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Topic: Chemical Equilibrium

Basic Multiple Choice Questions (Level 1 and Level 2 Learners)

1.
This reaction is in equilibrium.

$$\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g}) \quad \Delta H > 0$$

- The equilibrium can be disturbed by a change in
 (A) either the pressure, temperature or concentration.
 (B) only the temperature or pressure.
 (C) only the temperature and concentration.
 (D) only the concentration and pressure.

2.
When a catalyst is used in the Haber process to make ammonia, the yield and the activation energy of the reaction will be

	YIELD	ACTIVATION ENERGY
(A)	increased	decreased
(B)	increased	increased
(C)	unchanged	decreased
(D)	unchanged	increased

3.

$$\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) \quad \Delta H > 0$$

 In this reversible reaction a catalyst will
 (A) increase the activation energy of the reverse reaction.
 (B) speed up rate of both forward and reverse reactions.
 (C) cause an equilibrium shift to favour forming more products.
 (D) increase the heat of reaction.

4.
The following equilibrium exists in a saturated salt solution,

$$\text{NaCl}(\text{s}) \rightleftharpoons \text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq})$$

 Which action causes NaCl to precipitate ?
 (A) Increasing the pressure on the system.
 (B) Bubbling dichlorine gas through the solution.
 (C) Adding concentrated sulfuric acid.
 (D) Heating the system.

5.
The following reaction is in equilibrium,

$$\text{H}_2(\text{g}) + \text{I}_2(\text{g}) + 53\text{ kJ} \rightleftharpoons 2\text{HI}(\text{g})$$

- This reaction will not have its equilibrium disturbed by
 (A) heating it.
 (B) increasing the volume of the reaction chamber.
 (C) adding more hydrogen.
 (D) removing some product.

6.
The following reaction is in equilibrium,

$$\text{H}_2(\text{g}) + \text{F}_2(\text{g}) \rightleftharpoons 2\text{HF}(\text{g}) + 271\text{ kJ}$$

- This reaction will not have its equilibrium disturbed by
 (A) cooling it.
 (B) adding a suitable catalyst.
 (C) removing some hydrogen.
 (D) raising the temperature.

7.
The following reaction is in equilibrium,

$$\text{H}_2(\text{g}) + \text{F}_2(\text{g}) \rightleftharpoons 2\text{HF}(\text{g}) + 271\text{ kJ}$$

- The yield of HF will be increased by
 (A) cooling it.
 (B) adding a suitable catalyst.
 (C) removing some hydrogen.
 (D) raising the temperature.

8.
The following reaction is in equilibrium,

$$\text{H}_2(\text{g}) + \text{F}_2(\text{g}) \rightleftharpoons 2\text{HF}(\text{g}) \quad \Delta H < 0$$

- The yield of HF will be increased by
 (A) adding some fluorine.
 (B) lowering the pressure.
 (C) raising the pressure.
 (D) reducing the volume of the reaction vessel.

9.
A reaction in chemical equilibrium is **not** affected by an increase in the
 (A) concentration of reactants.
 (B) temperature.
 (C) concentration of products.
 (D) concentration of catalyst involved.

10.
The following reaction is in equilibrium

$$\text{C}_3\text{H}_6(\text{g}) + \text{H}_2(\text{g}) \rightleftharpoons \text{C}_3\text{H}_8(\text{g}) \quad \Delta H = -137\text{ kJ}$$

 An increase in pressure will
 (A) increase the yield.
 (B) decrease the yield.
 (C) favour the reverse reaction.
 (D) increase the concentration of hydrogen.

11.
Which of the following is an example of the **common ion effect**?
 (A) Dissolving salt in water.
 (B) Adding sodium ethanoate to ethanoic acid.
 (C) Adding copper metal to a copper(II) sulfate solution.
 (D) Adding sulfuric acid to a sodium chloride solution.

12.
In which of the following reactions will the forward reaction be favoured if the volume of the container is reduced ?
 (A) $\text{C}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g}) \rightleftharpoons \text{C}_2\text{H}_6(\text{g})$
 (B) $\text{CoCl}_2(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + \text{Cl}_2(\text{g})$
 (C) $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$
 (D) $2\text{KClO}_3(\text{l}) \rightleftharpoons 2\text{KCl}(\text{s}) + 3\text{O}_2(\text{g})$

13.
Which of the following statements concerning a catalyst is **wrong**?
 (A) It changes the rate of a reaction.
 (B) It changes the yield of a system.
 (C) It lowers the activation energy.
 (D) It offers an alternative lower energy path.

14.
The following reaction is in equilibrium at 200°C

$$\text{H}_2(\text{g}) + \text{F}_2(\text{g}) \rightleftharpoons 2\text{HF}(\text{g}) \quad \Delta H < 0$$

 The concentration of HF at 200°C will be influenced by
 (A) raising the pressure.
 (B) lowering the pressure.
 (C) increasing the concentration of the reactants.
 (D) adding a suitable catalyst.

