| Surname | Centre Number | Candidate Number |
|---|---|---|
| First name(s) | | 2 |

# GCE A LEVEL

A410U10-1

S24-A410U10-1

**MONDAY, 10 JUNE 2024 – MORNING**

## CHEMISTRY – A level component 1

### Physical and Inorganic Chemistry

2 hours 30 minutes

| | For Examiner's use only | | |
|---|---|---|---|
| | **Question** | **Maximum Mark** | **Mark Awarded** |
| **Section A** | **1. to 8.** | **15** | |
| **Section B** | **9.** | **15** | |
| | **10.** | **16** | |
| | **11.** | **18** | |
| | **12.** | **13** | |
| | **13.** | **14** | |
| | **14.** | **13** | |
| | **15.** | **16** | |
| | **Total** | **120** | |

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**ADDITIONAL MATERIALS**

- A calculator, pencil and ruler
- **Data Booklet** supplied by WJEC

**INSTRUCTIONS TO CANDIDATES**

Use black ink or black ball-point pen.
Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

**Section A** Answer **all** questions.
**Section B** Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

**INFORMATION FOR CANDIDATES**

The number of marks is given in brackets at the end of each question or part-question.

The maximum mark for this paper is 120.

Your answers must be relevant and must make full use of the information given to be awarded full marks for a question.

The assessment of the quality of extended response (QER) will take place in **Q11**(d) and **Q14**(a).

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## SECTION A

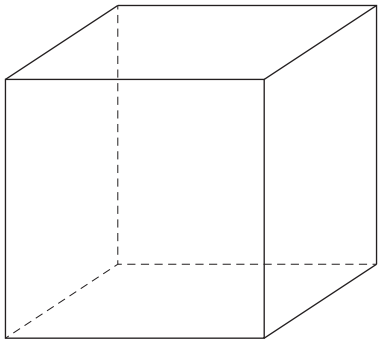
Answer **all** questions.

**1.** (a) Write the electronic structure of the $Na^+$ ion. [1]

.....

(b) Draw the shape of the orbital that contains the outermost electron of the $Na^+$ ion. [1]

**2.** (a) Draw the arrangement of ions in the structure of CsCl. Differentiate clearly between $Cs^+$ and $Cl^-$ ions. [1]



(b) Explain why CsCl conducts electricity when molten but not when solid. [1]

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**3.** Nitrogen and phosphorus can both form chlorides of formula $XCl_3$ but only phosphorus can form a chloride of formula $XCl_5$.

Explain why $PCl_5$ exists but $NCl_5$ does not. [2]

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**4.** Cyclohexene reacts with aqueous bromine to form the colourless compound 1,2-dibromocyclohexane.

(a) Suggest a method of measuring the rate of this reaction. [1]

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(b) The relative rate is measured using different concentrations of aqueous bromine and cyclohexene.

Use the results given in the table to find the rate equation for this reaction. [2]

| Initial concentration of cyclohexene / mol dm$^{-3}$ | Initial concentration of aqueous bromine / mol dm$^{-3}$ | Relative rate |
|---|---|---|
| 0.10 | 0.10 | 1 |
| 0.10 | 0.20 | 4 |
| 0.20 | 0.20 | 8 |

rate = .....

A410U101
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**5.** 10.0 g of magnesium hydroxide is heated until it undergoes thermal decomposition.

Calculate the maximum mass of magnesium oxide that can be formed in this reaction. [2]

Mass = ..... g

**6.** Interhalogen compounds contain two types of halogen atom only.

In a mass spectrum the molecular ion of one interhalogen compound appears as two peaks, one at m/z 92 and another at m/z 94 in the height ratio 3:1.

Find the formula of this interhalogen compound. [2]

Formula .....

**7.** State Le Chatelier's principle. [1]

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**8.** State the catalyst used in the contact process. [1]

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## SECTION B

Answer **all** questions.

