TAMPINES MERIDIAN JUNIOR COLLEGE

JC2 PRELIMINARY EXAMINATION

CANDIDATE NAME	
CIVICS GROUP	

H2 CHEMISTRY **9729/02**

Paper 2 Structured Questions **18 September 2025**

2 hours

Candidates answer on the Question Paper.

Additional materials: *Data Booklet*

READ THESE INSTRUCTIONS FIRST

Write your name and civics group in the spaces at the top of this page.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams and graphs.

Do not use paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the Question Paper.

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

A Data Booklet is provided.

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

For Examiner's Use	
1	**/ 7**
2	**/ 16**
3	**/ 11**
4	**/ 12**
5	**/ 16**
6	**/ 13**
Total	**/ 75**

1(a) The graph in Fig. 1.1 shows the atomic radii of some Period 4 metals.

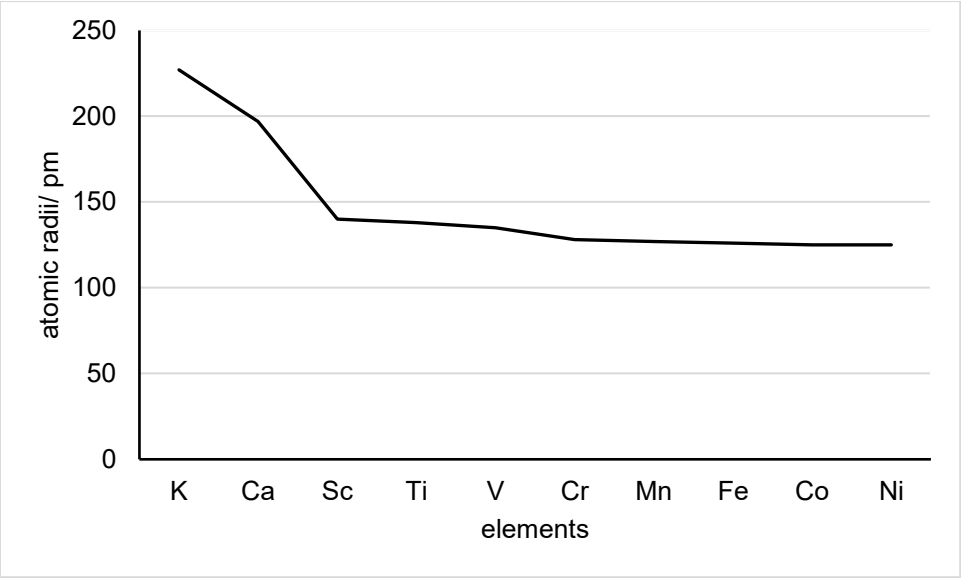


Fig. 1.1

(i) With reference to Fig. 1.1, explain briefly why the atomic radius of Ca is smaller than K.

.....

.....

.....

..... [1]

(ii) With reference to Fig. 1.1, describe and explain why the atomic radii from Cr to Ni are relatively constant.

.....

.....

.....

.....

.....

..... [2]

(b) (i) Shibuichi is an alloy of copper and silver and is used in traditional Japanese sword fittings. A particular sample of Shibuichi produced the following peaks in its mass spectrum as shown in Fig. 1.2.

