WACE Types Practice Questions

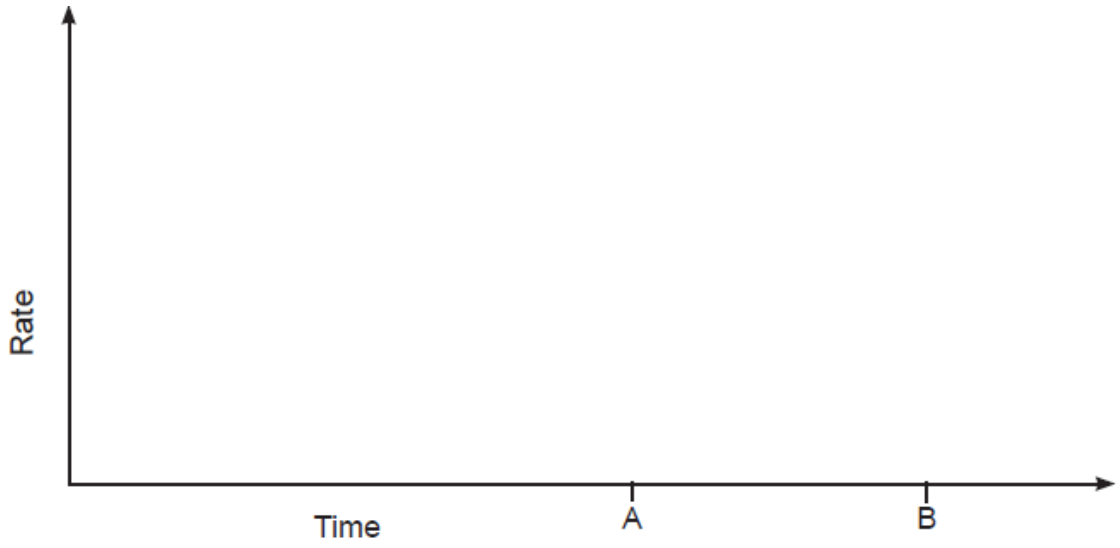
$$N_2(g) + 2\,O_2(g) \rightleftharpoons 2\,NO_2(g)$$

The following questions relate to the equilibrium system represented by this equation.

(a) Write the equilibrium expression for this reaction when it is in equilibrium. (2 marks)

(b) Assuming all other conditions remain constant, what happens to the equilibrium constant after the pressure of the system is lowered and equilibrium is re-established? (1 mark)

