Christ Church
Grammar School

Year 12 Chemistry

Equilibrium Test
2020

Time allowed: **45 minutes**

Name: **ANSWERS**

Teachers: **NMO** **CEM** **KLD** **MLC**

Mark = **...../47**

SECTION 1 **MULTIPLE CHOICE** **10 marks**

1. Which one of the options about the following reversible reaction is true?

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

(a) $K_c = \dfrac{[SO_2]^2\,[O_2]}{[SO_3]^2}$

(b) K_c is constant under all reaction conditions.

(c) Sulfur trioxide is being formed when the reaction is at equilibrium.

(d) Adding a catalyst will increase the yield of sulfur trioxide.

Questions 2 and 3 refer to the following reaction:

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

2. The equilibrium expression, K_c, for the reaction above would be

(a) $K_c = \dfrac{[N_2O_4]}{2[NO_2]}$

(b) $K_c = \dfrac{2[NO_2]}{[N_2O_4]}$

(c) $K_c = \dfrac{[N_2O_4]}{[NO_2]^2}$

(d) $K_c = \dfrac{[NO_2]^2}{[N_2O_4]}$

3. What will happen to the value of K_c in the reaction described in question 2, if the concentration of the N_2O_4 is doubled?

(a) K_c would not be affected.

(b) K_c would be halved.

(c) K_c would be doubled.

(d) K_c would increase by a factor of 4.

4. At constant temperature, the addition of a catalyst to an equilibrium system,

(a) increases the concentration of the products at equilibrium.

(b) increases the energy of the molecules so more can successfully collide.

(c) lowers the amount of energy released in the overall reaction.

(d) decreases the time required for equilibrium to be reached.

5. In which of the following systems will the mass of the products increase if the volume of the container is increased?

(a) $2NO_2\,(g) \rightleftharpoons N_2O_4\,(g)$

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

(c) $H_2O\,(g) + C\,(s) \rightleftharpoons H_2\,(g) + CO\,(g)$

(d) $H_2\,(g) + F_2\,(g) \rightleftharpoons 2HF\,(g)$

6. Consider the following reaction at equilibrium:

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g) + \text{heat}$$

Which one of the following changes will increase the concentration of $NO_2(g)$ in the mixture when equilibrium is re-established?

(a) decreasing the concentration of NO at constant temperature and pressure

(b) decreasing the concentration of O_2 at constant temperature and pressure

(c) increasing the volume

(d) decreasing the temperature

Questions 7 and 8 refer to the following reaction:

$$4NH_3(g) + 3O_2(g) \rightleftharpoons 2N_2(g) + 6H_2O(g) \qquad \Delta H = -1267kJ$$

The following changes can be made to the reaction:

(I) Increase the concentration of $NH_3(g)$

(II) Increase the concentration of $H_2O(g)$

(III) Decrease the temperature

7. Which of the changes will increase the yield of products?

(a) I only

(b) I and II

(c) I and III

(d) I, II and III

8. Which of the following will increase the rate of the forward reaction when equilibrium is re-established?

(a) II only

(b) I and II

(c) I only

(d) I, II and III

9. Consider the following system initially at equilibrium.

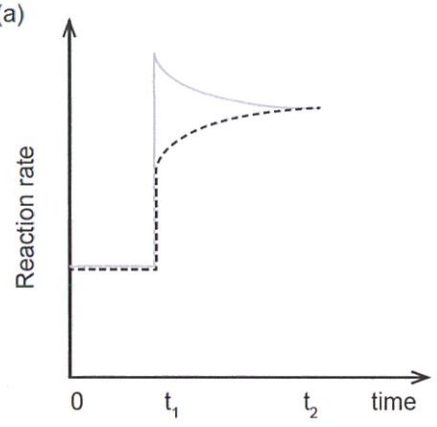
$$2\ C\ell F_3(g) \rightleftharpoons 3\ F_2(g) + C\ell_2(g) + \text{heat}$$

The system is initially at equilibrium. At time $\mathbf{t_1}$, the temperature of the system was increased. Which of the following best represents the changes in the forward and reverse reaction rates until equilibrium is re-established at time, $\mathbf{t_2}$?