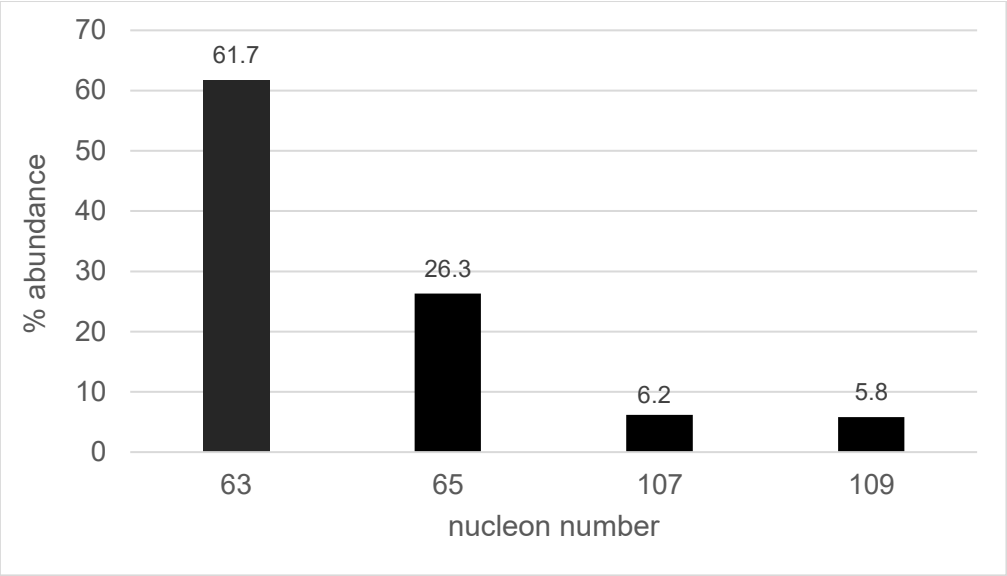


Fig. 1.2

Calculate the average A_r of copper from these data. [1]

(ii) With reference to Fig. 1.2, state the number of protons and neutrons present in the atom with nucleon number 109.

Number of protons: _____

Number of neutrons: _____

[1]

[Turn Over

(c) Table 1.2 shows the successive ionisation energies of element **B**.

Table 1.2

	1st	2nd	3rd	4th	5th	6th	7th	8th
I.E. / kJ mol^{-1}	900	1800	3250	4900	6050	12690	14200	16250

(i) State which group does element **B** belongs to.

.....[1]

(ii) Both element **A** and element **B** are consecutive elements in the Periodic Table and that element **A** is positioned to the left of element **B**.

Explain why the 3rd ionisation energy of element **B** is lower than element **A**.

.....

.....

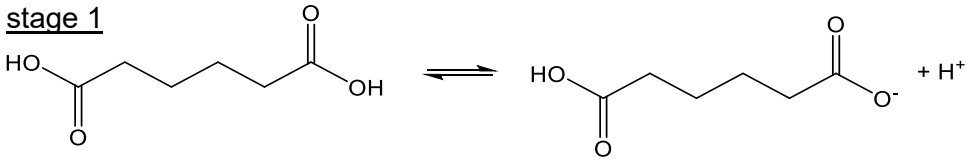
.....

.....[1]

[Total: 7]

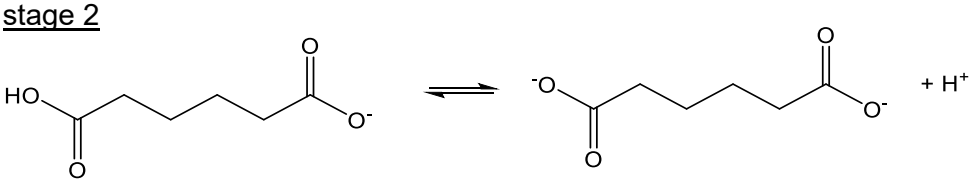
2 Adipic acid, $HOOC(CH_2)_4COOH$, is a flexible food additive used as a gelling aid, firming and buffering agent and can be found in many foods. It is a dibasic acid that ionises in 2 stages.

stage 1



K_{a1}= 3.72 x 10^{-5}

stage 2



K_{a2}= 3.89 x 10^{-6}

(a) **(i)** Write an expression for the first acid dissociation constant of adipic acid, K_{a1}.

[1]

(ii) Suggest a reason why the value of K_{a2} is lower than that of K_{a1}.

.....

.....

..... [1]

A mixture of adipic acid and its potassium salt can function as a buffer.

(iii) With the aid of a chemical equation, briefly explain how this mixture can act as a buffer when a small amount of base is added.

The effects of K_{a2} can be ignored in any buffer action.

.....

.....

.....

..... [2]

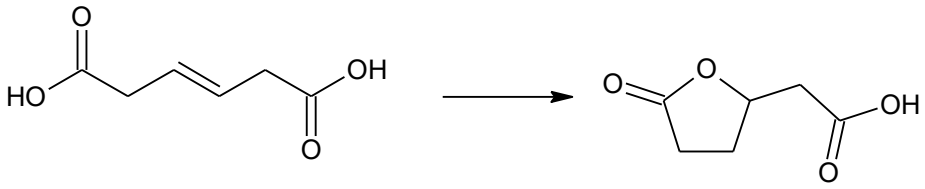
[Turn Over

(iv) Determine the volume of 0.200 mol dm^{-3} KOH(aq) that needs to be added to 100 cm^3 of 0.200 mol dm^{-3} adipic acid to form a buffer of pH 4.7.

