DUNMAN HIGH SCHOOL
Preliminary Examination 2017
Year 6

H1 CHEMISTRY

8872/01

Paper 1 Multiple Choice

25 September 2017
50 minutes

Additional Materials: Data Booklet
                              Optical Mark Sheet

INSTRUCTIONS TO CANDIDATES

1. Write your **name**, **index number** and **class** on this question paper and the OTAS Mark Sheet.

2. There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.

   Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Optical Mark Sheet.

3. Each correct answer will score one mark. A mark will not be deducted for wrong answer.

4. Any rough working should be done in this booklet.

5. The use of an approved scientific calculator is expected, where appropriate.

6. On the OTAS Mark Sheet, please shade the code as "Class/Index number".

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

Which of these samples of gas contains twice the number of atoms as 4 g of helium gas, He?

A   22 g of carbon dioxide, CO_2

B   8 g of methane, CH_4

C   4 g of hydrogen, H_2

D   12 g of steam, H_2O

2   Bones contain a complex mixture of calcium salts, protein and other material.

When a sample of 50.0 g bone is strongly heated in air, the only residue formed is calcium oxide and its mass is determined to be 14.0 g.

What is the percentage by mass of calcium in the bone?

A   10%

B   14%

C   20%

D   23%

3   Ethanedioate ions, $C_2O_4^{2-}$, are oxidised by acidified aqueous potassium manganate (VII) to give carbon dioxide. What volume of 0.020 mol dm^{-3} potassium manganate (VII) is required to completely oxidise 2.0 x 10^{-3} mol of the salt $NaHC_2O_4.H_2C_2O_4$?

The half equation for MnO_4^- is given below:

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$
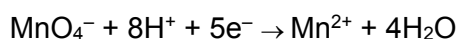
A   20 cm^3 B   40 cm^3

C   80 cm^3 D   100 cm^3

4   Which of the following corresponds to the electronic configuration of 3 electrons of highest energy for a Group 13 element at its ground state?

A $3s^23p^3$ B $1s^12s^12p^1$

C $4s^24p^1$ D $3s^13p^2$

5 The hydrogen molecule contains a covalent bond.

What holds the atoms together in this covalent molecule?

A The electrostatic attraction between the electrons in the bond pair and the two nuclei.

B The electrostatic attraction between the electron of one hydrogen atom and the nucleus of the other hydrogen atom.

C The electrostatic attraction between the atoms in the molecule.

D The energy released in the formation of the covalent bond.

6 $SCl_3{}^{n-}$ has a T–shaped structure as shown below.

What is the value of n?

A	0	**B**	1
C	2	**D**	4

7 When 5 mol of nitrogen gas and 9 mol of hydrogen gas were put into a 2 dm³ container and heated, the equilibrium mixture contained 2 mol of ammonia gas.

The equilibrium is represented by the following equation.

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

What is the numerical value of the equilibrium constant, K_c, at the temperature of the experiment?

A $\dfrac{1}{2(3^3)}$ **B** $\dfrac{2^2}{1(3^3)}$ **C** $\dfrac{2^2}{4(6^3)}$ **D** $\dfrac{2^2}{3(2\times3)^3}$

8 Which statement can be deduced from the following information?

$$2CO\ (g)\ +\ O_2(g)\ \rightleftharpoons\ 2CO_2(g) \qquad \Delta H = -566\ kJ\ mol^{-1}$$
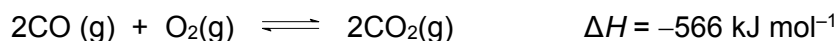
A Increasing the pressure at constant temperature increases the value of the equilibrium constant.

B Decreasing the volume of the container containing the reaction mixture at constant temperature decreases the amount of CO and O_2 at equilibrium.

C Increasing the temperature decreases the rate of the forward reaction.

D Adding a catalyst increases the yield and rate of production of CO_2.

9 The value of the ionic product of water, K_w, varies with temperature as shown.

Temperature / °C	K_w / mol² dm⁻⁶
25	1.0×10^{-14}
62	1.0×10^{-13}

Which statement is true?

A The ionic dissociation of water is exothermic.

B The pH of water is higher at 62°C than 25°C.

C Water is acidic at 62°C.

D $[OH^-] = 3.16 \times 10^{-7}$ mol dm⁻³ at 62°C.

10 A 2.0 cm³ solution of a strong acid has pH 1. What additional volume of water is needed to increase the pH of the solution to pH 3?

A 98 cm³
B 100 cm³
C 198 cm³
D 200 cm³

11 Using bond energy values from the *Data Booklet*, what is the enthalpy change of formation of N_2H_4 (g)?

A -250 kJ mol^{-1}

B -146 kJ mol^{-1}

C $+146$ kJ mol^{-1}

D $+250$ kJ mol^{-1}

12 250 cm^3 of 0.50 mol dm^{-3} KOH(aq) at 29.0 °C was mixed in a polystyrene cup, with an equal volume of 0.50 mol dm^{-3} H_2SO_4(aq) at the same initial temperature. The final temperature was 32.4 °C.

What is the enthalpy change of neutralisation of the reaction?

Given heat capacity of the mixture and polystyrene cup = 1.7 kJ K^{-1}

A $- 3760$ kJ mol^{-1}

B $- 57.1$ kJ mol^{-1}

C $- 46.2$ kJ mol^{-1}

D $- 28.6$ kJ mol^{-1}

13 Which compound has the most exothermic lattice energy?

A   Magnesium chloride

B   Sodium bromide

C   Aluminium fluoride

D   Lead (II) iodide

14 Which statement **does not** explain why addition of a catalyst leads to a significant increase in the rate of a reaction?

    A The average kinetic energy of the molecules is slightly greater in the presence of a catalyst.

    B The activation energy of the forward and backward reaction is lowered when a catalyst is added.

    C The frequency of effective collisions between molecules with kinetic energy greater than the activation energy is greater with the presence of a catalyst.

    D The number of reactant molecules with at least activation energy increases.

15 Consider the hypothetical reaction: $2A \rightarrow B + C$.

Given that the rate constant, k, of the reaction is 0.188 mol dm^{-3} s^{-1}, which of the following graphs correctly reflects the reaction kinetics of the reaction?
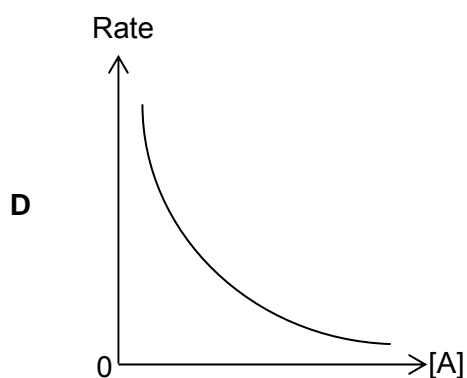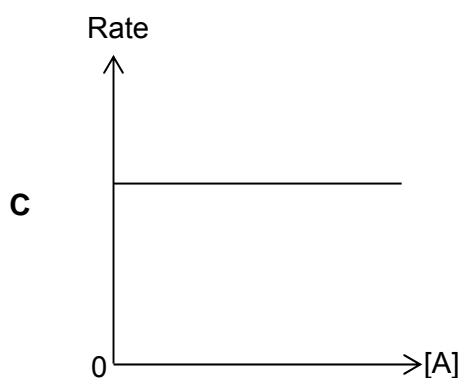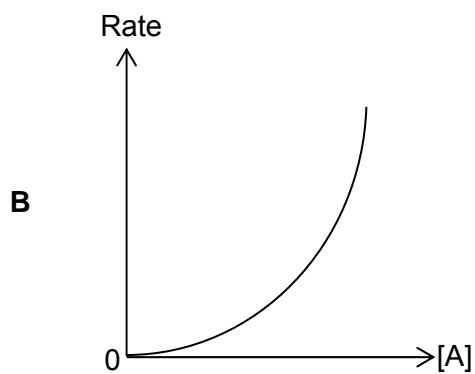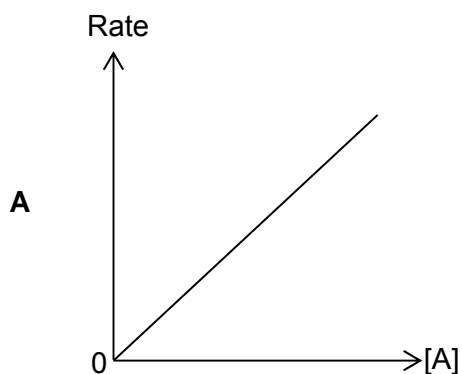
16 Elements can form chlorides by reacting them with Cl_2. The chlorides formed by elements **R** and **S** can conduct electricity in the molten state.
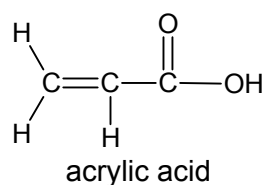
Which are the possible identities of **R** and **S**?