15.

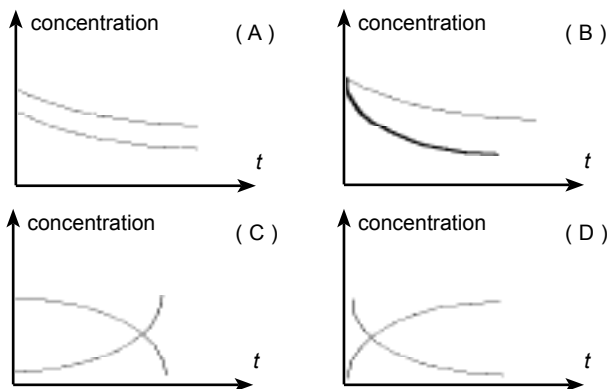
$$\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g}) + \text{energy}$$

 We can increase the yield of this reaction by
 (A) powdering the solid calcium carbonate.
 (B) heating the reaction.
 (C) increasing the volume of the reaction chamber.
 (D) adding a suitable catalyst.

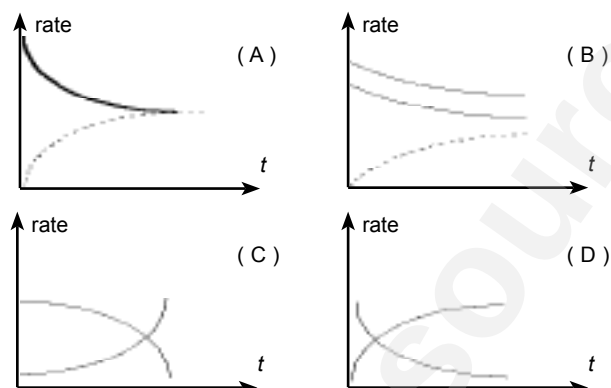
Topic: Chemical Equilibrium

Difficult Multiple Choice Questions (Level 5 - 7 Learners)

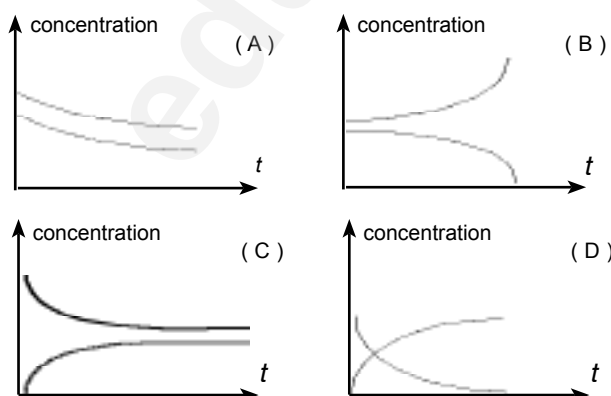
1. Which graph best represents the concentration of reactants and products, just before and just after equilibrium is reached?



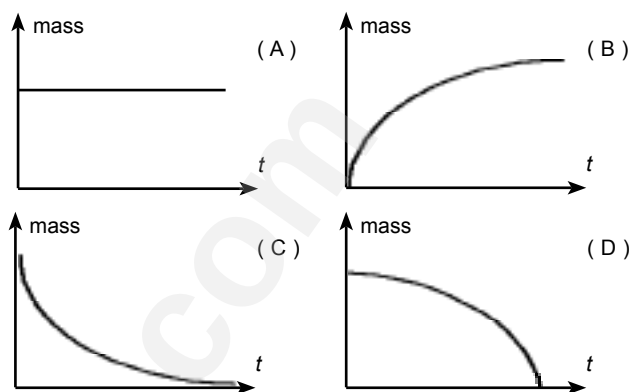
2. Which graph best represents the rate of the forward and reverse reactions, just before and just after equilibrium is reached?



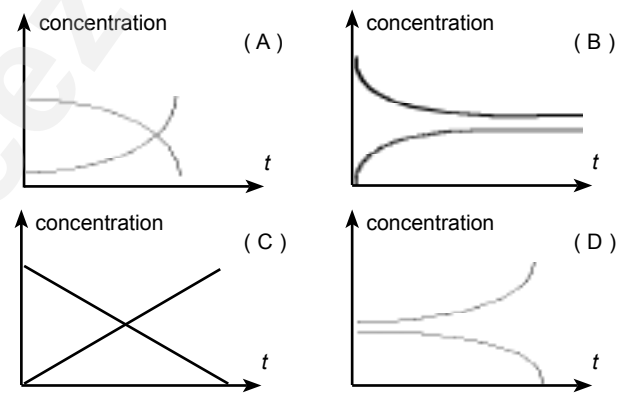
3. If all the reactants in a certain reaction are used up and the reaction goes to completion, which graph will best represent this reaction?