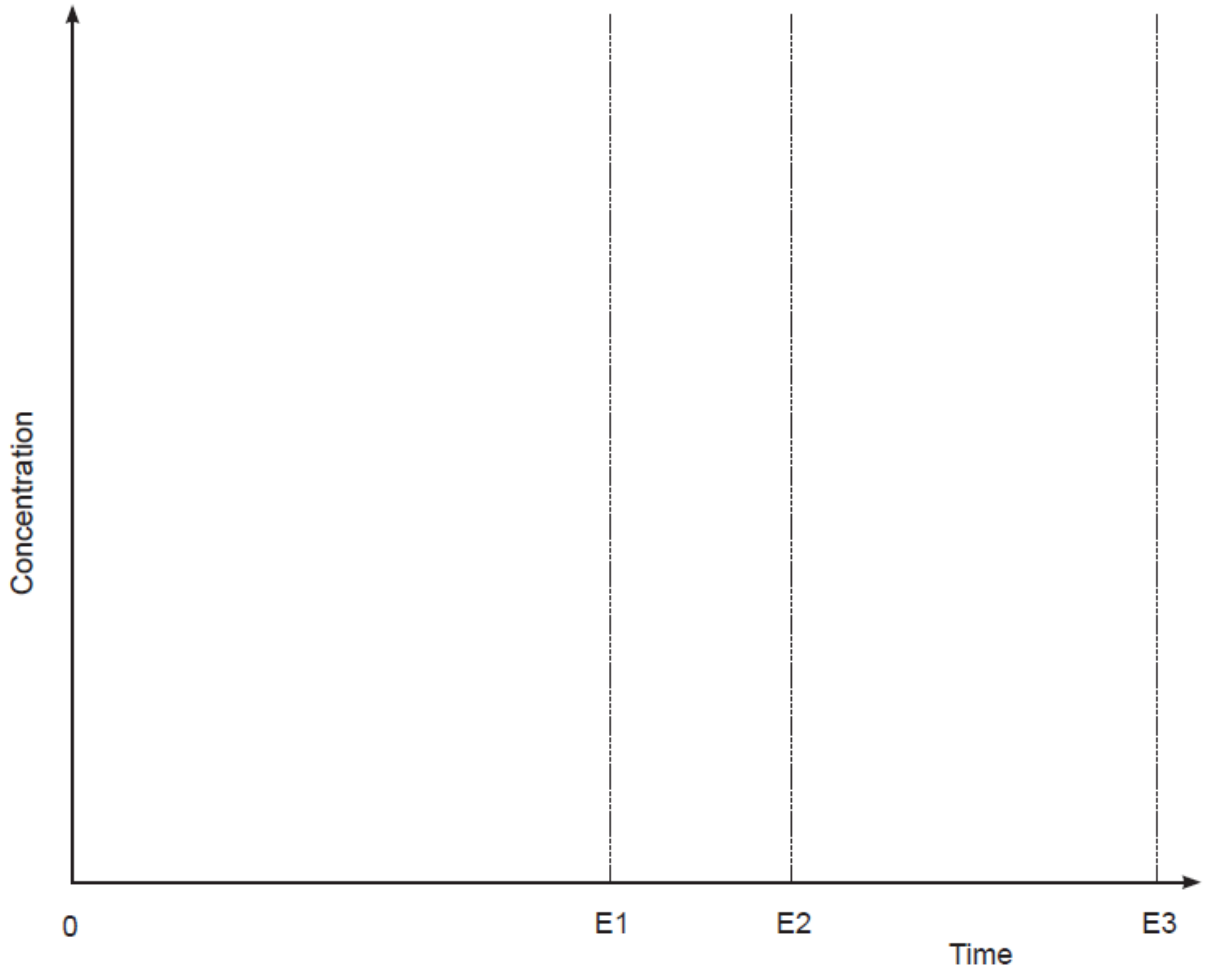
(c) (i) On the axes below, draw the forward (____) and reverse (- - -) reaction rates, starting at the moment the oxygen and nitrogen gases begin to react with each other until after equilibrium has been established at time A. Continue the graph until time B. (3 marks)



(ii) On the same axes above, draw and label clearly the effect of conducting the same reaction at a higher temperature. (2 marks)

(d) On the axes below, draw separate curves to show how the concentrations of the **three** gases change with time, starting at the moment the oxygen and nitrogen gases begin to react with each other until the system reaches equilibrium at Time E1. Continue the graph from Time E1 to Time E2. Assume that the initial concentrations of oxygen and nitrogen are identical.

Label clearly the line for each gas. (5 marks)



(e) At Time E2 shown on the axis, the reaction vessel is doubled in volume, and the system is then again allowed to reach equilibrium at Time E3. On the same graph above, show how the concentrations of the three gases would change in response to the change in volume, from Time E2 until equilibrium is re-established at Time E3. (3 marks)

2.

The two different coloured cobalt(II) complex ions, $Co(H_2O)_6^{2+}$ and $CoCl_4^{2-}$, exist together in equilibrium in solution in the presence of chloride ions. This is represented by the equation below.

$$\underset{\text{pink}}{Co(H_2O)_6^{2+}(aq)} + 4\,Cl^-(aq) \rightleftharpoons \underset{\text{blue}}{CoCl_4^{2-}(aq)} + 6\,H_2O(l)$$

An experiment is conducted to investigate the effects on the equilibrium position by imposing a series of changes on the system. The shift in equilibrium position can be indicated by any colour change of the solution.

Colour chart	
Species	**Colour**
$Co(H_2O)_6^{2+}(aq)$	pink
$CoCl_4^{2-}(aq)$	blue
Initial equilibrium mixture	purple

After a 3.00 mL sample of an initial equilibrium mixture was placed in each of three test tubes, changes to each system were made by adding a different substance, as indicated in the table below.

