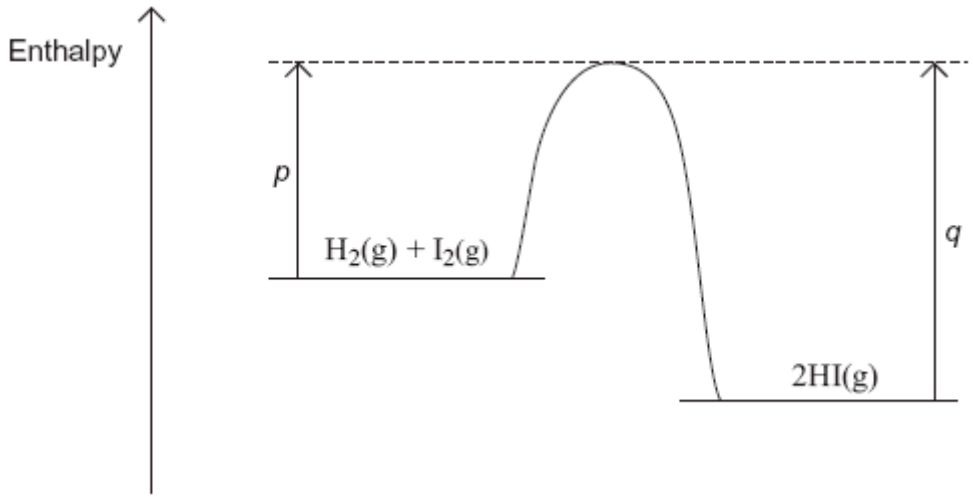
Q18.

An equation for the equilibrium reaction between hydrogen, iodine and hydrogen iodide is shown below.

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

(a) The curve in the diagram below illustrates the reaction profile for this equilibrium reaction without a catalyst.



(i) Draw on the diagram a curve to illustrate the reaction profile for this equilibrium reaction **with** a catalyst.

(2)

(ii) Use the diagram to deduce whether the formation of hydrogen iodide from hydrogen and iodine is exothermic or endothermic.

_____

(1)

(iii) State what the diagram suggests about the sum of the bond enthalpies for the reactant molecules compared with the product molecules.

_____

_____

(1)

(iv) In terms of *p* and *q*, identify the following for this equilibrium without a catalyst.

A value for the activation energy for the forward reaction _____

A value for the overall enthalpy change for the forward reaction

_____

(2)

(b) A mixture of $H_2(g)$ and $I_2(g)$ was allowed to reach equilibrium.

(i) State the effect of a catalyst on the rate of attainment of this equilibrium.

_____

(1)

(ii) State and explain the effect of an increase in total pressure on the rate of attainment of this equilibrium.

Effect of an increase in pressure on rate _____

Explanation _____

_____

_____

_____

_____

(3)

(Total 10 marks)

Q19.

An equation for the decomposition of hydrogen peroxide is shown below.

$$2H_2O_2 \longrightarrow 2H_2O + O_2$$

State the measurements you would take in order to investigate the rate of this reaction.

_____

_____

_____

_____

(Total 2 marks)

Q20.

Sodium thiosulfate solution ($Na_2S_2O_3$) reacts slowly with dilute hydrochloric acid to form a precipitate. The rate of this reaction can be studied by measuring the time (*t*) that it takes for a small fixed amount of precipitate to form under different conditions. The fixed amount of precipitate is taken as the amount needed to obscure a cross on paper.

The equation for this reaction is shown below.

$$Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + S + SO_2 + H_2O$$

(a) Identify the insoluble product of this reaction which forms the precipitate.

_____

(1)

(b) When this reaction takes place, the collision between the reacting particles requires an activation energy. State what is meant by the term *activation energy*.

_____

_____

(2)

(c) In terms of particles, explain why, at a fixed temperature, you might expect the rate of this reaction to double when the concentration of sodium thiosulfate is doubled and the concentration of hydrochloric acid remains the same.

