-link the polymer chains.

[1]



(iv) Once a hydrogel has absorbed water, it can be dried and re-used many times. Explain why this is possible, referring to the structure.

[1]

Water is held to the hydrogel by hydrogen bonds formed between water molecules and –COOH of the chain or –OH of the cross-link. These hydrogen bonds can be easily broken to release the held water molecules during drying.

(v) The amount of cross-linking has little effect on the ability of the gel to absorb water. Suggest why this is the case.

[1]

The amount of cross-linking does not affect the number of O-H groups available for hydrogen bonding.

(v) Suggest one property of the hydrogel that will change if more cross-linking takes place. Explain how the increased cross-linking brings about this change.

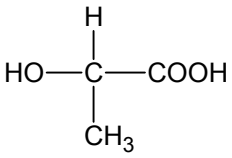
[2]

Hydrogel becomes harder / more rigid / less flexible / more brittle.

The strong cross-link covalent bonds between chains cannot be easily overcome. More cross–links hold the chains more tightly and strongly OR decreases the freedom of movement of individual chains

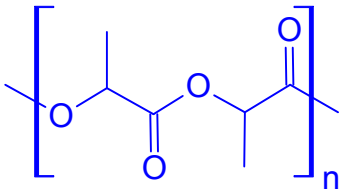
(c) Unlike hydrogel, the polymer, 'polyactide' or PLA is biodegradable. The monomer required to produce PLA is *lactic acid*, 2-hydroxypropanoic acid.

The structure of *lactic acid* is as shown.



(i) Draw the structure of the polymer PLA, showing two repeat units.

[1]



One of the reasons PLA has attracted so much attention is that it is biodegradable. This does, however restrict some potential uses. The polymer has a melting point of around 175 °C , but soften between 60 – 80°C. However, its properties enable it to have a range of uses in food packaging and in fibres.

(ii) Explain why PLA would not be a suitable packaging materials for food pickled in vinegar.

[1]

PLA contains ester linkages in the polymer which can be hydrolysed by the acid present in vinegar e.g. CH_3COOH (aq), under prolonged exposure.

(iii) Suggest why PLA containers are not usually used to hold hot drinks.

[1]

PLA is a thermoplastic polymer. PLA softens when heated and hence the PLA container changes shape easily as weak van der Waals' forces of attractions between chains are easily overcome and the chains are able to slide past each other.

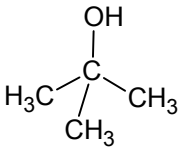
[Total: 12]

END OF SECTION A

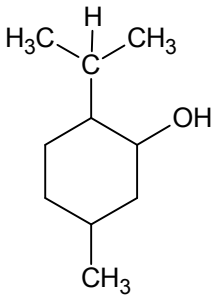
Section B

Answer **one** question from this section, in the spaces provided.

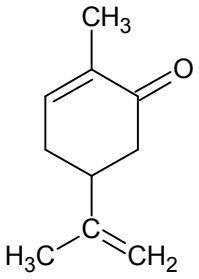
5(a) Three natural–occurring compounds used commercially are shown below:



2 methylpropan–2–ol



Menthol



Carvone

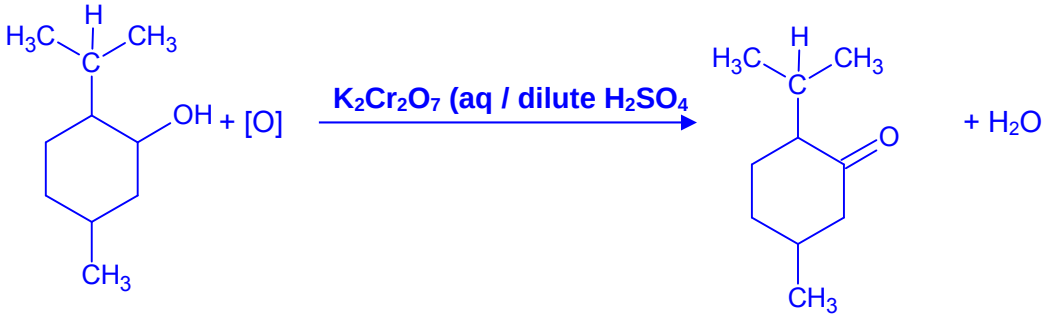
(i) Describe a set of two chemical tests that can be used to distinguish the above three compounds. Write an equation for each reaction that takes place.