[2]

3-hexenedioic acid can be converted to adipic acid and 3-bromohexanedioic acid which serve as precursors or intermediates for organic synthesis.

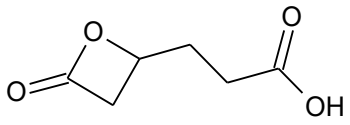
(b) **(i)** Propose a 2-step reaction synthesis to convert 3-hexenedioic acid to **D**. Show clearly all reagents and conditions and the structures of intermediates for each step.



3-hexenedioic acid **D**

[3]

(ii) Another possible product that could be produced from the synthesis method in **(i)** is shown below. Suggest why **D** is more likely to be formed than **E**.



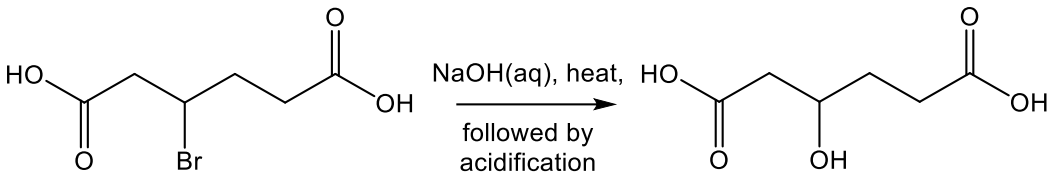
E

.....

.....

..... [1]

(c) A sample of 3-bromohexanedioic acid was able to rotate plane polarised light. After reacting with hot NaOH(aq) followed by acidification, the product obtained was no longer able to rotate plane polarised light. The reaction between 3-bromohexanedioic acid and NaOH(aq) is shown in the equation below.



(i) Describe the mechanism for the reaction between 3-bromohexanedioic acid and NaOH(aq). Include all relevant lone pairs, dipoles, curly arrows and charges.

[3]

[Turn Over

(ii) State the type of isomerism displayed by the products of the above reaction.

..... [1]

(iii) Draw the isomers produced in the above reaction.

[2]

[Total: 16]

3(a) Chlorate(V), ClO_3^-, reacts with chloride ions according to the equation as shown below.

$$2ClO_3^-(aq) + 2Cl^-(aq) + 4H^+(aq) \longrightarrow Cl_2(g) + 2ClO_2(aq) + 2H_2O(l)$$

An experiment was conducted using a mixture in which the concentrations of the reactants are as follows: 4.80×10^{-4} mol dm^{-3} of ClO_3^-, 0.1 mol dm^{-3} of Cl^- and 0.4 mol dm^{-3} of H^+.

At five-minute intervals, small samples of the reaction mixture were withdrawn, quenched and placed into the UV–vis spectrometer to record its absorbance value. The absorbance value corresponds to the concentration of the product ClO_2.

The graph of absorbance against time is shown in Fig. 3.1.

