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Level 2 Chemistry, 2016

91166 Demonstrate understanding of chemical reactivity

9.30 a.m. Monday 21 November 2016
Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of chemical reactivity.	Demonstrate in-depth understanding of chemical reactivity.	Demonstrate comprehensive understanding of chemical reactivity.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

A periodic table is provided on the Resource Sheet L2–CHEMR.

If you need more room for any answer, use the extra space provided at the back of this booklet and clearly number the question.

Check that this booklet has pages 2–12 in the correct order and that none of these pages is blank.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Merit

TOTAL 17

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QUESTION ONE

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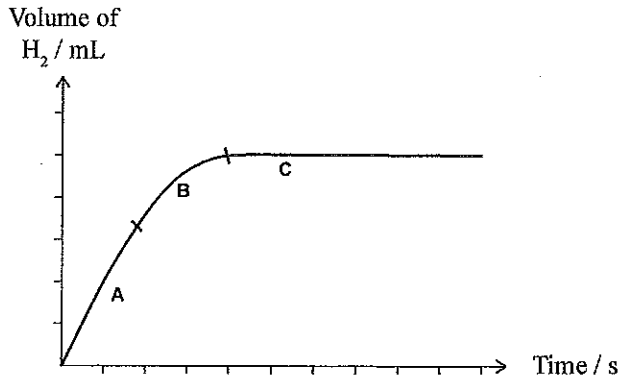
(a) Cleaned magnesium ribbon, Mg(*s*), reacts with a solution of hydrochloric acid, HCl(*aq*). The reaction is represented by the equation:

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

The reaction is monitored by measuring the volume of hydrogen gas produced over a given period of time. This is shown in the graph below.



Explain the changes in the rate of reaction between magnesium, Mg(*s*), and hydrochloric acid, HCl(*aq*), in terms of collision theory.

Refer to parts A, B, and C of the graph in your answer.

In part ~~one~~ A of the reaction, it has a high reaction rate due to the high concentration of magnesium & hydrochloric acid particles which results in an increase in the number of collisions which leads to a higher no. of successful collisions per unit/time to increase reaction rate. In part B of the reaction, the reaction rate has decreased due to the number of particles available for reactions has decreased ~~because~~ this leads to a decrease in collisions and a decrease in the ~~number of successful collisions~~ per unit/time = decrease reaction rate. In part C, the reaction has stopped occuring. This is because all the particles have been used in reactions and there are no more ~~possible~~ reactions possible which ~~there are no of~~ stops no. of collisions & keeps production of H2/mL stagnant.

(b) Compare and contrast the reactions of 0.5 g of magnesium ribbon, Mg(*s*), with ~~50.0 mL~~ of 0.100 mol L^{-1} hydrochloric acid, HCl(*aq*), and 0.5 g of magnesium powder, Mg(*s*), with 50.0 mL of 0.100 mol L^{-1} hydrochloric acid, HCl(*aq*).

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Refer to collision theory and rates of reaction in your answer.

The collision theory states that as surface area is increased, there are more available particles to react which therefore increases number of collisions per unit/time which leads to more successful collisions and an increased reaction rate.

By changing the magnesium ribbon → powder, all other variables are constant (concentration, temp) which therefore do not alter the reaction. But the powder increases the surface area of the magnesium which allows more magnesium particles to be available ~~for reaction~~ w HCl which leads to more collisions → more ~~successful collisions per unit time~~ → increase reaction rate

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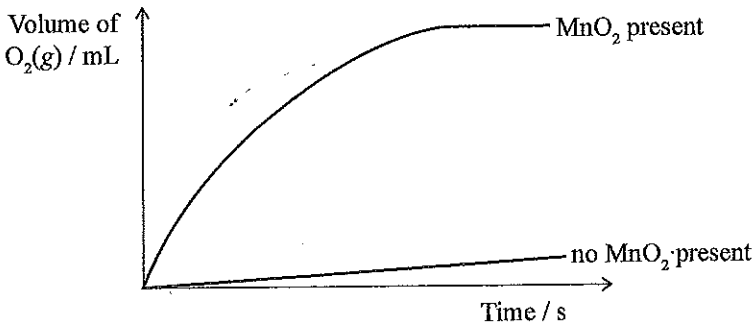
(c) The decomposition reaction of hydrogen peroxide solution, $H_2O_2(aq)$, is a slow reaction. This reaction is represented by the equation:

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

The rate of the decomposition reaction can be changed by adding a small amount of manganese dioxide, $MnO_2(s)$. The graph below shows the volume of oxygen gas formed in the reaction with and without manganese dioxide, $MnO_2(s)$.



successful collision occurs when particles collide with sufficient energy (activation) and at the correct orientation.

