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VCE Chemistry ¾
Le Chatelier's Principle [2.8]
Homework Solutions

Admin Info & Homework Outline:

Student Name	
Questions You Need Help For	
Compulsory Questions	Pg 2-Pg 13
Supplementary Questions	Pg 14-Pg 22

Section A: Compulsory Questions (43.5 Marks)

Sub-Section [2.8.1]: Explain the Effects of Addition/Removal of Substances or Pressure/Volume Changes on Equilibrium System

Question 1 (2.5 marks)

Maanya is experimenting with changes made to a sealed reaction vessel containing the following reaction:

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

In the table below, predict the direction in which the equilibrium system will shift (using a left or right arrow, or a dash for no change) when the following changes are made.

S. no	Change	Shift
a.	$N_2(g)$ is added.	→
b.	$H_2(g)$ is removed.	←
c.	$NH_3(g)$ is added.	←
d.	Volume of the vessel is halved.	→
e.	100 ml of water is added.	–

Space for Personal Notes

Question 2 (2 marks)

Melody is interested in the following reaction.

$$CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$$

Explain the direction in which the equilibrium system will shift if she removes a small amount of ethanoic acid (CH_3COOH).

If ethanoic acid is removed, ethanoic acid (Reactant) concentration will decrease. According to Le Châtelier's Principle, the system will partially oppose the change by increasing the concentration of ethanoic acid (1). Hence, the backward reaction is favoured (2).

Question 3 (3 marks)

Michelle sets up the following reaction in a 2 L vessel, which is half full, and allows it to reach equilibrium.

$$Cu^{2+}(aq) + 4NH_3(aq) \rightleftharpoons \{Cu(NH_3)_4]^{2+}(aq)$$

Given that she adds 500 mL of water to the reaction, explain whether the rate of the forward reaction will be greater, equal to or less than the rate of the reverse reaction.

If 500 ml of water is added, the concentration of all species will decrease (1). According to Le Châtelier's Principle, the system will partially oppose by shifting to the side of the equation with greater particles (2). Hence, the backward reaction is favored, meaning that the rate of the forward reaction will be LESS than the rate of the backward reaction (3).

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Sub-Section: Graph Effects of Addition/Removal of Substances or Pressure/Volume Changes on Equilibrium System

Question 4 (2 marks)

Shruti allows the following reaction to reach equilibrium.

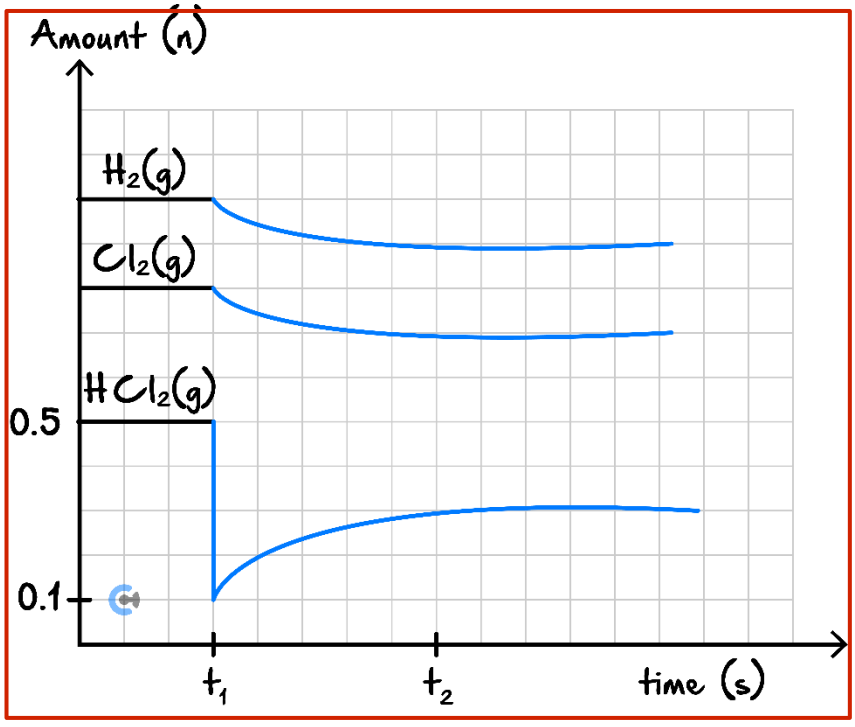
$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

She removes 0.40 mol of HCl from the vessel.

a. Determine the direction in which the system shifts.

