Trilogy Chemistry paper 2 Rates of Reaction- Checklist

Key Point	1	2
Rates and extent of chemical reactions		
Describe ways of measuring rates of reaction – e.g mass/volume of product in a specific amount of time		
Use collision theory to explain why rates of reaction slow down as they progress		
Describe and explain patterns in graphs showing rates of reaction		
Calculate rates of reaction given data or graphs, using change/time, **including drawing tangents to a curve**		
Describe and explain how reactions are affected by temperature, concentration, surface area, pressure (gaseous reactions) & catalysts		
Explain what is meant by a reversible reaction and know how to represent them in equations		
Define the terms 'closed system', 'yield' and 'dynamic equilibrium'		
Predict the energy change in a reversible reaction given information about one of the reactions		
Describe factors that can affect the position of equilibrium		
HT Apply Chatelier's principle to any given reaction to predict the effects on yield of changing temperature, pressure or concentration of reactants		
Predict optimum yield conditions given some information about a reversible reaction		
Explain why the conditions chosen industrially are often 'compromise' conditions		

- Rates of reaction - Revision Can you:
- Explain what is meant by the rate of a reaction?
- Explain how to collect data on the rate of a reaction?
- Calculate the mean rate of a reaction?
- (H) Calculate the rate of a reaction at a specific time?

Chemical Reactions

- A chemical reaction results in a product(s) which will have different properties than the reactants that made it.
- Chemical reactions can be both exothermic, were energy is transferred to the surroundings, or endothermic were heat is taken from the surroundings.
- Chemical reactions can be difficult to reverse, i.e. change the reactants back into products.
- To measure the rate of a reaction, you can either measure how quickly: a reactants is/are used up, or the product(s) of the reaction are made.

Task:

Q1) What name is given to the chemicals on the left hand side of a chemical reaction?

_____
_____
_____

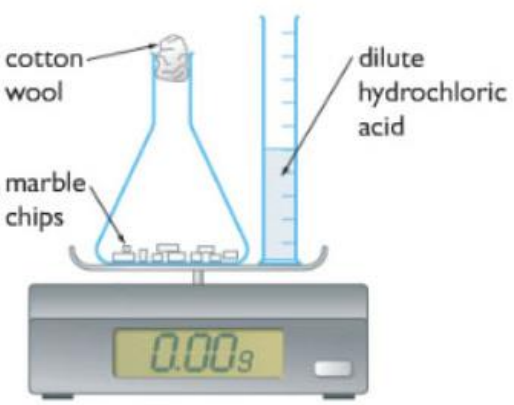
Q2) How is a chemical reaction different from a physical change?

_____
_____
_____
_____

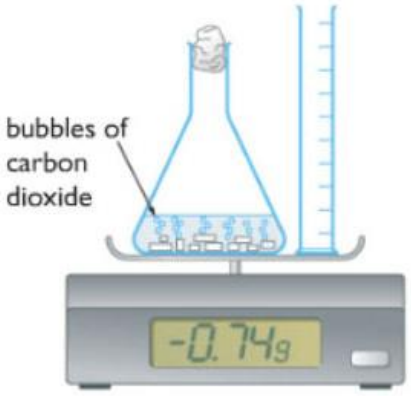
Q3) How can we determine the rate of a chemical reaction?

_____
_____
_____
_____

Measuring the decreasing mass of a reaction mixture



a) before reaction



b) during reaction

In the reaction between carbon dioxide and hydrochloric acid there is a loss in mass. CO_2 is a product of the reaction.

Q) Why is the cotton wool placed in the neck of the flask?

_____
_____
_____
_____

Q) If we wanted to determine the rate what other apparatus is needed?

_____
_____
_____
_____

Q) What would be the rate of this reaction if it took 2 minutes for the mass loss shown in the picture?

_____
_____
_____
_____

Q1.

A student investigated the effect of the size of marble chips on the rate of the reaction between marble chips and hydrochloric acid.

This is the method used.

1. Add 10.0 g of marble chips into the flask.
2. Add 50 cm^3 of hydrochloric acid and start a timer.
3. Record the mass lost from the flask every 10 seconds.
4. Repeat steps 1 to 3 with different sizes of marble chips.

Figure 1 shows the apparatus.

Figure 1

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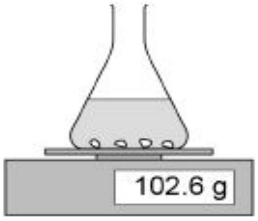
Figure 1



(a) Draw **one** line from each type of variable to the correct example of the variable.

Type of variable	Example of variable
	Mass lost from flask
Independent	Size of flask
	Size of marble chips
Control	Time taken
	Volume of acid

(b) The equation for the reaction is:

$$CaCO_3(s) + 2HCl(aq) \; CaCl_2(aq) + H_2O(l) + CO_2(g)$$

Name the **three** products.

1. _____

2. _____

3. _____

(d) The reaction produces 1.6 g of gas in 30 seconds.

Calculate the mean rate of the reaction in the first 30 seconds.

Use the equation:

$$\text{mean rate of reaction} = \frac{\text{mass of product produced in grams}}{\text{time in seconds}}$$

_____

_____

Mean rate of reaction = _____

(1)

(e) What is the unit for the mean rate of reaction calculated in part **(d)**?

Tick **one** box.

g ☐ g/s ☐ s ☐ s/g ☐

(1)

<u>Measuring the increasing volume of gas given off</u>

If a reaction produces a gas, you can measure the volume of gas at different time intervals. The tubing must be air- tight and the bung inserted as soon as the reactants are added together.

Q) What gas would be made from adding an acid to a metal carbonate?

_____

_____

Q) What gas would be made from reacting a reactive metal with hydrochloric acid?

_____

Q1.

A student investigated the rate of reaction of magnesium with dilute hydrochloric acid.

