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SUPERVISOR'S USE ONLY

91166

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NZQA

NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

QUALIFY FOR THE FUTURE WORLD
KIA NOHO TAKATŪ KI TŌ ĀMUA AO!

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.

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Low Achievement

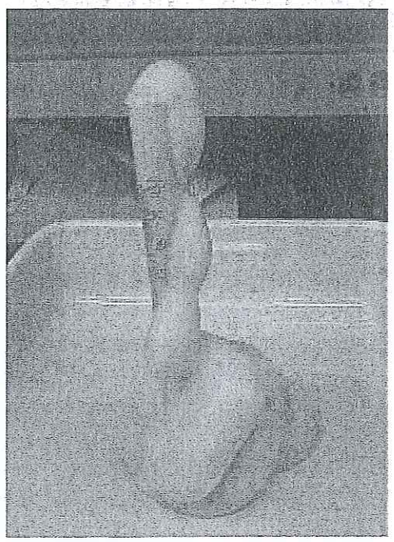
TOTAL 09

ASSESSOR'S USE ONLY

Low Achieved exemplar for 91166 2015	Total score 09

Grade score	Annotation
N2	The candidate was awarded N2 as they explained that a catalyst provides an alternative pathway but did not link it with lowered activation energy in part a). In part b an increase in temperature was linked to faster moving particles and more successful particle collisions but did not discuss this fully as activation energy. In part c) the candidate failed to link concentration to increased particles per unit volume.
A3	The candidate did not identify ammonia as basic in part a). HCO_3^--equations were balanced correctly in part b). Part c) was awarded a merit point for correct calculations with use of appropriate significant figures but did not provide units for concentration. In part d) ammonium chloride was identified as the better conductor but the reasoning was incorrect. In part e) HCl is identified as a strong acid with links to pH and hydronium ion concentration but fails to discuss dissociation.
A4	The candidate did not use reversible arrows in the equation in part a). Part b) lacked full discussions of equilibrium principles but had enough for achieved points: no direction for b)i or forward and reverse reaction discussion in b)ii . Part c) has a correct equilibrium expression and calculation but lacks discussion for the justification. Part d) is awarded an achieved point for indication that the forward exothermic reaction is favoured but needs to indicate this releases heat or that Kc increases for merit.

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

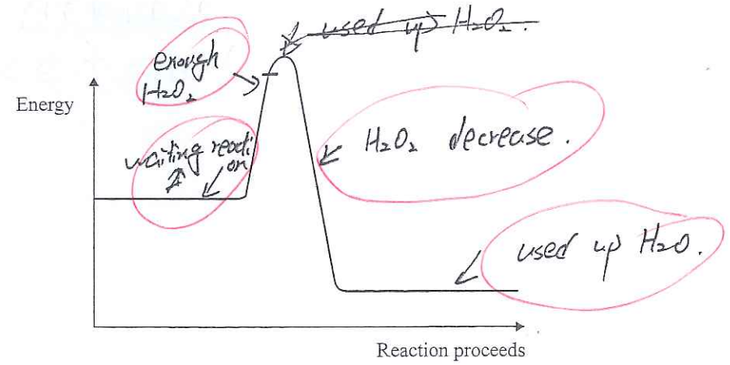
(a) The decomposition reaction of hydrogen peroxide, H_2O_2, is very slow. By adding a small amount of powdered manganese dioxide, MnO_2, the rate of the reaction can be increased.

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

Because MnO_2 is the catalyst. ~~Be~~ Adding a catalyst increase the reaction ~~,acc~~ rate. Because it produce a alternative pathway which allow more ~~collis~~ collision per unit time which result in more sucessful collision. So it is increa the rate of reaction.

(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.



without the manganese dioxide. It has not the the alternative pathway. So it has the time to wait before the reaction start. If has the MnO_2. ~~It~~ the time that waiting would be decrease. & the rate of the reaction will increase.

(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.