[5]

Test: Add $K_2Cr_2O_7$ (aq), H_2SO_4 (aq) to each compound separately and heat.

Observations:

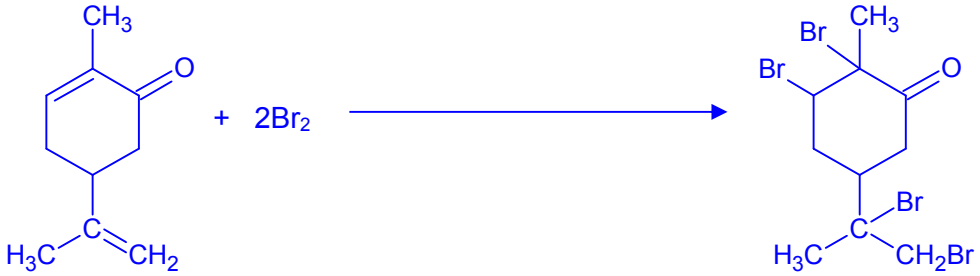
- 2 methylpropan–2–ol: Orange acidified $K_2Cr_2O_7$ remains.
- Menthol : Orange acidified $K_2Cr_2O_7$ turns green.
- Carvone: Orange acidified $K_2Cr_2O_7$ remains.



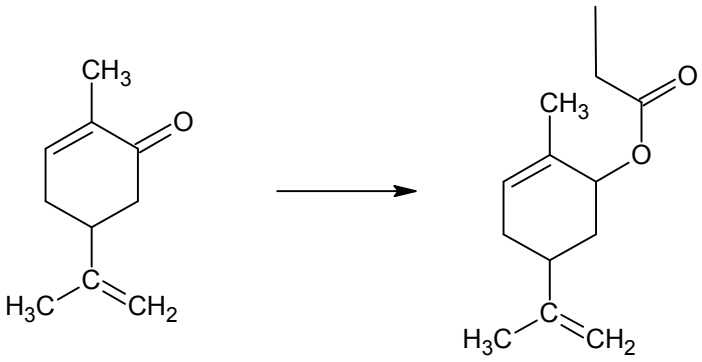
Test: Add Br_2 (CCl_4) / Br_2 (aq) to remaining compounds in the dark separately at r.t.p.

Observations:

- 2 methylpropan–2–ol: No decolourisation of orange–red Br_2 (CCl_4)
- Carvone: Decolourisation of orange–red Br_2(CCl_4)



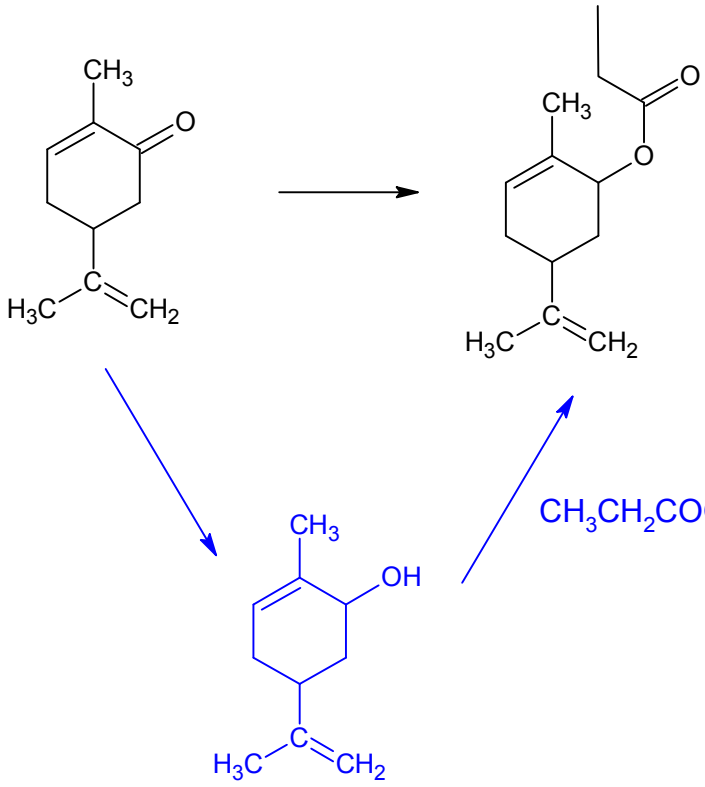
(ii) Carvone can be converted to organic compound D in two steps.



