| Candidate Name | Centre Number | Candidate Number |
|---|---|---|
| | | 2 |

# GCE AS/A level

1091/01

# CHEMISTRY CH1

A.M. THURSDAY, 14 January 2010

1½ hours

| FOR EXAMINER'S USE ONLY | | |
|---|---|---|
| Section | Question | Mark |
| A | 1-6 | |
| B | 7 | |
| | 8 | |
| | 9 | |
| | 10 | |
| TOTAL MARK | | |



**ADDITIONAL MATERIALS**

In addition to this examination paper, you will need a:
- calculator;
- copy of the **Periodic Table** supplied by WJEC. Refer to it for any **relative atomic masses** you require.

**INSTRUCTIONS TO CANDIDATES**

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

**Section A** Answer **all** questions in the spaces provided.
**Section B** Answer **all** questions in the spaces provided.

Candidates are advised to allocate their time appropriately between **Section A (10 marks)** and **Section B (70 marks)**.

**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 80.

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

You are reminded that marking will take into account the Quality of Written Communication used in all written answers.

Page 18 may be used for rough work.

Examiner only

## SECTION A

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

**1.** Complete the boxes below, by inserting arrows to represent electrons, to show the electron configuration of an atom of aluminium, Al. [1]


**2.** State which **one** of the following letters represents the first five ionisation energies of aluminium, Al. Give a reason for your choice. [2]

*Ionisation energy* / kJ $mol^{-1}$

| | 1st | 2nd | 3rd | 4th | 5th |
|---|---|---|---|---|---|
| **A** | 496 | 4563 | 6913 | 9544 | 13352 |
| **B** | 578 | 1817 | 2745 | 11578 | 14831 |
| **C** | 1402 | 2856 | 4578 | 7475 | 9445 |
| **D** | 789 | 1577 | 3232 | 4356 | 16091 |

*Letter* .....

*Reason* .....

.....

.....

Examiner only

**3.** *(a)* Complete the following definition of the ***mole***: [1]

A mole is the amount of material containing the same number of particles as there are atoms in ..... .

*(b)* State the number of moles of sulfur atoms, S, in 0.3 mol iron(III) sulfate, $Fe_2(SO_4)_3$. [1]

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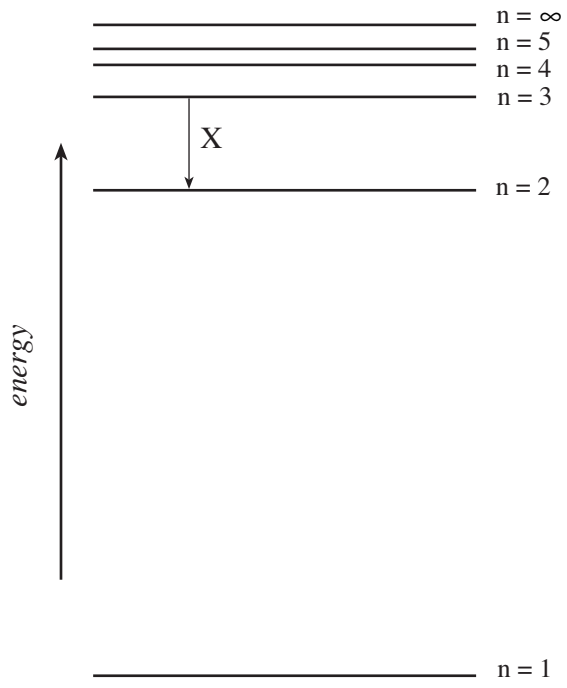
**4.** The diagram below shows the electron energy levels for a hydrogen atom.




*(a)* State which one of the following correctly describes the transition represented by arrow X: [1]

**A** The first line in the Lyman series
**B** The second line in the Lyman series
**C** The first line in the Balmer series
**D** The second line in the Balmer series

.....