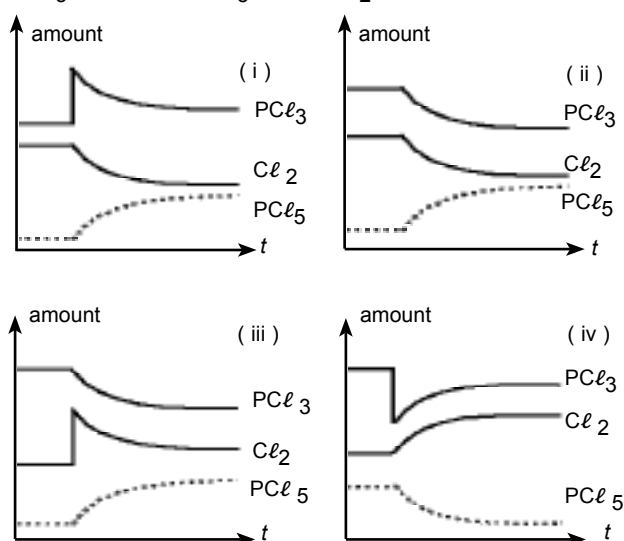
4. If a catalyst is added to a system in equilibrium, which graph represents the change of mass of the
(i) reactants
(ii) products
(iii) catalyst (even if the equilibrium is disturbed)



5. Which graph represents the concentration of reactants and products, just before and just after equilibrium is reached?



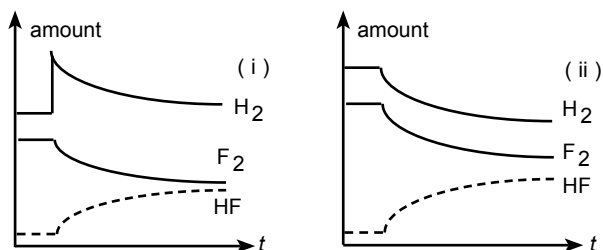
6. What event(s) occurred to disturb these equilibria ?
 $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g}) \quad \Delta H > 0$



(A) We added some more of one of the products.
(B) We removed some of the product.
(C) We heated the reaction.
(D) We cooled the reaction or we increased the pressure.

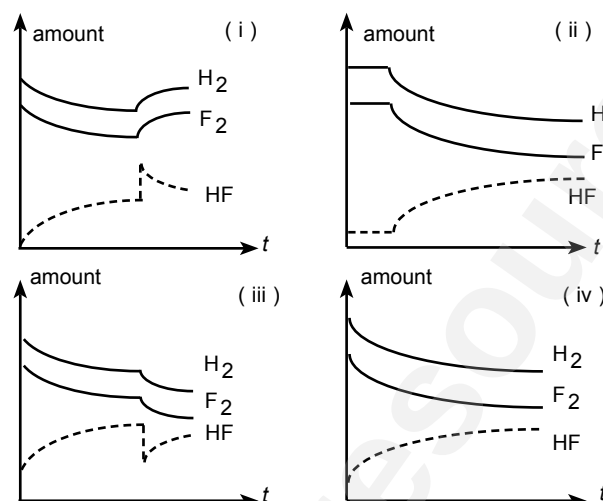
Difficult Multiple Choice Questions (Level 5 - 7 Learners)

7. What event(s) occurred to disturb these equilibria ?
 $\text{H}_2(\text{g}) + \text{F}_2(\text{g}) \rightleftharpoons 2\text{HF}(\text{g}) \quad \Delta H < 0$



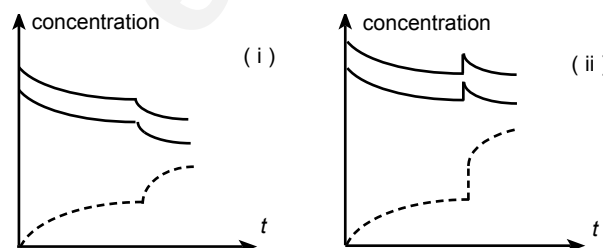
- (A) Nondumiso added some more hydrogen.
- (B) Nondumiso removed some of the fluorine.
- (C) Candace heated the reaction.
- (D) Candace cooled the reaction.

