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VCE Chemistry ¾
AOS 2 Revision II [2.10]
Workbook

Outline:

Section A: [2.6] – Rates of Reaction (17 Marks)

Sub-Section: Recap

Cheat Sheet

[2.6.1] – Explain how factors increase the frequency of collisions

Concentration	Pressure
Used for [aqueous (aq)] / [gaseous (g)] mixtures.	Used for [aqueous (aq)] / [gaseous (g)] mixtures.

- To increase the frequency of **successful** collisions with **correct orientation**, the frequency _____ collisions must be [increased] / [decreased].
- **Concentration/Pressure** can be **increased** by:

Amount (n)	Volume (V)
[increase] / [decrease] amount of particles.	[increase] / [decrease] volume of container.

- **Increase in Concentration or Pressure**
  - When concentration/pressure is increased, **particles move**: [closer together] / [further apart].
  - **Frequency of total collisions:** [increases] / [decreases].
  - **Frequency** of **fruitful/successful collisions** with **correct orientation** collisions: [increases] / [decreases].
  - **Overall rate of reaction:** [increases] / [decreases].
- Increase in Concentration or Pressure Flow Chart

Key Feature → _____ Freq. Collisions → Frequency of _____ Collisions with Correct Orientation → Rate of Reaction

- **Effect of Inert Gas on Rate of Reaction**
  - When an inert gas is added, the **overall pressure:** [increases] / [decreases] / [stays same].
  - Partial pressure of reactants: [increases] / [decreases] / [stays same].
  - Frequency of collisions between reactants: [increases] / [decreases] / [stays same].
  - Rate of reaction: [increases] / [decreases] / [stays same].
- **Surface Area**
  - Cutting/dividing substance into thin powder [increases] / [decreases] surface area.
  - **Contact between reactants:** [increases] / [decreases].
  - **Total frequency of collisions:** [increases] / [decreases].
  - **Frequency** of **fruitful/successful collisions** with **correct orientation** collisions: [increases] / [decreases].
  - **Overall rate of reaction:** [increases] / [decreases].

Cheat Sheet

[2.6.2] - Explain how temperature & catalyst affect the proportion of successful collisions

- Greatest effect on the rate of reaction: [frequency of collisions] / [energy upon collision].
- **Effect of Temperature on Rate (Sample Response)**
  - **Overall**: Increasing temperature [increases] / [decreases] average kinetic energy.

Energy Upon Collision	Frequency of Collision
Reacting particles collide with [greater] / [lesser] force.	Average moving speed of particles: [increases] / [decreases] / [same].
Probability of colliding with sufficient energy to overcome the activation energy: [increases] / [decreases] / [same].	Total frequency of collisions: [increases] / [decreases] / [same].
Proportion/probability of successful/fruitful collisions [increases] / [decreases] / [same].	Frequency of successful collisions: [increases] / [decreases] / [same].

- Energy Upon Collision Flow Chart:

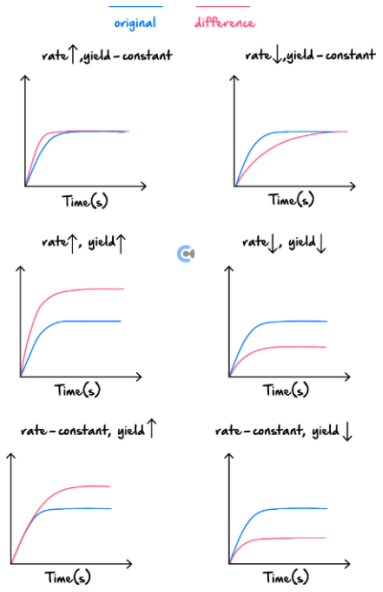
  _____ Energy → Greater _____ → Greater _____ for Collisions with _____ _____→ Greater Rate

- **Catalysts are** substances that _____ the rate of a chemical reaction without itself being _____.
- Catalysts alter the rate of reaction by providing an _____ reaction pathway with a _____ activation energy.
- Catalyst Sample Response:
  - A catalyst provides an alternative reaction pathway with lower activation energy by forming **temporary** and **partial intermolecular bonds** with the reacting particles.
  - **Activation Energy:** [increases] / [decreases] / [stays same].
  - **Rate of Reaction:** [increases] / [decreases] / [stays same].
  - Catalyst Before vs After: _____.

[2.6.3] - Graph differences in rate & yield

Method Of Measuring Rate	Conditions
Change in Volume (Gas Syringe).	Gaseous Products.
Change in Mass (Weighing Scale).	Gaseous Products.
Change in pH (pH meter/indicator).	H^+ or OH^- used/formed.
Change in Temperature (thermometer).	Reaction is endothermic/exothermic.

- **Rate vs Yield in Graphs**



Sub-Section: Questions

INSTRUCTION: 12 Marks. 12 Minutes Writing.

Question 1 (3 marks)

Ethan is studying the reaction that occurs between 1.0 M sulphuric acid and 17.90 g of solid copper oxide in a 500 mL beaker according to the reaction:

$$CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$$

State what effect each of the following would have on the rate of reaction observed when compared to the original set-up shown above.

a. Using 2.0 M sulphuric acid solution. (0.5 marks) **[2.6.1] [2.6.2]**

b. Using 0.5 M sulphuric acid. (0.5 marks) **[2.6.1] [2.6.2]**

c. Using powdered copper oxide. (0.5 marks) **[2.6.1] [2.6.2]**

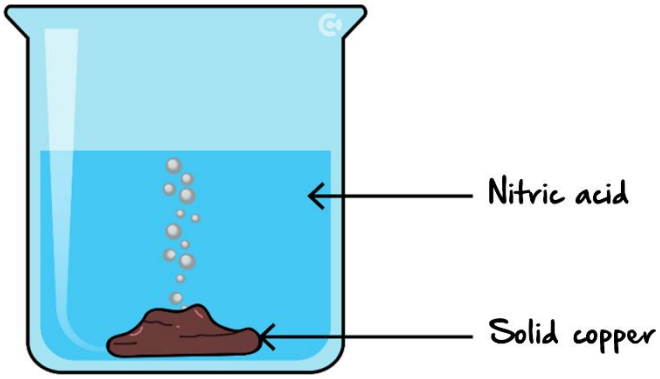
d. The same reaction took place, but this time a 1 L beaker was used instead. (0.5 marks) **[2.6.1] [2.6.2]**

e. A catalyst is added. (0.5 marks) **[2.6.1] [2.6.2]**

f. 100 mL of water is added. (0.5 marks) **[2.6.1] [2.6.2]**

The following information applies to the two questions that follow

$$Cu(s) + 4HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2NO_2(g) + 2H_2O(l)$$



Question 2 (1 mark) **[2.6.1] [2.6.2]**

Which one of the following will **not** increase the rate of the above reaction?

A. Decreasing the size of the solid copper particles.

B. Increasing the temperature of HNO_3 by 20°C.

C. Increasing the concentration of HNO_3.

D. Allowing NO_2 gas to escape.

Question 3 (1 mark) **[2.6.2]**

In the above reaction, the number of successful collisions per second is a small fraction of the total number of collisions.

The **major** reason for this is that:

A. The nitric acid is ionised in solution.

B. Some reactant particles have too much kinetic energy.

C. The kinetic energy of the particles is reduced when they collide with the container's walls.

D. Not all reactant particles have the minimum kinetic energy required to initiate the reaction.

Space for Personal Notes

Question 4 (1 mark) **[2.6.2]**

How does the addition of a catalyst affect a reversible reaction?