A   magnesium, phosphorus

B   sodium, aluminium

C   silicon, phosphorus

D   magnesium, sodium

17 Which compound can undergo a substitution reaction to form 2–chloropropane?

A $CH_3CH(OH)CH_3$

B $CH_3CH=CH_2$

C CH_3CH_2CHO

D $CH_3CH(NH_2)CH_3$

18 Acrylic acid is co–polymerised with other monomers to make sticky coatings.

acrylic acid

What are the numbers of σ and π bonds present in one molecule of acrylic acid?

|	σ	π
A	7	1
B	8	1
C	7	2
D	8	2

19 How many different products, including stereoisomers, are formed when $CH_3C(CH_3)_2CH(OH)CH_2CH_3$ is treated with hot concentrated sulfuric acid?

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

20 Which statement **best** explains why iodoalkanes are the most reactive halogenoalkane?

A Iodine has the most number of electrons.

B Iodine is the least electronegative halogen.

C The C–I bond is the longest.

D The iodide ion is the most stable halide.

21 The following compound is used to make light–cured dental fillings.
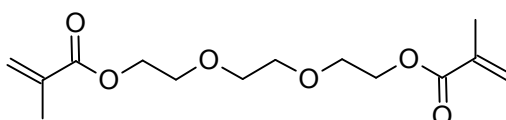
How many hydrogen atoms are present in one of these molecules?

A 20 **B** 22 **C** 24 **D** 26

22 Which pure compound would give only one positive test result with the following reagents?

- alkaline aqueous iodine
- phosphorous pentachloride
- 2,4–dinitrophenylhydrazine

A butanal

B butanone

C butan–2–ol

D ethanol

23 The diagram shows a reaction pathway.

1–bromobutane $\xrightarrow{\text{step 1}}$ intermediate $\xrightarrow{\text{step 2}}$ propanoic acid

Which reagents are suitable for steps 1 and 2?

	reagent for step 1	reagent for step 2
A	HCN, trace NaOH	dilute H_2SO_4
B	alcoholic KCN	dilute H_2SO_4
C	aqueous NaOH	$KMnO_4$
D	alcoholic NaOH	$KMnO_4$

24 Beta–damascenone is a major contributor to the aroma of roses.

beta–damascenone
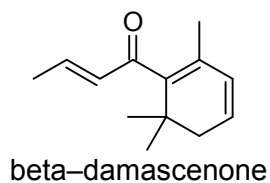
Which statement is true of this compound?

A All the C–C–C bond angles are 120°.

B It forms hydrogen bonds with water.

C It undergoes substitution with aqueous bromine.

D It reduces alkaline Cu^{2+} to Cu_2O.

25 An organic compound on complete combustion produces equal volumes of carbon dioxide and water vapour.

What is a possible identity of the compound?

A CH_4

B CH_3OH

C $CH_3CH_2CH_3$

D CH_3COCH_3

Section B

For each question, 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 which you consider to be correct).

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

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

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

26   The successive ionisation energies, in kJ mol^{-1}, of an elements **X** and **Y** are given below.

X	580	1820	2740	11600	14840	18380	23320
Y	940	2050	2970	4140	6590	7880	14900

Which of the following statements are true about element **X** and **Y**?

1   The first ionisation energy of **X** is lower than that of the element preceding it in the Periodic Table.

2   **X** and **Y** forms a compound with the formula X_2Y_3.

3   When oxides of **X** and **Y** are added separately to water containing Universal Indicator solution, the solution turns blue and red respectively.

27   Which of the following statements describe a phenomenon which can be explained by hydrogen bonding?

1   2–nitrobenzoic acid is more volatile than 4–nitrobenzoic acid.

2   Ice has a lower density than water at 0°C.

3   The boiling point of alcohol increases with increasing relative molecular mass.

28   Element **X** is one of the elements in the third period of the Periodic Table. The oxide of **X** has a giant ionic structure while the chloride of **X** has a simple molecular structure.
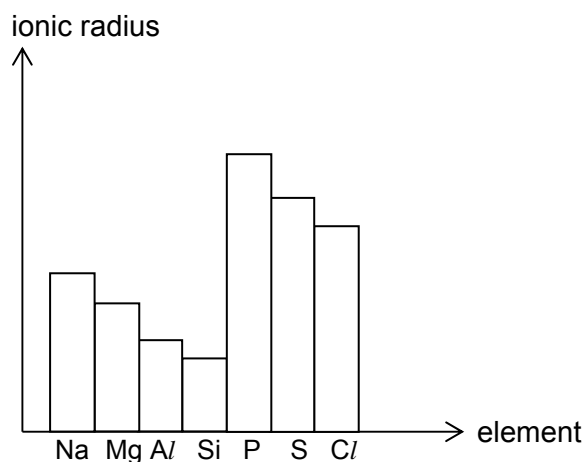
Which statements are **correct**?

1   The oxide of **X** has a higher melting point than that of magnesium oxide.

2   The oxide of **X** reacts with excess aqueous potassium hydroxide to form a colourless complex ion.

3   The third ionisation energy of **X** is lower than the second ionisation energy of sodium.

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

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

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

29 The graph below shows the ionic radii of seven elements found in Period 3.

Which statements correctly explain the trend shown in the graph?

1 The ionic radius decreases from P^{3-} ion to Cl^- ion due to increasing nuclear charge.

2 The ionic radius decreases from Na^+ ion to Si^{4+} ion due to decreasing shielding effect by inner shell electrons.

3 The ionic radius of P^{3-} ion is greater than that of Si^{4+} ion due to less attraction between electrons.

30 Which compounds will form CH_3COCH_2COOH upon treatment with hot alkaline $KMnO_4$, followed by acidification?

1

2

3

2017 DHS YEAR 6 H2 CHEMISTRY (8872) PRELIMINARY EXAMINATION
Paper 1 MCQ – Answers

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

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

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

Name:		Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examinations 2017
Year 6

H1 CHEMISTRY

8872/02

Paper 2 Section A (Structured)
Paper 2 Section B (Free Response)

11 September 2017
2 hours

Additional Materials: Data Booklet
Writing Paper
Cover Sheet

INSTRUCTIONS TO CANDIDATES

1   Answer **ALL** questions in both sections.

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

Section A

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

Section B

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

5   Write your answers on the separate writing papers provided.

6   Start each question on a fresh sheet of paper.

7   At the end of the examination:

- Fasten all your work securely together with the Cover Sheet on top.

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

You are advised to show all workings in calculations.

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

For Examiner's Use	
Question No.	Section A Marks
1	13
2	14
3	13
Total	40

This question paper consists of **17** printed pages and **1** blank page.

[Turn Over

Section A

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

1 **(a)** Vanadium is a metal with four possible stable oxidation states in aqueous solutions.

Vanadium–containing species	Oxidation state of vanadium	Colour of aqueous solution containing species
VO_2^+	+5	Yellow
VO^{2+}	+4	Blue
V^{3+}	+3	Green
V^{2+}	+2	Violet

A solution of VO_2^+ can be easily reduced by metals like zinc and tin. Depending on the reducing strength of the metal, VO_2^+ would be reduced to different products.

