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VCE Chemistry ¾
Le Chatelier's Principle [0.19]
Workshop

Error Logbook:

New Ideas/Concepts	Didn't Read Question
Pg / Q #: _____ Notes: Qc-time graph	Pg / Q #: _____ Notes:
Algebraic/Arithmetic/ Calculator Input Mistake	**Working Out Not Detailed Enough**
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Section A: Recap

Learning Objective: [2.9.1] - Explain the effects of temperature, inert gas or catalyst on equilibrium system

- Inert Gas on Equilibrium Position:
- Temperature:

Change to System	System's Respond (Le Chatelier's Effect)	Reaction Favoured
Increase in Temperature	[Increase] / [Decrease] temperature	[Endothermic] / [Exothermic]
Decrease in Temperature	[Increase] / [Decrease] temperature	[Endothermic] / [Exothermic]

- Equilibrium Constant (K_c):
- Sample Response:

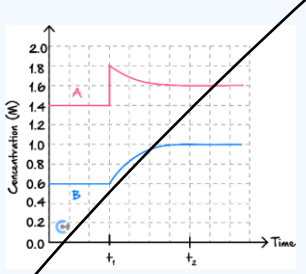
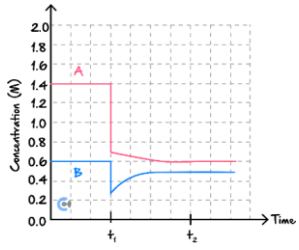
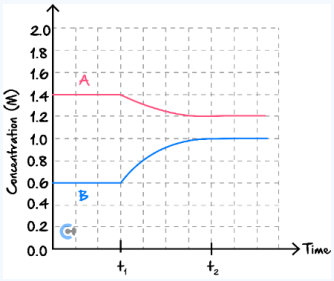
1. Temp is increased/decreased.
2. According to Le Chatelier's Principle, system _____ the change by increasing/decreasing temperature.
3. Favours endothermic/exothermic forwards/backwards reaction.

Space for Personal Notes

Learning Objective: [2.9.2] - Graph effects of temperature, inert gas catalyst on equilibrium system

- Temperature: [Has] / [Doesn't have] initial spike.
- Inert gas: Has _____ on equilibrium graph.
- In a rate-time graph
  - If the rate overall has increased, the temperature has [increased] / [decreased].
  - If the rate overall has decreased, the temperature has [increased] / [decreased].

Learning Objective: [2.9.3] - Find the change made to the system from the equilibrium graph

Graph	Change
	[Addition or removal of species] / [Pressure or volume change] / [Temperature change]
	[Addition or removal of species] / [Pressure or volume change] / [Temperature change]
	[Addition or removal of species] / [Pressure or volume change] / [Temperature change]

Learning Objective: [2.9.4] - Find equilibrium constant changes due to temperature

- During temperature change, if reaction shifts:

Forwards Overall	Reverse Overall
K_c value: [Increases] / [Remains constant] / [Decreases]	K_c value: [Increases] / [Remains constant] / [Decreases]

Learning Objective: [2.9.5] - Find optimum operating conditions in all circumstances such as the rate-yield conflict

- **Rate-Yield Conflict**
  - Example #1: $\mathrm{A} + \mathrm{B} \rightleftharpoons \mathrm{C} \quad \Delta H = -100\ kJ/mol$

Condition	Pressure	Temperature
Rate	[High] / [Low]	[High] / [Low]
Equilibrium Yield	[High] / [Low]	[High] / [Low]
Overall	[High] / [Medium] / [Low]	[High] / [Medium] / [Low]

  - Example #2: $\mathrm{A} + \mathrm{B} \rightleftharpoons \mathrm{C} + 2\mathrm{D} \quad \Delta H = +100\ kJ/mol$

Condition	Pressure	Temperature
Rate	[High] / [Low]	[High] / [Low]
Equilibrium Yield	[High] / [Low]	[High] / [Low]
Overall	[High] / [Medium] / [Low]	[High] / [Medium] / [Low]

- To maximise rate, always _____.
- To maximise yield, always _____.
- Green Chemistry Principles: _____.

Question 1 Walkthrough.

Iron (III) ions can react with thiocyanate (SCN^-) in the following manner:

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

It is known that Silver ions $(Ag^+(aq))$ react with the thiocyanate $(SCN^-(aq))$ to form a precipitate, AgSCN(s).

Explain the direction in which the equilibrium system will shift when Silver ions are added.

1. As Ag^+ is added, it reacts w/ SCN^-, effectively decreasing $[SCN^-]$
2. According to Le Chatelier's Principle, system partially opposes change by increasing $[SCN^-]$ back up.
3. Reverse reaction is favoured.

Space for Personal Notes

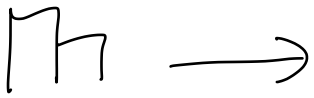
Question 2 Walkthrough.

Sulphur dioxide (SO_2) can react with Chlorine gas (Cl_2) in the following manner:

$$SO_2(g) + Cl_2(g) \rightleftharpoons SO_2Cl_2(g)$$

Draw an arrow, indicate the direction in which the system will shift in response if:

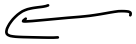
a. Chlorine gas is added.



b. Sulphur dioxide is removed.

c. Volume is increased.

split



d. Pressure is increased.

Space for Personal Notes

Question 3 Walkthrough.

split

Consider the following reaction, which is initially at equilibrium, before the volume is doubled.

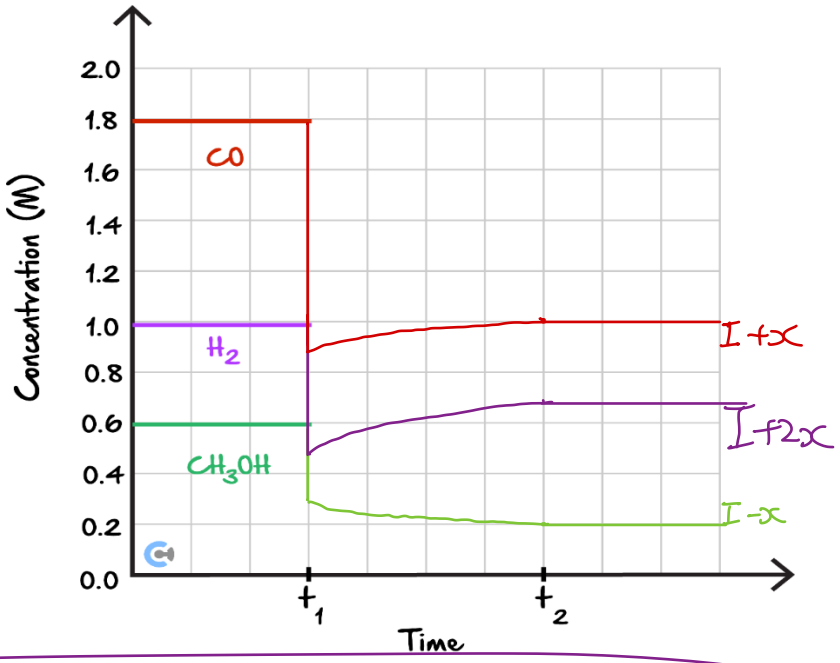
$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

3 1

a. State the direction in which the equilibrium system will shift overall in response.

← reverse

b. Show how the concentrations of each substance will change as a result on the graph provided below, assuming that the change is made at t_1 and equilibrium is re-established at t_2.



c. The equilibrium yield of hydrogen gas is to be investigated.

i. State and explain how the **concentration** of hydrogen gas changes overall.

decreases

ii. State and explain how the **amount** of hydrogen gas changes overall.

increases

Sub-Section: Reaction Quotient

Recap!

Active Recall: For the following equilibrium mixture, what is the expression for the equilibrium constant?

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

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

Active Recall: What is the symbol for the reaction quotient and the equilibrium constant?

Reaction Quotient	Equilibrium Constant
Q_c	K_c

Active Recall: What is the difference between the reaction quotient and the equilibrium constant?

Reaction Quotient	Equilibrium Constant
any point in time.	at equilibrium

Equilibrium Yield

- **Definition**: The amount of substance present at equilibrium.