_____

_____

_____

_____

(2)

(d) (i) State what is meant by the term *rate of reaction*.

_____

_____

(1)

(ii) Consider the description of the way in which this experiment is carried out. Use your understanding of the term *rate of reaction* to explain why it is possible to use a simplified formula $\frac{1}{t}$ as a measure of the rate of **this** reaction.

_____

_____

(1)

(Total 7 marks)

Q21.

The gas-phase reaction between hydrogen and chlorine is very slow at room temperature.

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

(a) Define the term *activation energy*.

_____

_____

(2)

(b) Give **one** reason why the reaction between hydrogen and chlorine is very slow at room temperature.

_____

_____

(1)

(c) Explain why an increase in pressure, at constant temperature, increases the rate of reaction between hydrogen and chlorine.

_____

_____

(2)

(d) Explain why a small increase in temperature can lead to a large increase in the rate of reaction between hydrogen and chlorine.

_____

_____

(2)

(e) Give the meaning of the term *catalyst*.

_____

_____

(1)

(f) Suggest **one** reason why a solid catalyst for a gas-phase reaction is often in the form of a powder.

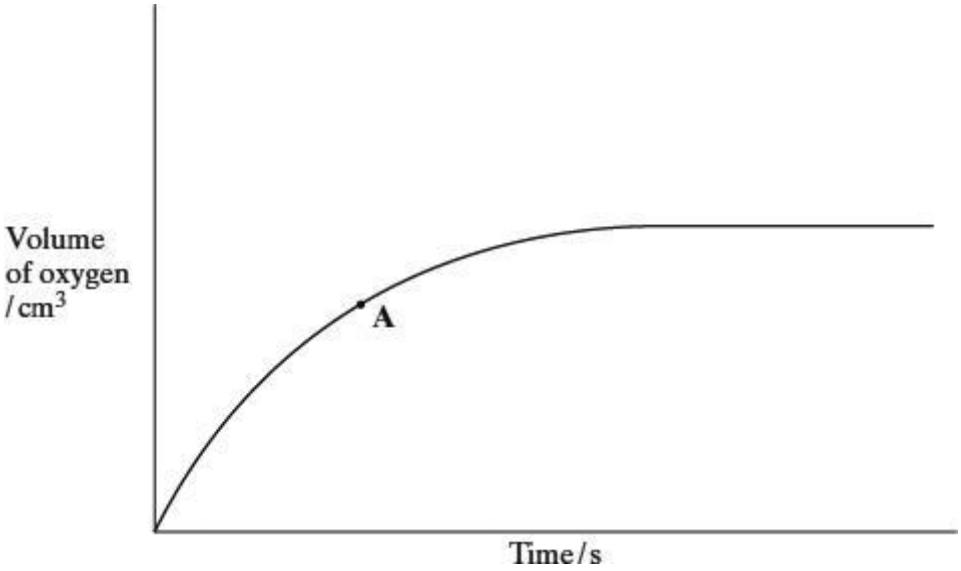
_____

(1)

(Total 9 marks)

Q22.

The curve below shows how the volume of oxygen evolved varies with time when 50 cm^3 of a 2.0 mol dm^{-3} solution of hydrogen peroxide, H_2O_2, decomposes at 298 K.



(a) State how you could use the curve to find the rate of reaction at point **A**.

_____

(1)

(b) Sketch curves, on the above axes, to illustrate how the volume of oxygen evolved would change with time if the experiment was repeated at 298 K using the following.

(i) 100 cm^3 of a 1.0 mol dm^{-3} solution of H_2O_2. Label this curve **X**.

(ii) 25 cm^3 of a 2.0 mol dm^{-3} solution of H_2O_2 in the presence of a catalyst. Label this curve **Y**.

(4)

(c) Hydrogen peroxide decomposes more rapidly in the presence of aqueous hydrogen bromide. The decomposition proceeds as shown by the following equations.

$$H_2O_2 + HBr \rightarrow HBrO + H_2O$$

$$HBrO + H_2O_2 \rightarrow H_2O + O_2 + HBr$$

(i) Write an equation for the overall reaction.

