CHEMISTRY
Stage 6

Module 5: Equilibrium and Acid Reactions
Factors that Affect Equilibrium

Teacher: Samantha Wong
Exam Equivalent Time: 103.5 minutes *(based on allocation of 1.5 minutes per mark)*

Questions

1. CHEMISTRY, M5 2023 HSC 12 MC

The industrial production of ammonia is represented by the Haber process reaction shown.

$$N_2\,(g) + 3H_2\,(g) \rightleftharpoons 2\,NH_3\,(g) \quad \Delta H = -\,91.8\text{ kJ mol}^{-1}$$

Factors such as temperature and pressure need to be considered in order to maximise yield.

Which of the following is correct?

A. A lower pressure would result in a higher yield.
B. A higher pressure would result in a higher yield.
C. A lower temperature would result in a lower yield.
D. A higher temperature would result in a higher yield.

2. CHEMISTRY, M5 2024 HSC 10 MC

The following system is at equilibrium.

$$\underset{\text{propan-2-ol}}{CH_3CHOHCH_3\,(g)} \rightleftharpoons \underset{\text{propan-2-one}}{CH_3COCH_3\,(g)} + H_2\,(g)$$

A catalyst is added to the system.

Which row of the table correctly identifies the change in the yield of propan-2-one and the reaction rates?

	Yield of propan-2-one	*Reaction Rates*
A.	Remains the same	Both forward and reverse rates are unchanged.
B.	Remains the same	Both forward and reverse rates increase equally
C.	Decreases	Reverse rate increases more than the forward rate increases.
D.	Increases	Forward rate increases more than the reverse rate increases.

3. CHEMISTRY, M5 2015 HSC 16 MC

The equation describes an equilibrium reaction occurring in a closed system.

$$X\,(g) + Y\,(g) \rightleftharpoons 4\,Z\,(g) \qquad \Delta H = +\,58\text{ kJ}$$

Under which set of conditions would the highest yield of $Z(g)$ be obtained?

	Temperature (°C)	*Pressure* (kPa)
A.	50	100
B.	50	200
C.	300	100
D.	300	200

4. CHEMISTRY, M5 2016 HSC 14 MC

Consider the following endothermic reaction taking place in a closed vessel.

$$N_2O_4(g) \rightleftharpoons 2\,NO_2(g)$$

Which of the following actions would cause more N_2O_4 to be produced?

A. Adding a catalyst
B. Decreasing the volume
C. Decreasing the pressure
D. Increasing the temperature

5. CHEMISTRY, M5 2019 HSC 12 MC

Methanol can be produced from the reaction of carbon monoxide and hydrogen, according to the following equation:

$$CO\,(g) + 2\,H_2\,(g) \rightleftharpoons CH_3OH\,(g) \qquad \Delta H_r^{\ominus} = -\,90\text{ kJ mol}^{-1}$$

Which set of conditions will produce the maximum yield of methanol?

A. Low pressure and low temperature
B. Low pressure and high temperature
C. High pressure and low temperature
D. High pressure and high temperature

6. CHEMISTRY, M5 2019 HSC 7 MC

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.

7. CHEMISTRY, M5 2022 HSC 13 MC

Nitrosyl bromide decomposes according to the following equation.

$$2\,NOBr\,(g) \rightleftharpoons 2\,NO\,(g) + Br_2\,(g)$$

A 0.64 mol sample of $NOBr$ is placed in an evacuated 1.00 L flask. After the system comes to equilibrium, the flask contains 0.46 mol $NOBr$.

What are the concentrations of NO and Br_2 in the flask at equilibrium?

	$[NO]\,(mol\,L^{-1})$	$[Br_2]\,(mol\,L^{-1})$
A.	0.18	0.09
B.	0.18	0.18
C.	0.36	0.18
D.	0.92	0.46

8. CHEMISTRY, M5 2024 HSC 7 MC

The following equilibrium was established in a container.

$$2\,SO_2\,(g) + O_2\,(g) \rightleftharpoons 2\,SO_3\,(g) \quad \Delta H = -198\,kJ\,mol^{-1}$$

Which of the following would increase the yield of $SO_3\,(g)$?

A. Increasing the volume

B. Increasing the temperature

C. Removing the product as it is formed

D. Keeping temperature and volume constant

9. CHEMISTRY, M5 2017 HSC 16 MC

The following equilibrium is established in a closed system.

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq) \qquad \Delta H = -19.4\ kJ\ mol^{-1}$$

How can the gas pressure in the system be decreased?

A. Add more $CO_2(g)$

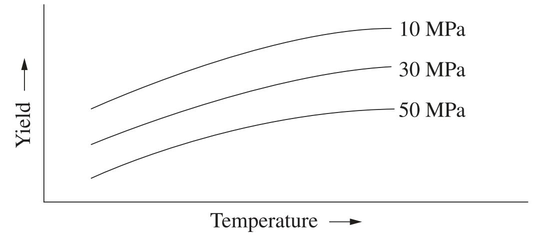
B. Add hydroxide ions to the solution

C. Decrease the volume of the container

D. Increase the temperature of the system

10. CHEMISTRY, M5 2020 HSC 16 MC

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. $X(g) + 3Y(g) \rightleftharpoons 2Z(g) \quad \Delta H > 0$

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

C. $2X(g) \rightleftharpoons 2Y(g) + Z(g) \quad \Delta H > 0$

D. $2X(g) \rightleftharpoons 2Y(g) + Z(g) \quad \Delta H < 0$

11. CHEMISTRY, M5 2022 HSC 14 MC

Nitrogen dioxide can react with itself to produce dinitrogen tetroxide.

$$2\,NO_2\,(g) \rightleftharpoons N_2O_4(g) \qquad K_{eq} = 0.010$$

In an experiment, 100.0 cm³ of NO_2 is placed in a syringe. The plunger is then pushed in until the volume is 50.0 cm³, while maintaining a constant temperature. The system is allowed to return to equilibrium.