→

b. Graph how the amounts of the species change with time. Assume HCl is removed at t_1, and equilibrium is re-established at t_2. (2 marks)



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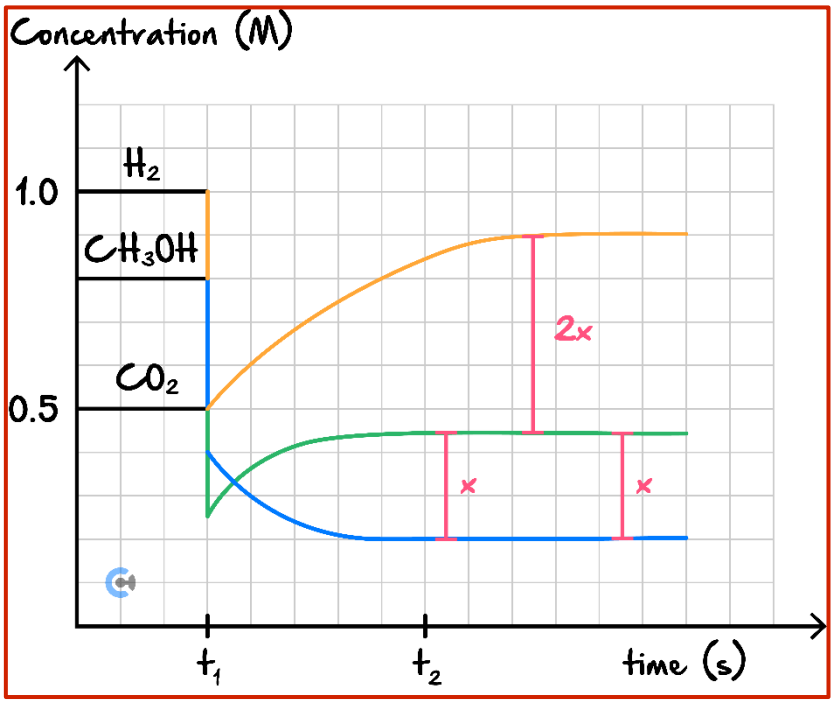
Question 5 (4 marks)

The following reaction is allowed to reach equilibrium in a 2.0 L vessel.

$$CO_2(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

Bhavya doubles the volume of the container.

a. Graph how the concentrations of the species change with time. Assume the volume is doubled at t_1, and equilibrium is re-established at t_2. (2 marks)



b. When the volume is doubled:

i. State the change to the amount of H_2 at t_1. (1 mark)

Stays the same.

ii. State the change to the amount of CO_2 at t_2. (1 mark)

Increases

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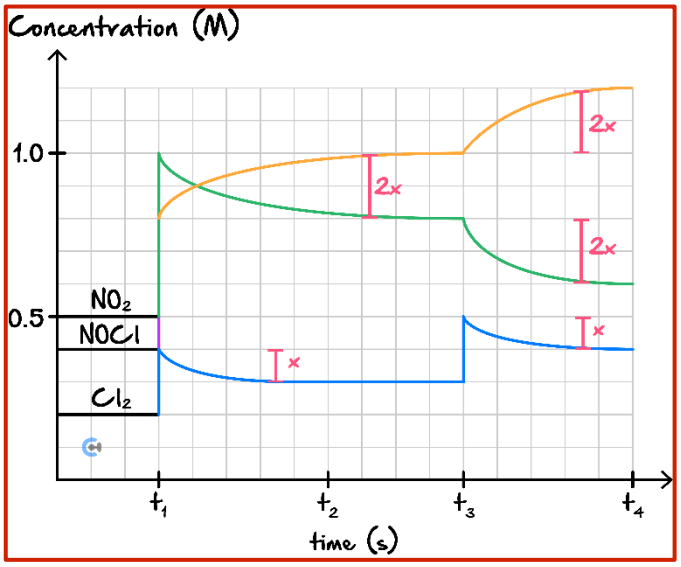
Question 6 (8 marks)

The following reaction is allowed to reach equilibrium in a 3.0 L container.

