14 20.0 cm^3 of hydrogen peroxide decomposes to water and oxygen in the presence of a suitable catalyst.

160 cm^3 of oxygen, measured at room conditions, is produced in 5.00 minutes.

What is the average rate of decomposition of hydrogen peroxide during this reaction period?

A $2.22 \times 10^{-5}\,mol\,s^{-1}$

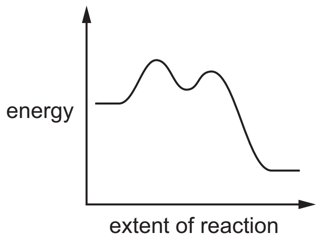
B $4.44 \times 10^{-5}\,mol\,s^{-1}$

C $1.76 \times 10^{-4}\,mol\,s^{-1}$

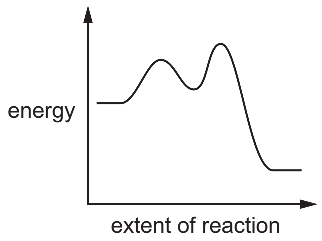
D $2.67 \times 10^{-3}\,mol\,s^{-1}$

15 Which reaction pathway diagram shows an endothermic reaction that occurs in two steps and in which the second step of the reaction is likely to be faster than the first?

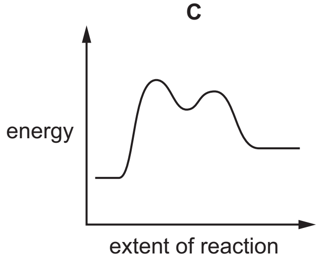
A



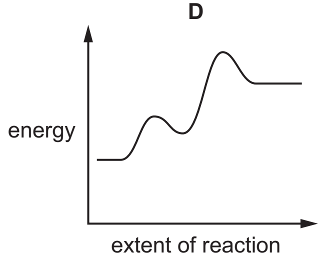
B



C



D



15 The reversible reaction between methanol and ethanoic acid liquids is catalysed by adding a small volume of concentrated sulfuric acid.

Two statements about this reaction are listed.

1 The sulfuric acid is a homogeneous catalyst.

2 The sulfuric acid lowers the activation energy of the reverse reaction.

Which statements are correct?

A both 1 and 2

B 1 only

C 2 only

D neither 1 nor 2

14 When two aqueous solutions are mixed, the reaction between them is very slow.

An effective catalyst is added to the mixture without any change in temperature.

Which statement about this catalyst is correct?

A It increases the average energy of the reactant particles.

B It changes the distribution of energies of the reactant particles.

C It allows a greater number of reactant particles to react per unit time.

D It increases the number of reactant particles with the most probable energy.

15 A mixture of gases reacts faster as its temperature increases.

Which row explains this?

	the activation energy remains unchanged	more particles have energy equal to or above the activation energy	there is an increase in the rate of successful collisions
A	false	false	false
B	true	true	true
C	false	true	true
D	true	false	false

2 Aluminium oxide, Al_2O_3, and phosphorus(V) oxide, P_4O_{10}, are both used as reagents and catalysts.

(a) The melting point of Al_2O_3 is 2072 °C. The melting point of P_4O_{10} is 340 °C.

Explain the difference in the melting points of these two compounds.

....

....

....

.... [3]

(b) A 5.00 dm^3 sealed flask contains 0.400 mol of CO(g) and 0.800 mol of H_2(g) and an Al_2O_3 catalyst. The flask is heated to a temperature of 290 °C and allowed to reach equilibrium. Equation 1 shows the reaction.

equation 1 $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$

The equilibrium constant, K_c, of equation 1 is given.

$$K_c = \frac{[CH_3OH]}{[CO][H_2]^2}$$

(i) State the units of K_c.

.... [1]

(ii) The equilibrium mixture contains 0.280 mol of CH_3OH(g).

Calculate the value of K_c.

Give your answer to **three** significant figures.

value of K_c = ... [3]

(iii) State and explain the effect, if any, on the value of K_c when the overall pressure in the sealed flask is increased.

....

.... [1]

(c) P_4O_{10} catalyses the reversible reaction of CO with H_2 to form CH_3OH.

equation 1 $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$

P_4O_{10} then acts as a dehydrating agent, causing CH_3OH to form CH_3OCH_3.