Which statement is true for the system at equilibrium?

A. The value of K_{eq} has increased.

B. The ratio $\dfrac{[NO_2]}{[N_2O_4]}$ has decreased.

C. The concentration of N_2O_4 has decreased.

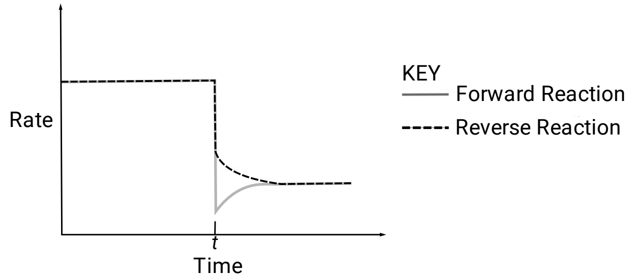
D. The concentrations of NO_2 and N_2O_4 have doubled.

12. CHEMISTRY, M5 2023 HSC 18 MC

Carbon dioxide reacts with hydrogen gas to form carbon monoxide and water vapour in a sealed flask, according to the following equation.

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

A temperature change was imposed on the equilibrium system at time t and the rates of both the forward and reverse reactions were monitored.



Which row of the table correctly identifies the nature of both temperature change at time t and the ΔH of the forward reaction?

	Temperature change at time t	*ΔH of the forward reaction*
A.	Decrease	+
B.	Decrease	−
C.	Increase	+
D.	Increase	−

13. CHEMISTRY, M5 EQ-Bank 12 MC

Nitrogen dioxide (a brown gas) and dinitrogen tetroxide (a colourless gas) are both forms of oxides of nitrogen. They are in equilibrium according to the equation

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

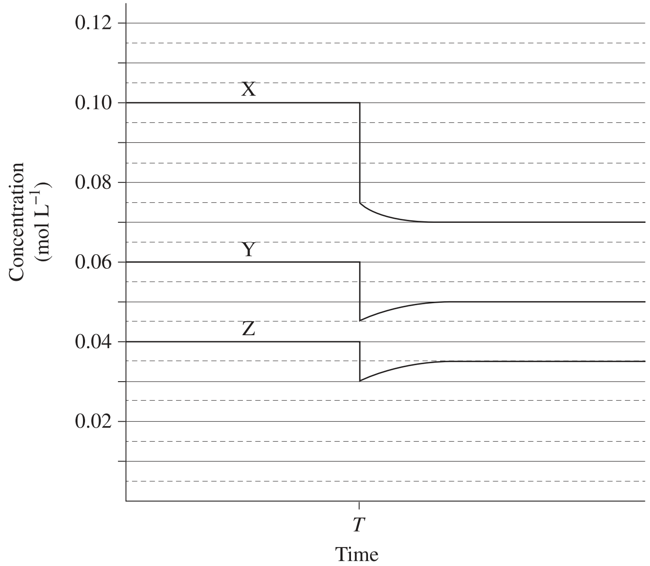
An equilibrium mixture of the two gases at room temperature is light brown but at higher temperatures the colour becomes a much deeper brown.

What conclusion can be drawn from this observation?

- **A.** The reverse reaction in the equation is endothermic.
- **B.** The forward reaction in the equation is endothermic.
- **C.** The brown colour is due to the strong nitrogen–oxygen bonds in NO_2.
- **D.** The equilibrium concentration of N_2O_4 is not dependent on temperature.

14. CHEMISTRY, M5 2017 HSC 18 MC

Three gases X, Y and Z were mixed in a closed container and allowed to reach equilibrium. A change was imposed at time T and the equilibrium was re-established. The concentration of each gas is plotted against time.



Which reaction is represented by the graph?

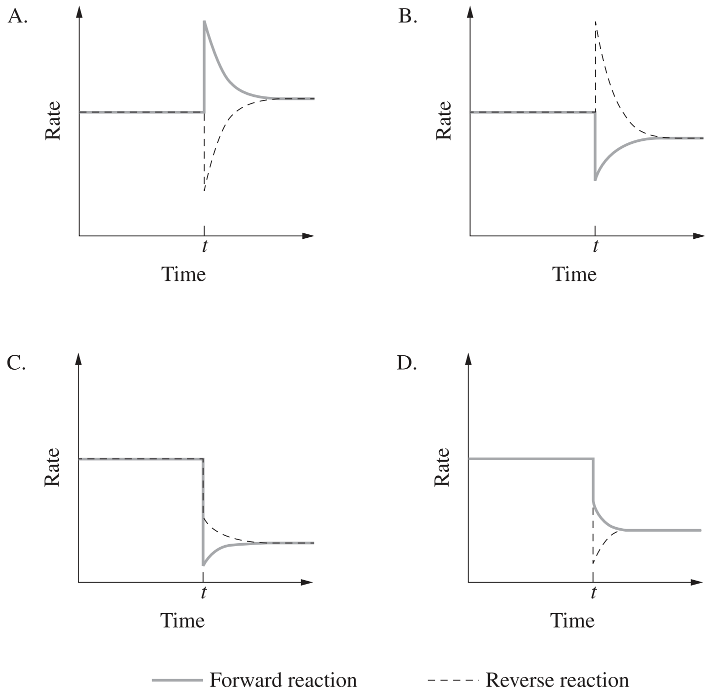
- **A.** $X(g) + Y(g) \rightleftharpoons 2Z(g)$
- **B.** $2X(g) \rightleftharpoons Y(g) + Z(g)$
- **C.** $2X(g) \rightleftharpoons Y(g) + 3Z(g)$
- **D.** $X(g) \rightleftharpoons Y(g) + Z(g)$