(i) State the role of manganese dioxide, $MnO_2(s)$, in this reaction.

as a catalyst. ✓

(ii) Elaborate on how manganese dioxide, $MnO_2(s)$, changes the rate of the decomposition reaction of the hydrogen peroxide, $H_2O_2(aq)$.

In your answer you should refer to the activation energy and collision theory.

You may also include diagrams in your answer.

A catalyst is a chemical which acts to increases the rate of reaction but is not used up in the reaction. The catalyst of $MnO_{2(s)}$ will work to provide an alternative pathway to the activation energy for particles which leads to more particles being above the activation energy leads to more collisions and ∴ more successful collisions per minute which increases rate of reaction ∴ increases volume of O_2/mL produced. ~~A catalyst also increases the kinetic energy of the particles which leads to more collisions due to more faster movements by the particles.~~ ✓

4

M5

QUESTION TWO

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(a) Water is an amphiprotic substance because it can accept or donate a proton, therefore acting as an acid or a base.

Complete the equations for the reactions of water, H_2O, with ammonia, NH_3, and the ammonium ion, NH_4^+, in the box below.

H_2O acting as	**Equation**
an acid	$H_2O(\ell) + NH_3(aq) \rightleftharpoons OH^- + NH_4^+$
a base	$H_2O(\ell) + NH_4^+(aq) \rightleftharpoons H_3O^+ + NH_3$

4

(b) Sodium carbonate, $Na_2CO_3(s)$, is a salt. When dissolved in water, it dissociates into ions.

Explain whether a solution of sodium carbonate would be acidic or basic.

In your answer you should include TWO relevant equations.

$Na_2CO_3(s) \xrightarrow{water} Na^{2+} + CO_3^{2-}$

$CO_3^- + H_2O \rightarrow C + OH^-$

(c) (i) Calculate the pH of a 0.0341 mol L^{-1} hydrochloric acid, $HCl(aq)$, solution.

$pH = -\log[H_3O^+]$

$pH = -\log[0.0341]$

$pH = 1.47$

4

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(ii) A solution of sodium hydroxide, NaOH(*aq*), has a pH of 12.4.

Calculate the concentrations of both hydronium ions, H_3O^+, and hydroxide ions, OH^-, in this solution.

$[H_3O^+] = 10^{-pH}$

$= 10^{-12.4}$

$[H_3O^+] = 3.98 \times 10^{-13}$ mol L^{-1}

$[OH^-] = 10^{-14} / [H_3O^+]$

$[OH^-] = 0.0251$ mol L^{-1}

C

(d) The table shows the pH of three acidic solutions, ammonium chloride, NH_4Cl, propanoic acid, C_2H_5COOH, and hydrogen chloride, HCl.

	$NH_4Cl(aq)$	$C_2H_5COOH(aq)$	$HCl(aq)$
Concentration/mol L^{-1}	0.1	0.1	0.1
pH	5.62	3.44	1.0

(i) Explain why each of the three solutions in the table above has the same concentration, but a different pH.

Use equations to support your answer.

Because NH_4Cl is a weaker acid than C_2H_5COOH which is a weaker acid than HCl. HCl fully dissociates to produce more $[H_3O^+]$ ions which leads to a lower pH & stronger acid than C_2H_5COOH which does not fully dissociate so produces less $[H_3O^+]$ ions & is a weaker acid, although it is a stronger acid & produces more $[H_3O^+]$ ions than NH_4Cl which is a very weak base & produces a little amount of $[H_3O^+]$ ions. NH_4Cl C_2H_5COOH HCl

$[H_3O^+] << [H_3O^+] << [H_3O^+]$

C

$HCl + H_2O \rightarrow Cl^- + H_3O^+$

$C_2H_5COOH + H_2O \rightleftharpoons C_2H_5COO^- + H_3O^+$

$NH_4Cl + H_2O \rightleftharpoons NH_3 + Cl^- + H_3O^+$

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(ii) Explain why the solution of ammonium chloride, $NH_4Cl(aq)$, is a good conductor of electricity, while the solution of propanoic acid, $C_2H_5COOH(aq)$, is a poor conductor of electricity.

