Topic 6 Test Kinetics Wed 4/5/17 *[28 marks]*

1. Consider the reaction between magnesium and hydrochloric acid. Which factors will affect the reaction rate? *[1 mark]*

   I.   The collision frequency of the reactant particles

   II.   The number of reactant particles with $E \geqslant E_a$

   III. The number of reactant particles that collide with the appropriate geometry

   A.   I and II only

   B.   I and III only
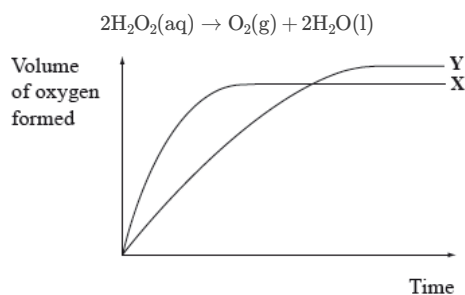
   C.   II and III only

   D.   I, II and III

Markscheme

D

Examiners report

[N/A]

2. Curve **X** on the graph below shows the volume of oxygen formed during the catalytic decomposition of a $1.0 \ \mathrm{mol \, dm^{-3}}$ solution of *[1 mark]* hydrogen peroxide.

$$2H_2O_2(aq) \rightarrow O_2(g) + 2H_2O(l)$$

Which change would produce the curve **Y**?

   A.   Adding water

   B.   Adding some 0.1 mol dm–3 hydrogen peroxide solution

   C.   Using a different catalyst

   D.   Lowering the temperature

Markscheme

B

Examiners report

Two respondents stated that this question was somewhat misleading. The question was one of the more challenging questions on the paper but 51.70% of candidates did get B. as the correct answer.

3. Sodium carbonate and hydrochloric acid react according to the equation below.   *[1 mark]*

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow CO_2(g) + 2NaCl(aq) + H_2O(l)$$

Which conditions will produce the fastest initial rate with 2.0 g of powdered sodium carbonate?

A. 100 cm^3 of 1.0 mol dm^{-3} hydrochloric acid at 323 K

B. 50 cm^3 of 2.0 mol dm^{-3} hydrochloric acid at 323 K

C. 100 cm^3 of 1.0 mol dm^{-3} hydrochloric acid at 348 K

D. 50 cm^3 of 2.0 mol dm^{-3} hydrochloric acid at 348 K

4. Which are appropriate units for the rate of a reaction?   *[1 mark]*

A. $mol\,dm^{-3}s^{-1}$

B. $mol\,dm^{-3}s$

C. $mol\,dm^{-3}$

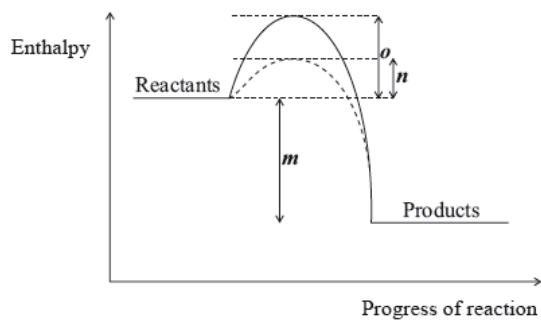D. s

5. The following enthalpy level diagram shows the effect of the addition of a catalyst on a chemical reaction. What do *m*, *n* and *o*   *[1 mark]*
represent?

	m	*n*	*o*
A.	ΔH	E_a (without a catalyst)	E_a (with a catalyst)
B.	E_a (with a catalyst)	ΔH	E_a (without a catalyst)
C.	E_a (with a catalyst)	E_a (without a catalyst)	ΔH
D.	ΔH	E_a (with a catalyst)	E_a (without a catalyst)

Markscheme

Examiners report

Chemical kinetics involves an understanding of how the molecular world changes with time.

For the reaction below, consider the following experimental data.

$$2ClO_2(aq) + 2OH^-(aq) \rightarrow ClO_3^-(aq) + ClO_2^-(aq) + H_2O(l)$$

Experiment	Initial $[ClO_2(aq)]$ / $mol\,dm^{-3}$	Initial $[OH^-(aq)]$ / $mol\,dm^{-3}$	Initial rate / $mol\,dm^{-3}\,s^{-1}$
1	1.00×10^{-1}	1.00×10^{-1}	2.30×10^{-1}
2	5.00×10^{-2}	1.00×10^{-1}	5.75×10^{-2}
3	5.00×10^{-2}	3.00×10^{-2}	1.73×10^{-2}

6a. (i) Deduce the rate expression. [5 marks]

(ii) Determine the rate constant, k, and state its units, using the data from Experiment 2.

(iii) Calculate the rate, in $mol\,dm^{-3}s^{-1}$, when $[ClO_2(aq)] = 1.50 \times 10^{-2}\,mol\,dm^{-3}$ and $[OH^-(aq)] = 2.35 \times 10^{-2}\,mol\,dm^{-3}$.

