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91166

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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.

Achievement

TOTAL 11

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QUESTION ONE

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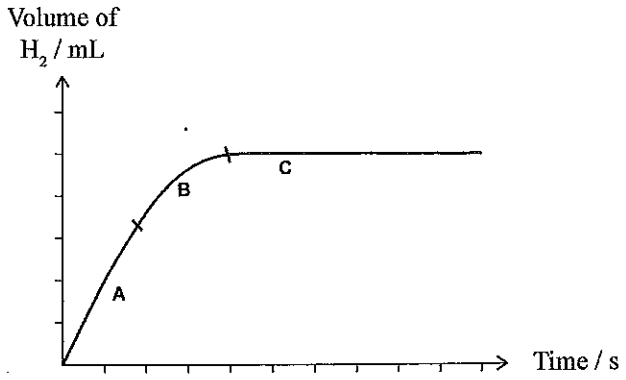
(a) Cleaned magnesium ribbon, Mg(*s*), reacts with a solution of hydrochloric acid, HCl(*aq*). The reaction is represented by the equation:

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

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 A, there are many successful collisions occuring as there are many reactants to react. This is why the graph has a steep incline. In part B, some of the reactants have been used up, meaning there are less collisions between reactants. There are however still collisions between reactants. In part C, all reactants have been used up, meaning that there are no more collisions of reactants as there are no more reatants, and only products remain.

(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*).

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

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The reaction of the magnesium powder will occur faster than the reaction of the magnesium ribbon. This is because there is more surface area, meaning there are more collisions compared with the ribbon. This means the reaction will take less time to occur.

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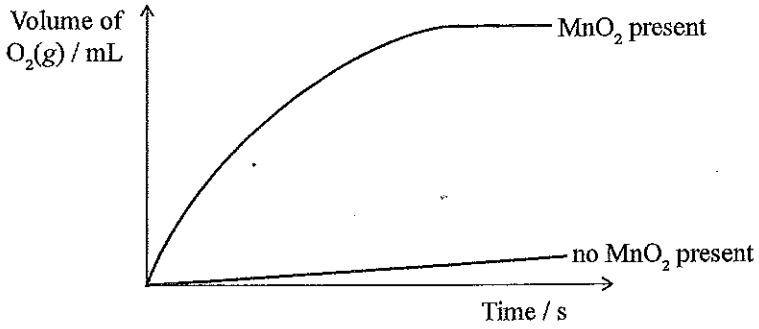
(c) The decomposition reaction of hydrogen peroxide solution, $H_2O_2(aq)$, is a slow reaction. This reaction is represented by the equation:

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

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, $MnO_2(s)$.



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

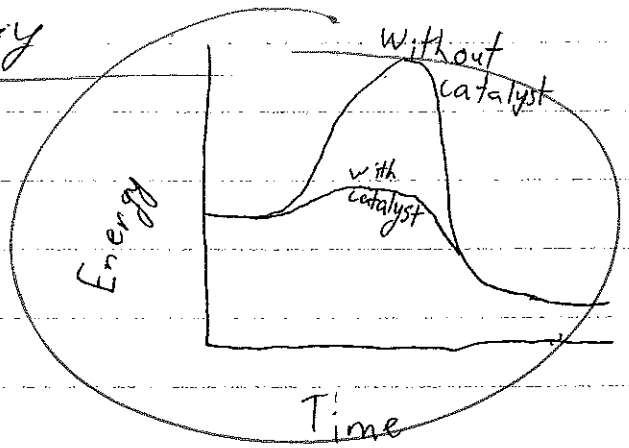
Catalyst

(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.

$MnO_2(s)$ is a catalyst. This means it decreases the amount of activation energy



This diagram shows that with a catalyst a reaction will go through faster as there is less activation energy required to start the reaction. It also means less energy is required when the particles collide to form products.

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A4

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	$H_2O(\ell) + NH_3(aq) \rightleftharpoons OH^-_{(aq)} + NH_4^+(aq)$
a base	$H_2O(\ell) + NH_4^+(aq) \rightleftharpoons H_3O^+_{(aq)} + NH_{3(aq)}$

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(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.~~

$2H_2O_{(l)} + Na_2CO_{3(s)} \rightarrow NaOH_{(aq)} + H_2CO_{3(aq)}$

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

pH = $-\log [HCl]$

$pH = -\log 0.0341$

$pH = 1.47$ (3sf)

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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.

$[H_3O^+]$ =

$[OH^-]$ =

(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.

Concentration is the amount of acid or base you have per litre while pH is the strength of the acid, or base. Because HCl is a strong acid, it fully dissociates in water. This means that it has a ~~lower~~ higher pH. $HCl_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$

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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 the C_2H_5COOH has a relatively long carbon chain, its polar end has little effect on the entire molecule as compared to NH_4Cl, which has no long carbon chain. This means that it is far better at moving charge, as it is a smaller molecule.

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QUESTION THREE

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

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

Write the equation for this reaction.

$CO_{(g)} + 2H_{2(g)} \rightleftharpoons CH_3OH_{(g)}$

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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 $K_w = 1 \times 10^{-14}$.

Water is very rarely ionised. This is because the equilibrium constant is 1×10^{-14}, meaning it is very far to the left.

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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:

As acid is added, the colour will change and become more orange. This is because the equilibrium has become unbalanced and

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(ii) dilute base is added:

(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}.

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

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

$6.2 = [HI]^2$

$\sqrt{6.2} = [HI]$

$[HI] = 2.5 \text{ mol/L}^{-1}$

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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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There is no effect. If pressure is increased, this will favour whichever side has less moles, however in this case both sides have 2 moles meaning that pressure has no effect on the position of the equilibrium.

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(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 foward reaction is exothermic. An exothermic reaction releases heat to go foward. To add heat to the chemical system you are favouring the reverse reaction, as the K_c is decreasing. This means that if K_c decreases and you are favouring the reverse reaction, the foward reaction must be exothermic.

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MS

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

QUESTION NUMBER

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Achievement exemplar 2016

Subject:	Chemistry	Standard:	91166	Total score:	11

Q	Grade score	Annotation
1	A4	The candidate has: described both the rate of reaction and the relative concentration of reactants for at least one stage of the graph; recognised that Mg powder has a greater surface area than Mg ribbon, and will therefore react at a faster rate; and identifies manganese dioxide as a catalyst that lowers the activation energy. If the candidate linked the lowered activation energy to the catalyst providing an alternative pathway, this would have provided evidence towards M5. Alternatively, if the candidate explained that the reaction rate increases with a powder due to an increased frequency of successful collisions, this would also have provided evidence towards M5.
2	N2	The candidate has: used proton transfer to complete equations to show the amphiprotic nature of water; and calculated the pH of a strong acid. If the candidate had recognised that pH is determined by the concentration of hydronium ions, this would have provided evidence towards A3. Alternatively, if the candidate had recognised that mobile charged particles are required for electrical conductivity, this would also have provided evidence towards A3.
3	M5	The candidate has: written an equilibrium equation from a K_c expression; recognised there is little dissociation in water; identified the colour change when the concentration of a reactant is changed; correctly calculated [HI] by substituting into a K_c expression; recognised that an increase in pressure will not affect the equilibrium position; and linked a decrease in K_c to the equilibrium favouring the reactants. If the candidate had linked the effect of pressure on the equilibrium to the number of gaseous moles on each side, this would have provided evidence towards M6.