Collision Theory

Question Paper 2

Level	A Level
Subject	Chemistry
Exam Board	AQA
Module	3.1 Physical Chemistry
Topic	3.1.5 Kinetics
Sub-Topic	3.1.5.1 Collision Theory
Booklet	Question Paper 2

Time Allowed: **52 minutes**

Score: **/50**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	75%	70%	60%	55%	50%	<50%

Q1. A student calculated that a value for the enthalpy change of neutralisation is –51.2 kJ mol^{-1}.

The design of a possible hand-warmer using hydrochloric acid and sodium hydroxide was discussed. It was proposed that 500 cm^3 of hydrochloric acid should be used in a flexible, sealed plastic container with a breakable tube of solid sodium hydroxide also in the container. On breaking the tube, the sodium hydroxide would be released, react with the acid and produce heat.
A 40 °C temperature rise was thought to be suitable.

(a) Calculate the heat energy, in J, required to raise the temperature of the reaction mixture by 40 °C. Assume that the reaction mixture has a density of 1.00 g cm^{-3} and a specific heat capacity of 4.18 J K^{-1} g^{-1}.
Assume that all of the heat energy given out is used to heat the reaction mixture.

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(2)

(b) Use your answer from part (a) and the value for the enthalpy change of neutralisation of –51.2 kJ mol^{-1} to calculate the minimum amount, in moles, and hence the minimum mass of sodium hydroxide required in the breakable tube.
(If you could not complete the calculation in part (a) assume that the heat energy required was 77 400 J. This is **not** the correct answer).

Show your working.

Moles of NaOH .....

.....

Mass of NaOH .....

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(3)

(c) Use the amount, in moles, of sodium hydroxide from part (b) to calculate the minimum concentration, in mol dm^{-3}, of hydrochloric acid required in the 500 cm^3 of solution used in the sealed container.

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(1)

(d) Suggest **one** possible risk to a person who uses a hand-warmer containing sodium hydroxide and hydrochloric acid.

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(1)

(e) A commercial hand-warmer uses powdered iron sealed in a plastic container.
A valve allows air to enter the container, and oxygen in the air reacts slowly with the iron to form solid iron(lll) oxide. The heat released warms the container.

(i) Write an equation for this reaction between iron and oxygen to form iron(lll) oxide.

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(1)

(ii) One version of an iron-oxygen hand-warmer advertises that it is designed to stay warm for up to four hours.
Other than by increasing the amount of iron in the container, state **one** change to the iron in the hand-warmer that would increase this time.
Explain why this change to the iron might **not** be an advantage.

Change to the iron .....

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Explanation .....

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(3)

(f) Another type of hand-warmer uses sodium thiosulfate. Sodium thiosulfate is very soluble in water at 80 °C but is much less soluble at room temperature.
When a hot, concentrated solution of sodium thiosulfate is cooled it does not immediately crystallise. The sodium thiosulfate stays dissolved as a stable 'super-saturated' solution until crystallisation is triggered.
Heat energy is then released when the sodium thiosulfate crystallises.

(i) This type of hand-warmer is re-usable.
Suggest **one** environmental advantage that a sodium thiosulfate hand-warmer

has over the other two types.

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(1)

(ii) Describe the **two** steps that you would take to make the sodium thiosulfate hand-warmer ready for re-use.

Step 1 .....

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Step 2 .....

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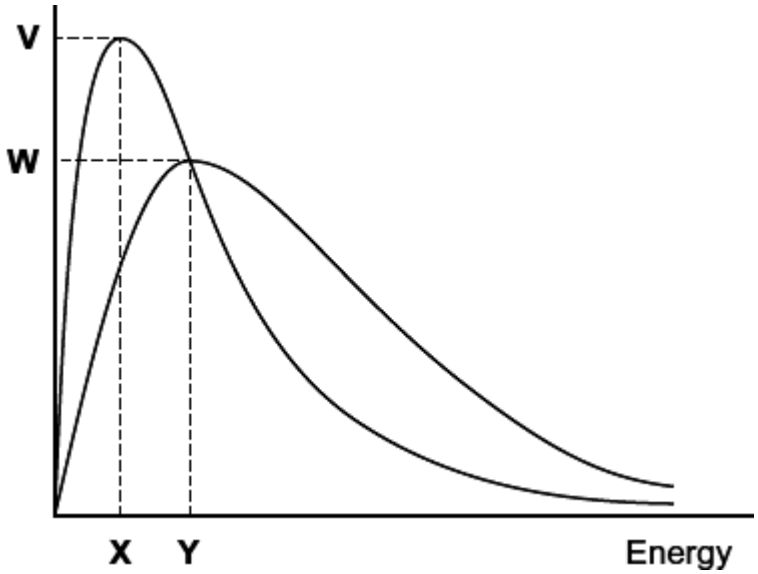
(2)
(Total 14 marks)

Q2. The diagram shows the Maxwell-Boltzmann distribution of molecular energies in a gas at two different temperatures.