_____

(ii) Define the term *catalyst*.

_____

_____

(iii) Give **two** reasons, other than an increase in the reaction rate, why these equations suggest that hydrogen bromide is behaving as a catalyst.

Reason 1 _____

Reason 2 _____

(5)

(Total 10 marks)

Q23.

(a) Define the term *activation energy* for a reaction.

_____

_____

(2)

(b) Give the meaning of the term *catalyst.*

_____

_____

(2)

(c) Explain in general terms how a catalyst works.

_____

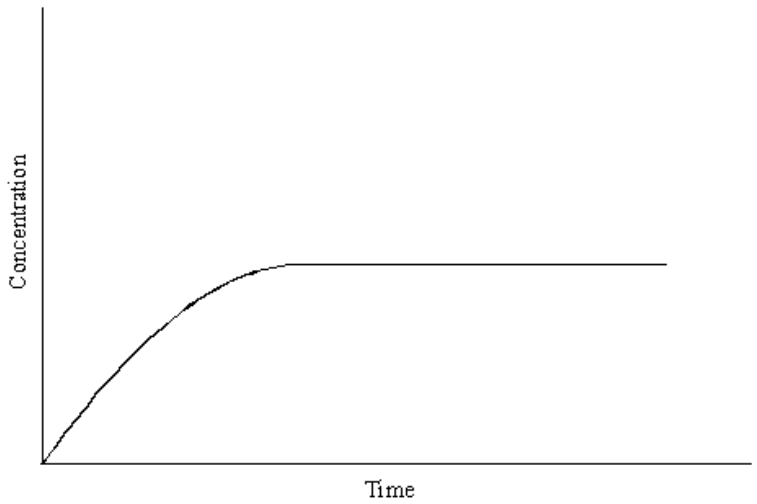
_____

(2)

(d) In an experiment, two moles of gas **W** reacted completely with solid **Y** to form one mole of gas **Z** as shown in the equation below.

$2W(g) + Y(s) \rightarrow Z(g)$

The graph below shows how the concentration of **Z** varied with time at constant temperature.



(i) On the axes above, sketch a curve to show how the concentration of **W** would change with time in the same experiment. Label this curve **W**.

(ii) On the axes above, sketch a curve to show how the concentration of **Z** would change with time if the reaction were to be repeated under the same conditions but in the presence of a catalyst. Label this curve **Z.**

(iii) In terms of the behaviour of particles, explain why the rate of this reaction decreases with time.

_____

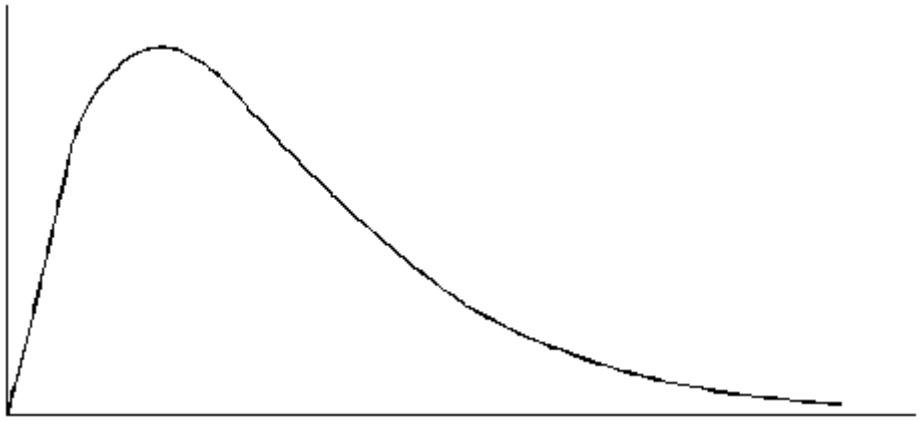
_____

(6)

(Total 12 marks)

Q24.