A 250 cm^3 solution containing 0.60 mol dm^{-3} $VO_2^+(aq)$ was reduced to $V^{2+}(aq)$ by an excess amount of zinc. After filtration to remove the excess zinc, 25.0 cm^3 of the filtrate containing $V^{2+}(aq)$ was pipetted into the conical flask and titrated against 1.0 mol dm^{-3} nitric acid, which acted as an oxidising agent, until there was no further change in the colour of the solution.

The half–equation for the reduction of nitric acid is

$$NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$$
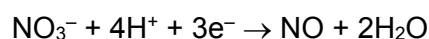
The titre values were as recorded.

Final burette reading / cm^3	11.00	21.05	31.45
Initial burette reading / cm^3	0.00	11.00	21.50
Volume of HNO_3 / cm^3	11.00	10.05	9.95

(i) By using appropriate titre values, calculate the average titre value for the titration.

[1]

(ii) Determine the reacting mole ratio of V^{2+} and NO_3^-.

[2]

(iii) Hence, determine the oxidation state of vanadium after titration and the colour of the vanadium–containing solution, using the table in **(a)**.

[2]

(iv) Using your answer in **(iii)**, construct a balanced equation for the reaction between V^{2+}(aq) and nitric acid.

[1]

(b) Describe the bonding in the element vanadium. Draw a diagram to illustrate your answer.

[2]

(c) **(i)** Write the full electronic configuration of vanadium in VO^{2+}.

[1]

(ii) Draw labelled diagrams of two p orbitals from different quantum shells of the element vanadium, illustrating their shapes and sizes.

[1]

(iii) Beams consisting of the particles, $^{16}O^{2-}$ and $^{51}V^{2+}$, are subjected to an electric field. The angle of deflection of the particles is proportional to their charge/mass ratio.

Given that the angle of deflection of $^{51}V^{2+}$ in the electric field is +5°, suggest the angle of deflection of $^{16}O^{2-}$ in the electric field.

[1]

(iv) Using your answer in **(iii)**, sketch and label on the diagram below to show how beams of each of the two particles are affected by the electric field.

+
———

———————>   ————

—
‒
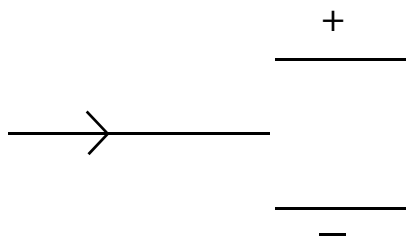
[2]
[Total: 13]

2 A coal–fired power station (which generates electricity) is fitted with a Flue Gas Desulfurisation (FGD) plant, which removes some of the sulfur dioxide from flue (waste) gases.

In the FGD plant, the flue gases are treated with powdered limestone, $CaCO_3$, where sulfur dioxide is absorbed and reacted to produce calcium sulfite, $CaSO_3$. This is oxidised by air to form solid calcium sulfate, $CaSO_4$.

The diagram below shows the amounts of substances used, and produced, by such a coal–fired power station with an FGD plant in **one** year.
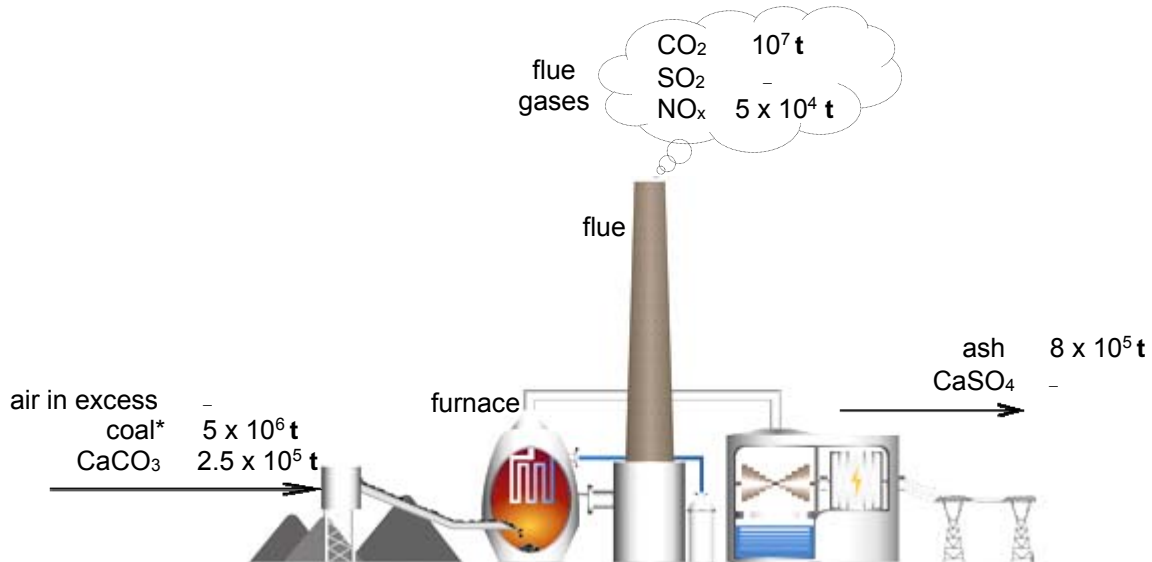
Power station & FGD plant

*coal is chiefly hydrocarbons

(a) (i) State the process that produces the energy in the power station.

....
[1]

(ii) Identify a gas, not listed in the diagram, which will be a chief component of the flue gas.

....
[1]

(iii) Explain why oxides of nitrogen (NO_x) are present in the flue gases.

....

....
[1]

(b) Write a balanced equation in each case to show how

- sulfur dioxide is removed from flue gases;

....

- calcium sulfate is formed.

....

[2]

(c) Using your answer in **(b)**, determine the maximum mass of sulfur dioxide which could be removed in the FGD plant.
[1**t** = 1 tonne = 1000 kg]

[1]

(d) Given that your answer in **(c)** was only 90% of the sulfur dioxide removed from the flue gases, calculate the mass of sulfur dioxide which is released into the atmosphere in **five** years by this power station when the same mass of coal is burnt each year.

[1]

(e) Another method for removing sulfur dioxide from the flue gases is to absorb it in a slurry of magnesium oxide, to produce magnesium sulfite, $MgSO_3$.

Explain why magnesium oxide can also be used to remove sulfur dioxide.

....

....
[1]

(f) Besides magnesium oxide, other metal oxides like sodium oxide and calcium oxide can also be used to remove sulfur dioxide.

The melting points of the three metal oxides are shown below.

oxides	m.p. / °C
MgO	2852
Na_2O	1132
CaO	2572

(i) Given that the ionic radius of O^{2-} is 0.140 nm and with reference to *Data Booklet*, calculate $\left| \dfrac{q_+ q_-}{r_+ + r_-} \right|$ for the metal oxides and complete the table below. (q represents the charge of ion and r represents its ionic radius)

oxides	$\left\| \dfrac{q_+ q_-}{r_+ + r_-} \right\|$
MgO	
Na_2O	8.5
CaO	

[1]

(ii) Using your answer in **(i)**, explain the melting points of these oxides.

----

[1]

(iii) For an ionic compound to dissolve in water, its ionic bonds have to be broken.

The pH of the resulting solutions when one mole of MgO and Na_2O are added to water separately are shown in the table below.

Predict and suggest an explanation for the pH value of CaO, with reference to your answer in **(i)**.

oxides	pH of resulting solution
MgO	9
Na_2O	13
CaO	

----
[2]

(g) Seawater is a natural reagent that can be used to absorb and remove SO_2. When SO_2 is absorbed in water, the following two equilibria reactions take place:

$$SO_2(g) + H_2O(l) + \tfrac{1}{2}O_2(g) \rightleftharpoons SO_4^{2-}(aq) + 2H^+(aq) \; — (1)$$

$$\underset{\text{(from seawater)}}{HCO_3^-(aq)} + H^+(aq) \rightleftharpoons H_2O(l) + CO_2(g) \; — (2)$$
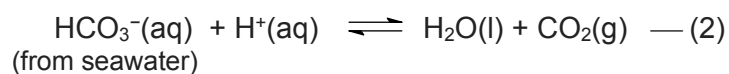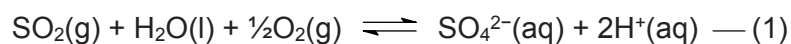
Explain how the use of seawater would allow the removal of sulfur dioxide.

