Cambridge Assessment International Education

# Cambridge International AS & A Level

CANDIDATE NAME

CENTRE NUMBER | | | | | |

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*9722950000*

**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, $KrF_2(g)$.

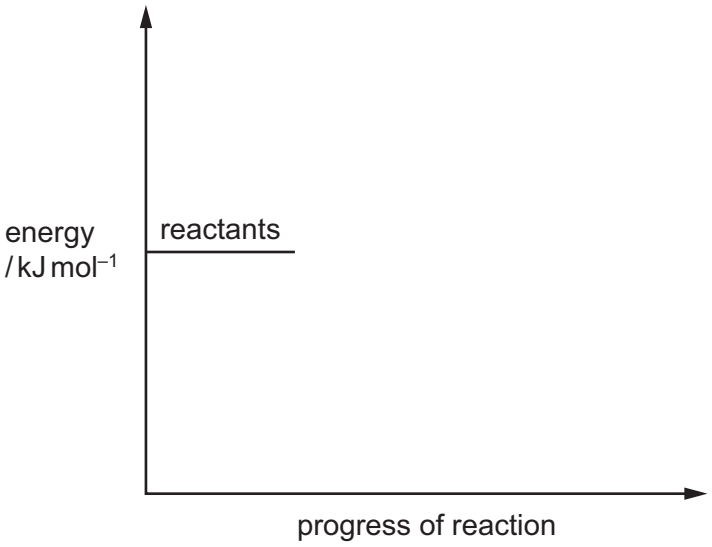
$$Kr(g) + F_2(g) \rightarrow KrF_2(g)$$

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 $\Delta H_f$ 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]





**[Turn over**

**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)** C$l_2$ 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 C$l_2$ with cold aqueous sodium hydroxide.

..... [1]





**[Turn over**

**(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.

**Z**$Cl_n$ 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]

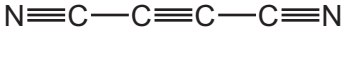




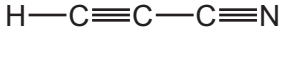
**[Turn over**

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

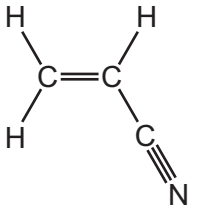
**P**



**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, $\Delta H_f$, of $CO_2(g)$ is $-384\,kJ\,mol^{-1}$.

Calculate the enthalpy change of formation, $\Delta H_f$, of **P**, in $kJ\,mol^{-1}$.

$\Delta H_f$ 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 ($\sigma$) and two pi ($\pi$) bonds.

Draw a labelled diagram to show the formation of one pi ($\pi$) 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 .....

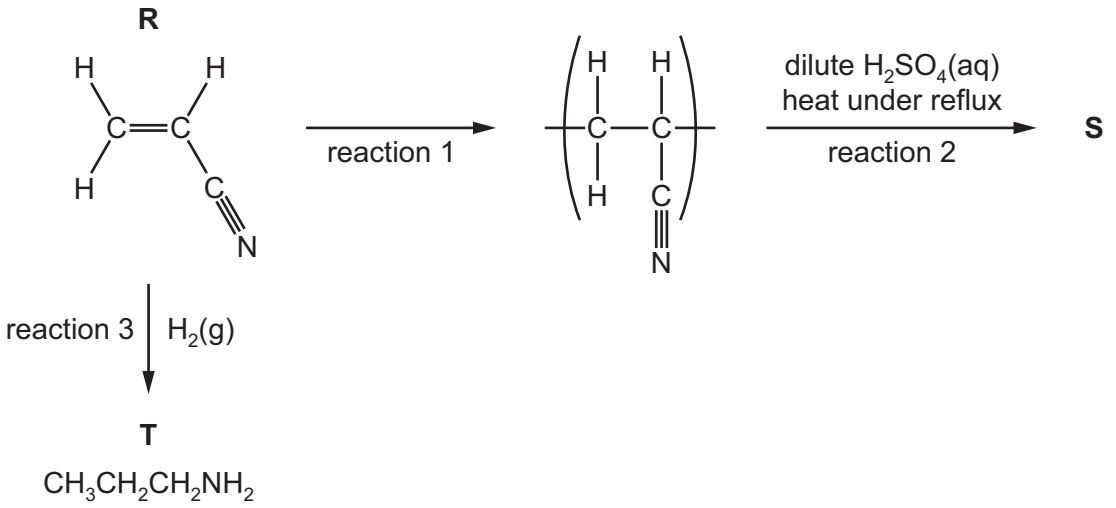
.....

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.

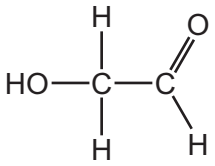
State the necessary conditions of this reaction.

..... [1]

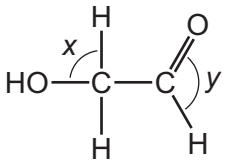
[Total: 13]

**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]

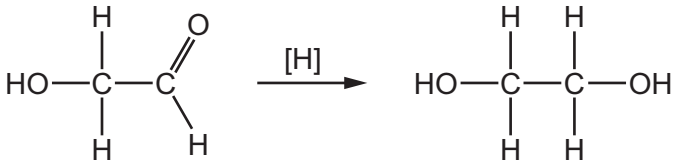




**[Turn over**

**(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]