Because NH_4Cl dissociates to form NH_3 and Cl^- ions which allow electrical conductivity compared to propanoic acid which dissociates to form less $C_2H_5COO^-$ ions, there are less free moving ions present in propanoic acid than ammonium so it is a poorer conductor of electricity

U

$pH = -\log[H_3O^+]$

$[H_3O^+] = 10^{-pH}$

E7

QUESTION THREE

ASSESSOR'S USE ONLY

(a) The equilibrium constant expression for a reaction is:

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

Write the equation for this reaction.

$CO + 2H_2 \rightleftharpoons CH_3OH$

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(b) The ionisation of water is represented by the equation:

$$2H_2O(\ell) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$

Give an account of the extent of ionisation of water, given $K_w = 1 \times 10^{-14}$.

Given that $K_w = 1 \times 10^{-14}$, it indicates the reactants of this reaction will be favoured over the products. Therefore the ionisation of water will have a faster reverse reaction.

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(c) When acid is added to a yellow solution of chromate ions, $CrO_4^{2-}(aq)$, the following equilibrium is established.

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(\ell)$$
yellow orange

Analyse this equilibrium using equilibrium principles to explain the effect on the colour of the solution when:

(i) more dilute acid is added:

Then the colour will turn more orange as the equilibrium tries to use up the added acid by producing more $Cr_2O_7^{2-}$ + H_2O. ✓

(ii) dilute base is added:

The colour will turn more yellow as the equilibrium tries to use up the added base by producing more H^+ & CrO_4^{2-} ions.

c

(d) When hydrogen gas, $H_2(g)$, and iodine gas, $I_2(g)$ are mixed, they react to form HI(g), and an equilibrium is established.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad K_c = 64 \text{ at } 445°C.$$

(i) Calculate the concentration of HI in an equilibrium mixture at 445°C when the concentrations of $H_2(g)$ and $I_2(g)$ are both 0.312 mol L^{-1}.

$K_c = \frac{[HI]^2}{[H_2][I_2]}$

$64 = \frac{[HI]^2}{[0.312][0.312]}$

$HI = 2.496 mol L^{-1}$

L

Question Three continues on the following page.

(ii) Explain the effect on the position of equilibrium if the overall pressure of the equilibrium system is increased.

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When the pressure of the system is increased, the equilibrium will shift to the left in order to favour the reaction which produces less moles/mL to decrease the pressure back to equilibrium.

(iii) When the temperature of the equilibrium system is increased to 510°C, the K_c value decreases to 46.

Justify, using equilibrium principles, whether the forward reaction is exothermic or endothermic.

The forward reaction is exothermic. This is shown because an exothermic reaction releases heat energy, therefore ~~by~~ ~~decre~~ in order to decrease the environmental temp back ~~eq~~ to equilibrium, the exothermic reaction is decreased ~~so~~ ~~to~~ to decrease amount of energy being released. The endothermic reaction becomes favoured as the reverse reaction because it absorbs heat from the environment so will therefore decrease the temp as the rate of endothermic reaction increases.

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M5

Extra paper if required.
Write the question number(s) if applicable.