----
[2]
[Total: 14]

3 Sulfuric acid is a strong mineral acid which is an important chemical used in industry and in the school laboratory. It is manufactured industrially by the Contact process.

The key reaction involves the reaction between sulfur dioxide and oxygen.

$$2SO_2(g) \ + \ O_2(g) \ \rightleftharpoons \ 2SO_3(g) \qquad \Delta H < 0$$
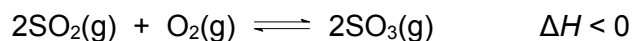
69.2 mol of sulfur dioxide is mixed with 34.6 mol of oxygen in a 2 dm^3 vessel and passed over several beds of loosely packed porous vanadium catalyst. The amount of sulfur trioxide at equilibrium is found to be 65.6 mol.

(a) (i) Calculate a value for the equilibrium constant, K_c, stating its units.

[2]

(ii) Use your value of K_c to calculate the $[O_2]$ necessary for 99% of the SO_2 to be converted to SO_3.

[2]

(iii) Explain qualitatively why the rate of achieving equilibrium increases in the presence of vanadium catalyst.

----

[2]

(iv) Sketch a graph to show how the rates of the forward and reverse reactions change from the time the two gases are mixed to the time the reaction reaches equilibrium. Label your lines clearly.

[1]

(b) Sulfuric acid is commonly used to acidify a solution of potassium manganate (VII).

(i) Draw the structure of the organic product formed when compound **W** is heated with acidified potassium manganate (VII).
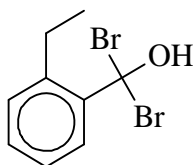
compound **W**

[1]

(ii) A derivative of compound **W** is shown below.
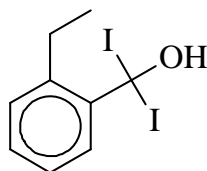
compound **X**

Describe a chemical test to distinguish samples containing compounds **W** and **X** and state what would be observed.

----

[2]

(iii) When compound **W** is treated with chlorine under two different conditions, isomeric monochlorides are formed.

Two isomers are formed via condition 1 and four isomers are formed via condition 2.

Draw the structures of one isomer formed via condition 1 and condition 2 respectively and state the reagents and conditions required for condition 1.

Isomer formed via Condition 1

Isomer formed via Condition 2

Condition 1

Reagent: …………………………………………

Conditions: …………………………………....

[3]
[Total: 13]

Section B

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

1 (a) The Contact Process is an industrial process for manufacturing sulfuric acid and occurs at 450 °C. The key stage in this process is the reaction between sulfur dioxide and oxygen.

$$2SO_2 (g) + O_2(g) \rightarrow 2SO_3(g)$$
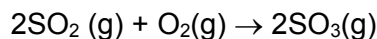
Two experiments were conducted at 450 °C to investigate the kinetics of this reaction. The graph below shows the results obtained when concentrations of sulfur dioxide were varied.

$[O_2]$ / mol dm^{-3}

Expt 1 $[SO_2]$ = 0.80 mol dm^{-3}

Expt 2 $[SO_2]$ = 1.20 mol dm^{-3}

Time / s
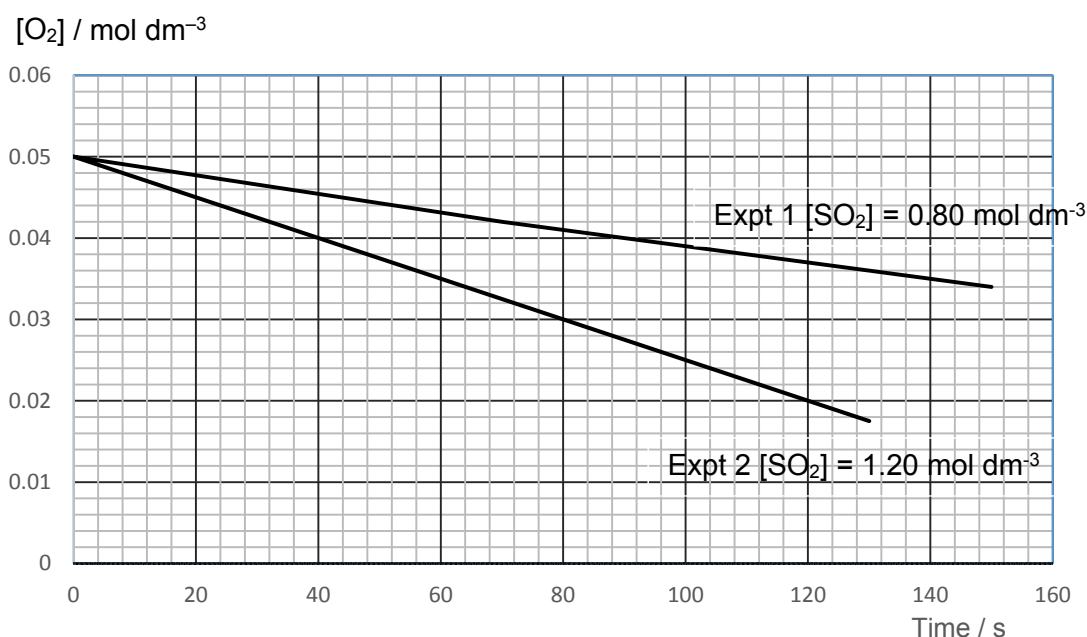
(i) Define the term *order of reaction.*

[1]

(ii) Use the graph above to deduce the order of reaction with respect to both sulfur dioxide and oxygen.

[3]

(iii) Using one of the graph above and your answer in **(ii)**, calculate the value of rate constant, stating its units.

[2]

(iv) Using your answer in **(ii)**, sketch the graph of concentration of sulfur dioxide against time for this reaction, while keeping $[O_2]$ constant. Use construction lines to label the first and second half-lives in your sketch.

[1]

(v) Sketch and label clearly, on the same axes as in **(iv)**, how the graph would look like if the experiment was conducted at 200 °C.

[1]

Ethylamine, $CH_3CH_2NH_2$, is a *weak base*.

$$CH_3CH_2NH_2 + H_2O \rightleftharpoons CH_3CH_2NH_3^+ + OH^-$$
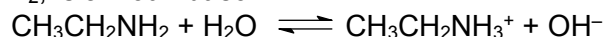
(b) What is meant by the term *weak base*?

[1]

(c) Write an expression for the base dissociation constant of ethylamine, K_b.

[1]

(d) The graph below shows the pH changes during the titration of 10.0 cm³ of 0.10 mol dm⁻³ sulfuric acid with 0.10 mol dm⁻³ ethylamine. During this titration, ethylamine is added gradually, from a burette, until a total volume of 30.00 cm³ has been added to the acid.
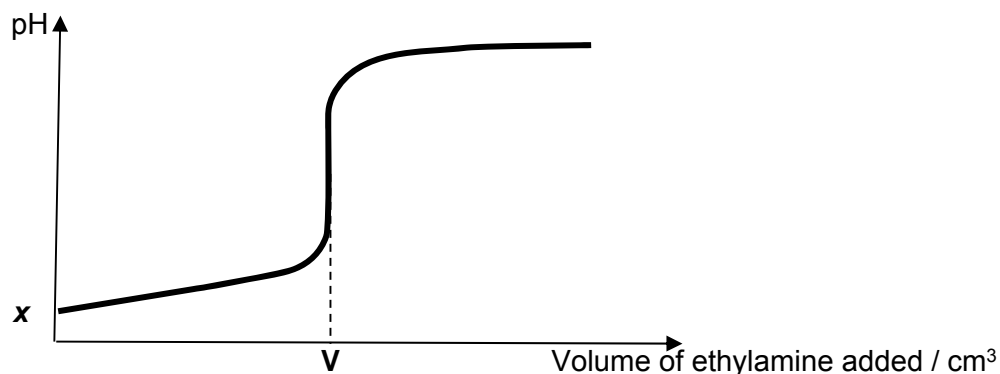
(i) Calculate **x**, the initial pH of sulfuric acid before titration.

