2

SUPERVISOR'S USE ONLY

91166

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NZQA

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

Level 2 Chemistry, 2017

91166 Demonstrate understanding of chemical reactivity

2.00 p.m. Thursday 16 November 2017
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 12

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QUESTION ONE

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(a) Propanoic acid, C_2H_5COOH, is dissolved in water and the resulting solution has a pH of 4.2.

(i) Complete the equation by writing the formulae of the two products.

A B B A

$$C_2H_5COOH(aq) + H_2O(\ell) \rightleftharpoons C_2H_5COO^- + H_3O^+$$

(ii) Explain the proton, H^+, transfer in this reaction, and identify the two conjugate acid-base pairs.

The H^+ in C_2H_5COOH is donated to H_2O to form H_3O^+. The H^+ in H_3O^+ is donated to $C_2H_5COO^-$ to make C_2H_5COOH. One conjugate acid-base pair is C_2H_5COOH (acid) and H_2O (base). Another one is $C_2H_5COO^-$ (base) and H_3O^+ (acid).

(b) Sodium ethanoate, $CH_3COONa(s)$, is a salt. When dissolved in water, it dissociates into ions.

Explain, including TWO relevant equations, whether a solution of sodium ethanoate is acidic or basic.

$CH_3COONa(s) \rightleftharpoons CH_3COO^- + Na^+$

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

A solution of sodium ethanoate is basic as a very small amount of OH^- ions are present in the solution.

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(c) (i) A solution of sodium hydroxide, NaOH(*aq*), has a pH of 11.6.

Calculate the hydronium ion concentration $[H_3O^+]$, and the hydroxide ion concentration, $[OH^-]$, in the solution.

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

$[H_3O^+] = 10^{-pH} = 10^{-11.6} = 2.51 \times 10^{-12}$ mol L^{-1}

$[OH^-] = \frac{1 \times 10^{-14}}{2.51 \times 10^{-12}} = 3.98 \times 10^{-3}$ mol L^{-1}

(ii) Calculate the pH of a 2.96×10^{-4} mol L^{-1} solution of potassium hydroxide, KOH(*aq*).

pH = $[H_3O^+] = \frac{1 \times 10^{-14}}{2.96 \times 10^{-4}}$ $[H_3O^+] = 3.38 \times 10^{-11}$ mol L^{-1}

$pH = -\log 3.38 \times 10^{-11}$

pH = 10.5

(d) Solutions of ammonia, $NH_3(aq)$, and sodium carbonate, $Na_2CO_3(aq)$, are both basic.

Compare and contrast the electrical conductivity of these two solutions.

$NH_3(aq)$ is a strong base. This means that it will completely dissociate into its ions. When dissociated the ions will be free to move and are able to conduct electricity (be conducted) due to having a charge. $Na_2CO_3(aq)$ is a weak base and only partially dissociates into it's ions. This means that it will be a poor conductor as although the ions are free to move, it is only some which can do so.

M5

QUESTION TWO

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The addition of a small amount of iron to a mixture of nitrogen and hydrogen gases helps to speed up the production of ammonia gas.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

(a) Identify and explain the role of iron in this reaction.

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

You may include a diagram or diagrams in your answer.

The iron in this reaction acts as a catalyst. It helps to speed up the production of ammonia gas. A catalyst speeds up the reaction as it lowers the activation energy. This means that the amount of energy needed in the reaction is lowered. This results in more successful collisions per unit time as the particles react more quickly. This means that the rate of reaction will decrease due to the more sucessful collisions occuring. So, the production of ammonia gas will not take along time to occur.

The reaction described above is an equilibrium reaction, as represented by the following equation:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

(b) (i) Write the equilibrium constant expression for this reaction.

$K_c =$ $\dfrac{[NH_3(g)]^2}{[N_2(g)][H_2(g)]^3}$

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(ii) The value of the equilibrium constant, K_c, is 640 at 25°C.

Show, by calculation, using the concentrations of the gases given in the table below, whether or not the reaction is at equilibrium.

Explain your answer.

Gas	N_2	H_2	NH_3
Concentration (mol L^{-1})	0.0821	0.0583	0.105

Is the mixture at equilibrium?

(Circle) **Yes** **No**

Calculation and explanation:

$K_c = \frac{0.105^2}{0.0821 \times 0.0583^2}$

$K_c = 39.5$

No, this mixture is not at equilibrium as the K_c value calculated does not match the K_c stated above.

temp ↑ T = Kc ↓

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(c) As the temperature increases, the value of the equilibrium constant, K_c, decreases from 640 at 25°C to 0.440 at 200°C.