15. CHEMISTRY, M5 2020 HSC 19 MC

Nitrogen dioxide reacts to form dinitrogen tetroxide in a sealed flask according to the following equation.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -57.2 \text{ kJ mol}^{-1}$$

Which graph best represents the rates of both the forward and reverse reactions when an equilibrium system containing these gases is cooled at time t ?



16. CHEMISTRY, M5 2021 HSC 11 MC

Consider this system in a fixed volume at constant temperature.

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

This system is initially at equilibrium. A small amount of solid PCl_5 is added.

Which statement is correct?

A. The amount of Cl_2 will increase.

B. The amount of PCl_3 will decrease.

C. The amount of Cl_2 will not change.

D. The amount of PCl_5 will increase then decrease.

17. CHEMISTRY, M5 2021 HSC 22

Consider the following equilibrium system.

$$\underset{\textit{yellow}}{2CrO_4^{2-}(aq)} + 2H^+(aq) \rightleftharpoons \underset{\textit{orange}}{Cr_2O_7^{2-}(aq)} + H_2O(l) \qquad \Delta H = -895 \text{ kJ mol}^{-1}$$

The solution is orange.

Justify TWO ways to shift the equilibrium to the left to change the colour of the solution. ***(3 marks)***

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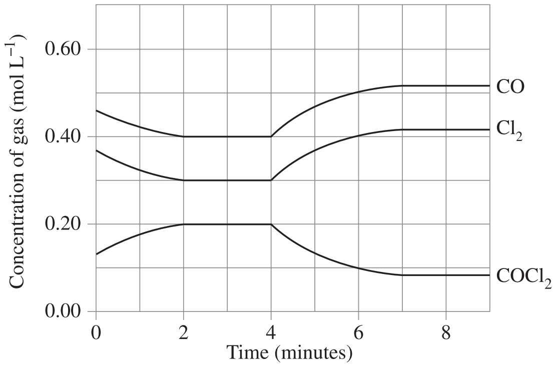
18. CHEMISTRY, M5 2016 HSC 28

A mixture of carbon monoxide, chlorine and phosgene $(COCl_2)$ gases was placed in a closed container. The concentrations of the gases were monitored over time.



a. At what time does the system first reach equilibrium? Justify your answer. ***(2 marks)***

b. At four minutes, the temperature of the container was increased.

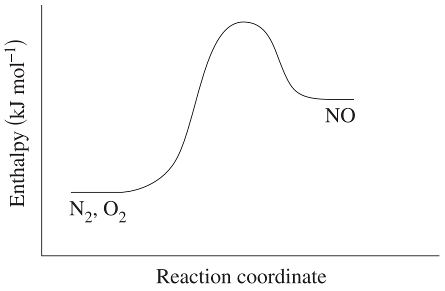
Explain, with reference to the graph, whether the decomposition of $COCl_2$ into CO and Cl_2 is exothermic or endothermic. ***(3 marks)***

19. CHEMISTRY, M5 2020 HSC 26

Nitric oxide gas (NO) can be produced from the direct combination of nitrogen gas and oxygen gas in a reversible reaction.

a. Write the balanced chemical equation for this reaction. ***(1 mark)***

b. The energy profile diagram for this reaction is shown.



Explain, using collision theory, how an increase in temperature would affect the value of K_{eq} for this system. Refer to the diagram in your answer. ***(4 marks)***

20. CHEMISTRY, M5 2022 HSC 23

Consider the following system which is at equilibrium in a rigid, sealed container.

$$4\,NH_3\,(g) + 5\,O_2\,(g) \rightleftharpoons 4\,NO\,(g) + 6\,H_2O\,(g) \qquad \Delta H = -\,950\ kJ\ mol^{-1}$$

a. Identify what would happen to the amount of $NO\,(g)$ if the temperature was increased. ***(1 mark)***

b. Explain why a catalyst does not affect the equilibrium position of this system. ***(2 marks)***

c. Using collision theory, explain what would happen to the concentration of $NO\,(g)$ if $H_2O\,(g)$ was removed from the system. ***(3 marks)***

21. CHEMISTRY, M5 EQ-Bank 30

A catalyst increases the value of the equilibrium constant, thus favouring the extent of the forward reaction, resulting in a greater yield of product.