[1]

(ii) What is the equivalence volume of ethylamine, **V**, for the neutralisation of 10.0 cm³ of 0.10 mol dm⁻³ sulfuric acid?

[2]

(iii) An aqueous solution of ethylamine and its salt can act as a buffer. Copy the titration curve onto your answer script and label the buffer region.

[1]

(iv) Use the data in the following table to suggest a suitable indicator for the titration of sulfuric acid with ethylamine. Justify your answer.

State the colour change of your chosen indicator at the end–point of this titration.

indicator	colour in acid	colour in alkali	pH range over which the colour change occurs
Bromocresol green	yellow	blue	3.8 – 5.4
Cresol red	yellow	red	7.2 – 8.8
Alizarin yellow	yellow	orange	10.1 – 13.0

[2]

(e) Concentrated sulfuric acid is a common reagent used in many organic reactions. When concentrated sulfuric acid is added to 3–hydroxypentanoic acid, one possible product formed is **A**, with the molecular formula $C_5H_8O_2$. **A** turns blue litmus paper red. **A** also gives effervescence when heated with acidified potassium manganate (VI) and only one organic product, **B,** is formed.

Suggest the structural formula of **A** and **B.**

[2]

(f) How would you expect the acidity of 3–hydroxypentanoic acid to compare with that of pentanoic acid? Explain your answer.

[2]

[Total: 20]

2 Below shows part of an edited abstract from a scientific journal.

'Two aluminium compounds, $AlCl_3$ and Al_2O_3, were used to determine the effect of Al compounds on pH and bioavailability of Al in 2 acid soils. Al–tolerant (ET8) wheat seedlings were used as a testing plant to confirm bioavailability of Al^{3+} in soil solution. The results showed that the $AlCl_3$ compound increased the bioavailability of Al^{3+} in soil solutions and decreased bulk soil pH. However, Al_2O_3 did not change soil pH and the bioavailability of Al^{3+} in soil solution.'

Md. Toufiq IQBAL (2012), Effect of Al compounds on soil pH and bioavailability of Al in two acid soils, Turk J Agric, 720 – 728

(a) **(i)** Suggest why Al_2O_3 did not change the bioavailability of Al^{3+} in soil solution.

[1]

(ii) Explain how does $AlCl_3$ decrease soil pH in solution? Giving a balanced equation to support your answer.

[3]

(b) Consider the following energy cycle involving Al_2O_3.

$$Al^{3+}(g) + \frac{3}{2}O^{2-}(g) \xrightarrow{\Delta H_4} \frac{1}{2}Al_2O_3(s)$$

$$\Delta H_3 \uparrow \qquad \qquad \uparrow \Delta H_1 = -835 \text{ kJ mol}^{-1}$$

$$Al^{3+}(g) + \frac{3}{4}O_2(g) + 3e^- \xleftarrow{\Delta H_2 = +5459 \text{ kJ mol}^{-1}} Al(s) + \frac{3}{4}O_2(g)$$
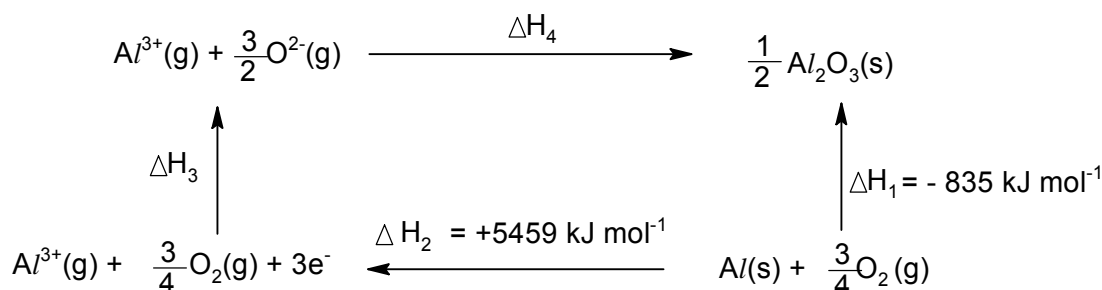
(i) What enthalpy change does ΔH_1 represent?

[1]

(ii) Explain what is meant by the term *enthalpy change of formation, ΔH_f, of $O^{2-}(g)$*.

Given that ΔH_f of $O^{2-}(g)$ is $+950$ kJ mol^{-1}, calculate ΔH_3.

[2]

(iii) Hence, use the above cycle and Hess' Law to calculate ΔH_4,

[1]

(iv) Construct a reaction pathway diagram for the reaction below, showing clearly the activation energy and the enthalpy change of the reaction.

$$Al(s) + \frac{3}{4}O_2(g) \longrightarrow \frac{1}{2}Al_2O_3(s) \quad \Delta H_1 = -835 \text{ kJ mol}^{-1} \quad E_a = +126 \text{ kJ mol}^{-1}$$

[2]

(v) Calculate the activation energy of the reverse reaction.

[1]

Most plant species tolerate the toxic effect of A*l* by forming stable complexes using an organic acid derivative, malate.

(c) Malate is formed when malic acid reacts with excess aqueous NaOH. Draw the displayed formula of malate.

$$HOOC-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle OH}{|}}{C}}-COOH$$

Malic acid

[2]

(d) Malic acid can be formed from ethene. CH_2BrCHO is one of the intermediates as seen in the reaction scheme below.

$$CH_2=CH_2 \xrightarrow{\text{ I }} A \xrightarrow{\text{ II }} CH_2BrCHO \xrightarrow{\text{ III }} \underset{C_3H_3NO}{B} \xrightarrow[\text{NaOH}]{\text{HCN}} C$$

$$\downarrow \text{ V}$$

$$HOOC-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle H}{|}}{C}}-\overset{\overset{\displaystyle H}{|}}{\underset{\underset{\displaystyle OH}{|}}{C}}-COOH$$

(i) Suggest an identity for compound **A**, **B** and **C**.

[3]

(ii) Suggest reagents and conditions for reaction **I, II**, **III** and **V**.

[4]
[Total: 20]

3 Ascorbic acid, better known as vitamin C, is a vitamin found in food and used as a dietary supplement. As a supplement, it is used to treat and prevent scurvy. It is known to be water soluble.

The building block for ascorbic acid is the glucose molecule. The proposed synthetic pathway is shown below.

Glucose → Intermediate product 1 → Intermediate product 2 → Ascorbic Acid
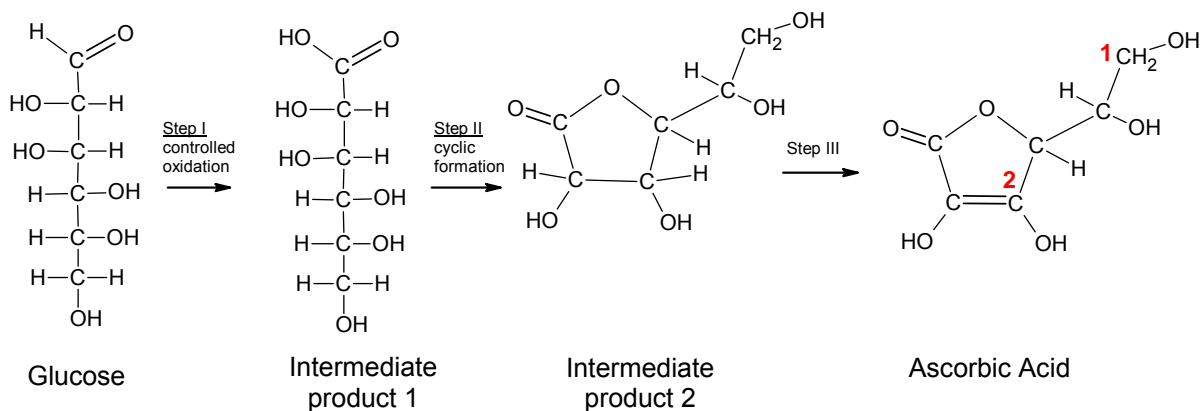
(a) **(i)** Name the functional groups present in intermediate product 2.