A. It increases the activation energy of the forward reaction only.

B. It decreases the activation energy of the forward reaction only.

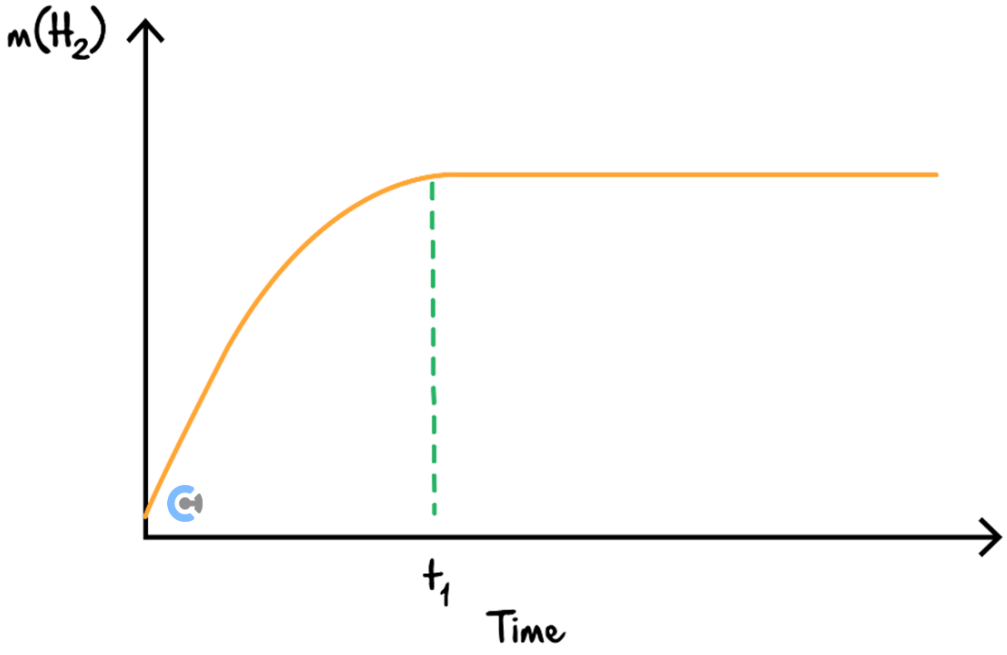
C. It increases the activation energy of both the forward and reverse reactions.

D. It decreases the activation energy of both the forward and reverse reactions.

Question 5 (6 marks)

A 2.0 g piece of magnesium ribbon was added to a known volume of 2.0 M hydrochloric acid.

The mass of hydrogen gas produced during the reaction was measured and recorded. The graph below shows the result of this experiment.



a. Write an equation for the reaction between magnesium and hydrochloric acid. (1 mark) **[1.7.1]**

_____

b. What event occurs at the time t_1? (1 mark) **[2.6.3]**

_____

c. In a second experiment, 2.0 *g* of magnesium ribbon was added to the same volume of 2.0 *M* hydrochloric acid, but a catalyst was added as well.

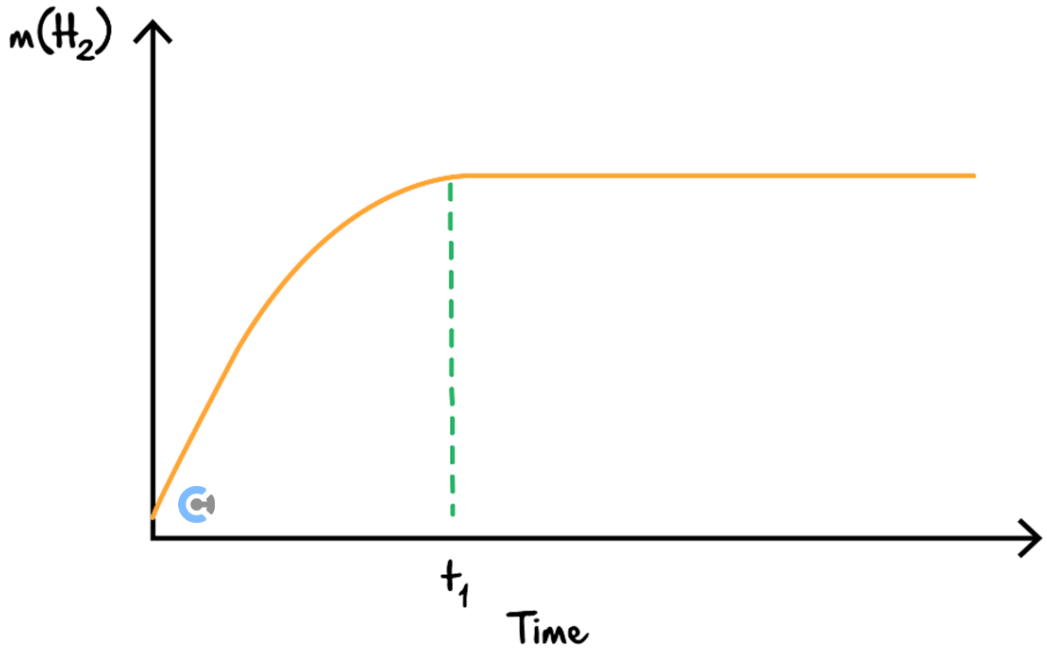
On the axes above, sketch the expected graph of the volume of hydrogen against time for this second experiment. Give an explanation for the shape of your graph. (2 marks) **[2.6.3]**

_____

_____

_____

d. In a third experiment, 1.0 *g* of powdered magnesium and the results are recorded. On the axes below, sketch the results of the third experiment compared to the first experiment. (2 marks) **[2.6.3]**



Check off any learning objectives obtained full marks from the "Contour Check" booklet!

Space for Personal Notes

Sub-Section: Additional Questions

Question 6 (3 marks) **[2.6.2]**

Explain the effect of decreasing the temperature of a system using collision theory.

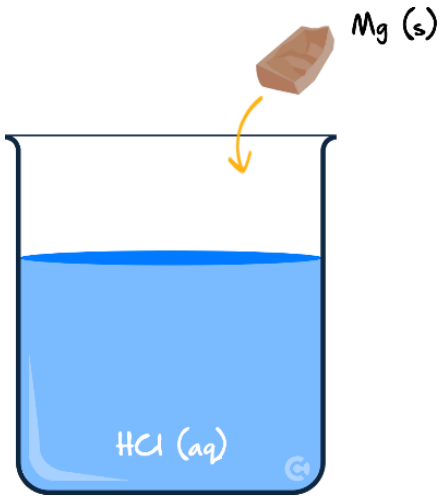
Space for Personal Notes

Question 7 (2 marks)

It is known that magnesium and hydrochloric acid react via the reaction:

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

The original magnesium blocks are thoroughly sanded prior to use and 50 g of Mg(s) blocks are dropped into the HCl solution.



