

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

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2

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[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.

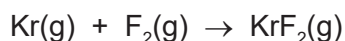
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..... [2]

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

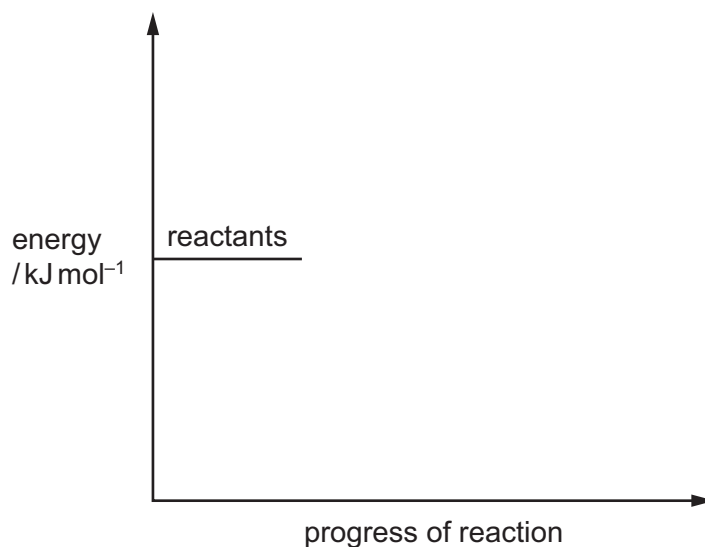


activation energy for the reaction, $E_a = +385 \text{ kJ mol}^{-1}$

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.

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..... [2]

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 .

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.....

..... [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 .

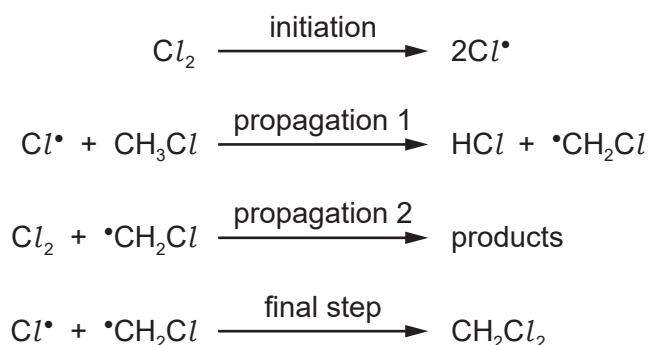
$n =$ [2]



(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 $\text{Cl}^\bullet$.

$1s^2$ [1]

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

..... [1]

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

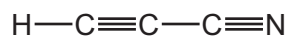
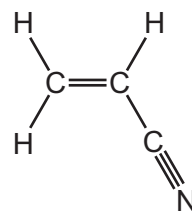
..... [1]

(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.

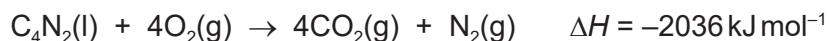
..... [1]

[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} .

ΔH_f of **P** = kJ mol^{-1} [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

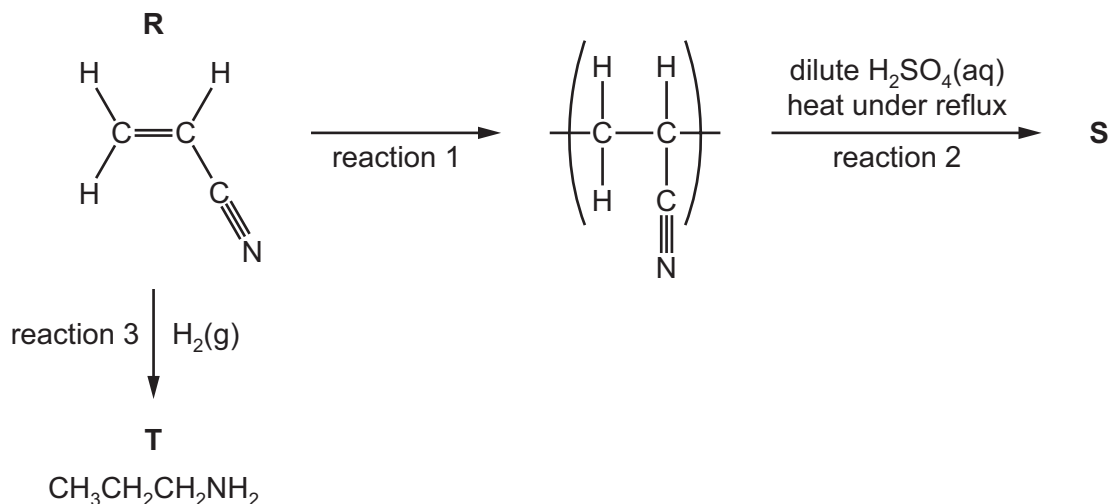
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2

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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.

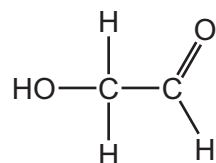
State the necessary conditions of this reaction.

..... [1]

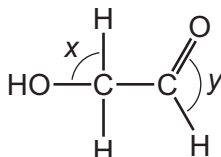
[Total: 13]

- 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]

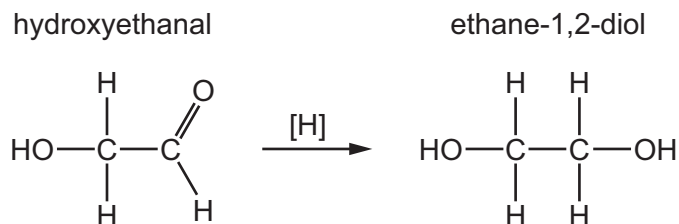
- (ii) State and explain any other necessary conditions for this reaction to be successful.

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.....

..... [2]

(d) Hydroxyethanal can be reduced to ethane-1,2-diol, $(\text{CH}_2\text{OH})_2$, as shown.



(i) Write an equation for the reduction of hydroxyethanal to $(\text{CH}_2\text{OH})_2$.

Use $[\text{H}]$ to represent an atom of hydrogen from the reducing agent.

..... [1]

(ii) Identify a reagent for this reduction reaction.

..... [1]

(iii) $(\text{CH}_2\text{OH})_2$ also forms when an alkene **A** reacts with cold, dilute, acidified manganate(VII) ions.

Name **A**.

..... [1]

[Total: 10]

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