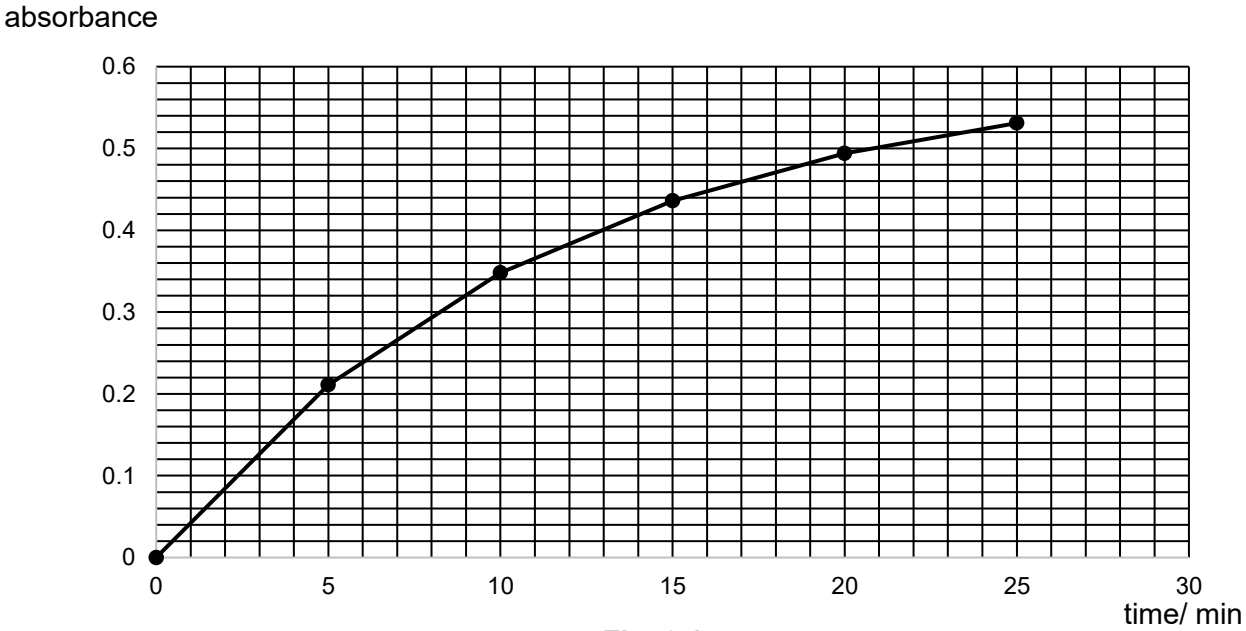


Fig. 3.1

(i) Beer-Lambert's Law states that the absorbance values is directly proportional to the concentration of absorbing species, c, as shown below.

$$A = \varepsilon c l$$

where ε is the molar extinction coefficient and l is the path length, which is usually 1.0 cm.

This equation can be used to calculate the absorbance value when maximum amount of ClO_2 was formed.

Calculate the concentration of ClO_2 in the reaction mixture. Show that the maximum absorbance value of the reaction is 0.600, given that ε of ClO_2 is 1250 mol^{-1} dm^3 cm^{-1}.

[2]

[Turn Over

(ii) With reference to Fig. 3.1, show that the reaction is first order with respect to ClO_3^-. Draw clearly any construction lines on the graph.

.....

.....

..... [2]

(iii) Another experiment was carried out using 2.40×10^{-4} mol dm^{-3} of ClO_3^- while keeping concentration of Cl^- and H^+ the same.

Deduce the half–life of ClO_3^- in this experiment.

.....

..... [1]

(b) A series of experiments were carried out to investigate the order of reaction with respect to H^+. The results are shown in Table 3.2.

Table 3.2

Experiment	$[ClO_3^-]$ / mol dm^{-3}	$[Cl^-]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.050	0.100	0.300	3.38×10^{-4}
2	0.100	0.100	0.100	7.50×10^{-5}

(i) Using the information in Table 3.2, determine the order of reaction with respect to H^+.

[2]

(ii) The rate of reaction was measured using different initial $[H^+]$ and keeping $[ClO_3^-]$ and $[Cl^-]$ constant. Sketch the graph of rate against initial $[H^+]$ in Fig. 3.3.

Fig. 3.3

[1]

(iii) Explain, with the aid of a labelled Boltzmann distribution diagram, the effect on a rate constant of increasing temperature.

.....

.....

.....

..... [2]

[Turn Over

(iv) The reaction between ClO_3^- and Cl^- can take place in the presence of Mn^{2+} catalyst. The five d orbitals in Mn^{2+} ion are degenerated but split into two levels when it is in an octahedral complex.

Sketch and label one d orbitals that is found in the higher energy level.

[1]

[Total: 11]

4(a) Compounds **V** and **W** both have molecular formula $C_5H_{10}O_2$. **V** has 2 chiral centres whereas **W** has none.

Table 4.1 shows the observations that occurred when separate samples of **V** and **W** were added to different reagents under specific conditions in two separate tests.

