Christ Church Grammar School

Year 12 Chemistry

Equilibrium Test 2022

Time allowed: **45 minutes**

Name: ANSWERS

Teachers: **MXC BLR NMOB**

Mark = ……/45

SECTION 1 **MULTIPLE CHOICE** **(10 marks)**

Questions 1 and 2 refer to the following information

Oxides of nitrogen are formed in air at the high temperatures generated in lightning flashes according to the equation

$$N_2(g) + O_2(g) \rightleftarrows 2\,NO(g) \qquad K_1 = 5 \times 10^{-3} \text{ at } 3000^\circ C$$

1. At 3000°C, the equilibrium constant K_2 for the reaction

$$2\,NO(g) \rightleftarrows N_2(g) + O_2(g)$$

would be:

(a) 4×10^4
(b) 2×10^2
(c) 1×10^{-2}
(d) 5×10^{-3}

2. A higher temperature in the lightning flash increases the rate of the reaction but does **not** increase the

(a) number of collisions
(b) fraction of reacting particles which possess energies greater than the activation energy
(c) the average velocity of the reacting particles
(d) activation energy

3. A change is made on a system at equilibrium and it is observed that the equilibrium position moves to the right (products side). Which of the following is consistent with this observation?

(a) $2\,Cl_2(g) + 7\,O_2(g) \rightleftarrows 2\,Cl_2O_7(g)$; the pressure is increased by adding Ne to the vessel at constant volume
(b) $H_2(g) + I_2(g) \rightleftarrows 2\,HI(g)$; the pressure is decreased by removal of some of the HI(g)
(c) $2\,H_2(g) + O_2(g) \rightleftarrows 2\,H_2O(g)$; $\Delta H = -484$ kJ; the temperature is increased.
(d) $I_2(s) \rightleftarrows I_2(g)$; solid iodine is added.

4. Under certain conditions, cyclohexane, C_6H_{12}, can react to form benzene, C_6H_6 and hydrogen according to the equation

$$C_6H_{12}(g) \rightleftarrows C_6H_6(g) + 3\,H_2(g) \qquad \Delta H = +206\ kJmol^{-1}$$

If the volume of the reaction vessel was increased at constant temperature, then:

(a) the equilibrium concentration of cyclohexane would decrease but its mass would increase.
(b) the equilibrium concentration of cyclohexane would be unchanged but its mass would decrease.
(c) the equilibrium concentration of benzene would decrease but its mass would increase.
(d) the equilibrium concentration of benzene would increase and its mass would increase.

5. For the reaction

$$Fe^{2+}(aq) + Ag^{+}(aq) \rightleftarrows Fe^{3+}(aq) + Ag(s) \qquad \Delta H = -65.7\ kJ\ mol^{-1}$$

Which of the following increases the value of the equilibrium constant, K?

(a) adding silver ions to the system.
(b) removing water from the system.
(c) decreasing the temperature.
(d) increasing the temperature.

6. Cobalt (II) salts generally appear pink due to the presence of $Co(H_2O)_6^{2+}$ (aq) but the tetrahedral complex $CoCl_4^{2-}$(aq) is blue in colour. For the reaction:

$$Co(H_2O)_6^{2+}(aq) + 4\,Cl^{-}(aq) \rightleftarrows CoCl_4^{2-}(aq) + 6\,H_2O(l) \qquad \Delta H = +12.4\ kJ\ mol^{-1}$$

Which of the following would cause the reaction mixture to take on a stronger BLUE colour?

I. adding a few drops of water
II. adding concentrated hydrochloric acid
III. adding silver nitrate solution
IV. heating
V cooling

(a) I, II and IV
(b) III and IV
(c) II and IV
(d) II and V

7. Methanol is prepared commercially by reacting CO with H_2 at 400°C in the presence of a catalyst.

$$CO(g) + 2\,H_2(g) \rightleftarrows CH_3OH(g) \qquad \Delta H = -92\ kJ\ mol^{-1}$$

If a mixure of CO, H_2 and CH_3OH were at equilibrium in a sealed container and the temperature of the gases were raised, the:

(a) total pressure of the gas mixture would decrease.
(b) rates of forward and reverse reactions would remain constant.
(c) total number of gas molecules would increase.
(d) the value of K would increase.

