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# Level 2 Chemistry, 2015

## 91166 Demonstrate understanding of chemical reactivity

9.30 a.m. Monday 23 November 2015
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.**

**Not Achieved**

TOTAL 6

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| Not Achieved exemplar for 91166 2015 | Total score 06 |
|---|---|

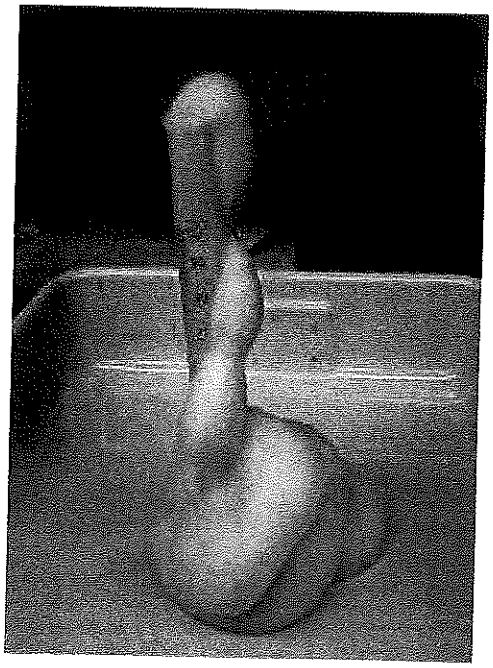
| Q | Grade score | Annotation |
|---|---|---|
| 1 | N1 | The candidate was awarded N1 as they explained that a catalyst increased the frequency of successful collisions but did not link it with lowered activation energy in part a). In part b) an increase in temperature was not linked to any meaningful achieved discussion point. In part c) the candidate failed to link concentration to increased particles per unit volume. |
| 2 | N2 | The candidate did not identify ammonia as basic in part a).The acidic $HCO_3^-$ equation was balanced correctly in part b). Part c) was awarded a merit point for two correct calculations with use of appropriate significant figures but did not provide units for concentration. Part d) incorrectly identified ethanoic acid as the better conductor. In part e) there is no discussion of strong and weak acids and appears to confuse strength with concentration. |
| 3 | A3 | The candidate did not use reversible arrows in the equation in part a). Part b)i confused directions but correctly explained the forward and reverse reactions and increased reaction speed in b)ii . Part c) has a correct equilibrium expression, calculation and discussion and was awarded an excellence point. Part d) incorrectly identified the endothermic reverse reaction as the favoured pathway. |

## QUESTION ONE

The 'elephant toothpaste' demonstration shows the decomposition of hydrogen peroxide, $H_2O_2$, into water and oxygen gas.

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

This reaction can be observed by adding detergent to the hydrogen peroxide solution. As oxygen gas is produced, the detergent foams up, as seen in the photograph on the right. The time taken for the foam to reach the top of the measuring cylinder can be used to measure the rate of the reaction.



Three experiments were carried out to investigate factors that change the rate of the reaction.

| Experiment | Concentration of $H_2O_2$ | Temperature °C | Presence of small amount of $MnO_2$ |
|---|---|---|---|
| 1 | 20% | 20 | yes |
| 2 | 20% | 30 | yes |
| 3 | 30% | 20 | yes |

(a) The decomposition reaction of hydrogen peroxide, $H_2O_2$, is very slow. By adding a small amount of powdered manganese dioxide, $MnO_2$, the rate of the reaction can be increased.

(i) Explain why only a small amount of manganese dioxide is needed to increase the rate of the reaction.

Because it has a large surface area (ie powdered) so it has a greater ~~has an exposed~~ exposure per unit volume, therefore there is greater frequency in collisim, therefore it is a succesful collisim.