Table 4.1

test	reagents and conditions	observations with **V**	observations with **W**
1	heat with acidified $KMnO_4$(aq)	mixture changes from purple to colourless single organic product made that • forms an orange precipitate with 2,4-dinitrophenylhydrazine • forms effervescence with Na_2CO_3(aq)	no change
2	heat with alkaline I_2(aq)	pale yellow precipitate forms	pale yellow precipitate forms

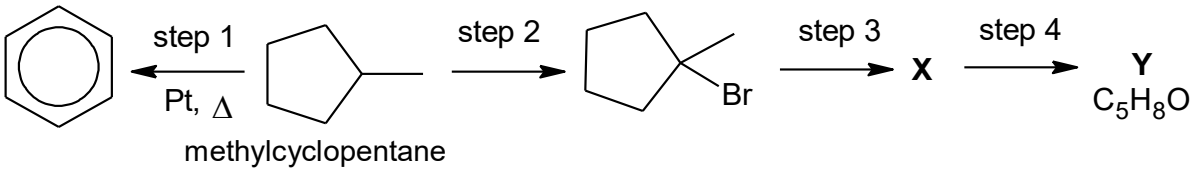
Draw a structure for **V** and for **W**.

V

W

[2]

(b) The following flowchart shows reactions of methylcyclopentane.



(i) In Step 1, methylcyclopentane is converted into benzene for the production of gasoline from petroleum. Suggest the type of reaction in step 1.

..... [1]

[Turn Over

(ii) Name and describe the mechanism in step 2.

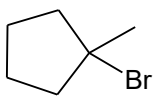
[3]

(iii) Other than the product shown in step 2, three other mono-substituted bromo-alkanes can also be formed in step 2.

Complete Table 4.2 with

- the structures of the three other bromo-alkanes.
- the expected ratio in which the four bromo-alkanes will be formed.

Table 4.2

Bromo -alkane				
Ratio				

[2]

(iv) Given that **Y** reacts with 2,4–DNPH, draw the structures of **X** and **Y**. Suggest the reagents and conditions for steps 3 and 4.

X

Y

	reagents and conditions
step 3	
step 4	

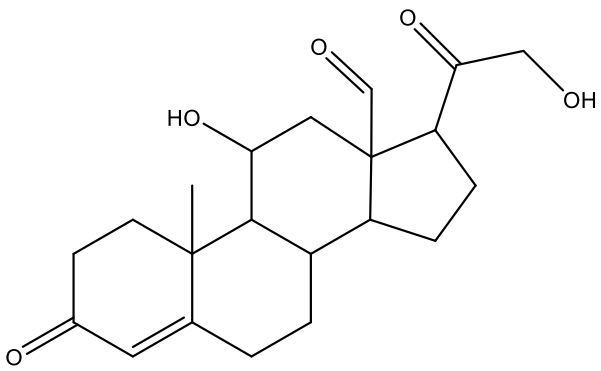
[4]

[Total: 12]

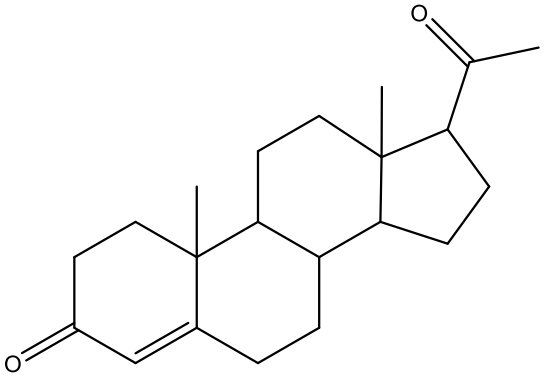
[Turn Over

5 Steroids are a class of natural or synthetic organic compounds characterised by a molecular structure of 17 carbon atoms arranged in four rings. Natural-occurring steroids are found in hormones in living organisms while synthetic steroids have anti-inflammatory properties.

(a) The chemical structures of some of the naturally occurring steroids are shown below.



aldosterone



progesterone

(i) Identify all functional groups found in aldosterone

.....[2]

(ii) Describe a chemical test that can be performed to distinguish between aldosterone and progesterone.