Evaluate this statement, giving reasons why it is correct or incorrect. ***(2 marks)***

22. CHEMISTRY, M5 2019 HSC 25

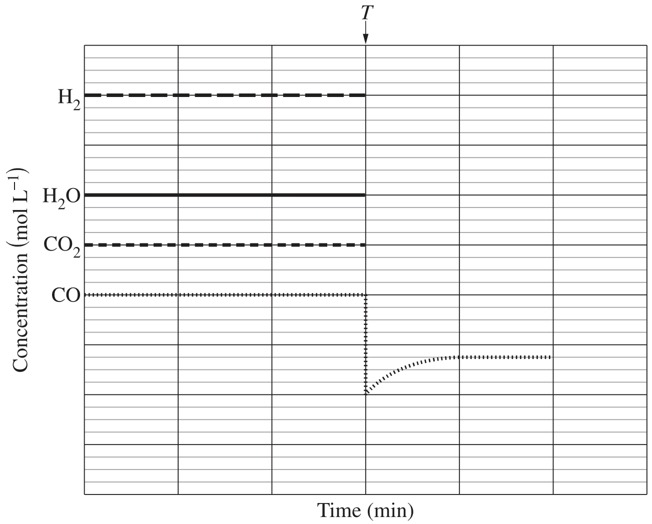
The concentrations of reactants and products as a function of time for the following system were determined.

$$\mathrm{CO}(g) + \mathrm{H_2O}(g) \rightleftharpoons \mathrm{CO_2}(g) + \mathrm{H_2}(g)$$

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

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

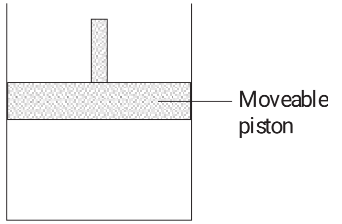
Sketch the concentrations after time T for the remaining species. ***(2 marks)***



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

23. CHEMISTRY, M5 2023 HSC 33

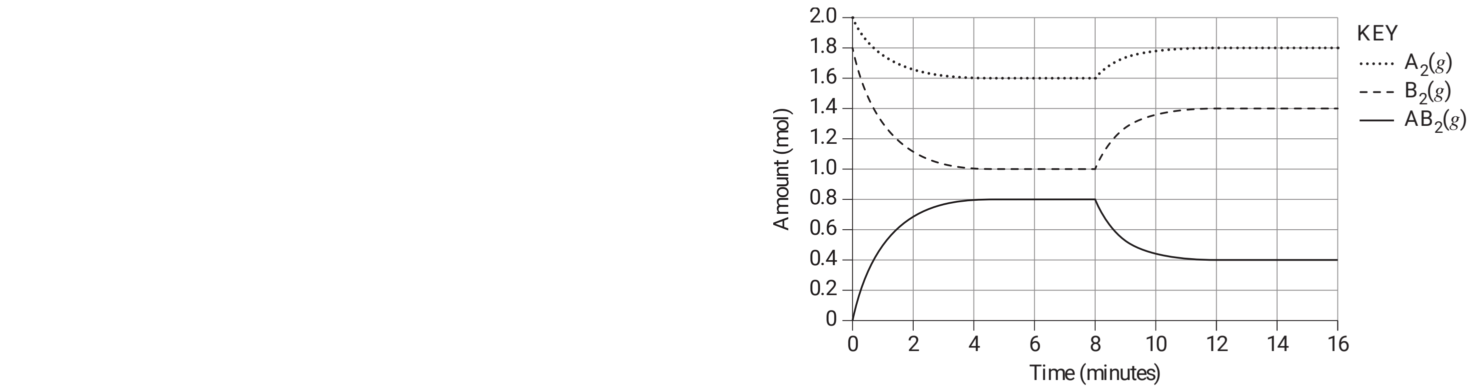
Gases A_2 and B_2 are placed in a closed container of variable volume, as shown.



The reaction between these substances is as follows.

$$A_2\,(g) + 2\,B_2\,(g) \rightleftharpoons 2\,AB_2\,(g) \quad \Delta H = -10\,\text{kJ mol}^{-1}$$

The following graph shows changes in the amounts (in mol) of these three substances over time in this container.

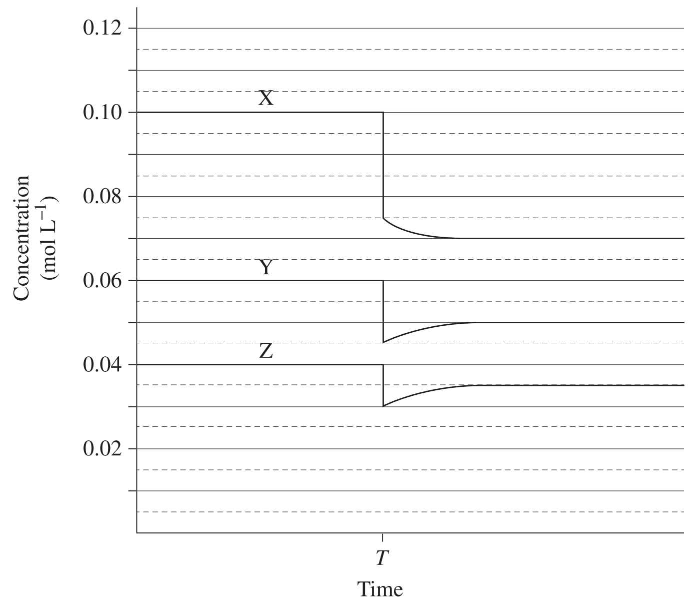


a. Explain what is happening in this system between 6 minutes and 8 minutes. ***(2 marks)***

b. Explain TWO different factors that could result in the disturbance at 8 minutes. ***(4 marks)***

24. CHEMISTRY, M5 EQ-Bank 21

Three gases X, Y and Z were mixed in a closed container and allowed to reach equilibrium. A change was imposed at time T and the equilibrium was re-established. The concentration of each gas is plotted against time.