8. What event(s) occurred to disturb these equilibria ?
 $\text{H}_2(\text{g}) + \text{F}_2(\text{g}) \rightleftharpoons 2\text{HF}(\text{g}) \quad \Delta H < 0$



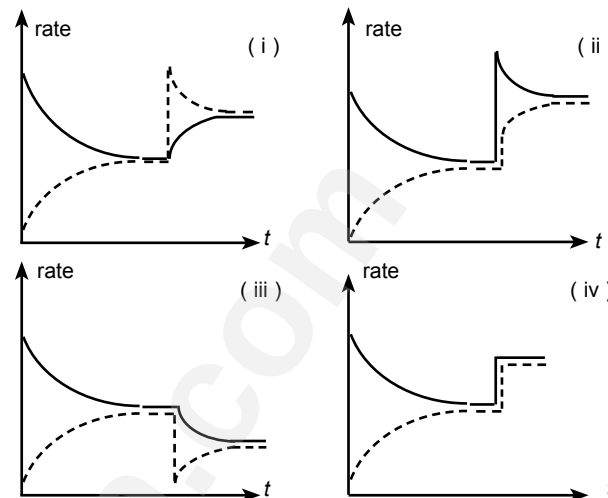
- (A) Taskeen added some more hydrogen fluoride.
- (B) Taskeen removed some of the product.
- (C) Maligay added a catalyst.
- (D) Maligay cooled the reaction.

9. What event(s) occurred to disturb these equilibria ?
 $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) \quad \Delta H < 0$



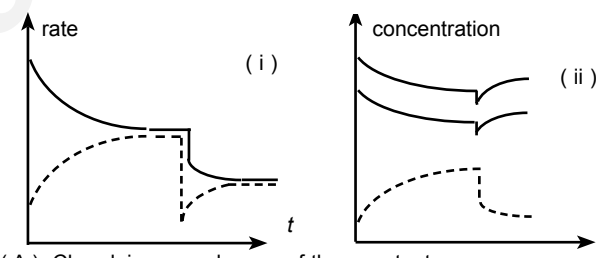
- (A) Meagan added some more of the reactants.
- (B) Meagan added some more of the product.
- (C) Heather lowered the temperature.
- (D) Heather increased the pressure.

10. What event(s) occurred to disturb these equilibria ?
 $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) \quad \Delta H < 0$



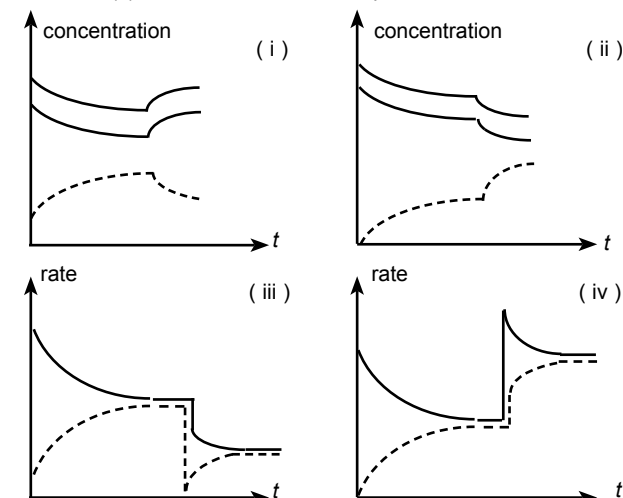
- (A) Sadiyya added some more ammonia.
- (B) Sadiyya removed some of the product.
- (C) Chandre added a catalyst.
- (D) Chandre increased the pressure.

11. What event(s) occurred to disturb these equilibria ?
 $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g}) \quad \Delta H < 0$



- (A) Chandni removed some of the reactants.
- (B) Chandni removed some of the product.
- (C) Jahaan lowered the temperature.
- (D) Jahaan decreased the pressure.

12. What event(s) occur to disturb these equilibria ?

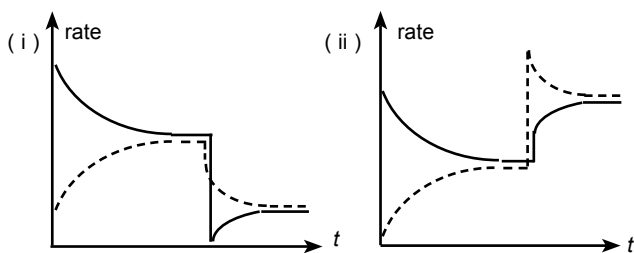


- (A) We heat an exothermic or cool an endothermic reaction.
- (B) We heat an endothermic or cool an exothermic reaction.
- (C) We cool an exothermic reaction.
- (D) We heat an endothermic reaction.

Topic: Chemical Equilibrium

Difficult Multiple Choice Questions (Level 5 - 7 Learners)

13. What event(s) occurred to disturb these equilibria ?



- (A) Lisa cooled an endothermic reaction.
(B) Lisa heated an exothermic reaction.
(C) Lisa cooled an exothermic reaction.
(D) Lisa heated an endothermic reaction.

14. Consider the following chemical equilibrium
 $\text{CO (g)} + 2 \text{H}_2 \text{(g)} \rightleftharpoons \text{CH}_3\text{OH (g)}$ $\Delta H < 0$

The equilibrium yield of methanol is maximised by Maligay who maintained the system at

- (A) high pressure and low temperature.
(B) high pressure and high temperature.
(C) low pressure and high temperature.
(D) low pressure and low temperature.