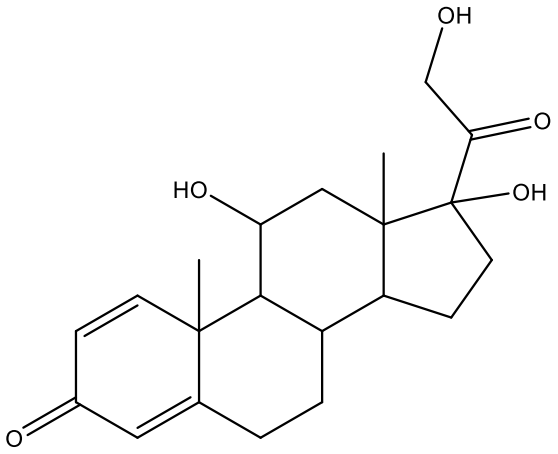
.....

.....

.....

.....[2]

Another steroid prednisolone (M*r* = 360.4) is a medicine used to treat allergies, blood disorders and inflammation. However, prolonged use of prednisolone comes with side-effects like fatigue and mood swings.



prednisolone

Prednisolone tends to be more fat-soluble than water soluble. When a medicine, such as prednisolone, is not very soluble in blood stream, it will have a low bioavailability, which gives a low efficiency. Bioavailability is defined as the percentage of the administered drug that reaches the blood circulation system. To increase the bioavailability of predinisolone, it is micronised into a smaller size than a conventional drug particle. On average, micronized prednisolone has a bioavailability of 86%.

The prescription of prednisolone depends on the severity of the patient's condition and body weight. The maximum intake of prednisolone each day should not exceed 0.5 mg per kg of the body weight of the patient. [1 mg = 0.001 g]

(b) A patient who weighs 60kg was put on a prednisolone course for four weeks. He was told to consume the maximum intake of prednisolone each day for the first week. This is what his prescription looked like on his medication packaging.

Tampines Meridian Clinic

Prescription:

First Week	**X** tablets each day, taken after breakfast
Second Week	4 tablets each day, taken after breakfast
Third Week	2 tablets each day, taken after breakfast
Fourth Week	1 tablet each day, taken after breakfast

Each tablet contains 5 mg of prednisolone.

[Turn Over

(i) Based on the information given, show that the number of tablets, **X**, the patient ingested each day during the first week is 6.

[1]

(ii) Taking into consideration the bioavailability of prednisolone, calculate the total amount of prednisolone that reaches the blood circulation system of the patient in the four weeks.

[2]

(iii) In theory, if two patients have the same body weight and severity of the same condition, suggest why the patient who has higher percentage of body fat will require a higher dosage of prednisolone.

.....

.....

..... [1]

(iv) Suggest why micronising a medicine into particles with a smaller size can increase its bioavailability and lead to higher efficiency.

.....

.....

..... [1]

(c) The following Table 5.1 shows the solubility of prednisolone in some common solvents.

Table 5.1

solvent	solubility of prednisolone
water	sparingly soluble
ethanol	soluble

(i) By considering all types of interactions between the solute and solvent, explain why ethanol is a better solvent than water to dissolve prednisolone.

.....

.....

.....

..... [2]

(ii) Another way to increase the solubility of prednisolone in water is to synthesise prednisolone as prednisolone phosphate salt without compromising its anti-inflammatory property.

Using Fig. 5.1, illustrate how a water molecule interacts with the prednisolone phosphate ion to increase its solubility. Label the main type of interaction involved.

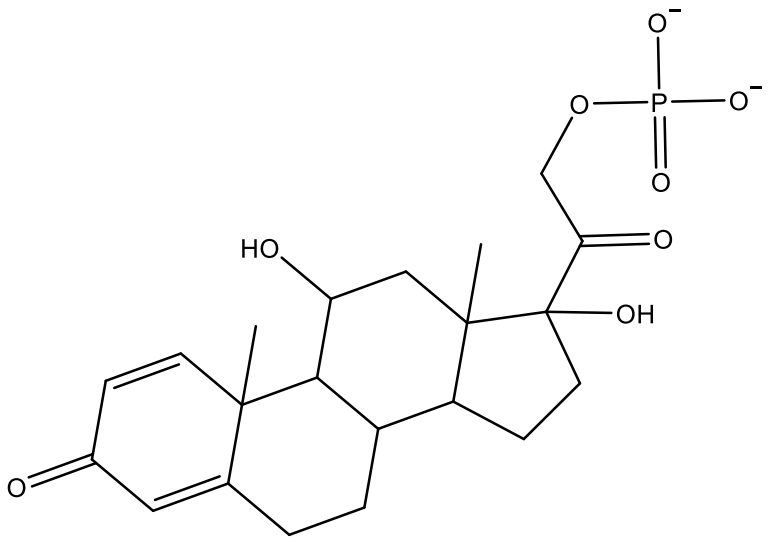


Fig. 5.1

[1]

