1 Which of the following gives the largest number of moles of particles?

A ions in 0.5 dm^3 of 0.1 mol dm^{-3} NaOH(aq)

B IO_3^- ions in 0.2 dm^3 of 0.5 mol dm^{-3} $KH(IO_3)_2$

C molecules in 480 cm^3 of ClO_2(g) at room temperature and pressure

D atoms in 1.92 g of O_3

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

Which of the following statements are correct?

1 The second ionisation of any element is always higher than its first ionisation energy.

2 The ionic size for Na^+ is the same as Al^{3+} because they are isoelectronic.

3 The removal of the two electrons from Cr to form Cr^{2+} is from the 3d subshell.

4 An aluminium atom will require more energy to form a gaseous ion with the charge of +4 compared to a silicon atom.

A 1 only

B 1 and 3 only

C 1 and 4 only

D 1, 2, 3 and 4

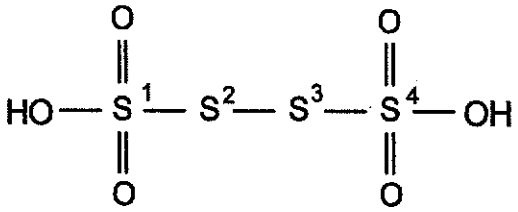
3 The table gives the successive ionisation energies for an element E in Period 4.

	1st	2nd	3rd	4th	5th	6th
Ionisation energy / kJ mol^{-1}	950	1800	2700	4800	6000	12300

What is the formula of the chloride of E?

A E*Cl* **B** ECl_2 **C** ECl_3 **D** ECl_4

4 Tetrathionic acid, $H_2S_4O_6$, has been used as an antidote in cyanide poisoning.



In tetrathionic acid, the oxidation number of hydrogen is +1 and oxygen is –2.

What could be the oxidation number of the four sulfur atoms?

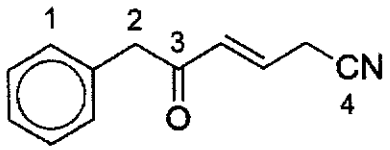
	S^1	S^2	S^3	S^4
A	+5	0	0	+5
B	+6	0	0	+6
C	+2	+2	+5	+5
D	+2	+2	+6	+6

5 Arsenic trioxide, As_2O_3, reacts with zinc in the presence of of a suitable acid. In this reaction, the oxidation number of zinc increases by 2 and the oxidation number of arsenic decreases by 6.

How many moles of zinc are needed to reduce 1 mole of As_2O_3 in this reaction?

A $\frac{1}{3}$ mol **B** $\frac{1}{6}$ mol **C** 3 mol **D** 6 mol

6 Consider the molecule,



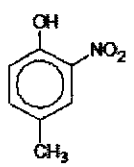
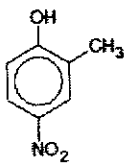
What is the hybridisation of each of the carbon atoms, C-1 to C-4?

	C-1	C-2	C-3	C-4
A	sp^2	sp^3	sp^2	sp
B	sp	sp^3	sp^2	sp^3
C	sp^2	sp^3	sp	sp^2
D	sp^3	sp^2	sp^2	sp

7 Which of the following **cannot** be explained by hydrogen bonding?

A The difference in the boiling points between water and ammonia.

B The difference in volatility between pentan-2-ol and octan-2-ol.

C The difference in boiling point between  and 

D The difference in the relative molecular mass of ethanoic acid molecules in benzene and in water.

8 Which of the following pairs consist of a planar molecule and a polar molecule?

A CH_2O and *cis*-$CH_3CH{=}CHCH_3$

B SO_3 and *trans*-$CH_3CH{=}CHCH_3$

C CH_3OCH_3 and CH_3CO_2H

D CH_3COCH_3 and CCl_4

9 Which of the following reactions resulted in an increase in the bond angle of the underlined substance?

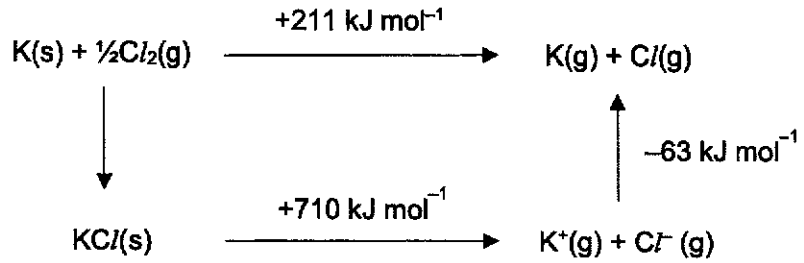
A $\underline{H_3O^+} + F^- \rightleftharpoons HF + \underline{H_2O}$

B $\underline{NaNH_2} + H_2O \longrightarrow NaOH + \underline{NH_3}$

C $\underline{BH_3} + NaH \longrightarrow \underline{NaBH_4}$

D $\underline{CO_2} + H_2O \rightleftharpoons 2H^+ + \underline{CO_3^{2-}}$

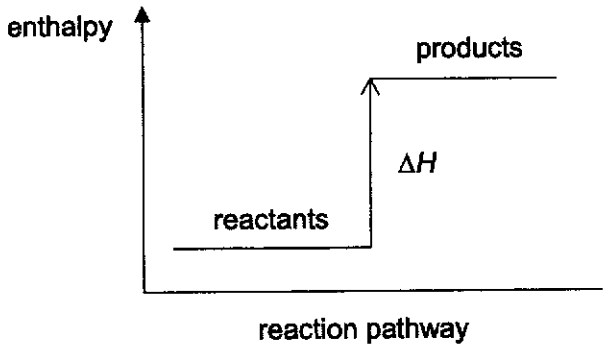
10 The enthalpy changes for some reactions are shown below.



Which of the following gives the correct signs of ΔH for the reactions?

	$K(s) + \frac{1}{2}Cl_2(g) \rightarrow KCl(s)$	$K^+(g) + Cl^-(g) \rightarrow K(s) + \frac{1}{2}Cl_2(g)$	$KCl(s) \rightarrow K(g) + Cl(g)$
A	–	+	+
B	–	–	+
C	+	–	–
D	+	+	–

11 Which enthalpy change could be correctly represented by the enthalpy diagram shown?



1 neutralisation

2 combustion

3 formation

A 1, 2 and 3

B 1 and 2

C 1 and 3

D 3 only

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

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

ΔH_1 $2NO_2(g) \rightarrow N_2O_4(g)$

ΔH_2 $CH_3(g) + Cl(g) \rightarrow CH_3Cl(g)$

ΔH_3 $CH_4(g) \rightarrow CH_3(g) + H(g)$

A $\Delta H_2 \rightarrow \Delta H_1 \rightarrow \Delta H_3$

B $\Delta H_3 \rightarrow \Delta H_1 \rightarrow \Delta H_2$

C $\Delta H_1 \rightarrow \Delta H_2 \rightarrow \Delta H_3$

D $\Delta H_1 \rightarrow \Delta H_3 \rightarrow \Delta H_2$

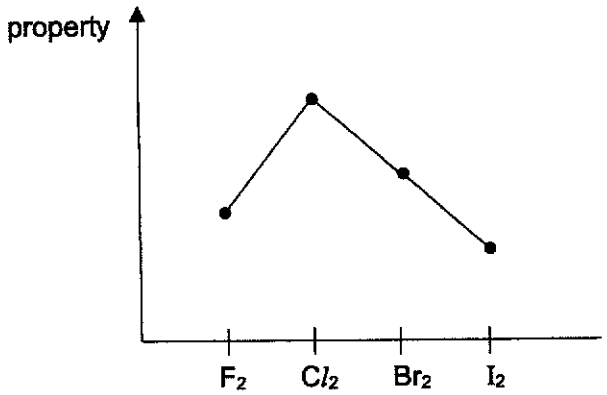
13 Element **X** is in Period 3 of the Periodic Table. After mixing 0.5 mol of the chloride of **X** with limited cold water, 1.0 mol of HCl was formed.

What is element **X**?

A Mg **B** Al **C** P **D** Si

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

The following shows the variation of a property of the halogen molecules.



What is the property?

A boiling point

B bond energy

C oxidising power

D intensity of colour

15 **X** is made up from two elements from Period 3 (excluding argon) of the Periodic Table. One of the elements has the highest melting point in the period. The other element has the smallest anion in the period.

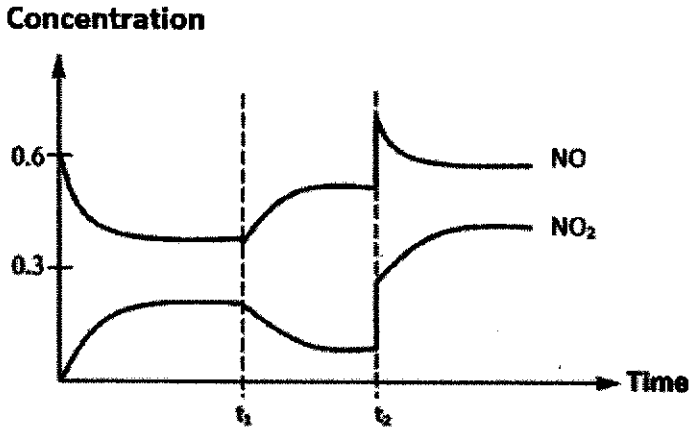
What is the formula of **X**?

