OXFORD

INTERNATIONAL AQA EXAMINATIONS

Topic Test: OxfordAQA International A level Chemistry

AS Physical Chemistry: Unit 2 content

Name: ______________________

Class: ______________________

Date: ______________________

Time: **79 minutes**

Marks: **73 marks**

Comments:

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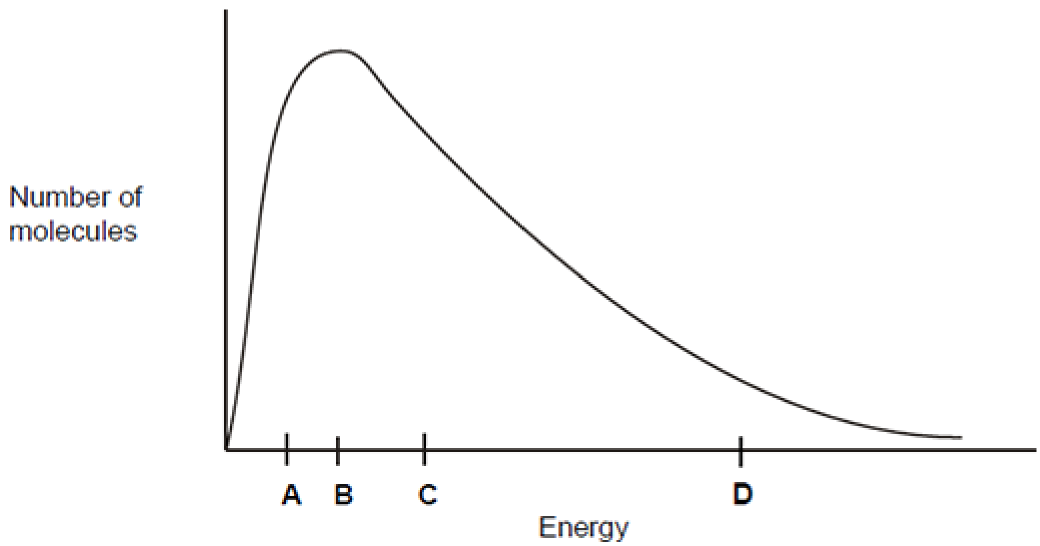
1 This question is about the Maxwell–Boltzmann distribution of molecular energies in a sample of a gas shown in the following figure.



What does the area under the curve represent?

A The total energy of the particles. ⬭

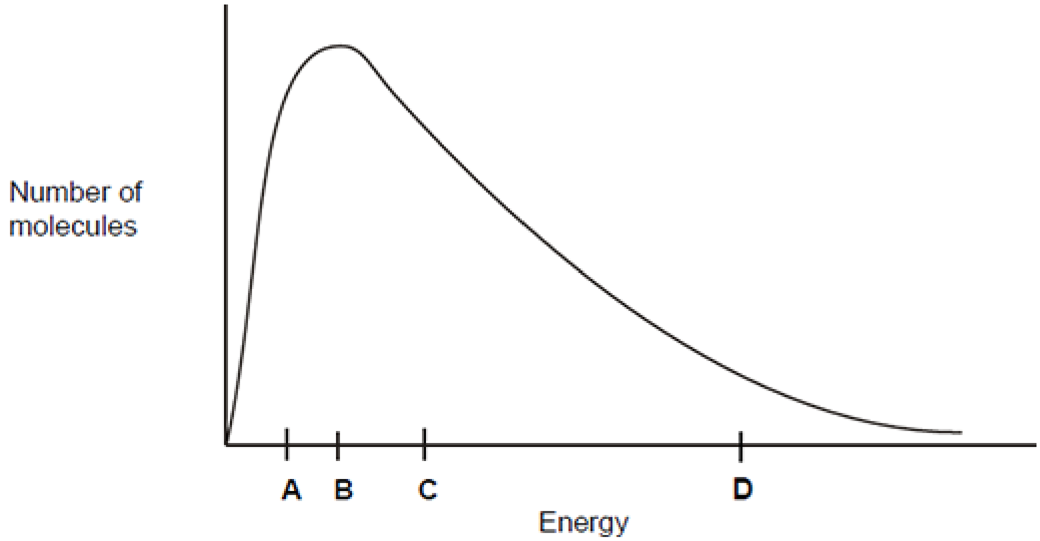
B The total number of particles. ⬭

C The number of particles that can react with each other. ⬭

D The total number of particles that have activation energy. ⬭

(Total 1 mark)

2 This question is about the Maxwell–Boltzmann distribution of molecular energies in a sample of a gas shown in the figure below.



Which letter best represents the mean energy of the molecules?