[Turn Over

(d) The half-life of a drug refers to the amount of time it takes for the concentration of its active component in the body to decrease by 50%. A drug is generally regarded as eliminated from the body, with no remaining clinical effect, after 5.5 half-lives.

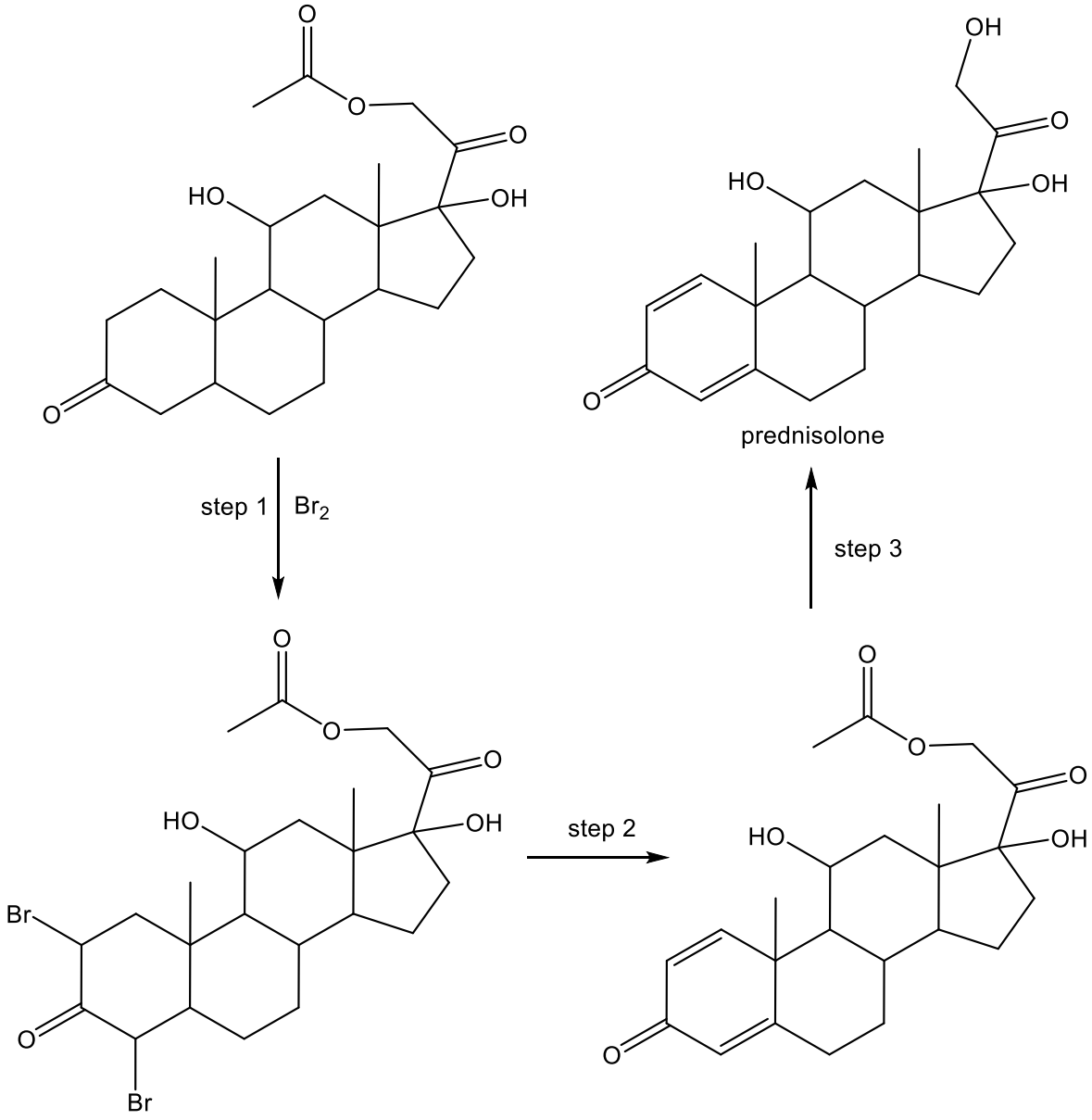
(i) Calculate the half-life of prednisolone given that the effect of prednisolone will last 16.5 hours after ingestion.