$$2NO_2(g) + Cl_2(g) \rightleftharpoons 2NOCl(g)$$

Catherine halves the volume of the container.

a. Graph how the concentrations of the species change with time. Assume the volume is halved at t_1, and equilibrium is re-established at t_2. (2 marks)



Catherine then adds 0.3 mol of chlorine gas (Cl_2) to the system.

b. Graph how the concentration of the species changes with time. Assume the chlorine gas is added at t_3, and equilibrium is re-established at t_4. (2 marks)

$(C = 0.3/1.5 = 0.2\ M)$

c. Compared to at t_1, at t_4:

i. Amount of NO_2 has: (1 mark)

Increased Stay the same Decreased

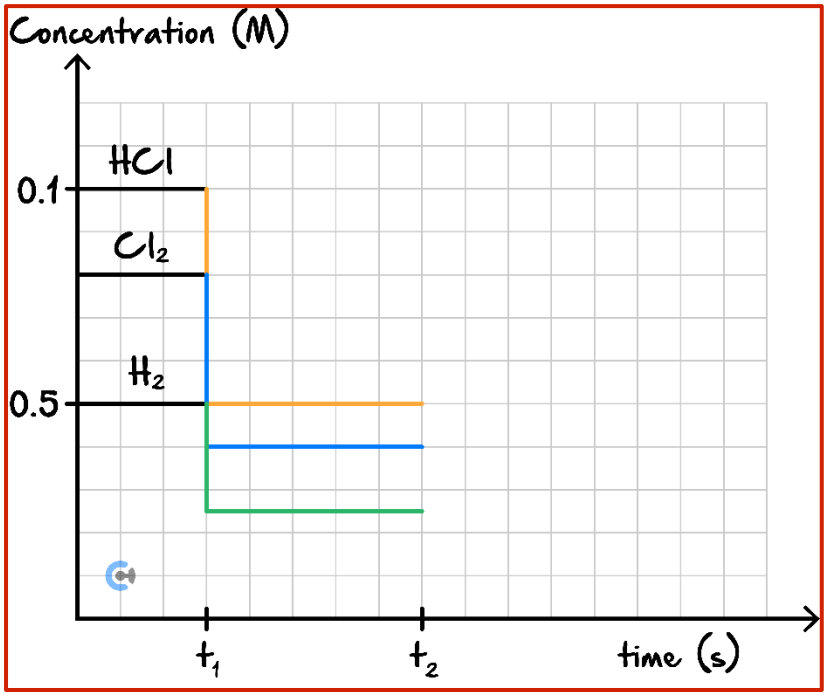
ii. Concentration of NOCl: (1 mark)

Increased Stay the same Decreased

d. In a separate setup, Catherine allows the following reaction to reach equilibrium.

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

She then doubles the volume of the vessel. Graph how the concentration of the species changes with time. Assume the volume is doubled at t_1 and equilibrium is re-established at t_2. (2 marks)



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Sub-Section: Apply Partial Opposition During Equilibrium to the Effects on Amount, Concentration & Colour of Substance

Question 7 (3 marks)

Claire sets up the following reaction, allowing it to reach equilibrium.

$$SO_2(g) + Br_2(g) \rightleftharpoons SO_2Br_2(g)$$

Claire adds 0.2 mol of Br_2 to the system, given that the colour of Br_2. Explain what happens to the intensity of the solution when equilibrium is re-established.

When Claire adds Br_2, it's concentration increases, meaning the brown intensity increases (1). According to Le Chatlier's principle, the system will attempt to partially oppose the change by favouring the forwards reaction (2). This will cause the intensity to fade, but still remain darker than prior to the addition of the substance as there still is a net increase in Br_2 concentration (3).

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Question 8 (6 marks)

Consider the following reaction where substance B is dark blue.

$$2A(aq) + B(aq) \leftrightarrow C(aq) + D(aq)$$

a. If A is added, state the change: (2 marks)

i. In intensity of blue.

Increased Stay the same Decreased

ii. In the amount of A.

Increased Stay the same Decreased

iii. In the amount of C.

Increased Stay the same Decreased

b. If B is removed, state the change: (2 marks)

i. In intensity of blue.

Increased Stay the same Decreased

ii. In the amount of A.

Increased Stay the same Decreased

iii. In the amount of C.