Test tube	Substance added to the test tube
1	10 to 12 drops of distilled water
2	20 to 25 drops of concentrated hydrochloric acid
3	20 to 25 drops of 0.200 mol L^{-1} silver nitrate solution, $AgNO_3(aq)$

(a) Complete the table below by predicting the:

- change in concentration, if any, of each of the ions in solution compared to the initial solution, after a new equilibrium position is reached.
- colour change, if any, that takes place from the initial purple-coloured solution.

(6 marks)

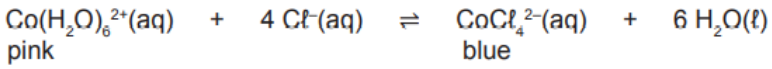
Additions to the test tube	**Change in concentration from initial equilibrium to final equilibrium (increase, decrease, unchanged)**			**Colour favoured (pink, blue or unchanged)**
	$[Co(H_2O)_6^{2+}]$	**$[Cl^-]$**	**$[CoCl_4^{2-}]$**	
1. add $H_2O(l)$				
2. add $HCl(aq)$				
3. add $AgNO_3(aq)$				

(b) Other than a colour change, what else should be observed in test tube 3? (1 mark)

(c) Using Collision Theory, explain your predicted observations when hydrochloric acid is added to test tube 2. (3 marks)

Another experiment was conducted to investigate the effect that changing the temperature had on the equilibrium mixture. When 3.00 mL of the original equilibrium mixture was placed in a test tube and then in an ice bath, the solution became pink.

(d) Determine whether the forward reaction, as illustrated by the equation below, is exothermic or endothermic. Use Le Châtelier's Principle to justify your answer.



(4 marks)

Ans Key

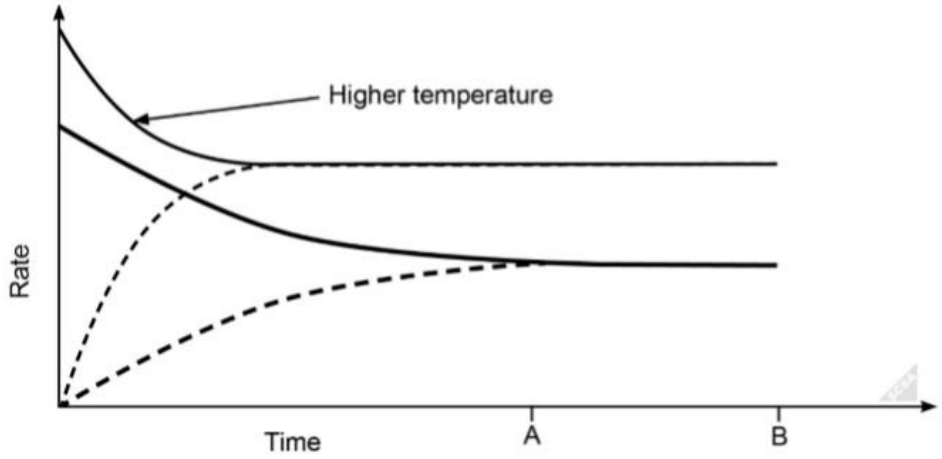
(a) Write the equilibrium expression for this reaction when it is in equilibrium. (2 marks)

Description	Marks
$K = \frac{pNO_2(g)^2}{pN_2(g)\ pO_2(g)^2}$ or $\frac{[NO_2]^2}{[N_2][O_2]^2}$	2
One superscript incorrect or missing	1
Total	**2**

(b) Assuming all other conditions remain constant, what happens to the equilibrium constant after the pressure of the system, is lowered and equilibrium is re-established? (1 mark)

Description	Marks
No change in K	1
Total	**1**

(c) (i) On the axes below, draw the forward (——) and reverse (- - -) reaction rates, starting at the moment the oxygen and nitrogen gases begin to react with each other until after equilibrium has been established at time A. Continue the graph until time B. (3 marks)