A $AlCl_3$ **B** Al_2S_3 **C** $SiCl_4$ **D** SiS_2

16 At a temperature T K, 0.60 mol dm^{-3} of NO and 0.30 mol dm^{-3} of O_2 were introduced into a 2 dm^3 vessel and allowed to reach equilibrium.

$$2\,NO\,(g) + O_2\,(g) \rightleftharpoons 2NO_2\,(g) \qquad \Delta H < 0$$

The graph below shows the changes in the amounts of NO and NO_2 in the system with time. A change was made to the system at time, t_1 and t_2.



What were the changes made at time, t_1 and t_2?

	t_1	t_2
A	The temperature was increased	Volume of the system is increased
B	The temperature was decreased	More O_2 was added
C	An inert gas was added at constant volume	More NO_2 was added
D	The temperature was increased	Volume of the system is decreased

17 An equilibrium can be represented by the following equation:

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

The equilibrium concentration of CH_3COOH is found to be 10 mol dm^{-3}. At equilibrium, 5 moles of CH_3COOH is added to a 1 dm^3 mixture.

Which of the following statements are correct?

1 The value of equilibrium constant will increase.

2 The position of equilibrium will shift to the right.

3 The new equilibrium concentration of CH_3COOH will be less than 10 mol dm^{-3}

4 The new equilibrium concentration of CH_3COOH will be between 10 mol dm^{-3} and 15 mol dm^{-3}

A 1 and 2 only **B** 2 and 4 only **C** 1, 2 and 3 only **D** 1, 2 and 4 only

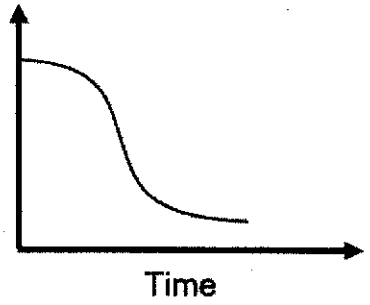
18 Nitrogen dioxide and methanoic acid reacted according to the equation below:

$$NO_2(g) + HCOOH(l) \rightarrow NO(g) + CO_2(g) + H_2O(l)$$

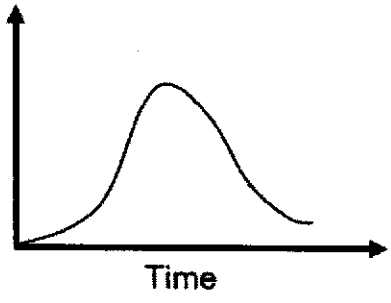
The progress of the reaction is monitored by the changes in concentration of NO_2. This reaction is unique as one of the products, NO, catalysed the reaction.

Which graph best describes the above reaction?

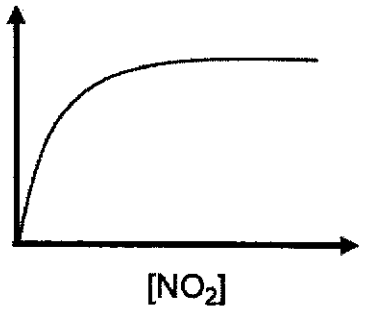
A



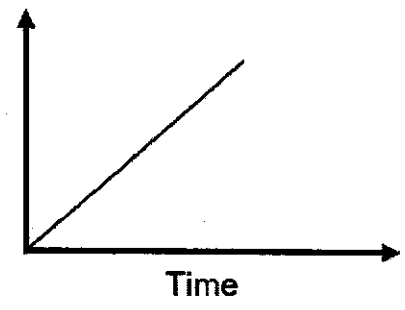
B



C



D



19 The amount of carbon dioxide dissolved in a fizzy drink is affected by the following reversible reaction.

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$$

The reaction of carbon dioxide with water to reach equilibrium with carbonic acid has been shown to have first order kinetics with a half-life of 0.030 s.

What is the time taken for the carbonic acid to reach 75% of its equilibrium concentration?

A 0.060 s

B 0.180 s

C 0.250 s

D 0.414 s

20 $Na_2S_2O_3$ reacts with dilute HC*l* to form a pale yellow precipitate.

If 1 cm^3 of 0.1 mol dm^{-3} HC*l* is added to 10 cm^3 of 0.02 mol dm^{-3} $Na_2S_2O_3$, the precipitate forms slowly. If the experiment is repeated with 1 cm^3 of 0.1 mol dm^{-3} HC*l* and 10 cm^3 of 0.05 mol dm^{-3} $Na_2S_2O_3$, the precipitate forms faster.

What is a possible explanation for the observation above?

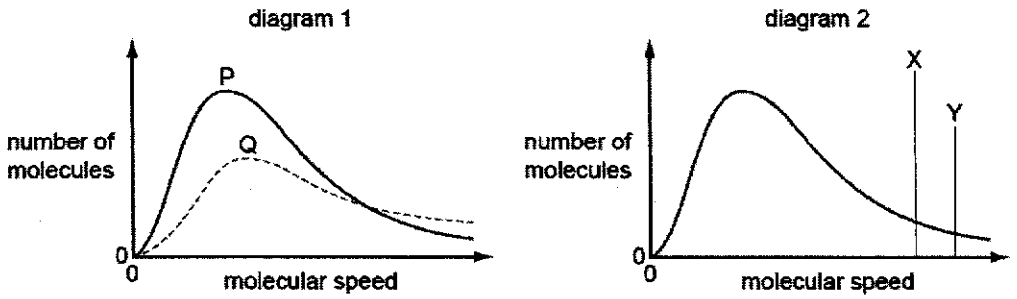
A The activation energy of the reaction is lower when 0.05 mol dm^{-3} $Na_2S_2O_3$ is used.

B The rate constant increases when 0.05 mol dm^{-3} $Na_2S_2O_3$ is used.

C The reactant particles collide with more energy when 0.05 mol dm^{-3} $Na_2S_2O_3$ is used.

D The reactant particles collide more frequently when 0.05 mol dm^{-3} $Na_2S_2O_3$ is used.

21 Different Maxwell-Boltzmann distribution curves are shown in the following diagrams.



In diagram 1, curve **P** or **Q** corresponds to a temperature higher than that of the other curve.

In diagram 2, line **X** or **Y** corresponds to the activation energy for a catalysed reaction and the other line corresponds to the activation energy of the same reaction when uncatalysed.

Which of the following statements are correct?

1 Using greater amount of catalyst does not further lower the activation energy.

2 The increase in temperature causes the curve in diagram 1 to change from **P** to **Q**.

3 Curve **Q** corresponds to the reaction occurring at a higher temperature while line **X** corresponds to a catalysed reaction.

4 When the temperature is increased, the fraction of molecules that have energy more than the activation energy will be increased.

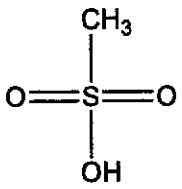
A All of the above

B 1, 2 and 3 only

C 2 and 3 only

D 2 and 4 only

22 Methanesulfonic acid is a non-volatile strong acid which is used to remove calcium carbonate from kettles.



Methanesulfonic acid

Which statement about methanesulfonic acid is **incorrect**?

A The gas evolved when methanesulfonic acid reacts with calcium carbonate is CO_2.

B 0.1 mol dm^{-3} methanesulfonic acid has a pH value of 1.

C The Brønsted-Lowry conjugate base of methanesulfonic acid is the $CH_3SO_3^-$ ion.

D The K_a value of methanesulfonic acid is very small.

23 Which of the following will give an acidic buffer solution when dissolved in 1 dm^3 of water?

1 1 mole of CH_3COOH and 0.5 mole of NaOH

2 1 mole of HCl and 1 mole of CH_3COONa

3 1 mole of CH_3COOH and 1 mole of CH_3COONa

A 1 and 2 only

B 1 and 3 only

C 2 and 3 only

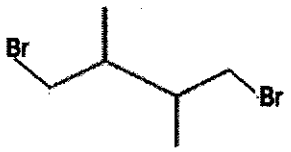
D 3 only

24 A compound **Z**, upon mono-chlorination with chlorine in the presence of UV light, forms 3 possible structural isomers.

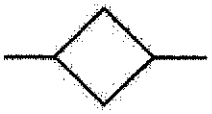
Which of the following compounds could be **Z**?

1

2



3



A 1, 2 and 3

B 1 and 3

C 2 and 3

D 1 only

25 Different chlorinated pentanes were separately treated with hot ethanolic sodium hydroxide. Two of these gave the same hydrocarbon, C_5H_8.

Which of the following pairs of chlorinated pentanes can form C_5H_8?