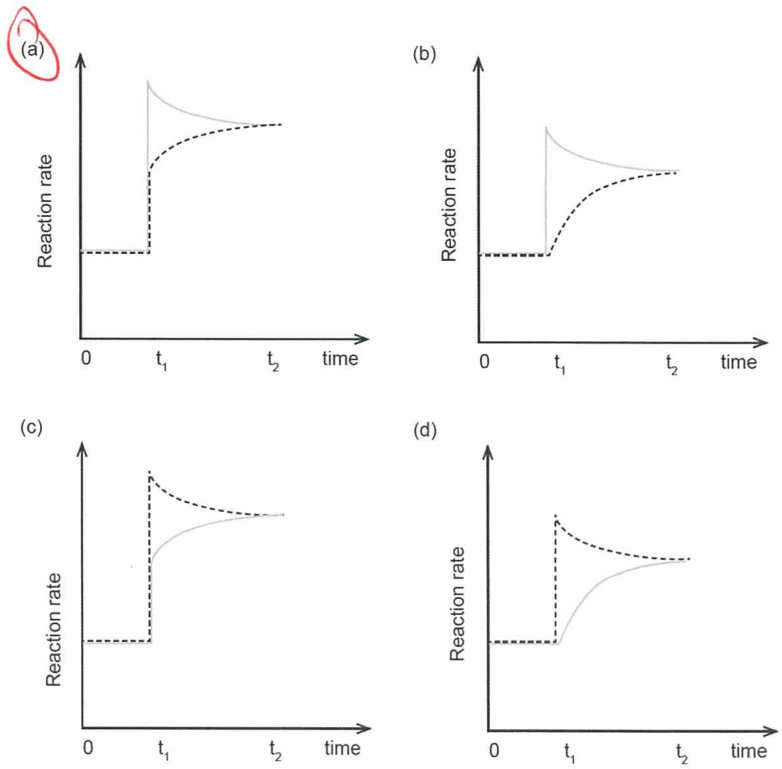
8. Consider the following equilibrium.

$$SO_3(g) \rightleftarrows SO_2(g) + O_2(g) \qquad \Delta H = +196\ kJmol^{-1}$$

The system is initially at equilibrium. At time 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, t_2?

The forward reaction rate is represented by ————

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



9. In which one or more of the following chemical equilibrium systems will the position of equilibrium be shifted to the left by an increase in pressure?

I $CaCO_3(s) \rightleftarrows CaO(s) + CO_2(g)$

II $2\ HI(g) \rightleftarrows H_2(g) + I_2(g)$

III $C_3H_8(g) + 5\ O_2(g) \rightleftarrows 3\ CO_2(g) + 4\ H_2O(g)$

IV $Cl_2(g) + 3\ F_2(g) \rightleftarrows 2\ ClF_3(g)$

(a) I only
(b) I and II only
(c) I and III only
(d) IV only

10. Hydrogen sulfide is used as a source of sulfide ions in qualitative analysis. The equations for the production of sulfide ions are:

$$H_2S(aq) \rightleftarrows H^+(aq) + HS^-(aq)$$
$$HS^-(aq) \rightleftarrows H^+(aq) + S^{2-}(aq)$$

When acid is added to the equilibrium mixture above, the sulfide ion concentration will:

(a) increase.
(b) remain constant.
(c) decrease.
(d) be always equal the hydrogen ion concentration.

SECTION 2 **WRITTEN ANSWERS** **(35 Marks)**

Question 11 **(6 marks)**

The industrial production of ethanoic acid is by the Monsanto process, which is as follows;

$$CH_3OH(g) + CO(g) \rightleftarrows CH_3COOH(g) \qquad \Delta H = -ve$$

The conditions used for this process are 200^{0}C and 3000 kPa. Outline the factors that would have been considered in choosing these as the optimum conditions. Use Le Chatelier's Principle to justify your answers.