A ⬭

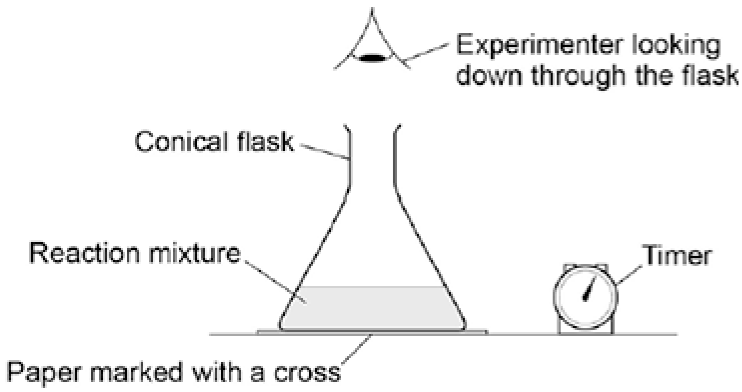
B ⬭

C ⬭

D ⬭

(Total 1 mark)

3 The apparatus in the figure below was set up to measure the time taken for 20.0 cm^3 of sodium thiosulfate solution to react with 5.0 cm^3 of hydrochloric acid in a 100 cm^3 conical flask at 20 °C.
The timer was started when the sodium thiosulfate solution was added to the acid in the flask.
The timer was stopped when it was no longer possible to see the cross on the paper.



What is likely to decrease the accuracy of the experiment?

A Rinsing the flask with acid before each new experiment. ☐

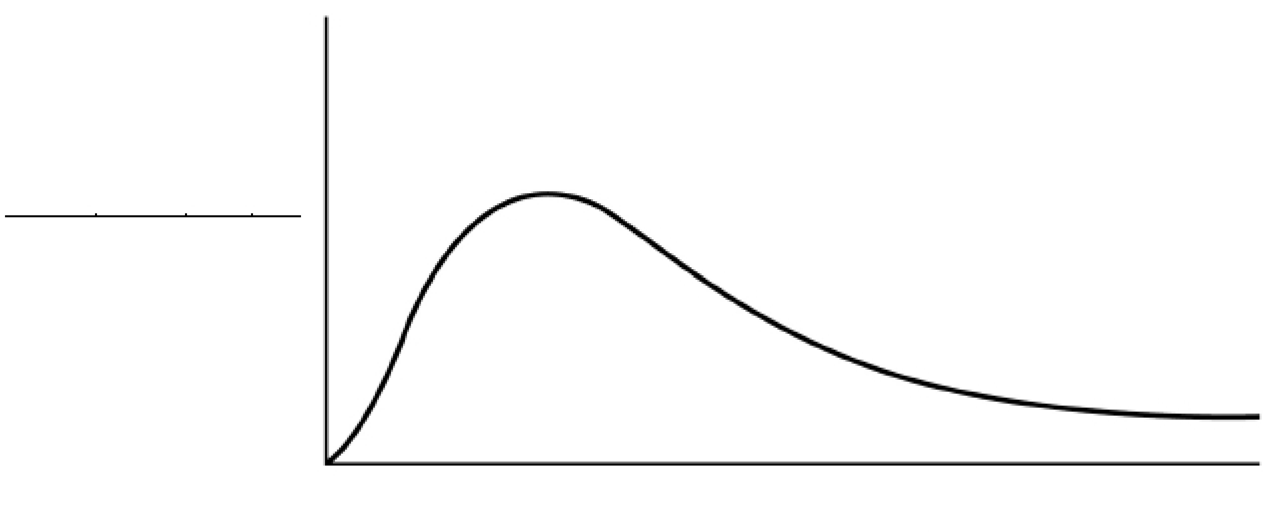
B Stirring the solution throughout each experiment. ☐

C Using the same piece of paper for each experiment. ☐

D Using different measuring cylinders to measure the volumes of acid and sodium thiosulfate. ☐

(Total 1 mark)

4 The diagram below represents a Maxwell–Boltzmann distribution curve for the particles in a sample of a gas **G**, at a given temperature, at the start of a reaction.



(a) Label both axes on the diagram above.

(2)

(b) Give a reason why the curve starts at the origin.

____

____

(1)

(c) Draw on the diagram above a distribution curve for the same sample of gas **G** at a **lower** temperature.

(2)

(d) A flask contains gas G at temperature *T*.
Gas **G** decomposes as shown in the equation.

$$\mathbf{G} \longrightarrow \text{products}$$

At temperature *T*, only a few particles of **G** have the activation energy needed to decompose.

Explain why all of **G** will eventually decompose.

____

____

(1)

(e) Explain why a small decrease in temperature can cause a large decrease in the rate of decomposition of gas **G**.

