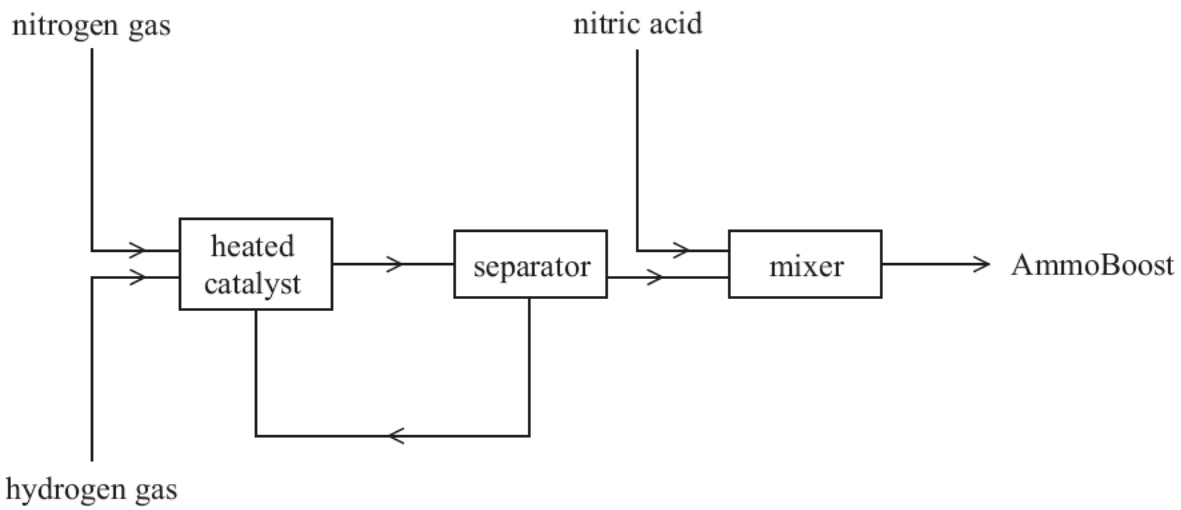
1 AmmoFert Chemicals is a company that manufactures fertilisers.

The flow chart shows how the company manufactures a fertiliser called AmmoBoost.



(a) The first step in the process is the conversion of nitrogen gas and hydrogen gas into ammonia.

(i) State a raw material used as the source of each gas.

(2)

nitrogen .....

hydrogen .....

(ii) Identify the catalyst used in this conversion.

(1)

.....

(iii) State **one** other condition used in this conversion.

(1)

.....

(iv) Only a small percentage of the nitrogen gas and hydrogen gas is converted into ammonia.
Explain how the unreacted gases are separated from the ammonia.

(2)

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(b) The equation for the production of ammonia is

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H \quad 92 \text{ kJ/mol}$$

Calculate the maximum mass of ammonia that can be obtained from 56 tonnes of nitrogen.
(1 tonne 1 000 000 grams)

(3)

(c) EnAitchThree is another company that manufactures ammonia using the same reaction as AmmoFert but using different conditions.
EnAitchThree uses a higher temperature and a higher pressure than AmmoFert.

(i) Predict the effect on the rate of reaction and on the equilibrium position by changing to the temperature used by EnAitchThree.

(2)

Effect of higher temperature on rate of reaction

.....

.....

Effect of higher temperature on equilibrium position

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.....

(ii) Predict the effect on the equilibrium position by changing to the pressure used by EnAitchThree. Justify your prediction.

(2)

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(d) The main compound in AmmoBoost contains 35% nitrogen and 5% hydrogen by mass. The remainder is oxygen.

(i) Calculate the percentage by mass of oxygen in the compound.

(1)

(ii) Determine the empirical formula of the compound.

(3)

(iii) What is the **name** of the main compound in AmmoBoost?

(1)

.....

(Total for Question 1 18 marks)

2 Some students investigated the rate of reaction between sodium thiosulfate solution and hydrochloric acid. The equation for the reaction is

$$Na_2S_2O_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + S(s) + SO_2(g)$$

The precipitate of sulfur makes the reaction mixture go cloudy.

The students used this method.

- Place a mixture of sodium thiosulfate solution and water in a conical flask
- Add some dilute hydrochloric acid, swirl the mixture and start a timer
- Place the flask over a black cross marked on a piece of paper
- Record the time taken for the cross to disappear when viewed from above

The students used 10 cm^3 of dilute hydrochloric acid in each experiment.

They carried out all the experiments at the same temperature.

They used different volumes of sodium thiosulfate solution and water in each experiment. They were told to keep the total volume of sodium thiosulfate solution and water constant.

The table shows their results.