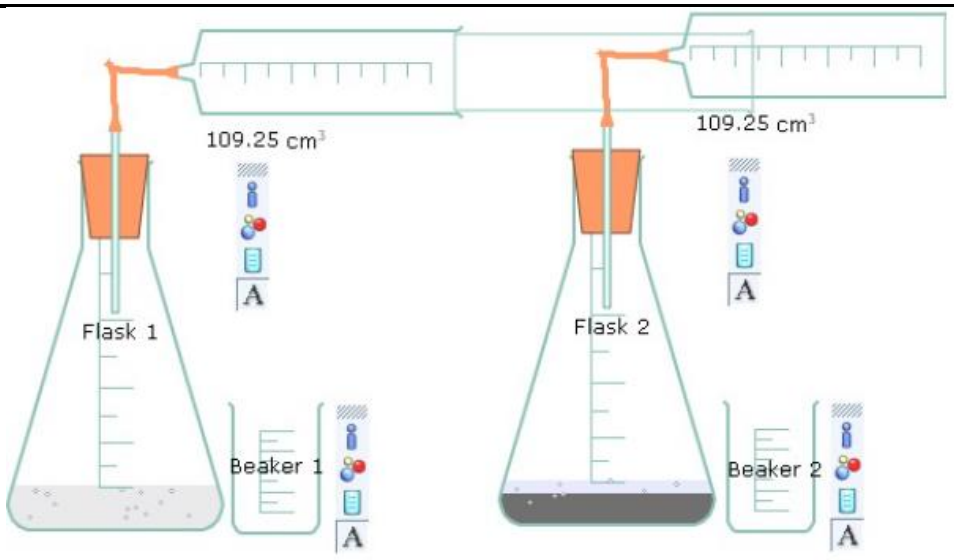
This is the method used.

1. Add 50 cm^3 of dilute hydrochloric acid to a conical flask.
2. Add 0.2 g of magnesium ribbon to the dilute hydrochloric acid in the conical flask.
3. Attach a gas syringe to the conical flask.
4. Record the volume of gas in the gas syringe every 10 seconds.

The graph below shows the student's results.

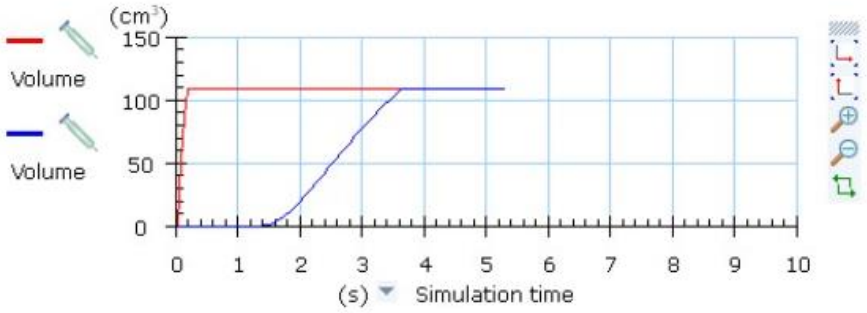
A

B



A

B



Using the information above answer the following questions:
Which reaction shows the biggest rate of reaction A or B?

_____

How can we tell from the graph that the reaction is over?

_____

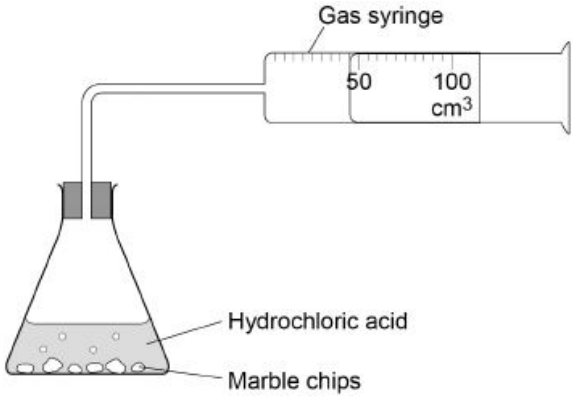
_____

When is the rate zero?

_____

Explain how you can identify if the reaction was carried out with powdered magnesium or a strip of magnesium ribbon?

_____



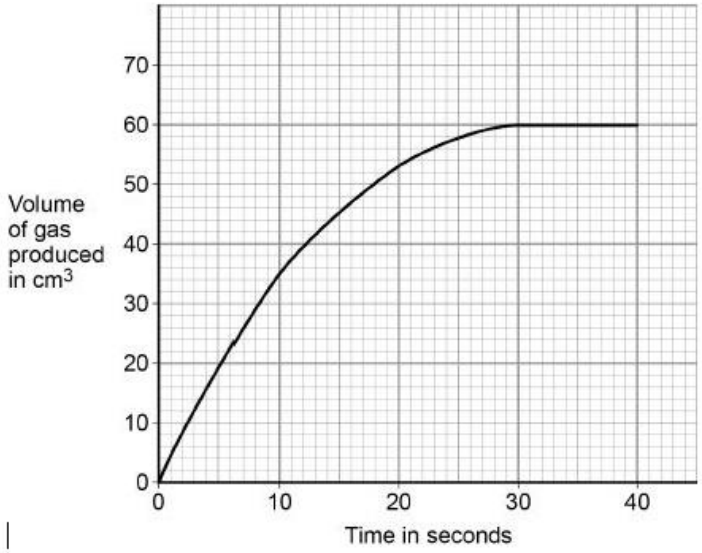
(a) Complete the equation for the reaction.

$CaCO_3 +$ _____ $HCl \rightarrow$ _____

(2)

Figure 2 shows the student's results.

Figure 2



(b) Describe the trend shown in **Figure 2**

Use values in your answer.

_____

_____

_____

(c) Describe how you would use **Figure 2** to find the rate of the reaction at 15 seconds.

You do **not** need to do a calculation.

_____

_____

_____

_____

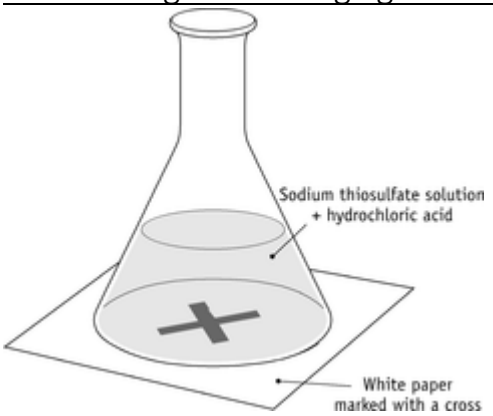
(2)

(d) Give the units for the rate of this reaction.