Increased Stay the same Decreased

c. If water is added, state the change: (2 marks)

i. In intensity of blue.

Increased Stay the same Decreased

ii. In the amount of A.

Increased Stay the same Decreased

iii. In the amount of C.

Increased Stay the same Decreased

Question 9

The following reaction is allowed to reach equilibrium. $Co^{2+}(aq)$ is pink in colour.

$$Co^{2+}(aq) + 4Cl^{-}(aq) \rightleftharpoons [CoCl_4]^{2-}(aq)$$

Place ticks in appropriate boxes to indicate the effect of each change once a new equilibrium has been established.

Change at Equilibrium	**Colour at New Equilibrium Compared with Initial Equilibrium**		**$[Cl^-]$ at New Equilibrium Compared with Initial Equilibrium**	
	Less Pink	More Pink	Decreased	Increased
Sample 1: 1 drop of $AgNO_3$ solution is added, forming an AgCl precipitate		✓	✓	
Sample 2: 1 drop of NaCl solution is added	✓			✓
Sample 3: A large volume of water is added	✓		✓	
Sample 4: A drop of K_2Co is added		✓	✓	

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Sub-Section: The 'Final Boss'

Question 10 (13 marks)

Commercially, the Haber process is the most viable method of synthesising ammonia gas. Albeit, sometimes the following reaction can be used instead as an alternative.

$$2NO(g) + 3H_2(g) \rightleftharpoons 4NH_3(g) + O_2(g)$$

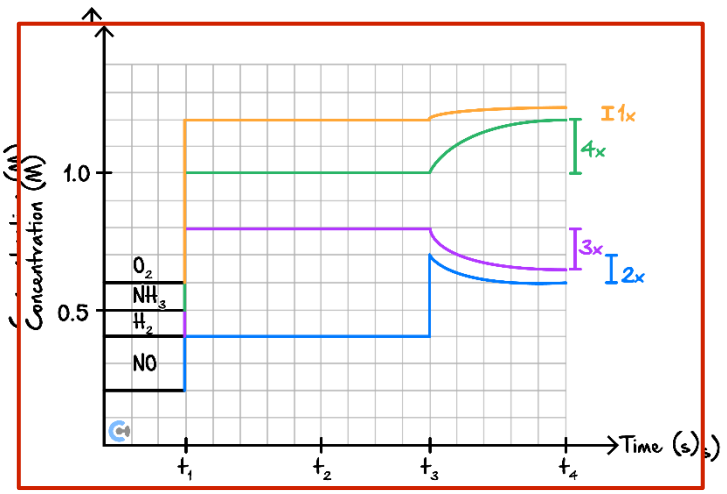
Celeste, interested in the reaction, sets up an experiment in a 4.0 L vessel and allows the reaction to reach equilibrium. She also adds substance X in excess amounts, which is known to produce a red colour in the presence of hydrogen gas.

a. She changes the vessel volume to 2.0 L.

i. Explain what happens to the intensity of the solution from the moment of volume change (t_1) to when equilibrium is re-established (t_2). (3 marks)

When Celeste changes the volume to 2.0 L, volume halves, meaning concentration of all species will double. This means that the intensity of red will increase also at t_1 (1). According to Le Chatlier's principle, the system will attempt to partially oppose the change by favouring side with a greater number of particles (2). As both sides have the same number of particles, neither reaction is favoured and hence, the colour intensity will remain at a higher intensity (3).

ii. Hence, graph how the concentrations of the species change with time. Assume the volume changes at t_1, and equilibrium is re-established at t_2. (2 marks)



b. She then adds 0.6 mol of NO(g) to the vessel.

i. Explain which direction the system will shift following this change. (2 marks)

When NO is added, the concentration of NO increases. According to Le Chatelier's principle, the system will partially oppose the change, by decreasing the concentration of NO (1). This is done by favouring the forwards reaction (2).

ii. Hence, graph how the concentrations of the species change with time on the graph above. Assume NO is added at t_3, and equilibrium is re-established at t_4. (2 marks)

$C = (0.6/2) = 0.3$

d. Hence, compared to t_1, at t_4: (2 marks)

i. Concentration of NO has:

Increased Stay the same Decreased

ii. Concentration of H_2:

Increased Stay the same Decreased

iii. Amount of H_2:

