Candidate Name	Centre Number	Candidate Number
		2

GCE AS/A level

1091/01

CHEMISTRY CH1

A.M. THURSDAY, 14 January 2010

$1\frac{1}{2}$ hours

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

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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.

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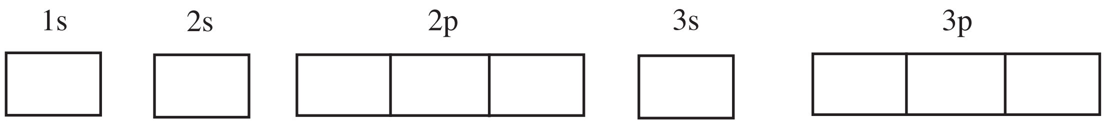
SECTION A

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 ....

....

....

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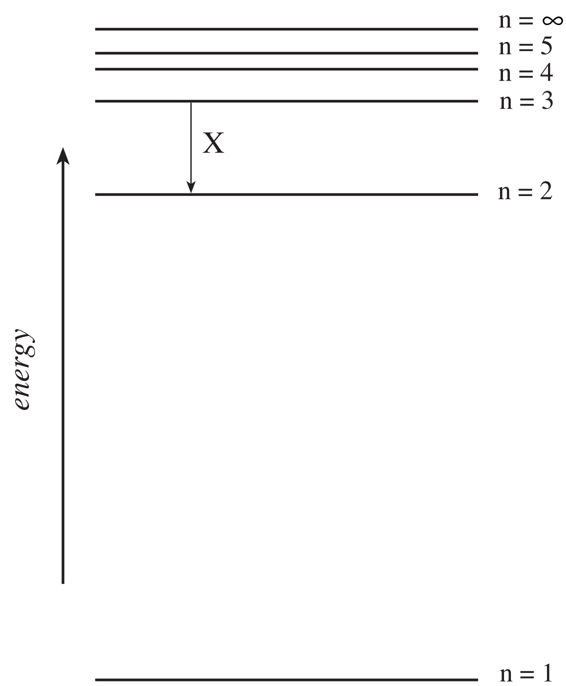
3. *(a)* Complete the following definition of the ***mole***: [1]

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]

....

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]

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Turn over.

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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]

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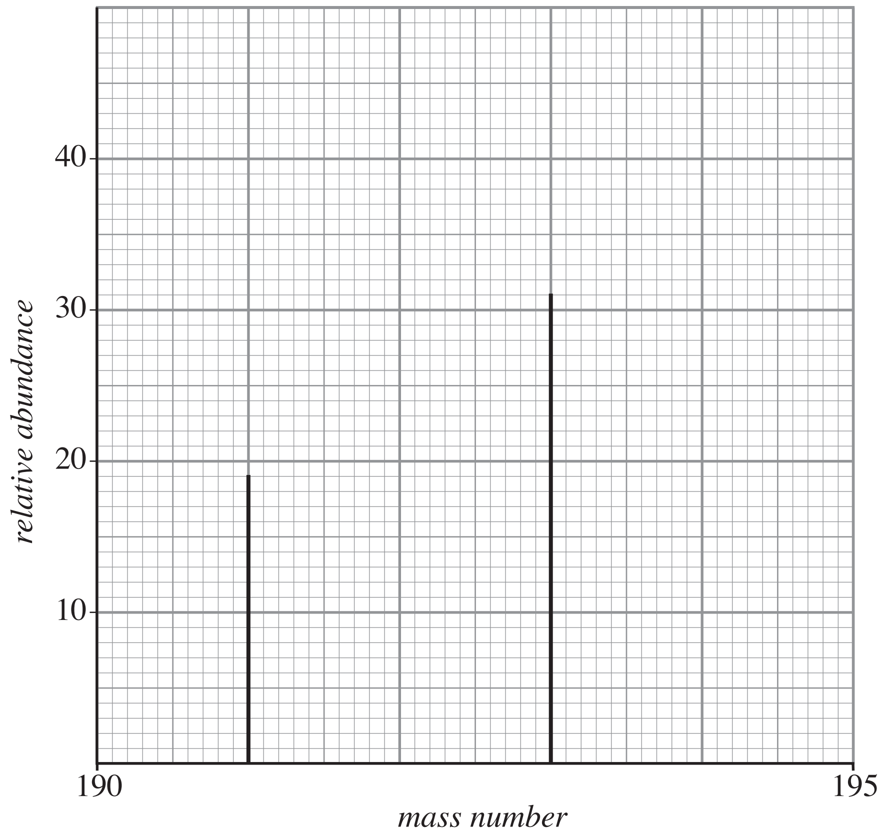
SECTION B

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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(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.

