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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.

Excellence

TOTAL 24

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QUESTION ONE

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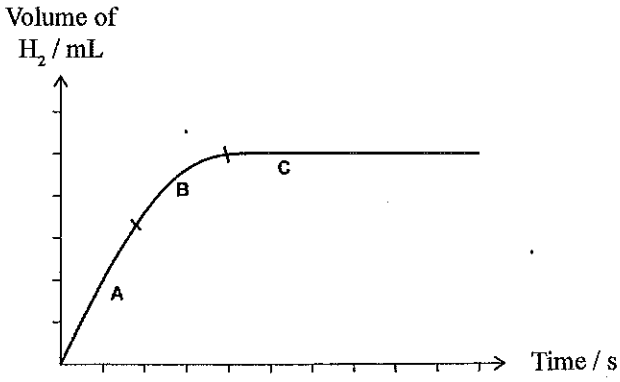
(a) Cleaned magnesium ribbon, $Mg(s)$, reacts with a solution of hydrochloric acid, $HCl(aq)$. The reaction is represented by the equation:

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

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 is a higher concentration of reactants (Mg and HCl) in the reaction than products. Therefore, there ~~is a higher fr~~ are more collisions between reactant particles per unit time in part A than either part B or C. Hence more effective collisions will occur per unit time, so the reaction is at its fastest (ie. volume of H_2 increasing at highest rate) in part A.

In part B, ~~many of much of~~ many of the reactant particles have reacted to form the products, hence there is a lower concentration of reactant particles in B than in A. Consequently, fewer collisions between reactant particles will occur ~~per unit time~~, thus less effective collisions will occur per unit time, so the reaction rate is slower.

In C, all of the reactant particles have reacted to form the products. Hence, no H_2 is produced as the reaction is complete.

(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 variable being changed is the surface area of the Mg. By using Mg powder, more Mg ~~particles~~ atoms are exposed to the HCl as there is a larger surface are. Therefore, the frequency of collisions between Mg and HCl particles will be higher when Mg powder is used, thus more effective collisions will occur per unit time. Therefore, the rate of reaction using Mg powder will be faster. As the same amount of Mg is used though, ~~too~~ and the same concentration and same volume of HCl is used in both reactions, the amount of products produced will be the same in both reactions, just the reaction with Mg ~~powder~~ powder will occur at a faster rate.

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

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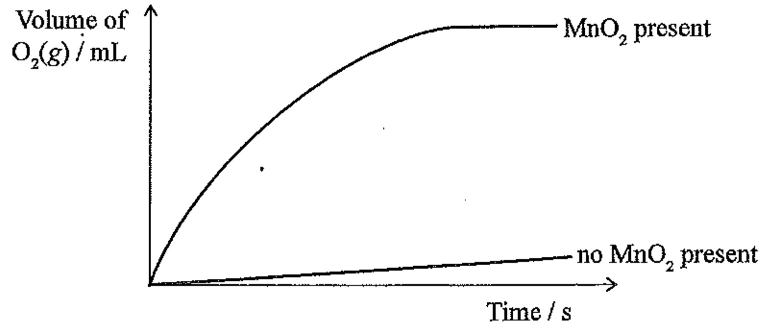
$$2H_2O_2(aq) \rightarrow 2H_2O(\ell) + O_2(g)$$

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.

It acts 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.

MnO_2 acts as a catalyst by providing an alternative pathway with less activation energy for the reaction to occur. Therefore, more particles will have an average kinetic energy higher than the activation energy required for them to react with the MnO_2. This means that more effective ~~the frequency of~~ collisions between the ~~part~~ H_2O_2 particles in the reaction will occur, hence the rate of reaction with MnO_2 will increase. Furthermore, more particles will be able to participate in the reaction as more of the necessary energy required to react, hence the total amount of O_2 will be higher with MnO_2. Without MnO_2, fewer particles can react as fewer have the required energy to do so

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	$H_2O(\ell) + NH_3(aq) \rightleftharpoons$ $NH_4^+ + OH^-$
a base	$H_2O(\ell) + NH_4^+(aq) \rightleftharpoons$ $NH_3 + H_3O^+$

(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 will fully dissocite into ions in solution:

$Na_2CO_3(aq) \rightarrow 2Na^+ + CO_3^{2-}$

The CO_3^{2-} will then act as a proton acceptor with H_2O, proving it to have basic qualities:

$CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$

As OH^- ions are produced in this reaction, $[OH^-]$ will be greater than $[H_3O^+]$, so a solution of sodium carbonate is basic as the pH will be greater than 7.

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

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

$-\log(0.0341)$

pH = 1.47

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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}

$= 10^{-12.4}$

$= 3.98 \times 10^{-13}$ mol L^{-1}

$[OH^-]$ = $\frac{1 \times 10^{-14}}{3.98 \times 10^{-13}}$ = 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.

Salt, strong acid.

	$NH_4Cl(aq)$	$C_2H_5COOH(aq)$	$HCl(aq)$
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. ~~- different~~ strengths.

Use equations to support your answer.