____

____

____

____

(2)

(Total 8 marks)

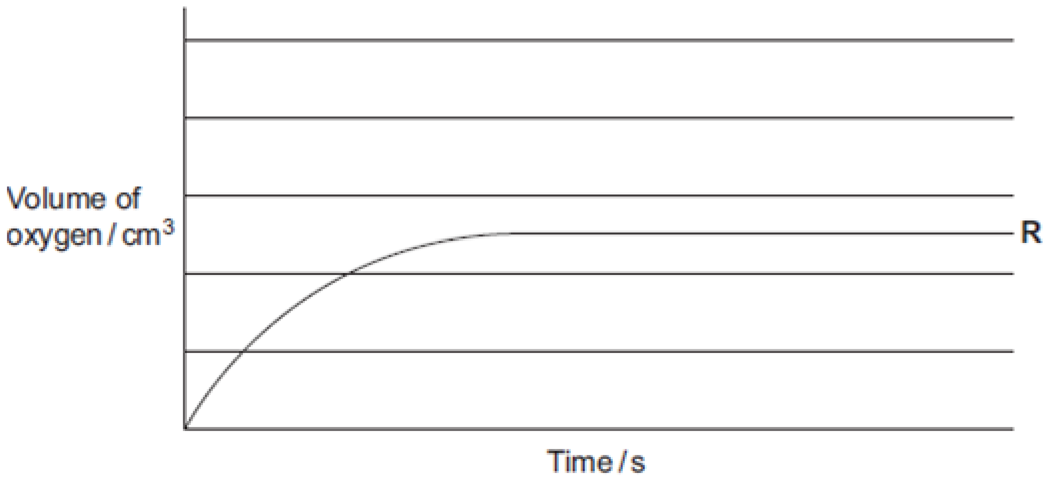
5 A student carried out an experiment to determine the rate of decomposition of hydrogen peroxide into water and oxygen gas.

The student used 100 cm^3 of a 1.0 mol dm^{-3} solution of hydrogen peroxide at 298 K and measured the volume of oxygen collected.

Curve **R**, in each of **Figures 1**, **2** and **3**, shows how the total volume of oxygen collected changed with time under these conditions.

(a) Draw a curve on **Figure 1** to show how the total volume of oxygen collected will change with time if the experiment is repeated at 298 K using 100 cm^3 of a 2.0 mol dm^{-3} solution of hydrogen peroxide.

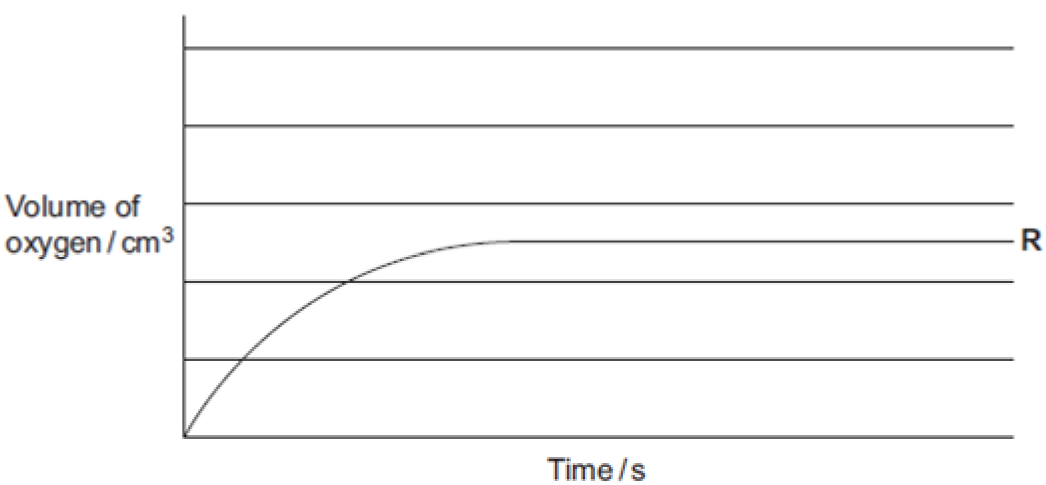
Figure 1



(2)

(b) Draw a curve on **Figure 2** to show how the total volume of oxygen collected will change with time if the experiment is repeated at 298 K using 100 cm^3 of a 0.4 mol dm^{-3} solution of hydrogen peroxide.