*(b)* Draw on the energy level diagram an arrow to represent the transition which occurs when a hydrogen atom is ionised. [1]





**Turn over.**

Examiner only

**5.** Sketch a diagram to show the shape of a p-orbital. [1]

**6.** *(a)* Explain the term *dynamic equilibrium* for a chemical system. [1]

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*(b)* Explain how you would tell, from the properties of the system, that equilibrium has been reached. [1]

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**Section A Total [10]**

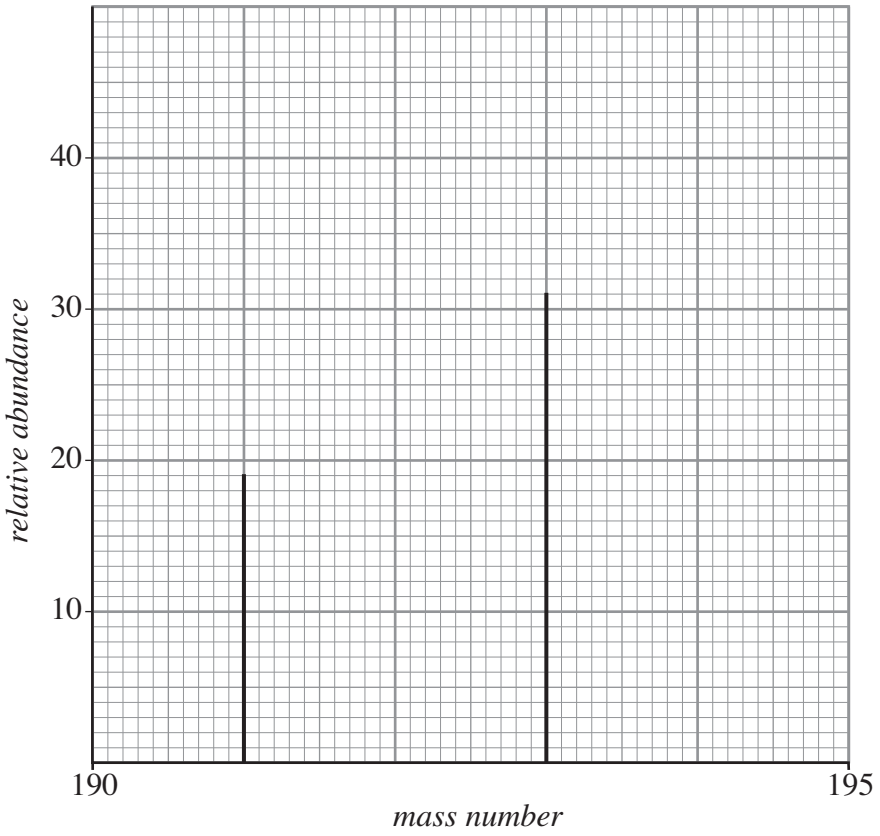
Examiner only

## SECTION B

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

**7.** Iridium, Ir, is the element with atomic number 77.

*(a)* Its mass spectrum shows that iridium has two naturally-occurring isotopes.




(i) Explain the term *isotopes*. [1]

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(ii) State the numbers of electrons, neutrons and protons present in **each** of the two isotopes. [2]

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(iii) Measure the height of each peak and hence calculate the percentage abundance of each isotope in naturally-occurring iridium. [2]

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**Turn over.**

Examiner only

*(b)* A further man-made, radioactive isotope of iridium, $^{192}$Ir, is manufactured by bombarding naturally-occurring iridium with neutrons in a nuclear reactor. $^{192}$Ir is used in the radiotherapy of certain cancers.

(i) $^{192}$Ir decays by β–emission. Explain what is meant by β–emission. [1]