(i) Explain how the presence of a catalyst affects a chemical reaction.

....

....

.... [1]

(ii) Construct an equation for the dehydration reaction of CH_3OH to form CH_3OCH_3.

.... [1]

(iii) Write an equation to show the reaction of P_4O_{10} with an excess of water.

.... [1]

[Total: 11]

1 The thiosulfate ion, $S_2O_3^{2-}$, decomposes when an acid is added.

$$S_2O_3^{2-}(aq) + 2H^+(aq) \rightarrow S(s) + SO_2(aq) + H_2O(l)$$

The rate of this reaction can be investigated by measuring how long it takes for the solid sulfur forming to obscure the print on the insert.
You will investigate how the concentration of the thiosulfate ion affects the rate of the reaction.

Note: A small amount of sulfur dioxide gas may be formed in the experiment. It is very important that you avoid inhaling any fumes. As soon as each experiment is complete, add the reaction mixture to the quenching bath and rinse the beaker thoroughly.

FA 1 is 0.100 mol dm^{-3} sodium thiosulfate, $Na_2S_2O_3$.
FA 2 is 2.00 mol dm^{-3} hydrochloric acid, HC*l*.

(a) Method

Experiment 1

- Fill a burette with **FA 1**.
- Run 40.00 cm^3 of **FA 1** into the 100 cm^3 beaker.
- Use the 25 cm^3 measuring cylinder to measure 10.0 cm^3 of **FA 2**.
- Add the **FA 2** to the **FA 1** in the beaker and start timing immediately.
- Stir the mixture once and place the beaker on the printed insert.
- View the printing on the insert from above through the solution.
- Stop timing when the print on the insert becomes obscured.
- Record this reaction time to the nearest second in the space for results.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker so it is ready to use in **Experiment 2**.

Experiment 2

- Refill the burette with **FA 1**.
- Fill the second burette with distilled water.
- Run 20.00 cm^3 of **FA 1** into the 100 cm^3 beaker.
- Run 20.00 cm^3 of distilled water into the same beaker.
- Use the 25 cm^3 measuring cylinder to measure 10.0 cm^3 of **FA 2**.
- Add the **FA 2** to the **FA 1** in the beaker and start timing immediately.
- Stir the mixture once and place the beaker on the printed insert.
- View the printing on the insert from above through the solution.
- Stop timing when the print on the insert becomes obscured.
- Record this reaction time to the nearest second in the space for results.
- Empty the contents of the beaker into the quenching bath.
- Rinse and dry the beaker so it is ready to use in the next experiment.

Experiments 3–5

- Carry out three further experiments to investigate how using different volumes of **FA 1** affects the reaction time.

Note: the combined volumes of **FA 1** and distilled water must always be 40.00 cm^3.
Do not use a volume of **FA 1** that is less than 15.00 cm^3.

Record all your results in a table. You should include the volume of **FA 1**, the volume of distilled water, the reaction time and the reaction rate for each of your five experiments.

The rate of reaction can be calculated using the following formula.

$$\text{rate} = \frac{1000}{\text{reaction time}}$$

Results

I	
II	
III	
IV	
V	
VI	
VII	
VIII	

[8]

(b) (i) On the grid in Fig. 1.1, plot the rate (*y*-axis) against the volume of **FA 1** (*x*-axis). Start each axis at the origin (0, 0).

Ring any anomalous points. Draw a line of best fit.