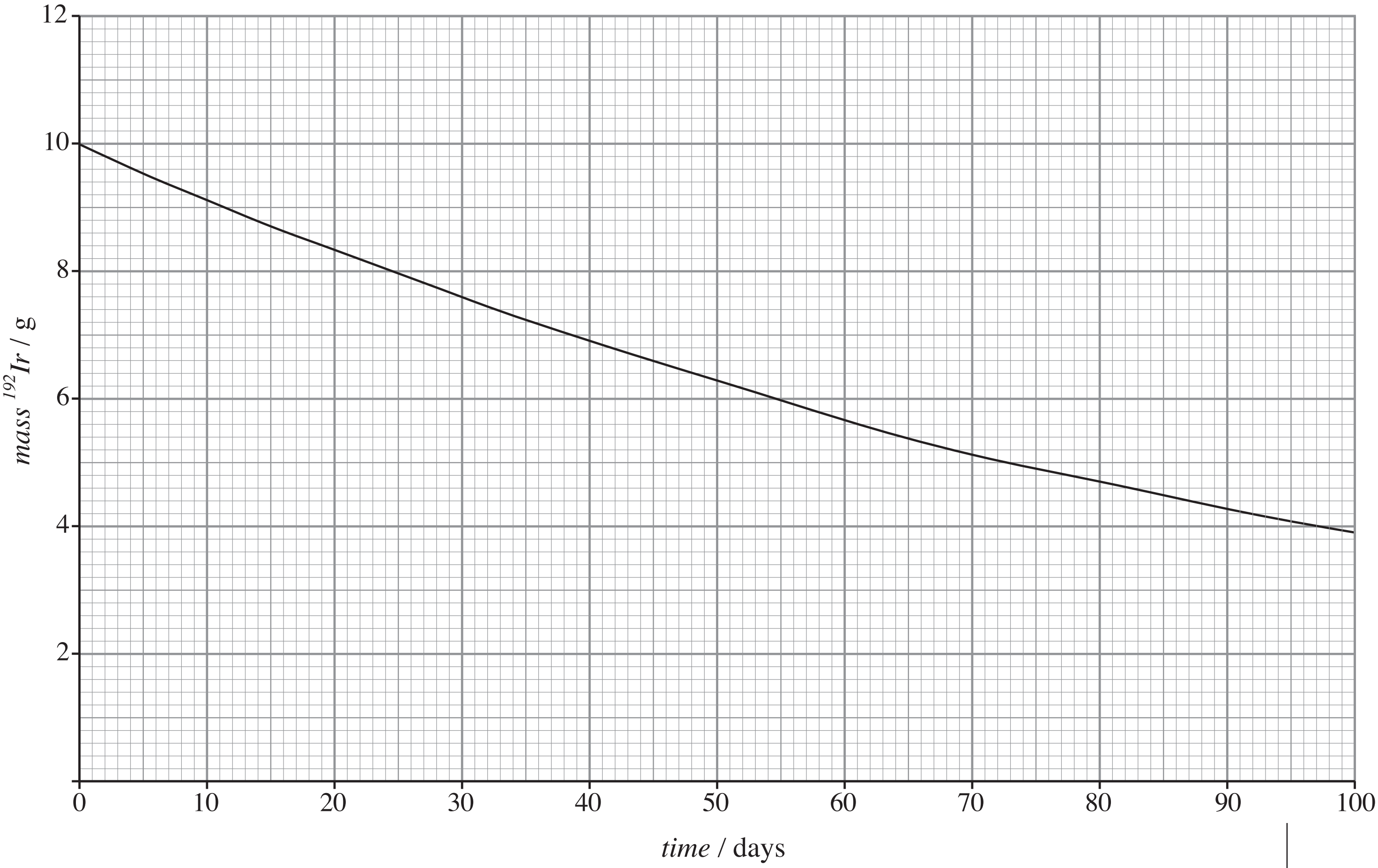
(i) ^{192}Ir decays by β–emission. Explain what is meant by β–emission. [1]

....