_____

(1)

Measuring decreasing light through a suspension

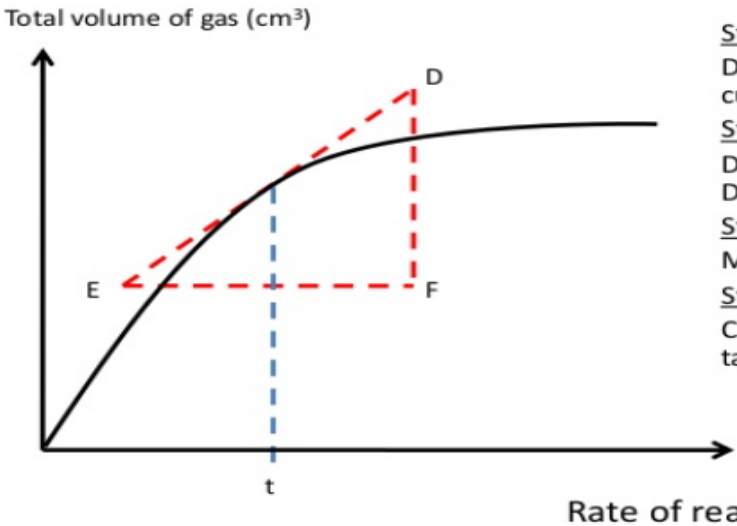


Some solutions make a precipitate making the solution go cloudy. This can be used to measure the rate of a rection.

Q) What advantages would there be to using a light sensor rather than using the disappearing cross technique?

Mean rate of reaction = $\frac{\text{Quantity of reactant used}}{\text{time}}$ **or** $\frac{\text{Quantity of product formed}}{\text{time}}$

Calculating the rate at a specific time (Higher)



Step 1
Draw a tangen (line DE) on the curve at time *t*.

Step 2
Draw the right-angled triangle DEF.

Step 3
Measure the length of DF and EF.

Step 4
Calculate the gradient of the tangent DE.

Rate of reaction at time t,
= gradient of curve at time t
= $\frac{\text{length of DF}}{\text{length of EF}}$ $cm^3\ s^{-1}$

Collision theory and surface area

You should be able to :

Identify the factors that can affect the rate of a reaction
Explain Collision theory
Explain how to use collision theory to explain the effect of surface area on reaction rate

There are five factors which can affect the rate of a reaction; **temperature, surface area** of solids, **concentrations** of solutions, the **pressure** of gases, and the presence of **a catalyst**.

For a chemical reaction to occur particles must collide with a greater amount of energy than the activation energy for that reaction.

Therefore, activation energy is the minimum amount of energy the colliding particles must have for a successful collision. i.e. one that makes products.

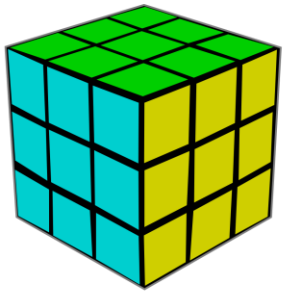
To make reactions more likely you need to:

- Increase the frequency of collisions
- Increase the energy they have when they collide

Surface area

Reactions can only occur if particles can collide. In a solid, only surface particles are exposed, so if the number of exposed particles is increased the likelihood of collisions is greater.

We can compare solids with different surface areas quantitatively by looking at their surface area to volume ratio.



sides = 3
surface = 3^2 x 6 = 54
volume = 3^3 = 27

surface/volume = 2

sides = 2
surface = 2^2 x 6 = 24
volume = 2^3 = 3

surface/volume = 3

sides = 1
surface = 1^2 x 6 = 6
volume = 1^3 = 1

surface/volume = 6

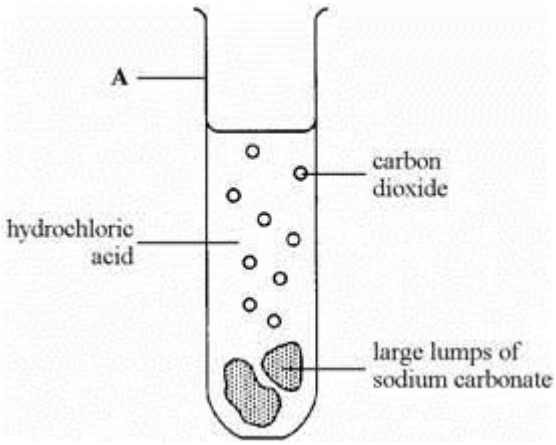
Breaking a solid up or making a powder increase the surface area to volume ratio.

Q1.

Dilute hydrochloric acid reacts with sodium carbonate. The word equation for this reaction is:

sodium carbonate + hydrochloric acid → sodium chloride + water + carbon dioxide

(a) The diagram shows apparatus used by student X to investigate this reaction.



(i) Name the piece of apparatus labelled **A**.

_____

(1)

(ii) **$NaCO_3$** **NaCl** **Na_2CO_3** **Na_2Cl**

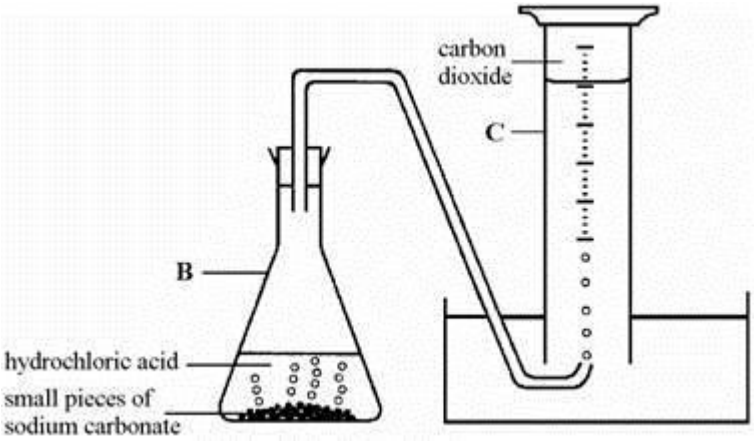
Use the Data Sheet to help you choose the correct formula from the list for:

sodium carbonate, _____

sodium chloride. _____

(2)

(b) The diagram below shows a different apparatus used by student Y to investigate the same reaction.



(i) Name the pieces of apparatus labelled **B** and **C**.

B

_____

C

_____

(2)

(ii) Both students X and Y used the same

- volume of acid
- concentration of acid
- temperature
- mass of sodium carbonate

Use information from the diagrams to explain why the reaction that student Y carried out was faster.