15. The following equilibrium is in a closed container
 $\text{X}_2 \text{(g)} + \text{Y}_2 \text{(g)} \rightleftharpoons 2 \text{XY (g)}$ $(\Delta H < 0)$

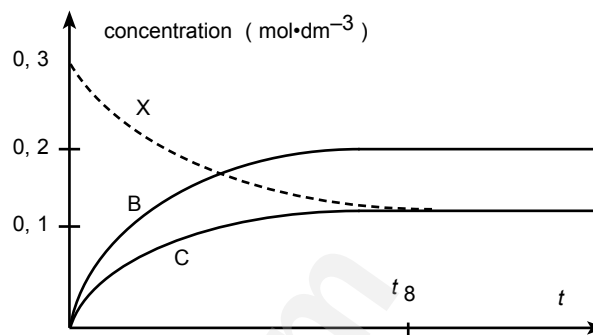
Which changes have **no effect** on the **yield** of XY ?

- (I) Increase pressure by decreasing volume.
(II) Introduction of a noble gas.
(III) Decrease in temperature.
(IV) Addition of catalyst.

- (A) I only (B) IV only
(C) I and II only (D) I ; II and IV only

16. For the reaction
 $\text{N}_2 \text{(g)} + 2 \text{CO}_2 \text{(g)} \rightleftharpoons 2 \text{NO (g)} + 2 \text{CO (g)}$
 $\Delta H > 0$
 the best yield of products at equilibrium is obtained by Heather keeping the reaction vessel at
 (A) low temperatures ; high pressures.
 (B) low temperatures ; low pressures.
 (C) high temperatures ; high pressures.
 (D) high temperatures ; low pressures.

17. A gas X introduced into a sealed evacuated container at $t = 0$ decomposes into gases B and C. A chemical equilibrium between the three gases is reached at t_8 as shown in the following accurate diagram.



At equilibrium the reaction is given by
 (A) $3 \text{X} \rightleftharpoons 2 \text{B} + \text{C}$

- (B) $\text{B} + \text{C} \rightleftharpoons \text{X}$
 (C) $\text{X} \rightleftharpoons 2 \text{B} + \text{C}$
 (D) $2 \text{X} \rightleftharpoons 2 \text{B} + \text{C}$

18. For the equilibrium reaction
 $\text{H}_2 \text{(g)} + \text{I}_2 \text{(g)} \rightleftharpoons 2 \text{HI (g)}$ $(\Delta H \text{ positive})$
 The equilibrium will not be influenced by
 (A) increasing the pressure
 (B) lowering the temperature
 (C) adding more iodine
 (D) removing some hydrogen

19. For the equilibrium reaction
 $\text{N}_2 \text{(g)} + 3 \text{H}_2 \text{(g)} \rightleftharpoons 2 \text{NH}_3 \text{(g)}$
 The ratio of the volume of hydrogen to ammonia is
 (A) 3 : 2 (B) 1 : 2 (C) 1 : 3 (D) 2 : 4

20. Chemical equilibrium occurs only when
 (A) all chemicals stop reacting.
 (B) the products react together at the same rate as they are formed.
 (C) nothing remains of the chemicals originally present.
 (D) the concentration of all chemicals becomes equal.

21. For the equilibrium reaction
 $2 \text{SO}_2 \text{(g)} + \text{O}_2 \text{(g)} \rightleftharpoons 2 \text{SO}_3 \text{(g)}$ $(\Delta H < 0)$
 A greater yield of SO_3 is best obtained by
 (A) increasing the pressure and the temperature.
 (B) lowering the temperature and the pressure.
 (C) increasing the temperature and decreasing the pressure.
 (D) increasing the pressure and decreasing the temperature.

22. For the equilibrium reaction
 $\text{N}_2 \text{(g)} + 3 \text{H}_2 \text{(g)} \rightleftharpoons 2 \text{NH}_3 \text{(g)}$ $(\Delta H < 0)$
 In industry, the Haber process operates under the following conditions
 (A) high pressure ; high temperature.
 (B) low temperature ; high pressure.
 (C) high temperature ; low pressure.
 (D) low pressure ; low temperature.

23. If we wish to increase both the yield and the rate of any reaction, we must increase the
 (A) concentration of the reactants.
 (B) concentration of the products.
 (C) temperature.
 (D) pressure.

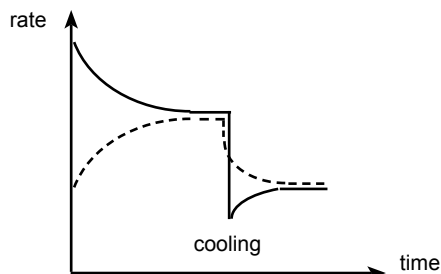
Topic: Chemical Equilibrium

Difficult Multiple Choice Questions (Level 5 - 7 Learners)

24.