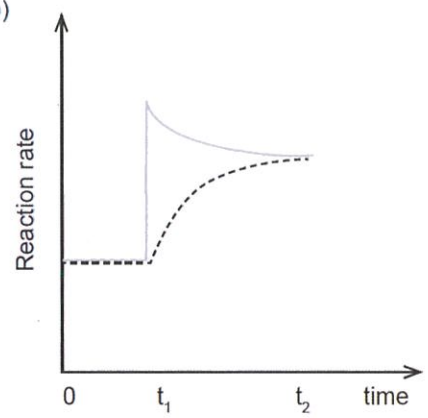
The forward reaction rate is represented by _____

The reverse reaction rate is represented by ----------

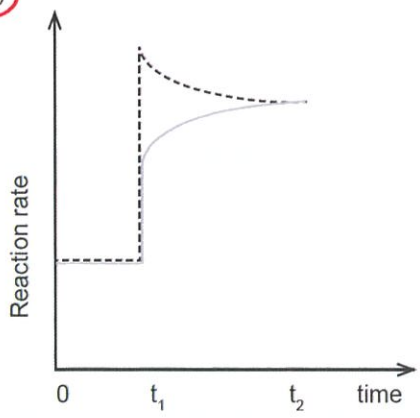
(a)



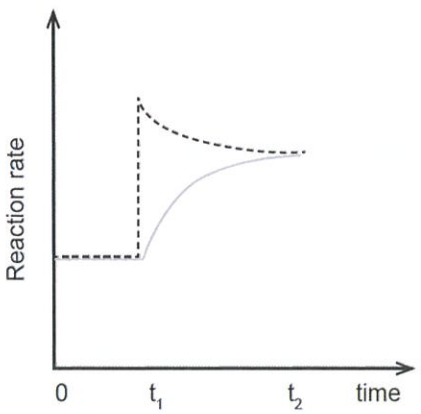
(b)



(c)



(d)



10. Lead iodide is slightly soluble in water and the following equilibrium is produced:

$$PbI_2\ (s) \rightleftharpoons Pb^{2+}\ (aq) + I^-\ (aq)$$

Some $Na_2SO_4\,(aq)$ was then added to the system and allowed to reach equilibrium. What would you expect to observe during this period?

(a) No visible change.

(b) White solid forms.

(c) Yellow solid forms.

(d) White solid forms and yellow solid decreases in mass.

SECTION 2 **SHORT ANSWERS** **37 marks**

Question 11 **21 marks**

When potassium thiocyanate (KNCS) is mixed with iron(III) nitrate ($Fe(NO_3)_3$) in solution, an equilibrium mixture of Fe^{3+}, SCN^-, and the ion $FeSCN^{2+}$ is formed according to the equation below. The formation of $FeSCN^{2+}$ is exothermic.

$$\underset{\textit{Pale brown}}{Fe^{3+}_{(aq)}} + \underset{\textit{colourless}}{SCN^-_{(aq)}} \rightleftharpoons \underset{\textit{blood red}}{FeSCN^{2+}_{(aq)}}$$

(a) Complete the table below using the terms *increase, decrease or no change* to indicate the effect of making the following changes to the system once equilibrium has been re-established. (12 marks)

Change made	**Rate of reverse reaction**	**Effect on $[Fe^{3+}]$**	**Effect on K**
Add $FeC\ell_3$ (s)	*increase*	*increase*	*no change*
Add H_2O	*decrease*	*decrease*	*no change*
Add a catalyst	*increase*	*no change*	*no change*
Decrease temperature	*decrease*	decrease	*increase*

(b) For the two changes listed below, describe what you would observe in the period until equilibrium is re-established. (3 marks)

$$\underset{\textit{Pale brown}}{Fe^{3+}_{(aq)}} + \underset{\textit{colourless}}{SCN^-_{(aq)}} \rightleftharpoons \underset{\textit{blood red}}{FeSCN^{2+}_{(aq)}} \quad \Delta H < 0$$

(i) Addition of water

Observation: *paler and more brown*

(ii) Decreasing temperature

Observation: *more red, (less brown)*

(c) Using collision theory, explain your observation when water is added to the equilibrium system above. (6 marks)

Concentration of all species decreases causing the colour to fade. (1)

Rates of both forward and reverse decrease due to decreasing the frequency of collisions. (2)

Forward rate is affected to a greater extent, so more reactants are initially produced then are consumed. (1)

$[Fe^{3+}]$ increases over time as is produced faster than is consumed so more brown. (1)

$[FeSCN^{2+}]$ decreases over time so less red. (1)