**9.** (a) Propanoic acid is a weak acid with a $K_a$ of $1.34 \times 10^{-5}\,\text{mol dm}^{-3}$ at 298 K.

(i) Propanoic acid can be neutralised using aqueous sodium hydroxide.

Calculate the pH of aqueous sodium hydroxide of concentration $0.500\,\text{mol dm}^{-3}$. [2]

pH = .....

(ii) $20.0\,\text{cm}^3$ of $0.500\,\text{mol dm}^{-3}$ aqueous sodium hydroxide is added to $40.0\,\text{cm}^3$ of $0.500\,\text{mol dm}^{-3}$ aqueous propanoic acid.

Calculate the pH of the resulting solution. [3]

pH = .....



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(iii) Propanoic acid reacts with calcium carbonate in an endothermic reaction.

I. Complete the equation for this reaction. [2]

..... $CH_3CH_2COOH$ + ..... $CaCO_3$ ⟶ ..... $H_2O$ + ..... $CO_2$ + .....

II. A student attempts to measure the enthalpy change of the reaction by following the method below.

- Measure 50.0 $cm^3$ of aqueous propanoic acid of concentration 0.200 mol $dm^{-3}$ and place in a glass beaker. Measure the temperature.
- Add a lump of calcium carbonate of known mass. Measure the temperature.
- Calculate the difference between the two temperatures and calculate the enthalpy change for the reaction.

State and explain **three** changes needed to improve this method. [3]

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(b) Transition metal ions in solution commonly form complex ions of formula $[M(H_2O)_6]^{n+}$. These can act as weak acids.

(i) Draw the structure of a $[Co(H_2O)_6]^{2+}$ ion. [1]

(ii) State the colour of the $[Co(H_2O)_6]^{2+}$ ion. [1]

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(c) (i) HOCl is a weak acid that is formed when chlorine is added to water.

Draw a dot and cross diagram of this molecule. [1]

(ii) Give the oxidation state of the chlorine atom in this molecule. [1]

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(iii) State the purpose of adding chlorine to water for public supply. [1]

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**10.** Actinium, aluminium and americium are the first three elements alphabetically.

(a) These three elements are all metals. Explain how the structure of metals allows them to conduct electricity.

Include a diagram as part of your answer. [2]

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(b) (i) The most stable isotope of actinium is $^{227}Ac$. It can decay by emission of either an alpha or beta particle.

Identify the isotopes formed in each case. [2]

Product of alpha decay

Symbol ..... Mass number .....

Product of beta decay

Symbol ..... Mass number .....

(ii) Naturally-occurring samples of actinium usually consist of mixtures of $^{227}Ac$ and $^{228}Ac$. One sample has a relative atomic mass of 227.12.

Calculate the percentage of $^{227}Ac$ in this sample. [3]

Percentage of $^{227}Ac$ = ..... %





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**Turn over.**

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(c) Aluminium is an amphoteric metal that produces electron-deficient compounds.

(i) Aluminium hydroxide is an amphoteric compound. Describe reactions that would show this amphoteric behaviour, including all relevant equations. [3]

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(ii) Explain why aluminium chloride molecules, $AlCl_3$, form dimers of formula $Al_2Cl_6$.

You may include a diagram as part of your answer. [3]

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(d) Americium-238 has a half-life of 98 minutes. It decomposes to form $^{238}Pu$ only. This plutonium isotope has a half-life of 88 years.

(i) A 10.0 mg sample of americium-238 is left for 294 minutes. Calculate the mass of plutonium present after 294 minutes. [2]

Mass = ..... mg

(ii) Suggest why it is important to know the half-life of the isotope formed when calculating the mass of plutonium. [1]

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**11.** Peroxynitrous acid, H — O — O — NO, is an isomer of nitric(V) acid, $HNO_3$.

(a) Peroxynitrous acid isomerises rapidly to form nitric acid with a rate constant of $4.52\,s^{-1}$ at a temperature of 37 °C.