Justify whether the formation of ammonia, $NH_3(g)$, is an endothermic or exothermic reaction.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

As the temperature increases, the Kc decreases. An increase in temperature will favour the forwards reaction as a product is being formed. In order for the forward reaction to be favoured, there must be heat being absorbed. This must mean that the forwards reaction is endothermic, making the formation of $NH_3(g)$ endothermic too.

A3

QUESTION THREE

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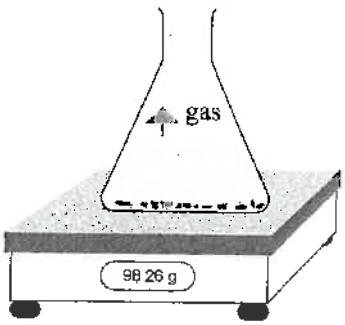
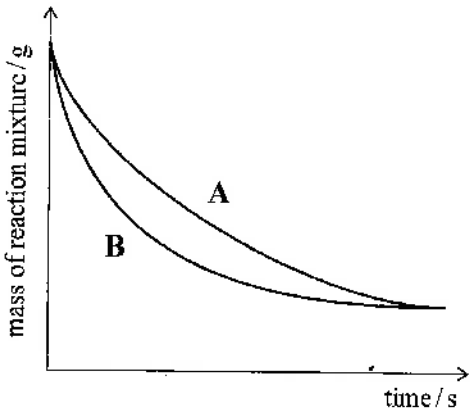
(a) Consider the reaction between calcium carbonate powder, $CaCO_3(s)$, and a solution of hydrochloric acid, $HCl(aq)$.

As the reaction proceeds, the mass of the reaction mixture decreases as carbon dioxide gas, $CO_2(g)$, escapes.

This is represented on the graph below.

Line A represents the reaction occurring at 20°C and line B represents the reaction occurring at 40°C.





Compare and contrast the reaction between calcium carbonate powder, $CaCO_3(s)$, and a solution of hydrochloric acid, $HCl(aq)$ at two temperatures: 20°C and 40°C, assuming all other conditions are kept the same.

Your answer should refer to collision theory and rates of reaction.

The reaction taking place at 40°C will occur quicker than the reaction at 20°C. This is because an increase in temperature will speed up the rate of reaction. This will not lower the activation energy but it will require less energy for the reaction to take place due to the temperature increase. The particles will collide more frequently which means more successful collisions occuring between HCl(aq) & $CaCO_3(s)$. There will be more reactions occuring per unit time as //

There is more space for your answer to this question on the following page.

the higher temp will make the particles move faster.

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(b) Two different cobalt(II) complex ions, $[Co(H_2O)_6]^{2+}$ and $[CoCl_4]^{2-}$, exist together in a solution in equilibrium with chloride ions, $Cl^-(aq)$.

The forward reaction is endothermic; ΔH is positive. The equation for this equilibrium is shown below.

$$[Co(H_2O)_6]^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons [CoCl_4]^{2-}(aq) + 6H_2O(\ell)$$

pink blue

Explain using equilibrium principles, the effect on the colour of the solution if:

(i) more water is added to the reaction mixture

The colour of the solution will be pink as it will want to use up the water which will favour the reverse reaction.

(ii) a test tube containing the reaction mixture is placed in a beaker of ice-cold water.

The colour of the solution will turn pink as the reverse reaction must be exothermic if the forwards is endothermic.

(c) Brown nitrogen dioxide gas, $NO_2(g)$, exists in equilibrium with the colourless gas, dinitrogen tetroxide, $N_2O_4(g)$.

$$2NO_2(g) \rightleftharpoons N_2O_4(g)$$
brown colourless

Explain using equilibrium principles, the effect of decreasing the volume of the container (therefore increasing the pressure) on the observations of this equilibrium mixture.

Increasing the pressure will favour the side with the least number of gaseous mols which is the forwards reaction so, the forwards reaction will be ~~favoured~~ and the mixture will turn colourless.

