Christ Church
Grammar School

Year 12 Chemistry

Equilibrium Test
2021

Time allowed: **45 minutes**

Name: Answers

Teachers: **JT DGM NMO**

Mark = **...../48**

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

The following information refers to questions 1,2 and 3.

Consider the following three equations

Reaction 1. $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

Reaction 2 $NO_2(g) \rightleftharpoons \frac{1}{2} N_2O_4(g)$

Reaction 3 $2NO_2(g) \rightleftharpoons N_2O_4(g)$

For reaction 1, K = 0.020 , ΔH = +58 kJ and the activation energy of the forwards reaction is +96kJ

1. What is ΔH for reaction 2?

   A. +29 kJ?
   B. -58 kJ
   C. -29 kJ
   D. +118 kJ

2. What is the value of the equilibrium constant K (at the same temperature) for reaction 3

   A. 50
   B. 20
   C. -0.02
   D. -50

3. What is activation energy of the backwards reaction in reaction 1?

   A. -58 kJ
   B. +58 kJ
   C. +154 kJ
   D. +38 kJ

4. Consider the information of the two acids below;

   $HF \rightleftharpoons H^+ + F^-$ $K = 5.6 \times 10^{-4}$
   $HCN \rightleftharpoons H^+ + CN^-$ $K = 4.0 \times 10^{-10}$

   Assuming that they are of the same concentration, which of the following statements is true?

   A. HCN is a stronger acid than HF.
   B. HCN has a higher concentration of hydrogen ions than HF.
   C. The concentration of HCN molecules in HCN is higher than the concentration of HF molecules in HF.
   D. The concentration of CN^- ions in HCN is higher than the concentration of F^- ions in HF.

5. Which of the following reactions would have the equilibrium constant equation below?

   $$K = 1/[Cl_2]$$

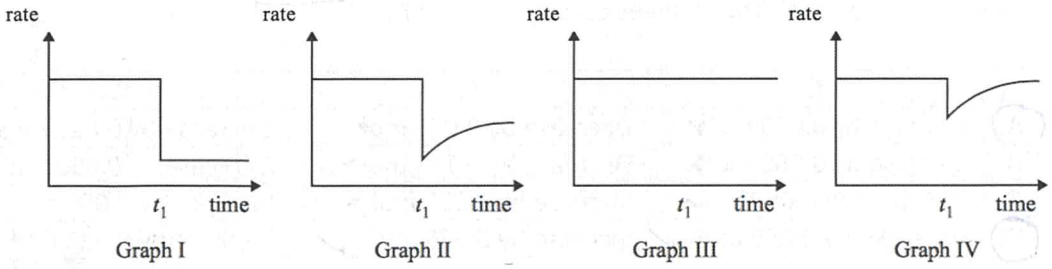
   I. $PCl_3(l) + Cl_2(g) \rightleftharpoons PCl_5(s)$
   II. $Cl_2(g) \rightleftharpoons Cl_2(l)$
   III. $Cl_2(l) \rightleftharpoons Cl_2(s)$
   IV. $PCl_5(s) \rightleftharpoons PCl_3(l) + Cl_2(g)$

   A. I and II only
   B. II and IV only
   C. all of them
   D. none of them

Questions 6 and 7 refer to the reaction;

$A(g) \rightleftharpoons 2B(g)$ ΔH = +ve

Consider the following graphs of the rate of the backwards reaction



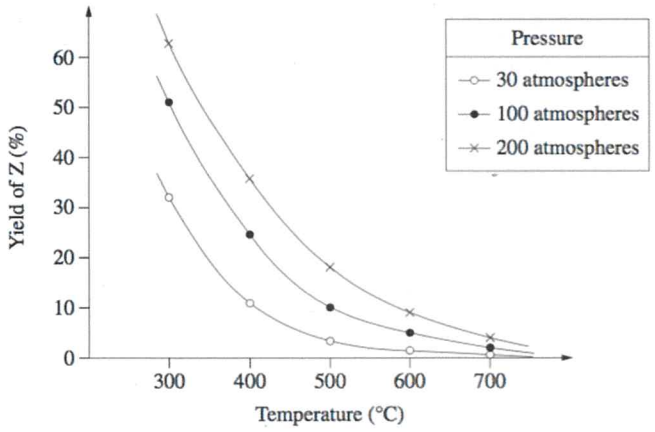
6. Which of the graphs above would be observed if some neon gas was added to the rigid reaction vessel (at constant volume) at time t_1?