The reaction $\text{H}_2 + \text{I}_2 \rightleftharpoons 2\text{HI}$ is cooled after it has reached equilibrium.

- (I) The forward reaction is favoured.
- (II) The reverse reaction is favoured.
- (III) The products are used up.
- (IV) The forward reaction is endothermic.

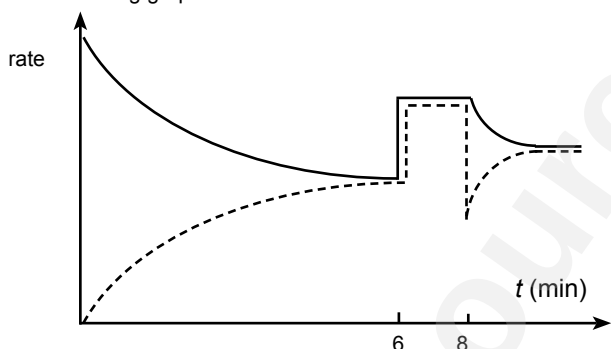


The correct answers are

- (A) I and II
- (B) II and III
- (C) II ; III and IV
- (D) III and IV

25.

The reaction $\text{H}_2(\text{g}) + \text{F}_2(\text{g}) \rightleftharpoons 2\text{HF}(\text{g})$ $\Delta H < 0$ has the following graph.

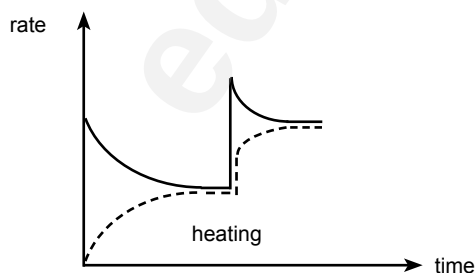


How was the equilibrium disturbed after (i) 6 (ii) 8 minutes ?

- (A) Roxanne removed some of the product.
- (B) Roxanne added a catalyst.
- (C) Roxanne reduced the volume of the container.
- (D) Roxanne lowered the temperature.

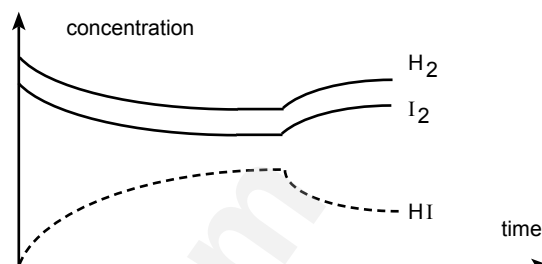
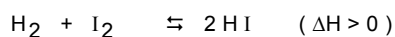
26.

The equilibrium reaction $\text{CH}_3\text{OH}(\text{g}) \rightleftharpoons 2\text{H}_2(\text{g}) + \text{CO}(\text{g})$ has the following graph when heated.



- (A) The forward reaction is endothermic.
- (B) The forward reaction is exothermic.
- (C) After heating, the reverse reaction is favoured.
- (D) $2\text{H}_2 + \text{CO} \rightarrow \text{CH}_3\text{OH}$ is an endothermic reaction.

27.

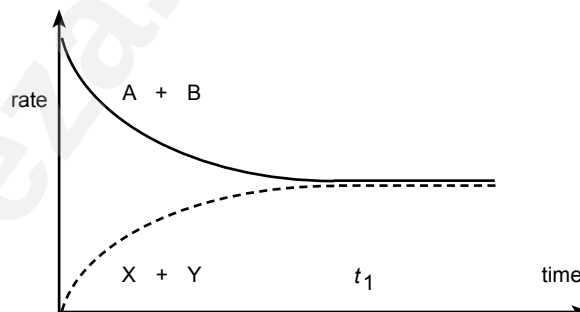


The reaction was allowed to reach equilibrium in the reaction vessel.

The equilibrium was then disturbed by Betty

- (A) increasing the pressure.
- (B) lowering the temperature.
- (C) adding some more of the reactants.
- (D) heating the reaction vessel.

28.