Compare with Experiment 2 and 1. The concentration of H_2O_2 is same. But the temperature is different. The temperature of 2 is higher than 1 which means that the rate of reaction of Experiment 2 is faster than experiment 1. Because increase the temperature, increase the reaction rate. Because it ~~it~~ has more activation energy. And moving fast.

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

which result in more successful collision occurs. which means more collision of particle ~~occurs~~ per unit time. which means reaction rate is increase. So Experiment 2 is faster than experiment 1.

(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.

Compare with Experiment 3 with Experiment 1. The temperature is the same. But the concentration of H_2O_2 is ~~be~~ different. Experiment 3 is 30% more than Experiment 2 1 & 20%. which result then reaction rate of Experiment 3 is faster than ~~re~~ experiment 2 1. Because increase the concentration of H_2O_2 increase the reaction rate. Because there will be more collision of particle occurs and react per unit time. which result in that more successful collision occurs. So the rate of reaction increase. So the Experiment 3 is faster than Experiment 1. the rate of reaction for 3 is faster than Experiment 1.

QUESTION TWO

(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.

~~$[NH_3]$ is ~~be~~ equal to $[H_3O^+]$~~

$[H_3O^+] > [OH^-]$ is an acidic.

$[OH^-] > [H_3O^+]$ is ~~an~~ a basic.

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

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

Because ammonia solution is the salt. NH_4OH is the name of the ammonia solution. And NH_4OH is the $NH_4^+ + OH^-$. If it's ~~the~~ a base react with a acid. so both name are appropriate. If it is NH_3 ~~p~~ $+ H_2O \rightarrow NH_4OH$.

(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	$HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$.

(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~~ $-\log [H_3O^+] = -\log 0.0243 = 1.614$

$[OH^-] = [H_3O^+] \times [OH^-] = 1\times10^{-14}$.

$[OH^-] = \frac{1\times10^{-14}}{[H_3O^+]} = 4.12\times10^{-13}$

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

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

$[H_3O^+] = 1.58\times10^{-12}$.

$[OH^-] = \frac{1.0\times10^{-14}}{1.0\times10^{-12}} = 0.0063$.

(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.

Because they are both weakly acidic. So the pH more closer than 7 will be the less electrical conductivity Because pH 7 is the neutral.

$CH_3COOH + H_2O \rightarrow CH_3COO^- + H_3O^+$

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

Because CH_3COOH has the pH which is more closer to pH 7. ~~so CH_3COOH~~ than NH_4Cl. So NH_4Cl has the greater conductivity.

(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.

Because the Hcl pH 1 is ~~a~~less than HCOOH pH 2.4. So that means Hcl is more acidic than HCOOH. which mean Hcl is stronger than HCOOH.

when the pH is lower than $[H_3O^+]$ will be more. when the concentration of H_3O^+ increase. The reaction rate will increase. Because more collision particle per unit time. And result in more successful collision occurs. So the Hcl reaction rate will faster than HCOOH's reaction rate.

QUESTION THREE

ASSESSOR USE ONLY

(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+B~~ 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.

when the more ethanol is add. the change will minised to decrease the ~~concentration of~~ ethanol so the product will be increase.

(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.

~~To~~ when ~~of~~ a catalyst is adding. there will be no change for the equilibrium. mixture. Because catalyst only helps the increase the rate of reaction. No use for the chemical mixture.

ASSESSOR'S USE ONLY

(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

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

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

(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.

$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = \frac{0.25^2}{0.3^2 \times 0.1} = \frac{0.0625}{0.009} = 6.9$.

$6.9 \neq 4.32$

$6.9 > 4.32$.

Question Three continues on the following page.

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

ASSESSOR USE ONLY

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

- the value of K_c
- the position of equilibrium.

when the temperature the value of ~~Kc~~ Kc will be decrease. And when the temperature decrease. It favours the exothermic. Because the ~~ΔrH=~~ ΔH = -200 KJmol^{-1}. that means the foward reaction is the exothermic reaction. So the foward reaction is favoured.

