Year 12 Chemistry **Topic Test # 1 (Equilibrium) - 2013**

Name: **ANSWERS** Mark = _____ / 47

Part 1: Multiple Choice Section **10 marks**

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1. **C** 2. **C** 3. **D** 4. **C** 5. **C** 6. **B** 7. **C** 8. **D** 9. **A** 10. **D** ✓ **each**

Part 2: Short Answer Section **37 marks**

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1. Methane and water react to produce carbon monoxide and hydrogen gas according to the equation:

$CH_4(g) + H_2O(g) \rightleftarrows CO(g) + 3\ H_2(g)$ $\Delta H = +200\ kJ\ mol^{-1}$

Assume this reaction is allowed to come to equilibrium at 200°C and a pressure of 150 kPa.

Using the terms: INCREASE, DECREASE, NO CHANGE answer (a), (b) and (c).

(a) How will the value of this equilibrium constant change, once equilibrium has been re-established, if the following changes occur?

(i) The volume of the vessel is halved. **no change** ✓

(ii) The temperature is raised to 500°C. **increase** ✓

(b) What happens to the equilibrium concentration of carbon monoxide, once equilibrium has been re-established, if the following changes occur?

(i) Water gas is added to the system. **increase** ✓

(ii) The pressure of the reaction vessel is doubled by adding argon gas. *(at constant volume and temperature)* **no change** ✓

(iii) The temperature is decreased to 100°C. **decrease** ✓

(c) What happens **initially** to the rate of the **forward** reaction if the following changes are made?

(i) More CO(g) is added to the mixture. **no change** ✓

(ii) The volume of the container is halved. **increase** ✓

(iii) A suitable catalyst is added. **increase** ✓

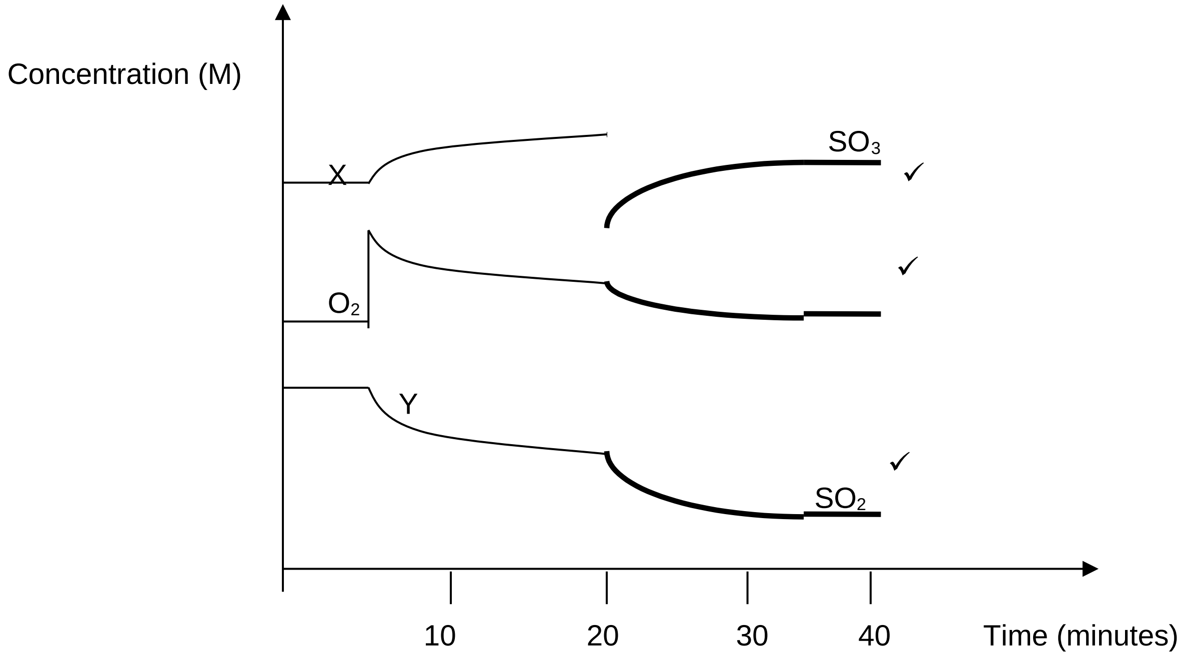
(8 marks)

2. Part of the Contact Process for the manufacture of sulfuric acid involves the conversion of sulfur dioxide to sulfur trioxide, as shown by the equation

$$2\ SO_2(g) + O_2(g) \rightleftarrows 2\ SO_3(g) \qquad \Delta H = -192\ kJ\ mol^{-1}$$

As part of a laboratory study of this process, a container was filled with an equilibrium mixture of sulfur dioxide, sulfur trioxide and oxygen in the presence of a catalyst. The container was initially at 450°C. The container had a fixed volume and was **thermally well insulated**.

Concentrations during a following experiment are shown on the diagram below.



(a) At t=5 minutes, a change was applied to the system. What was it? (1 mark)

O_2(g) has been added

(b) Which components of the equilibrium mixture are represented by X and Y?

X = **SO_3** Y = **SO_2** (1 mark)

(c) Would the temperature of the mixture **increase, decrease** or **remain the same** between 5 and 20 minutes? Explain your reasoning.