A. Graph I
B. Graph II
C. Graph III
D. Graph IV

7. Which of the following changes at time t_1 could **not** result in graph II being observed?

A. removal of some B
B. the temperature is decreased
C. the volume is increased
D. removal of some A

8. Which one of the following reactions could produce the trends shown in the graph below?



A. $X(g) + 4Y(g) \rightleftharpoons 3Z(g)$ ΔH = +100 kJ
B. $X(g) + Y(g) \rightleftharpoons 2Z(g)$ ΔH = -100 kJ
C. $X(g) + 2Y(g) \rightleftharpoons Z(g)$ ΔH = +100 kJ
D. $2X(g) + Y(g) \rightleftharpoons Z(g)$ ΔH = -100 kJ

9. Consider the reaction

$$2\ C\ell F_3\,(g) \rightleftharpoons 3\ F_2\,(g) + C\ell_2\,(g) \qquad \Delta H = \text{negative}$$

For a particular equilibrium mixture, the temperature is **lowered** and the amount of ClF_3 changes by 0.050 mol. The changes occurring would be:

	$C\ell F_3$	F_2	$C\ell_2$
A	Increase by 0.050 mol	Decrease by 0.075 mol	Decrease by 0.025 mol
B.	Increase by 0.050 mol	Decrease by 0.150 mol	Decrease by 0.050 mol
C.	Decrease by 0.050 mol	Increase by 0.150 mol	Increase by 0.050 mol
D.	Decrease by 0.050 mol	Increase by 0.075 mol	Increase by 0.025 mol

10. In which one of the following reactions would the position of the equilibrium **not** be affected by a volume change at constant temperature?

A. $2\ CO(g) + O_2(g) \rightleftharpoons 2\ CO_2(g)$
B. $C_2H_6(g) \rightleftharpoons C_2H_4(g) + H_2(g)$
C. $N_2O_4(g) \rightleftharpoons 2\ NO_2(g)$
D. $CO(g) + H_2O(g) \rightleftharpoons H_2(g) + CO_2(g)$

SECTION 2 **SHORT ANSWERS** **38 marks**

Question 11 **(3 marks)**

In the boxes provided, write expressions for the equilibrium constant, K, for the following two reactions

$2O_3(g) \rightleftharpoons 3O_2(g)$	$PC\ell_3(\ell) + 3H_2O(\ell) \rightleftharpoons H_3PO_3(aq) + 3HC\ell(g)$
$K = \frac{[O_2]^3}{[O_3]^2}$ ✓	$K = [H_3PO_3][HCl]^3$ ✓✓

Question 12 **(14 marks)**

Consider a solution in which the following equilibrium is established.

$$Br_2(aq) + 2OH^-(aq) \rightleftharpoons OBr^-(aq) + Br^-(aq) + H_2O(\ell) \qquad \Delta H = +15\ kJmol^{-1}$$

The bromine (Br_2) gives the aqueous solution a reddish-brown colour. All the other species present are colourless.

Complete the table below to indicate how (using 'increase', 'decrease' or 'no change') the following changes in conditions, once equilibrium is re-established, will affect

(i) the concentration of OH^- ions
(ii) the rate of the backwards reaction and
(iii) the value of the equilibrium constant, K

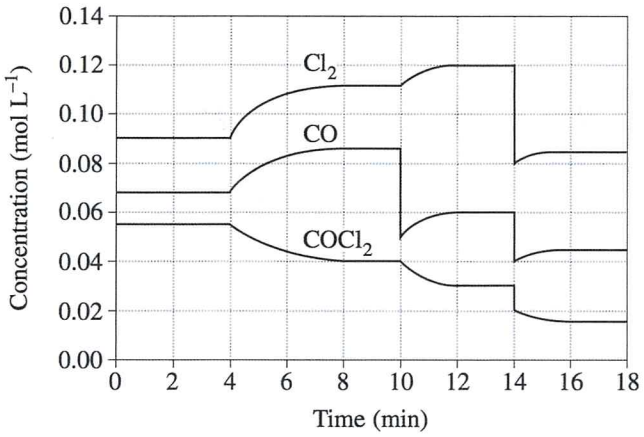
Also include any observations that you would expect to notice