Temperature

High T ⇒ high rate
Reaction is exothermic so low T ⇒ High yield
200°C is the compromise temperature
that produces acceptable rate and yield

(3 marks)

Pressure

High P ⇒ high rate
High P favours yield
3000 kPa gives an acceptable rate and
yield while keeping cost at an acceptable
level

(3 marks)

Question 12 **(15 marks)**

Consider the following equilibrium;

$$4\ NH_3(g) + 5\ O_2(g) \rightleftarrows 4\ NO(g) + 6\ H_2O(g) \quad \Delta H = -908\ kJ$$

(a) For each of the following changes, predict the effect on the value of the equilibrium constant (K), the rate of the forward reaction, the concentration of oxygen (O_2) and the mass of nitrous oxide (NO) once equilibrium has been re-established. Identify the changes as **increase, decrease** or **no change.**

Change	K	rate of forward reaction	$[O_2]$	mass of NO
Increase temperature	D	I	I	D
Remove some NH_3	NC	D	I	D
Add a catalyst	NC	I	NC	NC
Decrease the volume of the container	NC	I	I	D
Add neon gas at constant volume	NC	NC	NC	NC

(10 marks)

2 marks per row
− 1 mark per error

(b) Use collision theory to explain the effect (if any) on the concentration of O_2 when the temperature of the system is increased.

Increase in T increases the frequency and proportion of collisions with $E \geq E_a$

rate of both forward and reverse reactions increase

The endothermic reaction is affected by more than the exothermic reaction

O_2 is produced more quickly than it is consumed

∴ $[O_2]$ increases.

(5 marks)

Question 13 **(14 marks)**

Equilibrium is established between the yellow chromate ion (CrO_4^{2-}) and the orange dichromate ion ($Cr_2O_7^{2-}$) according to the following equation.

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftarrows Cr_2O_7^{2-}(aq) + H_2O(l)$$

Yellow Orange

Assume that an orange equilibrium mixture contains an excess of dichromate ions and a yellow mixture contains an excess of chromate ions.

(a) Write an expression for the equilibrium constant for this reaction.

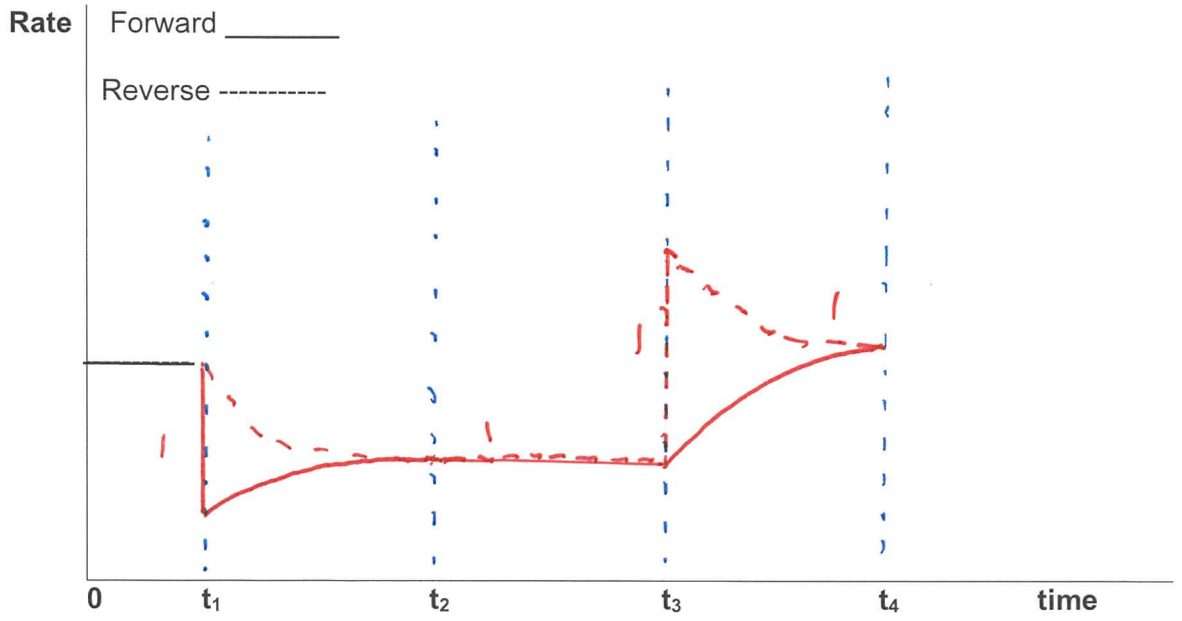
$$K_c = \frac{[Cr_2O_7^{2-}]}{[CrO_4^{2-}]^2[H^+]^2}$$

(1 mark)

(b) Consider an equilibrium mixture of these ions.