For the following questions, consider that there were two beakers with similar setups but one changed different conditions for the reactants.

a. If a 2.0 M HCl solution is compared to a 1.0 M HCl solution (all other conditions remain the same), which beaker would produce the most bubbles in 1 second? (1 mark) **[2.6.1]**

A. The beaker with 1.0 M HCl, because lower concentration speeds up the reaction.

B. The beaker with 2.0 M HCl, because higher concentration increases the rate of reaction.

C. Both beakers would produce the same amount of bubbles because concentration does not affect the rate.

D. The beaker with 1.0 M HCl, because it has fewer hydrogen ions to react with magnesium.

b. If for one beaker, the magnesium block is broken into 10 smaller pieces but left on a bench for 2 weeks, how would the rate of bubble production compare to the original block of sanded magnesium? (1 mark) **[2.6.1]**

A. The beaker with smaller pieces would produce more bubbles because of the increased surface area.

B. The beaker with the original block would produce more bubbles because the surface is freshly sanded.

C. Both beakers would produce the same amount of bubbles because the amount of magnesium is the same.

D. The beaker with smaller pieces would produce fewer bubbles because exposure to air for 2 weeks would cause oxidation.

Section B: [2.7] – Equilibrium (24 Marks)

Sub-Section: Recap

Cheat Sheet

[2.7.1] - Write equilibrium constant expression & find its value (including units)

- K_c Expression:

$$aA + bB + \ldots \rightleftharpoons cC + dD + \ldots$$

$$K_c = \_\_\_\_\_$$

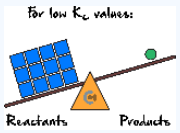
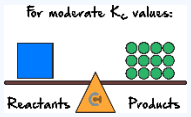
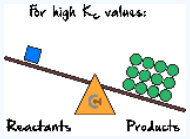
- **K_c value key property:** always has the _____ at a certain temperature, irrespective of the amounts of the reactants/products which we start off with!
- K_c units need to be calculated separately each time.

Homogenous Equilibrium	Heterogenous Equilibrium
[Only one] / [Multiple] state(s) of matter present in equation.	[Only one] / [Multiple] state(s) of matter present in equation.

Aqueous (aq) or Gaseous (g) Substances	Solid (s) or Liquid (l) Substances
[Have] / [Don't have] concentration.	[Have] / [Don't have] concentration.
Concentration is as stated.	Concentration is _____.

- When plugging values into K_c expression, [amount (mol)] / [concentration (M)] should be plugged in.
- Calculate units by.

[2.7.2] - Identify the extent of reaction

$K_c < 10^{-4}$	$10^{-4} < K_c < 10^4$	$K_c > 10^4$
[Small] / [Medium] / [Large] extent of reaction.	[Small] / [Medium] / [Large] extent of reaction.	[Small] / [Medium] / [Large] extent of reaction.
[Reactants] / [Both] / [Products] favoured at equilibrium.	[Reactants] / [Both] / [Products] favoured at equilibrium.	[Reactants] / [Both] / [Products] favoured at equilibrium.
		

[2.7.3] - Find equilibrium constant when equation is changed

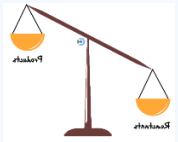
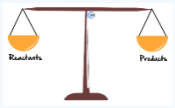
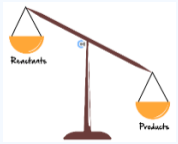
- When **reversing equations**, take the _____.
- When **multiplying by a coefficient**, take the _____ of that coefficient.
- **Units:** _____ how equation has been changed!

Cheat Sheet

[2.7.4] - Apply Q_c to find direction of equilibrium shift

Equilibrium Constant (K_c)	Reaction Quotient (Q_c)
$K_c = \frac{[C]^c \times [D]^d \times \dots}{[A]^a \times [B]^b \times \dots}$	$Q_c = \frac{[C]^c \times [D]^d \times \dots}{[A]^a \times [B]^b \times \dots}$
Is found by using concentrations **at equilibrium**!	Is found at **any point in time** (could be at equilibrium, could not be at equilibrium!).

- If $Q_c = K_c$, the system [is] / [is not] at equilibrium.
- If $Q_c \neq K_c$, the system [is] / [is not] at equilibrium.

$Q_c < K_c$	$Q_c = K_c$	$Q_c > K_c$
[undershot] / [perfect shot] / [overshot]	[undershot] / [perfect shot] / [overshot]	[undershot] / [perfect shot] / [overshot]
[forwards] / [neither] / [reverse] reaction favoured.	[forwards] / [neither] / [reverse] reaction favoured.	[forwards] / [neither] / [reverse] reaction favoured.
		

[2.7.5] - Apply RICE tables to find K_c

- Stands for
  - _____
  - _____
  - _____
  - _____
- **Good idea to add a fifth row**: _____.
- **Key Terms:** "Empty" or "evacuated" means there are _____ other substances present at the beginning.
- **Steps:**
  1. Fill out _____.
  2. Find _____.
  3. Find _____.

Let's walkthrough together!

Question 8 (4 marks) **Walkthrough.**

The following equation is used to show what occurs when nitrogen and hydrogen gas are mixed.

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

In a 9.00 L container, there is 8.00 mol of nitrogen gas and 1.29 mol of hydrogen gas.

The K_c value is found to be 0.00469 M^{-2}.

a. Determine the extent of the reaction. (1 mark) **[2.7.2]**

_____

b. Find the amount of ammonia gas present at equilibrium. (3 marks) **[2.7.1]**

_____

_____

_____

_____

_____

Space for Personal Notes

Question 9 (4 marks) **Walkthrough. [2.7.5]**

At a particular temperature, 5.20 mol of CS_2 and 14.50 mol of hydrogen gas is placed into an initially evacuated 3.0 L rigid container. The equation describing the system is shown below.

$$CH_4(g) + 2H_2S(g) \rightleftharpoons CS_2(g) + 4H_2(g)$$

At equilibrium, 3.5 mol of H_2S is present. Calculate the K_c value for this reaction.

Space for Personal Notes

Sub-Section: Questions

INSTRUCTION: 13 Marks. 13 Minutes Writing.

Question 10 (1 mark) **[2.7.2]**

Which pair of components must be equal for a chemical system to be at equilibrium?

A. The rate of the forward reaction and the rate of the reverse reaction.

B. The concentrations of the reactants and the concentrations of the products.

C. The enthalpy of the forward reaction and the enthalpy of the reverse reaction.

D. The time that an atom exists in a reactant molecule and in a product molecule.

Question 11 (1 mark) **[2.7.2]**

The value of the equilibrium constant, K_c, for a reaction is 1.0×10^{10}. Which statement about the extent of the reaction is correct?

A. The reaction hardly proceeds.

B. The reaction goes almost to completion.

C. The products have a higher concentration than the reactants.

D. The concentrations of reactants and products are the same.

Space for Personal Notes

Question 12 (2 marks) **[2.7.1]**

For the following equation:

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

Given the K_c value is 0.593 M at 25°C, and at equilibrium, the concentration of PCl_3 is 2.18 M and the concentration of Cl_2 is also 8.11 M, find the concentration of PCl_5 at equilibrium.

Question 13 (4 marks) **[2.7.5]**

At a particular temperature, 20.0 moles of SO_3 is placed into an initially evacuated 3.0 L rigid container, and the SO_3 dissociates by the reaction below.

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

At equilibrium, 3.5 moles of SO_2 is present. Calculate the K_c value for this reaction.

Question 14 (5 marks)

Consider the reaction shown in the following equation:

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = -\frac{9.4\ kJ}{mol}, \qquad K_c = 54.8 \text{ at } 700\ K$$

a. Write the expression for the equilibrium constant for this reaction. (1 mark) **[2.7.1]**

b. 10.00 mol of HI, 10.00 mol H_2 and 2.00 mol I_2 are placed in a 1.5 L container at 700 K. Predict in which direction the reaction will proceed. Justify your answer. (3 marks) **[2.7.4]**

c. For each of the following equations determine the K_c value and its subsequent units.

i. $2H_2(g) + 2I_2(g) \rightleftharpoons 4HI(g)$. (0.5 marks) **[2.7.3]**

ii. $5HI(g) \rightleftharpoons \frac{5}{2}H_2(g) + \frac{5}{2}I_2(g)$. (0.5 marks) **[2.7.3]**

Check off any learning objectives obtained full marks from the "Contour Check" booklet!