(i) The equation for the reaction is

- (A) $\text{A} + \text{B} \rightarrow \text{X} + \text{Y}$
- (B) $\text{X} + \text{Y} \rightarrow \text{A} + \text{B}$
- (C) $\text{X} + \text{Y} \rightleftharpoons \text{A} + \text{B}$
- (D) $\text{A} + \text{B} \rightleftharpoons \text{X} + \text{Y}$

(ii) $\text{A} + \text{B} \rightleftharpoons \text{X} + \text{Y}$ is true for

- (A) a time interval not shown on the graph.
- (B) $t < t_1$
- (C) $t = t_1$
- (D) $t > t_1$

(iii) $\text{A} + \text{B} \rightleftharpoons \text{X} + \text{Y}$ is true for

- (A) $t = 0$
- (B) $t < t_1$
- (C) a time interval not shown on the graph.
- (D) $t > t_1$

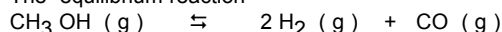
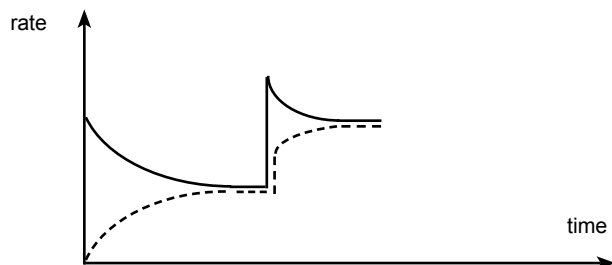
(iv) $\text{A} + \text{B} \rightleftharpoons \text{X} + \text{Y}$ is true for

- (A) a time interval not shown on the graph.
- (B) $t < t_1$
- (C) $t = t_1$
- (D) $t > t_1$

Difficult Multiple Choice Questions (Level 5 - 7 Learners)

29.

The equilibrium reaction

($\Delta H > 0$) was disturbed by

- (A) increasing the pressure.
 (B) increasing the temperature.
 (C) adding reactants.
 (D) adding products.

30.

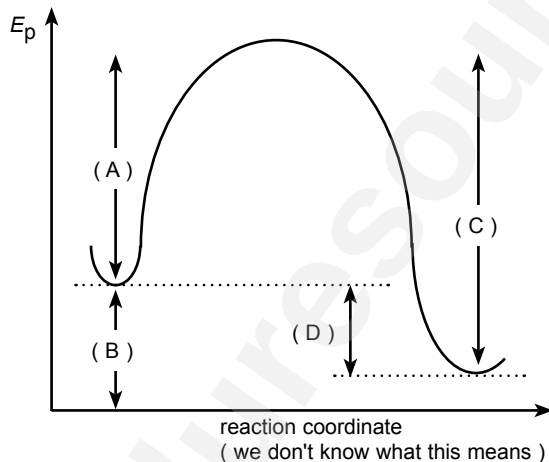
The following diagram represents the energy changes that occur during the reaction

($\Delta H < 0$)

Which energy must be exceeded for

(i) the reactants to form products?

(ii) the products to form reactants?

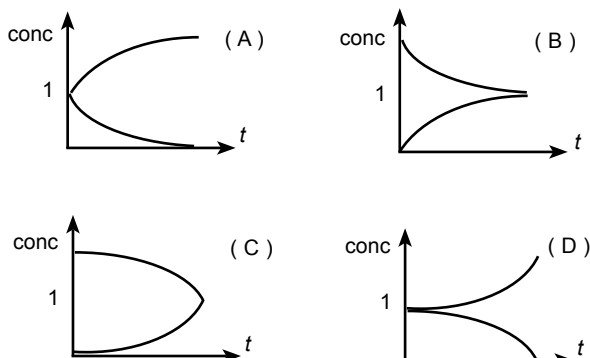


31.

A standard zinc - copper electrochemical cell operates for a long time.

How do the two electrolyte concentrations change with time?

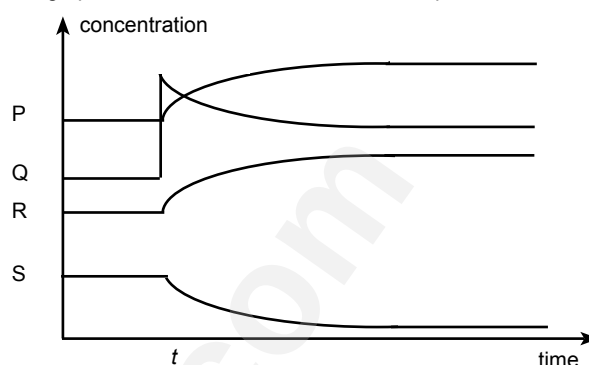
NB. "conc" is the abbreviation for "concentration".



32.

Four gases P, Q, R and S are in equilibrium in a closed container.

The graph shows their concentrations over a period of time.



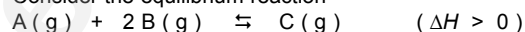
More of gas Q was added at t.

The equilibrium reaction is shown by

- (A) $\text{P} + \text{Q} \rightleftharpoons \text{R} + \text{S}$
 (B) $\text{S} + \text{Q} \rightleftharpoons \text{R} + \text{P}$
 (C) $\text{P} + \text{S} \rightleftharpoons \text{R} + \text{Q}$
 (D) $\text{Q} \rightleftharpoons \text{R} + \text{S} + \text{P}$

33.