Exploration: Reaction Quotient Value (Q_c)

- Consider the following system which is Initially at equilibrium.

$$\mathbf{A + 2B \rightleftharpoons C + D}$$

- **Equilibrium Constant:**

$$K_c = \frac{[C][D]}{[A][B]^2}$$

- **Given**: Equilibrium constant, K_c is known to be $1.0\ M^{-1}$ at a certain temperature.
- **Scenario #1:** The concentration of all substances is $1.0\ M$ in a $1.00\ L$ reaction vessel.
  - **Reaction quotient value (Q_c):**

$$Q_c = \frac{[C][D]}{[A][B]^2} = \frac{1 \times 1}{1 \times 1^2} = 1$$

  - **Q_c compared to K_c:**

$$Q_c = K_c$$

  - **At Equilibrium?** [Yes] / [No]

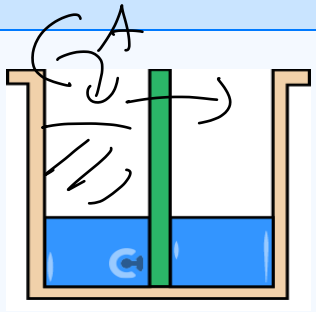
- **Scenario #2**: Some of the substance A is added, so that only its concentration goes from $1.0\ M$ to $2.0\ M$.
  - **Reaction quotient value (Q_c):**

$$Q_c = \frac{[C][D]}{[A][B]^2} = \frac{1 \times 1}{2 \times 1^2} = \frac{1}{2} = 0.5$$

  - **Q_c compared to K_c:**

$$Q_c \neq K_c$$

  - **At Equilibrium?** [Yes] / [No]
  - **System Shifts:** $Q_c < K_c$ ($0.5 < 1$) ⟶

Using Q_c	Using Water Analogy
$Q_c = \frac{[\text{products}]}{[\text{reactants}]}$	
[Forwards] / [Reverse] reaction favoured.	[Forwards] / [Reverse] reaction favoured.

- **Equation:**

$$\mathbf{A + 2B \rightleftharpoons C + D}$$

- After the **reaction shifts** forward, what happens to:

Reactants $(\mathbf{A + B})$	Products $(\mathbf{C + D})$
[used up] / [is produced]	[used up] / [is produced]
Amount [increases] / [decreases]	Amount [increases] / [decreases]

- **Amount of All Substances:**

Reaction	$\mathbf{A}$	$+$	$\mathbf{2B}$	$\rightleftharpoons$	$\mathbf{C}$	$+$	$\mathbf{D}$
n (initial)	$2.00\ mol$		$1.00\ mol$		$1.00\ mol$		$1.00\ mol$
n (change)	$-0.101\ mol$		$-0.202\ mol$		$+0.101\ mol$		$+0.101\ mol$
n (equilibrium)	$1.899\ mol$		$0.798\ mol$		$1.101\ mol$		$1.101\ mol$

- The equilibrium constant, K_c was $1.0\ M^{-1}$.
- **Reaction quotient value Q_c:**

$$Q_c = \frac{[C][D]}{[A][B]^2} = \frac{1.101 \times 1.101}{1.899 \times 0.798^2} = 1.00$$

- Q_c value compared to the K_c value: $Q_c = K_c$
- Is the system currently at equilibrium? [Yes] / [No]
- Did the equilibrium constant value (K_c) change? [Yes] / [No]

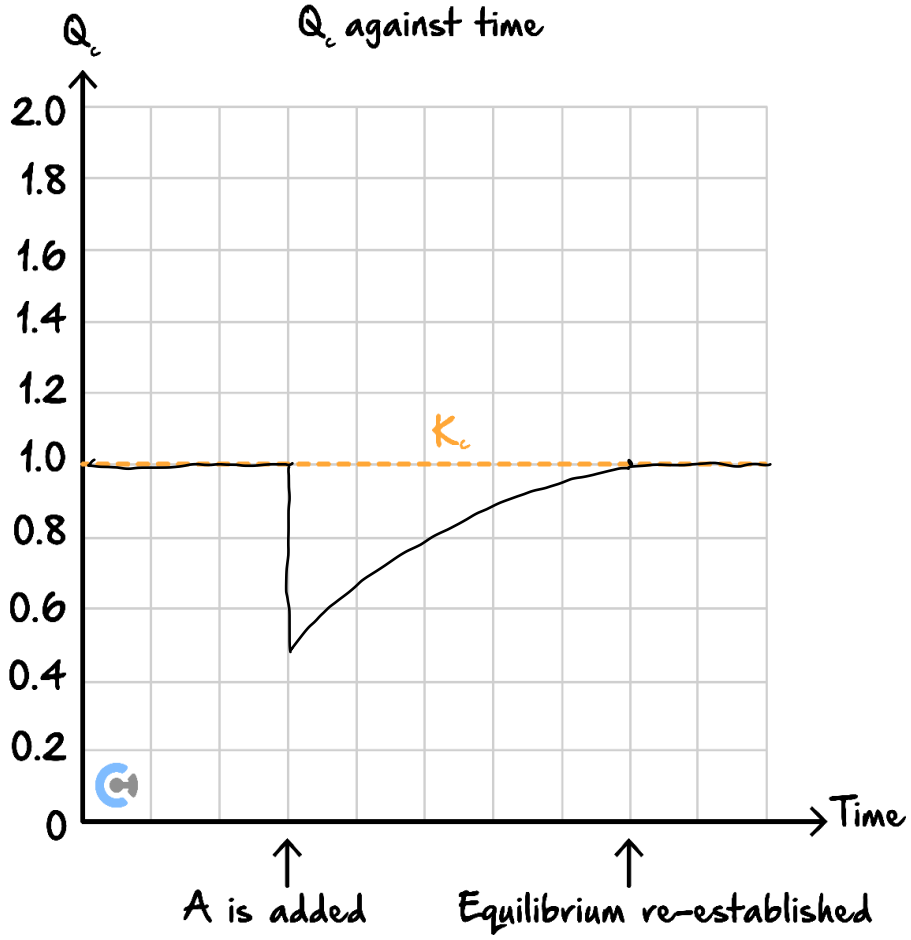
What happened to the reaction quotient (Q_c) value?

Exploration: Reaction Quotient Value (Q_c) in Detail

- The equilibrium constant value, K_c **stays constant** at $1.00\ M^{-1}$ in this example.
- **Changes in Amount:**

Reaction	A + 2B ⇌ C + D				Q_c	Compared to K_c
n (initial)	1.00 mol	1.00 mol	1.00 mol	1.00 mol	$1.00\ M^{-1}$	$Q_c = K_c$
n (1.00 mol A added)	2.00 mol	1.00 mol	1.00 mol	1.00 mol	$0.500\ M^{-1}$	$Q_c \neq K_c$
n (equilibrium)	1.899 mol	0.798 mol	1.101 mol	1.101 mol	$1.00\ M^{-1}$	$Q_c = K_c$

Let's plot how the Q_c value changes with time!



Definition

Changes in Q_c

Title *A*	Title *B*
At beginning	$Q_c = K_c$
After change is made to system	$Q_c \neq K_c$
After equilibrium is re-established	$Q_c = K_c$

- K_c value remains constant throughout.

Let's look at a question together!