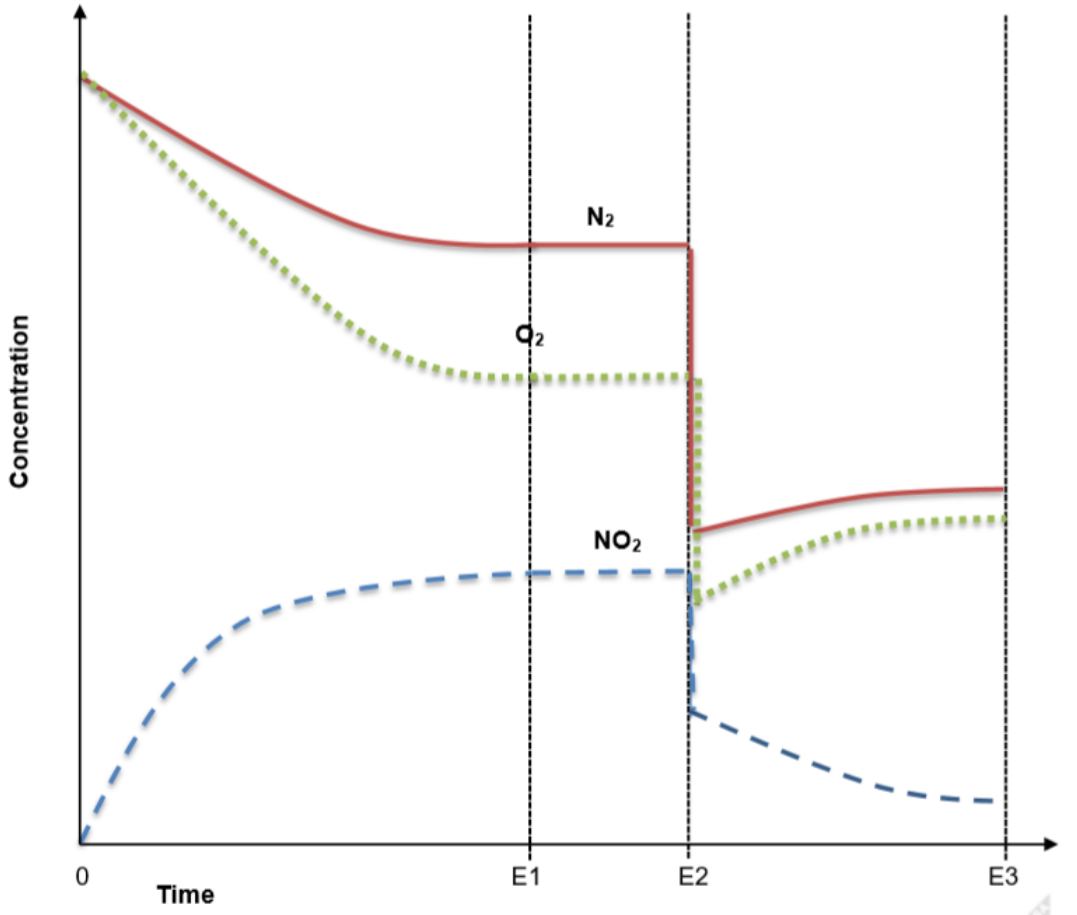
Description	Marks
Both curves have the correct shape & orientation	1
Both curves meeting at point A	1
Straight line between point A and B	1
Total	**3**

(ii) On the same axes, draw and label clearly the effect of conducting the same reaction at a higher temperature. (2 marks)

Description	Marks
The added curves show:	
Equilibrium reached sooner	1
Reaction rates are higher	1
Total	**2**

(d) On the axes below, draw separate curves to show how the concentrations of the **three** gases change with time, starting at the moment the oxygen and nitrogen gases begin to react with each other until the system reaches equilibrium at Time E1. Continue the graph from Time E1 to Time E2. Assume that the initial concentrations of oxygen and nitrogen are identical.