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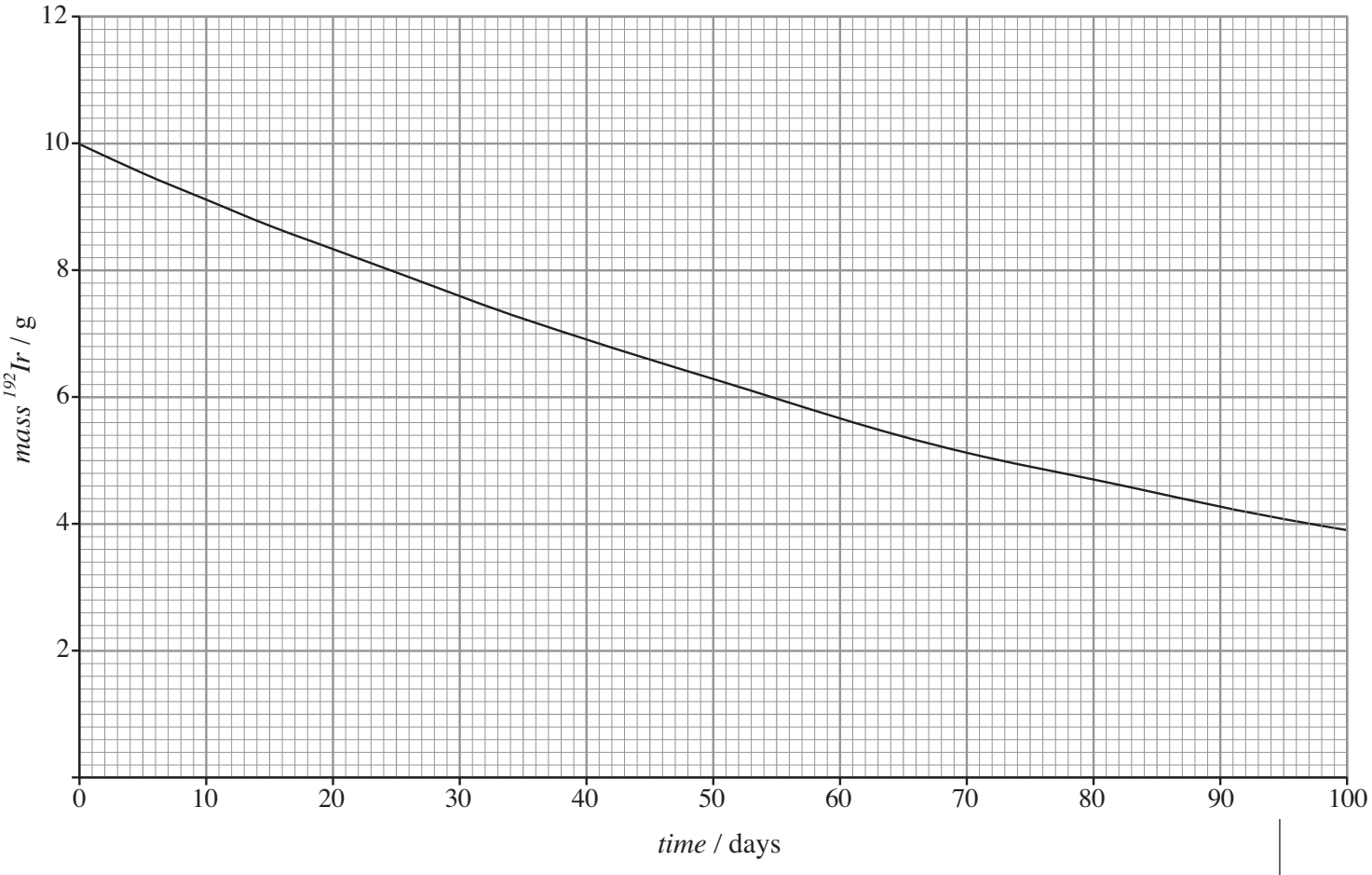
(ii) Give the mass number and symbol of the product atom in *(b)*(i). [2]

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

*(c)* The decay of a 10g sample of $^{192}$Ir with time is shown in the graph.




(i) Explain the term *half-life*. [1]

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(ii) Determine the half-life of $^{192}$Ir from the graph. [1]

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(iii) Determine the total time required for the 10 g mass of $^{192}$Ir to decay to 1.25 g. [2]

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(iv) Calculate, from the graph, the rate of decay of $^{192}$Ir (g day$^{-1}$) during the first 20 days. [2]

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*(d)* Compound **P**, one of the most important compounds of iridium, is a black solid containing 10.2 % sodium, Na, 42.6 % iridium, Ir, and 47.2 % chlorine, Cl, by mass.

(i) Calculate the empirical formula (which is also the molecular formula) of compound **P**.