Student	Volume of sodium thiosulfate solution in cm^3	Volume of water in cm^3	Time in s
1	50	0	26.6
2	40	10	55.9
3	35	15	76.4
4	30	20	105.6
5	25	25	149.0
6	20	30	223.5
7	15	40	321.4

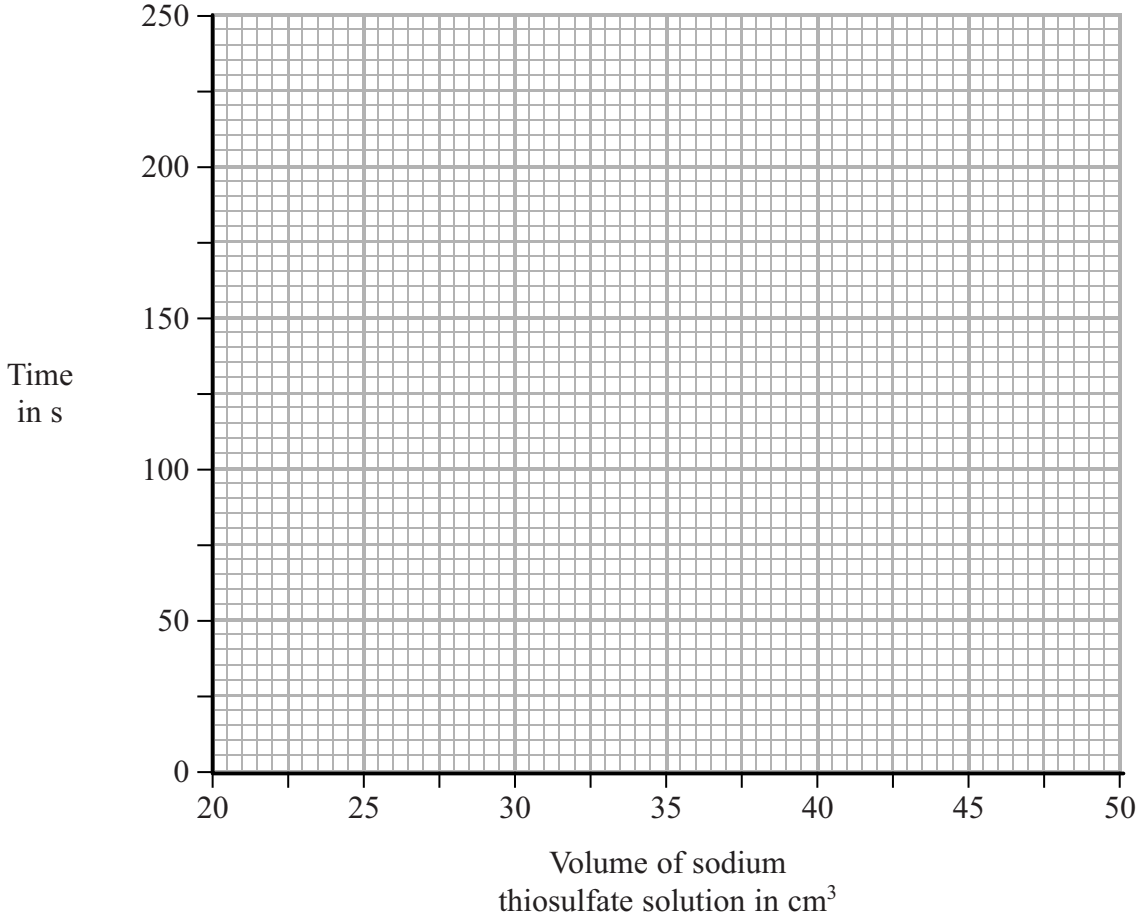
(a) Explain why the results of student 7 should not be used.

(1)

.....

(b) Plot the results of the six other students on the grid below. Draw a curve of best fit through the points.

(3)



(c) The students used this equation to calculate the rate of each reaction in their investigation.