Space for Personal Notes

Sub-Section: Additional Questions

Question 15 (1 mark) **[2.7.5]**

Nitrosyl chloride (NOCl) is a highly toxic gas that decomposes according to the equation:

$$2\text{NOCl(g)} \rightleftharpoons 2\text{NO(g)} + \text{Cl}_2\text{(g)}$$

To investigate the reaction, 1.2 mol of NOCl(g) is placed in an empty 1.0 L flask and allowed to reach equilibrium. The flask and its contents are kept at a constant temperature.

If $[\text{Cl}_2] = 0.20\ M$ at equilibrium, what is the equilibrium concentration of NOCl(g)?

A. 0.80 M

B. 1.00 M

C. 1.10 M

D. 1.40 M

Question 16 (1 mark) **[2.7.3]**

The equilibrium constant for the reaction: $\text{N}_2\text{O}_4\text{(g)} \rightleftharpoons 2\text{NO}_2\text{ (g)}$ is 0.212 M at 373 K. For the reaction:

$$\text{NO}_2\text{(g)} \rightleftharpoons \frac{1}{2}\text{N}_2\text{O}_4\text{(g)}$$

The value of the equilibrium constant at the same temperature would be:

A. 4.72

B. 2.17

C. 0.460

D. 0.212

Space for Personal Notes

Question 17 (1 mark) **[2.7.5]**

A mixture of 0.40 mol of $CO(g)$ and 0.40 mol of $H_2(g)$ was placed in a 1.00 dm^3 vessel. The following equilibrium was established.

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

At equilibrium, the mixture contained 0.25 mol of $CO(g)$. How many moles of $H_2(g)$ and $CH_3OH(g)$ were present at equilibrium?

	Equilibrium mol of H_2	Equilibrium mol of CH_3OH
A.	0.25	0.15
B.	0.50	0.25
C.	0.30	0.25
D.	0.10	0.15

Space for Personal Notes

Section C: [2.8] – Le Chatelier's Principle (27 Marks)

Sub-Section: Recap

Cheat Sheet

[2.8.1] – Explain effects of addition/removal of substances or pressure/volume changes on equilibrium system

- Principle:

"If a system is at equilibrium, and is subjected to a change, the equilibrium will shift to partially oppose the change."

- Explanation Response:

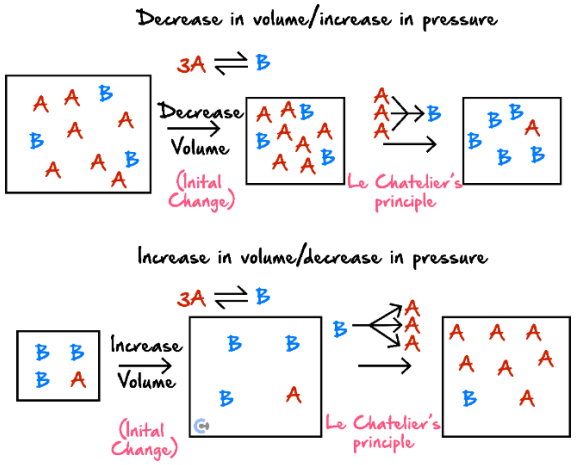
1. _____
2. _____
3. _____

- Adding/Removing Substances:

$$A + 2B \rightleftharpoons C + D$$

- Adding Reactants: shifts [left] / [right]
- Adding Products: shifts [left] / [right]
- Removing Reactants: shifts [left] / [right]
- Removing Products: shifts [left] / [right]
- Reacting Substances out: _____.

- Change Volume/Pressure:



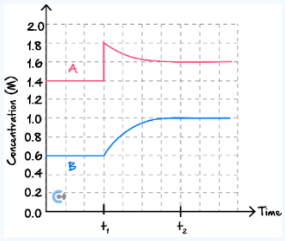
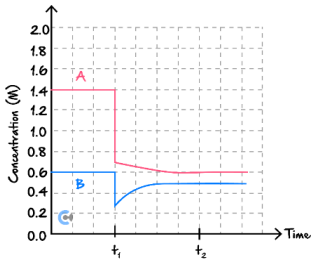
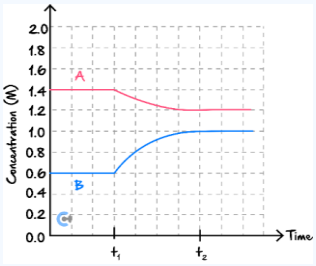
Volume Increase	Volume Decreased
Particles [squash together] / [pull apart].	Particles [squash together] / [pull apart].
Particles [merge] / [split apart].	Particles [merge] / [split apart].
Amount of particles [increase] / [decrease].	Amount of particles [increase] / [decrease].

- Volume/Pressure change when same number of particles on both sides: _____.

Cheat Sheet

[2.8.2] – Graph effects of addition/removal of substances or pressure/volume changes on equilibrium system

- **Steps for Graphing Le Chatelier's Principle**
  1. _____
  2. _____
     - _____
     - _____

Change	Graph
Addition/removal species	
Pressure/volume change	
Temperature change	

- **For Volume:**
  - Initial Changes: concentration for _____ changes based on the _____ concentration of everything, not stoichiometric ratios.
  - Equilibrium Changes: Substances increase/decrease based on _____.
- **Volume Change on Concentration vs Amount:**

Volume Change	Overall Concentration	Overall Amount
Initial → immediately after volume decrease	[increases] / [decreases] / [stays same]	[increases] / [decreases] / [stays same]
As system re-establishes equilibrium:	[increases] / [decreases] / [stays same]	[increases] / [decreases] / [stays same]
Overall Change	[increases] / [decreases] / [stays same]	[increases] / [decreases] / [stays same]

- **Main Trick**: For amount, **volume change** _____ affect the amount of particles!
- When graphing Q_c ,value overall [changes] / [stays same].
- K_c value _____ (unless temperature is changed).

[2.8.3] – Apply partial opposition during equilibrium to the effects on amount, concentration & colour of substance

- Change in Colour is based on the [amount] / [concentration] of substances.
- Le Chatelier's Principle only: _____

Let's walkthrough together!

Question 18 (3 marks) **Walkthrough. [2.8.1]**

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.

_____

_____

_____

_____

_____

Question 19 (2 marks) **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. Sulphur dioxide is removed. (1 mark) **[2.8.1]**