[1]

(ii) Calculate the percentage of prednisolone that remained in the body after 5.5 half-lives.

[1]

(e) The reaction scheme below shows the synthesis of prednisolone in the pharmaceutical industry.



Identify the type of reaction, and suggest the reagents and conditions required to achieve steps 2 and 3.

	reagents and conditions	type of reaction
step 2		
step 3		

[2]
[Total: 16]

[Turn Over

6 Dimethyl ether, CH_3OCH_3, is a colourless gas commonly used as a fuel, a spray and a refrigerant. It can react with carbon dioxide to produce carbon monoxide and hydrogen gas as shown in the equation below:

$$CH_3OCH_3(g) + CO_2(g) \rightleftharpoons 3CO(g) + 3H_2(g) \qquad \Delta H = +245 \text{ kJ mol}^{-1}$$

In an experiment, a mixture of CH_3OCH_3 and CO_2 was introduced into a 2500 dm^3 sealed vessel at 600 K and the initial total pressure was 15 atm. The reaction was allowed to reach dynamic equilibrium.

(a) **(i)** Explain what is meant by *dynamic equilibrium*.

.....

.....

..... [1]

(ii) Write an expression for the equilibrium constant, K_p, stating its units.

[2]

(iii) At equilibrium, the amount of H_2 was found to be 280 mol. Show that the equilibrium partial pressure of H_2 in the vessel was 5.5 atm.

[1]

(b) **(i)** It was found that 75% of the CH_3OCH_3 had dissociated at equilibrium at 600K. Calculate the equilibrium pressures of CH_3OCH_3 and CO_2 in atm.

[3]

(ii) Hence, calculate the value of K_p, for this reaction. Express your answer to 2 significant figures.

[1]

(c) **(i)** At constant temperature and volume, partial pressure of a gas is proportional to mole fraction. Hence, calculate the average M_r of the gaseous mixture at 600K.

[1]

[Turn Over

(ii) Explain the effect on the equilibrium position and the average M_r of the gaseous equilibrium mixture when the experiment was conducted at 700 K instead of 600 K.

.....

.....

.....

..... [2]

(d) A key property of an aerosol propellant is that it must exist as a gas under room temperature and pressure conditions.

The behaviour of 1 mol of ideal gas and 1 mol of CH_3OCH_3 at 293 K is shown in Fig. 6.1.

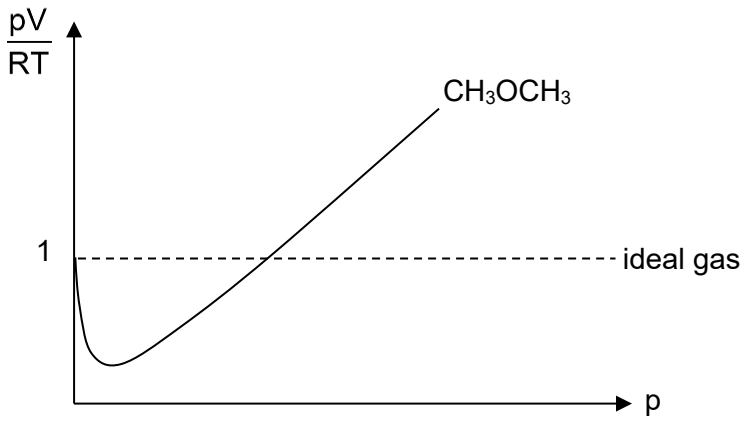


Fig. 6.1

On the **same** axes in Fig. 6.1, sketch and label the graph for 1 mol of CO_2 at 293 K. Explain your answer.

.....

.....

.....

.....

.....

..... [2]

[Total: 13]