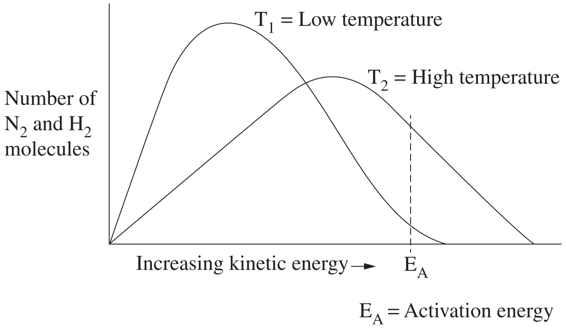


a. What is a possible change that was imposed at time T? ***(1 mark)***

b. Write a chemical reaction that is represented by the concentration graph above. ***(2 marks)***

25. CHEMISTRY, M5 2018 HSC 25

The graph shows the number of molecules of N_2 and H_2 that possess a certain kinetic energy at two different temperatures.



With reference to the graph, explain why changing the temperature and adding a catalyst would change the rate of production of ammonia. ***(4 marks)***

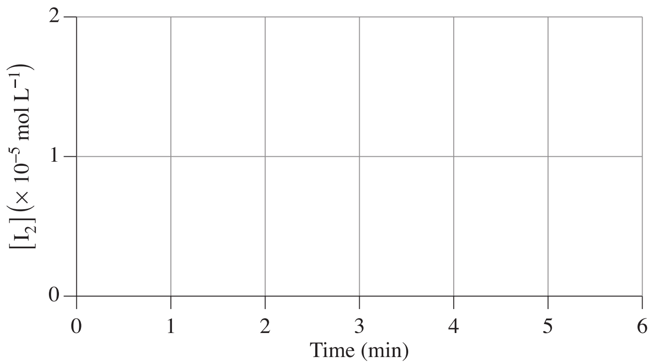
26. CHEMISTRY, M5 2024 HSC 26

The equilibrium equation for the reaction of iodine with hydrogen cyanide in aqueous solution is given.

$$I_2\,(aq) + HCN(aq) \rightleftharpoons ICN\,(aq) + I^-\,(aq) + H^+\,(aq)$$

At $t = 0$ min, I_2 was added to a mixture of $HCN,\ I^-$ and H^+, bringing $[I_2]$ to 2.0 × 10^{-5} mol L^{-1}. After 3 minutes, the system was at equilibrium, and an analysis of the mixture found that half of the I_2 had reacted.

a. On the axes provided, sketch a graph to show how $[I_2]$ changes in the solution between $t = 0$ min and $t = 6$ min. ***(2 marks)***

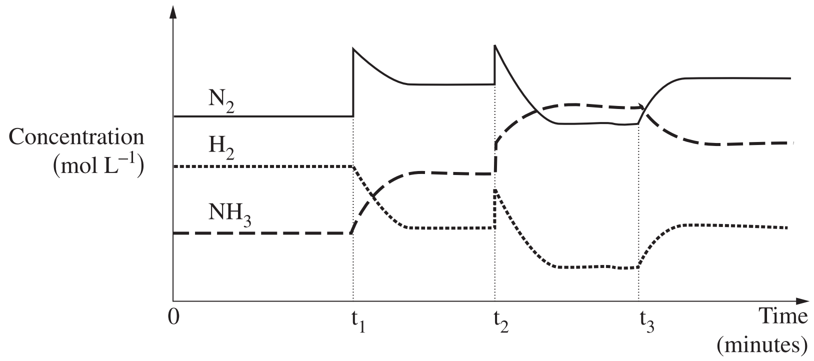


b. Using collision theory, explain the rate of reaction between $t = 0$ min and $t = 6$ min. Refer to the $[I_2]$ in your answer. ***(3 marks)***

27. CHEMISTRY, M5 EQ-Bank 12

An industrial plant makes ammonia from nitrogen gas and hydrogen gas. The reaction is exothermic.

The graph shows the adjustments made to increase the yield of ammonia.



Account for the changes in conditions that have shaped the graph during the time the system was observed. Include a relevant chemical equation in your answer. ***(5 marks)***

28. CHEMISTRY, M5 EQ-Bank 13

A student hypothesises that increasing the temperature of an exothermic reaction slows down the reaction rate because less products are produced. Is this student correct? Give reasons. ***(4 marks)***

Worked Solutions

1. CHEMISTRY, M5 2023 HSC 12 MC

→ Increasing the pressure would shift the position of equilibrium to the side of the equation with less moles (as per Le Chatelier's principle).

→ This would increase the yield of $\mathrm{NH_3}$

$\Rightarrow B$

2. CHEMISTRY, M5 2024 HSC 10 MC

→ Adding a catalyst to an equilibrium system will decrease the activation energy of both the forward and reverse reactions equally.

→ Thus, the reaction rate of the forward and reverse reactions will both increase and cause no change to the yield of the reaction.

$\Rightarrow B$

3. CHEMISTRY, M5 2015 HSC 16 MC

→ Forward reaction is endothermic $(\Delta H = +58\ \mathrm{kJ})$

→ High temperature will shift reaction to the right.

→ Right hand side has more gas molecules (4 vs 2) and therefore the forward reaction will benefit from lower pressure.

→ Highest yield of $\mathrm{Z}(g)$ when temperature is higher and pressure lower.

$\Rightarrow C$

4. CHEMISTRY, M5 2016 HSC 14 MC

→ By decreasing the volume, the equilibrium will shift to the left so that less gas molecules are present (Le Chatelier's principle).

$\Rightarrow B$

5. CHEMISTRY, M5 2019 HSC 12 MC

→ To maximise the methanol yield, the equation must shift towards the right hand side.

→ Pressure: If the pressure is increased, the system will shift to reduce this increase. In this reaction, a shift to the right hand side will occur because there are fewer gas molecules (1 on right vs 3 on the left).

