2

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91166

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QUALIFY FOR THE FUTURE WORLD
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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.

Merit

TOTAL 17

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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.

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

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

The proton, H^+, transfer is where the H moves, or transfers from the acid to the base (as an acid is a proton donor and a base is a proton acceptor). The acid in the above reaction is ~~C_2H_5COOH~~ ~~C_2H_5~~ C_2H_5COOH and the conjugate base is $C_2H_5COO^-$. The base in the above reaction is H_2O and the conjugate acid is H_3O^+.

(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.

$CH_3COONa \rightarrow CH_3COO^- + Na^+$

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

Sodium ethanoate is a basic solution. This is because when it reacts with water, after it has dissociated into its ions, it accepts a proton and OH^- (hydroxide ions) are produced, showing us it is basic.

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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.

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

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

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

$[OH^-]$ = $[OH^-] = \frac{(1 \times 10^{-14})}{(2.51 \times 10^{-12})}$ $\left(\frac{Kw}{[H_3O^+]}\right)$

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

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

pH = $[OH^-] = 2.96 \times 10^{-4}$ mol L^{-1}

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

$pH = -\log[H_3O^+] = 10.5$

(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.

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

$Na_2CO_3 + H_2O \rightarrow$ ~~Na_2CO_3~~ $Na_2HCO_3^+ + OH^-$

Electrical conductivity is dependant to how much of the solution breaks up into its ions. Ammonia only partially breaks up into its ions as it is a weak base. therefore it is a poor electrical conductor. On the other hand, sodium carbonate completely breaks up into its ions as it is a strong base, therefore it is a good electrical conductor.

M6

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.

In this reaction, iron is acting as a catalyst. A catalyst is something that speeds up a reaction by providing an alternative pathway with a lower activation energy, without being used up itself. When a reaction has a lower activation energy, more particles have sufficient energy to ~~overcome~~ the minimum energy can also overcome the activation energy barrier.* ^ Particles ^ collide more effectively, increases ^ therefore the number of successful collisions per second ^ therefore increasing the rate of reaction.

* which is the minimum amount of energy required for the reaction to take place.

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.

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

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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: $Q = \frac{(0.105^2)}{(0.0821 \times (0.0583)^3)} = 678$

Because Q (the quotient, used when the mixture is not at equilibrium) is not the same as K_c. The direction of the reaction must have been forwards, as for Q to be larger than K_c, there must be a greater amount of products than reactants. To attain ~~equilibrium~~ equilibrium, the reaction should favour the reverse direction, to decrease Q until it reaches K_c.

(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.

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

The formation of ammonia is an endothermic reaction. This is because to get a smaller K_c value, the reactants must be greater than the products (as the reactants are the denominator in the equation). Because K_c decreased as the temperature increased, we can clearly see the exothermic direction (producing heat), does not favour the ~~product~~ formation of ammonia. Therefore, the formation of ammonia is an endothermic reaction.

M6

QUESTION THREE

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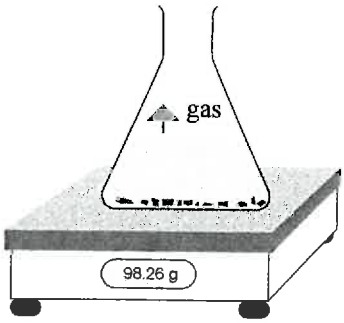
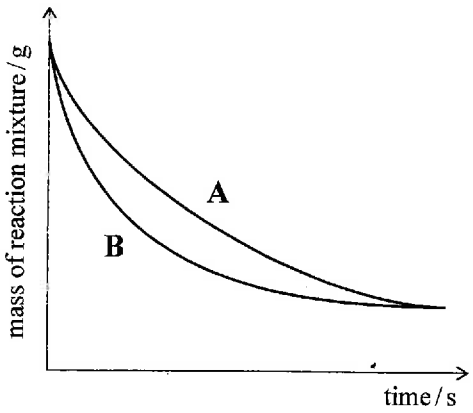
(a) Consider the reaction between calcium carbonate powder, $CaCO_3(s)$, and a solution of hydrochloric acid, $HCl(aq)$.

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.

Increasing ~~te~~ the temperature increases the amount of kinetic energy, ~~then~~ When particles have a greater amount of kinetic energy, they are more likely to collide with sufficient force to overcome the activation energy barrier. Furthermore, because the particles are moving faster, the frequency of collisions increases. This increases the number of successful collisions per second therefore, increasing the rate of reaction. For this reason, the reaction represented by line B at 40°C will take less time than the reaction represented by line A at 20°C. However, assuming the same amounts of calcium carbonate powder and hydrochloric acid were the same, and

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

the rest of the conditions were kept the same, the same amount of carbon dioxide gas will be released by both reactions (the products will be the same, it will just take longer for them to be produced in the reaction at 20°C)

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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 equilibrium system acts to oppose the change, therefore the reverse reaction will be favoured to decrease the amount of water. This will increase the amount of pink ~~to~~ $[Co(H_2O)_6]^{2+}$, therefore the solution will turn pink.