(2 marks)

Temperature increases ✓

Equilibrium has shifted right since [O_2] has decreased and the since forward reaction is exothermic hence the temperature increases. ✓

(d) At t = 20 minutes, some SO_3 was removed from the container. Continue the graph to represent the changes made to the concentrations of X, Y and O_2 until equilibrium has been re-established at 35 minutes.

(3 marks)

SEE GRAPH

3. Consider a solution in which the following equilibrium is established.

$$Br_2(aq) + 2\,OH^-(aq) \rightleftarrows OBr^-(aq) + Br^-(aq) + H_2O(l) \qquad \Delta H = +15\ kJ\ mol^{-1}$$

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

(a) The tests described in the table below are carried out on separate samples of the solution.

For each of the tests, give any observations from when the change is made until equilibrium has been re-established and, in each case, give an explanation for your answer.

	Observations	Explanation
Test 1 A few mL of a concentrated solution of bromine are mixed into the solution.	**Colour becomes darker reddish brown initially ✓** **Then fades slightly ✓** (one mark for overall darker)	**The addition of Br_2 leads to an increase in $[Br_2]$ hence the darker colour initially ✓** **Since $[Br_2]$ is increased, $rate_{fwd} > rate_{rev}$ until a new equilibrium is established, therefore system shifts right - the colour fades as $[Br_2]$ decreases. ✓**
Test 2 A few mL of water is added to the solution.	**Colour becomes paler ✓** **Then goes darker ✓** (one mark for overall lighter/paler)	**Addition of water causes the concentration of all solute particles to decreases, hence, since $[Br_2]$ decreases, the colour lightens. ✓** **Since 3:2 ratio for aqueous species, $rate_{rev} > rate_{fwd}$ until a new equilibrium is established, therefore system shifts left – the colour darkens as $[Br_2]$ increases. ✓**
Test 3 The solution is heated from room temperature to 60°C.	**Becomes paler / lighter ✓**	**Temperature increase favours the reaction which absorbs energy (the endothermic reaction) which is the forward reaction in this case. ✓** **Since equilibrium has shifted right, $[Br_2]$ decreases and the colour fades. ✓**

(4 + 4 + 3 = 11 marks)

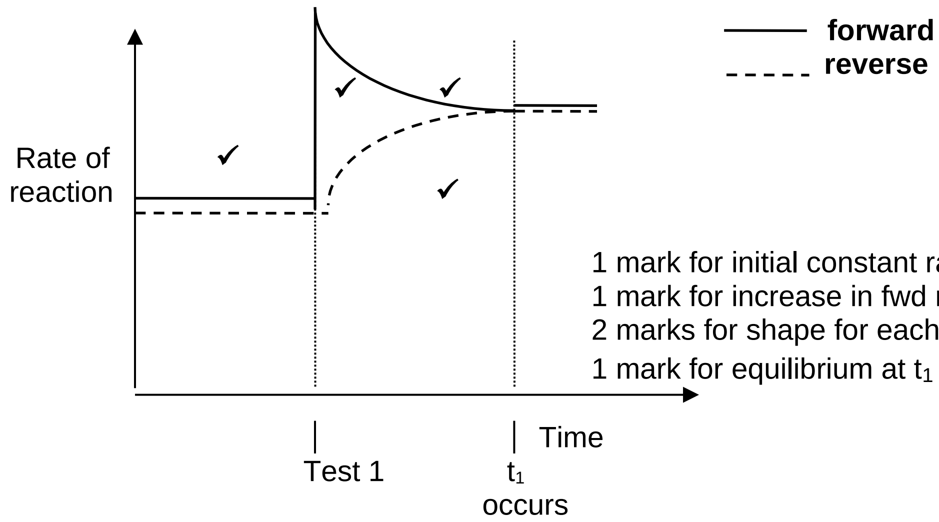
(b) Write the expression for the equilibrium constant (K) for reaction:

(1 mark)

$$K = \frac{[Br^-]\,[OBr^-]}{[Br_2]\,[OH^-]^2}$$

(c) Sketch graphs of what happens to the rate of the **forward** and **reverse** reactions for **test 1,** from before the change is made until equilibrium has been re-established at **t_1.** Clearly indicate which graph represents the forward reaction and which represents the reverse reaction.

(5 marks)



1 mark for initial constant rates for both
1 mark for increase in fwd reaction
2 marks for shape for each
1 mark for equilibrium at t_1

(d) Explain (with reference to Kinetic and Collision Theory when appropriate) why the rate of the **FORWARD** reaction changes in the way shown in your sketch, from before test 1 to t_1.

(5 marks)

Before test 1:
Since the reaction is at equilibrium and [reactants] remains constant, the rate of the forward reaction is constant. ✓

At test 1:
With increasing [Br_2], the rate of the reaction increases due the increase in the frequency of collisions . ✓

Between test 1 and t_1
The rate of the forward reaction decreases as [reactants] decrease over time, ✓
since forward rate is greater than reverse rate between equilibria ✓

At t_1:
The system is at equilibrium again, [reactants] remains constant and therefore forward rate is constant ✓

End of Test