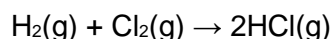


**Q17.**

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



- (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)

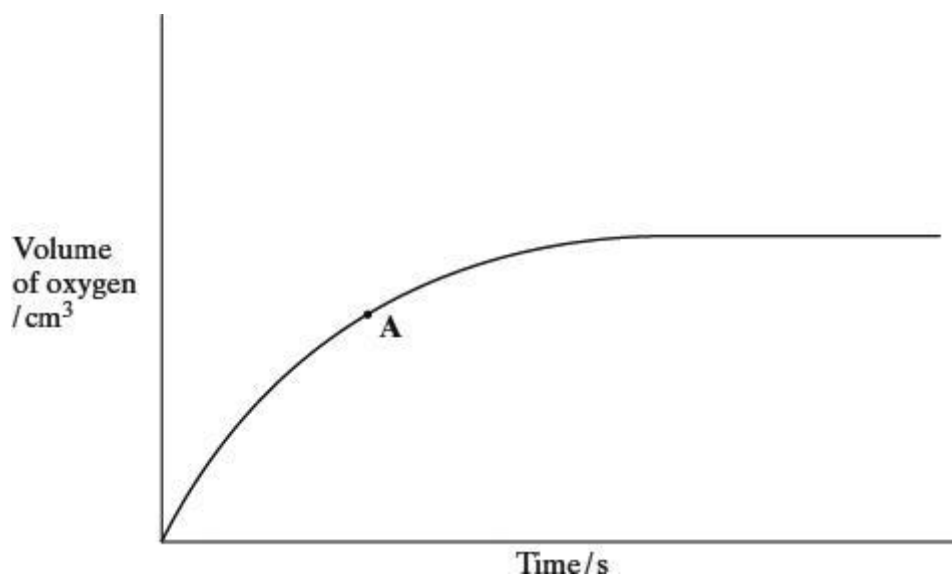
- (f) Suggest **one** reason why a solid catalyst for a gas-phase reaction is often in the form of a powder.

(1)

(Total 9 marks)

**Q18.**

The curve below shows how the volume of oxygen evolved varies with time when 50 cm³ of a 2.0 mol dm⁻³ solution of hydrogen peroxide, H₂O₂, decomposes at 298 K.



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

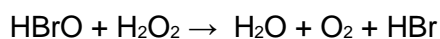
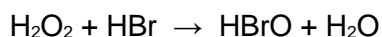
(1)

- (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 cm³ of a 1.0 mol dm⁻³ solution of H₂O₂. Label this curve **X**.
- (ii) 25 cm³ of a 2.0 mol dm⁻³ solution of H₂O₂ 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.



- (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 _____

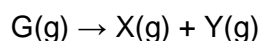
Reason 2 _____

(5)

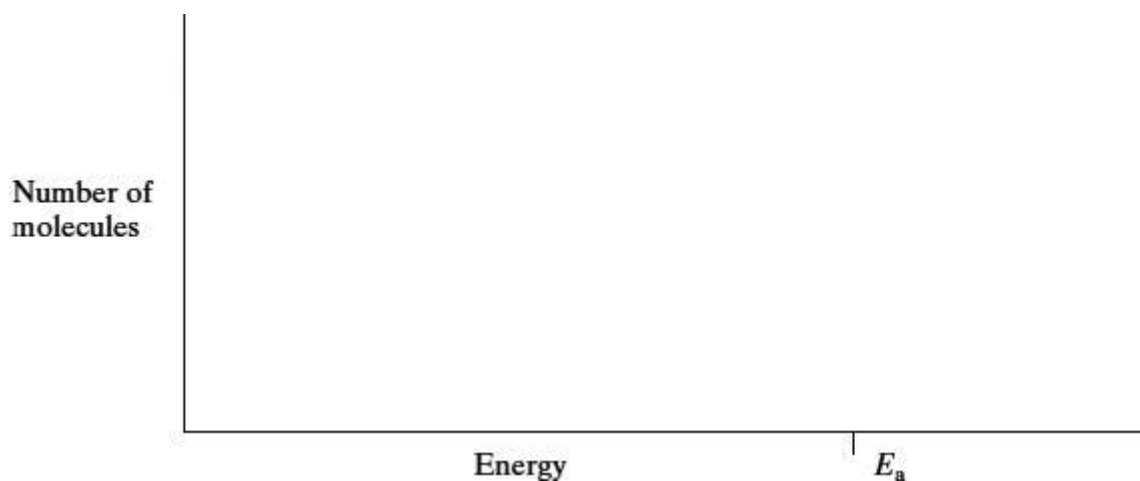
(Total 10 marks)

Q19.