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

The exothermic direction will be favoured to oppose the change. As the forwards reaction is endothermic, the reverse reaction must be exothermic, therefore the reverse reaction will be favoured. This will increase the amount of pink (please see extra paper)

(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.

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Increasing the pressure causes the system to shift and favour the direction with the least number of gaseous moles. In this reaction, there are 2 gaseous reactant moles and ~~one~~ 1 gaseous product mole. This means the forward reaction will be favoured. This will increase the amount of colourless ~~N_2O_4~~ N_2O_4. Therefore the solution will go colourless.

MS

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

QUESTION NUMBER

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36n ~~EE~~ $[Co(H_2O)_6]^{2+}$, therefore the solution will turn pink.

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

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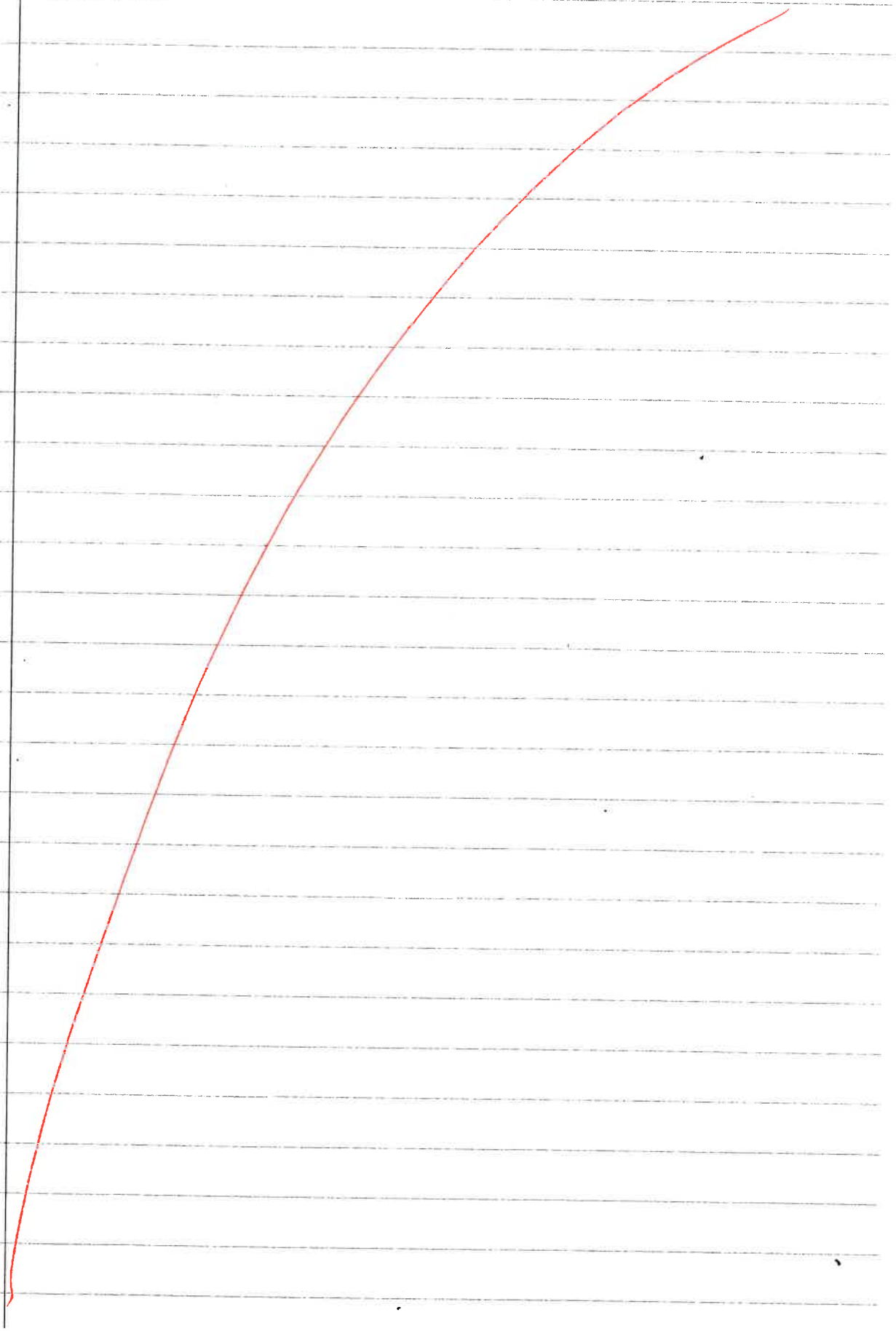