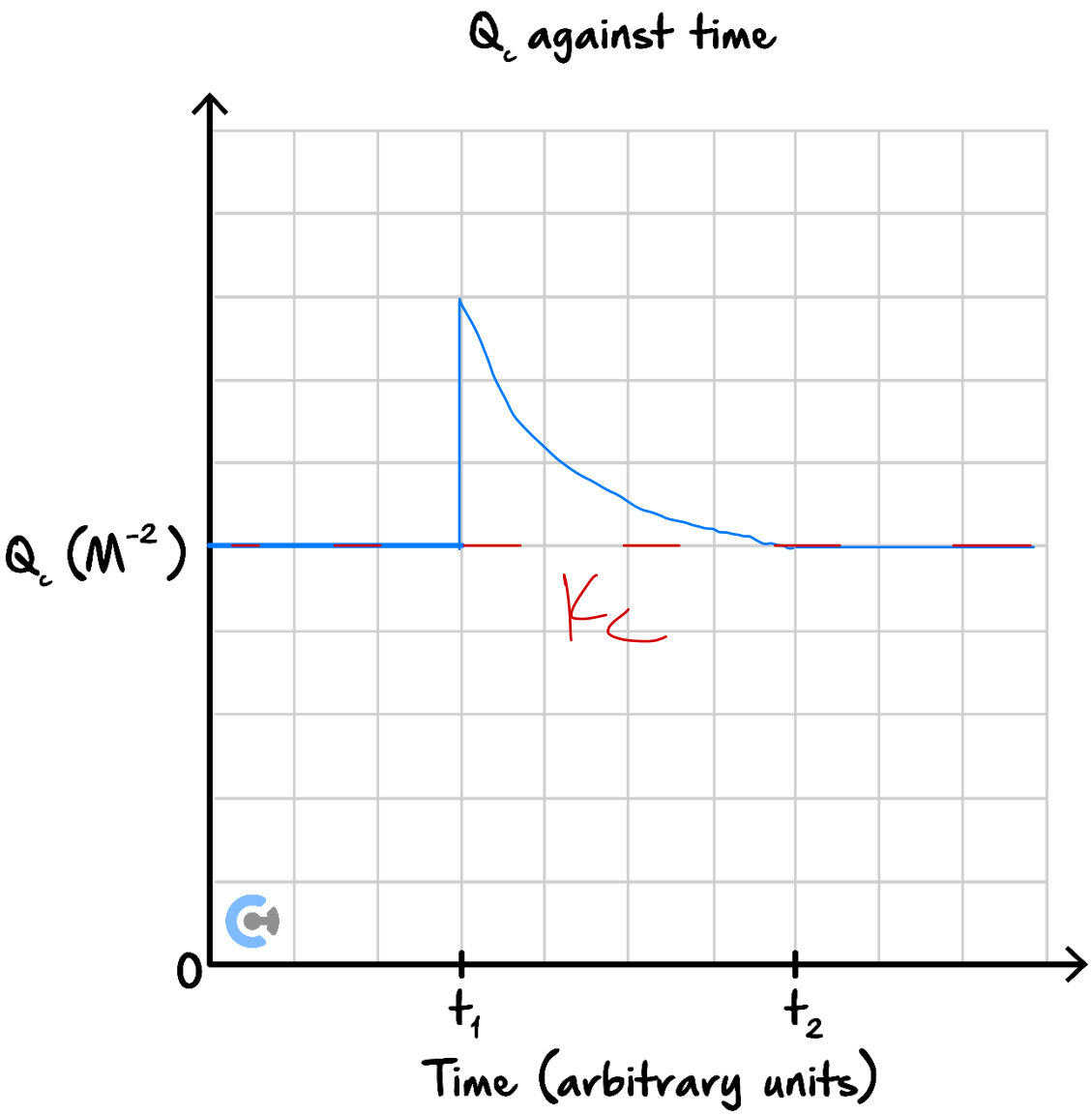
Question 4 Walkthrough.

Consider the following equilibrium mixture with sulphur dioxide and oxygen which can react to form sulphur trioxide.

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

The equilibrium mixture is altered, whereby some sulphur dioxide was removed from the equilibrium mixture at t_1.

Complete the graph on the axes provided below, showing how the reaction quotient value changes over time, given that equilibrium was re-established at t_2. No calculations are required.



Your turn!

Question 5

An equilibrium system involves the second half of steam reforming to produce hydrogen gas.

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

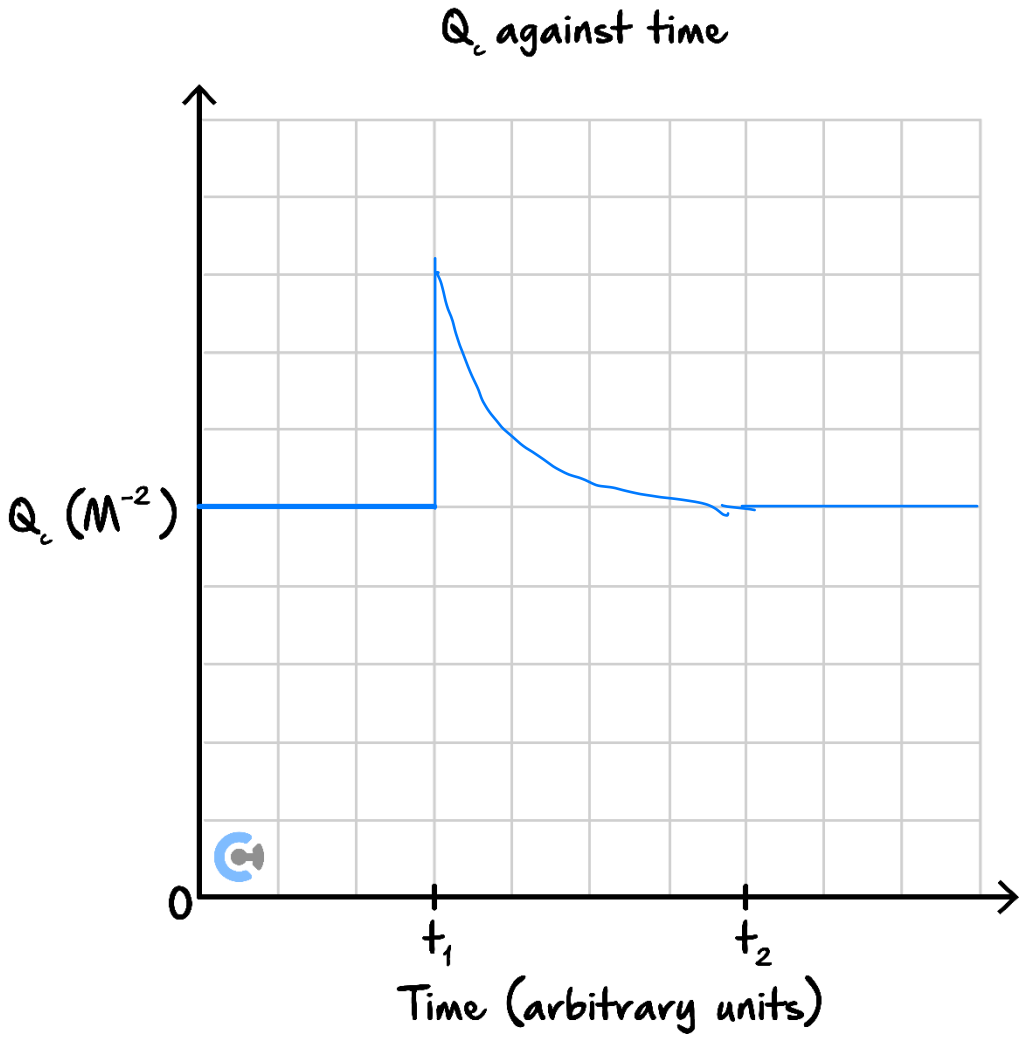
$Q_c = \frac{P \downarrow}{R}$

a. The equilibrium mixture is altered, whereby some hydrogen gas was added to the equilibrium mixture at t_1.

i. State the direction in which the equilibrium system will shift.

left

ii. Complete the graph on the axes provided below, showing how the reaction quotient value changes over time, given that equilibrium was re-established at t_2. No calculations are required.