(a) Below is a Maxwell–Boltzmann curve showing the distribution of molecular energies for a sample of gas at a temperature *T*.



(i) Label the axes on the diagram above.

(ii) What does the area under the curve represent?

_____

(iii) State why this curve starts at the origin.

_____

(4)

(b) (i) State what is meant by the term *activation energy*.

_____

_____

(ii) The rate of a chemical reaction may be increased by an increase in reactant concentration, by an increase in temperature and by the addition of a catalyst.

State which, if any, of these changes involves a different activation energy. Explain your answer.

Change(s) _____

Explanation _____

_____

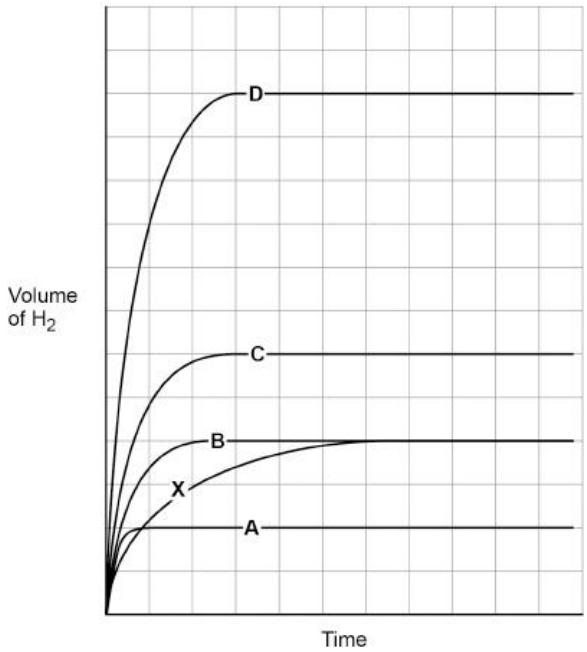
(5)

(Total 9 marks)

Q25.

Magnesium reacts with an acid to form hydrogen gas.

Line **X** on the graph shows how the volume of hydrogen gas varies with time when 50 cm^3 of 0.50 mol dm^{-3} acid reacts with an excess of magnesium.



The reaction is repeated under the same conditions but using 25 cm^3 of 1.50 mol dm^{-3} acid. The magnesium is in excess.

Which line represents this second reaction?

A line **A** ○

B line **B** ○

C line **C** ○

D line **D** ○

(Total 1 mark)

Mark Scheme

Q18.

(a) (i) **M1** drawn curve starts at reactants and ends at products

Tapered lines into the original curve gain credit for M1

M2 curve peak is below the one drawn in the question (and may show one/two humps)

Mark M1 and M2 independently

2

(ii) Exothermic (reaction)

Ignore "ΔH is negative"

1

(iii) Σ bond (enthalpy) reactants < Σ bond (enthalpy) products

The sum for H_2 and I_2/reactants is less than/lower than/smaller than the sum for 2HI/products
OR
The sum for 2HI/products is more than/larger than/bigger than the sum for H_2 and $I_{2/reactants}$

Accept "It OR the sum will be smaller or less"

1

(iv) **M1** *p*

2

M2 – (*q* – *p*)

OR

p – *q*

OR

– *q* + *p*

M2 demands that the sign for an exothermic reaction is part of the outcome mathematically.
Ignore case

(b) (i) Increase/speed up/faster (rate of attainment of equilibrium)

OR

Increase/speed up/faster rate of both forward and reverse reaction

OR

Increase/speed up/faster rate of reaction

Credit "It took less time"

1

(ii) **M1** Increase/speed up/faster (rate of attainment of equilibrium)

M2 More particles/molecules in a given volume/space
OR the particles/molecules are closer together
OR an increase in concentration.