b. Volume is increased. (1 mark) **[2.8.1]**

Question 20 (5 marks) **Walkthrough.**

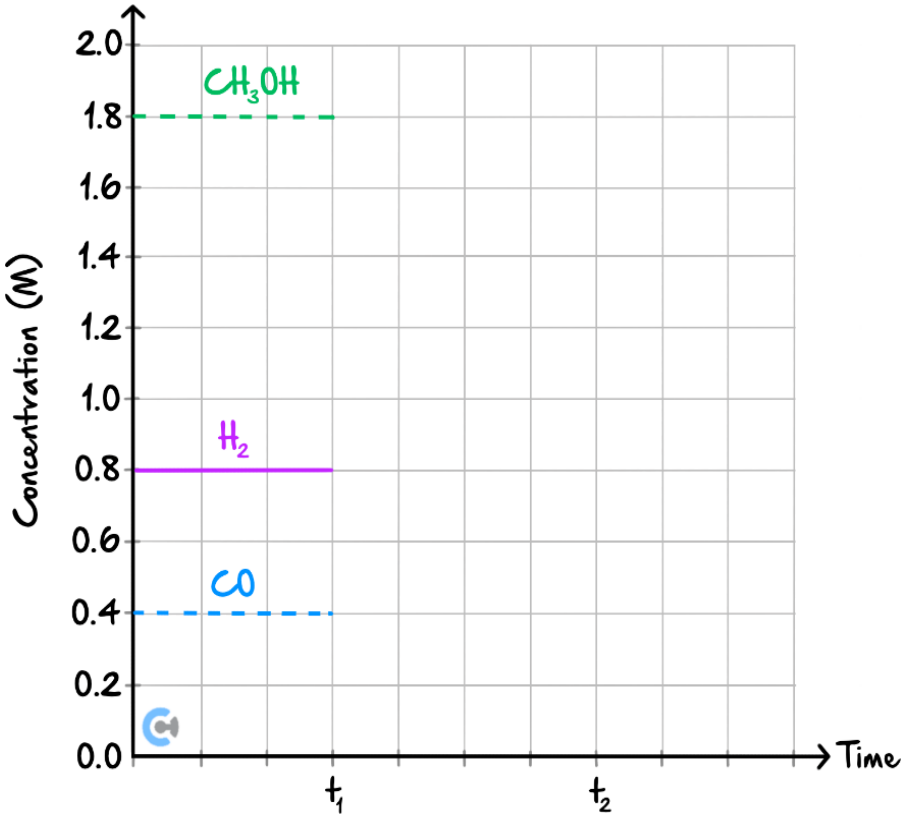
Consider the following reaction, which is initially at equilibrium, before the volume is doubled.

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

a. State the direction in which the equilibrium system will shift overall in response. (1 mark) **[2.8.1]**

_____

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. (2 marks) **[2.8.2]**



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

i. Identify how the **concentration** of hydrogen gas changes overall. (1 mark) **[2.8.3]**

_____

ii. Identify how the **amount** of hydrogen gas changes overall. (1 mark) **[2.8.3]**

_____

Sub-Section: Questions

INSTRUCTION: 12 Marks. 12 Minutes Writing.

Question 21 (2 marks)

For the following equilibrium reaction determine the direction in which the system will shift to re-establish equilibrium.

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

a. The volume is decreased. (0.5 marks) **[2.8.1]**

b. The pressure is decreased. (0.5 marks) **[2.8.1]**

c. Ammonia gas is added. (0.5 marks) **[2.8.1]**

d. Nitrogen gas is removed. (0.5 marks) **[2.8.1]**

Space for Personal Notes

Question 22 (2 marks)

For the following reaction, *B* is yellow whilst the other species is colourless.

$$2A(aq) + B(aq) \rightleftharpoons 3C(aq)$$

a. Determine the direction the system would shift if the volume is halved. (1 mark) **[2.8.1]**

_____

b. Determine the overall change in colour. (1 mark) **[2.8.3]**

_____

Question 23 (7 marks)

The equation of the system:

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

The system was allowed to reach equilibrium before the volume was halved.

a. Using Le Chatelier's Principle, explain how the system will react to this change. (3 marks) **[2.8.1]**

_____

_____

_____

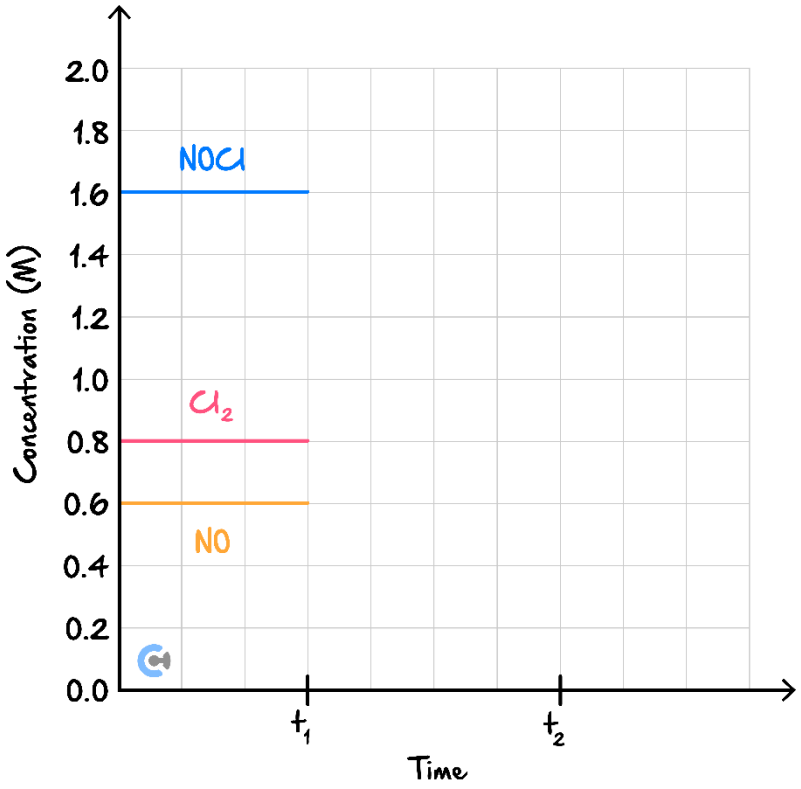
_____

b. A different change is then made, which comprised of adding 0.200 mol of chlorine gas ($Cl_2(g)$) into the 0.500 L reaction vessel.

i. Identify how the system will react to the change. (1 mark) **[2.8.1]**

_____

ii. Complete the concentration-time graph for the reaction, using the initial concentrations provided, where t_1 is the time of increasing reaction vessel volume while t_2 is the time of re-establishing equilibrium. (2 marks) **[2.8.2]**



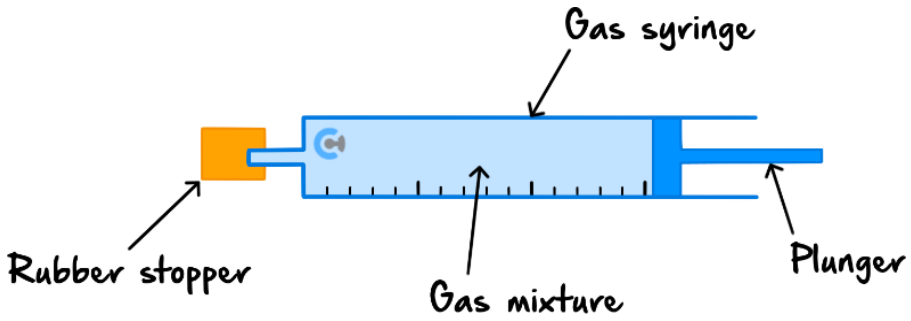
iii. It is found that chlorine gas has a greenish-yellow colour. Compare the intensity of this greenish-yellow colour from before t_1 to at t_2. (1 mark) **[2.8.3]**

_____

Space for Personal Notes

Question 24 (1 mark) **[2.8.2]**

A sealed gas syringe contains an equilibrium mixture of brown nitrogen dioxide gas NO_2, and colourless dinitrogen tetroxide gas N_2O_4. This is shown in the diagram below.