Carvone Compound D

State the reagents and conditions necessary for each step. Give the structure of the intermediate involved in the conversion.

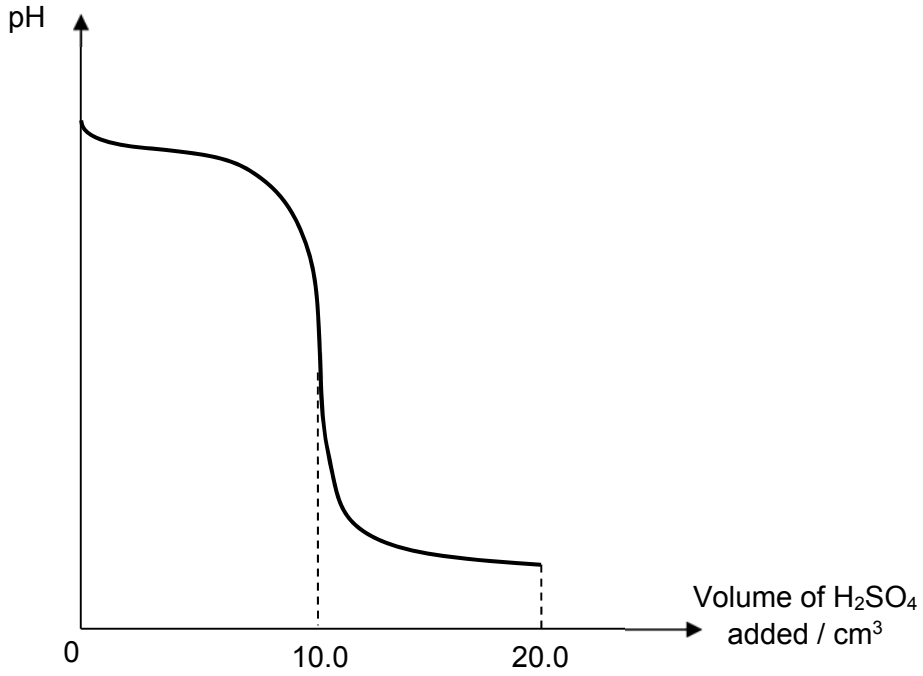
[3]



(b) Ammonia was used in smelling salts to treat fainting. Modern smelling salt solution may contain other products such as lavender oil to act in conjunction with aqueous ammonia.

When 40 cm^3 of aqueous ammonia was titrated against 0.200 mol dm^{-3} sulfuric acid, H_2SO_4 using a pH meter, the following graph was obtained.

$$2NH_3\,(aq) + H_2SO_4\,(aq) \longrightarrow (NH_4)_2SO_4\,(aq)$$



The base dissociation constant for ammonia, K_b is 1.78 x 10^{-5} mol dm^{-3}.

(i) Explain what is meant by the terms *Bronsted–Lowry base* and *conjugate acid–base pair*. Illustrate your explanation using ammonia in the above reaction with sulfuric acid.

Explain why the *Arrhenius* definition of base does not apply for ammonia in the above reaction.

[3]

A Bronsted–Lowry base is a proton acceptor.
A conjugate acid–base pair is a pair of species that differs from each other by a proton.

$NH_3\,(aq)$ + $H^+\,(aq)$ $\longrightarrow$ $NH_4^+\,(aq)$

proton acceptor — base; proton from H_2SO_4; conjugate acid

An Arrhenius base is a substance that has OH in its formula and releases OH^- when dissolved in water. This definition does not explain basic property of ammonia that does not contain the OH group.

(ii) Write an expression for the base dissociation constant, K_b, of ammonia.

[1]

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ $\qquad K_b = \dfrac{[NH_4^+][OH^-]}{[NH_3]}$

(iii) Using the titration curve provided, state the volume of sulfuric acid needed for the exact neutralisation of 40 cm^3 of aqueous ammonia. Calculate the initial concentration of aqueous ammonia.

[2]

From the graph, the equivalence volume is 10.0 cm^3.