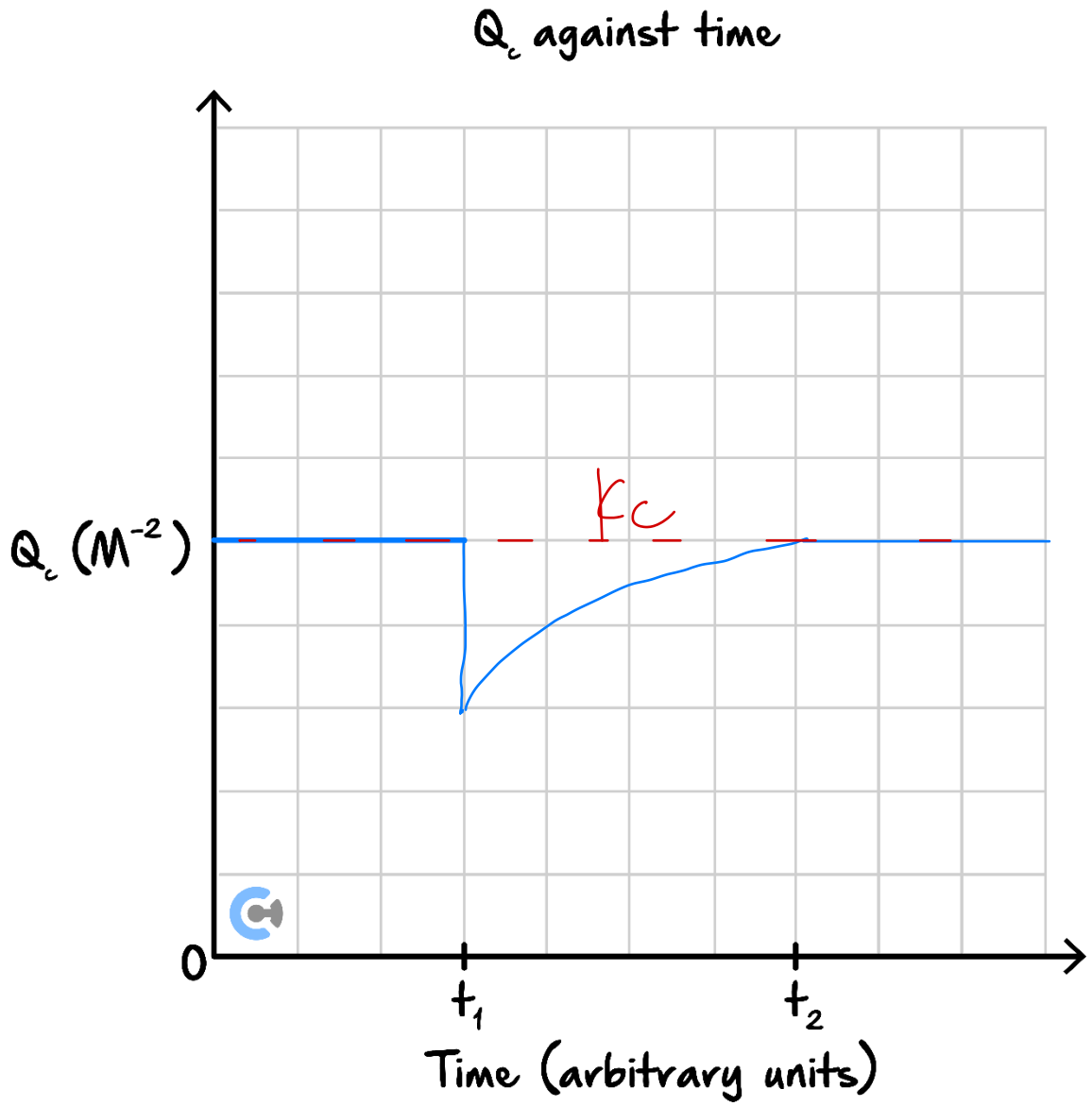


b. The equilibrium mixture is altered, whereby some carbon dioxide was removed from the equilibrium mixture at t_1.

i. Compare the rate of the forwards to reverse rate of reaction as the system re-establishes equilibrium.

forwards rate > reverse rate

ii. Complete the graph on the axes provided below, showing how the reaction quotient value changes over time, given that equilibrium was re-established at t_2. No calculations are required.



iii. State how the equilibrium constant value changes throughout the reaction.

Kc does not change

The following information applies to the two questions that follow.

For the equilibrium system:

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

A change is made to the system, whereby $SO_2(g)$ is removed.

Question 6 Additional Question.

What happens to Q_c immediately after the change is made?

A. Q_c increases.

B. Q_c decreases.

C. Q_c remains the same.

D. It depends on temperature.

Question 7 Additional Question.

What happens to Q_c overall from before the change is made, to after equilibrium has been re-established?

A. Q_c increases.

B. Q_c decreases.

C. Q_c remains the same

D. It depends on temperature.

So far, we've only looked at adding and removing substances.
Let's now have a look at what happens if the overall volume is changed!

Space for Personal Notes

Section B: Warm Up (14 Marks)

INSTRUCTION: 14 Marks. 9 Minutes Writing.

Question 3 (2 marks)

Consider the following reaction:

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

Draw an arrow to indicate the direction the reaction will shift to re-establish equilibrium.

a. More PCl_5 is added. (0.5 marks)

b. More Cl_2 is added. (0.5 marks)

c. PCl_3 is removed. (0.5 marks)

d. PCl_5 is removed. (0.5 marks)

Question 12 (1 mark)

For the equilibrium reaction below:

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

Draw an arrow to indicate the direction the reaction will shift to re-establish equilibrium.

a. Volume is doubled. (0.5 marks)

b. Pressure is increased. (0.5 marks)

Question 13 (1 mark)

For the equilibrium reaction below:

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

Draw an arrow to indicate the direction the reaction will shift to re-establish equilibrium.

c. Hydrogen gas is removed. (0.5 marks)

←

d. Volume is halved. (0.5 marks)

—

Question 14 (3 marks)

Nitrogen and hydrogen gas can react to form ammonia as shown in the equation below:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H < 0$$

Explain how the system which is initially at equilibrium will react if the volume is doubled.

As volume is doubled, concentration overall is halved.
According to Le Chatelier's Principle, the system will partaillly oppose the change by increasing overall concentration back up, favouring the side with more particles. (LHS)
It does so by favouring the reverse reaction, and thus the system shifts to the left

Question 15 (3 marks)

For the reaction below:

$$HCl(aq) \rightleftharpoons H^+(aq) + Cl^-(aq)$$

It is known that AgCl is a precipitate. A solution of silver nitrate, $AgNO_3(aq)$, is added to the system at equilibrium.

Explain the direction that the system will shift in response using Le Chatelier's Principle.

As silver nitrate is added, it reacts with chloride ions to form a precipitate, effectively decreasing concentrations of chloride ions present.

According to Le Chateliet'rs Principle, system will partially oppose the change by increasing concentration of chloride ions, favouring the forwards reaction. System shifts right overall.

Space for Personal Notes

Question 16 (4 marks)

$C = \frac{n}{V} = \frac{0.4}{2} = 0.2M$

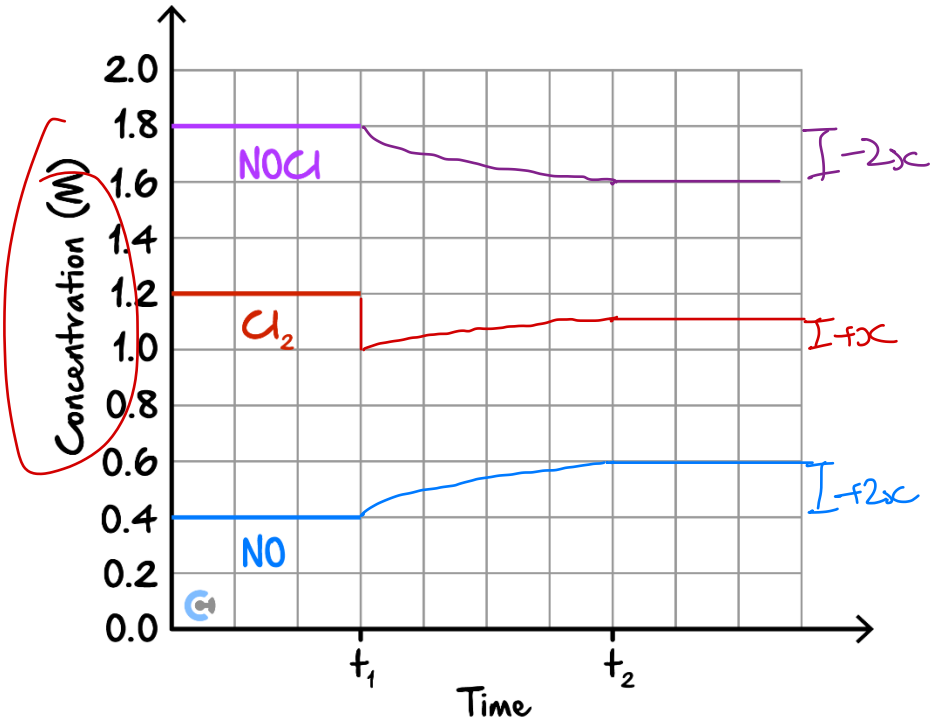
When the system is at equilibrium in a 2.00 L reaction vessel, 0.400 mol of Cl_2 is removed.