$A_r$(Na) = 23.0; $A_r$(Cl) = 35.5; $A_r$(Ir) = 192. [2]

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(ii) Compound **P** is made by reacting a mixture of sodium chloride, NaCl, and an iridium chloride, $IrCl_x$. There is only one product of the reaction. By constructing a balanced equation, or otherwise, determine the value of **x** in the iridium chloride formula, $IrCl_x$. [1]

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Total [17]

Examiner only

**8.** Because of the link to global warming, much effort is being devoted to investigating how emissions of carbon dioxide, $CO_2$, into the atmosphere by power stations burning fossil fuels can be reduced or eliminated.

*(a)* One area of investigation is the removal of $CO_2$ by sodium carbonate. Three possible reactions are:

$Na_2CO_3(s) + CO_2(g) + H_2O(g) \rightleftharpoons 2NaHCO_3(s)$ **Reaction 1**

$3Na_2CO_3(s) + CO_2(g) + 5H_2O(g) \rightleftharpoons 2Na_2CO_3.NaHCO_3.2H_2O(s)$ **Reaction 2**

$5Na_2CO_3(s) + 3CO_2(g) + 3H_2O(g) \rightleftharpoons 2Na_2CO_3.3NaHCO_3(s)$ (Wegscheider's Salt) **Reaction 3**

(i) Giving a reason, determine from the equations which of the three reactions uses sodium carbonate, $Na_2CO_3(s)$, most effectively to absorb $CO_2(g)$. [2]

*QWC* [1]

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(ii) State Le Chatelier's Principle. [1]

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(iii) Giving your reasons, use Le Chatelier's Principle to determine whether $CO_2(g)$ removal will be more efficient at high gas pressure or low gas pressure. [2]

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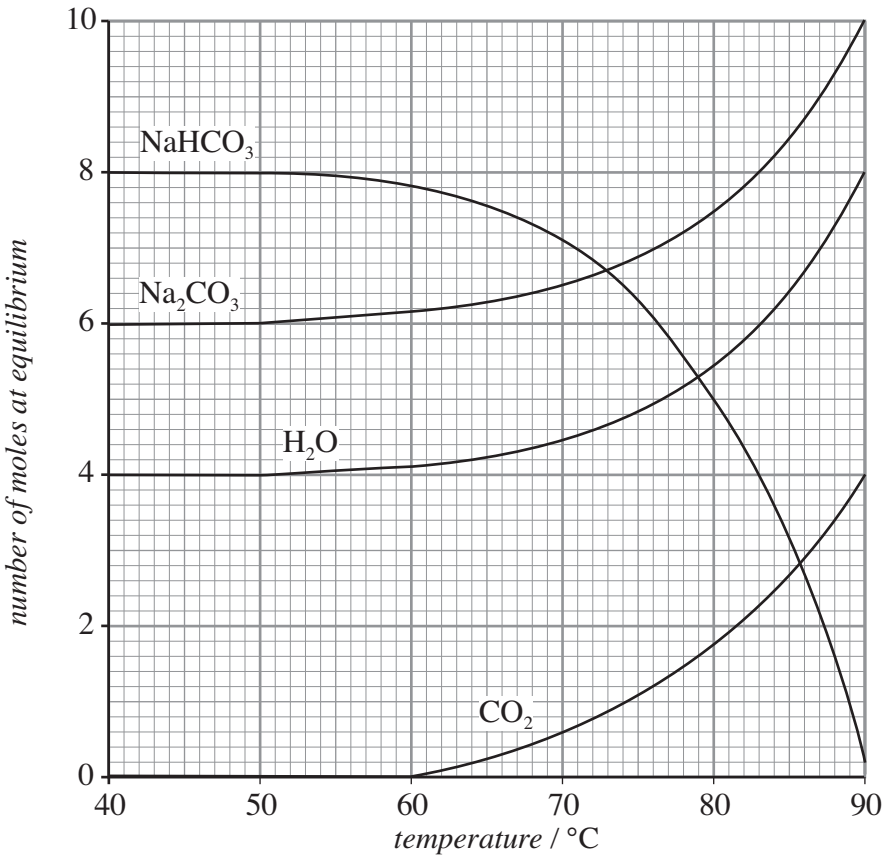
Examiner only

*(b)* For one industrial system using **Reaction 1**

$$Na_2CO_3(s) + CO_2(g) + H_2O(g) \rightleftharpoons 2NaHCO_3(s)$$

the amount of each species present at equilibrium was measured over a range of temperatures. The graph below shows the results.