$$\text{rate of reaction} \quad \frac{1000}{\text{time taken}}$$

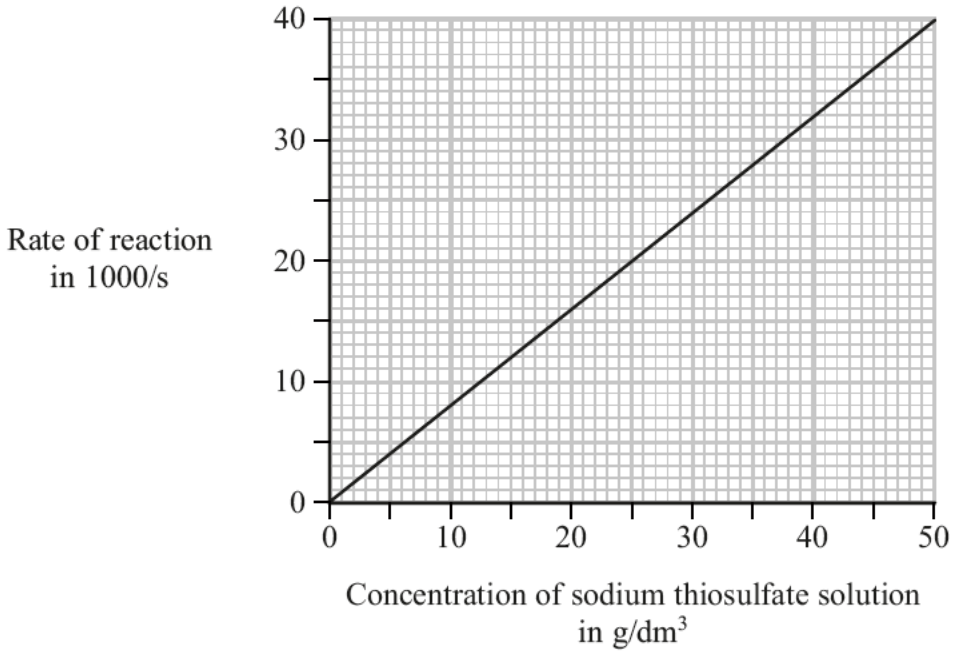
Calculate the rate of reaction for student 1's experiment.

Give your answer to **one** decimal place.

(2)

Rate .....

(d) Another group of students used the same method but with different solutions of sodium thiosulfate and hydrochloric acid. They calculated the rate of reaction for each experiment they did. Their results are shown on the following graph.



(i) Describe the relationship between rate and concentration as shown by the graph.

(2)

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(ii) Explain why increasing the concentration has this effect on the rate.

(3)

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(Total for Question 2 11 marks)

3 A manufacturer investigates some reactions that produce hydrogen.

The table shows three possible reversible reactions that he could use. The enthalpy changes are also shown.

Reaction	Equation	ΔH in kJ/mol
1	$CH_4(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 4H_2(g)$	+165
2	$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$	−41
3	$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$	−206

(a) (i) For reaction 1, predict whether the pressure should be low or high to give the greatest yield of products.

(1)

.....

(ii) Give a reason for your choice.

(1)

.....

.....

(b) (i) For reaction 1, predict whether the temperature should be low or high to give the greatest yield of products.

(1)

.....

(ii) Give a reason for your choice.

(1)

.....

.....

(c) For reaction 2, suggest why changing the temperature will have less effect on the yield of products than in reactions 1 and 3.

(1)

.....

.....

(d) (i) For reaction 3, predict the effect on the rate of the forward reaction of increasing the pressure, without changing the temperature.

(1)

.....

(ii) Explain your prediction in terms of the particle collision theory.

(2)

.....

.....

.....

.....

(e) The manufacturer makes a batch of ethanoic acid from methanol and carbon monoxide using this reaction.

$$CH_3OH + CO \rightarrow CH_3COOH$$

He starts with 64 kg of methanol.

Calculate the maximum mass of ethanoic acid he could obtain.

(3)

maximum mass of ethanoic acid = ... kg

(Total for Question 3 = 11 marks)

4 The equation for a reaction that occurs in the manufacture of nitric acid is

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -900 \text{ kJ/mol}$$

(a) (i) State the meanings of the symbols $\rightleftharpoons$ and ΔH.

(2)

$\rightleftharpoons$ .....

ΔH .....

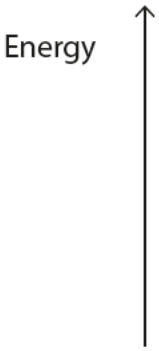
(ii) What does the negative sign of ΔH indicate about the reaction?

(1)

.....

(b) Complete the energy level diagram for this reaction.

(2)



(c) Typical conditions used for this reaction are a temperature of 900 °C and a pressure of 10 atmospheres.

Deduce the effects of changing the conditions as shown in the table. Choose from the words **increased**, **decreased** or **unchanged** to complete the table.

(4)

Change	Effect on rate of reaction	Effect on yield of products
increase in temperature		
addition of catalyst		

(d) A manufacturer considers using a pressure of 5 atm instead of 10 atm.

(i) Predict and explain the effect on the rate of reaction of changing the pressure to 5 atm.

(3)

Effect on rate of reaction .....

.....

Explanation .....

.....

.....

.....

.....

(ii) Predict and explain the effect on the position of equilibrium of changing the pressure to 5 atm.

(2)

Effect on position of equilibrium .....

.....

Explanation .....

.....

.....

(e) Balance the equation that represents the last stage in the manufacture of nitric acid.

$$\text{.....}NO_2 + \text{.....}O_2 + \text{.....}H_2O \rightarrow \text{.....}HNO_3$$

(1)

(Total for Question 4 = 15 marks)