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High Achievement

TOTAL 12

ASSESSOR'S USE ONLY

High Achieved exemplar for 91166 2015	Total score 12

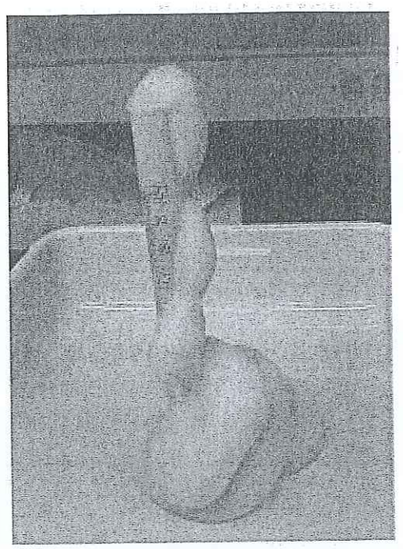
Q	Grade score	Annotation
1	A3	The candidate was awarded A3 as they explained that a catalyst provides an alternative pathway with lowered activation energy correctly but failed to link this to an increased reaction rate in part a). In part b an increase in temperature and E_K was linked to frequent and successful particle collisions but did not discuss this fully as activation energy. In part c) the candidate failed to link concentration to increased particles per unit volume but did achieve in this question by stating the "same amount of space".
2	M5	The candidate correctly identified ammonia as basic with reversible arrows in the equation in part a) but did not recognise the equilibrium mixture with ammonium hydroxide. HCO_3^- equations had incorrect formulae in part b). Part c) was awarded excellence for correct calculations with use of appropriate significant figures and units. In part d) ammonium chloride was identified as the better conductor but the reasoning was incorrect. In part e) HCl is identified as a strong acid with links to pH and hydronium ion concentration but fails to relate this to particle collisions. Methanoic acid is incorrectluy defined as a strong acid.
3	A4	The candidate did use reversible arrows in the equation in part a). Part b) lacked full discussions of equilibrium principles but had enough for achieved points: no reduction of ethanol in b)i or forward and reverse reaction discussion in b)ii . Part c) has a correct equilibrium expression but lacks any calculation. Part d) lacks any meaningful clear direction and confuses directions so no achieved points.

QUESTION ONE

ASSESSOR'S USE ONLY

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.

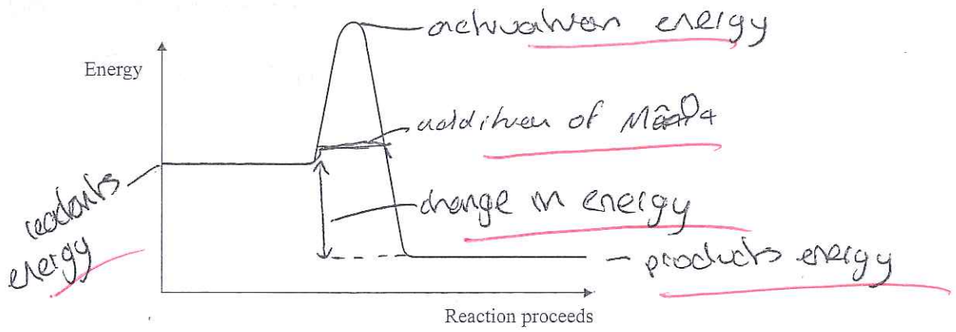
(i) Explain why only a small amount of manganese dioxide is needed to increase the rate of the reaction.

Manganese dioxide acts as a catalyst and lowers the amount of activation energy required for a collision reaction to occur, it does this by creating an alternate pathway for the molecules. //

ASSESSOR'S USE ONLY

(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.



When MnO_4 is added as shown in the diagram an alternate pathway is formed for the molecules which lowers the amount of activation energy required for a reaction. // 4

(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.

Experiment 1 and 2 use the same concentration of H_2O_2 and both use a small amount of MnO_4 though in experiment 2 the reaction would occur faster because it is carried out at a higher temperature. The higher temperature increased the kinetic energy of the molecules. // 5

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

and allows collisions to happen more frequently and with sufficient amount of energy for a reaction to occur.