Increased Stay the same Decreased

iv. Intensity of red colour:

Increased Stay the same Decreased

c. Celeste finally adds 100 ml of water to the system. Explain the direction in which the system will shift. (2 marks)

No shift (1). Adding water doesn't change volume as all species are gaseous. (2)

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Section B: Supplementary Questions (33.5 Marks)

Sub-Section [2.8.1]: Explain Effects of Addition/Removal of Substances or Pressure/Volume Changes on Equilibrium System

Question 11 (2.5 marks)

Precious is experimenting with changes made to a sealed reaction vessel containing the following reaction:

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

In the table below, predict the direction in which the equilibrium system will shift (using a left or right arrow, or a dash for no change) when the following changes are made:

S. no	Change	Shift
a.	$N_2(g)$ is removed.	←
b.	$H_2(g)$ is added.	→
c.	$NH_3(g)$ is removed.	→
d.	Volume of the vessel is doubled.	←
e.	100 ml of water is removed.	–

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Question 12 (2 marks)

Melody is interested in the following reaction:

$$CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$$

Explain the direction in which the equilibrium system will shift if she removes a small amount of ethanoic acid (CH_3COOH).

If ethanoic acid is removed, ethanoic acid (Reactant) concentration will decrease. According to Le Châtelier's Principle, the system will partially oppose the change by increasing the concentration of ethanoic acid (1). Hence, the backward reaction is favoured (2).

Question 13 (3 marks)

Shiven sets up the following reaction in a 2.0 L vessel, which is half full, and allows it to reach equilibrium.

$$Fe^{3+}(aq) + SCN^-(aq) \rightleftharpoons FeSCN^{2+}(aq)$$

Given that Shiven adds 1000 mL of water to the reaction, explain whether the rate of the forwards reaction will be greater, equal to, or less than the rate of the reverse reaction.

If 1000 ml of water is added, the concentration of all species will decrease (1). According to Le Châtelier's Principle, the system will partially oppose by shifting to the side of the equation with greater particles (2). Hence, the backward reaction is favoured, meaning that the rate of the forward reaction will be LESS than the rate of the backward reaction (3).

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Question 14 (4 marks)

Olivia observes the reaction shown below:

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq)$$

She is informed that the $FeSCN^{2+}$ ions produced a distinct red colour whilst all other ions in the system are colourless. At equilibrium, she finds there is 1.5 mol of Fe^{3+}, 1.0 mol of SCN^{-} and 0.75 mol of $FeSCN^{2+}$ present within the 1.0 L vessel.

Olivia adds 0.5 mol of $Fe^{3+}(aq)$ to the system.

When adding iron (III) ions to the solution, she notices that the solution within the vessel increases in intensity to a darker red. Explain this observation.

By adding Fe^{3+} to the system, the concentration of the reactants increases (1). According to Le Chatelier's principle, the system will partially oppose the change by decreasing the concentration of Iron ions (2). This results in the forward reaction being favoured (3), whereby the concentration of $FeSCN^{2+}$ ions increase causing an increase in intensity of the red colour of the solution (4).

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Sub-Section: Graph Effects of Addition/Removal of Substances or Pressure/Volume Changes on Equilibrium System

Question 15 (3 marks)

Merna allows the following reaction to reach equilibrium.

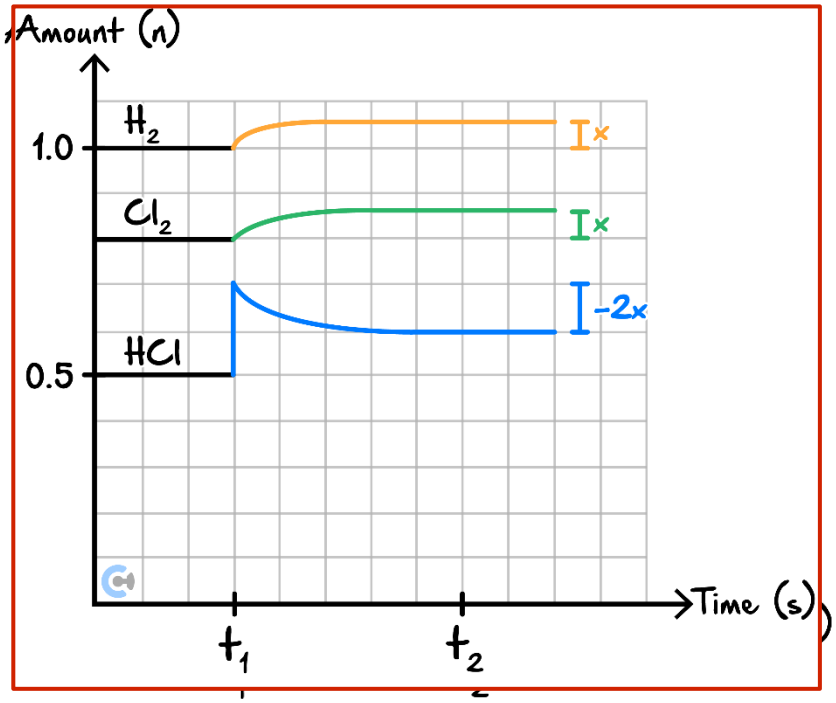
$$H_2(g) + Cl_2(g) \rightarrow 2HCL(g)$$