Amount of H_2SO_4 in 10.0 cm^3 = $\dfrac{10}{1000} \times 0.200$ = 0.00200 mol

Mole ratio: $2NH_3 \equiv H_2SO_4$
Amount of NH_3 in 40.0 cm^3 solution = 0.00400 mol
Initial concentration of ammonia in 40.0 cm^3 = $\dfrac{0.00400}{\left(\dfrac{40.0}{1000}\right)}$ = 0.100 mol dm^{-3}

(iv) The resultant solution at the end of the titration can be considered as a sulfuric acid solution of concentration 0.0333 mol dm^{-3}. Calculate the pH of this resultant solution to 2 decimal place.

[1]

$[H_2SO_4]$ = 0.0333 mol dm^{-3}

Since H_2SO_4 is a strong diprotic acid,

$[H^+]$ = 2 x 0.0333 = 0.0666 mol dm^{-3}

pH = - lg $[H^+]$ = - lg (0.0666) = 1.18 (2 d.p.)

(v) Suggest an appropriate indicator for the titration, giving a reason for your choice.

[1]

Methyl orange / methyl red may be used for this strong acid–weak base titration.

The pH transition range of the indicator (around 3.0 – 4.5) lies within the region of the rapid pH change (around 3 – 7) over the equivalence point.

(vi) Explain what do you understand by the term *buffer solution*.

[1]

A buffer solution is one which is capable of maintaining a fairly constant pH when small amounts of acid or base are added to it.

(vii) The *Henderson–Hasselbalch* equation is useful for the estimation of the pH of a buffer solution.

An alternative form of the equation is shown below which can be used to determine the pOH of a basic buffer solution.

$$pOH = pK_b + \log_{10} \frac{[BH^+]}{[B]}$$

Calculate the pH of a basic buffer solution, if the solution contains NH_4^+ and NH_3 in a 2 : 1 ratio. given that the base dissociation constant, K_b of ammonia, NH_3 is 1.78×10^{-5} mol dm^{-3}.

[2]

$$pOH = pK_b + \log_{10} \frac{[NH_4^+]}{[NH_3]}$$

$$pOH = -\log (1.78 \times 10^{-5}) + \log_{10} \left(\frac{2}{1}\right)$$

$$pOH = 5.05$$

$$pOH = 14 - pH = 14 - 5.05 = 8.95$$

(viii) The enthalpy changes of neutralisation involving sulfuric acid with two bases are shown below.

sodium hydroxide, NaOH	– 57.3 kJ mol^{-1}
ethylamine, $CH_3CH_2NH_2$	– 51.5 kJ mol^{-1}

Comment and explain for the above observation as fully as you can.

[1]

Ethylamine is a weak base. $CH_3CH_2NH_2$ is only slightly dissociated in aqueous solution.

$$CH_3CH_2NH_2 + H_2O \rightleftharpoons CH_3CH_2NH_3^+ + OH^-$$

Some of the energy evolved from the neutralisation process is used to further dissociate the weak base completely.

Hence, the enthalpy change of neutralisation involving $CH_3CH_2NH_2$ is less exothermic.

[Total: 20]

6(a) Hydroxylamine, NH_2OH is commonly used in photography developing solution. Prolonged exposure to hydroxylamine by photography developers might cause irritation to their respiratory tract. To minimise the health hazard on these developers, the safety limit of the concentration of hydroxylamine is capped at below 0.00200 mol dm^{-3}.

A scientist performed the following experiment to determine if a sample of photography developing solution was within the safety limit.

100 cm^3 of NH_2OH solution was added to 40 cm^3 of 0.015 mol dm^{-3} acidified I_2 (aq) solution. In this reaction, iodine is used in excess and NH_2OH is oxidised to form dinitrogen monoxide, N_2O.

(i) Using half-equations, write a balanced equation for the reaction between NH_2OH (aq) and I_2 (aq) in an acidic medium.

[2]

Reduction: $I_2 + 2e \longrightarrow 2\,I^-$

Oxidation: $2\,NH_2OH \longrightarrow N_2O + H_2O + 4H^+ + 4e$

Overall: $2NH_2OH + 2I_2 \longrightarrow N_2O + H_2O + 4I^- + 4H^+$

A 25.0 cm^3 aliquot of the resultant reaction mixture was then titrated with a standard solution of 0.00500 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$ (aq).

$$I_2\,(aq) + 2\,S_2O_3^{2-}\,(aq) \longrightarrow 2I^-\,(aq) + S_4O_6^{2-}\,(aq)$$

Starch solution was added as indicator for this titration to enhance the contrast of the colour change at the end-point of the titration. 22.50 cm^3 of $Na_2S_2O_3$ (aq) was required.