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A4

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

QUESTION NUMBER

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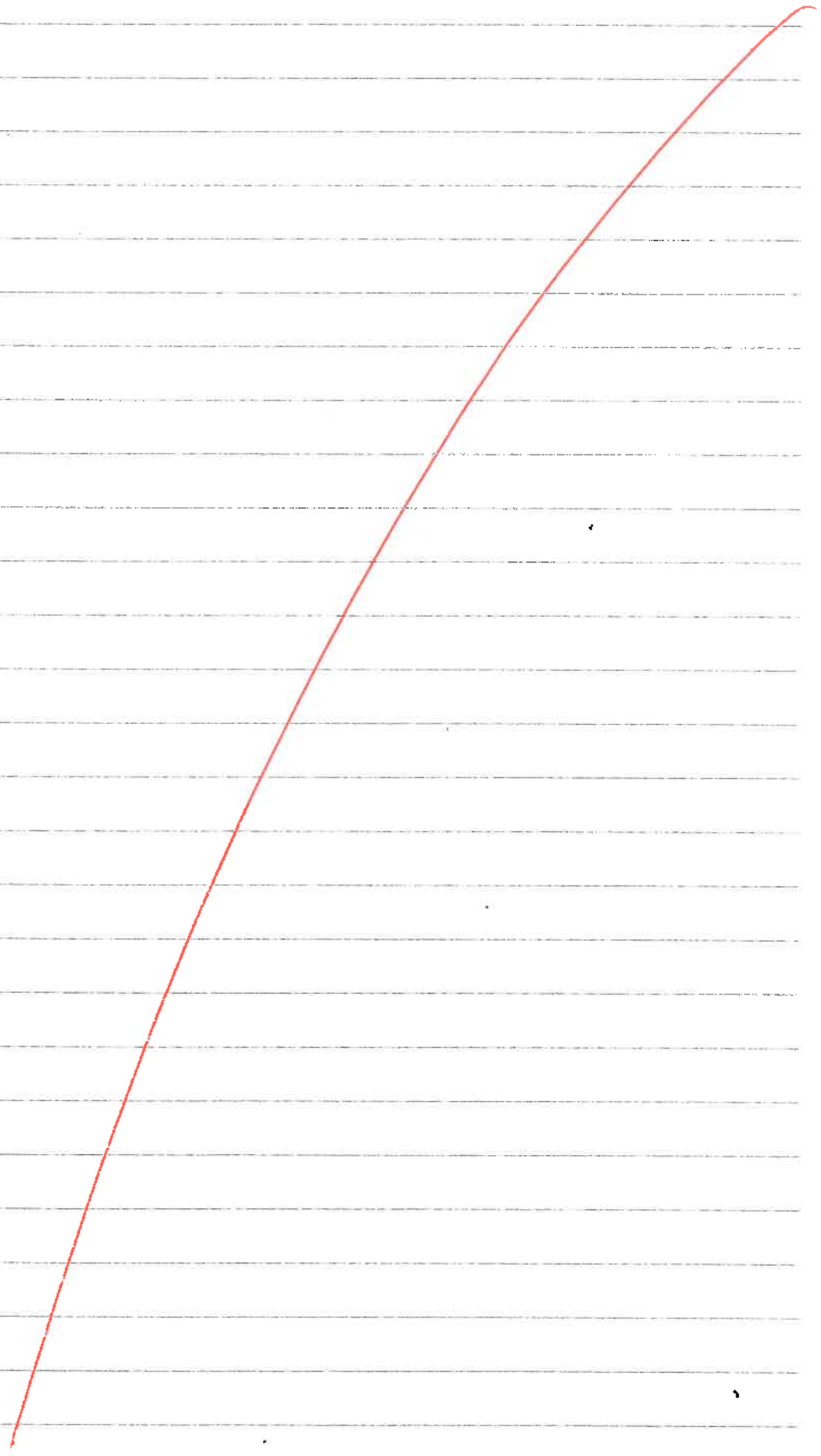