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Markscheme

(i)   second order in ClO_2 **and** first order in OH^-;

$rate = k[ClO_2]^2[OH^-]$;

Award [2] for correct final answer.

(ii) $k = 2.30 \times 10^2/230$;

$mol^{-2}dm^6s^{-1}$;
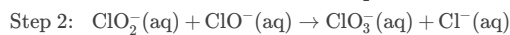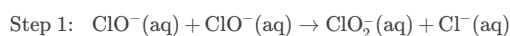
(iii) $1.22 \times 10^{-3}/0.00122 \, (mol\,dm^{-3}s^{-1})$;

Examiners report

In part (d), many candidates also scored highly though the units of k in (ii) did cause a problem for some candidates.

A two-step mechanism has been proposed for the following reaction.

$$Step\ 1: \quad ClO^-(aq) + ClO^-(aq) \rightarrow ClO_2^-(aq) + Cl^-(aq)$$
$$Step\ 2: \quad ClO_2^-(aq) + ClO^-(aq) \rightarrow ClO_3^-(aq) + Cl^-(aq)$$

6b.   Deduce the overall equation for the reaction.   *[1 mark]*

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Markscheme

$3ClO^-(aq) \rightarrow ClO_3^-(aq) + 2Cl^-(aq)$;
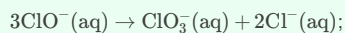
Ignore state symbols.

Examiners report

One respondent stated that part (f) (ii) would be difficult for candidates. (f) certainly did prove challenging and the rate expression for step two was often given incorrectly. This question became a good discriminating question in Section B. However the better students did manage to score all three marks in part (f).

6c. Deduce the rate expression for each step. *[2 marks]*

Step 1:

Step 2:

Markscheme

Step 1: rate $= k[\text{ClO}^-]^2$;

*Step 2*: rate $= k[\text{ClO}_2^-][\text{ClO}^-]$;

Penalize missing k once only.

Examiners report

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7. Which graph best represents the relationship between the average kinetic energy of molecules of a gas and temperature in K? *[1 mark]*
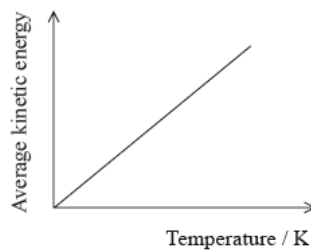
A.

B.

C.

D.
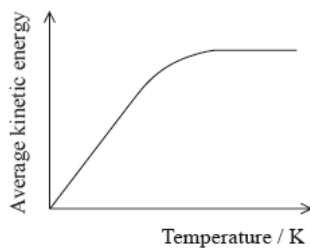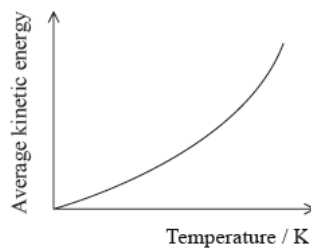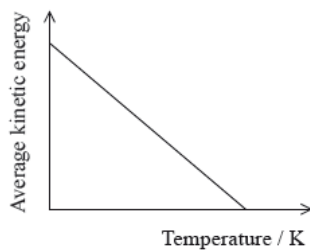
Examiners report

Some respondents mentioned in their G2 forms that the question was not appropriate as they could not find in the syllabus details where the specific relationship between temperature in K and average kinetic energy of molecules of gas is mentioned. In assessment statement 6.2.1 in the syllabus details it is clearly stated that "average kinetic energy is proportional to temperature in kelvins". 48.33% of the candidates chose the correct answer D. The discrimination index for this question was 0.42 which is reasonably good.

8a. Define the term *rate of reaction*. [1 mark]

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Markscheme

change in concentration of reactant/product with time / rate of change of concentration;

Accept "increase" instead of "change" for product and "decrease" instead of "change" for reactant.
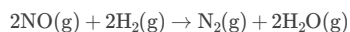
Accept "mass/amount/volume" instead of "concentration".
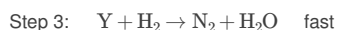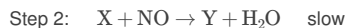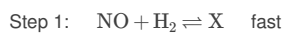
Do not accept substance.

Examiners report

Although most candidates were able to define the rate of reaction, some of weaker candidates gave imprecise answers which did not refer to concentration of the reactants or products and the "the time for the reaction to go to completion" was not an uncommon response. Most candidates realized that the surface area would decrease but, as in previous sessions, lost marks as they did not refer to the reduced "frequency" of collisions. Most candidates were able to identify the rate determining step and correctly state that the reaction would be first order with respect to hydrogen however only a minority could explain their answer in sufficient detail *i.e.* that H_2 was involved only once in the formation of the intermediate before the rate determining step.