_____

_____

_____

_____

<u>The effect of temperature</u>

Increasing temperature increases the rate of a reaction, the effect is twofold. Increasing temperature causes the particles to move around faster, as a consequence they will collide more frequently. Secondly, increasing temperature causes more energetic collisions. A greater proportion of collisions will have energy greater than the activation energy. The increased energy of collisions has a greater effect than increasing the frequency of collisions.

- Please note, when explaining rates of reaction, refer to more frequent collisions or collisions occur more often. **Do not** say more collisions. Rate is a measure of something in a given time.

Task:

Whay does increasing temperature affect the rate of a reaction?

_____

_____

What is temperature a measure of?

_____

_____

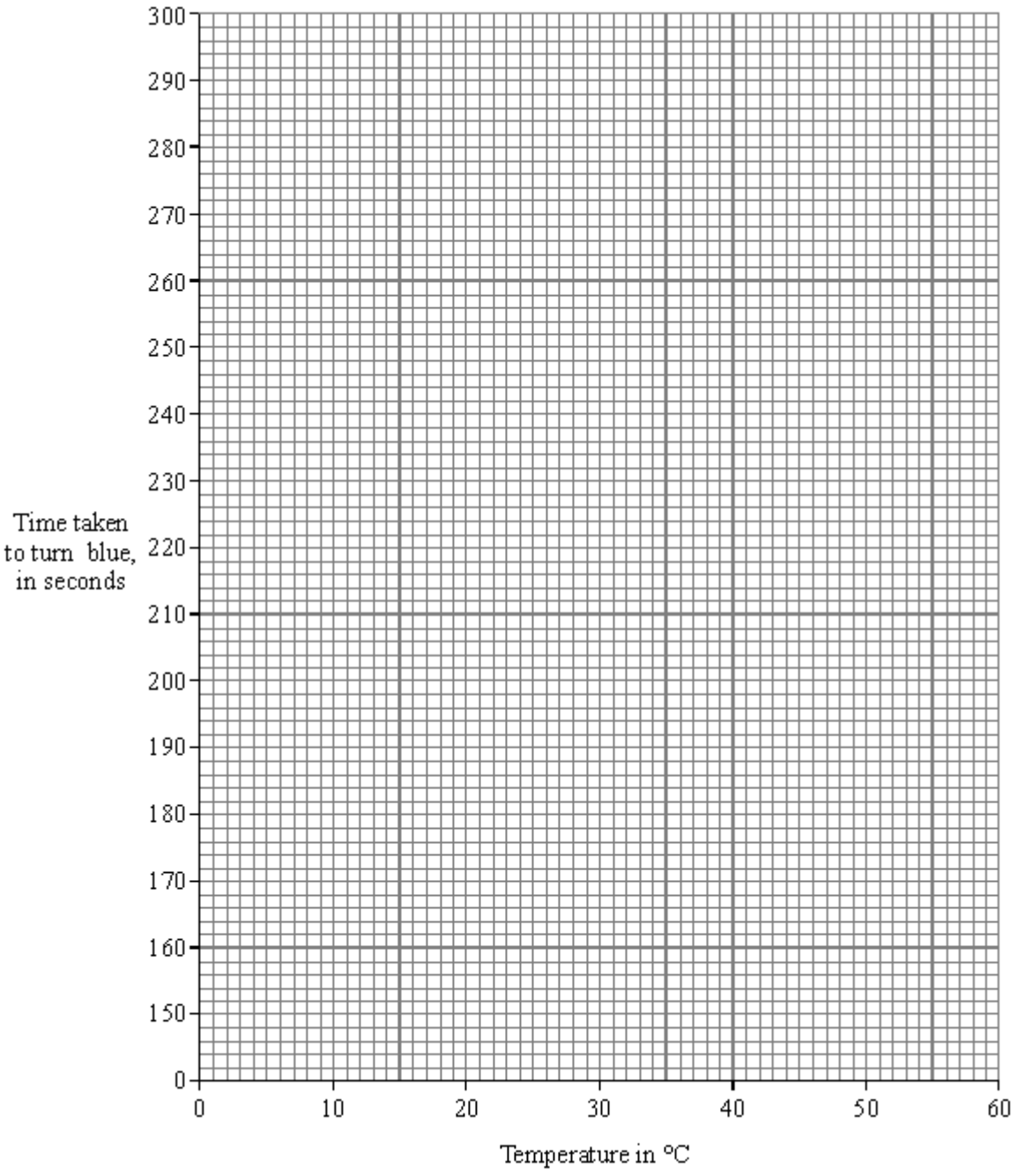
Q1.

Solutions **A** and **B** are colourless. When they are mixed, they react and turn blue after a period of time. A student investigated how temperature affected the rate of reaction between solutions **A** and **B**. The rate was measured by timing how long the mixture took to turn blue.

The results are shown in the table.

Temperature in °C	22	25	34	45	51
Time taken to turn blue, in seconds	290	250	200	170	160

(a) (i) Draw a graph for these results.



(3)

(ii) Use your graph to find how long it takes the solution to turn blue at 40°C.

Time = _____ s

(1)

(b) (i) How does the rate of reaction change as the temperature is increased?

_____
_____
_____

(1)

(ii) Explain, in terms of particles, why temperature has this effect on the rate of reaction.

To gain full marks in this question you should write your ideas in good English.
Put them into a sensible order and use the correct scientific words.

_____
_____
_____
_____
_____

(3)

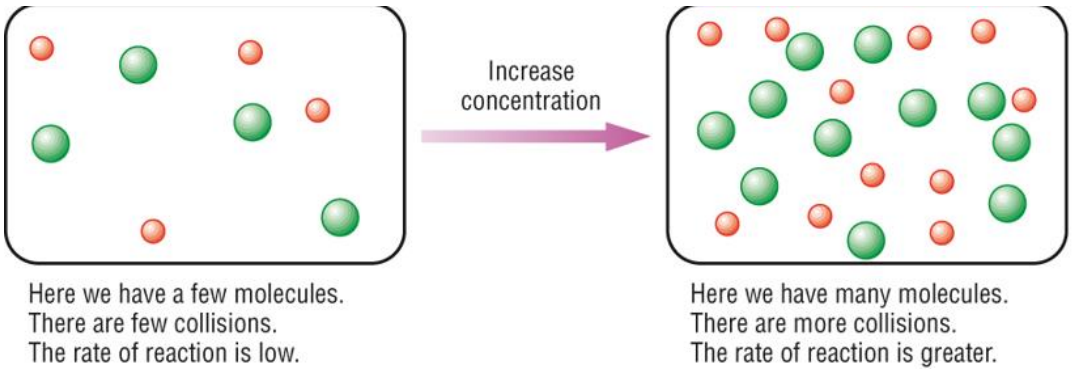
(c) State **one** variable that must be kept constant to make this experiment a fair test.