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

a. State what happens to the equilibrium yield of NOCl(g). (1 mark)

decreases

b. Graph how the concentration of the species change with time given the initial concentrations. Cl_2 is removed at t_1 and equilibrium is re-established at t_2. (3 marks)



Space for Personal Notes

Section C: Ramping Up (8 Marks)

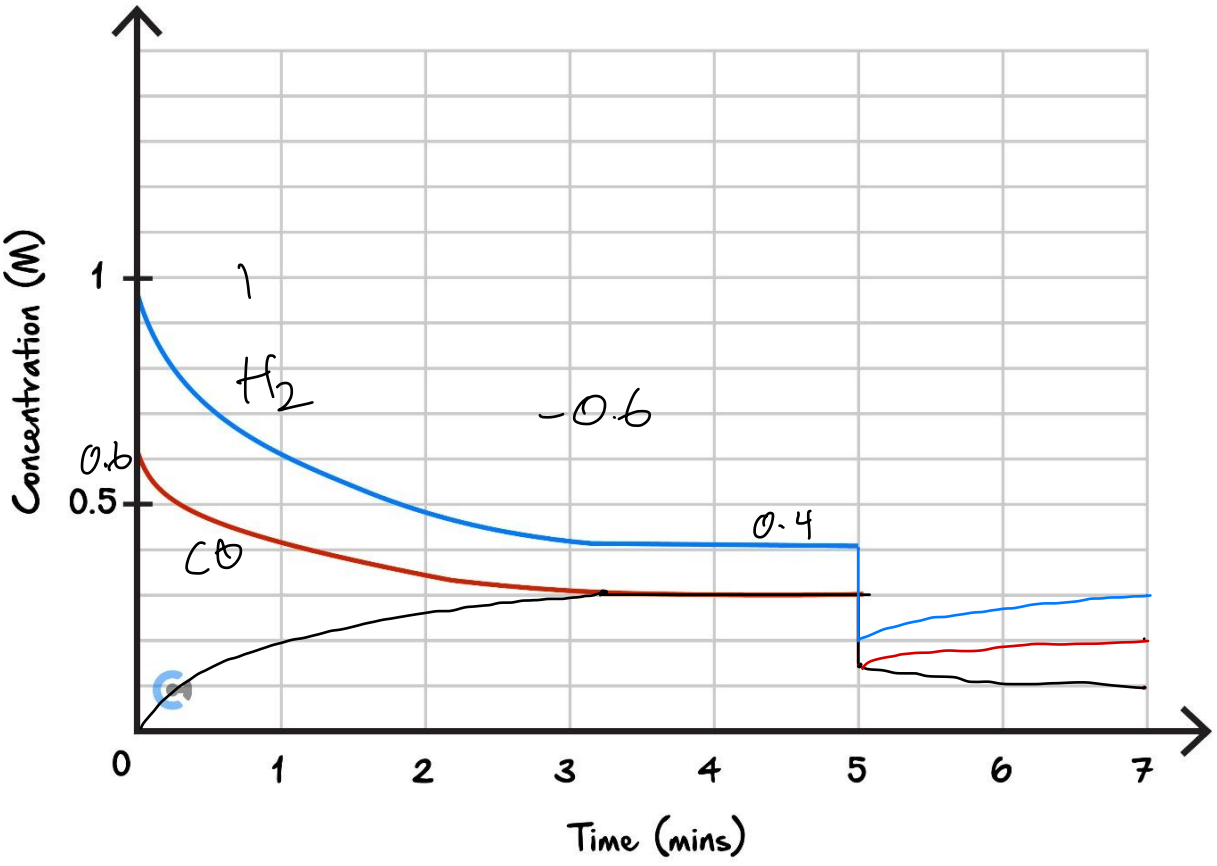
INSTRUCTION: 8 Marks. 6 Minutes Writing.

Question 14 (8 marks)

Methanol can be formed from the reversible reaction between carbon monoxide and hydrogen gases.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \quad \Delta H = 88\ kJ\ mol^{-1}$$

a. Samples of carbon monoxide and hydrogen are added to an empty $2.00\ L$ reactor at 120°C. Their concentrations are shown on the graph below.



i. Label on the axes provided above which graph represents the concentration of hydrogen gas and carbon monoxide gas. (1 mark)

ii. Draw the curve for the concentration of methanol. (1 mark)

b.

i. Calculate a value for K at 120°C for this reaction. (2 marks)

$K_c = \frac{[CH_3OH]}{[CO][H_2]^2} = \frac{0.3}{0.3 \times 0.4^2} = 6.25\ M^{-2}$

$= 6.3\ M^{-2}$

ii. Find the amount, in moles, of methanol gas that is present at equilibrium. (1 mark)

$n(CH_3OH) = cV = 0.3M \times 2L = 0.60mol$

c. At the 5 minutes mark, the volume of the reactor is doubled. Equilibrium is re-established at 7.0 minutes.

i. Complete the graph on the axes provided above to show how the system will react to this change. (2 marks)

ii. State how the amount and concentration of carbon monoxide compare from 4 minutes compared to 7 minutes. (1 mark)

Amount: increases

Concentration: decreases

Space for Personal Notes

Section D: Getting Trickier I (10 Marks)

INSTRUCTION: 10 Marks. 8 Minutes Writing.

Question 15 (10 marks)

The following equilibrium system takes place in solution:

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

The reactants are virtually colourless but the $FeSCN^{2+}$ poses a deep red colour.

a.

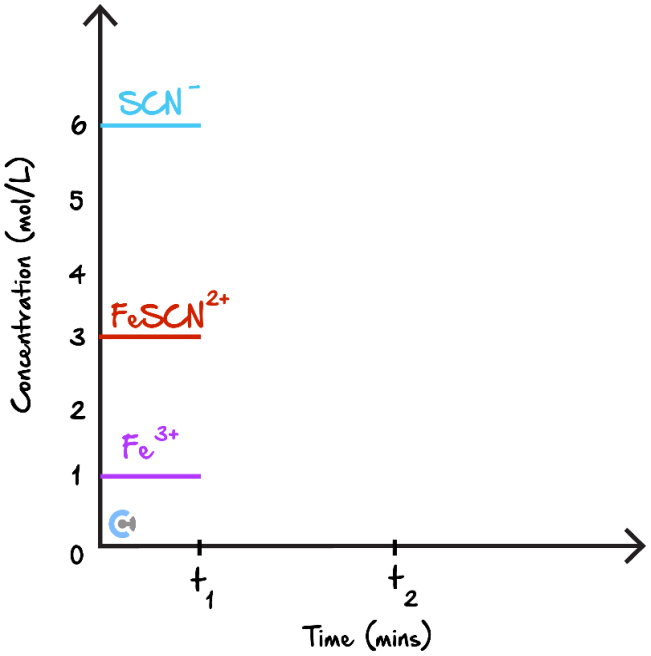
i. If more water were to be added to the system, state the effect on the colour of the system **immediately after** the change is imposed. (1 mark)

less red

ii. As the system **re-establishes equilibrium**, explain what **further changes** will occur to the colour of the solution. (2 marks)

less red

b. If the pre-existing equilibrium is taking place within 100 mL of solution, draw the changes which would take place to the concentrations of each of the species if **a further 200 mL** of water were added to the system. (3 marks)



c. Explain how the colour of the solution would have changed if, rather than adding water:

i. The entire solution was transferred to an empty container which had double the capacity of the original container. (2 marks)

No change

ii. Drops of $FeSCN^{2+}$ are added such that the amount of $FeSCN^{2+}$ now present is **double** that of the amount present before the drops were added. (2 marks)

Section E: Getting Trickier II (11 Marks)

INSTRUCTION: 11 Marks. 10 Minutes Writing.

