1 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)

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(ii) Give a reason for your choice.

(1)

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(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)

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

(1)

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

(2)

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(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.

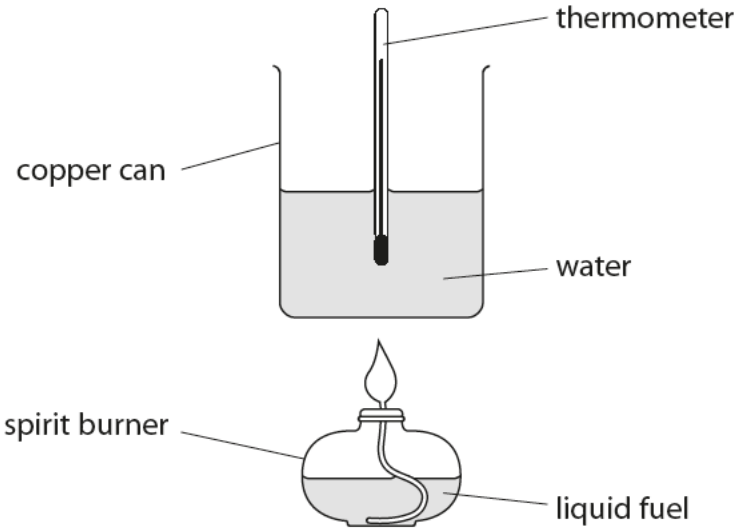
(3)

maximum mass of ethanoic acid = ... kg

(Total for Question 1 = 11 marks)

2 A student burned four liquid fuels in order to compare the amount of energy they released, in the form of heat.

She used this apparatus.



The energy released when each fuel was burned was used to raise the temperature of 100 g of water. For each fuel, the student recorded the mass of fuel burned and the increase in temperature of the water.

Her results are shown in the table.

Fuel	Average relative formula mass	Mass of fuel burned in g	Amount of fuel burned in mol	Increase in temperature in °C
diesel	170	4	0.024	15
ethanol	46	3	0.065	10
methanol	32	2	0.063	5
petrol	114	1	0.009	4

The best fuel is the one that releases the most energy.

(a) The student suggested that petrol was the best fuel.

Explain why, using the information in the table.

(1)

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(b) Another student suggested that diesel was the best fuel.

Explain why, using the information in the table.

(1)

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(c) In another experiment, a student burned propanol and then used his results to calculate the energy released when one mole of propanol was burned.

He then compared his result with a value from a data book.

The values are shown in the table.

	Energy released per mole of propanol burned in kJ
Student's result	1020
Data book value	2010

Suggest two reasons why the student's result is lower than the data book value.

(2)

1 .....

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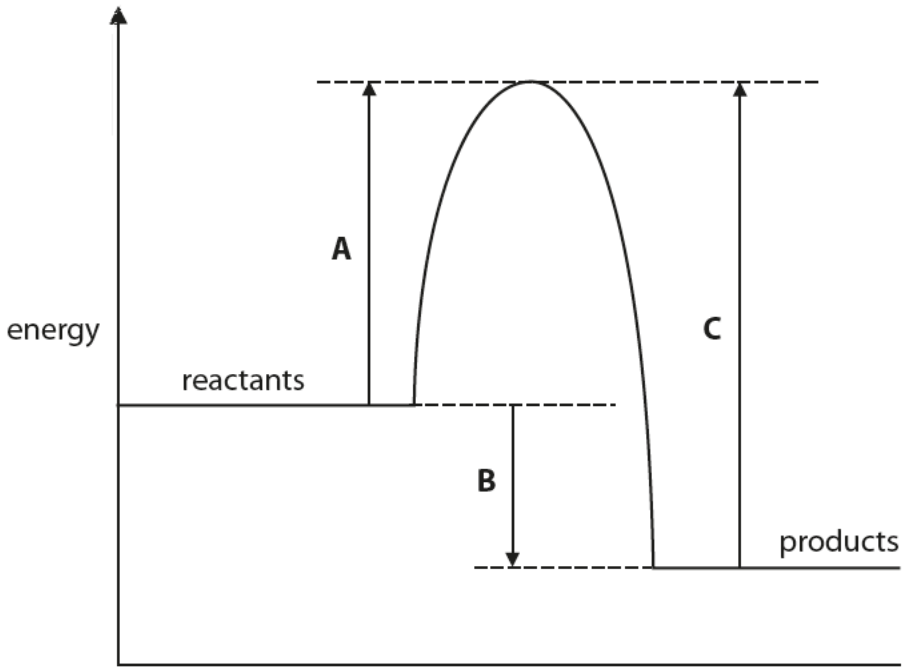
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2 .....

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(d) The diagram shows the energy profile for burning a fuel.



Which of the energy changes A, B or C represents

- the activation energy for the reaction
- the amount of energy given out during the reaction?

(2)

Activation energy = ...

Energy released = ...

(e) Explain, in terms of bond breaking and bond making, why this reaction gives out energy.