_____
_____

(1)

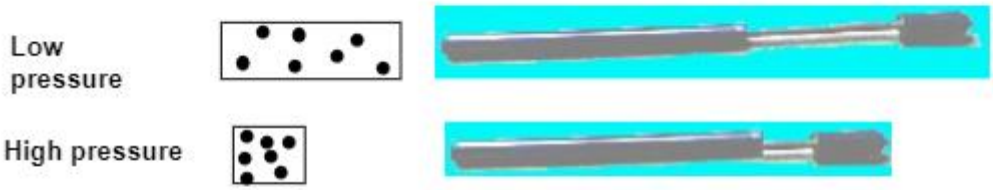
(Total 9 marks)

<u>The effect of concentration and pressure</u>



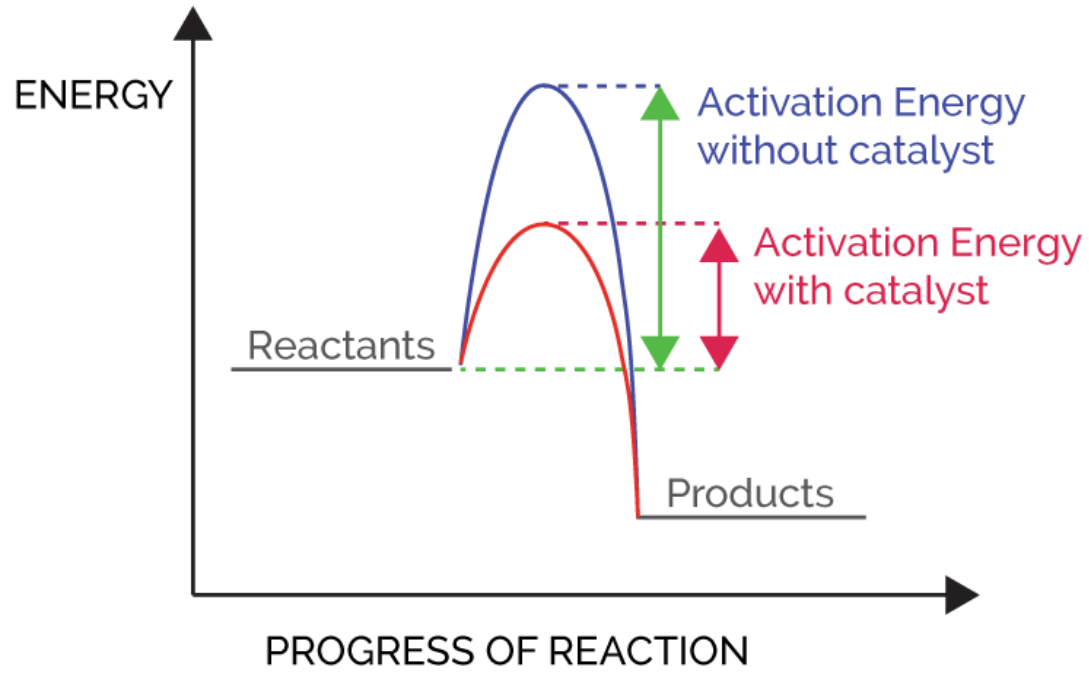
To express the idea of concentration use the terms ‘more crowded’ or ‘that there are more particles in the same volume’. If I have two beakers of the same concentration, one contains 50cm3 whilst the other contains 100cm3, one contains more particles but they are of the same concentration.

- Reactions involving gases are affected by the pressure of the gases present.
- If we cover one end of a bicycle pump and push in the plunger we increase the pressure.



- What we are doing is squeezing the gas molecules *closer together* or making them more concentrated.
- And so - pressure speeds up gas reactions

The effect of a Catalyst



The figure above shows a reaction profile of an uncatalysed and catalysed exothermic reaction.

You can see from the figure above that using a catalyst **lowers the activation energy**, that is, the minimum amount of energy needed for a successful reaction. This is achieved by providing an **alternative reaction pathway** to the products.

Advantages of using Catalysts

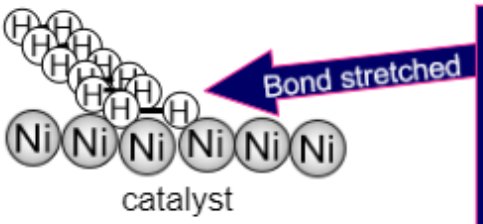
Despite often being made of expensive materials it is still usually cheaper to use catalysts that pay for the extra energy without one. To produce a product(s) at the same rate as the catalyst higher temperatures and pressures would be needed.

Using high temperatures and pressures often involves burning fossil fuels, so catalyst preserve these non-renewable resources and reduces the quantity of carbon dioxide going into the atmosphere. This helps combat climate change.

Catalyst do not get used up in a reaction and are often only **used in very small quantities**. So after the initial financial outlay we can **use them again and again.** However, eventually impurities in the reactant mixture **poisons** the catalyst.

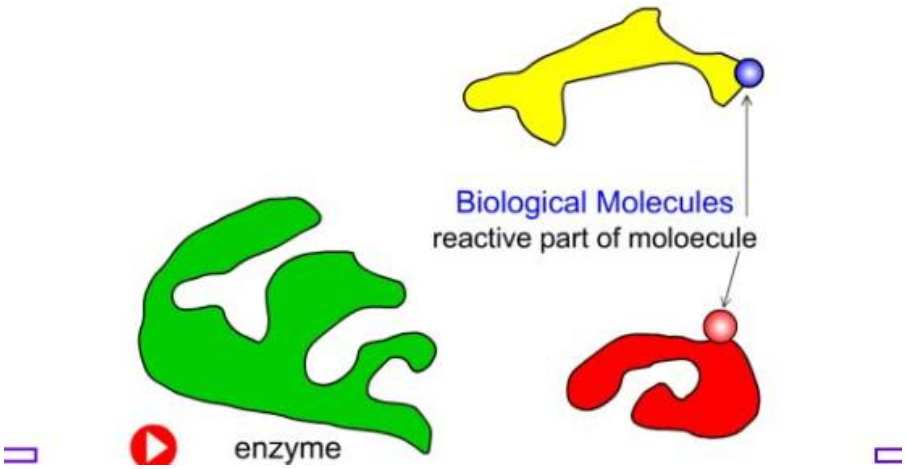
If a catalyst is used in a reaction, we show it by writing it above the reaction arrow. This indicates that the reactants and products are not changed by the catalyst, only the pathway taken.