Question 16 (11 marks)

The following system is being investigated at SLC:

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

It is given that the equilibrium constant value at this temperature is $10\ M^{-2}$. A change is made whereby the pressure of the system is halved by doubling the volume.

a. Explain the direction the system will shift to re-establish equilibrium and state the effect on the **concentration** of each substance. (3 marks)

As volume is doubled, overall concentration and pressure decreased. According to Le Chatelier's Principle, system partially opposes the change by increasing overall concentration and pressure, favouring the side with more particles. It does so by favouring the reverse reaction, shifting to the left overall. (1) direction

As volume is doubled, the concentration of each substance will decrease. Regardless as to which way the system shifts, the concentration overall is still lower (1)

b. State what happens to the **amount** of nitrogen, N_2, for the change described in **part a.** Justify your answer. (2 marks)

(1)

As the volume is changed, the amount of nitrogen gas does not change.

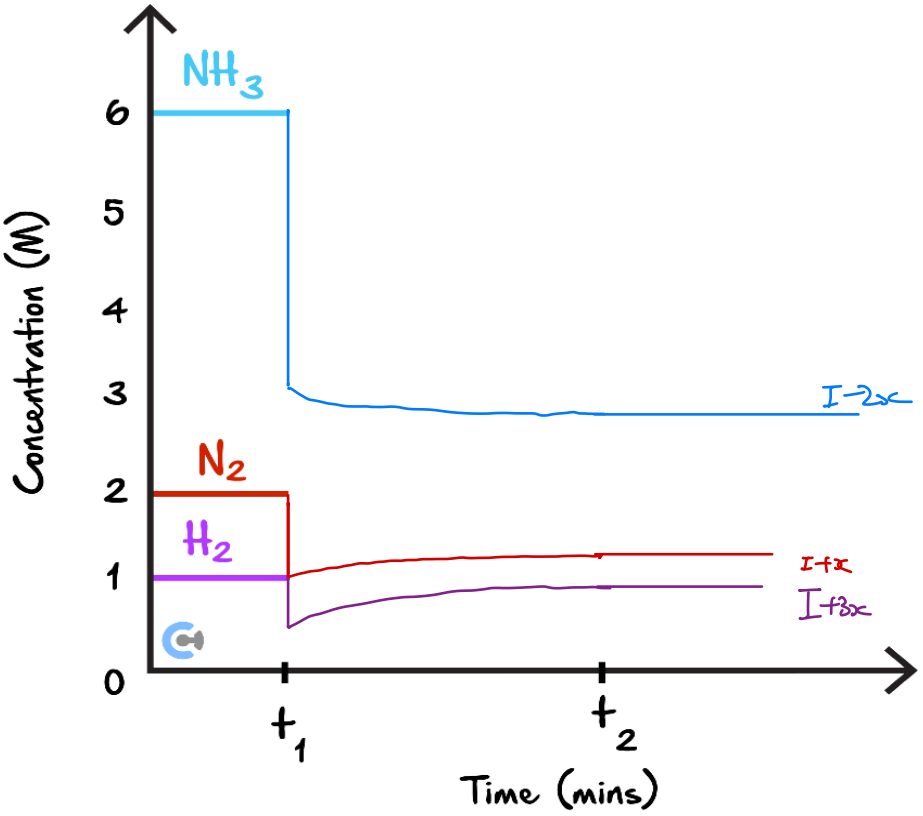
The reverse reaction is favoured, increase n(N2).

Overall, $n(N_2)$ increases

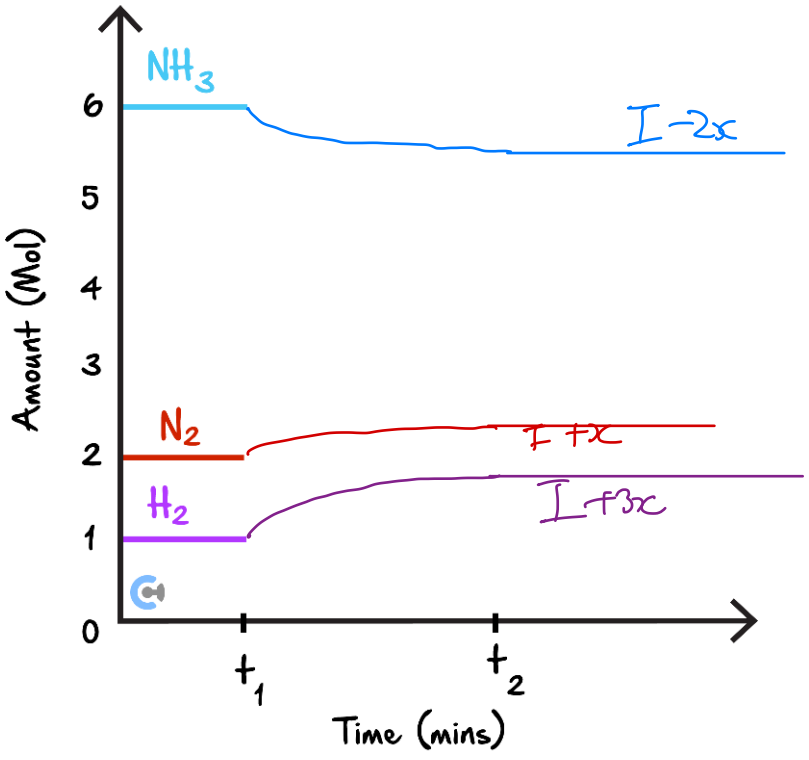
(1)

c. Complete each of the following graphs, assuming the container has a capacity of 1 *L*:

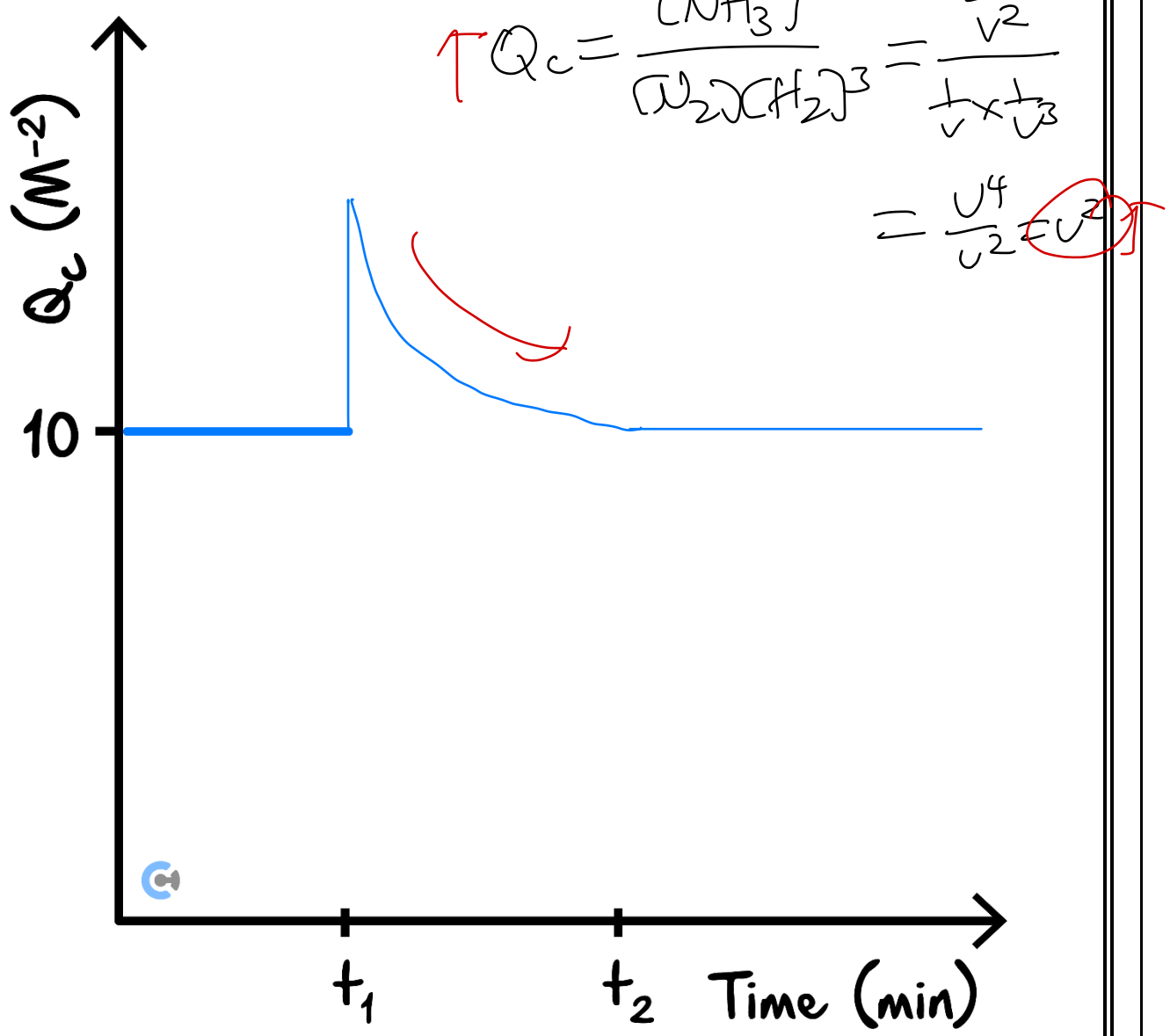
i. Concentration - time graph. (3 marks)