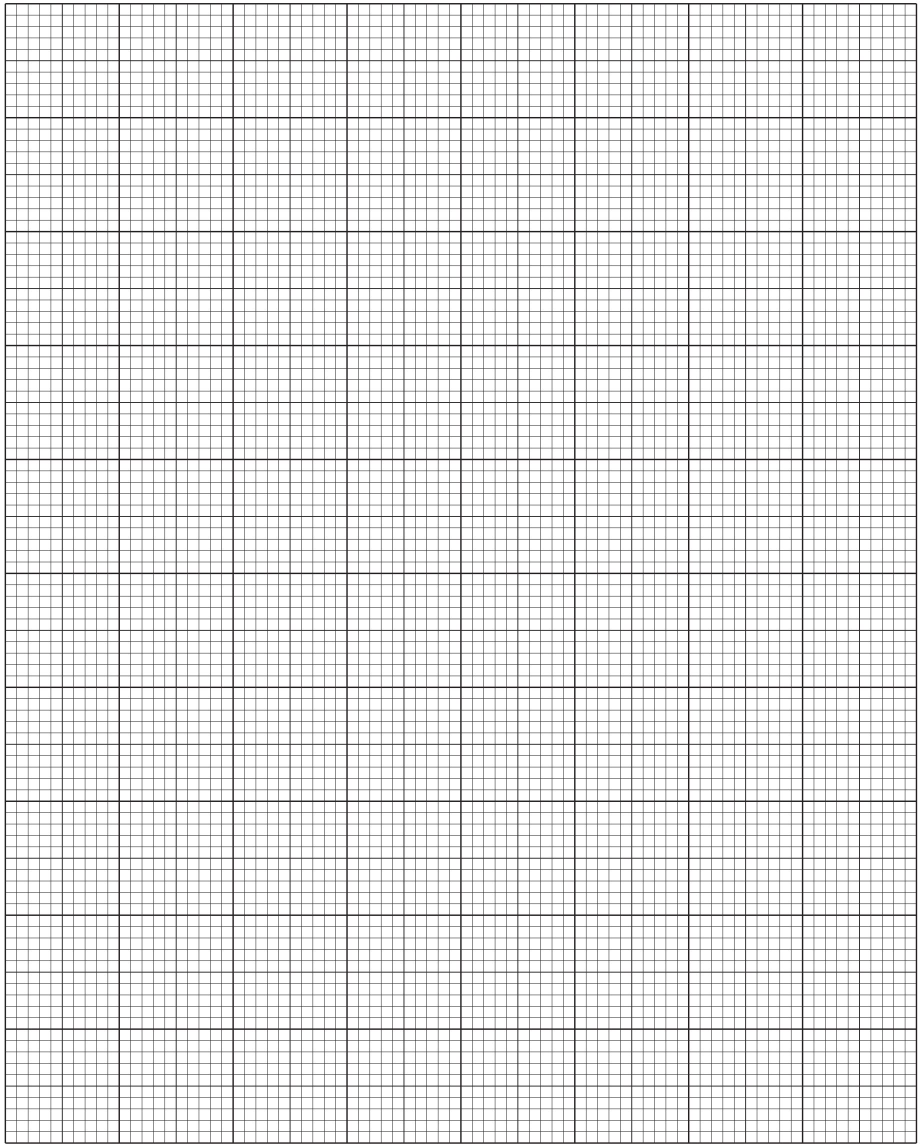


Fig. 1.1

I	
II	
III	

[3]

(ii) Use your graph in Fig. 1.1 to determine the time it would take for the print to be obscured if 7.50 cm^3 of **FA 1**, 32.50 cm^3 of water and 10.0 cm^3 of **FA 2** had been used.
Show clearly on the graph how you worked out your answer.

time for printing to be obscured = ... s [2]

(c) A student carries out the same method as given in **(a)** but using a different concentration of acid. The student's calculated values for the rate are plotted on the grid in Fig. 1.2.

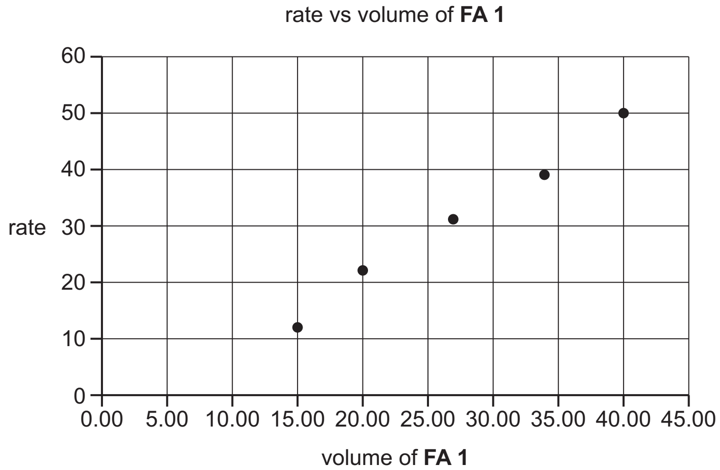


Fig. 1.2

State whether the student's results show that the rate is directly proportional to the volume of **FA 1** used.
Explain your answer.

....

.... [2]

[Total: 15]