→ Temperature: If the temperature is decreased, the equilibrium will shift to the exothermic side which absorbs heat (right hand side). This compensation will result in more methanol.

$\Rightarrow C$

6. CHEMISTRY, M5 2019 HSC 7 MC

→ A catalyst helps to make a chemical reaction happen more easily by offering a different pathway for the reaction to occur.

→ This reduction in the required activation energy applies to both the forward and reverse reactions.

$\Rightarrow D$

7. CHEMISTRY, M5 2022 HSC 13 MC

	NOBr	NO	Br_2
Initial	0.64	0	0
Change	-0.18	$+0.18$	$+0.09$
Equilibrium	0.46	0.18	0.09

$[NO] = 0.18\ \text{mol L}^{-1}$

$[Br_2] = 0.09\ \text{mol L}^{-1}$

$\Rightarrow A$

8. CHEMISTRY, M5 2024 HSC 7 MC

→ A: Increasing the volume decreases the pressure of the system → favours the reverse reaction, decreasing yield.

→ B: Increasing the temperature will favour the reverse endothermic reaction, decreasing yield.

→ C: Removing $SO_3\,(g)$ as it is formed decreases the concentration of $SO_3\,(g)$. By Le Chatelier's principle, the equilibrium system will shift to increase the concentration of $SO_3\,(g)$, increasing the yield.

→ D: Keeping temp and volume constant will have no impact on the equilibrium system.

$\Rightarrow C$

9. CHEMISTRY, M5 2017 HSC 16 MC

→ Gas pressure can be decreased if the equilibrium shifts to the right.

→ If hydroxide ions are added to the solution by adding NaOH, this will neutralise the carbonic acid and cause an equilibrium shift to the right.

♦♦ Mean mark 32%.

$\Rightarrow B$

10. CHEMISTRY, M5 2020 HSC 16 MC

→ The yield of Z increases as temperature increases, thus, endothermic reaction $\Delta H > 0$.

♦ Mean mark 49%.

→ The yield of Z increases as pressure decreases, thus more gaseous moles on the product side.

$\Rightarrow C$

11. CHEMISTRY, M5 2022 HSC 14 MC

→ As the volume is decreased, the pressure increases. According to Le Chatelier's Principle, the equilibrium will shift toward the right with fewer moles of gas in order to counteract the change in equilibrium (ie decrease pressure).

♦♦ Mean mark 35%.

→ As a result, $[N_2O_4]$ will increase and $[NO_2]$ will decrease.

→ Therefore, $\dfrac{[NO_2]}{[N_2O_4]}$ will decrease.

$\Rightarrow B$

12. CHEMISTRY, M5 2023 HSC 18 MC

→ The rate decrease is associated with a decrease in temperature (collision theory).

♦♦ Mean mark 39%.

→ Since the rate slowed, the forward reaction is endothermic (requires heat to react) and thus has a positive (+) ΔH

$\Rightarrow A$

13. CHEMISTRY, M5 EQ-Bank 12 MC

→ Le Chatelier's principle states that when an equilibrium system is subject to a change in conditions, it will shift such as to partially counteract the imposed change.

→ When the temperature of the system is increased, it will shift to favour the endothermic reaction, counteracting the increase in temperature.

→ In this case, the deeper brown colour shows the conversion to nitrogen dioxide is favoured following an increase in temperature. The reverse reaction is therefore endothermic.

$\Rightarrow A$

14. CHEMISTRY, M5 2017 HSC 18 MC

Concentration changes at T:

→ Concentrations of X ↓ 25%, Y ↓ 25%, Z ↓ 25%

♦ Mean mark 42%.

New equilibrium after T:

→ Concentrations of X ↓ 0.005 mol L $^{-1}$, Y ↑ 0.005 mol L $^{-1}$, Z ↑ 0.005 mol L $^{-1}$

→ Shift is equimolar (1:1:1) and Y and Z are on the same side of the equation (both increase)

$\Rightarrow D$

15. CHEMISTRY, M5 2020 HSC 19 MC

→ When the temperature decreases, both the forward and reverse reaction rates will decrease (eliminate A).

♦♦♦ Mean mark 22%.

→ Exothermic reactions have a lower activation energy threshold (i.e. their reaction rates are less affected by cooling).

→ Therefore, the exothermic reaction rate will decrease to a smaller extent (eliminate B and C).

$\Rightarrow D$

16. CHEMISTRY, M5 2021 HSC 11 MC

The equilibrium constant expression is: $\mathrm{K}_{eq} = [\mathrm{Cl_2}(g)]$

♦♦♦ Mean mark 19%.

→ As we can see from the equilibrium constant expression, the value of K_{eq} is only dependent on the concentration of $\mathrm{Cl_2}$.

→ As a result, the addition of solid $\mathrm{PCl_5}$ will have no affect on the value of K_{eq} and thus has no impact on the equilibrium position.

→ Thus, the amount of $\mathrm{Cl_2}$ will not change.

$\Rightarrow C$

17. CHEMISTRY, M5 2021 HSC 22

Answers could include two of the following methods.

Add $\mathrm{Cr_2O_7}^{\ 2-}$ ions:

→ This would increase the concentration of $\mathrm{Cr_2O_7}^{\ 2-}$ ions.

→ According to Le Chatelier's Principle, this would cause the equilibrium to shift left to counteract the change and decrease the concentration of $\mathrm{Cr_2O_7}^{\ 2-}$ ions.