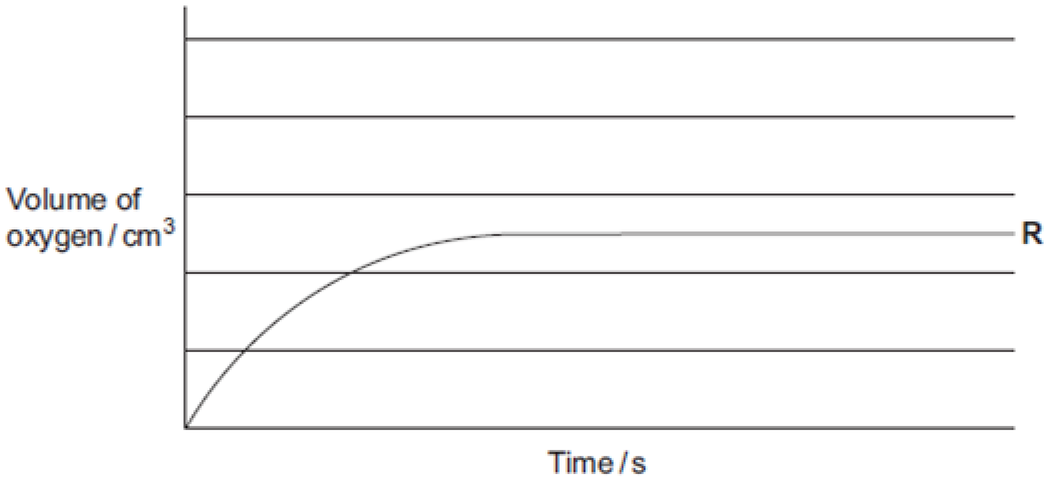
Figure 2



(2)

(c) Draw a curve on **Figure 3** to show how the total volume of oxygen collected will change with time if the **original** experiment is repeated at a temperature higher than 298 K.
You should assume that the gas is collected at a temperature of 298 K.

Figure 3



(2)

(d) Explain why the slope (gradient) of curve **R** decreases as time increases.

____

____

____

____

(2)

(e) The student discovered that hydrogen peroxide decomposes at a faster rate when a few drops of aqueous hydrogen bromide are added to the solution.
The student found on the Internet that this decomposition is thought to proceed in two steps as shown by the following equations.

Step **1** $H_2O_2 + HBr \longrightarrow HBrO + H_2O$

Step **2** $HBrO + H_2O_2 \longrightarrow H_2O + O_2 + HBr$

(i) Write an equation for the overall reaction.

____

(1)

(ii) Give **one** reason, other than the increase in rate of reaction, why the student was able to deduce that hydrogen bromide behaves as a catalyst in this two-step reaction.

___

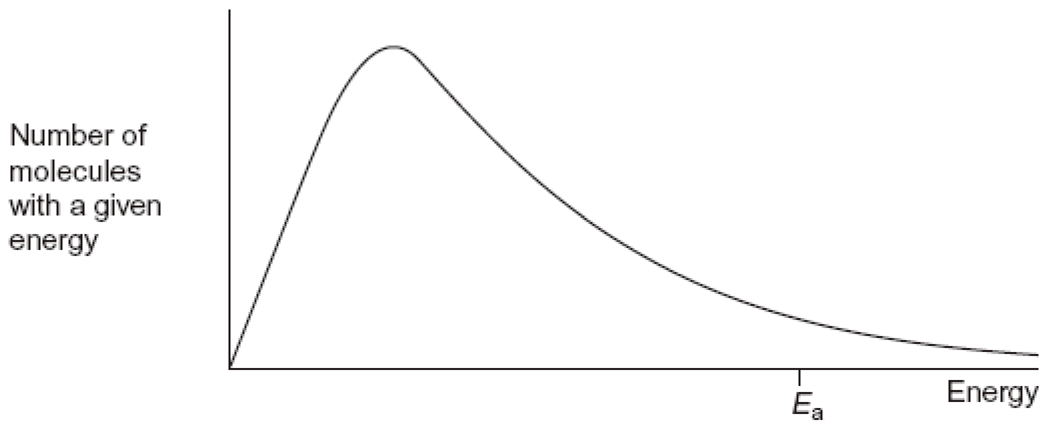
___

___

(1)

(Total 10 marks)

6 The diagram below shows a Maxwell–Boltzmann distribution for a sample of gas at a fixed temperature.
E_a is the activation energy for the decomposition of this gas.



(a) (i) On this diagram, sketch the distribution for the same sample of gas at a higher temperature.

(2)

(ii) With reference to the Maxwell–Boltzmann distribution, explain why an increase in temperature increases the rate of a chemical reaction.

___

___

___

___

___

(2)

(b) Dinitrogen oxide (N_2O) is used as a rocket fuel. The data in the table below show how the activation energy for the decomposition of dinitrogen oxide differs with different catalysts.

$$2N_2O(g) \longrightarrow 2N_2(g) + O_2(g)$$

	Ea / kJ mol^{-1}
Without a catalyst	245
With a gold catalyst	121
With an iron catalyst	116
With a platinum catalyst	136

(i) Use the data in the table to deduce which is the most effective catalyst for this decomposition.