Whilst all ~~are~~ the solutions have the same concentration, their strengths vary. HCl is the strongest acid - it will fully dissociate into ions in solution:

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

C

Therefore, in a solution of HCl, there is a very high concentration of H_3O^+ ions. As pH is a measure of the $[H_3O^+]$, HCl will have the lowest pH.

Furthermore, propanoic acid is a weaker acid than HCl, but is stronger than NH_4Cl. Whilst it will partially dissociate into ions in solution, more ions compared to NH_4Cl will be formed:

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

As H_3O^+ ions are still produced - whilst only partially - there will be a higher $[H_3O^+]$ than $[OH^-]$, so it will be acidic. As pH is a measure of $[H_3O^+]$, propanoic acid will have a low pH (3.44)

(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.

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NH_4Cl is a salt, so fully dissociates into ions when in solution:

$NH_4Cl_{(aq)} \rightarrow NH_4^+ + Cl^-$

Therefore, a solution of NH_4Cl contains NH_4^+ and Cl^- ions. As conductivity is dependent on the presence of charged particles (in this case ions) free to move, a solution of NH_4Cl is a good conductor of electricity, due to the high concentration of NH_4^+ and Cl^- ions that are free to move in the solution.

However, propanoic acid is a weak acid, so it ~~dissolves partially~~ dissociates partially into ions when in solution:

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

Therefore, there are fewer ions in a solution of propanoic acid than in NH_4Cl. Hence, it is a poor conductor as there ~~are~~ is a low concentration of ions in a ~~[illegible]~~ solution of propanoic acid.

e

E8

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.

$CO + 2H_2 \rightleftharpoons CH_3OH$

N1

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

~~the~~ As K_w is a lot less than 1, the ionisation of water will be heavily reactant favoured. Therefore, H_2O will barely ionise at all as the equilibrium ~~heavily~~ favours the reverse direction. ~~As~~ H_2O will therefore be found naturally in liquid form, with very few H_2O particles ~~to~~ having been ionised

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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.

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

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

(i) more dilute acid is added:

When more dilute acid is added, the concentration ~~equilibrium~~ of the reactants will increase. Hence, equilibrium will favour the forward direction to remove the acid, so more $Cr_2O_7^{2-}$ and H_2O is produced, so the solution will turn more ~~orange~~ orange.

C

(ii) dilute base is added:

When dilute base is added, this will react with the dilute ~~acid to form water~~ through neutralisation. Hence, the concentration of reactants will decrease, so the equilibrium will ~~to~~ favour the reverse direction to replace the reactants. Thus, the concentration of CrO_4^{2-} will increase, so the solution will become more yellow

(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.

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ $K_c = 64$ 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}.

$$K_c = \frac{[HI]^2}{[H_2] \times [I_2]} = 64$$

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

$$8 = \frac{[HI]}{0.312}$$

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

$[HI] = 2.50$ mol L^{-1}

L¹

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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If the pressure of the system is increased, then the equilibrium ~~will favour the~~ position will remain unchanged. This is because both sides of the eqm have ~~the same~~ two moles of gas, so a change in pressure has no effect on the eqm position.

(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.

When the temperature of the equilibrium is increased, the K_c value decreases. This means that as the temperature is increased, the equilibrium becomes more reactant favoured. Furthermore, if the temperature is increased, the endothermic direction of the equilibrium is favoured. Therefore, the reverse direction is endothermic, hence the forward direction must be exothermic.

E8

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

QUESTION NUMBER

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2.d. Finally, a solution of NH_4Cl is the weakest of the three ~~acids~~ solutions. ~~It will partially dissociate into ions in solution:~~ As it is a ~~$NH_4Cl + H_2O \rightarrow$~~ salt, it will fully dissociate into ions:

$$NH_4Cl + H_2O \rightarrow NH_4^+ + Cl^-$$

However, NH_4^+ has weak acidic properties, thus it will partially dissociate in solution:

$$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$$

As H_3O^+ ions are produced, the $[H_3O^+]$ will be greater than the $[OH^-]$. However, compared to the two other acids, the $[H_3O^+]$ will be lower as fewer H_3O^+ ions are produced due to partial dissociation, thus a solution of NH_4Cl will have the highest pH of the three acids.

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

QUESTION NUMBER

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Subject:	Chemistry	Standard:	91166	Total score:	24

Q	Grade score	Annotation
1	E8	The candidate has: compared and contrasted the reaction rates of Mg ribbon versus powder, with reference to the proportion of Mg atoms exposed for collision, the frequency of collisions, and the amount of product produced for each; and elaborated on the role of manganese dioxide in providing an alternative pathway with a lower activation energy, and the effect of this on the proportion of reactant particles with sufficient energy to overcome E_a.
2	E8	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 three correct chemical equations; and explained how the degree of dissociation affects the relative amount of ions in solution and consequently the electrical conductivity of a solution.
3	E8	The candidate has used equilibrium principles to: analyse the effect of changing reactant concentration on the position of the equilibrium for both scenarios; and justify why the forward reaction of the HI equilibrium is exothermic.