Decrease the concentration of $\mathrm{H^+}$ ions by adding a base:

→ This would decrease the concentration of $\mathrm{H^+}$ ions through an acid-base reaction.

→ According to Le Chatelier's Principle, this would cause the equilibrium to shift left to counteract the change and increase the concentration of $\mathrm{H^+}$ ions.

Increase the temperature:

→ According to Le Chatelier's Principle, this would cause the equilibrium to shift left towards the endothermic side to counteract the change and decrease the temperature.

18. CHEMISTRY, M5 2016 HSC 28

a. At two minutes (where the concentrations stop changing)

b. $\mathrm{CO\,(g) + Cl_2\,(g) \rightleftharpoons COCl_2\,(g)}$

→ From the graph, when the temperature is increased, the $\mathrm{COCl_2}$ concentration decreases while CO and $\mathrm{Cl_2}$ concentrations increases.

→ The reaction is countering the increase in temperature by shifting to the left and absorbing heat (Le Chatelier's principle).

→ Therefore the decomposition of $\mathrm{COCl_2\,(g)}$ is endothermic.

19. CHEMISTRY, M5 2020 HSC 26

a. $\mathrm{N_2\,(g) + O_2\,(g) \rightleftharpoons 2\,NO\,(g)}$

b. → From the graph, the forward reaction is endothermic.

→ The activation energy of the forward endothermic reaction is greater than the activation energy of the reverse exothermic reaction.

→ An increase in temperature would cause the rates of both the forward and reverse reaction due to the higher average kinetic energy, resulting in a larger likelihood of a successful collisions.

→ However, the rate of the forward reaction would increase to a higher extent than the reverse reaction, since it is an endothermic reaction.

→ Using $K_{eq} = \dfrac{[\mathrm{NO}]^2}{[\mathrm{N_2}]\,[\mathrm{O_2}]}$, as the equilibrium shifts right, the equilibrium constant would increase.

20. CHEMISTRY, M5 2022 HSC 23

a. The amount of NO_2 decreases.

b. Catalyst affect on equilibrium:

→ A catalyst lowers the activation energy and equally increases the rate of both the forward and reverse reactions.

→ As a result, there is no net change in equilibrium, and thus the equilibrium position remains unchanged.

c. If H_2O is removed from the system:

→ This would cause the reverse reaction to decrease because there would be a lower likelihood of successful collisions between NO and H_2O molecules.

→ As a result, the forward reaction rate is greater than the reverse reaction rate, thus, the equilibrium would shift to the right, causing $[NO]$ and $[H_2O]$ to increase.

→ As the equilibrium is shifting to the right, the forward reaction rate decreases, whilst the reverse reaction rate increases, until they reach equilibrium.

→ At equilibrium, the concentration of all substances remain constant.

21. CHEMISTRY, M5 EQ-Bank 30

The statement is incorrect.

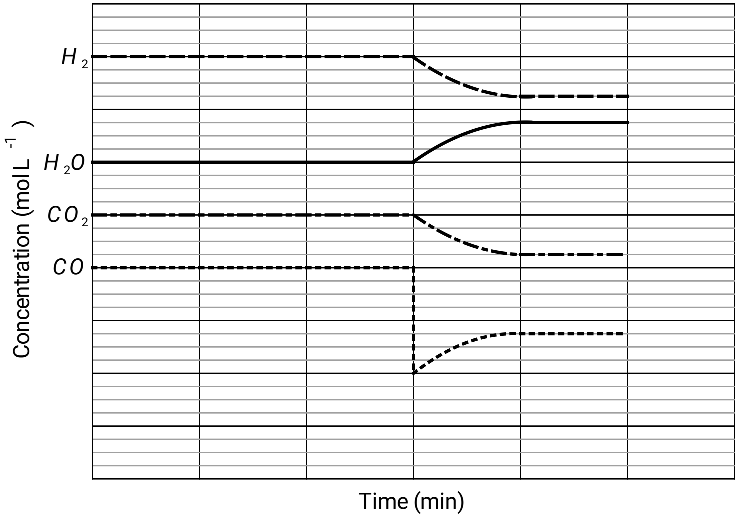
→ A catalyst does not affect relative amounts of reactants and products at equilibrium.

→ Only a change in the position of equilibrium will change the value of the equilibrium constant (i.e. the yield of product).

→ A catalyst increases the rates of forward and reverse reactions equally, getting the system to equilibrium faster.

22. CHEMISTRY, M5 2019 HSC 25

a.



b. Changes in CO after time T:

→ The removal of CO from the system leads to a decrease in the concentration of CO, which in turn leads to a decrease in the rate of the forward reaction.

→ This is because there are fewer collisions between CO and H_2O molecules, which are necessary for the forward reaction to occur.

→ The rate of the reverse reaction increases, becoming greater than the rate of the forward reaction. This results in a shift in the equilibrium to the left, leading to an increase in the concentration of CO and H_2O and a decrease in the concentration of H_2 and CO_2.

→ Over time, the rate of the forward reaction subsequently increases until it becomes equal to the rate of the reverse reaction, at which point the system reaches a new equilibrium state with constant concentrations of all species.

23. CHEMISTRY, M5 2023 HSC 33

a. Between 6 and 8 minutes:

→ The system is in equilibrium.

→ The horizontal lines of each reactant in the graph indicate that the amount of reactants and products remain constant and hence the forward and reverse reactions are proceeding at the same rate.

b. After 8 minutes AB_2 is consumed, and A_2 and B_2 are produced.

Factor 1:

→ An increase in temperature that decreases the equilibrium constant, K.