____

(1)

(ii) Explain how a catalyst increases the rate of a reaction.

____

____

____

____

(2)

(Total 7 marks)

7 When one mole of ammonia is heated to a given temperature, 50% of the compound dissociates and the following equilibrium is established.

$$NH_3(g) \rightleftharpoons \tfrac{1}{2}N_2(g) + \tfrac{3}{2}H_2(g)$$

What is the total number of moles of gas present in this equilibrium mixture?

A 1.5 ⬭

B 2.0 ⬭

C 2.5 ⬭

D 3.0 ⬭

(Total 1 mark)

8 (a) A mixture of 1.50 mol of hydrogen and 1.20 mol of gaseous iodine was sealed in a container of volume V dm^3. The mixture was left to reach equilibrium as shown by the following equation.

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

At a given temperature, the equilibrium mixture contained 2.06 mol of hydrogen iodide.

(i) Calculate the amounts, in moles, of hydrogen and of iodine in the equilibrium mixture.

Moles of hydrogen ____

Moles of iodine ____

(2)

(ii) Write an expression for the equilibrium constant (K_c) for this equilibrium.

____

____

(1)

(iii) K_c for this equilibrium has no units.
State why the units cancel in the expression for K_c

____

____

(1)

(iv) A different mixture of hydrogen, iodine and hydrogen iodide was left to reach equilibrium at the same temperature in a container of the same volume.
This second equilibrium mixture contained 0.38 mol of hydrogen, 0.19 mol of iodine and 1.94 mol of hydrogen iodide.

Calculate a value for K_c for this equilibrium at this temperature.

____

____

____

____

(2)

(b) This question concerns changes made to the four equilibria shown in parts (b)(i) to (b)(iv). In each case, use the information in the table to help you choose from the letters **A** to **E** the best description of what happens as a result of the change described. Write your answer in the box.

Each letter may be used once, more than once or not at all.

	Position of equilibrium	Value of equilibrium constant, K_c
A	remains the same	same
B	moves to the right	same
C	moves to the left	same
D	moves to the right	different
E	moves to the left	different

(i) Change: increase the temperature of the equilibrium mixture at constant pressure.

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H^\ominus = +52\ kJ\ mol^{-1}$

(1)

(ii) Change: increase the total pressure of the equilibrium mixture at constant temperature.

$3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H^\ominus = -92\ kJ\ mol^{-1}$

(1)

(iii) Change: add a catalyst to the equilibrium mixture at constant temperature.

$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g) \qquad \Delta H^\ominus = -41\ kJ\ mol^{-1}$

(1)

(iv) Change: add chlorine to the equilibrium mixture at constant temperature.

$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g) \qquad \Delta H^\ominus = +93\ kJ\ mol^{-1}$

(1)

(Total 10 marks)

9 This question is about the equilibrium between N_2O_4 and NO_2

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \quad \Delta H^\ominus = +58.1 \text{ kJ mol}^{-1}$$

(a) A 25.2 g sample of N_2O_4 was heated in a closed flask.
At equilibrium, the mixture was found to contain 0.220 mol of NO_2

Calculate the amount, in moles, of N_2O_4 in the 25.2 g sample.
Calculate the amount, in moles, of N_2O_4 in the equilibrium mixture.
Show your working.

Amount of N_2O_4 in the 25.2 g sample = ____________________ mol

Amount of N_2O_4 in the equilibrium mixture = ____________________ mol

(3)

(b) In a different experiment, a sample of N_2O_4 was heated in a closed flask of volume 5.00 dm^3. The equilibrium mixture formed at temperature *T* contained 0.230 mol of N_2O_4 and 0.542 mol of NO_2

Write an expression for the equilibrium constant K_c for this reaction.
Calculate a value for K_c at temperature *T* and deduce its units.

K_c = ________________________ Units ________________________

(4)

(c) A student repeated the experiment in part (b) but at a temperature lower than T.

State and explain the effect of this lower temperature on the time taken to reach equilibrium and on the amount of NO_2 formed in the equilibrium mixture.

Effect on time taken ____

Explanation ____

____

____

____

Effect on amount of NO_2 ____

Explanation ____

____

____

____

(6)

(Total 13 marks)

10 Ammonia is manufactured by the Haber process in which the following equilibrium is established.

$$N_2(g) \quad + \quad 3H_2(g) \quad \rightleftharpoons \quad 2NH_3(g)$$

(a) Give **two** features of a reaction at equilibrium.

Feature 1 ____

____

____

____

Feature 2 ____

____

____

____

(2)

(b) Explain why a catalyst has no effect on the position of an equilibrium.

