



Cambridge International AS & A Level

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CHEMISTRY

9701/22

Paper 2 AS Level Structured Questions

February/March 2021

1 hour 15 minutes

You must answer on the question paper.

You will need: Data booklet

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working, use appropriate units and use an appropriate number of significant figures.

INFORMATION

- The total mark for this paper is 60.
- The number of marks for each question or part question is shown in brackets [].

This document has **12** pages.



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

1 The rate of chemical reactions is affected by changes in temperature and pressure.

(a) (i) Draw a curve on the axes to show the Boltzmann distribution of energy of particles in a sample of gaseous krypton atoms at a given temperature.

Label the curve **T1** and label the axes.



[2]

(ii) On the diagram in (a)(i), draw a second curve to show the distribution of energies of the krypton atoms at a higher temperature.

Label the second curve **T2**.

[1]

(b) The Boltzmann distribution assumes that the particles behave as an ideal gas.

(i) State **two** assumptions of the kinetic theory as applied to an ideal gas.

1

.....

2

.....

[2]

(ii) 2.00 g of krypton gas, Kr(g), is placed in a sealed 5.00 dm³ container at 120 °C.

Calculate the pressure, in Pa, of Kr(g) in the container.

Assume Kr(g) behaves as an ideal gas.

Show your working.

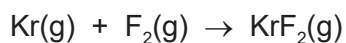
pressure = Pa [3]

- (iii) State and explain the conditions at which krypton behaves most like an ideal gas.

.....

 [2]

- (c) Krypton reacts with fluorine in the presence of ultraviolet light to make krypton difluoride, $\text{KrF}_2(\text{g})$.

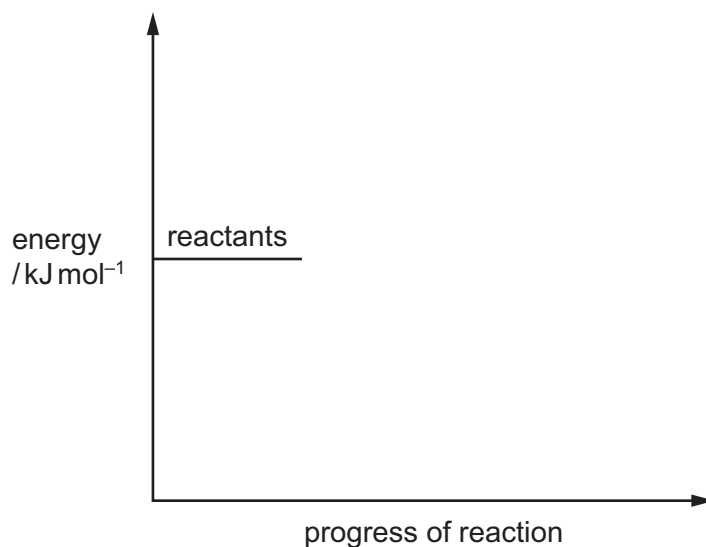


activation energy for the reaction, $E_a = +385 \text{ kJ mol}^{-1}$

enthalpy change of formation of KrF_2 , $\Delta H_f = +60.2 \text{ kJ mol}^{-1}$

- (i) Use this information to complete the reaction profile diagram for the formation of KrF_2 . Label E_a and ΔH_f on the diagram.

Assume the reaction proceeds in one step.



[2]

- (ii) Explain, in terms of activation energy, E_a , and the collision of particles, how an increase in temperature affects the rate of a chemical reaction.

.....

 [2]

[Total: 14]

2 Chlorine, Cl_2 , is a reactive yellow-green gas. It is a strong oxidising agent.

(a) State how Cl_2 is used in water purification.

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

(b) Chlorine has the highest first ionisation energy of the Period 3 elements Na to Cl.

(i) Construct an equation for the first ionisation energy of chlorine.

Include state symbols.

..... [1]

(ii) Explain the general increase in the first ionisation energies of the Period 3 elements.

.....
.....
.....
..... [2]

(c) The halide ions, X^- (where $X = Cl, Br, I$), show clear trends in their physical and chemical properties.

(i) State and explain the relative thermal stabilities of the hydrogen halides, HX .

.....

.....

..... [2]

The halide ions react easily with concentrated H_2SO_4 .