Gas **G** decomposes as shown in the equation below.



- (a) Draw, on the axes below, a Maxwell–Boltzmann distribution curve for a sample of **G** in which only a small proportion of molecules has energy greater than the activation energy, E_a .



(3)

- (b) Define the term *activation energy*.

(2)

- (c) At any time, most of the molecules of **G** have energy less than the activation energy. Suggest why, at a constant temperature, most of **G** eventually decomposes.

(2)



- (d) State the effect, if any, of adding a catalyst on the time required for **G** to decompose, compared with a similar sample without a catalyst. Explain in general terms how the catalyst has this effect.

Time for decomposition _____

Explanation _____

(3)

(Total 10 marks)

Q20.

The diagram below represents a Maxwell–Boltzmann distribution curve for the particles in a sample of a gas at a given temperature. The questions below refer to this sample of particles.



- (a) Label the axes on the diagram. (2)
- (b) On the diagram draw a curve to show the distribution for this sample at a **lower** temperature. (2)
- (c) In order for two particles to react they must collide. Explain why most collisions do not result in a reaction. (1)
- _____
- (d) State one way in which the collision frequency between particles in a gas can be increased without changing the temperature. (1)
- _____



- (e) Suggest why a small increase in temperature can lead to a large increase in the reaction rate between colliding particles.

(2)

- (f) Explain in general terms how a catalyst works.

(2)

(Total 10 marks)

Q21.

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

(2)

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

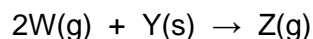
(2)

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

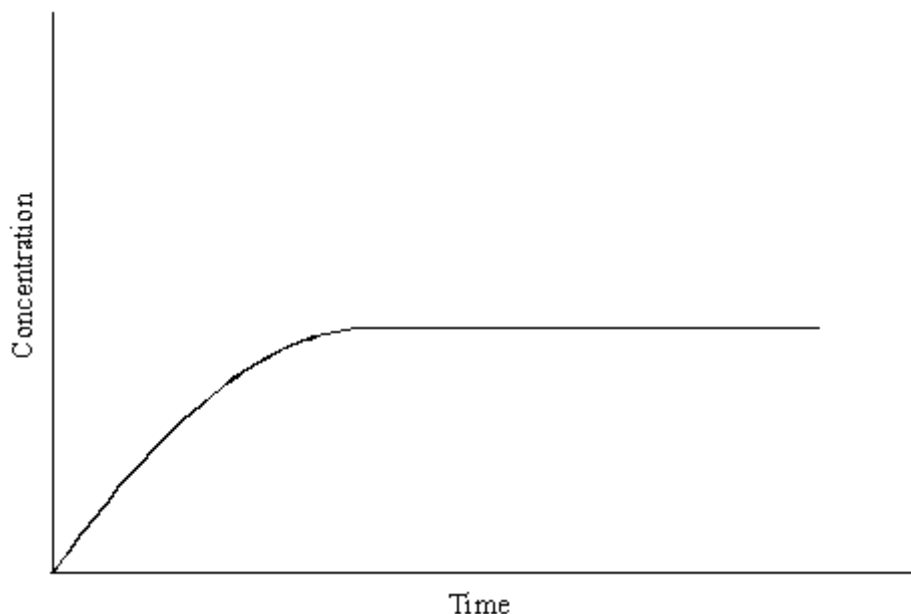
(2)



- (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.



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

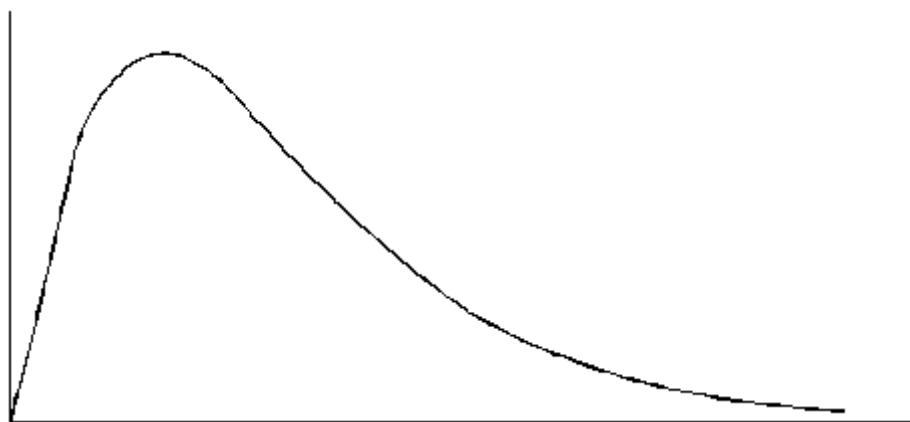


- (i) On the axes above, sketch a curve to show how the concentration of **W** would change with time in the same experiment. Label this curve **W**.
- (ii) On the axes above, sketch a curve to show how the concentration of **Z** would change with time if the reaction were to be repeated under the same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

**Q22.**

- (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 _____

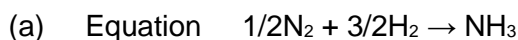
(5)

(Total 9 marks)



Mark Scheme

Q16.