[1]

(ii) State the type of reaction found in **step II** and hence, copy *intermediate product 1* and **circle** the functional group(s) that is/are involved in the reaction.

[2]

(iii) With reference to structure and bonding, explain why ascorbic acid is soluble in water.

[2]

(iv) Predict, with reason, the relative solubility of ascorbic acid and glucose.

[1]

(v) The ascorbic acid molecule was heated with acidified potassium dichromate (VI) to form the compound shown below.
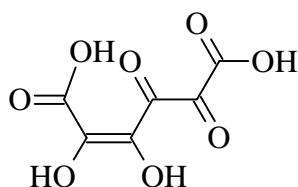
It was then reacted with hydrazine, $H_2N=NH_2$, which reacts in a similar way to 2,4–dinitrophenylhydrazine.

Draw the structural formula of the product formed upon reaction with hydrazine.

[1]

(vi) Write a balanced equation for the reaction between one mole of intermediate product 1 and excess PCl_5.

[1]

(vii) For each of C_1 and C_2 of ascorbic acid, state

    I type of hybridisation
    II shape
    III no. of σ and π bonds

[3]

(b) Vitamin C and K are both important nutrients with many health benefits. The structure of Vitamin K is shown below.
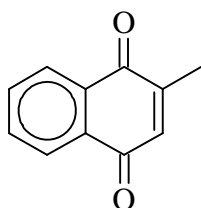
Vitamin K

Compound **A** ($C_{11}H_8O_2$) is a constitutional isomer of Vitamin K.
Compound **A** gives a yellow precipitate with alkaline aqueous iodine. When treated with
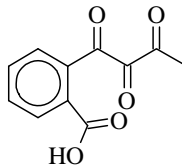
hot acidified KMnO$_4$, the product   HO   is formed. One mole of compound **A** also reacts with one mole of bromine in tetrachloromethane but does not react with Na.

Compound **B** is formed when HC*l*(g) is added to compound **A**. Compound **B** is heated with aqueous NaOH to give compound **C**. Compound **C** does not react with acidified $K_2Cr_2O_7$.

Suggest the structures for **A**-**C**, and explain the observations described above.

[9]

18

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Dunman High School
2017 Year 6 H1 Chemistry (8872) Preliminary Examination
Paper 2

Section A

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

1 **(a)** **(i)** Average titre value = (10.05 + 9.95) / 2
$$= 10.00 \text{ cm}^3$$

(ii) Amount of nitric acid = (10.0/1000) / 1 = 0.01 mol
Since $VO_2^+ \equiv V^{2+}$,
Amount of V^{2+} in 25.0 cm^3 = 25/250 x 0.60 x 250/1000
$$= 0.015 \text{ mol}$$
Mole ratio of V^{2+}: NO_3^- = 0.015 : 0.01
$$= 3 : 2$$

(iii) Let final oxidation state of vanadium be x.
$$NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$$
$$V^{2+} \rightarrow V^{x+} + (x-2)e^-$$
Since V^{2+}: NO_3^- = 3 : 2,
$$6 = 3(x-2)$$
$$x = +4$$

Final oxidation product: VO^{2+}
Colour of solution: Blue

(iv) $NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$

$3V^{2+} + 2NO_3^- + 2H^+ \rightarrow 3VO^{2+} + 2NO + H_2O$

(b)

delocalised electrons
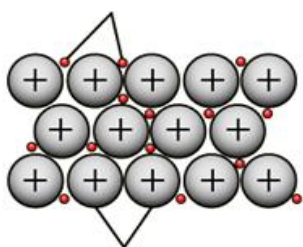
vanadium ions

Metallic bonding is present in vanadium where there is electrostatic forces of attraction between vanadium ions and the delocalised sea of electrons.

(c) **(i)** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1$

(ii)

2p   **3p**
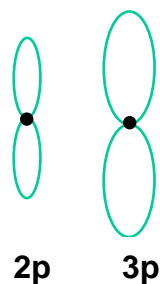
(iii) −15.9°

(iv)
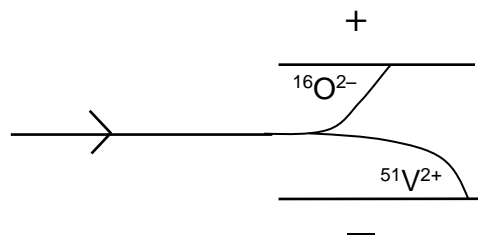
2 (a) (i) Combustion of coal.

(ii) $H_2O(g)$ or water vapour.

(iii) NO_x is likely formed from reaction of oxygen and nitrogen in the air at high temperatures during combustion of coal.

(b) $SO_2 + CaCO_3 \rightarrow CaSO_3 + CO_2$

$CaSO_3 + \frac{1}{2} O_2 \rightarrow CaSO_4$

(c) Mass of SO_2 that could be removed in FGD plant depends on mass of $CaCO_3$ used.

Moles of $CaCO_3$ used = $2.5 \times 10^5 \times 10^6 / 100.1 = 2.4975 \times 10^9$ mol
Maximum moles of SO_2 can be removed = Moles of $CaCO_3$ used

Maximum mass of SO_2 = $2.4975 \times 10^9 \times 64.1$
$= 1.60 \times 10^{11}$ g or 1.60×10^8 kg or 1.60×10^5 t

(d)
Mass of SO_2 in flue gases 5 year = $(1.6009 \times 10^{11}$ g $\times 0.10/0.90) \times 5$
$= 8.89 \times 10^{10}$ g or 8.89×10^7 kg or 8.89×10^4 t

(e) Magnesium oxide is basic and can undergo acid-base reaction with (acidic) sulfur dioxide.

(f) **(i)**

oxides	$\left|\dfrac{q_+q_-}{r_++r_-}\right|$
MgO	19.5
Na$_2$O	8.5
CaO	16.7

(ii) $\left|\dfrac{q_+q_-}{r_++r_-}\right|$: MgO > CaO > Na$_2$O

Magnitude of lattice energy (given by $\left|\dfrac{q_+q_-}{r_++r_-}\right|$) : MgO > CaO > Na$_2$O

Ionic bond strength of metal oxides: MgO > CaO > Na$_2$O

Amount of energy to overcome ionic bonds in oxide: MgO > CaO > Na$_2$O
∴ melting point: MgO > CaO > Na$_2$O

(iii)

oxides	pH of resulting solution
MgO	9
Na$_2$O	13
CaO	10 pH of MgO < pH < pH of Na$_2$O

CaO has a less exothermic/ lower magnitude of lattice energy than MgO. Thus, CaO should be more soluble than MgO and so giving a higher concentration of OH$^-$ ions when oxide is added to water. pH of the resulting solution of CaO is between that of Na$_2$O and MgO.

(g) When SO$_2$ is absorbed in the water, it will react with water and oxygen to from sulfate and H$^+$ ions. The presence of HCO$_3^-$ in the seawater will remove H$^+$ ions, causing a decrease in [H$^+$]. This will shift the position of equilibrium (1) to the right, removing SO$_2$.
OR
When SO$_2$ is absorbed in the water, it will react with water and oxygen to from sulfate and H$^+$ ions. The presence of HCO$_3^-$ in the seawater will remove H$^+$ ions as CO$_2$, which will escape into the atmosphere. This will shift the position of equilibrium (2) forward, which in turn shifts the position of equilibrium (1) to the right , removing SO$_2$.