____

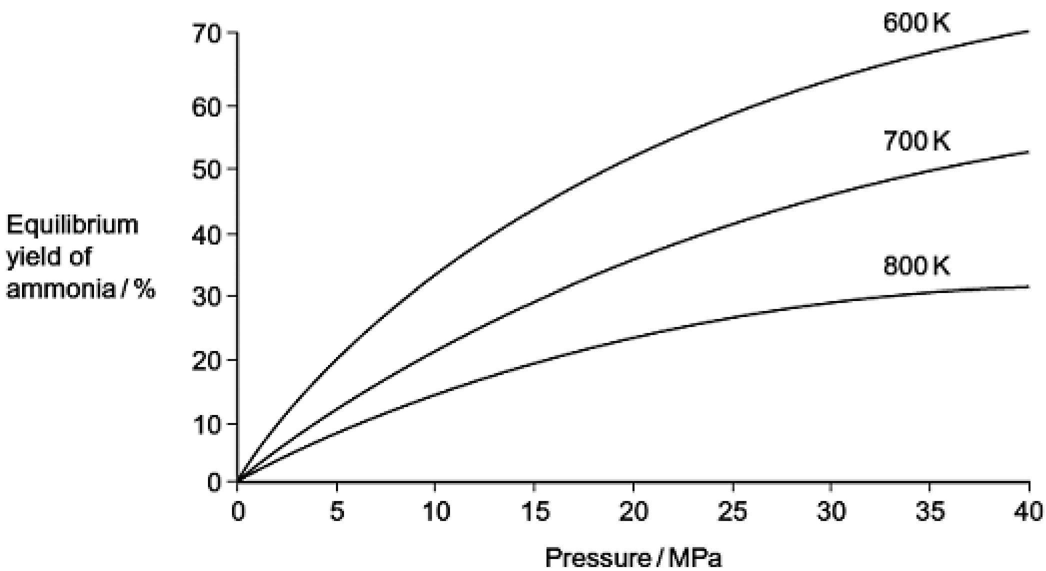
____

____

____

(2)

(c) The diagram shows how the equilibrium yield of ammonia varies with changes in pressure and temperature.



(i) Use the diagram to state the effect of an **increase** in pressure at constant temperature on the yield of ammonia. Use Le Chatelier's principle to explain this effect.

Effect on yield ____

Explanation ____

____

____

____

____

____

(3)

(ii) Use the diagram to state the effect of an **increase** in temperature at constant pressure on the yield of ammonia. Use Le Chatelier's principle to explain this effect.

Effect on yield ____

Explanation ____

____

____

____

____

____

(3)

(d) At equilibrium, with a pressure of 35 MPa and a temperature of 600 K, the yield of ammonia is 65%.

(i) State why industry uses a temperature higher than 600 K.

____

____

(1)

(ii) State why industry uses a pressure lower than 35 MPa. Do **not** include references to safety.

____

____

(1)

(Total 12 marks)

11 When heated above 100 °C, nitrosyl chloride (NOCl) partly decomposes to form nitrogen monoxide and chlorine as shown in the equation.

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

(a) A 2.50 mol sample of NOCl was heated in a sealed container and equilibrium was established at a given temperature. The equilibrium mixture formed contained 0.80 mol of NO.

Calculate the amount, in moles, of Cl_2 and of NOCl in this equilibrium mixture.

Moles of Cl_2 ____

Moles of NOCl ____

(2)

(b) A different mixture of NOCl, NO and Cl_2 reached equilibrium in a sealed container of volume 15.0 dm^3. The equilibrium mixture formed contained 1.90 mol of NOCl and 0.86 mol of NO at temperature *T*.

The value of K_c for the equilibrium at temperature *T* was 7.4×10^{-3} mol dm^{-3}.

(i) Write an expression for the equilibrium constant K_c

____

____

(1)

(ii) Calculate the amount, in moles, of Cl_2 in this equilibrium mixture.

____

____

____

____

____

____

____

____

____

(4)

(iii) Consider this alternative equation for the equilibrium at temperature *T*.

$$NOCl(g) \rightleftharpoons NO(g) + \frac{1}{2}Cl_2(g)$$

Calculate a value for the different equilibrium constant K_c for the equilibrium as shown in this alternative equation. Deduce the units of this K_c

Calculation ____

____

____

____

Units ____

____

(2)

(Total 9 marks)

Mark schemes

1 B

[1]

2 C

[1]

3 A

[1]

4 (a) (y axis) %/fraction of particles/molecules/atoms

1

(x axis) energy

1

(b) no particles/molecules have no energy or all particles/molecules have some energy