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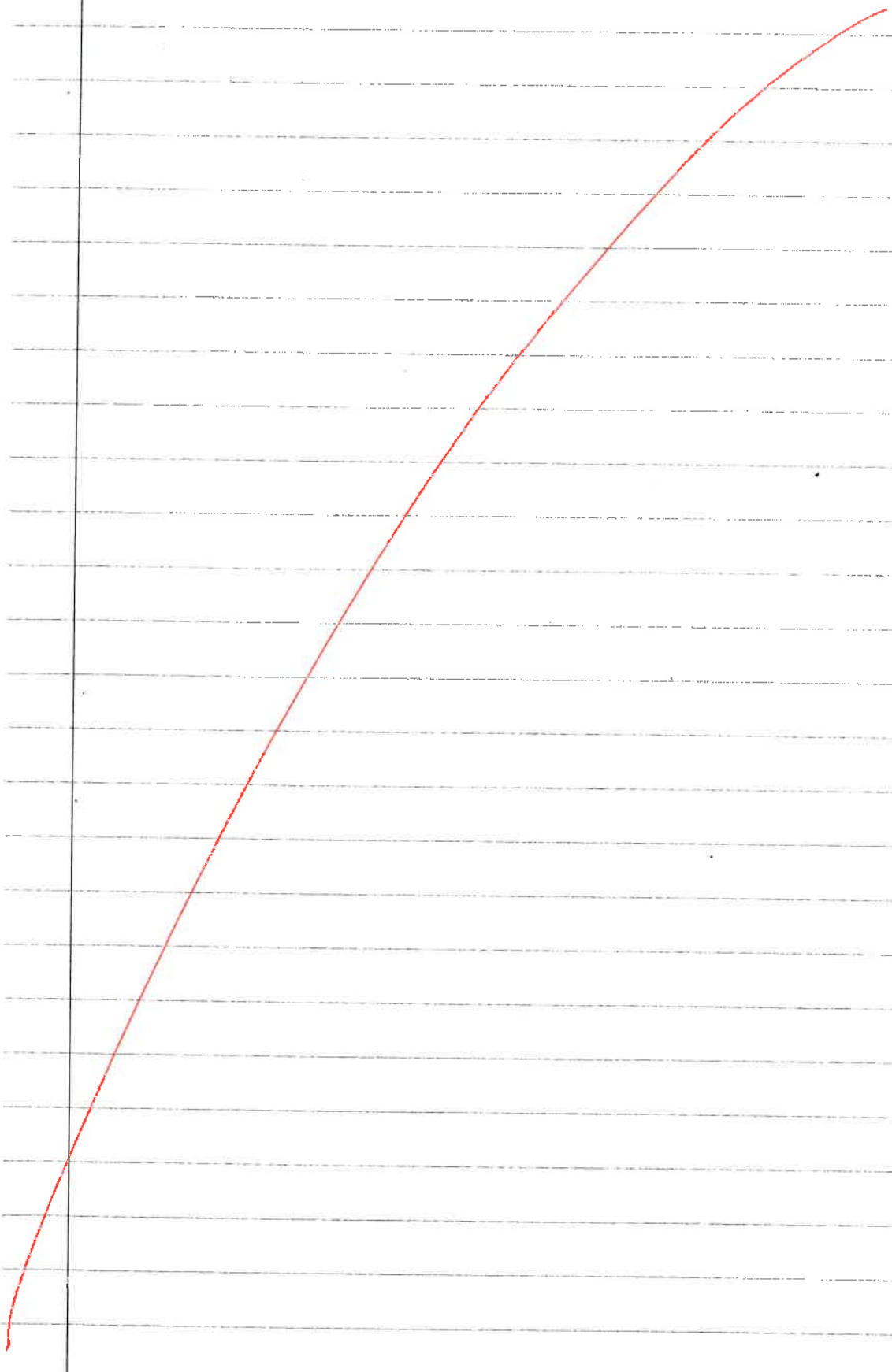