The main sulfur-containing product of each reaction is shown in the table.

| | | | |
|--|-----------|--------|--------|
| halide ion | Cl^- | Br^- | I^- |
| main sulfur-containing product of reaction with concentrated H_2SO_4 | HSO_4^- | SO_2 | H_2S |
| oxidation number of sulfur | | | |

(ii) Complete the table to show the oxidation number of sulfur in each of the sulfur-containing products. [1]

(iii) Explain why different sulfur-containing products are produced when each of these halide ions reacts with concentrated H_2SO_4 .

.....

..... [1]

(d) Cl_2 reacts with aqueous sodium hydroxide in a disproportionation reaction.

(i) State what is meant by *disproportionation*.

.....

..... [1]

(ii) Write an equation for the reaction of Cl_2 with cold aqueous sodium hydroxide.

..... [1]

- (e) Aluminium reacts with chlorine to form aluminium chloride.

Aluminium chloride can exist as the gaseous molecule $Al_2Cl_6(g)$. This molecule contains coordinate bonds.

- (i) Draw a diagram that clearly shows all the types of bond present in $Al_2Cl_6(g)$.

[2]

- (ii) Describe what you would see when solid aluminium chloride reacts with water.

Name the type of reaction that occurs.

.....

 [2]

- (f) 0.020 mol of element **Z** reacts with excess Cl_2 to form 0.020 mol of a liquid chloride.

The liquid chloride has formula ZCl_n , where n is an integer.

ZCl_n reacts vigorously with water at room temperature to give an acidic solution and a white solid.

When excess $AgNO_3(aq)$ is added to the solution, 11.54 g of $AgCl(s)$ forms.

- (i) Suggest the type of bonding and structure shown by ZCl_n .

..... [1]

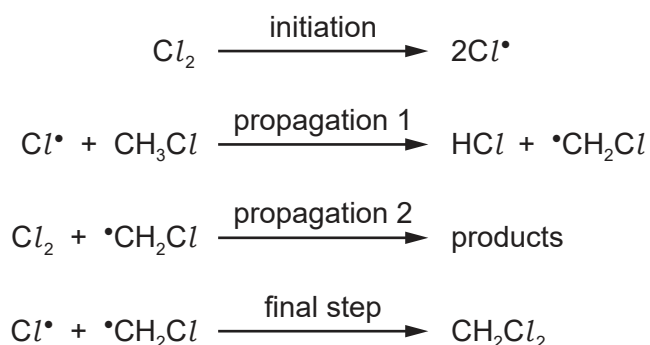
- (ii) Calculate the value of n in ZCl_n .

$n = \dots\dots\dots$ [2]

(g) Dichloromethane, CH_2Cl_2 , is widely used as an organic solvent.

CH_2Cl_2 can be prepared by reacting CH_3Cl and Cl_2 at room temperature.

The reaction proceeds via several steps, as shown.



(i) Give the name of the mechanism of this reaction.

..... [1]

(ii) State the essential condition required for the initiation step to take place.

..... [1]

(iii) Give the electronic configuration of Cl^\bullet .

$1s^2$ [1]

(iv) Identify the products of the step labelled propagation 2.

..... [1]

(v) Name the type of reaction shown in the final step.

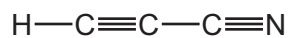
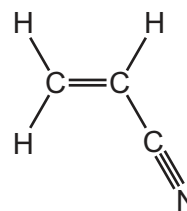
..... [1]

(vi) Suggest the identity of another organic molecule that is a product of the reaction of CH_3Cl and Cl_2 under the same conditions.

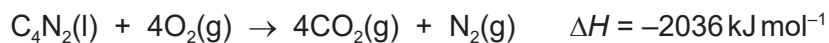
..... [1]

[Total: 23]

3 Compounds **P**, **Q** and **R** have all been found in the atmosphere of one of Saturn's moons.

P**Q****R**

(a) The equation for the complete combustion of **P**, $\text{C}_4\text{N}_2(\text{l})$, is shown.



(i) The enthalpy change of formation, ΔH_f , of $\text{CO}_2(\text{g})$ is -384 kJ mol^{-1} .

Calculate the enthalpy change of formation, ΔH_f , of **P**, in kJ mol^{-1} .

$$\Delta H_f \text{ of } \mathbf{P} = \dots\dots\dots \text{ kJ mol}^{-1} \quad [2]$$

(ii) One of the products of the complete combustion of **P** is nitrogen gas, $\text{N}_2(\text{g})$.

Explain the lack of reactivity of nitrogen.