Nitrogen(II) oxide reacts with hydrogen according to the equation below.

$$2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(g)$$

A suggested mechanism for this reaction is:

Step 1: $NO + H_2 \rightleftharpoons X$ fast

Step 2: $X + NO \rightarrow Y + H_2O$ slow

Step 3: $Y + H_2 \rightarrow N_2 + H_2O$ fast

8b. Identify the rate-determining step. [1 mark]

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9. Consider the following reaction mechanism. *[1 mark]*

$$\text{Step 1} \quad H_2O_2 + I^- \rightarrow H_2O + IO^- \qquad \text{slow}$$
$$\text{Step 2} \quad H_2O_2 + IO^- \rightarrow H_2O + O_2 + I^- \qquad \text{fast}$$
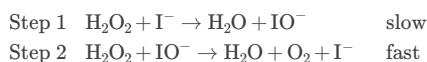
Which statement correctly identifies the rate-determining step and the explanation?

A. Step 2 because it is the faster step

B. Step 1 because it is the slower step

C. Step 1 because it is the first step

D. Step 2 because it is the last step

10. The following data were obtained for the reaction between gases A and B. *[1 mark]*

Experiment	Initial [A] / mol dm^{-3}	Initial [B] / mol dm^{-3}	Initial rate / $\text{mol dm}^{-3} \text{ min}^{-1}$
1	1.0×10^{-3}	1.0×10^{-3}	2.0×10^{-4}
2	2.0×10^{-3}	1.0×10^{-3}	2.0×10^{-4}
3	2.0×10^{-3}	2.0×10^{-3}	4.0×10^{-4}

Which relationship represents the rate expression for the reaction?

A. $\text{rate} = k[B]^2$

B. $\text{rate} = k[A]^2$

C. $\text{rate} = k[A]$

D. $\text{rate} = k[B]$

11. What happens when the temperature of a reaction increases? *[1 mark]*

   A.   The activation energy increases.

   B.   The rate constant increases.

   C.   The enthalpy change increases.

   D.   The order of the reaction increases.
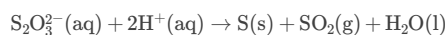
Markscheme

B

Examiners report

[N/A]

Sodium thiosulfate solution, $Na_2S_2O_3(aq)$, and hydrochloric acid, $HCl(aq)$, react to produce solid sulfur as in the equation below.

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

The following results to determine the initial rate were obtained:

Experiment	$[S_2O_3^{2-}(aq)]$ / $mol\,dm^{-3}$	$[H^+(aq)]$ / $mol\,dm^{-3}$	Initial rate / $mol\,dm^{-3}\,s^{-1}$
1	0.200	2.00	0.036
2	0.200	1.00	0.036
3	0.100	1.00	0.018

12a. Deduce, with a reason, the order of reaction with respect to each reactant. *[2 marks]*

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Markscheme

experiments 1 and 2 ($[S_2O_3^{2-}]$ remains constant) change in $[H^+]$ does not affect the rate so zero order with respect to $H^+(aq)$ / *OWTTE*;

experiment 1/2 and 3 ($[H^+]$ has no effect) $[S_2O_3^{2-}]$ is halved and rate is also halved so first order with respect to $[S_2O_3^{2-}]$ / *OWTTE*;

Accept explanation given in mathematical terms.

Award [1 max] if both [S₂O₃²⁻] is first order, and [H⁺] is zero order are stated without reason.

12b. State the rate expression for this reaction. *[1 mark]*

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Markscheme

rate $= k[\text{S}_2\text{O}_3^{2-}]$;

Examiners report

The interpretation of orders of rate from experimental data was well understood, and explained. Calculations of both the value and units of K_c were also done well. Very few candidates produced an acceptable equation for the rate determining step, many did not realise the importance of balancing both the number of atoms and charge on both sides. The required careful explanation of how E_a is determined from experimental data was lacking, too often a vague description of using gradient and R without context was considered sufficient by many candidates.

12c. Determine the value of the rate constant, k, and state its units. *[2 marks]*

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Markscheme

0.18;

s^{-1};

12d. State an equation for a possible rate-determining step for the reaction. *[1 mark]*

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Markscheme

$S_2O_3^{2-} \rightarrow S + SO_3^{2-}$;
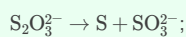
Accept any balanced equation that starts with only one $S_2O_3^{2-}$.

Equations must be balanced in terms of number of atoms and charge.

Examiners report

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12e. Suggest how the activation energy, E_a, for this reaction may be determined. *[3 marks]*

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Markscheme

determine rate at a range of temperatures (while keeping concentrations constant);

calculate k for each temperature;

plot graph of $\ln k$ against T^{-1};

gradient is $\frac{-E_a}{R}$ / *OWTTE*;

Examiners report

The interpretation of orders of rate from experimental data was well understood, and explained. Calculations of both the value and units of K_c were also done well. Very few candidates produced an acceptable equation for the rate determining step, many did not realise the importance of balancing both the number of atoms and charge on both sides. The required careful explanation of how E_a is determined from experimental data was lacking, too often a vague description of using gradient and R without context was considered sufficient by many candidates.