(i) State the order of this reaction. Give a reason for your answer. [1]

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(ii) The frequency factor, *A*, for this reaction is $1.47 \times 10^9\,s^{-1}$.

Calculate the activation energy of the reaction. [3]

Activation energy = ..... $kJ\,mol^{-1}$



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(b) Peroxynitrous acid is an oxidising agent with a standard electrode potential of 1.42 V.

(i) State what is meant by the term standard electrode potential. [2]

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(ii) The table below shows the standard electrode potentials for some metal ions.

| | Standard electrode potential, $E^{\theta}$/V |
|---|---|
| $Co^{3+} + e^- \rightleftharpoons Co^{2+}$ | +1.82 |
| $Mn^{3+} + e^- \rightleftharpoons Mn^{2+}$ | +1.51 |
| $Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$ | +0.77 |
| $Cr^{3+} + e^- \rightleftharpoons Cr^{2+}$ | −0.41 |
| $Ti^{3+} + e^- \rightleftharpoons Ti^{2+}$ | −0.37 |

State which of the metal ions shown can be oxidised by peroxynitrous acid. Give your reasoning. [2]

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A410U101 15



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(c) Peroxynitrous acid is a weak acid with a $K_a$ of $1.6 \times 10^{-7}$ mol dm$^{-3}$. Nitric(V) acid is a strong acid.

Calculate the change in pH when a 0.100 mol dm$^{-3}$ solution of peroxynitrous acid isomerises fully to form nitric(V) acid. [4]

Change in pH = .....



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(d) The concentration of a solution of nitric acid can be found by titration against a standard solution of sodium hydrogencarbonate, $NaHCO_3$.

$250.0\,cm^3$ of a standard solution of sodium hydrogencarbonate is made using 20.0 g of solid $NaHCO_3$.

Describe how this standard solution should be prepared and calculate its concentration.
[6 QER]

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**12.** Chukanovite is an insoluble iron-containing mineral with a formula $Fe_a(OH)_b(CO_3)_c$.

A student performs a series of tests to analyse the mineral.

| Number | Test | Results |
|---|---|---|
| 1 | Add $1.56 \times 10^{-3}$ mol of the mineral to 25.0 $cm^3$ of 0.500 mol $dm^{-3}$ nitric acid (an excess) and measure the volume of gas produced | 37.2 $cm^3$ of gas was produced at a pressure of 1 atm and a temperature of 290 K |
| 2 | Titrate the remaining acid from test 1 against sodium hydroxide solution of concentration 0.300 mol $dm^{-3}$ | Titration was repeated four times and the titres recorded were 20.55 $cm^3$, 20.95 $cm^3$, 20.90 $cm^3$ and 20.85 $cm^3$ |
| 3 | Analyse the mineral to find its relative molecular mass | $M_r$ was found to be $2.1 \times 10^2$ (to **two** significant figures) |

(a) Calculate the value of **c**.

You **must** show your working. [3]

**c** = .....

(b) Calculate the mean titre in test 2. [1]

Mean titre = ..... $cm^3$



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(c) The acid in test 1 reacts with all the carbonate ions and hydroxide ions.

Use the information provided in test 1 and test 2 to show that the value of **b** is 2. [4]

(d) Find the value of **a**. Use this and your answers to parts (a) and (c) to give the formula of chukanovite. [2]

Formula .....

(e) (i) Identify the oxidation state of the iron in chukanovite. Give a reason for your answer. [1]

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(ii) Suggest a chemical test that could be used to confirm the oxidation state of the iron in chukanovite. [2]

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**13.** Nitrous oxide, $N_2O$, is a gas that can be part of several different gas phase equilibria. Two of these equilibria are shown below.

Equilibrium 1

$$2N_2O(g) + 3O_2(g) \rightleftharpoons 2N_2O_4(g) \qquad K_p = 1.57 \times 10^6\,Pa^{-3}$$

Equilibrium 2

$$2N_2(g) + O_2(g) \rightleftharpoons 2N_2O(g) \qquad K_p = 1.24 \times 10^{-35}$$ .....