Change	Effect on $[OH^-]$	Effect on backwards rate of reaction	Effect on the value of K	Observation(s)
A small amount of concentrated NaBr(aq) is added	increase	increase	Do not fill in this box	more red/brown
A small amount of concentrated nitric acid is added	decrease	decrease	Do not fill in this box	more red/brown
The temperature is decreased	increase	decrease	decrease	more red/brown
The volume of solution is doubled by the addition of water	decrease	decrease	no change.	Do not fill in this box

Question 13 **(9 marks)**

A mixture of $COCl_2$, Cl_2 and CO is placed in a container with a volume that can be changed. The mixture is allowed to come to equilibrium. The graph below shows the variation in concentration of reactant and products as a function of time for the following system.

$$COCl_2(g) \rightleftharpoons Cl_2(g) + CO(g) \qquad \Delta H = +108 \text{ kJmol}^{-1}$$



At time = 4 minutes, 10 minutes and 14 minutes, changes were made to the reaction conditions.

(i) What change was made at 4 minutes?

increase in temperature

(1 mark)

(ii) Explain, using collision theory, why the changes at 4 minutes occurred

as temp ↑, rates of forward and backwards reactions ↑. Both frequency of collisions and proportion with $E > E_{act}$ ↑. Endothermic (forwards reaction) speeds up by more. Position of equilibrium shifts to the right hand side

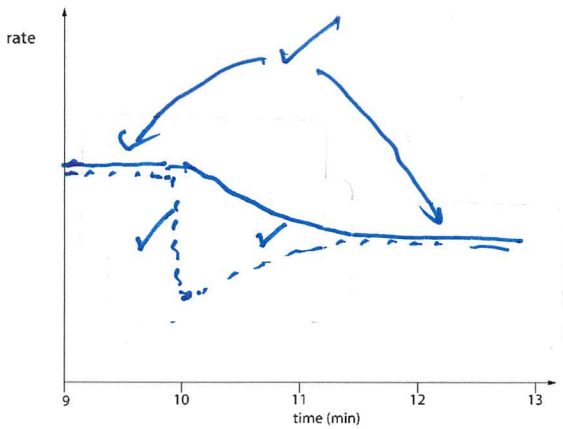
(4 marks)

(iii) What change was made at 10 minutes?

some CO was removed.

(1 mark)

(iv) Sketch a graph to show how the rates of the forwards (—) and backwards (-----) reactions would change between 9 and 13 minutes



(3 marks)

Question 14 **(12 marks)**

The industrial manufacture of nitric acid from ammonia is called the Ostwald Process and involves several stages, the first two of which can be summarised below

Stage 1. $4NH_3(g) + 5O_2(g) = 4NO(g) + 6H_2O(g)$ $\Delta H = -905$ kJ

Stage 2. $2NO(g) + O_2(g) = 2NO_2(aq)$ (5) $\Delta H = -114$ kJ

Looking at Stage 1, use your knowledge of rates of reaction and equilibrium to select either 'high', 'moderate' or 'low' (circle your choice below) for what your consider to be optimal conditions of temperature and pressure, with an explanation of your choices.

(a) Temperature

✓ HIGH (MODERATE) LOW

Explanation

• High rate favoured by high temp., due to frequency
✓ of collisions and proportion with $E > E_{act}$ increasing.
• High yield favoured by low temp., as this will
✓ favour the exothermic forwards reaction
✓ • Compromise needed. (4 marks)

(b) Pressure

✓ HIGH (MODERATE) LOW

Explanation

✓ : High rate favoured by high temp, due to frequency of collisions increasing.
✓ : High yield favoured by low pressure, as side of equation with more moles of gas favoured
✓ • Compromise needed. (4 marks)

(c) If it was possible to remove the NO formed in stage 1 and transfer it to a different reaction vessel for stage 2, what change in conditions might you suggest for the stage 2 reaction vessel, compared to those used in stage 1?

✓ • High pressure, because now there are
✓ fewer moles of gas on the right hand side

(2 marks)

(d) Stage 1 uses a catalyst made out of an alloy of platinum and rhodium. Circle the correct option ('increase', 'decrease' or 'no change') to indicate the effect of a catalyst on the following;

(i) Percentage yield of NO; increase decrease (no change)

(ii) Rate of formation of NO; (increase) decrease no change

(2 marks)