ii. Amount - time graph. (2 marks)



iii. Q_c - time graph. (1 mark)



Let's take a BREAK!

Space for Personal Notes

Section F: VCAA-Level Questions I (10 Marks)

INSTRUCTION: 10 Marks. 30 Seconds Reading. ~~30~~ 12 Minutes Writing.

Question 17 (10 marks)

Inspired from VCAA Chemistry Exam 2017
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2017/2017chem-w.pdf#page=21

Sulfur trioxide, SO_3, is made by the reaction of Sulfur dioxide, SO_2, and Oxygen, O_2, in the presence of a catalyst, according to the equation below.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H < 0$$

3 → 2

In a closed system in the presence of the catalyst, the reaction quickly achieves equilibrium at 1000 K.

a. A mixture of 2.00 *mol* of $SO_2(g)$ and 2.00 *mol* of $O_2(g)$ was placed in a 4.00 *L* evacuated, sealed the vessel and kept it at 1000 K until equilibrium was reached. At equilibrium, the vessel was found to contain 1.66 *mol* of $SO_3(g)$. Calculate the equilibrium constant, K_c, at 1000 K. (4 marks)

R	$2SO_2$	+ O_2	⇌ $2SO_3$
n_i	2.00mol	2.00mol	0.00mol
n_c	−1.66	−0.83	+1.66
n_e	0.34	1.17	1.66mol

① RICE

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = \frac{\left(\frac{1.66}{4}\right)^2}{\left(\frac{0.34}{4}\right)^2 \times \left(\frac{1.17}{4}\right)} = 81\,M^{-1}$$

① K_c exp ① answer + units

b. A manufacturer of SO_3 investigates changes to the reaction conditions used in **part a.** in order to increase the percentage yield of the product in a closed system, where the volume may be changed, if required.

i. What changes would the manufacturer make to the volume of the system in order to increase the percentage yield of SO_3? Justify your answer. (2 marks)

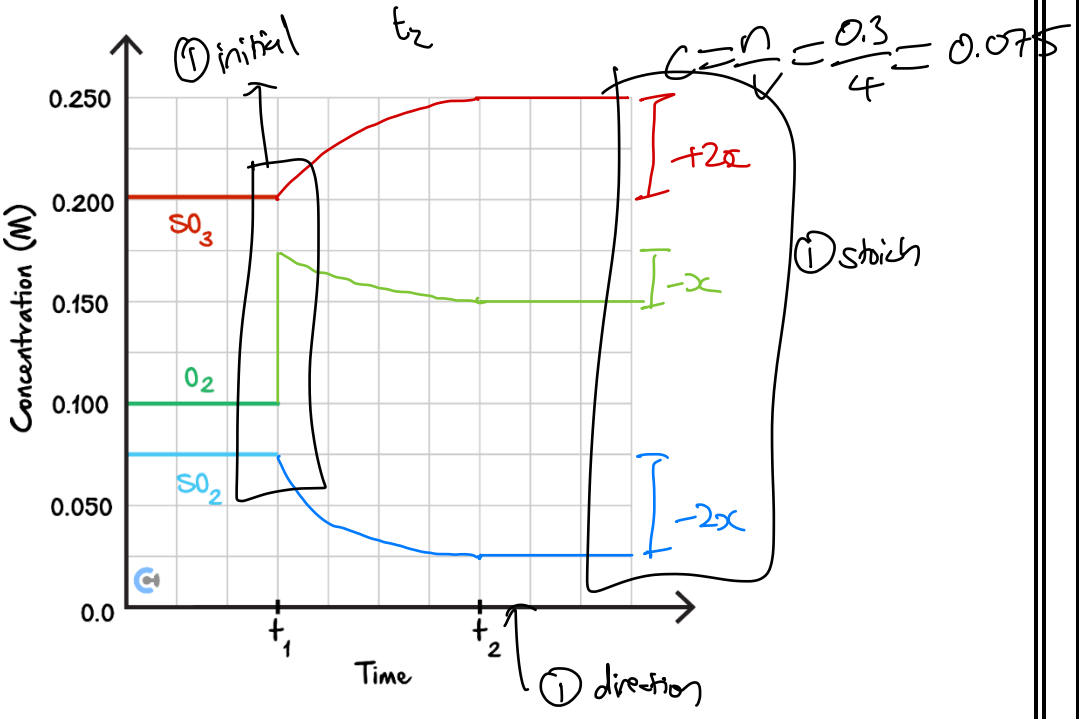
Volume should be decreased (1) ans

If volume decreases, concentration overall increases, according to Le Chatelier's Principle, system will partially oppose the change by decreasing overall concentration, favouring side w/ less particles & shifting forwards overall (1) exp

ii. State how the equilibrium constant value will change if the change in **part b. i.** is made. (1 mark)

no change

c. In another scenario and at a different temperature, the system reaches equilibrium in a 4.00 L reaction vessel. The manufacturer decides to add 0.300 mol of Oxygen gas at t_1. Continue the concentrations on the axes provided below, whereby equilibrium is re-established at t_2. (3 marks)



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Section G: Multiple Choice Questions (8 Marks)

INSTRUCTION: 8 Marks. 8 Minutes Writing.

Question 18 (1 mark)

Which of the following will shift the position of equilibrium to the right in the Haber process?

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

I. Decreasing the concentration of $NH_3(g)$.

II. Increasing the amount of Nitrogen gas present.

III. Increasing the pressure.

A. I and II only.

B. I and III only.

C. II and III only.

D. I, II and III.

Question 19 (1 mark)

It is known that $Fe(SCN)^{2+}(aq)$ is orange-red. For the equilibrium reaction below:

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

The volume of the reaction vessel in which the system is at equilibrium is suddenly reduced to 25% of what it once was.

The intensity of the colour, compared to before the volume was changed will be:

A. Unchanged.

B. Increases in intensity, then decreases back down to the original intensity.

C. Reduced orange-red.

D. Increased red.

Question 20 (1 mark)

Which of the following equilibria would be affected by volume changes at constant temperature?

1. $C_2H_4\ (g) + H_2\ (g) \rightleftharpoons C_2H_6\ (g)$

2. $4NH_3\ (g) + 5O_2\ (g) \rightleftharpoons 4NO\ (g) + 6H_2O\ (l)$

3. $SO_3\ (g) + NO\ (g) \rightleftharpoons NO_2\ (g) + SO_2\ (g)$

A. 3 only.

B. 1 and 2 only.

C. 1 and 3 only.

D. 2 and 3 only.

Question 21 (1 mark)

At a certain temperature, the value of the concentrations for all reactants and products is $0.2\ mol\ L^{-1}$. What happens to the value of K_c when the concentration values of the reactants are doubled to $0.4\ mol\ L^{-1}$ at the same temperature?