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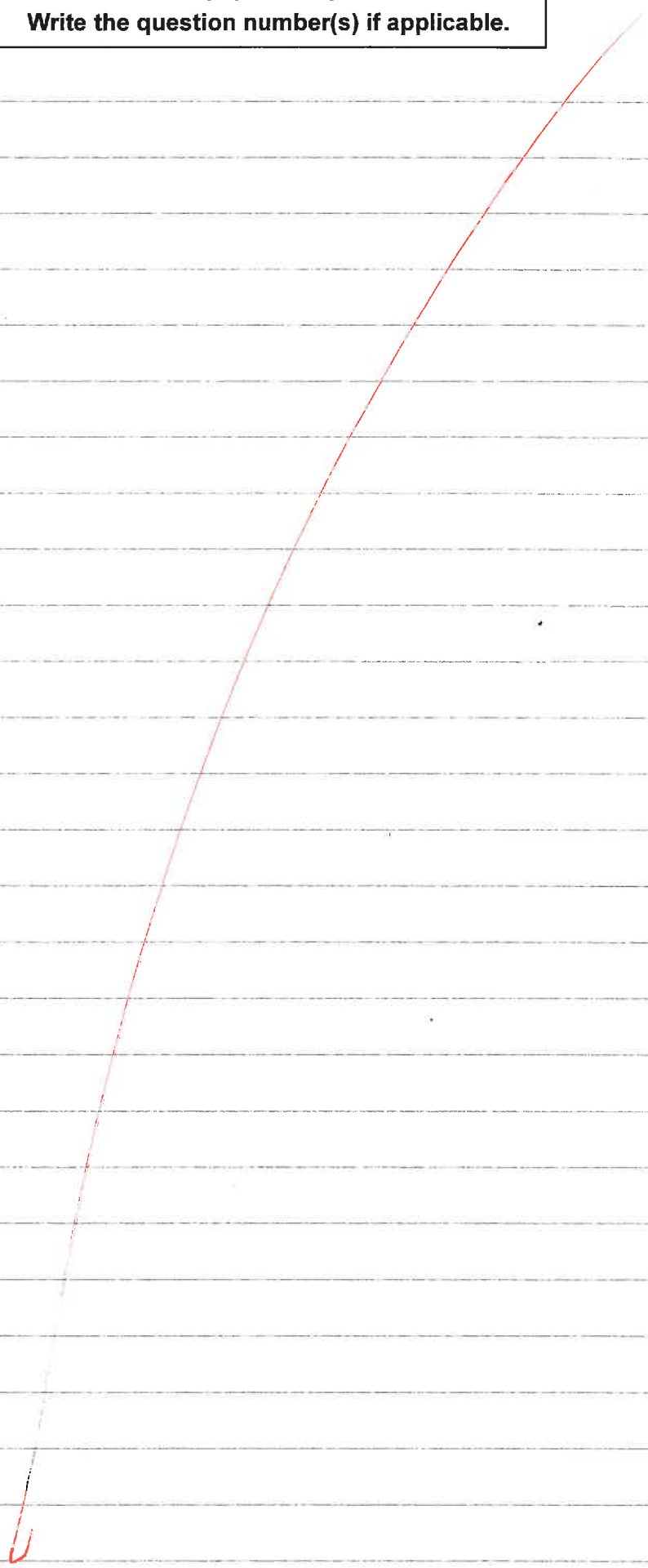

Merit exemplar for 91166 2017		Total score	17
Q	**Grade score**	**Annotation**	
1	M6	The candidate has: completed the equation for propanoic acid reacting with water; identified the correct conjugate acid-base pairs, including an explanation of proton transfer; explained why sodium ethanoate is basic 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, and that sodium carbonate is a better electrical conductor than ammonia. If the candidate had linked the degree of dissociation of ammonia and sodium carbonate with the relative concentration of ions, this would have provided evidence towards E7 (minor error for labelling sodium carbonate as a strong base).	
2	M6	The candidate has: explained that a catalyst provides an alternative pathway with a lower activation energy, so more particles have sufficient energy to overcome the activation energy; written the correct equilibrium constant expression; calculated the correct K_c and explained why the reaction is not at equilibrium; and linked the decrease in K_c to an increase in the concentration of reactants (although this is poorly explained). If the candidate had explained that the production of ammonia is exothermic since the reaction is moving towards the reactants in the endothermic direction as the temperature is increased, this would have provided evidence towards E7 or E8.	
3	M5	The candidate has: explained that particles have more kinetic energy and will collide more frequently at a higher temperature, but the same total mass of carbon dioxide is produced at each temperature; explained the effect of changing the concentration of a product on the position of an equilibrium; recognised that the equilibrium will move in the exothermic direction when the temperature is decreased; and explained that 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 M6. Alternatively, if the candidate had explained that particles are more likely to collide with sufficient energy, rather than 'force', at a higher temperature to overcome the activation energy, this would have provided evidence towards E7.	