(ii) State the expected colour change at the end-point of the titration.

[1]

Blue-black to colourless.

(iii) Calculate the amount of I_2 remaining in the reaction mixture.

[2]

Amount of $Na_2S_2O_3$ required = $\frac{22.50}{1000} \times 0.00500 = 1.125 \times 10^{-4}$ mol

$2S_2O_3^{2-} \equiv I_2$

Amount of I_2 remaining in 25 cm^3 of the reaction mixture $= \frac{1}{2} \times 1.125 \times 10^{-4}$

$= 5.625 \times 10^{-5}$ mol

Amount of I_2 remaining in reaction mixture (140 cm^3) $= \frac{140}{25.0} \times 5.625 \times 10^{-5}$

$= 3.15 \times 10^{-4}$ mol

(iv) Calculate the concentration of NH_2OH in 100 cm^3 sample of the photography developing solution. Hence conclude whether the solution is within the safety limit.

[2]

Amount of I_2 reacted with NH_2OH $= \left(\frac{40.0}{1000} \times 0.015\right)$ mol – 3.15 x 10^{-4} mol

= 2.85 x 10^{-4} mol

$NH_2OH \equiv I_2$

Amount of NH_2OH present in 100 cm^3 = 2.85 x 10^{-4} mol

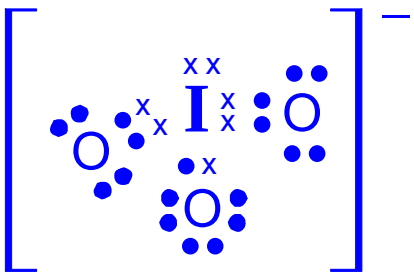
$[NH_2OH]$ = 2.85 x 10^{-4} mol / (100/1000) = 0.00285 mol dm^{-3}

Solution is > 0.00200 mol dm^{-3}, hence it is NOT within the safety limit.

(v) Iodate(V) ion, IO_3^- was used to generate iodine required for the reaction with NH_2OH.

In this IO_3^- ion, the central iodine atom can expand its octet structure. Draw the dot-and-cross diagram of IO_3^- ion.

[1]



(vi) From your answer in **(a)(v)**, state the bond angle around the central iodine atom and account for the shape of IO_3^- ion.

[2]

IO_3^- have 3 bond pairs and 1 lone pair around the central I atom.

To minimise repulsion and maximise stability, the 4 electron pairs are directed toward the corners of a regular tetrahedron.

Lone pair – bond pair repulsion > bond pair – bond pair repulsion

IO_3^- is trigonal pyramidal, with a bond angle of 107°

(b) In an industrial process, 5 mol of dinitrogen tetroxide, N_2O_4 and 7 mol of nitrogen monoxide, NO was heated in a 2.0 dm^3 vessel. The temperature is kept at 500 °C. The two gases react slowly to form blue dinitrogen trioxide, N_2O_3 according to the following equation. It was found that the equilibrium mixture contains 2.3 mol of NO.

$$N_2O_4\ (g) + 2NO\ (g) \rightleftharpoons 2N_2O_3\ (g) \quad \Delta H = -30.5\ kJmol^{-1}$$

(i) Write an expression for the equilibrium constant, K_c for the reaction, stating the units.

[1]

$$K_c = \frac{[N_2O_3]^2}{[N_2O_4]\,[NO]^2} \quad mol^{-1}\ dm^3$$

(ii) Determine the equilibrium concentrations of the three gases. Hence, calculate the value of K_c.

[2]

	$N_2O_4\ (g)$ +	$2NO\ (g)$ $\rightleftharpoons$	$2N_2O_3\ (g)$
Initial amount / mol	5	7	0
Change in amount/ mol	- ½ (4.7) = - 2.35	- 4.7	+4.7
Equilibrium amount / mol	2.65	2.3	+4.7

$$K_c = \frac{[N_2O_3]^2}{[N_2O_4][NO]^2}$$

$$K_c = \frac{\left(\frac{4.70}{2.0}\right)^2}{\left(\frac{2.65}{2.0}\right)\left(\frac{2.30}{2.0}\right)^2}$$

K_c = 3.15 mol^{-1} dm^3

(iii) Predict and explain the effect of increasing temperature on the equilibrium position and equilibrium composition.