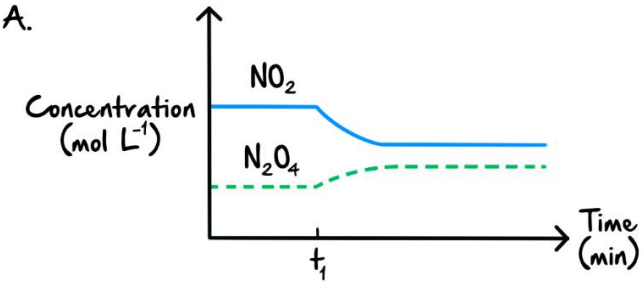
The equation for this equilibrium reaction is:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = +57.20\ kJ\ mol^{-1}$$

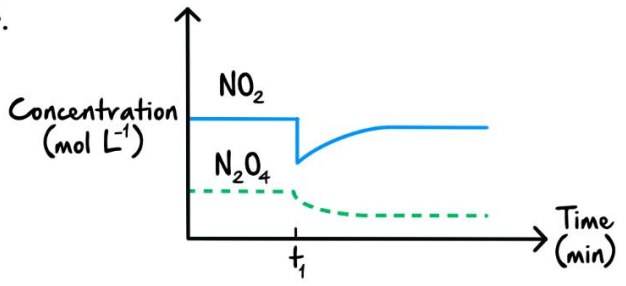
The plunger is suddenly pushed in at the time t_1, thus decreasing the total volume of the gas mixture. The temperature of the gas mixture is kept constant.

Which one of the following concentration-time graphs represents the change that occurs?

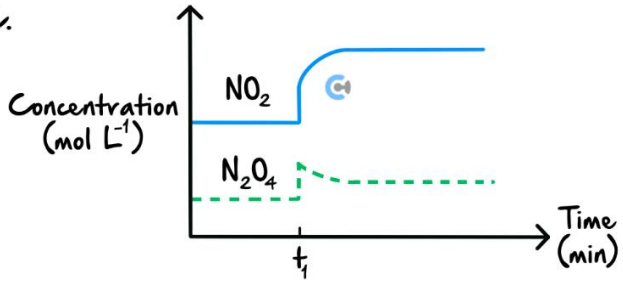
A.



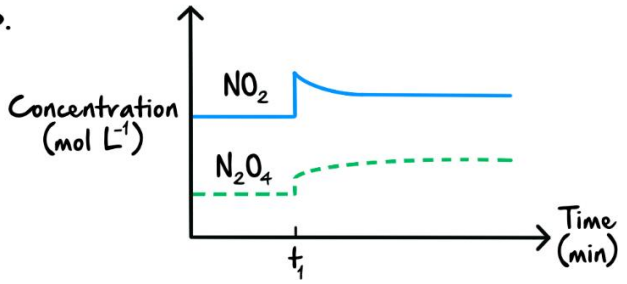
B.



C.



D.



Check off any learning objectives obtained full marks from the "Contour Check" booklet!

Sub-Section: Additional Questions

Question 25 (5 marks)

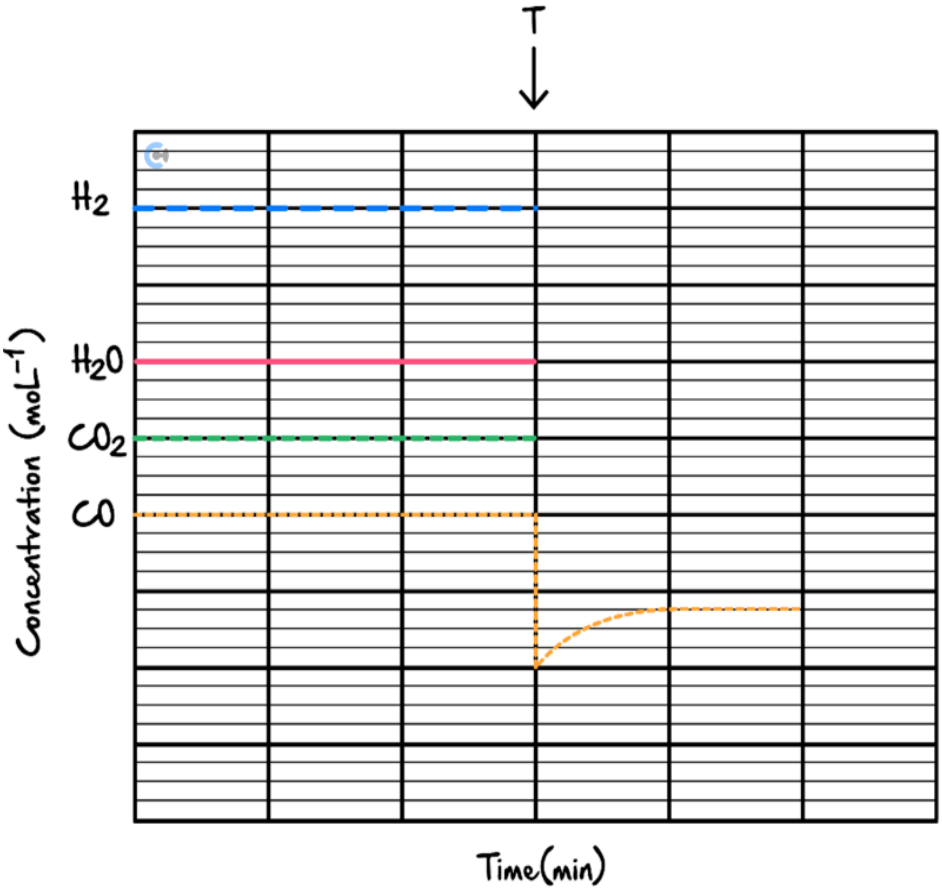
The concentrations of reactants and products as a function of time for the following system were determined.

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

At time T, some $CO(g)$ was removed from the system.

a. The concentration of CO after time T is shown.

Sketch the concentrations after time T for the remaining species. (2 marks)



b. Using collision theory, explain the change in the concentration of CO after time T. (3 marks)

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Section D: [2.9] – Rate Yield Conflict (29 Marks)

Sub-Section: Recap

Cheat Sheet

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

- Inert Gas on Equilibrium Position: _____
- Temperature:

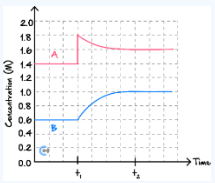
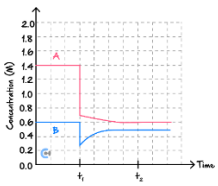
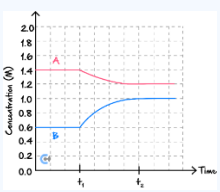
Change to System	System's Respond (Le Chatelier's Effect)	Reaction Favoured
Increase in Temperature	[increase] / [decrease] temperature.	[endothermic] / [exothermic]
Decrease in Temperature	[increase] / [decrease] temperature.	[endothermic] / [exothermic]

- 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.

[2.9.2] - Graph effects of temperature, inert gas catalyst on an 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].

[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]

Cheat Sheet

[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]

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

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

Condition	Pressure	Temperature
Rate	[high] / [low]	[high] / [low]
Equilibrium Yield	[high] / [low]	[high] / [low]
Overall	[high] / [medium] / [low]	[high] / [medium] / [low]

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

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: _____.

Let's walkthrough together!

Question 26 (4 marks) **Walkthrough.**

The following equilibrium system is shown. However, the sign of the change in enthalpy is unknown. The coefficient of B is also unknown.

$$3\mathrm{A(g)} \rightleftharpoons x\mathrm{B(g)} + \mathrm{C(g)}$$

a. When temperature is increased, the concentration of C is seen to decrease.

State whether the forward reaction is endothermic or exothermic. Justify your reasoning. (2 marks) **[2.9.1] [2.9.3]**

_____

_____

_____

_____

b. The coefficient, 'x' is known to have a value of either $1, 2,$ or 3. When the volume of the container is increased at a constant temperature, the amount of B present is seen to decrease.

Identify the value of the coefficient 'x', giving justification for your reasoning. (2 marks) **[2.9.1] [2.9.3]**

_____

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Sub-Section: Question Set *A*

INSTRUCTION: 10 Marks. 10 Minutes Writing.