(a) One of the axes is labelled. Complete the diagram by labelling the other axis.

(1)

(b) State the effect, if any, of a solid catalyst on the shape of either of these distributions.

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(1)

(c) In the box, write the letter, **V**, **W**, **X** or **Y**, that represents the most probable energy of the molecules at the lower temperature.

(1)

(d) Explain what must happen for a reaction to occur between molecules of two different gases.

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(2)

(e) Explain why a small increase in temperature has a large effect on the initial rate of a reaction.

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(1)
(Total 6 marks)

Q3. The rate of a chemical reaction is influenced by the size of the activation energy. Catalysts are used to increase the rates of chemical reactions but are not used up in the reactions.

(a) Give the meaning of the term *activation energy*.

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(2)

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

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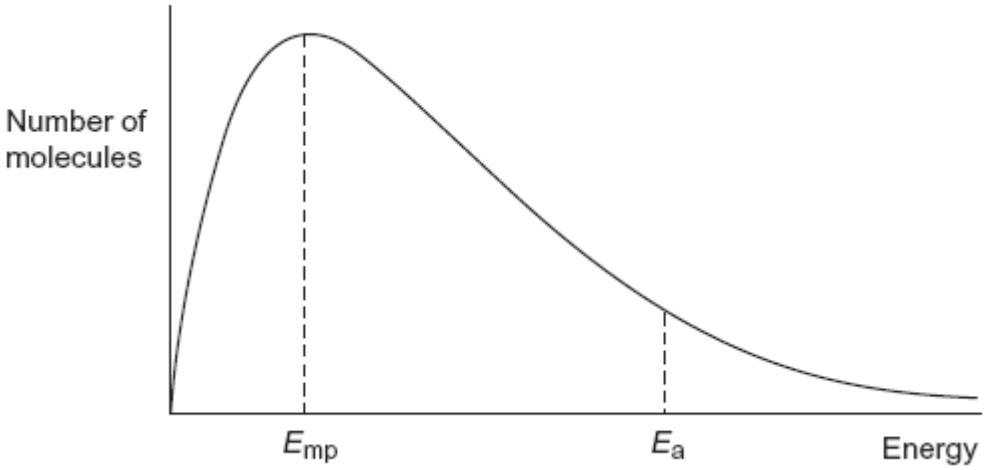
(2)

(c) The diagram below shows the Maxwell–Boltzmann distribution of molecular energies, at a constant temperature, in a gas at the start of a reaction.
On this diagram the most probable molecular energy at this temperature is shown by the symbol E_{mp}
The activation energy is shown by the symbol E_a



To answer the questions (c)(i) to (c)(iv), you should use the words **increases**, **decreases** or **stays the same**. You may use each of these answers once, more than once or not at all.

(i) State how, if at all, the value of the most probable energy (E_{mp}) changes as the total number of molecules is increased at constant temperature.

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(1)

(ii) State how, if at all, the number of molecules with the most probable energy (E_{mp}) changes as the temperature is decreased without changing the total number of molecules.

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(1)

(iii) State how, if at all, the number of molecules with energy greater than the activation energy (E_a) changes as the temperature is increased without c hanging the total number of molecules.

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(1)

(iv) State how, if at all, the area under the molecular energy distribution curve changes as a catalyst is introduced without changing the temperature or the total number of molecules.

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(1)

(d) For each of the following reactions, identify a catalyst and name the organic product of the reaction.

(i) The fermentation of an aqueous solution of glucose.

Catalyst .....

Name of organic product .....

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(2)

(ii) The hydration of but-2-ene.

Catalyst .....

Name of organic product .....

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(2)
(Total 12 marks)

Q4. A method of synthesising ammonia directly from nitrogen and hydrogen was developed by Fritz Haber. On an industrial scale, this synthesis requires a high temperature, a high pressure and a catalyst and is very expensive to operate.

(a) Use the data given below to calculate a value for the enthalpy of formation of ammonia

Bond	N ≡N	H – H	N – H
Mean bond enthalpy/kJ mol^{-1}	945	436	391

(3)

(b) A manager in charge of ammonia production wished to increase the daily production of ammonia and reduce the production costs. How would a chemist explain the factors that would influence the commercial efficiency of this production process?

(8)
(Total 11 marks)

Q5. 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.

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(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*.

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(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.

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(2)

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

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(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.

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(1)
(Total 7 marks)