→ In this case, the reaction quotient Q will be greater than K. This will result in AB_2 being consumed and A_2 and B_2 being produced until Q approaches K and the system reaches equilibrium again.

Factor 2:

→ Increase in volume of the container.

→ This will increase the reaction quotient Q while K stays the same. Again, this will cause AB_2 to be consumed and A_2 and B_2 to be produced until Q approaches K and the system reaches equilibrium again.

24. CHEMISTRY, M5 EQ-Bank 21

a. At time T:

→ The concentration of all species decreases by an amount proportional to their initial concentration.

→ This could be due to an increase in the volume of the container.

b. Chemical reaction:

→ After the system change, equilibrium re-establishes by favouring the conversion of X into Y and Z .

→ As change in concentration of all species is equal, they react in a 1:1:1 molar ratio.

→ Therefore the chemical reaction is: $X(g) \rightleftharpoons Y(g) + Z(g)$

25. CHEMISTRY, M5 2018 HSC 25

→ Gas particles need to attain activation energy E_A in order to react when they collide.

Mean mark 53%.

→ E_A is a level of kinetic energy that is sufficient for reactions to occur.

→ Some N_2 and H_2 particles have a kinetic energy above E_A when the temperature is lower at T_1 (see graph above).

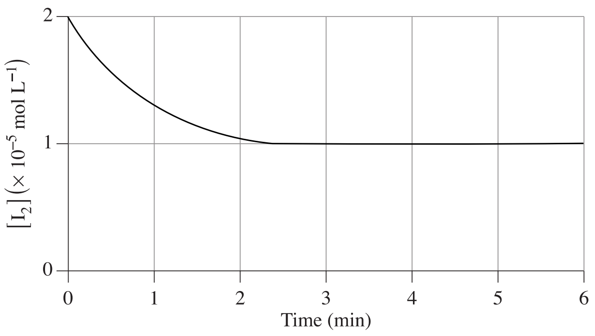
→ However, the number of N_2 and H_2 particles with enough energy to react and produce ammonia is significantly greater at the higher temperature T_2, where the graph has shifted to the right.

→ A catalyst lowers the E_A. On the graph, this would shift the dotted E_A line to the left.

→ In the presence of a catalyst, both graphs show there will be a greater number of particles that can react in a given time and therefore the rate of ammonia production will increase in both cases.

26. CHEMISTRY, M5 2024 HSC 26

a.



b. Initially, the high $[I_2]$ results in a large number of collisions between reactants.

Mean mark (b) 56%.

→ This results in an initially high reaction rate for the forward reaction.

→ Between $t = 0$ and $t = 3$, the concentration of I_2 decreases. Less collisions between reactant particles occur leading to a decrease in the rate of the forward reaction.

→ Between $t = 0$ and $t = 3$, as the concentration of reactants decrease, the concentration of the products increase. This leads to an increase in the number of successful collisions between product particles and a subsequent increase in the rate of the reverse reaction.

→ Between $t = 3$ and $t = 6$, the concentration of I_2 remains constant. This is due to the system reaching a state of dynamic equilibrium so the frequency of successful collisions between the reactants is equal to the frequency of successful collisions between the products. i.e. the rates of the forward and reverse reactions are equal.

27. CHEMISTRY, M5 EQ-Bank 12

$$\mathrm{N_2\,(g) + 3\,H_2\,(g) \rightleftharpoons 2\,NH_3\,(g) \quad \Delta H = -92\,kJ\,mol^{-1}}$$

From t_0 to t_1: the system is in equilibrium.

At t_1:

→ Nitrogen is introduced to the system and its concentration increases sharply.

→ Le Chatelier's principle states that when a system in equilibrium is disturbed, the equilibrium will shift in the direction that minimises the change. In this case, the equilibrium will shift to the right to use up more nitrogen. A greater yield of ammonia will result until equilibrium is re-established.

At t_2:

→ The concentration of both reactants and products increases. This effect could be caused by a decrease in volume of the reaction vessel which will result in an increase in pressure on the system.

→ The above equation shows that 4 moles of gas (on the left-hand side) react to form 2 moles of gas (on the right-hand side). Le Chatelier's principle dictates that this increase in pressure will cause the system to again shift right, to the side with fewer moles of gas, to counteract the change.

→ This right shift will further increase the yield of ammonia until equilibrium is re-established.

At t_3:

→ There is a change to the system that shifts the reaction back to the left. The gradual change in concentrations indicate that this could be due to a change in temperature.

→ Since this reaction is exothermic, the reverse reaction (left shift) absorbs heat. An increase in temperature would cause this shift, lowering the yield of ammonia until equilibrium is again restored.

28. CHEMISTRY, M5 EQ-Bank 13

→ The student is incorrect.

→ Exothermic reactions release heat to the surrounding environment, as modelled in this general reaction equation:

$$\mathrm{R_{(1)} + R_{(2)} \rightleftharpoons P_{(1)} + P_{(2)} + Heat}$$

→ Increasing the temperature will result in fewer products being produced as the position of equilibrium shifts to the left (as per Le Chatelier's principle).

→ However, contrary to the student's hypothesis, fewer products being produced does not cause the reaction rate to slow down.

→ In fact, the rate of reaction will increase as the kinetic energy of particles will increase, leading to more successful particle collisions that exceed E_a.

→ The mistake the student has made is viewing fewer products as causing a decrease in reaction rate. The actual occurrence has been a shift in equilibrium to the left and an increase in the (forward) reaction rate to reach equilibrium.