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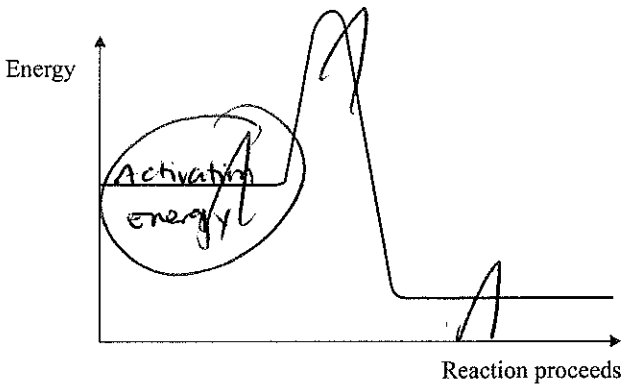
(ii) The diagram below shows the energy diagram for the decomposition reaction **without** manganese dioxide.

Label this diagram and use it to help you explain how the addition of manganese dioxide speeds up the rate of the reaction.




The addition of manganese, increases the ~~increase~~ rate of reaction as it acts as a catalyst, which means that it increases rate of kinetic energy to overcome activation energy ~~reactio~~ per second, therefore it results to succesful collisions.

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(b) Compare Experiment 2 with Experiment 1.

In your answer, you should:

- identify the factor being changed, and the effect this will have on the rate of reaction
- explain the effect on the rate of reaction by referring to the collision of particles and activation energy, where appropriate.

The factor being changed is the temperature. According to the collision theory, an increase in temperature is an increase in the frequency of collision due to the more frequency of kinetic energy / per second to overcome activation energy, and therefore there is more successful collisions. Experiment 2 has a higher temperature ie 30°C compared to Experiment

1.

**There is more space for your answer to Question One (b) on the following page.**

I with 20°C, so this would indicate that Experiment 2 will react faster. //

(c) Compare Experiment 3 with Experiment 1.

In your answer, you should:

- identify the factor being changed, and the effect this will have on the rate of reaction
- explain the effect on the rate of reaction by referring to the collision of particles and activation energy, where appropriate.

The factor being changed is the concentration of $H_2O_2$. According to the collision theory, an increase in concentration leads to more frequency of collision due to the more particles colliding per second which overcomes activation energy and leads to succesful collision. Experiment 3 has larger concentration ie 30%. compared to Experiment 1, so this means that Experiment 3 will collide faster. //

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## QUESTION TWO

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(a) Ammonia solution, $NH_3(aq)$, is a common chemical in the school laboratory.

(i) Explain, using an equation, whether ammonia solution is acidic or basic.

$NH_3$ + $H_3O^+$ → $NH_2$ + $OH^-$

It is an acid as it is a proton donor.

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(ii) Bottles of ammonia solution are often labelled ammonium hydroxide, $NH_4OH(aq)$.

Explain why both names, ammonia and ammonium hydroxide, are appropriate.

because it produces $OH^-$

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(b) The hydrogen carbonate ion, $HCO_3^-$, is an amphiprotic species because it can donate or accept a proton, therefore acting as an acid or base.

Write equations for the reactions of $HCO_3^-$ with water: one where it acts as an acid, and one where it acts as a base.

| $HCO_3^-$ acting as | Equation |
|---|---|
| an acid | $HCO_3^- + H_2O \rightleftharpoons$ $CO_3^{2-}$ + $H_3O^+$ |
| a base | $HCO_3^- + H_2O \rightleftharpoons$ $H_2CO_3$ + $OH^-$ |

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(c) (i) A solution of nitric acid, $HNO_3(aq)$, has a hydronium ion, $H_3O^+$, concentration of 0.0243 mol $L^{-1}$.

Determine, by calculation, the pH and the concentration of hydroxide ions, $OH^-$, in this solution.

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

pH = $-\log(0.0243)$

$= 1.61$ (2dp)

$[OH^-] = \frac{1 \times 10^{-14}}{0.0243} = 4.12 \times 10^{-13}$ (2 dp)

(ii) Determine the hydroxide ion concentration, $[OH^-]$, of a solution of potassium hydroxide, $KOH(aq)$, with a pH of 11.8.

$1.58 \times 10^{-12}$

(d) Ethanoic acid solution, $CH_3COOH(aq)$, and ammonium chloride solution, $NH_4Cl(aq)$, are both weakly acidic.