1

(c) curve should be higher and displaced to the left

1

curve must start at the origin and must not touch x axis and must only cross the drawn curve once

1

(d) particles/molecules will gain/transfer energy when they collide

1

(e) far fewer particles/molecules have energy > Ea

1

(far) fewer collisions per second/per unit time

must mention frequency of collisions

1

[8]

5 (a) **Award in either order for curve**

"Steeper" requires line to be on the left of the original line, starting from the origin

M1 curve is steeper than original and starts at the origin

M2 curve levels at the top line on the graph

2

(b) **Award in either order for curve**

"Shallower" requires line to be on the right of the original line, starting from the origin

M1 curve is shallower than original and starts at the origin

M2 curve levels at the first line on the graph

2

(c) **M1** curve would be steeper than original

"Steeper" requires line to be on the left of the original line, starting from the origin

M2 curve levels at the same original volume of O_2

2

(d) **M1** The (concentration / amount of) H_2O_2 or reactant falls / decreases / used up

Mark independently

OR

The number of H_2O_2 or reactant molecules/ particles falls / decreases

M2

The rate of reaction / rate of decomposition / rate of formation of oxygen / frequency of collisions / (effective) collisions in a given time decreases / is slower

2

(e) (i) $\mathbf{2}H_2O_2 \rightarrow \mathbf{2}H_2O + O_2$

Ignore state symbols

Accept only this equation or its multiples

Extra species must be crossed through

1

(ii) hydrogen bromide / it does not appear in the overall equation

OR

hydrogen bromide / it is not used up in the reaction / unchanged at the end of the reaction

OR

hydrogen bromide / it is regenerated / re-formed (in Step 2)

1

[10]

6 (a) (i) **M1** The peak of the new curve is displaced to the right.

M2 All of the following are required

- The new curve starts at the origin
- The peak of the new curve is lower than the original
- and the new curve only crosses the original curve once
- and an attempt has been made to draw the new curve correctly towards the energy axis but not to touch the original curve
- the new curve must not start to diverge from the original curve

M1 is low demand

M2 is higher demand.

2

(ii) **M1** Increase in the number/proportion of molecules with $E \geq E_a$

OR more molecules have $E \geq E_a$

OR more molecules have sufficient energy to react

M2 More effective/productive/successful collisions

Ignore "molecules have more energy"

Ignore "more energetic collisions"

Ignore "molecules gain activation energy"

Ignore "more collisions"

Accept "particles" for "molecules" but NOT "atoms"

Ignore "chance of collision"; this alone does not gain M2

2

(b) (i) Iron ***OR*** Fe

1

(ii) **M1** Catalysts provide an alternative route/pathway/mechanism

OR

(in this case) surface adsorption/surface reaction occurs.

For M1, not simply "provides a surface" alone

M2 that has a lower activation energy

OR

lowers the activation energy

For M2, the candidate may use a definition of activation energy without referring to the term

2

[7]

7 A

[1]

8 (a) (i) mol H_2 = 0.47

1

mol I_2 = 0.17

If answers reversed, ie

mol H_2 = 0.17

mol I_2 = 0.47

then allow one mark (for second answer).

1

(ii) $\frac{[HI]^2}{[H_2][I_2]}$

Penalise expression containing V
But mark on in (a)(iv)

***Penalise missing square brackets** in this part*
(and not elsewhere in paper) but mark on in (a)(iv)

1

(iii) equal number of <u>moles</u> (on each side of equation)

OR

equal <u>moles</u> (top and bottom of *K*c expression)

1

(iv)

$\frac{[1.94]^2}{[0.38][0{,}19]}$

Ignore V

If Kc wrong in (a)(ii) (wrong powers or upside down etc) no marks here

1

= 52(.1)

1

(b) (i) **D**

1

(ii) **B**

1

(iii) **A**

1

(iv) **C**

1

[10]

9 (a) 25.2 ÷ 92(.0) = 0.274 mol

1

(0.220 ÷ 2 =) 0.110 moles N_2O_4 used

1

(0.274 − 0.110 =) 0.164 mol N_2O_4 left

This also scores M2

1

(b) $K_c = \frac{[NO_2]^2}{[N_2O_4]}$

1

$= \frac{(0.542 \div 5.00)^2}{(0.230 \div 5.00)}$

1

= 0.255

If not divided by volume then can only score M1 and M4

1

mol dm^{-3}

1

(c) Takes longer time

M1 − answer must refer to time (not rate). If dec rate seen then do not allow M1 but mark on

1

Particles have less energy and collide less frequently

1

Fewer particles or fewer collisions have energy above activation energy

1

Smaller amount

M4 allow 'lower yield' or 'decreased yield'