Question 12 **11 marks**

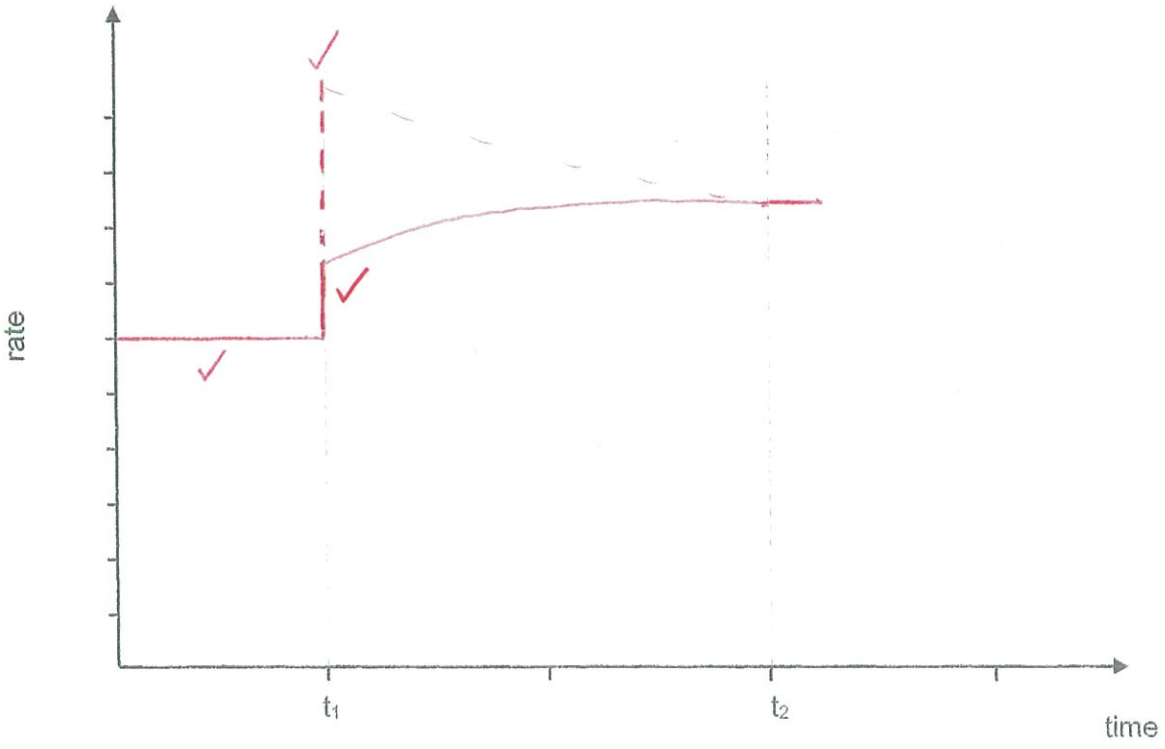
In the first stage of the production of nitric acid, ammonia is reacted with oxygen to produce nitrogen monoxide.

A hot platinum catalyst is used. The reaction is highly exothermic, and the heat given out by the reaction is sufficient to maintain the temperature needed to give a fast rate.

The system is at equilibrium until t_1 and then at t_1, the volume of the vessel is reduced at constant temperature. Equilibrium is re-established at t_2.

Stage 1: $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$ $\Delta H < 0$

(a) Sketch the rate-time graph for the forward and reverse reactions to show the changes in rate until the return to equilibrium.
Use forward ———— reverse ---------- in your sketch below. (3 marks)



(b) Using *'increase, decrease or no change'* in the table below, identify the effect of reducing the volume on the mass and concentration of NH_3 and NO once equilibrium has been re-established. (4 marks)

	NH_3	NO
Mass	*increase*	*decrease*
Concentration	*increase*	*increase*

(c) The second stage involves the reaction of nitrogen monoxide with more oxygen to form nitrogen dioxide.