She adds 0.20 mol of HCl from the vessel.

a. Determine the direction in which the system shifts. (1 mark)

←

b. Graph how the amounts of the species change with time. Assume HCl is removed at t_1, and equilibrium is re-established at t_2. (2 marks)



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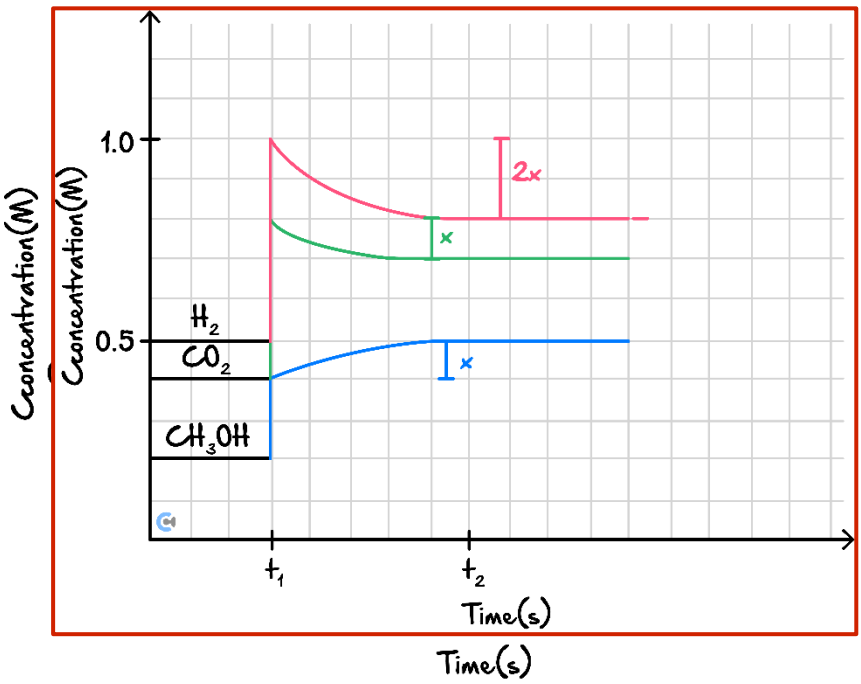
Question 16 (4 marks)

The following reaction is allowed to reach equilibrium in a 2.0 L vessel.

$$CO_2(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

Katie halves the volume of the container.

a. Graph how the concentrations of the species change with time. Assume the volume is doubled at t_1, and equilibrium is re-established at t_2. (2 marks)



b. When the volume is halved:

i. State the change in the amount of H_2 at t_1. (1 mark)

Stays the same.