(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]

....

....

(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]

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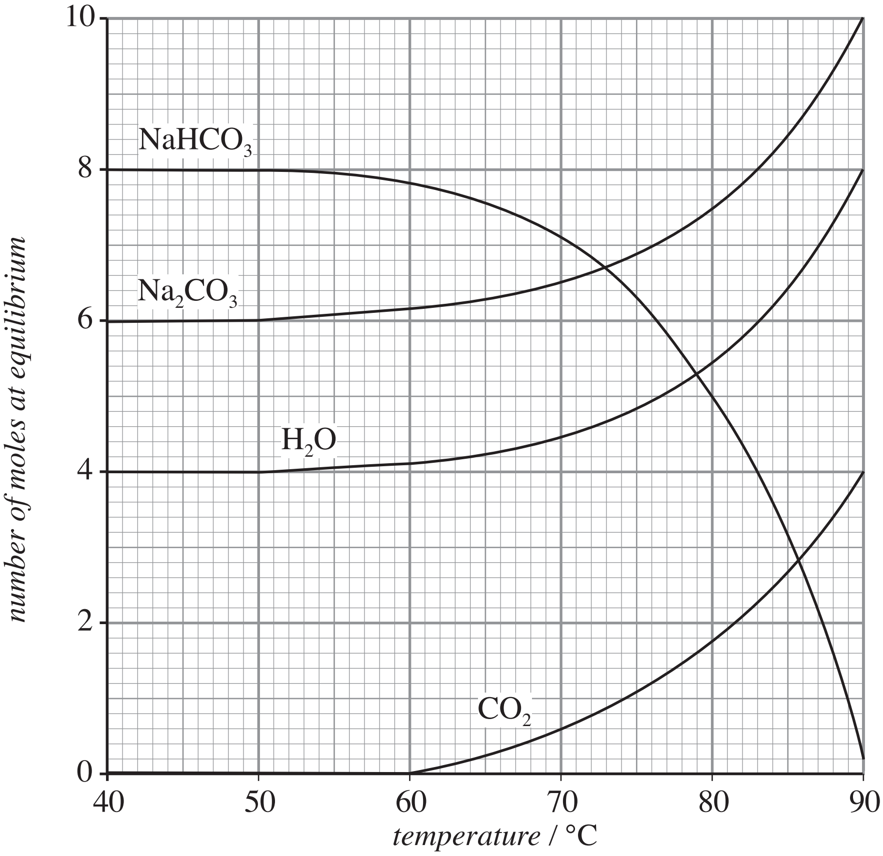
(b) For one industrial system using **Reaction 1**

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

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]

....

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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(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]

....

....

[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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(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, $I_2(g)$,

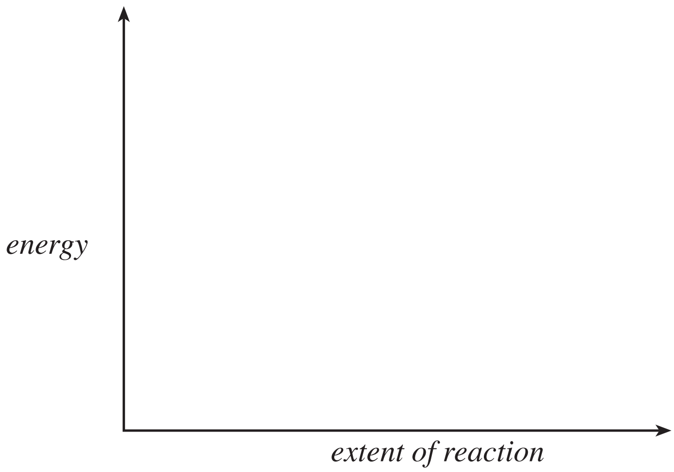
$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

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]



Total [18]

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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, ΔH, is –53.4 kJ mol^{-1}, use the equation below to calculate n, the number of moles of ammonia, NH_3, which has reacted.

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

where v is the **total** volume of solution (cm^3)
c is the specific heat capacity (4.2 J cm^{-3} $°C^{-1}$)
ΔT 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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(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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(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]

....

....

....

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]

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Rough Work