1

$$\Delta H_f = [(945 \times 0.5) + (426 \times 1.5)] - (391 \times 3)$$

1

$$= -46.5 \text{ kJ mol}^{-1}$$

1

Mark Range	<p>The marking scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC). There are no discrete marks for the assessment of QWC but the candidates' QWC in this answer will be one of the criteria used to assign a level and award the marks for this part of the question</p> <p style="text-align: center;">Descriptor</p> <p style="text-align: center;">an answer will be expected to meet most of the criteria in the level descriptor</p>
4-5	<ul style="list-style-type: none"> – claims supported by an appropriate range of evidence – good use of information or ideas about chemistry, going beyond those given in the question – argument well structured with minimal repetition or irrelevant points – accurate and clear expression of ideas with only minor errors of grammar, punctuation and spelling
2-3	<ul style="list-style-type: none"> – claims partially supported by evidence – good use of information or ideas about chemistry given in the question but limited beyond this – the argument shows some attempt at structure – the ideas are expressed with reasonable clarity but with a few errors of grammar, punctuation and spelling
0-1	<ul style="list-style-type: none"> – valid points but not clearly linked to an argument structure – limited use of information or ideas about chemistry – unstructured – errors in spelling, punctuation and grammar or lack of fluency

(b) The higher the temperature the faster the reaction QWC

1

but, since the reaction is exothermic

1

the equilibrium yield is lower QWC



The higher the pressure the greater the equilibrium yield QWC

1

because there is a reduction in the number of moles of gas in the reaction

1

but higher pressure is expensive to produce or plant is more expensive to build QWC

1

A better catalyst would lessen the time to reach equilibrium

1

and allow more ammonia to be produced in a given time QWC

1

1

[11]

Q17.

(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]

Q18.

(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) $2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$ 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]

Q19.

- (a) Graph starts at origin 1
 Graph skewed to left and has decreasing gradient to maximum 1
 Graph after maximum decreases in steepness, never touches x axis, levels out less than 5 mm from x axis. 1
- (b) Minimum energy 1
 To start a reaction (*or for a reaction to occur*) 1
- (c) Molecules gain energy (*or always some molecules have $E > E_a$*) 1
 Due to collisions 1
- (d) Decreases 1
 E_a lowered (1)
By alternative route (1)
So more molecules have energy $> E_a$ (1)

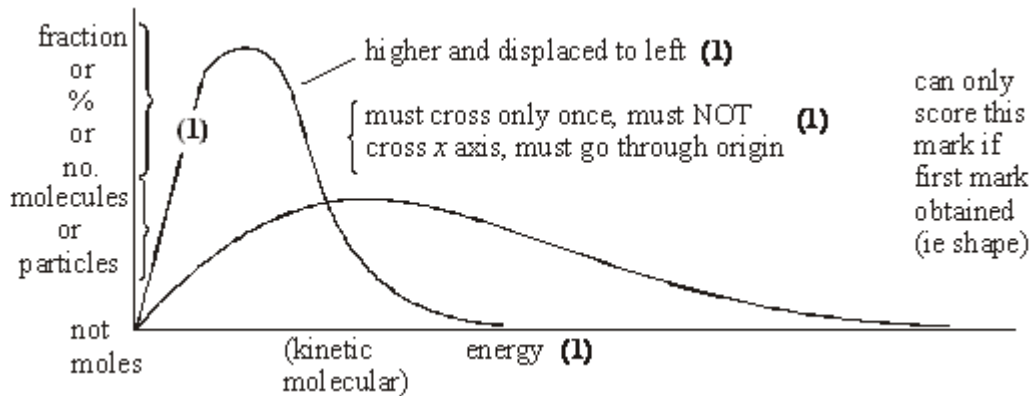


max 2

[10]

Q20.