3 (a) (i)

	2SO₂(g) +	O₂(g) ⇌	2SO₃(g)
initial moles / mol	69.2	34.6	0
change in moles / mol	− 65.6	− 32.8	+ 65.6
moles at eqm / mol	3.6	1.8	65.6
conc at eqm / mol dm⁻³	1.8	0.9	32.8

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

$$= \frac{(32.8)^2}{(1.8)^2(0.9)}$$

$$= 368.94$$

$$= 369 \text{ mol}^{-1} \text{ dm}^3$$

(ii)

For 99% SO_2 to be converted to SO_3, it means that 1% SO_2 remains.

$$\frac{[SO_3]}{[SO_2]} = \frac{99}{1}$$

Hence, $K_c = 368.94 = \left(\frac{99}{1}\right)^2 \frac{1}{[O_2]}$

$$[O_2] = 26.565$$

$$= 26.6 \text{ mol dm}^{-3}$$

(iii) When a catalyst is present,
- number of reactant particles with at least the activation energy (E$_a$'$_{(cat)}$) increases
- number of effective collisions per unit time taking place in the reaction increases. Rate of reaction is proportional to the frequency of effective collisions.
  Hence, rate of reaction increases.

(iv)
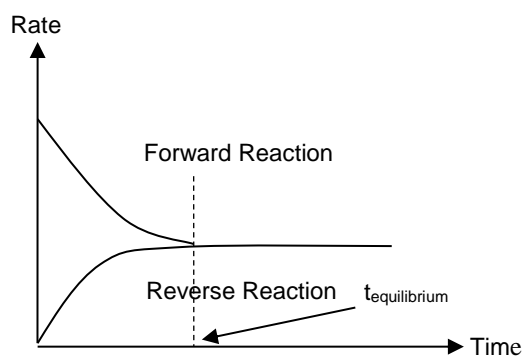
(b) (i)
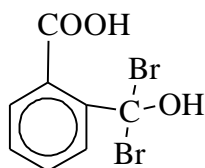
(ii) Add an equal volume of NaOH(aq) to RX and heat (in a water bath). Cool the mixture and add excess aqueous HNO_3. Finally, add aqueous $AgNO_3$.

For compound W: cream AgBr precipitate was obtained
For compound X: yellow AgI precipitate was obtained

(iii)

Isomer formed via Condition 1	

Isomer formed via Condition 2	
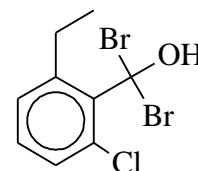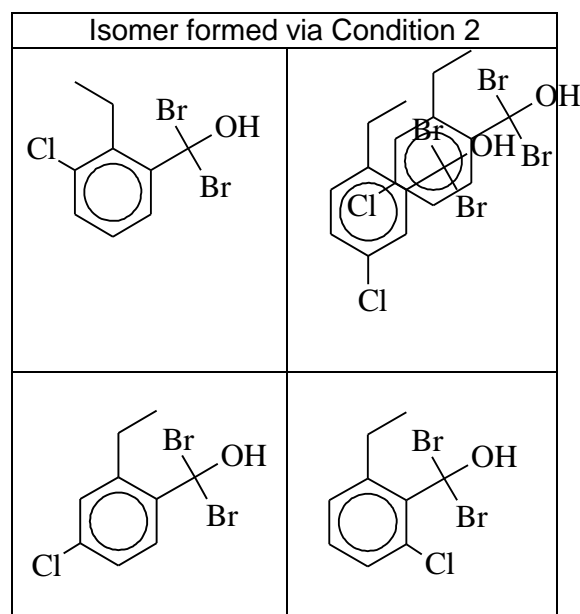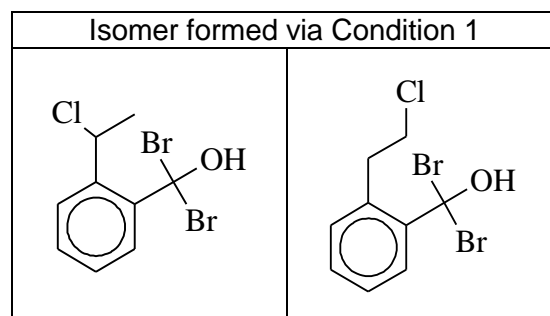
Condition 1
Reagent: limited Cl_2(g)
Conditions: uv light or high temperature

Section B

1 (a) (i) *Order of reaction* is the power to which the concentration of that reactant is raised in the rate equation.

(ii) Order w.r.t O_2 is zero as the graph of $[O_2]$ against time is a downward sloping straight line / the gradient of the line i.e. rate of reaction is constant with changing $[O_2]$.

When $[SO_2]$ = 0.80 mol dm^{-3},

r_1, rate of reaction = $\left| \dfrac{0.04 - 0.05}{88} \right|$ = 1.13 x 10^{-4}

When $[SO_2]$ = 1.20 mol dm^{-3},

r_2, rate of reaction = $\left| \dfrac{0.030 - 0.05}{80} \right|$ = 2.50 x 10^{-4}

r_2/r_1 = 2.21 ≈ 2.25

When $[SO_2]$ x 1.5 times, rate of reaction x 2.25 times, reaction is second order w.r.t SO_2.

(iii) rate = $k[SO_2]^2$
When $[SO_2]$ = 0.8 mol dm^{-3},
k = 1.77 x 10^{-4} mol^{-1} dm^3 s^{-1}

(k = 1.74 x 10^{-4} if $[SO_2]$ = 1.2 mol dm^{-3})

(iii) $[SO_2]$ / mol dm^{-3}
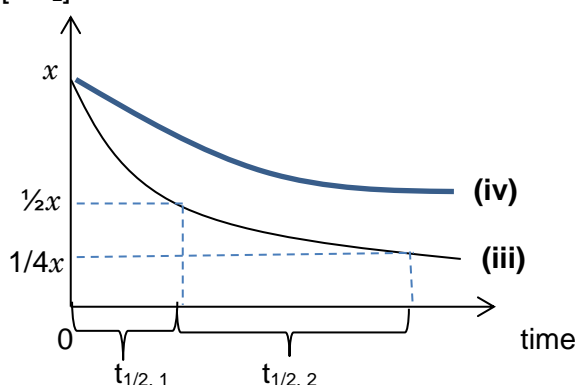
(b) Weak base is one which **dissociates partially** in water to **give hydroxide ions**.

(c)

$$K_b = \frac{\left\lfloor CH_3CH_2NH_3^+ \right\rfloor \left\lfloor OH^- \right\rfloor}{\left[CH_3CH_2NH_2 \right]} \text{ mol dm}^{-3}$$

(d) (i) $[H^+]$ = 0.20 mol dm^{-3}
pH = $-\lg(0.20)$
= 0.699

(ii) $2CH_3CH_2NH_2 + H_2SO_4 \rightarrow (CH_3CH_2NH_3^+)_2SO_4^{2-}$
amount of sulfuric acid = 10.0/1000 x 0.1
= 0.001 mol
amount of $CH_3CH_2NH_2$ = 0.002 mol
equivalence volume = 0.002 / 0.10
= 20.0 cm^3

(iii)
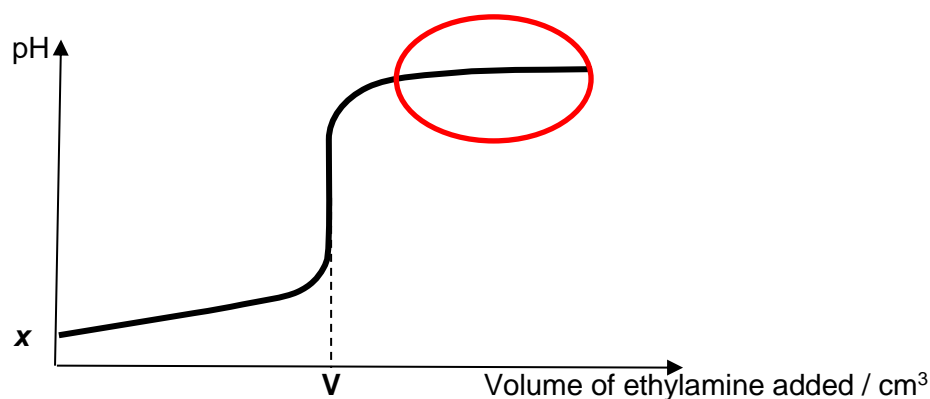
(iv) This is a strong acid–weak base titration and hence the salt is acidic.
Bromocresol green will be a suitable indicator as the pH transition range of the indicator lies within the rapid pH change over the equivalence point.
Colour change at the end-point will be yellow to green/blue.