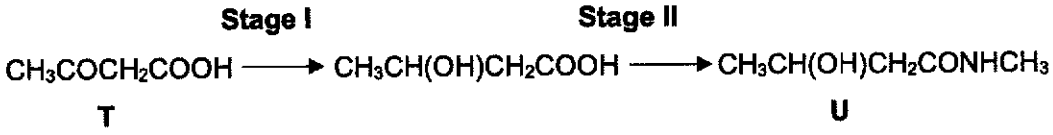
A $CH_3CH_2CH_2CH_2CH_2Cl$ and $CH_3CH_2CH_2CH_2CHCl_2$

B $CH_3CH_2CH_2CH_2CH_2Cl$ and $ClCH_2CH_2CH_2CH_2CH_2Cl$

C $CH_3CH_2CHClCH_2CH_3$ and $ClCH_2CH_2CH_2CH_2CHCl_2$

D $CH_3CHClCH_2CHClCH_3$ and $ClCH_2CH_2CH_2CH_2CH_2Cl$

26 **T** can be converted to **U** as shown below.



Which of the following statements are correct?

1 Stage I may involve the use of sodium borohydride.

2 Stage I may involve the use of lithium aluminium hydride.

3 Stage II may involve the use of DCC and methylamine.

A 1, 2 and 3

B 1 and 3

C 2 and 3

D 1 only

27 Which of the following products are formed when $CH_3CH_2CO_2CH_2NHCOCH_2CH_3$ is heated with excess aqueous sodium hydroxide?

A $CH_3CH_2CO_2CH_2NH_2$ and CH_3CH_2COOH

B $CH_3CO_2CH_2NH_2$ and CH_3CH_2COONa

C CH_3CH_2COOH and $HOCH_2NH_2$

D CH_3CH_2COONa and $HOCH_2NH_2$

28 Which of the following reactions forms an organic product that contains a deuterium atom?
[Deuterium, D: ^2H]

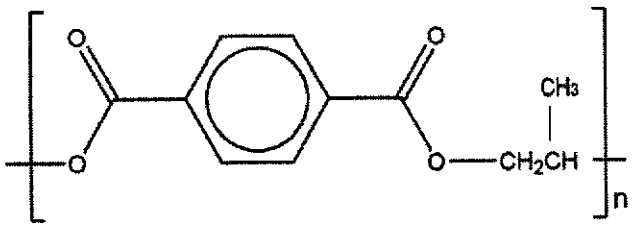
A $CH_3CH_2Br \xrightarrow[\text{heat}]{NaOD(aq)}$

B $CH_3CH_2OH \xrightarrow[\text{heat}]{MnO_4^-, NaOD(aq)}$

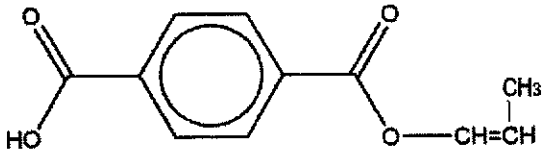
C $CH_3CH_2OH \xrightarrow[\text{heat}]{\text{conc } D_2SO_4}$

D $CH_3CO_2H + CH_3OH \xrightarrow[\text{heat}]{\text{conc } D_2SO_4}$

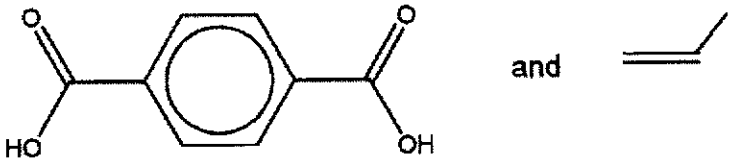
29 The structure of a polymer is shown below. Which of the following correctly show its corresponding monomer(s)?



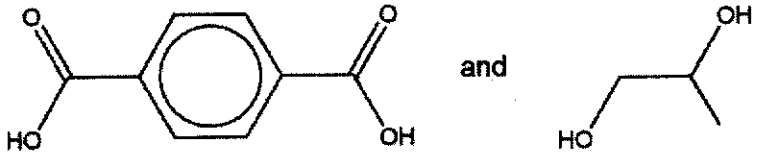
A



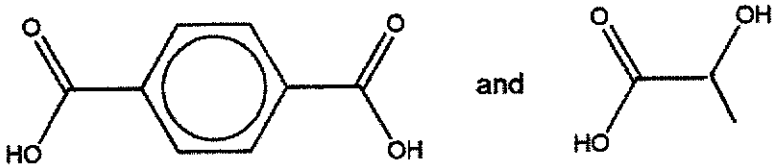
B



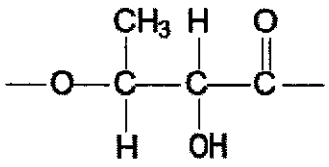
C



D



30 The repeat unit of a polymer is shown below.



Which deductions about this polymer can be made from the repeat unit?

1 It is a polyester.

2 It could be readily made from $HOCH_2CH_2CH_2CO_2H$.

3 There are hydrogen bonds formed between two polymer chains.

A 1 only

B 1 and 3 only

C 2 and 3 only

D 1, 2 and 3

SECTION A

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

1 **(a)** Elements can be synthetically produced via nuclear reactions.

During the process, protons or neutrons are injected 'like bullets' at the nucleus of an atom in making the synthetic element.

A scientist attempts to produce ^{32}P using a neutron and an isotope **E** of another element.

$$\text{one neutron} + \text{isotope } \mathbf{E} \rightarrow {}^{32}_{15}P + {}^{3}_{1}H$$

(i) Identify isotope E.

.....[1]

(ii) Draw the energy level diagram, showing the electronic configuration of $^{32}_{15}P$ in the ground state. [2]

Energy / kJ

(iii) Draw a clearly-labelled diagram to show the shape of one of the *singly-occupied* orbital in ^{32}P.

[1]

(iv) Describe one similarity and one difference between a 3s and a 3p orbital.

	Similarity	Difference
3s and 3p orbital		

[1]

(b) Elements with an unstable atomic nucleus undergo radioactive decay.

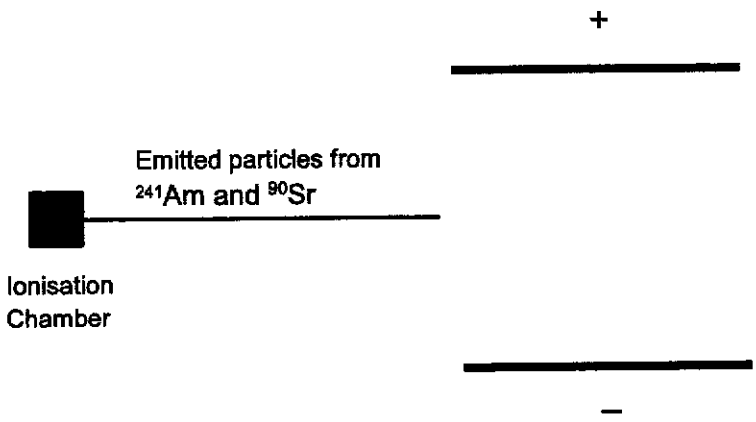
Americium–241 is used commonly in smoke detectors. It works by emitting a constant stream of α–particles, which are similar to the nucleus of Helium–4.

Strontium–90 is another radioactive substance. On decaying, it emits β–particles, which can be considered as electrons.

A small amount of Americium–241 and Strontium–90 are placed separately in an ionisation chamber to emit a constant stream of radiation and the emitted particles are passed through an electric field.

(i) On the diagram below, sketch the deflection path for the emitted particles in an electric field.

You may label the emitted particles from Americium–241 and Strontium–90 as α–particles and β–particles respectively.



[1]

(ii) Explain the difference in deflection path and angle respectively for the emitted particles in **c(i)**.

.....

.....

.....[1]

(iii) A deflection of –8° was observed when a beam of α–particles was passed through an electric field.

In another experiment, a beam of doubly charged particles **X** was passed through the electric field under the same experimental conditions. The angle of deflection was found to be +2°.

Identify the ion **X**. Show your working.

[2]

[Total: 9]

2 (a) Boron and its compounds have many uses. Boron trichloride, BCl_3 can be used in refining process of aluminium. Boric acid, H_3BO_3 sometimes known as $B(OH)_3$, is one of the most commonly produced borates and is widely used in the pharmaceutical and cosmetic industries.

Boric acid and borate salts such as sodium tetraborate, $NaB(OH)_4$, exist naturally in rocks, soil, plants and water.

(i) With reference to the *Valence Shell Electron Pair Repulsion Theory*, explain the shape and bond angle with respect to the B atom in $B(OH)_3$.

.....

.....

.....

..... [2]

(ii) Draw the dot-and-cross diagrams for BCl_3 and $B(OH)_4^-$. Clearly indicate any co-ordinate (dative covalent) bonds present.

[3]

Table 2.1 shows the melting points for boron compounds.

Table 2.1

Compound	Melting point / °C
Boron trichloride	-107.3
Boric acid	170.9
Sodium tetraborate	741

(iii) With reference to structure and bonding, explain the difference in melting points of the three componds in Table 2.1.

.....

.....

.....

.....[2]

(b) **(i)** BCl_3 can undergo hydrolysis to form boric acid and a gas that turns Universal Indicator red. Write an equation for this reaction forming $B(OH)_3$ from BCl_3.

.....[1]

(ii) Using appropriate bond energy values from the *Data Booklet*, and taking the bond energies for the B–C*l* bond and B–O bond to be 456 kJ mol^{-1} and 536 kJ mol^{-1} respectively, calculate the enthalpy change for the reaction in **(b)(i)**.

[2]

(iii) Suggest a reason why the enthalpy change calculated in **(b)(ii)** is only an approximate value.