ASSESSOR'S USE ONLY

4

(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 that is changed is ~~that~~ in experiment 3 the concentration of H_2O_2 is 10% higher than that of experiment 2. The increased concentration increases the amount of H_2O_2 molecules in the same amount of space which makes collisions more frequent. The more collisions will result in more reactions occuring which speeds up ~~increases~~ the reaction time of the solution so experiment 3 will react faster than experiment 1.

4

A3

QUESTION TWO

ASSESSOR'S USE ONLY

(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 is ~~acidic~~ basic because it is able to ~~donate~~ accept a H^+ to is reactant to become it's conjugate ~~base~~ acid as in the reaction below with H_2O

$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

i

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

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

because in the reaction of NH_3 with H_2O, OH^- ions are formed which make the solution basic with the same Ph of NH_3 before the reaction so it can be either amonia ~~as~~ or ammonium hydroxide.

1

(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	$HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$

X1

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

ASSESSOR'S USE ONLY

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

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

pH = $-\log[0.0243] = 1.61$

$[OH^-] = \frac{1 \times 10^{-14}}{[0.0243]} = 4.12 \times 10^{-13}$ mol L^{-1}

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

$H_3O^+ = 10^{-11.8} = 1.58 \times 10^{-12}$ mol L^{-1}

$[OH] = \frac{1 \times 10^{-14}}{1.58 \times 10^{-12}} = 6.333 \times 10^{-3}$ mol L^{-1}

$[OH]^- = 6.33 \times 10^{-3}$ mol L^{-1}

C.

(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.

$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$

$NH_4Cl + H_2O \rightleftharpoons NH_3Cl^+ + H_3O^+$

ethanoic acid solution is weakly acidic because it does not fully dissociate so it does not create as many ions so cannot carry an electrical current very well. NH_4Cl when reacted with water also does not fully dissociate so does not carry a current well though when it becomes NH_3Cl it can still act as an acid and donate a proton H^+ and create more ions so will carry an electrical current better than ethanoic acid.

U.

(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}.

ASSESSOR'S USE ONLY

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.

HCl has a lower pH than HCOOH so is therefore a stronger acid which will dissociate more and create more H_3O^+ ions.
Because HCl is a stronger acid when reacted with the strip of magnesium it will fully dissociate and faster to become its conjugate base in a reaction.
HCOOH is also a strong acid though will still have some molecules that do not dissociate and therefore does not react with magnesium as fast as the HCl will.

U.

M5

QUESTION THREE

ASSESSOR'S USE ONLY

(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.

$A + 2B \rightleftharpoons 3C + D$

4

(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 $\rightleftharpoons$ 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.

When more ethanol is added, the system will react by making more of the ethyl ethanoate and H_2O to restore equilibrium. It will do this by shifting to the right and favouring the forwards reaction to create more ethyl ethanoate and water which will restore the equilibrium.

4

(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.

Adding a catalyst will not change the equilibrium at all as it will only speed up the rate of reaction still producing equal amounts of each substance only faster.

4

ASSESSOR'S USE ONLY

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

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

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

$K_c = \dfrac{[SO_3]^2}{[SO_2]^2[O_2]}$

4

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

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

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

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

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.

This mixture is not at equilibrium because the concentrations of SO_2 + O_2 should equal the concentration of SO_3. This means that the system has been changed by increasing the amount of SO_2 or O_2 or decreasing the pressure so that the equilibrium shifts to the left to favour the reverse reaction and creating more of the SO_2 and O_2 gasses.

7

Question Three continues on the following page.

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

ASSESSOR USE ONLY

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

- the value of K_c
- the position of equilibrium.

The value of Kc would then reduce because the ~~reaction~~ Kc at 600° is 4.32 which means the forward reaction has been favoured in a endothermic reaction to create more SO_3. this means that the equilibrium has shifted to the left to create more of the SO_2 and O_2 in the exothermic reaction to reduce the temperature by absorbing heat.

A4