(i) Giving your reasoning, determine from the graph whether the forward reaction in **Reaction 1** is exothermic or endothermic. [2]

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(ii) After the removal of $CO_2(g)$, the solid $NaHCO_3$ residue is taken away and recycled to regenerate sodium carbonate, $Na_2CO_3(s)$.

I By using the graph, or otherwise, determine how sodium carbonate, $Na_2CO_3(s)$, can be regenerated from the $NaHCO_3$ residue. [1]

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II State **one** problem associated with the regeneration of sodium carbonate, $Na_2CO_3(s)$, by the method you have given. [1]

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Examiner only

*(c)* Another area of investigation is the use of a new type of plastic membrane, structured by means of nanotechnology, to catch carbon dioxide gas whilst allowing other waste gases to pass freely through.

If 1000 $dm^3$ of waste gas at 25 °C yielded 275 g of carbon dioxide, separated by a plastic membrane, calculate:

(i) the number of moles of carbon dioxide in the 275 g separated by the membrane; [2]

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(ii) the volume of carbon dioxide separated at 25 °C; [1]

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[One mole of gas has a volume of 24.0 $dm^3$ at 25 °C and 1 atm pressure]

(iii) the percentage by volume of carbon dioxide in the waste gas. [1]

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*(d)* Carbon dioxide, $CO_2$ is an *acid gas*.

(i) Define the term *acid*. [1]

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(ii) By considering its interaction with water, explain how carbon dioxide can behave as an acid. [1]

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(iii) Though the pH of pure water is 7, explain why naturally-occurring water in contact with air has a pH of less than 7. [1]

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Total [17]

Examiner only

**9.** *(a)* (i) Given the bond enthalpy values

| *Bond* | *Bond enthalpy value* / kJ $mol^{-1}$ |
|---|---|
| Cl – Cl | 243 |
| H – Cl | 432 |
| H – H | 436 |

calculate the standard enthalpy change, $\Delta H^{\ominus}$, for the gaseous reaction

$$H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$$ [2]

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(ii) Using your answer to *(a)*(i) calculate the standard enthalpy change of formation, $\Delta H_f^{\ominus}$, for gaseous hydrogen chloride, HCl(g). [1]

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(iii) State the standard conditions which apply to *standard* enthalpy changes. [2]

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(iv) By reference to the bond enthalpy values in *(a)*(i), state which bond will break first in the reaction. [1]

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Examiner only

(v) Typical energies associated with visible light are

| *Colour of light* | *Typical energy* / kJ $mol^{-1}$ |
|---|---|
| red | 171 |
| yellow | 200 |
| green | 226 |
| blue | 254 |
| violet | 285 |

State and explain which colours of light will cause a mixture of hydrogen and chlorine to react. [3]

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(vi) Explain why shining visible light has very little effect on the reverse reaction

$$2HCl(g) \longrightarrow H_2(g) + Cl_2(g)$$ [1]

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Examiner only

*(b)* The corresponding reaction between hydrogen, $H_2(g)$, and iodine, $I_2(g)$,

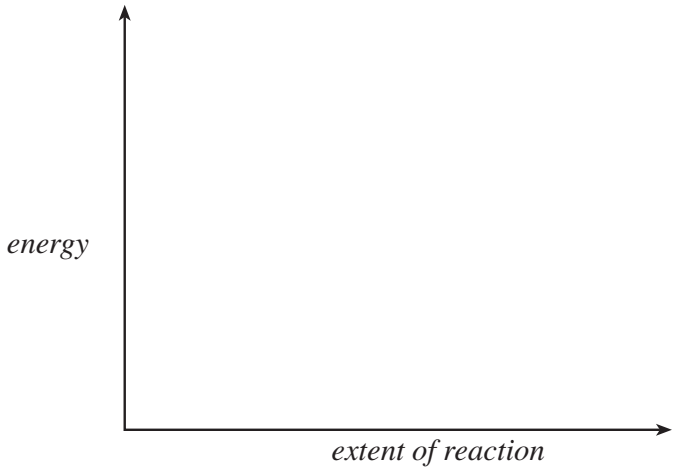
$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

for which the standard enthalpy change of reaction, $\Delta H^{\ominus}$, = –9.6 kJ $mol^{-1}$, is a system unaffected by light.