ii. State the change in the amount of CO_2 at t_2. (1 mark)

decreases

Space for Personal Notes

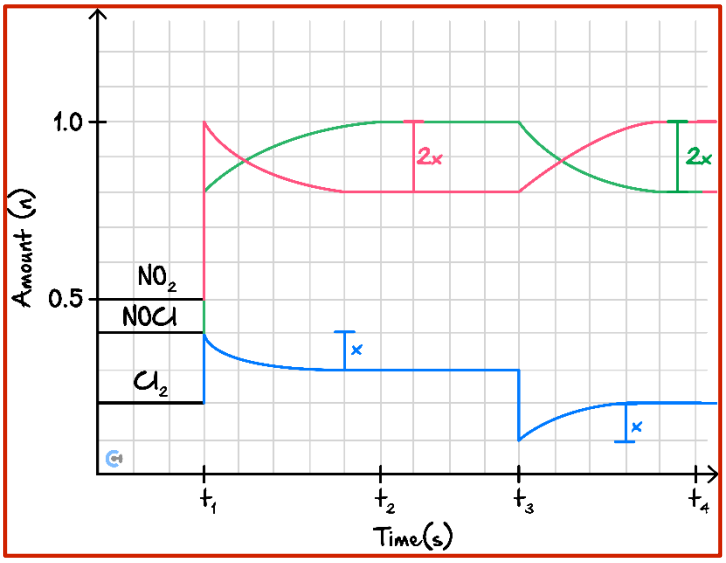
Question 17 (6 marks)

The following reaction is allowed to reach equilibrium in a 3.0 L container.

$$2NO_2(g) + Cl_2(g) \rightleftharpoons 2NOCL(g)$$

Nour halves the volume of the container.

a. Graph how the concentrations of the species change with time. Assume the volume is halved at t_1, and equilibrium is re-established at t_2. (2 marks)



Nour then removes 0.3 mol of chlorine gas (Cl_2) from the system.

b. Graph how the concentration of the species changes with time. Assume the chlorine gas is added at t_3, and equilibrium is re-established at t_4. (2 marks)

$(C = 0.3/1.5 = 0.2\ M)$

c. Compared to t_1, at t_4:

i. Amount of NO_2: (1 mark)

Increased Stays the same Decreased

ii. Concentration of NOCl: (1 mark)

Increased Stays the same Decreased

Sub-Section: Apply Partial Opposition during Equilibrium to the Effects on Amount, Concentration & Colour of Substance

Question 18 (3 marks)

Claire sets up the following reaction, allowing it to reach equilibrium.

$$SO_2(g) + Br_2(g) \rightleftharpoons SO_2Br_2(g)$$

Claire removes 0.2 mol of Br_2 from the system. Given that the colour of Br_2, explain what happens to the intensity of the solution when equilibrium is re-established.

When Claire removes Br_2, its concentration decreases, meaning the brown intensity decreases (1). According to Le Chatlier's principle, the system will attempt to partially oppose the change by favouring the backwards reaction (2). This will cause the intensity to increase, but still remain lighter than prior to the removal of the substance as there still is a net decrease in Br_2 concentration (3).

Question 19 (6 marks)

Consider the following reaction where substance B is dark blue.

$$2A(aq) + B(aq) \leftrightarrow C(aq) + D(aq)$$

a. If A is removed, state the change: (2 marks)

i. In the intensity of blue:

Increased Stay the same Decreased

ii. In the amount of A:

Increased Stay the same Decreased

iii. In the amount of C:

Increased Stay the same Decreased

b. If B is added, state the change: (2 marks)

i. In the intensity of blue:

Increased Stay the same Decreased

ii. In the amount of A:

Increased Stay the same Decreased

iii. In the amount of C:

Increased Stay the same Decreased

c. If water is added, state the change: (2 marks)

i. In the intensity of blue:

Increased Stay the same Decreased

ii. In the amount of A:

Increased Stay the same Decreased

iii. In the amount of C:

Increased Stay the same Decreased

Space for Personal Notes

Question 20

The following reaction is allowed to reach equilibrium. $Co^{2+}(aq)$ is pink in colour.

$$Co^{2+}(aq) + 4Cl^{-}(aq) \rightleftharpoons [CoCl_4]^{2-}(aq)$$

Place ticks in appropriate boxes to indicate the effect of each change once a new equilibrium has been established.

Change at Equilibrium	**Colour at New Equilibrium Compared with Initial Equilibrium**		**$[CoCl_4]^{2-}$ at New Equilibrium Compared with Initial Equilibrium**	
	Less Pink	More Pink	Decreased	Increased
Sample 1: 1 drop of $AgNO_3$ solution is added, forming a AgCl precipitate.		✓	✓	
Sample 2: 1 drop of NaCl solution is added.	✓			✓
Sample 3: A large volume of water is removed.		✓		✓
Sample 4: A drop of K_2Co is added.		✓		✓

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