1.5 0.75. 1.5

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$

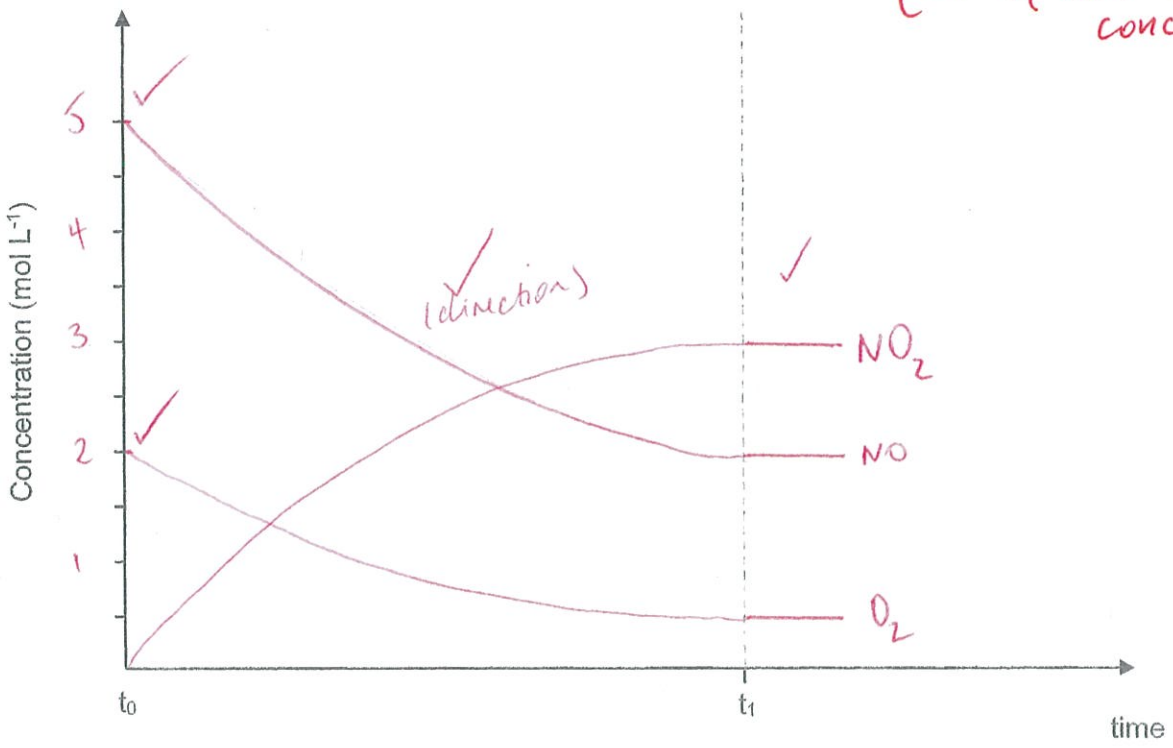
At t_0, 2.5 mol of NO and 1 mol of O_2 were injected into a 500 mL container.

At t_1, equilibrium was reached with only 1 mol of NO remaining.

Use this information to construct a detailed graph for how the concentrations of NO, O_2 and NO_2 varied between t_0 and t_1.

(4 marks)

(-1 if not calc. concentration)



$[NO]$ at $t_0 = \frac{2.5}{0.5} = 5$ mol L^{-1}

$[O_2]$ at $t_0 = \frac{1}{0.5} = 2$ mol L^{-1}

$[NO_2]$ at $t_0 = 0$

$n(NO)$ reacted $= 2.5 - 1 = 1.5$ moles.

$[NO]$ at $t_1 = \frac{1}{0.5} = 2$ mol L^{-1}

$n(O_2)$ reacted $= 1.5 \div 2 = 0.75$

$[O_2]$ at $t_1 = \frac{0.25}{0.5} = 0.5$ mol L^{-1}

$1 - 0.75 = 0.25$

$n(NO_2)$ produced $= 1.5$

$[NO_2]$ at $t_1 = \frac{1.5}{0.5} = 3$ mol L^{-1}

Question 13 **5 marks**

Ethanol (C_2H_5OH) can be made by the reaction of ethene with steam as shown:

$$C_2H_4\ (g) + H_2O\ (g) \rightleftharpoons C_2H_5OH\ (g) \qquad \Delta H = -46\ kJ$$

A moderate temperature of 300 °C is used for the manufacturing of ethanol.

(a) Explain, using collision theory, why this temperature is used to optimise the production of ethanol. (5 marks)

High temperatures favour an increased rate of reaction due to increasing the average kinetic energy and increasing the frequency of collisions. A greater proportion of collisions will have $E>E_a$. *(2 marks)*

Low temperature favours a high yield of ethanol due to the forwards reaction being exothermic and high temperatures favour the endothermic reaction. High temperatures have a greater effect on the proportion of collisions with sufficient energy for the endothermic reaction. (2 mark)

Low temperatures lower running costs, therefore a moderate compromised temperature is used to balance cost, yield and rate of production of ethanol. *(1 mark)*

END OF TEST