(a) Use the words **high** or **low** to complete the sentences below. [1]

The concentration of $N_2O$ in an equilibrium mixture formed for equilibrium 1 is

.....

The concentration of $N_2O$ in an equilibrium mixture formed for equilibrium 2 is

.....

(b) Write an expression for $K_p$ for equilibrium 2. Give its unit. [2]

Unit .....



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(c) A different equilibrium involving $N_2O$ is shown below.

$$3NO(g) \rightleftharpoons N_2O(g) + NO_2(g)$$

A sample of NO at a total pressure of 1 atm was allowed to reach equilibrium and the mixture formed had a partial pressure of $8.9 \times 10^{-4}$ Pa of NO.

Calculate the value of $K_p$ for this reaction. [4]

$K_p$ = ..... $Pa^{-1}$



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(d) Another method of producing oxides of nitrogen is by decomposition of metal nitrates, such as calcium nitrate.

$$2Ca(NO_3)_2(s) \longrightarrow 2CaO(s) + 4NO_2(g) + O_2(g)$$

| | Standard enthalpy change of formation, $\Delta_f H^\theta$ / kJ mol$^{-1}$ | Standard entropy, $S^\theta$ / J K$^{-1}$ mol$^{-1}$ |
|---|---|---|
| $Ca(NO_3)_2(s)$ | –937 | 193 |
| $CaO(s)$ | –635 | 40 |
| $NO_2(g)$ | 34 | 240 |
| $O_2(g)$ | 0 | 205 |

(i) Give a reason why the standard enthalpy change of formation for oxygen is 0 kJ mol$^{-1}$. [1]

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(ii) Calculate the standard enthalpy change for this reaction. [2]

$\Delta H^\theta$ = ..... kJ mol$^{-1}$



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(iii) Calculate the standard entropy change for this reaction. [2]

$\Delta S^{\theta}$ = ..... $JK^{-1}mol^{-1}$

(iv) Calculate the minimum temperature required for this thermal decomposition. [2]

$T$ = ..... °C

14



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**14.** (a) You are provided with six unlabelled solid mixtures.

**A** lead(II) nitrate and magnesium chloride

**B** magnesium chloride and barium chloride

**C** barium chloride and copper(II) nitrate

**D** copper(II) nitrate and lead(II) carbonate

**E** lead(II) carbonate and aluminium nitrate

**F** aluminium nitrate and lead(II) nitrate

You have access to common laboratory equipment and the following solutions.

- deionised water
- dilute nitric acid
- dilute hydrochloric acid
- aqueous sodium hydroxide

Suggest how you would identify which mixture is which. Give the observations expected for any tests you undertake. [6 QER]



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(b) You are provided with a solution that is one of the following.

**G** aqueous sodium bromide

**H** a mixture of aqueous sodium chloride and aqueous sodium iodide

(i) Give the observations expected with these solutions when aqueous silver nitrate is added. [1]

Solution **G** .....

Solution **H** .....

(ii) Give a further test that would allow you to confirm which of the two solutions you were given. [2]

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(c) Solution **J** contains iodide ions, $I^-(aq)$.

(i) State what is observed when aqueous lead(II) nitrate is added to solution **J**.

Give an ionic equation for the reaction. [2]

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(ii) State what is observed when aqueous copper(II) sulfate is added to solution **J**.

Give an ionic equation for the reaction. [2]

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**15.** (a) State what is meant by the term first ionisation energy. [1]

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(b) The **second** ionisation energies of four elements are given below. The elements are lithium, magnesium, silicon and sodium but not in that order.