Question 27 (1 mark) **[2.9.1]**

What happens when the temperature of the following equilibrium system is increased?

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91\ kJ$$

	Position of equilibrium	Reaction rates of forward and reverse reactions
A.	Shifts to the left	Increase
B.	Shifts to the left	Decrease
C.	Shifts to the right	Decrease
D.	Shifts to the right	Increase

Question 28 (1 mark) **[2.9.1]**

Sulphur dioxide and oxygen are mixed to form sulphur trioxide according to the equation below. Which one of the following best describes the effect of adding the catalyst V_2O_5 to the mixture?

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

	Equilibrium yield	Reaction rate
A.	Increases	Increases
B.	No change	Increases
C.	No change	No change
D.	Increases	No change

Question 29 (4 marks)

When the colourless ions $Fe^{3+}(aq)$ and $SCN^{-}(aq)$ react together, the complex ion $Fe(SCN)^{2+}(aq)$ forms in an equilibrium reaction. The complex ion is a deep red colour. At room temperature the equilibrium constant favours the product side of the reaction.

The reaction is shown below.

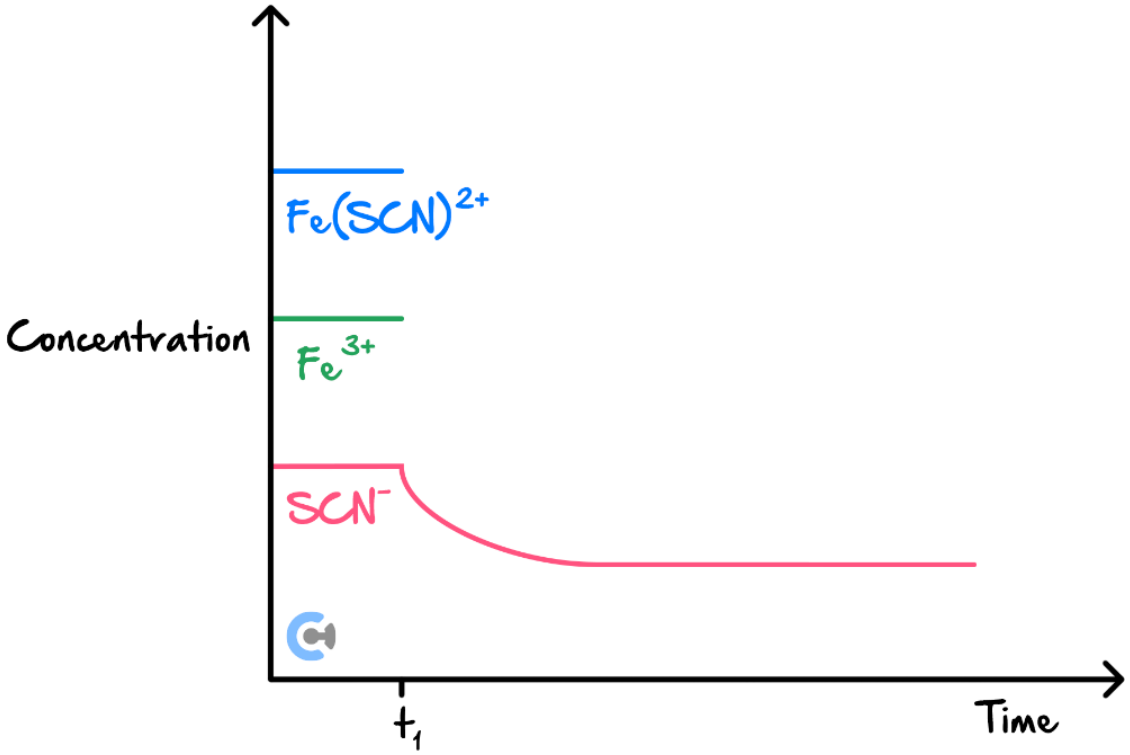
$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq)$$

a. $50\ mL$ of $1.0\ M$ $Fe^{3+}(aq)$ and $50\ mL$ of $1.0\ M$ $SCN^{-}(aq)$ are mixed in a beaker and allowed to reach equilibrium.

Tick the correct statement/s for the equilibrium system in the table below. (1 mark)

The contents of the beaker will be coloured red.	
The concentration of Fe^{3+} ions in the beaker is $1.0\ M$.	
The formation of $FeSCN^{2+}(aq)$ ceases at equilibrium.	
The $[SCN^{-}]$ remains constant at equilibrium.	

b. Another sample of an equilibrium mixture was cooled at a time t_1.The graph below shows the initial concentrations of ions in the mixture and how the concentration of SCN^- ions changed after the **cooling** at the time t_1.



i. Complete the graph by showing the changes in concentrations in Fe^{3+} and $Fe(SCN)^{2+}$ until equilibrium is reached again. (1 mark) **[2.9.2]**

ii. Based on the information given, is the formation of $Fe(SCN)^{2+}$ an endothermic or exothermic reaction? Explain your choice. (2 marks) **[2.9.1]**

_____

_____

_____

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Question 30 (4 marks)

A solution is prepared for the following equilibrium. The value of the equilibrium constant at 20°C is 50.

$$A(aq) + 2B(aq) \rightleftharpoons 2C(aq) + D(aq) \qquad \Delta H = +100\ kJ\ mol^{-1}$$

A(aq) is a dark blue colour but all of the other species present are colourless. The following tests are carried out on separate samples of the solution.

Test 1	A few mL of a concentrated solution of A are mixed into the solution.
Test 2	A few mL of a concentrated solution that reacts readily with B **only** are mixed into the solution.
Test 3	The solution is heated from 20°C to 40°C.
Test 4	A catalyst is added to the solution.

a. For each of the tests, predict whether the mixture would be darker, lighter or unchanged. Place a tick (✓) in the column of your choice. (2 marks) **[2.8.3] [2.9.1]**

	Test result: Solution colour		
	Darker	**Lighter**	**No change**
Test 1			
Test 2			
Test 3			
Test 4			

b. For each of the tests, predict whether the value of the equilibrium constant would be greater than, less than or equal to 50. For each of your predictions give an explanation. (2 marks) **[2.9.4]**

	Test result: Value of K_c		
	> 50	**= 50**	**< 50**
Test 1			
Test 2			
Test 3			
Test 4			

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Sub-Section: Question Set B

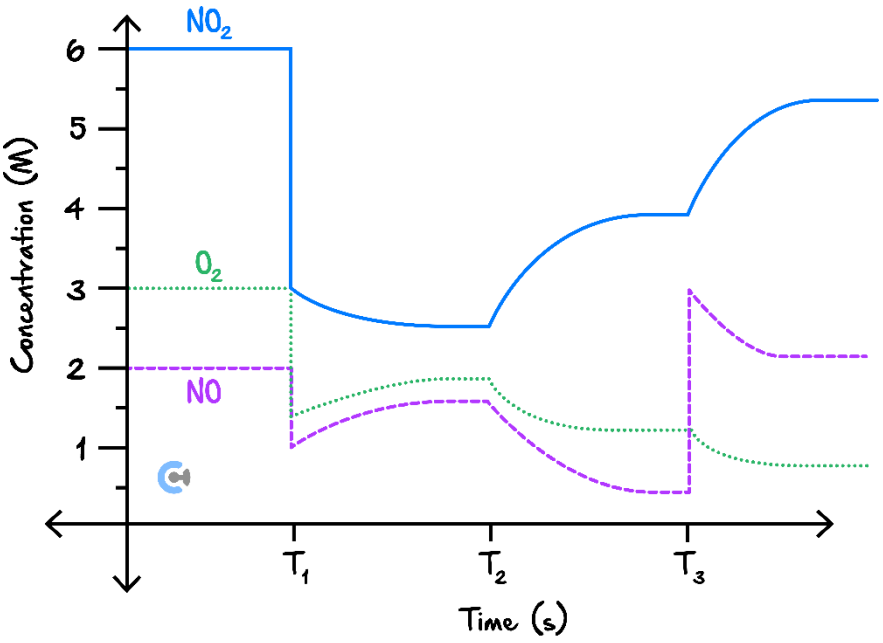
INSTRUCTION: 12 Marks. 12 Minutes Writing.