.....

.....[1]

(c) Boronic acid is an alkyl or aryl substituted boric acid.

Ethylboronic acid, $CH_3CH_2B(OH)_2$, has shown potency to be used as a drug in chemotherapy where certain proteolytic enzymes are blocked which would otherwise degrade proteins.

(i) The equation below represents the enthalpy change of combustion of ethylboronic acid.

$$\boldsymbol{a}CH_3CH_2B(OH)_2(s) + \boldsymbol{b}O_2(g) \longrightarrow \boldsymbol{c}B_2O_3(s) + \boldsymbol{d}CO_2(g) + \boldsymbol{e}H_2O(l)$$

Define the *standard enthalpy change of combustion of ethylboronic acid* and determine the values of ***a*** to ***e*** in the equation.

a : _____, ***b***: _____, ***c***: _____, ***d***: _____, ***e***: _____

.....

.....

.....

.....[2]

(ii) In an experiment, a scientist burns 1.5 g of ethylboronic acid with 2.5 dm^3 of pure oxygen gas.

The reaction mixture is then allowed to cool to room temperature and pressure.

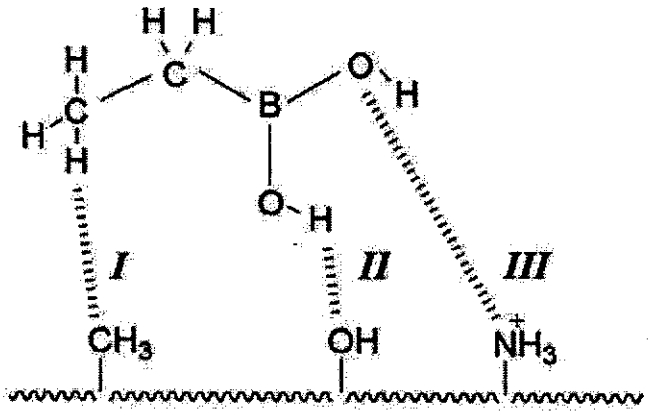
Calculate the change in volume of gas, assuming ethylboronic acid is completely burned in the experiment.

[2]

(iii) For a drug to achieve the therapeutic effect, it must form interactions with the target active sites.

Ethylboronic acid forms interaction with certain proteolytic enzymes at the enzyme active site and blocks the enzymatic actions, which in turn achieves the chemotherapeutic effect.

The diagram below shows three interactions between ethylboronic acid and the enzyme active site.



Enzyme active site

Name all the interactions, *I* to *III*, shown in the diagram.

I: .....

II: .....

III: .....

[3]

[Total: 18]

3 (a) A flameless ration heater (FRH) is a water activated chemical heater included with meals, ready-to-eat (MREs) used by the United States military.

The heater contains finely powdered magnesium metal alloyed with small amount of iron and sodium chloride. Water is added to activate the reaction.

$$Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2$$

(i) The reaction between magnesium and excess water produces 6900 cm^3 of hydrogen at s.t.p.

Calculate the mass of magnesium that has reacted.

[1]

(ii) Suggest why sodium cannot be used in place of magnesium in the FRH.

.....

.....[1]

(b) Exothermic reactions that do not produce hydrogen gas are being explored as alternatives in FRH. Some examples include the reaction of phosphorus(V) oxide and sodium oxide with water.

(i) Write an equation and give the approximate pH of the resulting solution when

- phosphorus(V) oxide reacts with water

- sodium oxide reacts with water

[2]

(ii) Sodium oxide reacts with phosphorus(V) oxide to produce sodium phosphate as the only product. Write a balanced equation for this reaction.

.....[1]

(iii) Phosphorus(V) oxide differs in its bonding from that of sodium oxide, as reflected by the different ways in which they react with water.

Explain why the difference in bonding arises between sodium oxide and phosphorus(V) oxide.

.....

.....

.....

.....[2]

(iv) The acid-base behaviour of beryllium oxide shows similarities to that of sodium oxide and phosphorus(V) oxide.

Explain this behaviour of beryllium oxide.

.....

.....

.....

.....[2]

(c) Magnesium oxide reacts reversibly with chlorine according to the following equation.

$$2MgO(s) + 2Cl_2(g) \rightleftharpoons 2MgCl_2(s) + O_2(g) \quad \Delta H_r = -80 \text{ kJ mol}^{-1}$$

Under certain conditions, a dynamic equilibrium is established.

(i) Explain why magnesium oxide has a higher melting point than magnesium chloride.

.....

.....

.....[1]

(ii) Given that the enthalpy change of formation of MgO is - 602 kJ mol^{-1}, calculate the enthalpy change of formation of $MgCl_2(s)$.

[2]

(iii) Predict and explain the effect of increasing temperature on the amount of oxygen at equilibrium.

.....

.....

.....

.....[2]

(d) Three test tubes were filled with hydrogen chloride, hydrogen bromide and hydrogen iodide gases respectively. A red-hot wire was placed into each test tube. The observations were recorded in Table 3.1.

Table 3.1

Gas	Observation
hydrogen chloride	no observable change
hydrogen bromide	reddish brown vapour formed after some time
hydrogen iodide	purple fumes formed immediately

With reference to the thermal stability of the hydrogen halides, explain the above observations.

.....

.....

.....

.....

.....[2]

[Total: 16]

4 Hydrazine, N_2H_4, is a popular choice of rocket fuels during outer space explorations. The stored hydrazine is passed over iridium catalyst and it decomposes to its elements. This rapid production of hot gaseous elements provides the thrust required. During the decomposition process, ammonia can also be formed as an intermediate.

The use of hydrazine as a fuel has been extended for use in aircraft as well. The first ever rocket-powered fighter plane was the Messerschmitt Me 163 *Komet*, The *Komet* was powered by the reaction between a hydrazine-methanol fuel mixture and oxidizer hydrogen peroxide. These reactants ignites spontaneously upon contact. Table 4.1 shows some properties about the fuels.

Table 4.1

	ΔH_c^e / kJ mol^{-1}	Density/ g cm^{-3}
N_2H_4 (*l*)	-622.2	1.02
CH_3OH(*l*)	-726.0	0.792

(a) In the *Komet*, the hydrazine-methanol mixture reacts to propel the plane.
A fully filled fighter plane carries 225 litres of hydrazine and 268 litres of methanol.

Using the data in Table 4.1, calculate the total heat evolved under standard conditions for combustion of this quantity of hydrazine-methanol mixture.
Assume that all the hydrazine and methanol are fully combusted.

[2]

(b) Write a balanced equation for decomposition of hydrazine to form ammonia and nitrogen gas.

.....[1]

(c) Using the concept of activation energy and an appropriate sketch of the Boltzmann distribution, explain why the use of iridium catalyst speeds up the chemical reaction in **(b)**.

.....

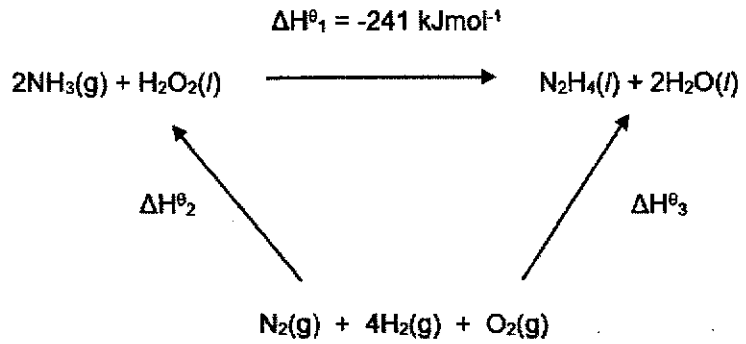
.....

.....

.....

[2]

(d) An energy cycle involving hydrazine at 298K and 1bar is shown below.



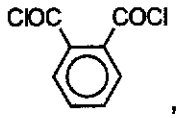
Use the following data and the above energy cycle, calculate the standard enthalpy change of formation of hydrazine.

$\Delta H^{\theta}_f(NH_3) = -46.1$ kJ mol^{-1}, $\Delta H^{\theta}_f(H_2O_2) = -187.8$ kJ mol^{-1}, $\Delta H^{\theta}_c(H_2) = -285.8$ kJ mol^{-1}

[2]

[Total: 7]

5 (a) Ethanoyl chloride, CH_3COCl, reacts with ethanol to form ethyl ethanoate and hydrogen chloride.

Similarly, for 

, it will react with $CH_2=CHCH_2OH$ to form compound **P** and hydrogen chloride.

Draw the structure of **P**.

P

[1]

(b) **P** undergoes polymerization reaction to form polymer **Q**.

(i) Draw the structure of the polymer **Q**.

Q

[1]

(ii) State the type of polymerisation for the formation of **Q**.

.....[1]

(iii) Based on the structure drawn in **(b)(i)**, predict whether polymer **Q** is a thermosetting or a thermoplastic polymer. Explain your answer.

.....

.....