Sketch on the axes below the energy profile (*energy* v *extent of reaction*) for the reaction between hydrogen and iodine and use it to explain:

- the concept of *activation energy*;
- the effect of increasing temperature on the rate of reaction;
- the effect of adding a catalyst to a reaction mixture. [6]

*QWC* [2]

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Total [18]



**Turn over.**

Examiner only

**10.** Ammonia, $NH_3$, and hydrochloric acid, HCl, undergo an acid-base reaction in aqueous solution.

$$NH_3(aq) + HCl(aq) \longrightarrow NH_4^+(aq) + Cl^-(aq)$$

*(a)* Explain why this is an acid-base reaction, clearly identifying **both** the acidic and basic reactants. [2]

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*(b)* A 25 $cm^3$ sample taken from a stock aqueous solution of ammonia was mixed with 25 $cm^3$ of a solution containing excess hydrochloric acid. The temperature of the mixture rose by 0.7 °C.

(i) Given that the enthalpy change for the reaction, $\Delta H$, is –53.4 kJ $mol^{-1}$, use the equation below to calculate n, the number of moles of ammonia, $NH_3$, which has reacted.

$$\Delta H = \frac{-vc\Delta T}{n}$$

where v is the **total** volume of solution ($cm^3$)
c is the specific heat capacity (4.2 J $cm^{-3}$ $°C^{-1}$)
$\Delta T$ is the temperature change (°C)
n is the number of moles of ammonia reacted [3]

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(ii) Calculate the concentration (mol $dm^{-3}$) of the original ammonia stock solution. [1]

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Examiner only

*(c)* The concentration of the same stock aqueous solution of ammonia used in part *(b)* was also determined by an acid-base titration. Three separate 25.00 $cm^3$ samples of the ammonia solution were titrated against hydrochloric acid of concentration 0.1000 mol $dm^{-3}$ from a burette, using an appropriate indicator.

The three titre volumes were 31.25 $cm^3$, 31.25 $cm^3$ and 31.20 $cm^3$ respectively.

(i) Calculate the mean titre volume and use this to find the concentration (mol $dm^{-3}$) of the ammonia solution. [2]

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(ii) Compare the concentration values for the stock ammonia solution obtained by the two experimental methods, *(b)*(ii) and *(c)*(i). State which experiment will give the more precise value, giving **two** reasons for your choice. [3]

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Examiner only

*(d)* During World War II, ammonia was used as a fuel for running buses in Belgium. With the current problems associated with fossil fuels, interest in the use of ammonia as a fuel is being revived.
Some relevant standard enthalpy changes of formation, $\Delta H_f^{\ominus}$, are given in the table below.

| *Species* | $\Delta H_f^{\ominus}$ / kJ mol$^{-1}$ |
|---|---|
| $CH_4(g)$ | –74.8 |
| $CO_2(g)$ | –393.5 |
| $H_2O(g)$ | –241.8 |
| $N_2(g)$ | 0 |
| $NH_3(g)$ | –46.1 |
| $O_2(g)$ | 0 |

(i) Explain why $N_2(g)$ and $O_2(g)$ each have a value of zero for their standard enthalpy change of formation, $\Delta H_f^{\ominus}$. [1]

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(ii) Use the $\Delta H_f^{\ominus}$ values given to calculate:

I the standard enthalpy change, $\Delta H^{\ominus}$, for the combustion of ammonia;

$$4NH_3(g) + 3O_2(g) \longrightarrow 2N_2(g) + 6H_2O(g)$$ [2]

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II the standard enthalpy change, $\Delta H^{\ominus}$, for the combustion of methane (as an example of a fossil fuel).

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$$ [2]

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Examiner only

(iii) State **one** advantage and **one** disadvantage of using ammonia as a fuel compared to using methane. [2]

*Advantage of using ammonia* .....

.....

*Disadvantage of using ammonia* .....

.....

Total [18]

**Section B Total [70]**



**Turn over.**

Examiner only

## Rough Work