(e) $CH_3CH_2CH=CHCOOH$
CH_3CH_2COOH
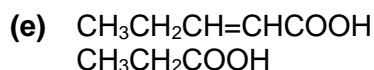
(f) 3–hydroxypentanoic acid is a stronger acid than pentanoic acid.
–OH, hydroxyl group is electron–withdrawing and hence disperse the negative charge of the conjugate base. This stabilises the conjugate base and makes 3–hydroxypentanoic acid a stronger acid.

2 (a) (i) Al_2O_3 is insoluble in water. Hence bioavailability of Al^{3+} is not increased in solution

(ii) $AlCl_3$ undergoes hydrolysis to give an acidic solution.

The high charge density of hydrated Al^{3+} ion enables it to attract electrons away from one of its surrounding water molecules, thereby polarising or weakening the O–H bond which results in the release of a proton.

$$[Al(H_2O)_6]^{3+} \rightleftharpoons [Al(H_2O)_5(OH)]^{2+} + H^+$$

(b) (i) Enthalpy change of combustion of Al or ½ $\Delta H_f (Al_2O_3)$

(ii) Enthalpy change of formation is the energy change when 1 mol of $O^{2-}(g)$ is formed from $O_2 (g)$.

$$\Delta H_3 = 950 \times \frac{3}{2}$$
$$= + 1.43 \times 10^3 \text{ kJ mol}^{-1}$$

(iii) $\Delta H_4 = -\Delta H_3 - \Delta H_2 + \Delta H_1$
$$= - (1.43 \times 10^3) - (5459) - 835$$
$$= - 7.72 \times 10^3 \text{ kJ mol}^{-1}$$

(iv)

Energy / kJ mol^{-1} (y-axis), Progress of reaction (x-axis)

$Al(s) + \frac{3}{4} O_2(g)$

$E_a = 126$ kJ mol^{-1}

$\Delta H_1 = -835$ kJ mol^{-1}

$\frac{1}{2} Al_2O_3 (s)$
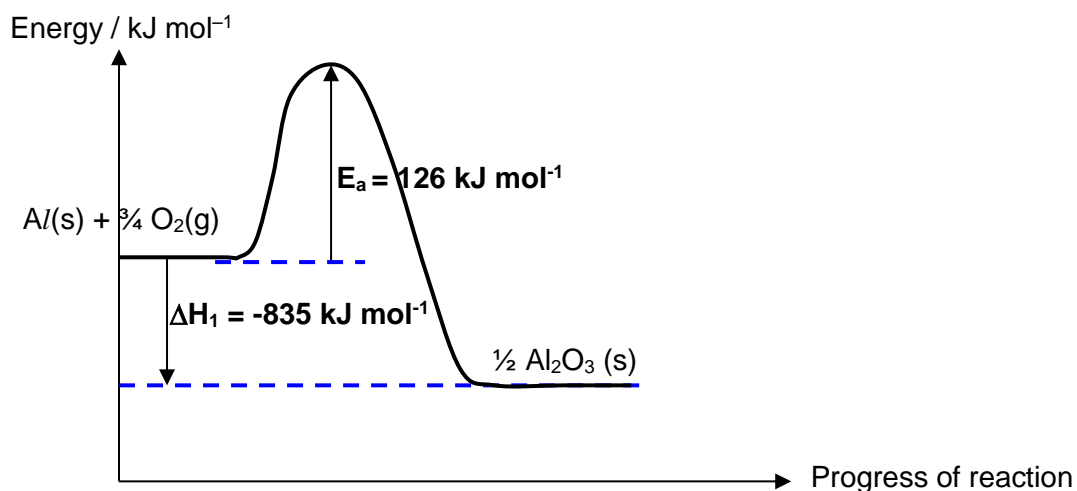
(v) Activation energy of the reverse reaction = 835 + 126
= 961 kJ mol^{-1}

(c)

(d) **(i)**

A   B   C
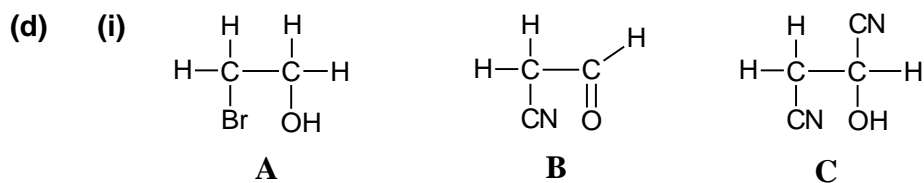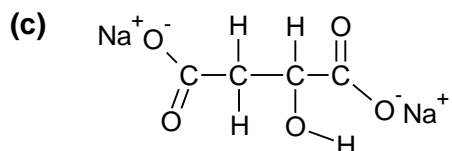
(ii) Reaction I – aqueous bromine
Reaction II – $K_2Cr_2O_7$ in dilute H_2SO_4, heat with immediate distillation
Reaction III – KCN in ethanol, heat under reflux
Reaction V – dilute H_2SO_4, heat under reflux

**3** **(a)** **(i)** Alcohol and ester.

(ii) Condensation.
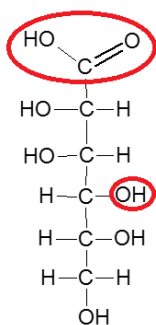
(iii) Ascorbic acid has a simple molecular structure. The hydrogen bonds formed between ascorbic acid and water molecules releases sufficient energy to overcome the intermolecular hydrogen bonding between ascorbic acid and also between water.

(iv) Glucose is more soluble in water than ascorbic acid as there are more alcohol groups available to form more extensive hydrogen bonds with water.
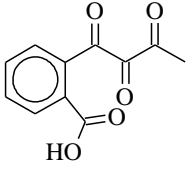
(v)

(vi)

$+ 6PCl_5 \rightarrow CH_2Cl(CHCl)_4COCl + 6HCl + 6POCl_3$
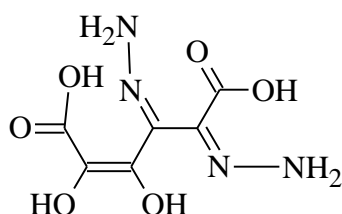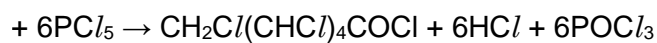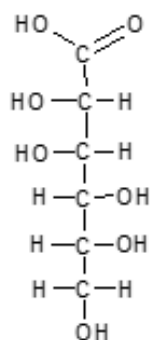
(vii)

Carbon atom	Type of hybridisation	Shape	No. of σ and π bonds
C_1	sp^3 hybridised	tetrahedral	4σ bonds
C_2	sp^2 hybridised	trigonal planar	3σ and 1π bonds

(b)

Observations	Deductions
Compound **A** gives a yellow precipitate with alkaline aqueous iodine.	• Compound **A** undergoes oxidation. ⇒ either –COCH₃ or –CH(OH)CH₃ present.
When treated with hot concentrated KMnO₄, the product ![structure] HO is formed.	• Compound **A** undergoes oxidation. ⇒ Alkene is present. ⇒ Secondary alcohol may be present.
One mole of Compound **A** also reacts with one mole of bromine in tetrachloromethane	• Compound **A** undergoes (electrophilic) addition. ⇒ One C=C bond is present.
but does not react with Na.	• Compound **A** does not undergo acid–metal displacement / redox with Na. ⇒ no alcohol, or carboxylic acid present.
Compound **B** is formed when HC*l*(g) is added to Compound **A**.	• Compound **A** undergoes (electrophilic) addition. ⇒ Alkene is present. ⇒ Compound B is a chloroalkane.
When Compound **B** is heated with aqueous NaOH, followed by aqueous AgNO₃, Compound **C** and a white precipitate is formed.	• Compound **B** undergoes (nucleophilic) substitution. ⇒ Alcohol present in Compound **C**.
Compound **C** does not react with acidified K₂Cr₂O₇.	• Compound **C** does not undergo oxidation. ⇒ Tertiary alcohol present in Compound **C**.

Compound **A**	Compound **B**	Compound **C**