- At time t_1 several drops of a concentrated solution of sodium hydroxide (NaOH) were added.
- At time t_2 equilibrium is re-established.
- At time t_3 $Na_2Cr_2O_7(s)$ was added.
- At time t_4 equilibrium is re-established.

Sketch a qualitative graph demonstrating the change in the rates of the forward and reverse reactions during these events until equilibrium is re-established at t_4. From t=0 to t = t_1 the rates of the forward and reverse reactions are equal.



(4 marks)

Question 13 continued

Water is now added to an equilibrium mixture of chromate and dichromate ions which was orange in colour so that its volume is doubled.

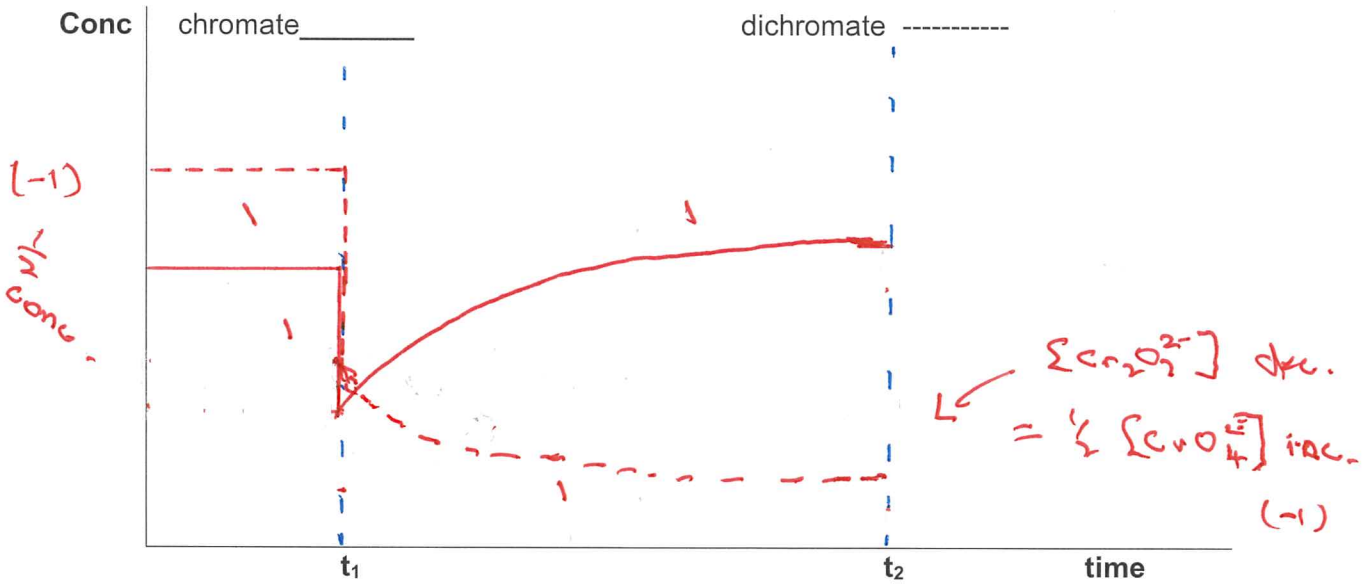
(c) Give an observation predicting the colour change(s) you would observe (if any).

The orange colour fades then the solution turns yellow

(2 marks)

(d)(i) On the axes below show the relative concentrations of the chromate and dichromate ions in equilibrium before the water is added at t_1.

(ii) Sketch a qualitative graph of the concentration of the chromate and dichromate ions in solution as water is added at t_1 until it comes to equilibrium at t_2.



(4 marks)

(e) A student wanted to prepare a solution of potassium dichromate ($K_2Cr_2O_7$) but only had solid potassium chromate (K_2CrO_4) available. Explain how the student would do this. Explain your reasoning.

1. Dissolve K_2CrO_4 (s) in H_2O
2. Add a small quantity of concentrated H^+

As the $[H^+]$ increases in the solution the equilibrium shifts to the right producing $Cr_2O_7^{2-}$.

(3 marks)

End of Test