(a)



2

(b) See above

2

(c) Energy $< E_a$ or must have enough energy (to react) (1)

1

(d) Increase concentration (or pressure) (1)

1

(e) Many (1) more molecules have $E > E_a$ / enough energy (1)
NOT KE increases with T

2

(f) Lowers E_a (1)
alternative route (1)

2

[10]

Q21.

(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

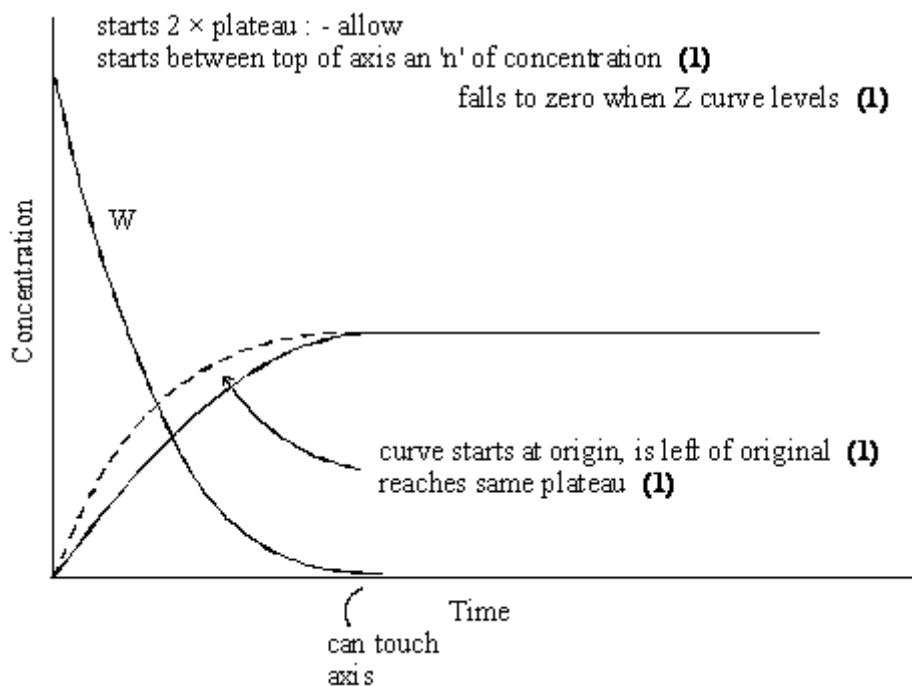
(c) provides alternative reaction route (1)
with a lower activation energy (1)
in (b) and (c) reward 4 marks for 4 points wherever found

2

(d) (i)



(ii)



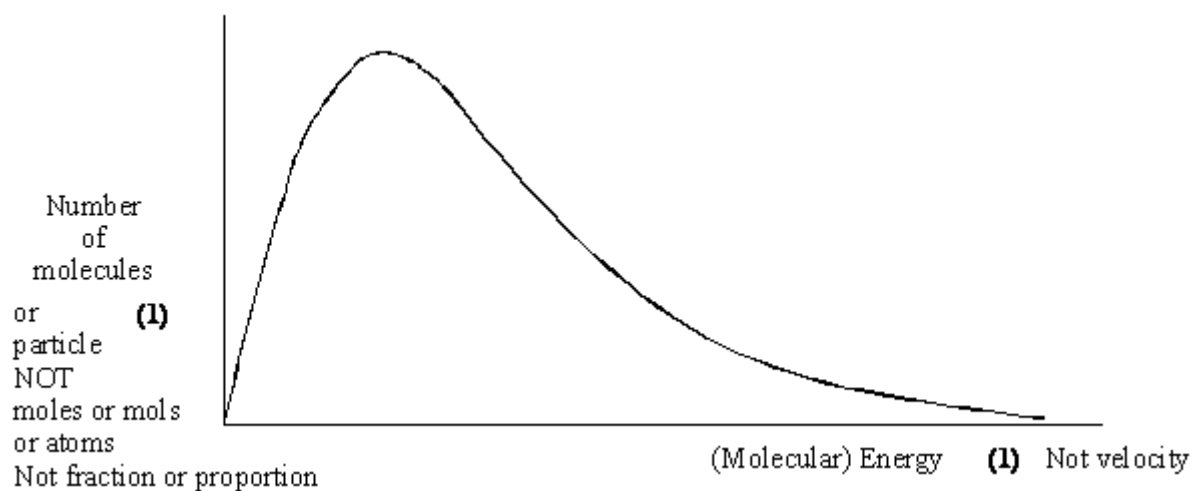
- (iii) fewer collisions **(1)**
W used up **(1)**
or reactants
or reagents
or fewer particles

6

[12]

Q22.

(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]