M3 More/higher chance of successful/effective/productive collisions (between particles)
OR more collisions/higher chance of collisions (of particles) with $E>E_{Act}$

If M1 is blank, mark on and credit M1 in the text

If M1 is given as "decrease"/"no effect"/"no change" then CE = 0 for clip

In M1, if increase both the forward and reverse reaction, but no mention of rate, penalise M1 but mark on.

In M1, if increase either forward rate or reverse rate only, then penalise M1 but mark on.

Penalise M3 if an increase in the value of E_{Act}/energy of particles is stated.

Max 1 for M2 and M3 if reference to "atoms"

3

[10]

Q19.

Measure volume of gas / mass loss

If 'measure concentration' must explain how to score mark

1

At (regular) time intervals

Ignore references to temperature
Accept 'against time'
Do not accept 'with time' or 'over time' on its own

1

[2]

Q20.

(a) Sulfur OR S OR S_8

Sulphur

1

(b) **M1** The activation energy is the minimum / least / lowest

Mark these independently

1

M2 Energy for a reaction to occur / to go / to start
OR
Energy for a successful / effective collision

1

(c) Explanation:
M1 Twice as many / double number of particles

M1 NOT molecules

1

M2 More / twice / double (effective) collisions (in a given time)
OR
Double / greater / increased collision frequency

1

(d) (i) (Measured) change in concentration (of a substance) in unit time / given time

May be written mathematically
OR the gradient of the concentration (against) time

1

(ii) The measured change / amount (of precipitate) / cloudiness is fixed or constant or unchanged

1

[7]

Q21.

(a) minimum energy

1

to start a reaction/ for a reaction to occur/ for a successful collision

1

(b) activation energy is high / few molecules/particles have sufficient energy to react/few molecules/particles have the required activation energy

(or breaking bonds needs much energy)

1

(c) molecules are closer together/ more particles in a given volume

1

therefore collide more often

1

(d) many

1

more molecules have energy greater than activation energy (QoL)

1

(e) speeds up a reaction but is chemically unchanged at the end

1

(f) increases the surface area

1

[9]

Q22.

(a) Gradient (or slope) (or draw a tangent)

1

(b) (i) Curve **X** is lower and starts at origin

1

And levels out at same volume as original curve

1

(ii) Curve **Y** is steeper than original and starts at origin

1

Then levels out at half the volume of the original

1

(c) (i) $2H_2O_2 \rightarrow 2H_2O + O_2$

1

(ii) Speeds up (alters the rate of) a chemical reaction

1

Remains unchanged (or not used up)

1

(iii) Remains unchanged (or not used up or not in the overall reaction equation)

1

Offers alternative reaction route (or acts as an intermediate)

1

[10]

Q23.

(a) minimum energy **(1)**
required before a reaction can occur or go or start **(1)**

2

(b) speeds up (changes) reaction rate **(1)**
without being (chemically) changed **(used up) (1)**

2

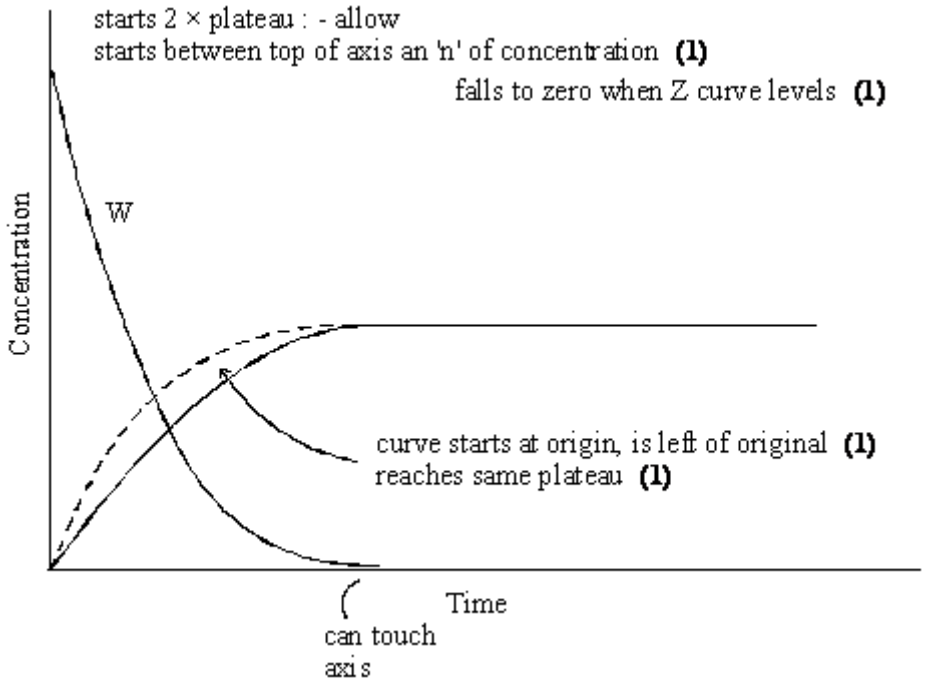
(c) provides alternative reaction route **(1)**
with a lower activation energy **(1)**