Question 31 (7 marks)

For the reaction:

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g), \qquad \Delta H < 0$$

a. The system has some changes made at three different times, as shown in the graph below.



i. Identify a change that could have been made to the system at T_1. (1 mark) **[2.9.3]**

_____

ii. At T_2. (1 mark) **[2.9.3] [2.9.1]**

A. The rate of the reverse reaction has increased.

B. The rate of the forward reaction has decreased.

C. Temperature was increased.

D. The equilibrium constant value decreased.

iii. At T_3. (1 mark) **[2.9.3]**

A. The equilibrium constant changed value.

B. More of both reactants were added to the reaction vessel.

C. Some of the products were removed.

D. Nitrogen dioxide gas is formed at a faster rate of reaction.

b. Determine the pressure and temperature conditions required to maximise the:

i. Rate of reaction. (1 mark) **[2.9.5]**

_____

ii. Equilibrium yield of NO_2. (1 mark) **[2.9.5]**

_____

c. Determine the pressure and temperature conditions that should be used to maximise the rate and equilibrium yield of nitrogen dioxide gas. Justify your answer. (2 marks) **[2.9.5]**

_____

_____

_____

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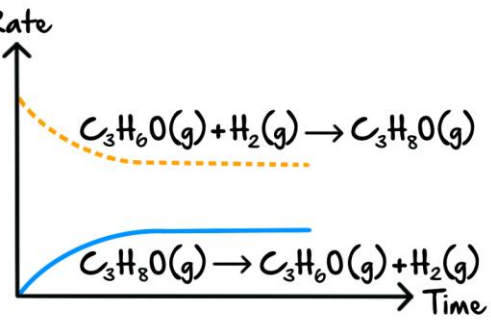
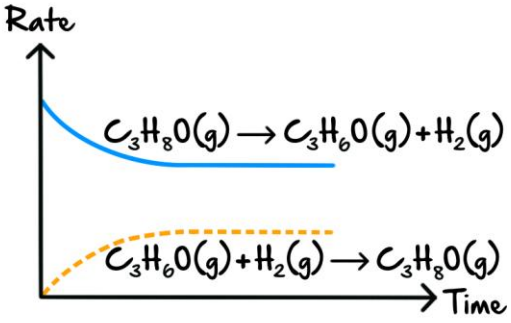
Question 32 (1 mark) **[2.8.3]**

When 2-propanol (C_3H_8O) reacts to form an equilibrium mixture with propanone (C_3H_6O) and hydrogen gas, which one of the following best represents how the **rates** of the forward and back reactions change over time?

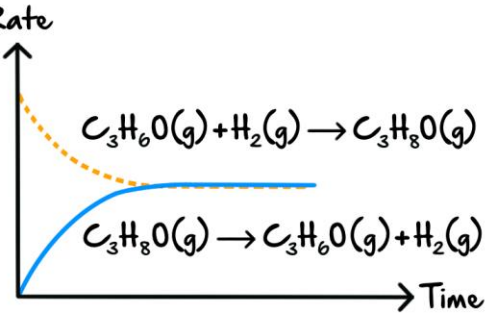
A.



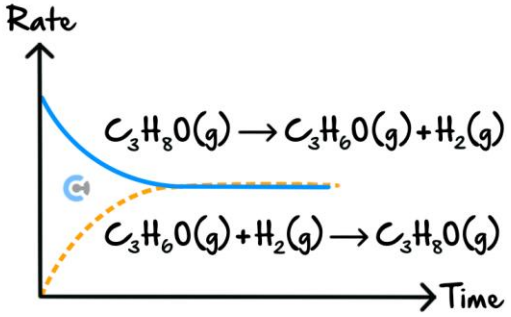
B.



C.



D.



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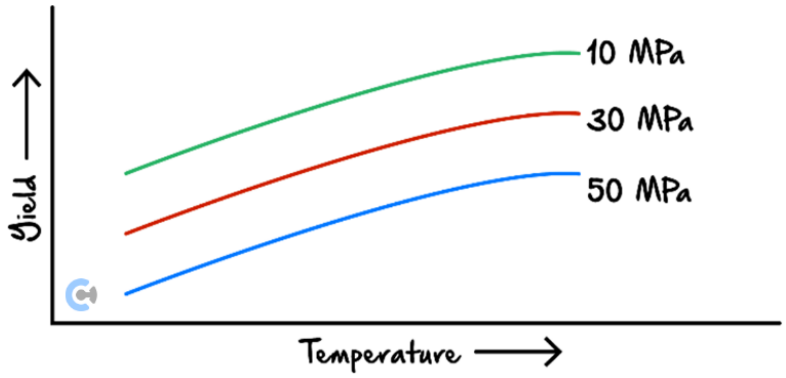
Question 33 (1 mark) **[2.9.5]**

Compounds X, Y and Z are in equilibrium. The diagram shows the effects of temperature and pressure on the equilibrium yield of compound Z.



Which equation would be consistent with this data?

A. $X + 3Y \rightleftharpoons 2Z \quad \Delta H > 0$

B. $X + 3Y \rightleftharpoons 2Z \quad \Delta H < 0$

C. $2X \rightleftharpoons 2Y + Z \quad \Delta H < 0$

D. $2X \rightleftharpoons 2Y + Z \quad \Delta H > 0$

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Question 34 (3 marks) **[2.9.1]**

A gas mixture is placed in the following gas syringe:

Sulphur dioxide and oxygen gas are placed into the gas syringe, whereby they are allowed to reach equilibrium according to the following equation:

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

Once the system reaches equilibrium, some helium gas is added to the mixture. Describe the effect this has on the position of equilibrium. Justify your answer.

_____

_____

_____

_____

_____

Check off any learning objectives obtained full marks from the "Contour Check" booklet!

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Sub-Section: Additional Questions

Question 35 (3 marks)

Inspired from VCAA Chemistry Exam 1 2005
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/05chem1.pdf#page=20

Dinitrogen tetroxide (N_2O_4) is a colourless gas. It exists in equilibrium with nitrogen dioxide (NO_2), a brown gas. The concentration of NO_2 in a gas mixture can be determined using a spectrophotometer. The equation for the reaction is:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g); K = 5.5 \times 10^{-3}\ M \text{ at } 25℃ \quad \text{.....(1)}$$
brown

Some pure NO_2 is placed in a gas syringe at 25℃ and allowed to reach equilibrium.

a. Keeping the volume constant, the temperature is then raised to 35℃. The brown colour then becomes more intense. Is the above reaction (1) exothermic or endothermic? Explain your answer. (2 marks) **[2.8.1]**

_____

_____

_____

_____

b. Keeping the temperature at 35℃ the plunger of the syringe is then pushed in so as to halve the volume. Equilibrium is then re-established. Is the brown colour of the mixture more intense or less intense than before the volume was halved? (1 mark) **[2.8.3]**

_____

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