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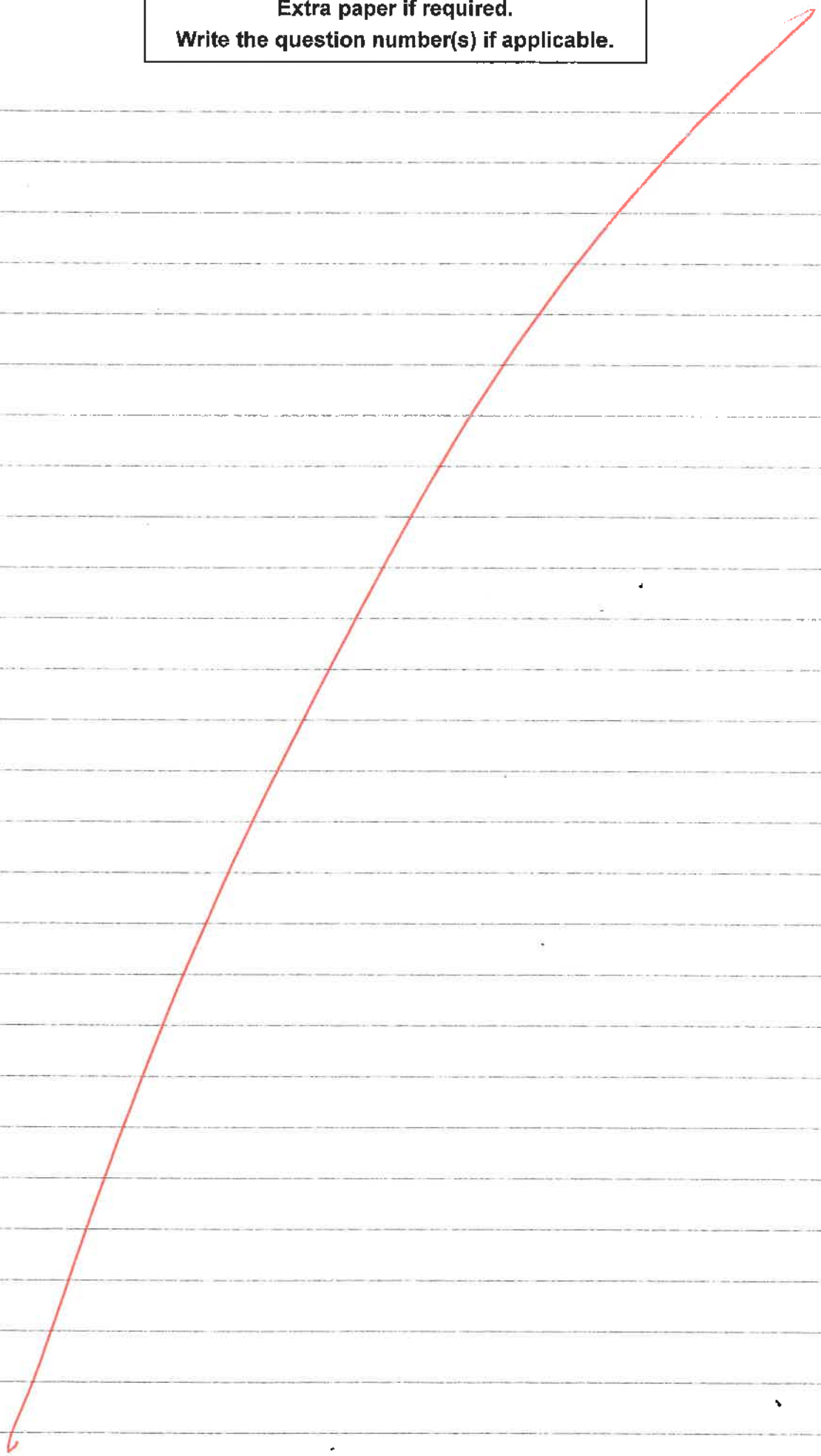

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Achieved exemplar for 91166 2017		Total score	12
Q	**Grade score**	**Annotation**	
1	M5	The candidate has: completed the equation for propanoic acid reacting with water; identified propanoic acid as an acid and water as a base; explained why sodium ethanoate is basic with the relevant equation; calculated $[H_3O^+]$, $[OH^-]$, and the pH of a strong base; and identified that ions are required for the electrical conductivity of solutions. If the candidate had paired the conjugate acid-base pairs correctly, this would have provided evidence towards M6. Alternatively, if the candidate had correctly recognised the extent of dissociation of either the weak base or the basic salt, and linked this to relative concentration of ions, this would also have provided evidence towards M6.	
2	A3	The candidate has: recognised iron is a catalyst and lowers the activation energy; and explained, using an incorrectly calculated K_c value, why the reaction is not at equilibrium. If the candidate had written the correct equilibrium constant expression, this would have provided evidence towards A4. Alternatively, if the candidate had explained that an increase in temperature causes an equilibrium to shift in the endothermic direction, this would also have provided evidence towards A4.	
3	A4	The candidate has: explained that particles will collide more frequently at a higher temperature; explained the effect of changing the concentration of a product on the position of an equilibrium; provided some correct colour changes; and recognised an increase in pressure will favour the side with the least number of gaseous moles. If the candidate had linked the correct colour change to the explanation regarding the increase in pressure, this would have provided evidence towards M5. Alternatively, if the candidate had linked the increase in the frequency of collisions to the increase in the kinetic energy of the particles, this would also have provided evidence towards M5.	