Cambridge Assessment International Education

Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

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.

[Turn over

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 dm^3 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, $KrF_2(g)$.

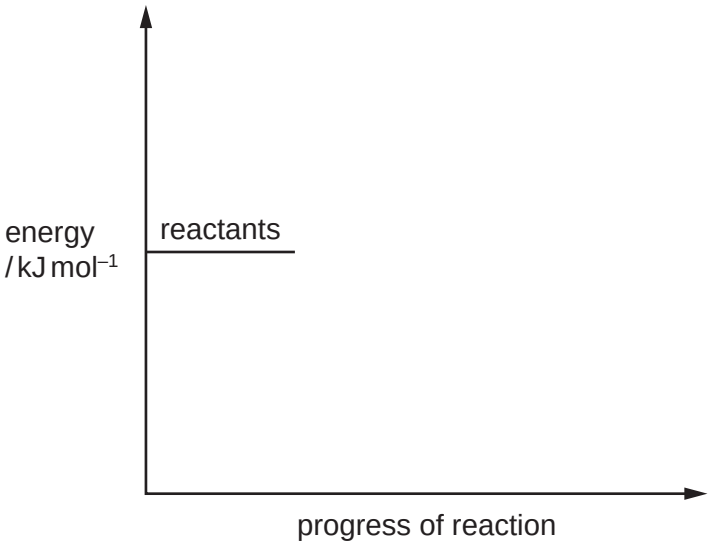
$$Kr(g) + F_2(g) \rightarrow KrF_2(g)$$

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

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

(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 = C*l*, 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	C*l*$^-$	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 **Z**Cl_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 **Z**Cl_n.

..... [1]

(ii) Calculate the value of *n* in **Z**Cl_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.

$$Cl_2 \xrightarrow{\text{initiation}} 2Cl^{\bullet}$$

$$Cl^{\bullet} + CH_3Cl \xrightarrow{\text{propagation 1}} HCl + {}^{\bullet}CH_2Cl$$

$$Cl_2 + {}^{\bullet}CH_2Cl \xrightarrow{\text{propagation 2}} \text{products}$$

$$Cl^{\bullet} + {}^{\bullet}CH_2Cl \xrightarrow{\text{final step}} CH_2Cl_2$$

(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]

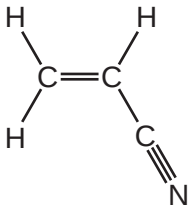
[Total: 23]

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**, $C_4N_2(l)$, is shown.

$$C_4N_2(l) + 4O_2(g) \rightarrow 4CO_2(g) + N_2(g) \qquad \Delta H = -2036\,kJ\,mol^{-1}$$

(i) The enthalpy change of formation, ΔH_f, of $CO_2(g)$ 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, $N_2(g)$.

Explain the lack of reactivity of nitrogen.

..... [1]

(b) **Q** forms when HCN reacts with ethyne, H—C≡C—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 .....

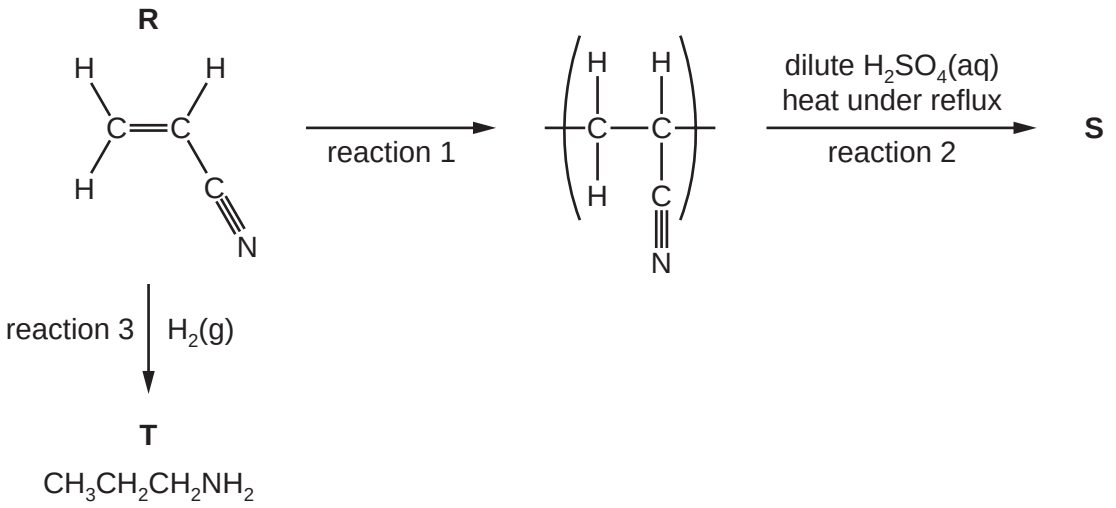
.....

2 .....

.....

[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 $CH_3CH_2CH_2Br$ with ammonia.

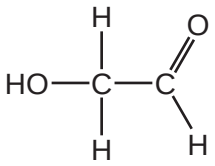
State the necessary conditions of this reaction.

..... [1]

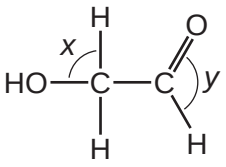
[Total: 13]

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 = ...°

y = ...°

[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, $(CO_2H)_2$, when it reacts with excess acidified dichromate(VI) ions, $Cr_2O_7^{2-}$.

(i) State the role of acidified $Cr_2O_7^{2-}$ in this reaction.

..... [1]

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

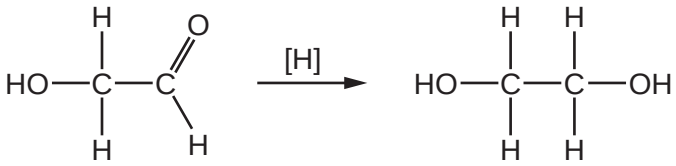
.....

.....

..... [2]

(d) Hydroxyethanal can be reduced to ethane-1,2-diol, $(CH_2OH)_2$, as shown.

hydroxyethanal ethane-1,2-diol



(i) Write an equation for the reduction of hydroxyethanal to $(CH_2OH)_2$.

Use [H] to represent an atom of hydrogen from the reducing agent.

..... [1]

(ii) Identify a reagent for this reduction reaction.

..... [1]

(iii) $(CH_2OH)_2$ also forms when an alkene **A** reacts with cold, dilute, acidified manganate(VII) ions.

Name **A**.

..... [1]

[Total: 10]