- In the presence of a nickel catalyst vegetable oil and hydrogen react to form margarine.
- Nickel adsorbs hydrogen gas onto its surface in such a way that the bond holding the hydrogen molecule together becomes stretched.
- This partial breaking of the bond lowers the activation energy making hydrogen more reactive.



The stretching of the H-H bond lowers the activation energy and helps hydrogen react with the oil

Other catalysts, especially enzymes, absorb molecules in a way that not only stretches bonds but also brings the reacting parts of reactants right next to each other.



Catalysts are used in the manufacture or application of a huge number of products.

Biological soap powder uses biological catalysts (enzymes)

Enzymes in pineapple help cooked ham to be more tender.

Manufacture of fertiliser via the Haber Process involves use of an iron catalyst.

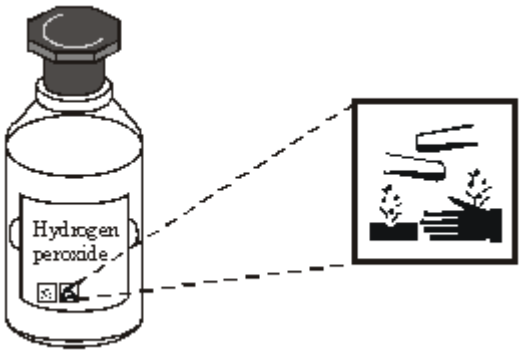
Synthetic materials like polyester are made using a catalyst.

Plastics are made using catalysts.

Q1. Hydrogen peroxide (H_2O_2) contains the same elements as water (H_2O).

(a) Name the hazard symbol shown by using the correct word from the box.

corrosive	**flammable**	**oxidising**	**toxic**



.....

(1)

(b) Hydrogen peroxide decomposes in the presence of a catalyst.

$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$

(i) Complete the word equation for this chemical reaction.

hydrogen peroxide → water + ...

(1)

(ii) What does a catalyst do to a chemical reaction?

.....
.....

.....
.....

(1)
(Total 3 marks)

Q2. The rate of chemical reactions can be changed by changing the conditions.

(a) Methane burns in oxygen to produce carbon dioxide and water.

The activation energy for the reaction is 2648 kJ / mol.

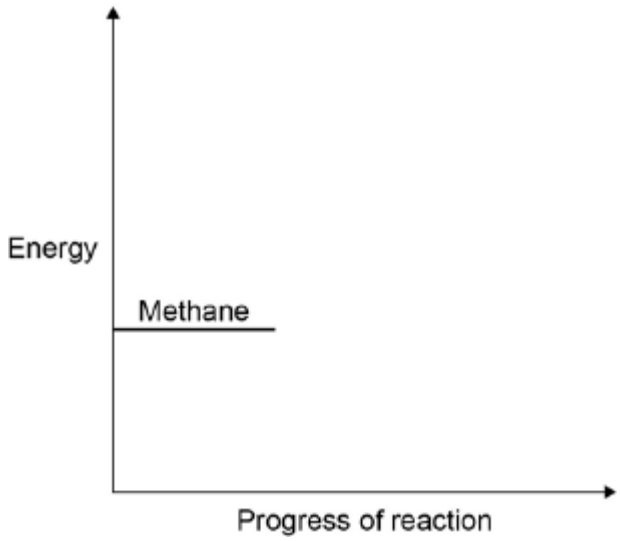
The reaction gives out 818 kJ / mol of energy.

The figure below shows the reaction profile for this reaction.

Complete the reaction profile.

Draw arrows to represent:

- the activation energy
- the energy given out.



(4)

(b) What percentage of the activation energy is the energy given out?

.....
.....

(1)

(c) Calcium carbonate decomposes when it is heated:

The decomposition of calcium carbonate is an endothermic reaction.

How would the reaction profile for decomposition of calcium carbonate be different from the reaction profile of methane burning in oxygen?

.....
.....

(1)

(d) Catalysts are used in chemical reactions in industry.

Give **two** properties of catalysts.

For each property, explain why it makes the catalyst useful in industry.

.....

.....

.....

.....

.....

.....

.....

.....

(4)

(e) Enzymes are biological catalysts.

What type of molecule is an enzyme?

Tick **one** box.

Carbohydrate ☐

Hydrocarbon ☐

Lipid ☐

Protein ☐

(1)

(f) If enzymes are denatured they stop working.

Give **two** ways an enzyme can be denatured.

1
.....

2
.....

(2)

Reversible reactions

In some reactions the products can react together to make the original reactants again. This is called a reversible reaction.

A reversible reaction can go both ways so two 'Half –arrows' are used.

We still put the reactants on the left and the products on the right hand side of the equation. Sometimes we refer to the forward and backward reaction.

Examples of reversible reactions include:

Litmus in acid and alkaline solutions; HLit $\rightleftharpoons H^+ + Lit^-$
Salts and their water of crystallization e.g. hydrated copper sulfate $CuSO_4.5H_2O$
Thermal decomposition of Ammonium chloride NH_4Cl

Energy in reversible reactions

If the forward reaction is exothermic, the reverse reaction will be endothermic. The amount of energy released from the forward reaction is the same as the energy taken in from the surroundings in the reverse reaction i.e. when products form reactancts.

Q1. Hydrated copper sulphate is a blue solid. When it is heated, white solid anhydrous copper sulphate is made. This is a reversible reaction.

Hydrated copper sulphate (blue) [+ heat energy] ⇌ anhydrous copper sulphate (white) + water

(1) To make the forward reaction work, the hydrated copper sulphate must be heated all the time.

What type of reaction is this?

.....

…..