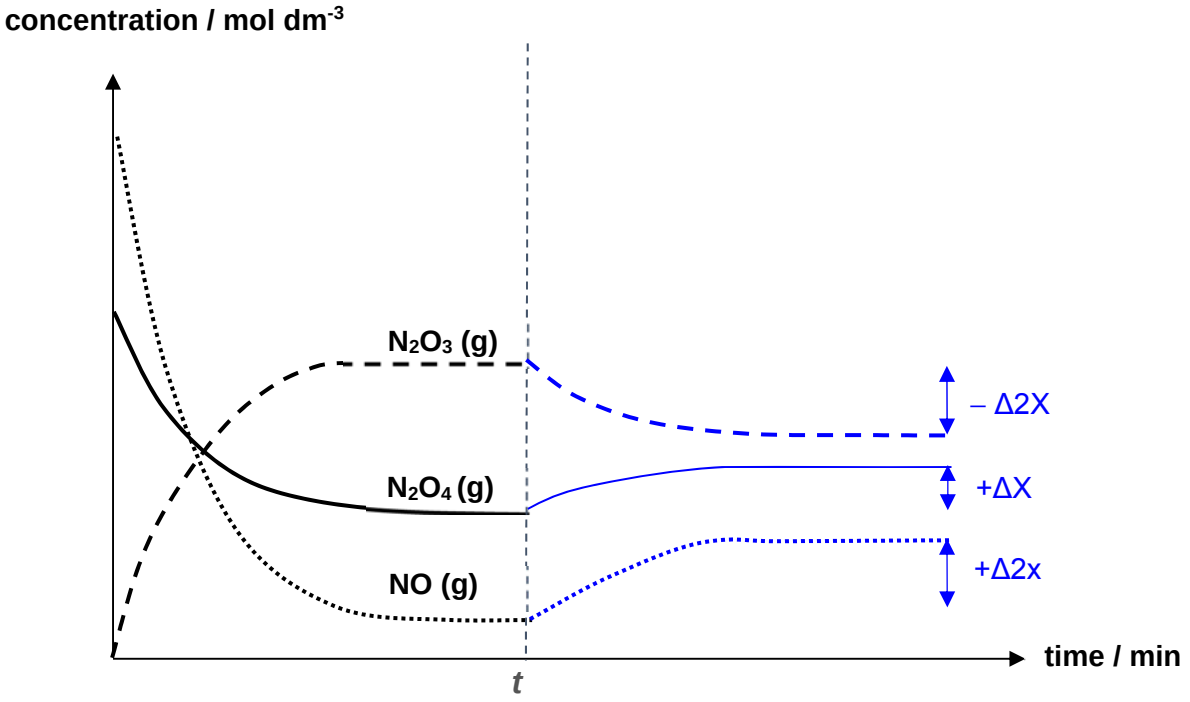
[2]

As temperature increases, the system will try to remove the heat added. By Le Chatelier's Principle, the equilibrium position will shift left towards the endothermic reaction to absorb heat.

The new equilibrium mixture contains less product, N_2O_3 and more reactants N_2O_4 and NO.

(iv) Sketch on the same axes, how the concentration of the three gases will change when temperature was increased at ***t***.

[2]



(v) State the operating pressure and temperature (high or low) required to obtain a high yield of N_2O_3. Explain your answer.

[2]

To obtain a high yield of N_2O_3, a high pressure and low temperature should be used instead.

At high pressure, the system will try to reduce the pressure
By Le Chatelier's Principle, the equilibrium position shifts right to decrease the number of moles of gases to decrease pressure. [N_2O_3] increases, resulting in a higher yield.

To obtain a high yield of N_2O_3, a low temperature should be used instead.
At low temperature, the system will try to produce heat. By Le Chatelier's Principle, the equilibrium position will shift right towards the exothermic reaction to release heat. [N_2O_3] increases, resulting in a higher yield.

(vi) Hence, suggest why the operating temperature is fixed at a moderately high temperature of 500 °C.

[1]

If the temperature is too low, the rate of reaction will be too slow. Hence, a moderately high temperature is chosen as a compromise between the conflicting demands of rate and yield of the reaction.

[Total: 20]

END OF PAPER