.....[2]

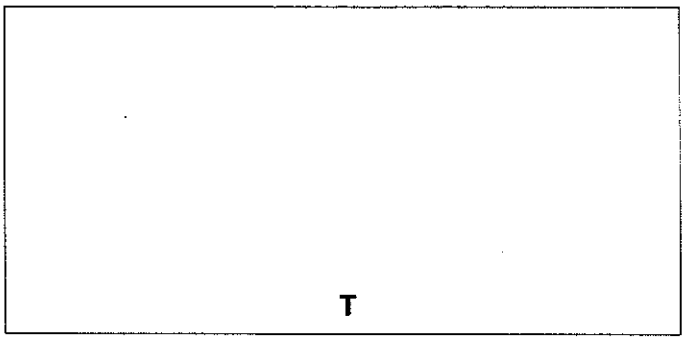
(iv) Suggest a use for polymer **Q** in consideration of its physical properties.

.....

..... [2]

(c) $CH_2=CHCH_2OH$ reacts with hot acidified $K_2Cr_2O_7$ to form compound **T**.

(i) Draw the structure of compound **T**.



[1]

(ii) Draw the structure of **two** repeat units of the polymer formed from compound **T** when mixed with potassium hydroxide in the presence of an initiator.

[1]

(iii) The polymer formed in **(c)(ii)** has the capability to absorb *large* quantities of water. Explain why this is so.

.....

.....

.....

.....[1]

[Total:10]

Section B

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

6 **(a)** 0.10 mole of an organic compound $C_xH_yO_z$, gives 0.40 mole of carbon dioxide and 0.40 mole of water vapour upon complete combustion.
8.8 g of $C_xH_yO_z$, when vaporised, was found to occupy 2.4 dm^3 at room temperature and pressure.

Determine the molecular formula of this organic compound.

[3]

(b) Ethanoic acid, also commonly known as acetic acid, is an important chemical due to its varied uses in the industry.
The preferred industrial method for its manufacture is by carbonylation of methanol, CH_3OH accounting for 65% of the total world ethanoic acid, CH_3CO_2H manufacturing capacity.

$$CH_3OH(aq) + CO(g) \rightleftharpoons CH_3CO_2H(aq)$$

In an experiment, the above process is carried out in a 2 dm^3 reaction vessel.
3.40 moles of methanol and 2.75 moles of carbon monoxide are reacted at 200 °C and allowed to reach dynamic equilibrium. 1.20 mole of ethanoic acid is found to be present in the equilibrium mixture. Calculate the value for the equilibrium constant, K_c, for the reaction. State its units.

[2]

(c) 50.0 cm^3 of 3.00 mol dm^{-3} ethanoic acid is added to 50.0 cm^3 of 1.40 mol dm^{-3} barium hydroxide in a polystyrene cup. The maximum temperature rise recorded was 12.5 °C.

Given that the specific heat capacity of the solution is 4.18 J g^{-1} K^{-1}.

(i) Define what is meant by the *standard enthalpy change of neutralisation*.

.....

.....[1]

(ii) Write a balanced chemical equation for the neutralisation of ethanoic acid with barium hydroxide.

.....[1]

(iii) Given that the neutralisation process was 70% efficient, calculate the standard enthalpy change of neutralisation for the reaction in **(ii)**.

[3]

(d) Buffered ethanoic acid mixes have been used as preservatives. To ensure its effectiveness, the ethanoic acid/sodium ethanoate buffer solution is maintained at pH 6.

(i) What is meant by the term *buffer solution*?

.....

.....[1]

(ii) Explain, with the aid of equations, how the mixture can act as a buffer upon addition of a small amount of acid and alkali.

.....

.....

.....

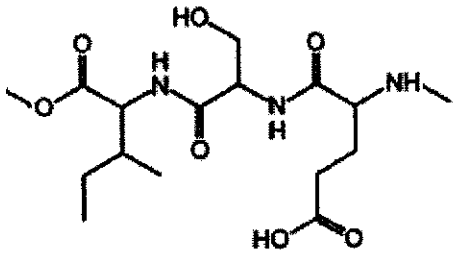
.....

.....[2]

(e) Explain, with the aid of a diagram, why the relative molecular mass of ethanoic acid is found to be 120 when dissolved in a suitable solvent.

[2]

(f) **V** is a fragment of polymer.



V

(i) Draw the structural formulae of the monomers found in **V**.

[1]

(ii) State the reagent and conditions that could be used to completely hydrolyse **V**.

.....[1]

(iii) Name the two compounds that can be polymerised together to produce a polyamide with **four** carbon atoms per repeat unit.

.....

.....[2]

(iv) State the condition required for the formation of the polyamide found in **(f)(iii)**.

..... [1]

[Total:20]

7 **(a)** 20 cm^3 of a hydride of nitrogen, N_xH_y is combusted in an excess of oxygen at 110 °C. 10 cm^3 of nitrogen and 30 cm^3 of steam are formed. Deduce the formula for this hydride.

[2]

(b) Draw the two molecules, NH_3 and H_2O, and indicate for each one the polarity of each of the bonds it contains, and the overall polarity of the molecule.

NH_3	H_2O

[2]

(c) Barium hydroxide, $Ba(OH)_2$ is a strong Bronsted Lowry base.

(i) Explain the meaning of the term *Bronsted Lowry base*.

.....

.....[1]

Fig. 7.1 shows the pH change that occurs when 15.0 cm^3 of 0.30 mol dm^{-3} of lactic acid, $CH_3CH(OH)COOH$ is titrated with barium hydroxide.

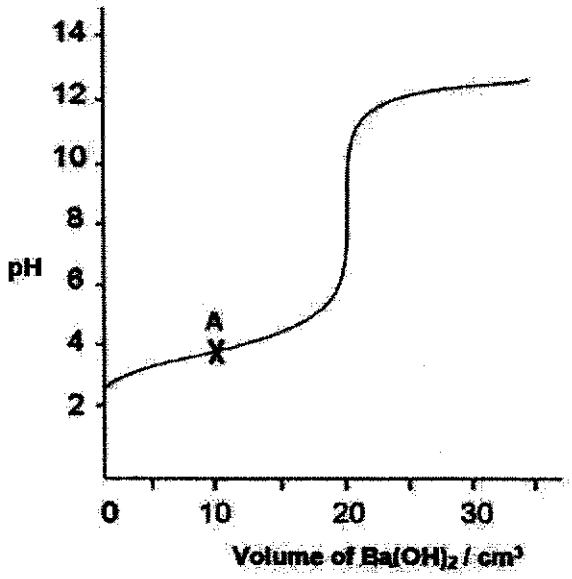


Fig. 7.1

(ii) Write a balanced equation for the reaction between lactic acid and barium hydroxide.

.....[1]

(iii) Calculate the concentration of barium hydroxide used in this titration and its pH value.

[2]

(iv) The solution at point **A** can act as a *buffer*.

Write a chemical equation to show how the solution at point **A** can act as a buffer when a small amount of H^+ is added to it.

.....

.....[1]

(v) From the following list, suggest with reasoning, a suitable indicator to be used for the titration.

Indicators	pH range
Methyl violet	0 – 1
Methyl orange	3 – 4
Phenolphthalein	9 –10

.....

.....

.....[2]

(d) The standard enthalpy change of neutralisation for the reaction in **(c)(ii)** can be determined experimentally by mixing known volumes of 1.0 mol dm^{-3} lactic acid and 1.0 mol dm^{-3} barium hydroxide. The following results are obtained.

Volume of lactic acid used = 40.0 cm^3

Volume of barium hydroxide used = 20.0 cm^3

Initial temperature of mixture = 26 °C

Final temperature of mixture = 34 °C

Specific heat capacity of the solution is 4.18 J g^{-1} K^{-1}.

(i) Use the data given to calculate the standard enthalpy change of neutralisation.

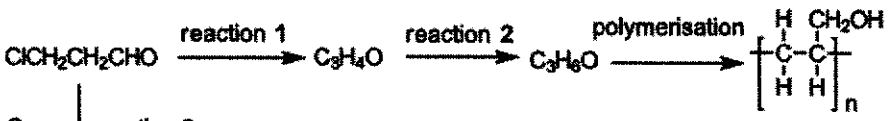
[2]

(ii) Using the value calculated in **d(i)**, draw a labelled energy profile diagram for the reaction, given that the activation energy is +5 kJ mol^{-1}.

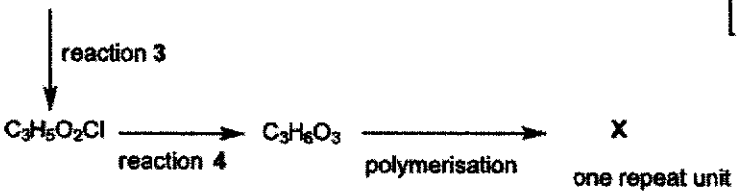
[2]

(e) Two synthetic routes are shown below for converting $ClCH_2CH_2CHO$ into two different polymers.

Synthesis 1



Synthesis 2



(i) Name the reagents and conditions used in reactions **1** to **4**.

reaction **1**: .....

reaction **2**: .....

reaction **3**: .....

reaction **4**: .....

[4]

(ii) Draw the structure of compound **X**.