(1)

(b) Anhydrous copper sulphate can be used in a test for water. What **two** things will happen when water is added to anhydrous copper sulphate?

1 …..

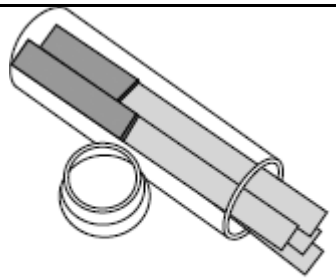
…..

2 …..

…..

(2)
(Total 3 marks)

Q2. Read the information and then answer the questions.



COBALT CHLORIDE PAPER

Cobalt chloride paper can be used to test for water.

The paper contains anhydrous cobalt chloride.

The jar containing the papers must be kept closed when not being used.

The equation shows the reaction between anhydrous cobalt chloride and water.

$CoCl_2$ + 6 H_2O $\rightleftharpoons$ $CoCl_2.6H_2O$

anhydrous cobalt chloride (blue) — hydrated cobalt chloride (pink)

(1) Choose **one** word from the box to complete the sentence.

Endothermic	**exothermic**	**reversible**

The symbol $\rightleftharpoons$ means that the reaction is …..

(1)

(b) Describe the colour change when water is added to the cobalt chloride paper.

…..

…..

(1)

(c) Suggest why the jar containing the unused cobalt chloride papers must be kept closed.

…..

…..

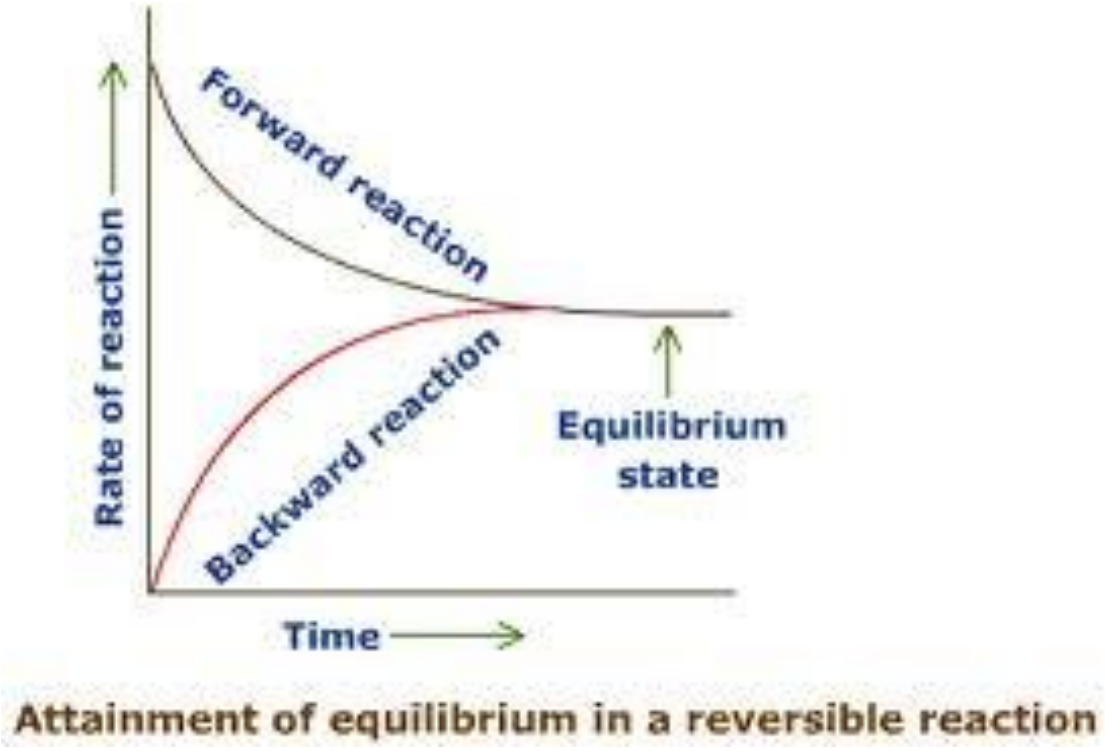
(1)
(Total 3 marks)

Dynamic Equilibrium

In a closed system, that is, one were neither reactants or products can get in or out, there reaches a point were the rate of the forward reaction is equal to the rate of the reverse reaction.

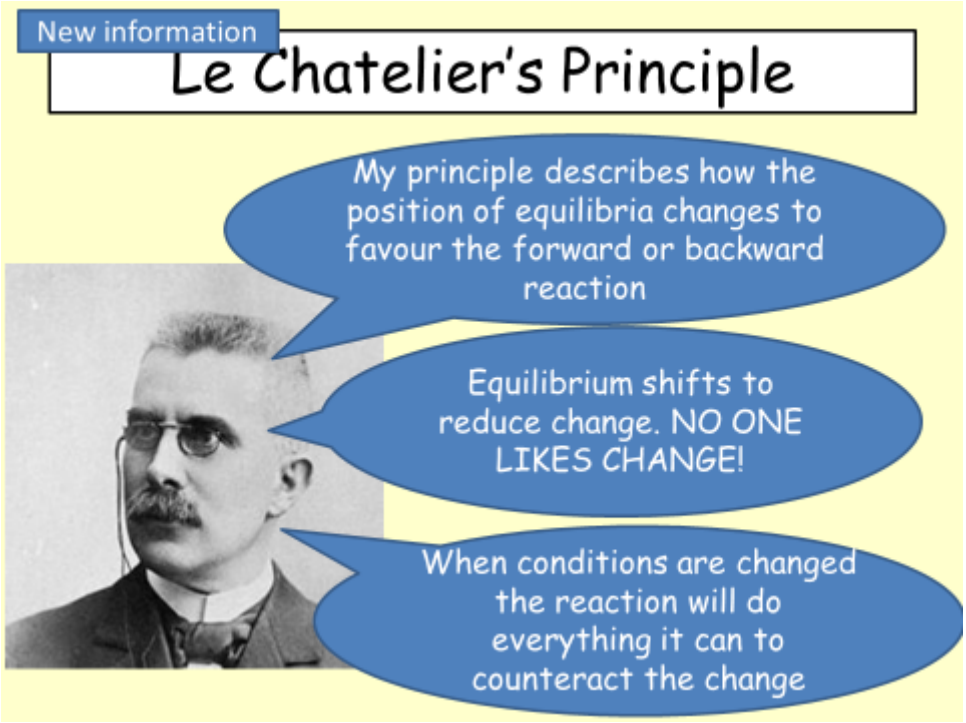
We use the term dynamic to illustrate that reactants are still forming products and products are still forming reactants.