(3)

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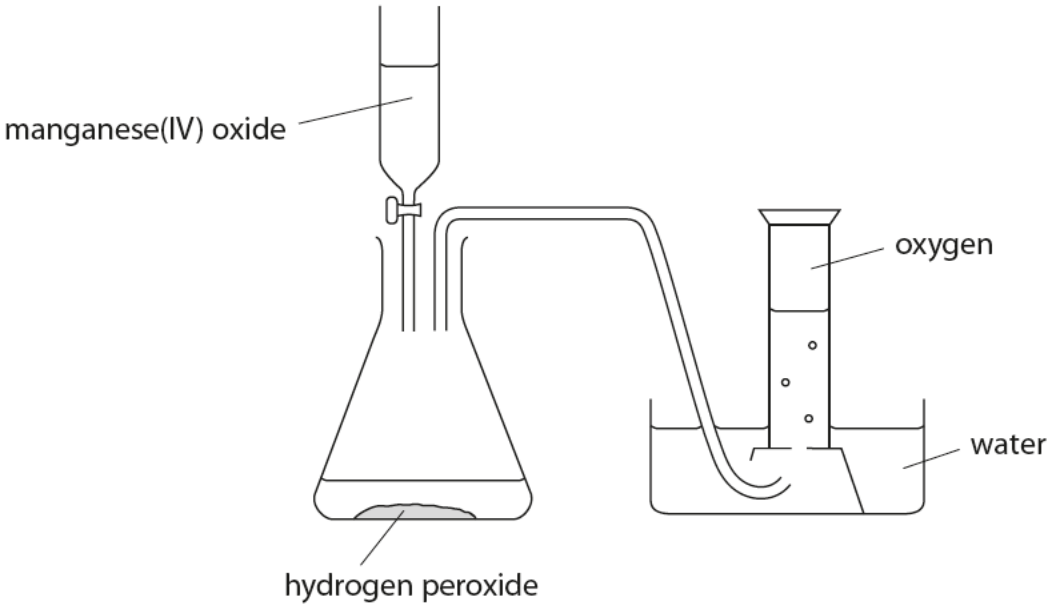
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(Total for Question 2 = 9 marks)

3 A student draws this diagram to show how he plans to prepare and collect oxygen gas in a laboratory.



(a) The student makes a mistake in the labelling. He also misses out a piece of apparatus.

(i) State the mistake in the labelling of the diagram.

(1)

.....

.....

(ii) Identify the piece of apparatus missing from the diagram.

(1)

.....

(iii) State why this piece of apparatus is necessary.

(1)

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.....

(b) The student adds the missing piece of apparatus, then collects some oxygen gas. This oxygen gas contains water vapour.

Suggest how he could alter the apparatus so that he could collect dry oxygen gas.

(1)

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.....

(c) Balance the equation for the reaction used in this preparation of oxygen.

(1)

..... H_2O_2 → ..... H_2O + ... O_2

(d) The manganese(IV) oxide acts as a catalyst.

What is meant by the term **catalyst**?

(2)

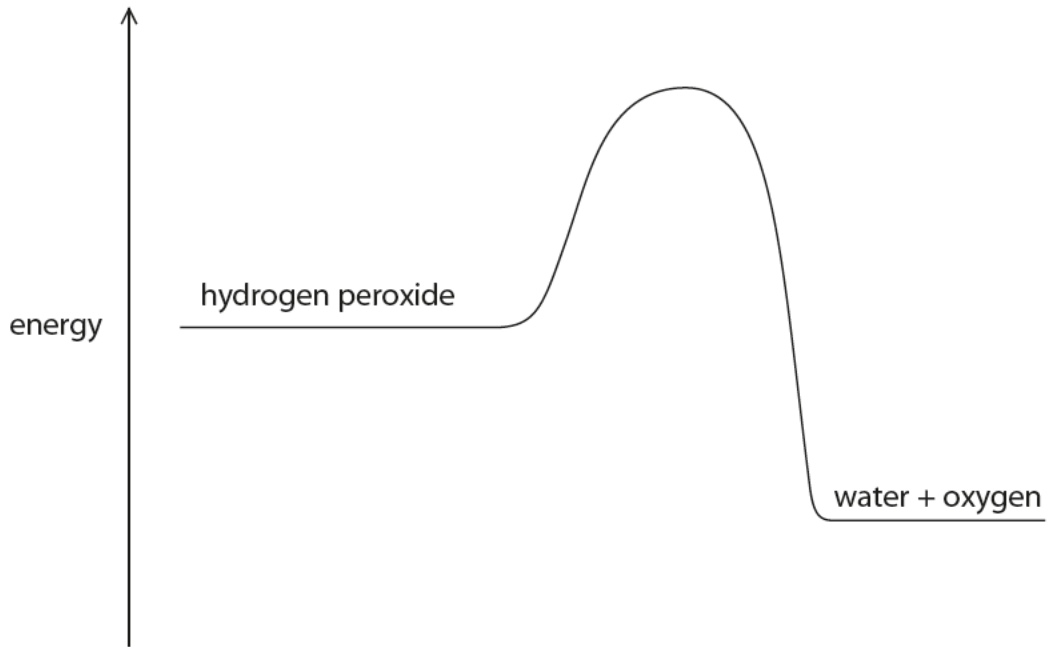
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(e) The diagram shows the reaction profile for the decomposition of hydrogen peroxide without a catalyst.



(i) Label the diagram to show the activation energy (E_a) for this reaction.

(1)

(ii) On the diagram, draw a curve to represent the reaction profile for the same reaction when a catalyst is used.

(1)

(Total for Question 3 = 9 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)