..... [1]

(b) **Q** forms when HCN reacts with ethyne, $\text{H}-\text{C}\equiv\text{C}-\text{H}$.

(i) Ethyne, HCN and **Q** are all weak Brønsted–Lowry acids.

Explain what is meant by the term *weak Brønsted–Lowry acid*.

.....

.....

..... [2]

(ii) Ethyne, HCN and **Q** all contain triple bonds between two atoms.

A triple bond consists of one sigma (σ) and two pi (π) bonds.

Draw a labelled diagram to show the formation of one pi (π) bond.

[2]

(c) **P** and **Q** can be detected in the atmosphere by infrared spectroscopy.

Identify **two** absorptions, and the bonds that correspond to these absorptions, that will appear in the infrared spectra of both **P** and **Q**.

1

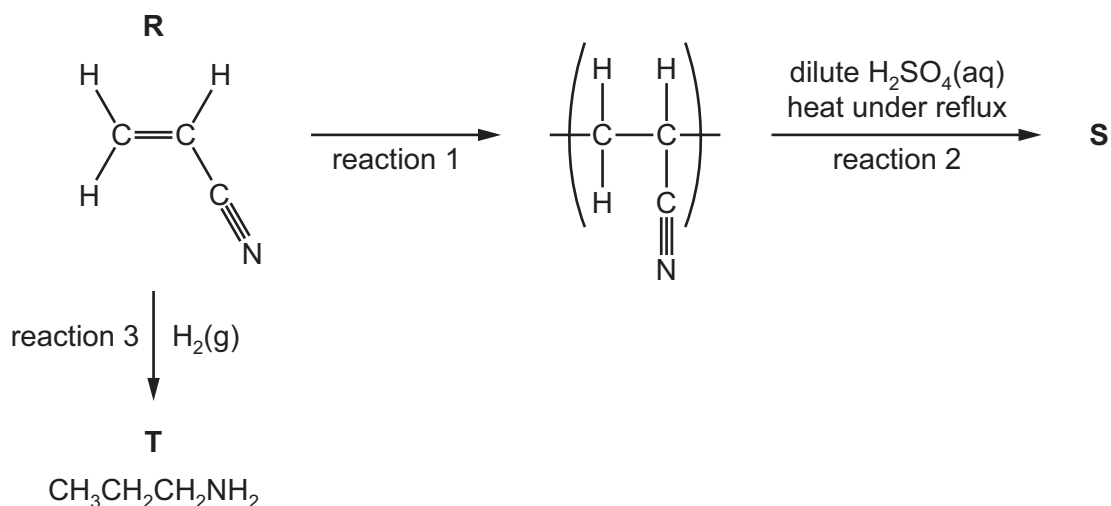
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2

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[2]

(d) The flow chart shows some reactions of **R**.



(i) Name the type of reaction shown in reaction 1.

..... [1]

(ii) Draw the structure of **S**, the organic product of reaction 2.

[1]

(iii) Name **T**.

..... [1]

(iv) **T** can also be formed by the reaction of $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br}$ with ammonia.

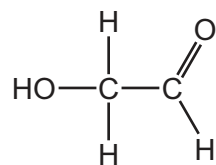
State the necessary conditions of this reaction.

..... [1]

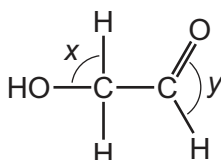
[Total: 13]

- 4 Hydroxyethanal, HOCH_2CHO , has been observed in dust clouds near the centre of our galaxy.

hydroxyethanal



- (a) Predict the bond angles labelled x and y in the diagram of hydroxyethanal.



$x = \dots\dots\dots^\circ$

$y = \dots\dots\dots^\circ$

[2]

- (b) Hydroxyethanal reacts separately with 2,4-dinitrophenylhydrazine (2,4-DNPH) and with Tollens' reagent.

State what you would observe in each reaction.

reaction with 2,4-DNPH

reaction with Tollens' reagent

[2]

- (c) Hydroxyethanal is converted to ethanedioic acid, $(\text{CO}_2\text{H})_2$, when it reacts with excess acidified dichromate(VI) ions, $\text{Cr}_2\text{O}_7^{2-}$.

- (i) State the role of acidified $\text{Cr}_2\text{O}_7^{2-}$ in this reaction.

..... [1]

- (ii) State and explain any other necessary conditions for this reaction to be successful.

.....

.....

..... [2]