1

Reaction is endothermic

1

Equilibrium moves in the reverse/exothermic direction to produce heat/oppose the decrease in temperature

1

[13]

10 (a) **In either order**

For M1 accept [ ] for concentration

M1 Concentrations (of reactants and products) remain or stay constant / the same

NOT "equal concentrations" and NOT "concentration(s) is / are the same"

M2 Forward rate = Reverse / backward rate

NOT "amount"

Ignore "dynamic" and ignore "speed"

Ignore "closed system"

It is possible to score both marks under the heading of a single feature

2

(b) **M1** Catalysts increase rate of / speed up both forward and reverse / backward reactions

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

M2 increase in rate / affect on rate / speed is equal / the same

Ignore references to "decrease in rate"

2

(c) (i) **M1** (The yield) increases / goes up / gets more

If M1 is given as "decreases" / "no effect" / "no change" then CE= 0 for clip, but mark on from a blank.

M2 There are more moles / molecules (of gas) on the left / of reactants

Ignore "volumes", "articles" "atoms" and "species" for M2

OR fewer moles / molecules (of gas) on the right / products

OR there are 4 moles / molecules (of gas) on the left and 2 moles / molecules on the right.

OR (equilibrium) shifts / moves to the side with less moles / molecules

M3 Can only score M3 if M2 is correct

The equilibrium shifts / moves (from left to right) to oppose the increase in pressure

For M3, not simply "to oppose the change"

For M3 credit the equilibrium shifts / moves to lower / decrease the pressure

(There must be a specific reference to the change that is opposed)

3

(ii) **M1** The yield decreases / goes down / gets less

If M1 is given as "increase" / "no effect" / "no change" then CE= 0 for clip, but mark on from a blank.

M2 (Forward) reaction is exothermic ***OR*** gives out / releases heat

OR

reverse reaction is endothermic ***OR*** takes in / absorbs heat

Can only score M3 if M2 is correct

The equilibrium shifts / moves (from right to left) to oppose the increase in temperature

For M3, not simply "to oppose the change"

For M3 credit the equilibrium shifts / moves

to absorb the heat OR

to cool the reaction OR

to lower the temperature

(There must be a specific reference to the change that is opposed)

3

(d) (i) Must be comparative

Credit correct reference to rate being too (s)low / (s)lower at temperatures less than 600 K

Higher rate of reaction

OR increase / speed up the rate (of reaction)

Ignore statements about the "yield of ammonia"

OR Gets to equilibrium faster/ quicker

OR faster or quicker rate / speed of attainment of equilibrium

1

(ii) Less electrical pumping cost

Not just "less expensive" alone

OR

Not just "less energy or saves energy" alone

Use lower pressure equipment / valves / gaskets / piping etc.

Credit correct qualified references to higher pressures

OR

Uses less expensive equipment

Ignore references to safety

1

[12]

11 (a) Cl_2 0.4

1

NOCl 1.7

1

(b) (i) $K_c = \frac{[NO]^2[Cl_2]}{[NOCl]^2}$

Penalise expression containing V
Allow ( ) here, but must have all brackets.
If K_c expression wrong, max 2 in (b)(ii) for
M1 for correct rearrangement of their K_c and
M4 for multiplying by 15

1

(ii) M1 $[Cl_2] = K_c \times \frac{[NOCl]^2}{[NO]^2}$

Mark is for rearrangement of correct K_c expression.
If K_c rearrangement wrong, can only score max 2 for:
M3 and M4

1

M2

$$[Cl_2] = \frac{(7.4\times10^{-3})\times(1.90/15)^2}{(0.86/15)^2}\left(= \frac{(7.4\times10^{-3})\times(0.127)^2}{(0.0573)^2}\right)$$

Rounding 1.90 / 15 wrongly to 0.126 is AE

1

M3 $[Cl_2]$ = 0.0361 to 0.0365 (min 2 sfs)

Mark for correct calculation of $[Cl_2]$

1

M4 mol Cl_2 = 0.54 to 0.55

Correct answer scores 4 ignore working

Mark is for <u>answer</u> of (M3 × 15)

1

(iii) ($\sqrt{}$?(7.4 × 10^{-3}) =) 0.086

Allow 0.085 to 0.086)

*Mark for answer **OR** conseq on their Cl_2*

$$K_c = \sqrt{\frac{M4}{15}} \times \frac{0.86}{1.90} = \sqrt{M4} \times 0.117$$

Or $\sqrt{M3} \times 0.453$

1

<u>mol ^{½} dm$^{-3/2}$</u> ***OR*** <u>mol $^{0.5}$ dm $^{-1.5}$</u>

NOT $\sqrt{\text{mol dm}^{-3}}$ nor $(\text{mol dm}^{-3})^{1/2}$

1

[9]