[1]

[Total:20]

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2020TJC JC2 H1 Chemistry Prelim MCQ Worked Solutions

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

Question 1 Answer: B

no. of moles of Na^+ and OH^- ions = (0.5 x 0.1) x 2 = 0.10 mol

no. of moles of IO_3^- ions = (0.2 x 0.5) x 2 = 0.20 mol

no. of moles of molecules = 480 / 24000 = 0.02 mol

no. of moles of O atoms = (1.92 ÷ 48.0) x 3 = 0.12 mol

Question 2 Answer: C

Option 1 is correct as the 2nd electron removed is experienced greater attraction.

Option 2 is incorrect because the ionic size is also dependent on the nuclear charge, i.e. the no. of protons. Isoelectronic only implies they have the same number of electrons but not the same no. of protons.

Option 3 is incorrect. The two electrons are from 3d and 4s.

Option 4 is correct as the further electron removed from Al is from inner quantum shell.

Question 3 Answer: C

Using the IE values, the greatest jump is between 5th and 6th IE. Hence, E belongs to Group 15. E is likely to be P.

Question 4 Answer: A

Let average O.N of S be x.

2(+1) + 4x + 6(-2) = 0

x = +2.5

Option A is correct as the average O.N of S = (0 + 0 + 5 + 5) / 4 = +2.5

Alternative – calculate O.N of each S (refer to Redox notes page 6)

O.N of S^1 = O.N of S^4

= +1 + 0 + (+2) + (+2) = +5

(S–O bond) (S–S bond) (S=O bond) (S=O bond)

O.N of S^2 = O.N of S^3 = 0 (S–S bond)

Question 5 Answer: D

Amount of electrons gained by 1 mole of As_2O_3

= 6 x 2 = 12 mol

= amount of electrons lost by Zn

Since each mole of Zn loses 2 moles of electrons, amount of Zn needed to react with 1 mole of As_2O_3

= 12/2

= 6 mol

Question 6 Answer: A

C-1 and C-3 are unsaturated with sp^2 hybridisation. C-2 is sp^3 hybridised, C-4 is -C≡N so it is a sp C atom.

Question 7 Answer: B

Option B is incorrect as the difference between the volatility pentan-2-ol and octan-2-ol is dependent on the strength and extent of the id-id interactions.

Question 8 Answer: A

Option B does not have a polar molecule

Option C does not have a planar molecule

Option D does not have planar molecule

Question 9 Answer: B

$\underline{H_3O^+} + F^- \rightleftharpoons HF + \underline{H_2O}$ (107° to 104°)

$\underline{NaNH_2} + H_2O \longrightarrow NaOH + \underline{NH_3}$ (104° to 107°)

$\underline{BH_3} + NaH \longrightarrow \underline{NaBH_4}$ (120° to 109°)

$\underline{CO_2} + H_2O \rightleftharpoons 2H^+ + \underline{CO_3^{2-}}$ (180° to 120°)

Question 10 Answer: B

$K(s) + \frac{1}{2}Cl_2(g) \rightarrow KCl(s)$	$\Delta H = +211 - (-63) - (+710) = -436$ kJ mol^{-1}
$K^+(g) + Cl^-(g) \rightarrow K(s) + \frac{1}{2}Cl_2(g)$	$\Delta H = -63 - (+211) = -274$ kJ mol^{-1}
$KCl(s) \rightarrow K(g) + Cl(g)$	$\Delta H = +710 + (-63) = +647$ kJ mol^{-1}

Question 11 Answer: D

Enthalpy change of neutralisation and combustion are always negative. Enthalpy change of formation could be negative or positive.

Question 12 Answer: A

From data booklet, ΔH when N–N bond is formed = –160 kJ mol^{-1}
ΔH when C–Cl bond is formed = –340 kJ mol^{-1}
ΔH when C–H bond is broken = +410 kJ mol^{-1}

Question 13 Answer: C

- $MgCl_2 + 6H_2O \rightarrow [Mg(H_2O)_6]^{2+} + 2Cl^-$
  $[Mg(H_2O)_6]^{2+} \rightleftharpoons [Mg(H_2O)_5(OH)]^{2+} + H^+$ (hydrolyses only to a small extent in water)
- $AlCl_3 + 3H_2O \rightarrow Al(OH)_3 + 3HCl$
- $PCl_5 + 4H_2O \rightarrow POCl_3 + 2HCl$
  0.5 mol 1.0 mol
- $SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$

Question 14 Answer: B

Boiling point increases down the group due to increasing electron cloud size.

From the data booklet, BE (F–F) = 158 kJ mol^{-1}, BE (Cl-Cl) = 244 kJ mol^{-1}, BE (Br–Br) = 193 kJ mol^{-1} and BE (I-I) = 151 kJ mol^{-1}.

Oxidising power of halogens decreases down the group due to increasing atomic radius.

Intensity of colour increases down the Group (see Data Booklet for colour).

Question 15 Answer: C

Si has the highest melting point due to its giant covalent structure with numerous strong covalent bonds between atoms.

Cl^- has the smallest ionic radius among anions P^{3-} to Cl^- due to its highest nuclear charge.

Question 16 Answer: D

As the reaction is exothermic, an increased in the temperature at t_1 will favour the endothermic reaction, position of equilibrium shifts to the left. At t_2, the pressure of the vessel is increased which shift the position of equilibrium to the right to reduce the number of gaseous molecules.

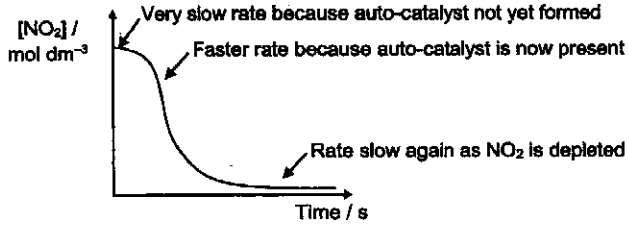
Question 17 Answer: B

Option 1 is incorrect as the equilibrium constant will change when temperature change.
Option 3 is incorrect as the equilibrium concentration will increase until it reaches the new equilibrium is reached.

Question 18 Answer: A

Reaction rate of an autocatalysis reaction will be low initially, high in between, and low eventually because, the product, NO formed in the reaction acts as a catalyst.

A Tangent of a concentration–time graph gives reaction rate. Tangent is low initially, high in between, and low eventually.



B For this shape of graph to correctly represent an autocatalysis reaction – the correct axis label should be rate vs time.

C This rate–concentration graph is typical of an enzyme–substrate reaction, not an autocatalysis reaction.

D This rate–time graph is increasing throughout, not an autocatalysis reaction.

Question 19 Answer: A

Analysis: When H_2CO_3 reaches 75% equilibrium conc, only 25% CO_2 is left

Let n = no of half-lifes for CO_2 to drop to 1%

$0.25 = (\frac{1}{2})^n$
n = 2
Time taken = 2 x 0.03 = 0.060 s

Question 20 Answer: D

When higher [$Na_2S_2O_3$] is used, there is greater no of reactant molecules having energy > or = Ea hence frequency of collisions increases leading to faster rate.

Question 21 Answer: A

Option1 : is **correct** as the use of catalyst does lower the activation energy, but increasing the amount of the catalyst does not make it even lower.

Option 2 : is **correct** as the shape of the graph will shift towards the right (showing more molecules having more energy) when temperature rises.

Option 3: is **correct** as the use of catalyst lower the activation energy from **Y** to **X**. Curve **Q** corresponds to the reaction occurring at a higher temperature as area under curve is proportional to number of reactant particles. When temperature is increased, number of reactant particles with $E \geq E_a$ increases. This results in the peak of curve **P** shifting rightwards to give curve **Q**.

Option 4: is **correct**. When temperature increases, the rate of reaction will increase as the fraction of molecules that have energy more than the activation energy will increase

Question 22 **Answer: D**

For strong acid, because it is fully dissociated in solution, its Ka value will be a large value.

Question 23 **Answer: B**

Acidic buffer includes a weak acid and its salt.

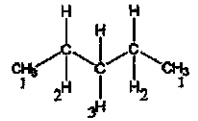
Option 1: excess weak acid CH_3COOH and salt CH_3COONa present

Option 2: no weak acid present

Option 3: weak acid - CH_3COOH and salt - CH_3COONa present

Question 24 **Answer: A**

1



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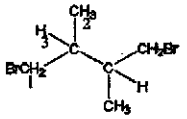

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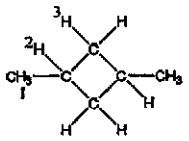


Question 25 **Answer: D**

Hydrocarbon, C_5H_8 hence it is a diene (with 2 C=C)

Hence there must be 2 elimination to form 2 C=C

$CH_3CHCICH_2CHCICH_3$ → $CH_2{=}CHCH_2CH{=}CH_2$

$ClCH_2CH_2CH_2CH_2CH_2Cl$ → $CH_2{=}CHCH_2CH{=}CH_2$

Question 26 **Answer:B**

Option 2 is incorrect as lithium aluminium hydride will reduce the carboxylic acid to primary alcohol

Question 27 **Answer: D**

Ester and amide undergo basic hydrolysis simultaneously to form CH_3CH_2COONa and $HOCH_2NH_2$.

Question 28 **Answer: A**

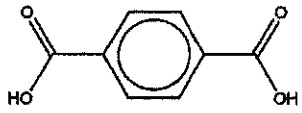
A) substitution gives CH_3CH_2OD.