QUESTION NUMBER

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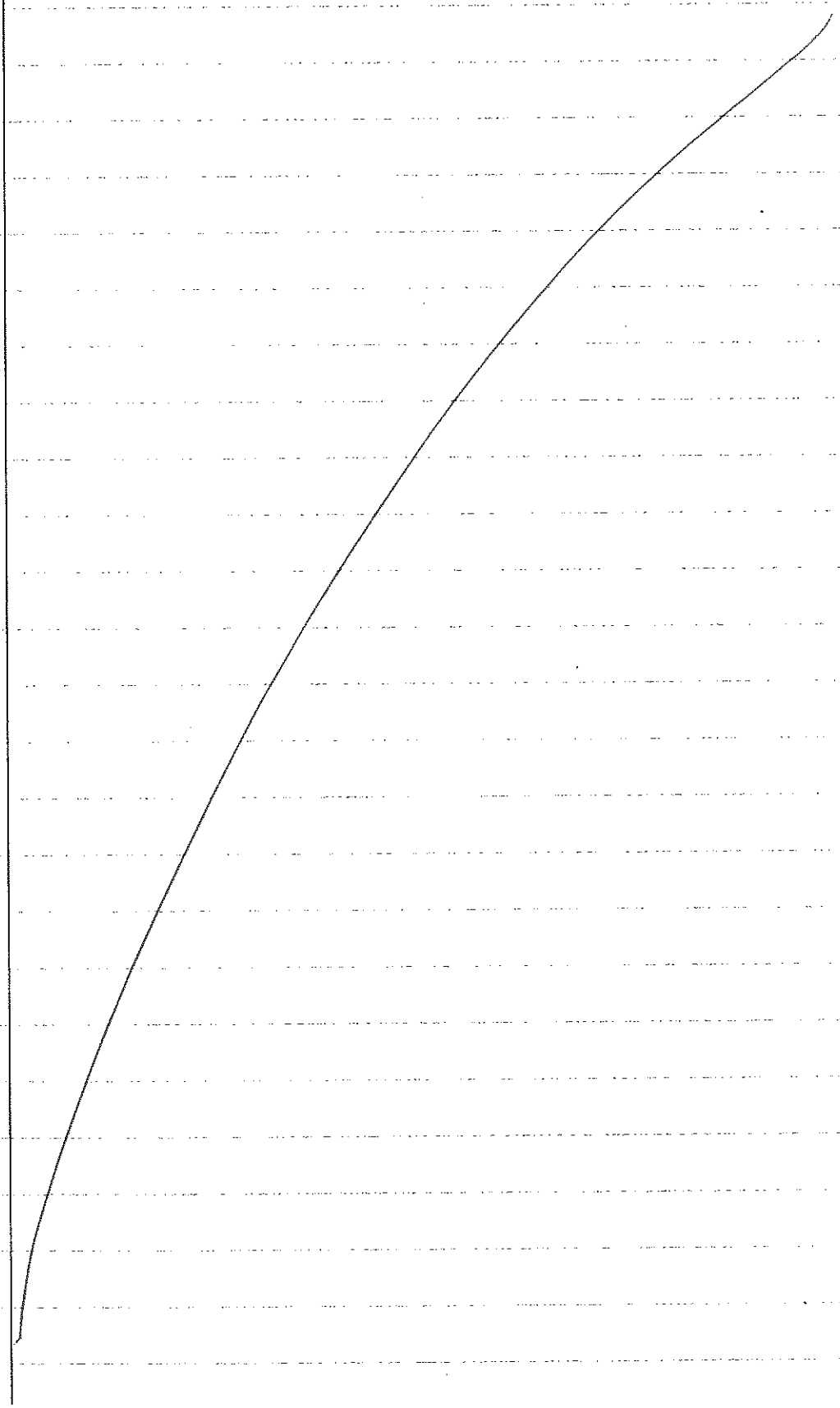

Merit exemplar 2016

Subject:	Chemistry	Standard:	91166	Total score:	17

Q	Grade score	Annotation
1	M5	The candidate has: explained the rate of reaction for two sections of the graph in terms of reactant 'concentration' and the frequency of collisions; linked the increased surface area of the Mg powder to a higher frequency of collisions (more collisions per unit time) and therefore a faster rate; and identified manganese dioxide as a catalyst that provides an alternative pathway. If the candidate had linked the alternative pathway to a lower activation energy, this would have provided evidence towards M6. Alternatively, if the candidate had explained that the same amount of product would be formed for either the Mg ribbon or the Mg powder reaction, this would have provided evidence towards E7.
2	E7	The candidate has: used appropriate formulae to calculate pH, $[H_3O^+]$, and $[OH^-]$ for strong acids and bases; linked the pH of strong and weak acids to the degree of dissociation and $[H_3O^+]$ present in the solution, with support from two correct chemical equations; and recognised that ions contribute to electrical conductivity. If the candidate had linked the relative amount of ions available to conduct electricity to the degree of dissociation, this would have provided evidence towards E8.
3	M5	The candidate has: written an equilibrium equation from a K_c expression; analysed the direction the equilibrium will shift when the concentration of a reactant is changed; calculated the correct [HI] by substituting into and rearranging a K_c expression; and recognised an increase temperature favours the endothermic reaction. If the candidate had linked the decrease in K_c to an increase in [reactant], this would have provided evidence towards M6. Alternatively, if the candidate had linked the effect of pressure on the equilibrium to the number of gaseous moles on each side, this would also have provided evidence towards M6.