Label clearly the line for each gas. (5 marks)



Description	Marks
Correct shape and orientation for curves depicting $N_2(aq)$ and $O_2(g)$	1
Correct shape and orientation for curve depicting $NO_2(g)$	1
Curve for $NO_2(g)$ starting at zero	1
Ratio of change 2:1 for $O_2(g)$ compared with $N_2(g)$	1
Straight horizontal lines between E1 and E2	1
Total	**5**

(e) At Time E2 shown on the axis, the reaction vessel is doubled in volume, and the system is then again allowed to reach equilibrium at Time E3. On the same graph above, show how the concentrations of the three gases would change in response to the change in volume, from Time E2 until equilibrium is re-established at Time E3. (3 marks)

Description	Marks
Immediate reduction (halving) of concentration for all gases	1
Correct shape and orientation for curve for $N_2(g)$ and $O_2(g)$	1
Correct shape and orientation for curve for $NO_2(g)$	1
Total	**3**

Question 2

(a) Complete the table below by predicting the:

- change in concentration, if any, of each of the ions in solution compared to the inital solution, after a new equilibrium position is reached.
- colour change, if any, that takes place from the initial purple-coloured solution.

(6 marks)

Description					Marks
One mark for each row of correct concentrations of ions. One mark for each correct colour change.					
Additions to the test tube	**Change in concentration from initial equilibrium to final equilibrium (increase, decrease, unchanged)**			**Colour favoured (pink, blue or unchanged)**	
	$[Co(H_2O)_6^{2+}]$	**$[C\ell^-]$**	**$[CoC\ell_4^{2-}]$**		
1. add $H_2O(\ell)$	decrease	decrease	decrease	pink	1–2
2. add $HC\ell(aq)$	decrease	increase	increase	blue	1–2
3. add $AgNO_3(aq)$	increase	decrease	decrease	pink	1–2
				Total	**6**

(b) Other than a colour change, what else should be observed in test tube 3? (1 mark)

Description	Marks
Recognition that a precipitate is produced. Eg: • The test tube goes cloudy or becomes opaque when shaken • A (white) precipitate forms	1
Total	**1**

(c) Using Collision Theory, explain your predicted observations when hydrochloric acid is added to test tube 2. (3 marks)

Description	Marks
Addition of $HC\ell(aq)$ causes the concentration of the chloride ions to increase and hence the number of collisions between $Co(H_2O)_6^{2+}$ and $C\ell^-$ increases	1
The rate of the forward reaction increases relative to the reverse reaction (and hence shifts right)	1
This leads to a greater concentration of the blue $CoC\ell_4^{2-}$ (and a lower concentration of the pink $Co(H_2O)_6^{2+}$ ion, hence the solution looks more blue)	1
Total	**3**

$Co(H_2O)_6^{2+}(aq) + 4\ C\ell^-(aq) \rightleftharpoons CoC\ell_4^{2-}(aq) + 6\ H_2O(\ell)$
pink blue

(4 marks)

Description	Marks
Decreasing the temperature shifts the equilibrium position to the left favouring the production $Co(H_2O)_6^{2+}(aq)$, a pink solution	1
(According to Le Châtelier's principle) decreasing the temperature favours the exothermic reaction to oppose/counteract the change	1
Since the reverse reaction has been favoured, it is the exothermic reaction	1
Hence the forward reaction is endothermic	1
Total	**4**
Note: The corollary is true and acceptable. • When increasing the temperature the reaction to the right is favoured as indicated by the formation of the blue coloured $CoC\ell_4^{2-}(aq)$. • (According to Le Châtelier's principle), increasing the temperature favours the endothermic reaction to oppose/counteract the change. • Therefore the forward reaction as written is endothermic.	

(e) State **one** specific hazard to the environment that the disposal of chemicals from this experiment poses and state what could be done in the laboratory to reduce this hazard.

(2 marks)

Description	Marks
One mark for hazard. Any reasonable hazard that is relevant to this specific experiment. For example:	
• the disposal of concentrated hydrochloric acid • many chemicals such as transition metals are poisonous. • cobalt and silver salts are in fact poisonous.	1
One mark for method. Any reasonable method that is relevant to this specific experiment. For example:	
• dilute with copious amounts of water when emptying down the sink (add acid to the running water) • neutralise the acid (with a sodium carbonate) before emptying down the sink • it is safe practice that unless the toxicity of a substance is known to treated it as poisonous. Rather than emptying down the sink, empty into a hazardous waste disposal or recover the cobalt and silver salts by precipitation ready for re-use.	1
Total	**2**