A. It is halved.

B. It doubles.

C. It does not change.

D. It decreases by the factor of 4.

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Question 22 (1 mark)

The following reaction has reached equilibrium:

$$Cu^{2+}(aq) + Sn^{2+}(aq) \rightleftharpoons Cu(s) + Sn^{4+}(aq)$$

Which one of the following would cause precipitation of more Copper?

A. Adding water to the mixture.

B. Taking out some of the solid Copper.

C. Addition of more $Sn^{2+}(aq)$ ions.

D. Increasing the concentration of $Sn^{4+}(aq)$ ions.

Question 23 (3 marks)

In carbonated drinks containing dissolved Carbon dioxide under high pressure, the following dynamic equilibrium exists.

$$CO_2(aq) \rightleftharpoons CO_2(g)$$

Describe the effect of opening a carbonated drink container and outline how this equilibrium is affected.

By opening the can, the pressure of gas decreases. LCP states systems will partially oppose change by increasing pressure of gas back up by favouring the forwards reaction. As such, system shifts to the right.

Space for Personal Notes

Section H: VCAA-Level Questions II (12 Marks)

INSTRUCTION: 12 Marks. 30 Seconds Reading. 11 Minutes Writing.

REMINDERS: Look at page 8 of the databook which is the solubility table to figure out if any precipitates form.

Question 24 (12 marks)

Katie is studying the dissolution of Calcium carbonate as part of her research investigation poster:

$$CaCO_3(s) \rightleftharpoons Ca^{2+}(aq) + {CO_3}^{2-}(aq)$$

Throughout this question, you may assume the system is at equilibrium before any changes have been imposed.

Mistakenly, she tips a bottle of calcium chloride, $CaCl_2$, into the reaction vessel.

a. Explain how this affects the amount of $CaCO_3$ dissolved in solution. (3 marks)

_____

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b. In response, Katie adds drops of $Ba(NO_3)_2$ solution to the system.

Explain how this change causes the equilibrium system to shift, and identify whether it reverses the amount of $CaCO_3$ dissolved in solution from **part a.** (3 marks)

_____

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_____

The K_c value for this reaction is 5×10^{-3} (undisclosed units) at SLC.

c. State whether the reaction has a small, moderate or large extent of the reaction, and describe the solubility of $CaCO_3$ in water at the same temperature. (2 marks)

_____

_____

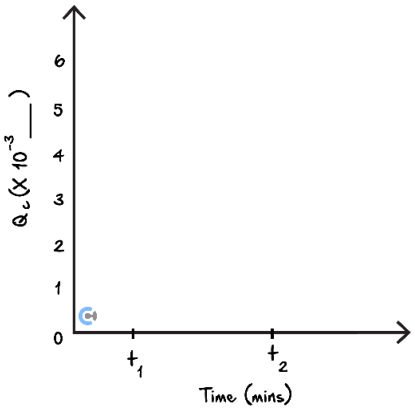
_____

d. Sketch the following graphs, whereby

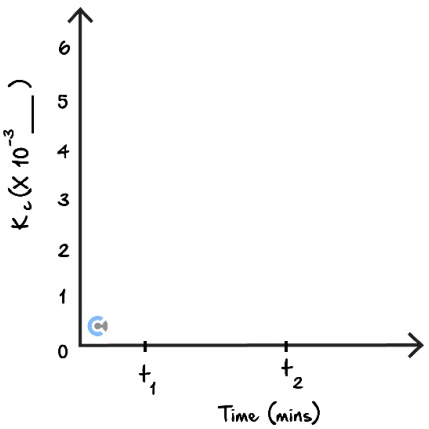
- t_1 represents the time at which **only one** change is imposed: the one stated in **part b.** which was the addition of $Ba(NO_3)_2$
- t_2 is the point in time at which the system reaches equilibrium once again.

*Ensure to include **the units** for both Q_c and K_c in the blank space provided on the vertical axes.*

i. Q_c against time. (2 marks)



ii. K_c against time. (2 marks)



Section I: Extension Questions (9 Marks)

Question 25 (9 marks)

The reversible reaction between the gases SO_2 and Cl_2 is as follows:

$$SO_2(g) + Cl_2(g) \rightleftharpoons SO_2Cl_2(g)$$

A mixture of these gases is at equilibrium, and the mixture possesses a mild green tinge. The volume of the vessel is suddenly doubled, and the system is allowed to re-establish equilibrium.

a. Explain how the system will behave in order to re-establish equilibrium, and hence, outline what happens to the colour of the system. (3 marks)

As volume is doubled, concentration overall will decrease (by half)

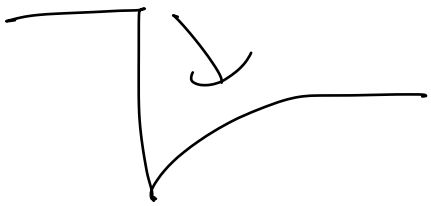
According to Le Chatelier's Principle, the system will partiallly oppose the change by increasing overall concentration back up, favouring the side with more particles (LHS)

As such, the reverse reaction is favoured, and teh equilibrium system shifts to the left.

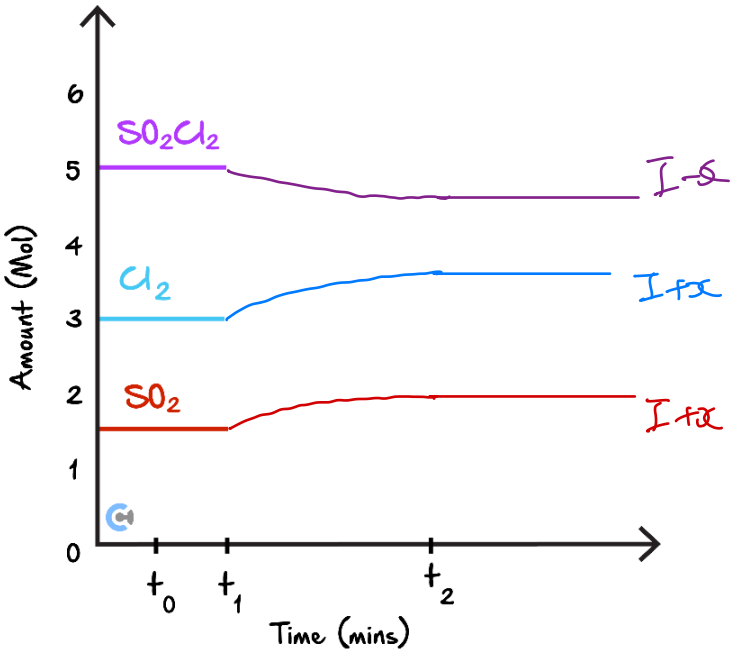
For colour, as volume is doubled, concentration of chlorine gas is decreased, decrease intensity of green colour at the beginning.

As the system shifts left, more chlorine is produced, increases intensity of green colour.

Overall, the intensity of the green colour decreases, as LCP states system will only PARTIALLY oppose the change.



b. The graph below depicts the amounts of each of the species at time t_0 – a random point in time **before** the volume of the vessel was doubled.



i. Calculate the reaction quotient, Q_c, at time t_0. The volume of the vessel was initially 500 mL. (2 marks)

$$Q_c = \frac{[SO_2Cl_2]}{[SO_2][Cl_2]} = \frac{\frac{5}{0.5}}{\frac{1.5}{0.5} \times \frac{3}{0.5}} = 0.556\ M^{-1}$$

$$= 0.56\ M^{-1}$$

ii. Explain whether the reaction quotient would be equal to the equilibrium constant, K_c, at time t_0. Justify your response using information provided in the graph. (2 marks)

$Q_c = K_c$ as the system is at equilibrium. This is known as the concentration of each substance at t_0 is not changing.

iii. Complete the graph to show how the amounts of each of the species will vary from time t_1 – when the volume was doubled – until t_2 – when equilibrium is re-established. (2 marks)

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