1450 kJ mol$^{-1}$ 1580 kJ mol$^{-1}$ 4560 kJ mol$^{-1}$ 7300 kJ mol$^{-1}$

State which ionisation energy is associated with each element. Explain your choices. [5]

lithium ..... kJ mol$^{-1}$ magnesium ..... kJ mol$^{-1}$

silicon ..... kJ mol$^{-1}$ sodium ..... kJ mol$^{-1}$

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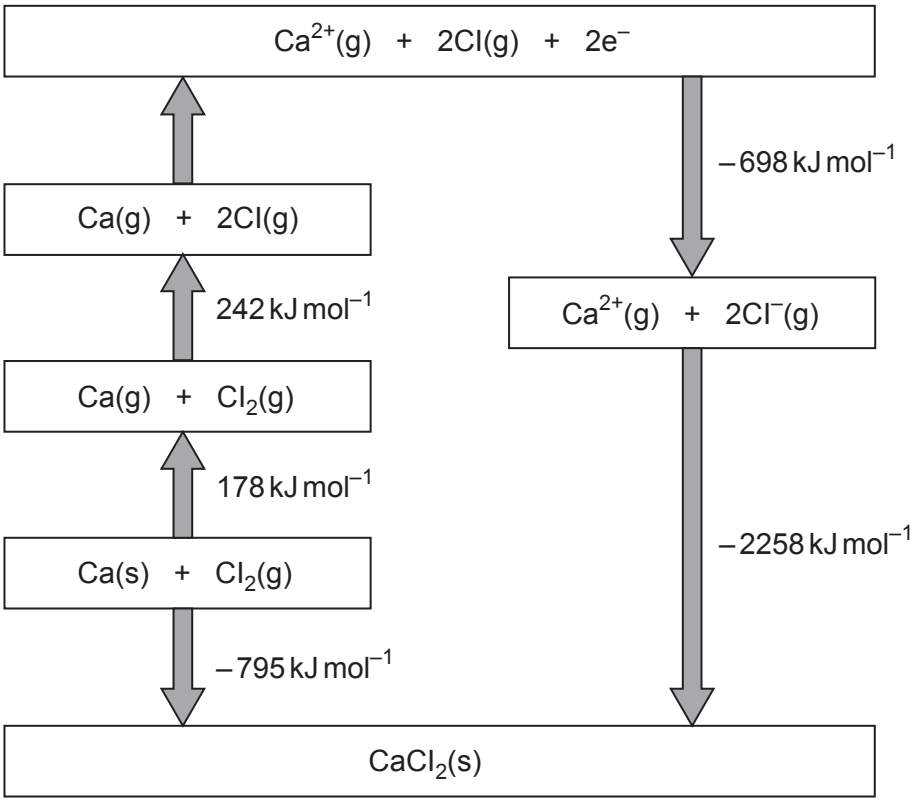
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(c) (i) Use the Born-Haber cycle to calculate the energy required to form a $Ca^{2+}(g)$ ion from a Ca(g) atom. [2]




Energy required = ..... $kJ\,mol^{-1}$

(ii) Suggest a value for the **first** ionisation energy of calcium. Give a reason for your answer. [1]

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(d) Most noble gases do not form compounds due to their very high ionisation energies. Amongst the very few noble gas compounds to form are $XeF_2$, $XeF_4$ and $XeF_6$.

(i) Although $XeF_6$ has six fluorine atoms bonded to the Xe atom, it does not have an octahedral shape. Explain why this is so. [2]

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(ii) $XeF_2$ is soluble in anhydrous HF with a solubility of 162 g per 100 g of HF at 20 °C. The density of anhydrous HF is 1.66 g cm$^{-3}$.

Calculate the solubility of $XeF_2$ in HF at 20 °C in mol dm$^{-3}$. [3]

Solubility = ..... mol dm$^{-3}$

(iii) The melting temperature of $XeF_4$ is 117 °C, whilst that of $SiF_4$ is –95 °C.

Explain why the melting temperature of $SiF_4$ is lower than that of $XeF_4$. [2]

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16

**END OF PAPER**



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| Question number | Additional page, if required.<br>Write the question number(s) in the left-hand margin. |
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