B) oxidation to give $CH_3CO_2^-$

C) Elimination to give $CH_2{=}CH_2$

D) Condensation to give $CH_3CO_2CH_3$

Question 29 **Answer: C**



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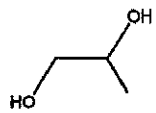


Carboxylic acid functional group will condense with the alcohol group of the monomers to give the polymer.

Question 30 **Answer: B**

1: An ester linkage is formed when you join the repeat units together.

2: It is made from $HOCH(CH_3)CH(OH)CO_2H$.

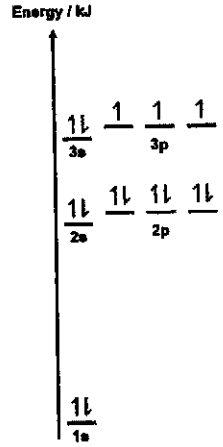
3: This polyester has OH groups hence hydrogen bonding can be formed between polymers chains.

SECTION A

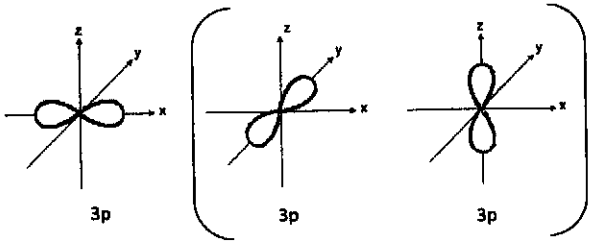
Answer all the questions in the spaces provided.

1 (a) (i) $^{34}_{16}S$

(ii) P: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$



(iii)

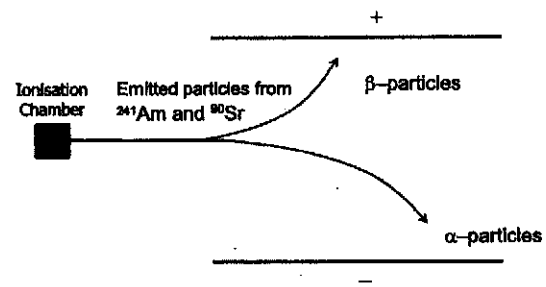


(iv)

3s and 3p orbital	**Similarity** **Both 3s and 3p orbitals belong to the same principal quantum shell.**	**Difference** **3s orbital has spherical shape while 3p orbital has dumb-bell shape.**

[Turn over

(c) (i)



(ii) **Analysis : α–particles = $^4He^{2+}$; β–particles = $^0e^-$**

$\frac{charge}{mass}$ **for $^4He^{2+}$ = $\frac{2}{4}$**

$\frac{charge}{mass}$ **for e^- = $\frac{1}{1/1836}$**

α–particles will be deflected towards the negative plate and by a smaller magnitude due to greater mass/charge ratio (or show numerical $\frac{q}{m}$) than β–particles, which is towards positive plate and by a larger magnitude.

(iii) **Since X is doubly charged and the deflection is towards the positive plate ⇒ X^{2-}**

$\frac{q}{m}$ ratio for α–particles ($^4He^{2+}$) nuclei = $\frac{2}{4} = \frac{1}{2}$

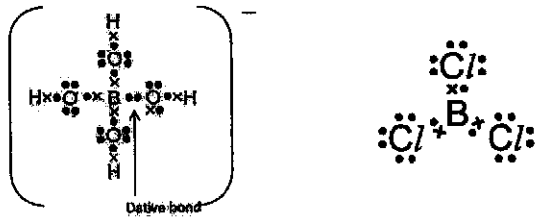
$\frac{q}{m}$ ratio for X^{2-} = $-\frac{2}{m}$

$+2^\bullet = (-\frac{2}{m} \div \frac{1}{2}) \times -8^\bullet \Rightarrow m = 16 \Rightarrow X$ is O^{2-}

[Total: 9]

2 (a) (i) **There are 3 bond pairs and no lone pairs around B atom. To minimise repulsion and maximize stability, the 3 electron pairs are directed in a trigonal planar manner. Hence, shape is trigonal planar with bond angle 120°.**

(ii)



(iii) ✓ **Sodium tetraborate has a giant ionic lattice structure, while boron trichloride and boric acid are simple molecular structures.**

✓ More energy is required to overcome the stronger hydrogen bonds between boric acid molecules than the weak id-id between boron trichloride molecules, hence, boric acid has a higher melting point.

✓ More energy is required to overcome the stronger ionic bonds between oppositely charge ions in sodium tetraborate than the weaker hydrogen bonds between boric acid molecules, hence sodium tetraborate has a higher melting point.

(b) (i) • $BCl_3 + 3H_2O \rightarrow B(OH)_3 + 3HCl$

(ii)

Bonds broken:		Bonds formed:	
B–Cl	: 3 (456)	B–O	: 3 (536)
O–H	: 6 (460)	O–H	: 3 (460)
		H–Cl	: 3 (431)
Total energy required: 4128 kJ mol^{-1}		Total energy released: 4281 kJ mol^{-1}	

• ΔH = Σ Bond energies of reactants – Σ Bond energies of products

= +4128 – 4281

= – 153 kJ mol^{-1}

(iii) • It is an approximation as the bond energies from the Data Booklet are only average values and would not apply to the exact molecules in the reaction.

or

• Bond energies are for breaking of bonds in the gaseous phase. However the substances in the reaction are not all in the gaseous phase under standard conditions.

(c) (i) • The standard enthalpy change of combustion of ethylboronic acid is the energy released when 1 mole of ethylboronic acid is completely burnt in excess oxygen under standard conditions of 298K and 1 bar.

• $a = 1$, $b = 7/2$, $c = 1/2$, $d = 2$ and $e = 7/2$

(ii) Number of moles of ethylboronic acid = 1.5 / 73.8 = 0.0203 mol
•Volume of O_2 reacted at rtp = 7/2 x 0.0203 x 24 = 1.71 dm^3
Volume of unreacted O_2 = 2.5 – 1.71 = 0.793 dm^3
Volume of CO_2 produced = 2 x 0.0203 x 24 = 0.976 dm^3
Change in volume = Total vol of O_2 – [Vol of O_2 unreacted+ Vol CO_2]
•Decrease in volume of gas = 2.5 –[0.793 + 0.976] = 0.731 dm^3

(iii) I: instantaneous dipole-induced dipole
II: hydrogen bond
III: ion-dipole interactions

[Total: 18]

3 (a) (i) number of moles of H_2 = 6 900/ 22 700 = 0.304 mol
• mass of Mg = 0.304 x 24.3 = 7.39 g

(ii) • The reaction will be unsafe as sodium reacts explosively/ vigorously with water.

OR

Sodium reacts readily with oxygen to form sodium oxide, so it cannot be stored easily as sodium metal in the FRH.

(b) (i) • $P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$ pH = 2
• $Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$ pH = 13

(ii) $6Na_2O + P_4O_{10} \rightarrow 4Na_3PO_4$

(iii) • There is a great electronegativity difference between Na and O, hence Na_2O is an ionic compound.
• There is small electronegativity difference between P and O, hence P_4O_{10} is a covalent compound.

(iv) • BeO is an amphoteric oxide due to the high charge density of the Be^{2+} ion polarising the O^{2-} anion causing the bonds between the Be^{2+} and O^{2-} ions to be mainly ionic with some covalent characteristics.

(c) (i) Lattice energy of MgO is higher due to the higher charge of O^{2-} compared to Cl^-. More energy is needed to overcome the stronger ionic bonds of magnesium oxide.

(ii) $\Delta H_r = \Sigma\Delta H_f$ products – $\Sigma\Delta H_f$ reactants
- 80 = 2 x ΔH_f ($MgCl_2$) – 2 x (-602)
ΔH_f ($MgCl_2$) = - 642 kJ mol^{-1}

(iii) By Le Chatelier's Principle, the system will counteract the increase in temperature by favouring the endothermic reaction to remove heat. Position of equilibrium will shift to the left and amount of oxygen will be lower at equilibrium.

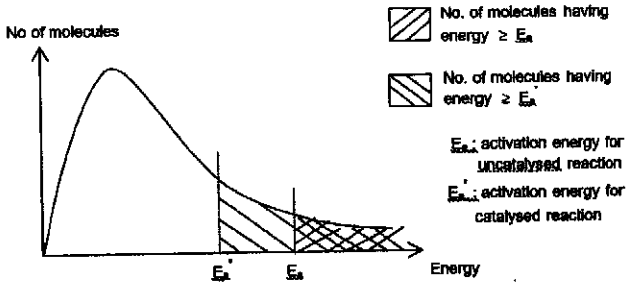
(d) Covalent bond strength and hence bond energy of H–X decreases from H–Cl to H–Br to H–I. Hence thermal stability of HX decreases from HCl to HBr to HI. The energy supplied by the red-hot wire was insufficient to decompose HCl, was able to decompose some HBr to form reddish brown Br_2 vapour after some time, and was able to decompose HI readily to form purple I_2 fumes immediately.