Initially, the rate of the forward reaction is high, the rate decreases as there are less reactant particles available for collisions. The greater the number of product particles formed the greater the chance that they will collide and form reactants. Eventually at equilibrium the rates are equal.



Attainment of equilibrium in a reversible reaction

Altering conditions in a reversible reaction



New information

Le Chatelier's Principle

Therefore if the temperature changes the reaction will shift to favour the side that will reduce the temp (e.g. endothermic)

If the concentration increases on one side they are more likely to react together shifting the equilibrium so the concentration decreases

Increasing the pressure shifts the reaction to favour the reaction that produces a smaller number of products

New information

This is called shifting equilibrium

Reactants ⇌ Products

- If equilibrium shifts so the "forward" reaction is favoured (Reactants→Products) we say equilibrium shifts to the right. (More products are made)

- If equilibrium shifts to favour the "backward" reaction (Products→Reactants) we say equilibrium shifts to the Left (We make more reactants)

New information

Effects on Equilibria

- If you increase the temperature it will try and reduce it
- If you increase the concentration of the reactants it will try and get rid of some
- If you increase the pressure it will try and reduce it

Construct

In a reversible reaction. One direction will be exothermic. The other direction will be endothermic

All reversible reactions are exothermic (give out heat) in one direction and endothermic (take in heat) in the other. E.g. nitrogen dioxide (NO_2) joins to form dinitrogen tetroxide (N_2O_4) exothermically.

Gets cold going **backward** (endothermic)

$$2NO_2 \rightleftharpoons N_2O_4$$

Gets hot going **forward** (exothermic)

The hotter a reaction is, the more likely it is to go in the endothermic direction.

1. If we increase the temperature what will happen to the yield? Which way has equilibrium shifted?
2. If we decrease the temperature what will happen to the yield? Which way has equilibrium shifted?

Construct

Pressure

This applies to gas reactions.
Here the rule depends upon the number of gas molecules on each side of the equation

Get more gas molecules in backward direction

$$2NO_{2(g)} \rightleftharpoons N_2O_{4\,(g)}$$

Get fewer gas molecules in forward direction

The higher the pressure, the more the reaction moves in the direction with fewer gas molecules.

1. If we increase the pressure what will happen to the yield? Which way has the equilibrium shifted and why?
2. If we decrease the pressure what will happen to the yield? Which way has equilibrium been shifted and why?

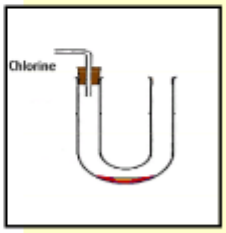
Construct

Concentration

Chlorine gas reacts with iodine chloride (a brown liquid) converting it to iodine trichloride (a yellow solid).

$$\underset{\text{brown}}{ICl\ (l)} + \underset{\text{pale green}}{Cl_2\ (g)} \rightleftharpoons \underset{\text{yellow}}{ICl_3\ (s)}$$

1. What effect will adding more chlorine have on the colour of the mixture in the U-tube?
2. If the U-tube is turned on its side, chlorine gas pours out of the tube.
3. In which way will this change the equilibrium?



Changing temperature

Increasing temperature makes the reaction go in the endothermic direction

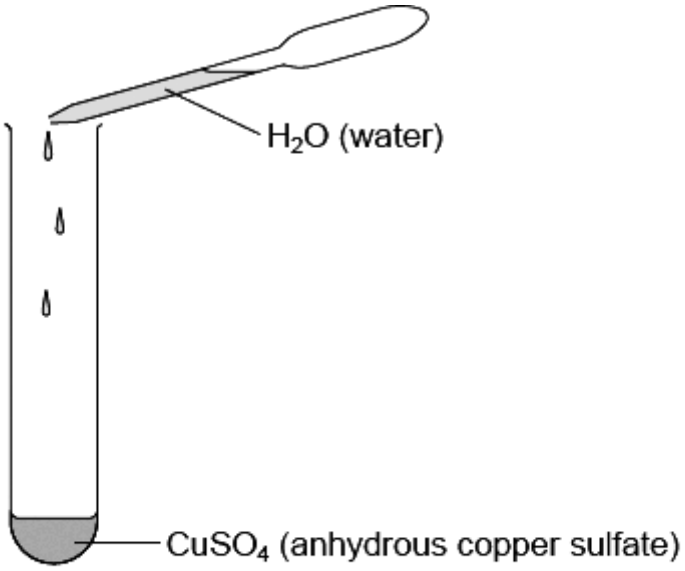
Decreasing temperature makes the reaction go in the exothermic direction

- $A + B \rightleftharpoons C \quad \Delta H = -100 kJmol^{-1}$
- If I heat up the reaction will it go to the left or to the right?

Changing pressure

- Increasing pressure sends the equilibrium towards the side with less molecules
- Decreasing pressure sends the equilibrium towards the side with more molecules
- If I increase pressure, which way will this reaction go?
- $2A+B \rightleftharpoons C + D$

Q3. The diagram shows how anhydrous copper sulfate can be used to test for water.



$$\underset{\text{white}}{CuSO_4} + \underset{\text{colourless}}{5H_2O} \rightleftharpoons \underset{\text{blue}}{CuSO_4 . 5H_2O}$$

(a) What colour change will you see when water is added to the $CuSO_4$?

Colour changes from ..... to .....

(1)

(b) Draw a ring around the meaning of the symbol $\rightleftharpoons$

endothermic exothermic **reversible**

(1)

(Total 2 marks)

Q4. Methanol is a fuel that is used in some racing cars instead of petrol.

Methanol can be made from carbon monoxide and hydrogen. The equation for this reaction is shown below.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

The forward reaction is exothermic.

(a) A high pressure (between 50 and 100 atmospheres) is used in this process.

Explain why the highest equilibrium yield of methanol is obtained at high pressure.

.....

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(1)

(b) The temperature used in this process is about 250 °C.

It has been stated that, ‘the use of this temperature is a compromise between the equilibrium yield of product and the rate of reaction’.

Explain this statement.

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(3)

(Total 4 marks)