Identify and justify, using equations, which acid solution has greater electrical conductivity.

$CH_3COOH + H_3O^+ \rightarrow CH_3COO^- + OH^-$

$NH_4Cl + H_3O^+ \rightarrow NH_3Cl^- + H_2O$

$CH_3COOH$ has greater electrical conductivity due to the hydroxide ions it has ie they are mobile charged particles and therefore can conduct electricity because electrons are free to move around.

(e) The table shows the pH of two acidic solutions, methanoic acid, HCOOH, and hydrochloric acid, HCl, which both have a concentration of 0.1 mol $L^{-1}$.

| **Solution** | HCOOH(*aq*) | HCl(*aq*) |
|---|---|---|
| **pH** | 2.4 | 1 |

Compare and contrast the pH of each solution, and their expected rate of reaction with a 2 cm strip of cleaned magnesium ribbon, Mg.

The pH of HCl is less than the pH of HCOOH which means that it is more acidic, because the pH scale tells us that 1-6 is acidic, 7 is neutral and 8-14 is basic. Furthermore HCl having pH of 1 means that it is also more concentrated that HCOOH that has a pH of 2.4, which tells us that when these 2 are used as a catalyst, HCl solution tend to have a faster rate of reaction because increase in concentration is an increase of frequency of collision due to having lots of particles reacting per second and therefore successful collision takes place.

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## QUESTION THREE

(a) The equilibrium constant for a reaction involving compounds A, B, C, and D is shown as:

$$K_c = \frac{[C]^3[D]}{[A][B]^2}$$

Write the chemical equation for this reaction.

A + 2B → 3C + D

(b) The reaction between ethanoic acid and ethanol is reversible. Ethyl ethanoate and water are the products formed. In a closed system, a dynamic equilibrium is set up.

ethanoic acid + ethanol ⇌ ethyl ethanoate + water

$CH_3COOH(aq) + C_2H_5OH(aq) \rightleftharpoons CH_3COOC_2H_5(aq) + H_2O(\ell)$

(i) Explain, using equilibrium principles, the effect of adding more ethanol to the reaction mixture.

An increase in $C_2H_5OH$ will shift the equilibrium towards the reactants to minimise the increase of $C_2H_5OH$, therefore as a result, this would produce more product.

(ii) The reaction is quite slow, so a small amount of concentrated sulfuric acid is added as a catalyst.

Explain, using equilibrium principles, the effect of adding this catalyst to the equilibrium mixture.

using catalyst will make the forward and reverse reaction faster but equilibrium remains constant. ie it only speeds up the process of reaction but does not affect the molecules

(c) The following chemical equation represents a reaction that is part of the Contact Process which produces sulfuric acid.

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $\Delta H = -200$ kJ mol$^{-1}$, $K_c = 4.32$ at 600°C

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(i) Write an equilibrium constant expression for this reaction.

$K_c = \dfrac{[SO_3]^2}{[SO_2]^2 \times [O_2]} = \dfrac{[0.250]^2}{[0.300]^2 \times [0.100]} = 6.944$

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(ii) A reaction mixture has the following concentration of gases at 600°C:

$[SO_2(g)] = 0.300$ mol L$^{-1}$

$[O_2(g)] = 0.100$ mol L$^{-1}$

$[SO_3(g)] = 0.250$ mol L$^{-1}$

Justify why this reaction mixture is not at equilibrium.

In your answer you should use the equilibrium expression from part (c)(i) and the data provided above to show that the reaction mixture is not at equilibrium.

the data given to me states that at 600°C, it has a Kc of 4.32 but according to my calculation it is 6.94 (2dp), which shows that mixture is not they are not equal, therefore, equilibrium is.

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**Question Three continues on the following page.**

(iii) The reaction on the previous page was repeated at 450°C.

Explain, using equilibrium principles, how the change in temperature will affect:

- the value of $K_c$
- the position of equilibrium.

The increase in temperature shifts the equilibrium towards the reactants to minimise the increase in temperature, so it becomes an endothermic reaction.

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