[Total: 16]

(a) Amount of hydrazine = 225000 x 1.02/32.0 = 7172 mol
Amount of methanol = 268000 x 0.792/32.0 = 6633 mol
Total heat evolved = 7172 x 622.2 + 6633 x 726.0 = 9.28 x 10^6 kJ

(b) • $3N_2H_4 \rightarrow N_2 + 4NH_3$

(c) In the presence of a catalyst, the number of reactant molecules having energy greater than or equal to the lower activation energy, E_a, increases significantly.
Hence the frequency of effective collisions increases and the rate increases.

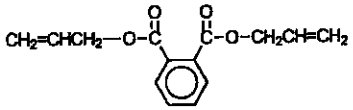


(d) By Hess' law,

- $\Delta H^\ominus_1 = \Delta H^\ominus_3 - \Delta H^\ominus_2$
  $-241 = \Delta H^\ominus_f(N_2H_4) + 2(-285.8) - [2(-46.1) + (-187.8)]$
- $\Delta H^\ominus_f(N_2H_4) = -241 + 2(285.8) + [2(-46.1) + (-187.8)]$
  $= \underline{+50.6\ kJ\ mol^{-1}}$

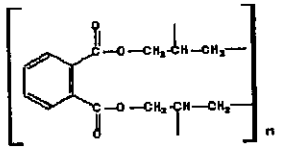
[Total: 7]

5 (a)



[1]

b (i)



[1]

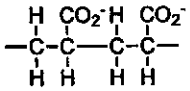
(ii) Addition polymerisation

(iii) Q is a thermosetting polymer because there are extensive strong covalent bonds and cross-links between polymer chains.

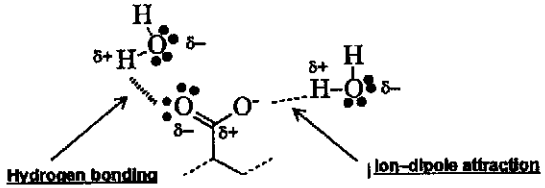
(iv) Q is used for high-performance military and commercial electrical components. It can retain its insulating properties, even when subjected to high heat and high humidity over long time periods.

(c) (i)

(ii)



(iii) Presence of hydrogen bonding and ion–dipole interactions [1] between the polymer chain and H_2O molecules enable polymer to absorb large quantities of water.



[Total:10]

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

6 **(a)**

$$C_xH_yO_z(l) + \left(x+\frac{y}{4}-\frac{z}{2}\right)O_2(g) \rightarrow xCO_2(g) + \frac{y}{2}H_2O(g)$$

0.10 mol 0.40 mol 0.40 mol

- Comparing mole ratio, $x = 4$, $y = 8$

Molecular formula of **A** = $C_4H_8O_z$

Amount of **A** at r.t.p = $\frac{2.4}{24.0}$ = 0.100 mol

- Molar mass of **A** = $\frac{8.8}{0.100}$ = 88.0 g mol^{-1}

M_r of **A** = 88.0

To solve for the value of z: $4(12) + 8(1) + z(16) = 88$

$z = 2$

- molecular formula of **A** is $C_4H_8O_2$

(b)

	$CH_3OH(aq)$ +	$CO(g)$ $\rightleftharpoons$	$CH_3CO_2H(aq)$
Initial no. of mol	3.40	2.75	0
Change in no. of mol	–1.20	–1.20	+1.20
Eqm no. of mol	2.20	1.55	1.20

K_c = (1.20/2) / [(2.20/2)(1.55/2)] = 0.704 mol^{-1}dm^3

(c) **(i)** **Standard enthalpy change of neutralisation (ΔH_n^θ) is the heat evolved when one mole of water is formed from the neutralisation between acid and alkali under standard conditions of 298K and 1 bar**

(ii) $2CH_3COOH(aq) + Ba(OH)_2(aq) \longrightarrow (CH_3COO^-)_2Ba^{2+}(aq) + 2H_2O(l)$

(iii) $2CH_3COOH\ (aq) + Ba(OH)_2\ (aq) \longrightarrow (CH_3COO^-)_2Ba^{2+}(aq) + 2H_2O\ (l)$

No. of moles of CH_3COOH = 50/1000 x 3.00 = 0.150 mol
No. of moles of $Ba(OH)_2$ = 50/1000 x 1.4 = 0.0700 mol
$\Rightarrow$ $Ba(OH)_2$ is the limiting reagent.

Heat evolved = mcΔT
= 100 x 4.18 x 12.5
= 5225 J
Actual heat evolved = 5225/70 x 100
= 7464J

$$\Delta H_n^\theta = -\frac{Q}{n_{H_2O}}$$

= –7464 / 0.14
= –53316
= 53300 J mol^{-1} or –53.3 kJ mol^{-1}

(d) **(i)** A buffer solution is one which is capable of maintaining a fairly constant pH (by resisting pH change) when small amounts of acid or base are added to it.

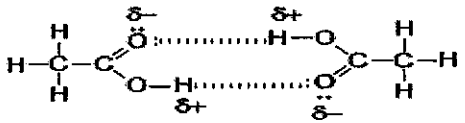
(ii) When a small amount of H^+ is added
$CH_3COO^- + H^+ \rightarrow CH_3COOH$

The H^+ is removed by CH_3COO^-.
$[H^+]$ is slightly changed and pH of buffer solution remains fairly constant.

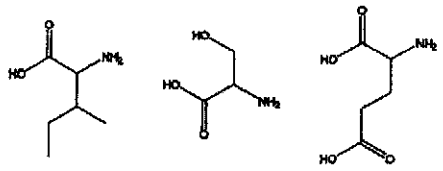
When a small amount of OH^- is added
$CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$

The OH^- is removed by CH_3COOH .
$[OH^-]$ is slightly changed and pH of buffer solution remains fairly constant

(e) Dimerisation has occurred between 2 molecules of ethanoic acid



(f) **(i)**



(ii) Heat with aqueous NaOH/KOH/OH^- OR
Heat with Aqueous HCl/H_2SO_4/H^+

(iii) Ethanedioic acid & ethane-1,2-diamine OR
Ethanedioyl chloride & ethane-1,2-diamine

(iv) DCC

[Total:20]

7 (a)

$$N_xH_y + \frac{y}{4}O_2 \rightarrow \frac{x}{2}N_2 + \frac{y}{2}H_2O$$

Initial vol/cm³	20	in excess	-	-
Change in vol/cm³	-20	-a	+10	+30

Comparing the coefficient of N_xH_y and N_2

•

$$\frac{1}{\frac{x}{2}} = \frac{20}{10}$$

$x = 1$

Comparing the coefficient of N_xH_y and H_2O

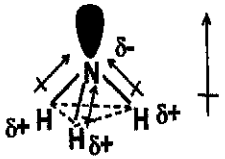
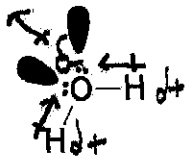
•

$$\frac{1}{\frac{y}{2}} = \frac{20}{30}$$

$y = 3$

The formula is **NH_3.**

(b)

Shape : Trigonal pyramidal **N-H bond is polar**	Shape: Bent **O-H bond is polar**
	
There is an overall dipole moment and NH_3 is polar.	**There is an overall dipole moment and H_2O is polar.**

(c) (i) A Bronsted Lowry base is a proton acceptor.

(ii) $2CH_3CH(OH)COOH(aq) + Ba(OH)_2(aq) \longrightarrow (CH_3CH(OH)COO^-)_2Ba^{2+}(aq) + 2H_2O(l)$

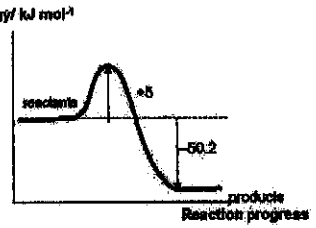
(iii) n(lactic acid) = 0.0150 x 0.30 = 0.00450 mol
n[$(Ba(OH)_2$] = 0.00450/2 mol
= 0.00225 mol
[$Ba(OH)_2$] = 0.00225/0.020 = **<u>0.1125 mol dm^{-3}</u>**
$Ba(OH)_2 \rightarrow Ba^{2+} + 2OH^-$
[$Ba(OH)_2$] ≡ 2[OH^-] since barium hydroxide is a strong base
[OH^-] = 0.225 mol dm^{-3}
pOH = $-\log_{10}$ [OH^-] = 0.648
pH = 14 – 0.648 = **<u>13.4</u>**

(iv) $CH_3CH(OH)COO^- + H^+ \rightarrow CH_3CH(OH)COOH$

(v) Phenolphthalein
Its working range of 9-10 lies within the long vertical part of the pH curve.

(d) (i) Heat evolved Q = mcΔT
= (4.18 x 60.0) x (34 – 26) = 2006 J
ΔH_n^{θ} = –2006/0.0400 = **<u>–50.2 kJ mol^{-1}</u>**

(ii)



(e) (i) reaction 1: **ethanolic NaOH, heat**
reaction 2: **LIAlH_4 in dry ether, rtp or $NaBH_4$ in ethanol, rtp**
reaction 3: **$K_2Cr_2O_7$, dilute H_2SO_4, heat or $KMnO_4$, dilute H_2SO_4, heat**
reaction 4: **aqueous NaOH, heat**

(ii) X is $-O-CH_2CH_2\overset{\overset{O}{\|}}{C}-$

[Total:20]