in (b) and (c) reward 4 marks for 4 points wherever found

2

(d) (i)

(ii)



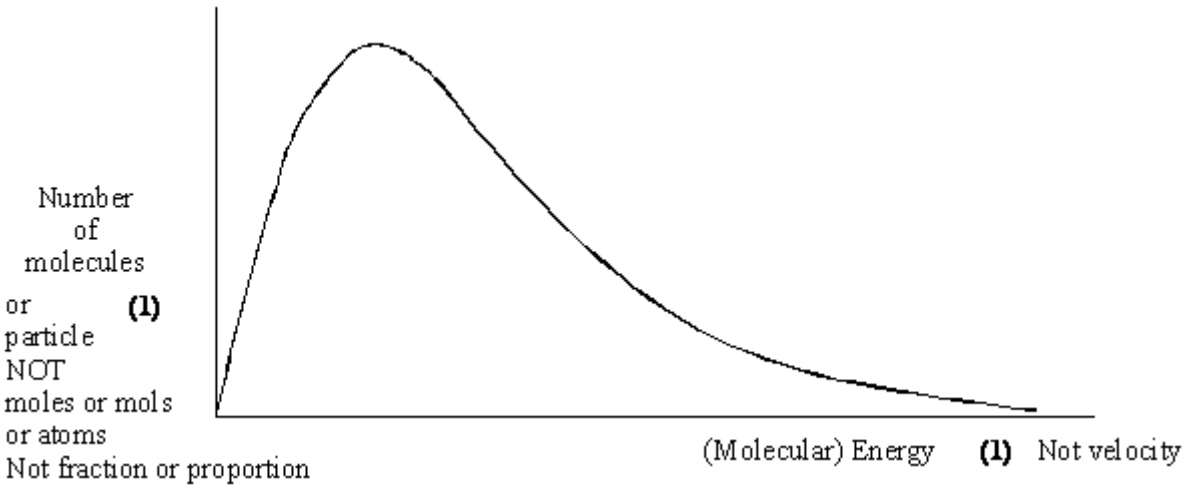
(iii) fewer collisions **(1)**
W used up **(1)**
or reactants
or reagents
or fewer particles

6

[12]

Q24.

(a) (i)



(ii) The total number of particles (or molecules) in the sample
OR the number of molecules present

(iii) No molecules have no energy
OR all molecules have some energy
Do not allow "if there are no molecules there is no energy"

4

(b) (i) The minimum energy required **(1)**

for a reaction to occur **(1)**

OR to start reaction or for a successful collision

(ii) Changes: Catalyst **(1)**

Explanation: Alternative route **(1),** with a lower activation energy **(1)**

OR a lower activation energy (1)
so more molecules can react (1)/more molecules have this energy

If change incorrect CE = 0

Allow answers anywhere in b (ii)

5

[9]

Q25.

C

*line **C***

[1]