Consider the equilibrium reaction



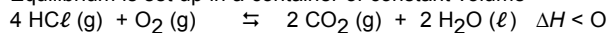
taking place in a closed container.

The yield is reduced by

- (A) reducing the volume of the container.
 (B) adding more of gas B.
 (C) increasing the temperature.
 (D) decreasing the temperature.

34.

Equilibrium is set up in a container of constant volume

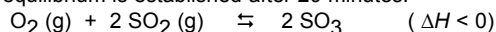


The yield for the above reaction can be increased by

- A decreasing the pressure on the system.
 B increasing the pressure on the system.
 C increasing the temperature of the system.
 D adding a catalyst.

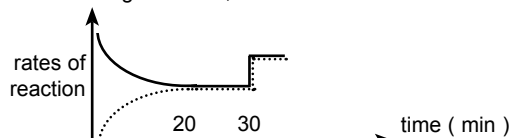
35.

Oxygen and sulphur dioxide are placed in a closed container and this equilibrium is established after 20 minutes.



At t = 30 minutes the equilibrium conditions are changed.

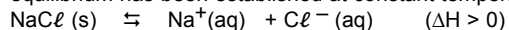
The change at t = 30 minutes in the graph, showing the rates of reaction against time, can be attributed to



- A the addition of oxygen to the container.
 B an increase in the temperature inside the container.
 C a decrease in the volume of the container.
 D the addition of a catalyst to the mixture.

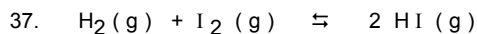
36.

Sodium chloride is dissolved in water until the following equilibrium has been established at constant temperature:

How will the concentration of the Na^+ be affected if a few drops of a solution of AgNO_3 are added to the above solution at constant temperature?[Na^+] ...

- (A) increases (B) remains constant (C) decreases.

Difficult Multiple Choice Questions (Level 5 - 7 Learners)

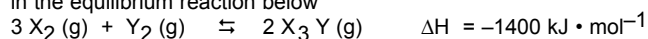


Compress the equilibrium mixture at constant temperature then

	concentration	yield
A	increases	decreases
B	decreases	no change
C	decreases	increases
D	increases	no change

38.

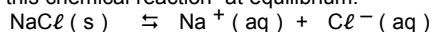
Which of the following changes will increase the amount of $\text{Y}_2(\text{g})$ in the equilibrium reaction below



- A The pressure on the reaction mixture should be increased to cause a change in volume.
- B A catalyst should be added to the reaction mixture.
- C The concentration of $\text{X}_2(\text{g})$ should be increased.
- D The concentration of $\text{X}_3\text{Y}(\text{g})$ should be increased.

39.

Consider this chemical reaction at equilibrium:



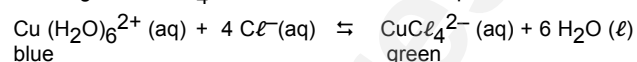
If a small amount of concentrated solution of silver nitrate is added to the system, while the temperature is constant,

- A the forward reaction is favoured.
- B the backward reaction is favoured and the value of the yield is increased.
- C the backward reaction is favoured and the value of the yield remains the same.
- D the backward reaction is favoured and the value of the yield is decreased.

40.

The $\text{Cu}(\text{H}_2\text{O})_6^{2+}$ ion causes the blue colour of a dilute aqueous solution of copper(II) chloride. If concentrated HCl is added, the solution turns green owing to the formation of the CuCl_4^{2-} ion.

Forming the CuCl_4^{2-} ion is an endothermic process.



The formation of the BLUE solution will be promoted by

- (A) adding a few drops of hydrochloric acid.
- (B) increasing the temperature of the solution.
- (C) adding a few crystals of AgNO_3 .
- (D) adding concentrated sulfuric acid.

Basic Activities (Level 1 and Level 2 Learners)

1.
 - 1.1 State le Chatelier' s principle.
 - 1.2 What three factors influence the yield of a chemical reaction ?

2.
 - 2.1 If a reaction is in equilibrium and we add some excess reactant, how will the system react to this disturbance.
 - 2.2 If a reaction is in equilibrium and we remove some of the product, how will the system react to this disturbance.
3.

$$\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightarrow 2\text{HI}(\text{g})$$
 - 3.1 If this reaction produces 2 moles of $\text{HI}(\text{g})$ then how many moles of $\text{H}_2(\text{g})$ and $\text{I}_2(\text{g})$ were used up.
 - 3.2 If this reaction produces 4 moles of $\text{HI}(\text{g})$ then how many moles of $\text{H}_2(\text{g})$ and $\text{I}_2(\text{g})$ were used up.
4.

$$3\text{H}_2(\text{g}) + \text{N}_2(\text{g}) \rightarrow 2\text{NH}_3(\text{g})$$
 - 4.1 If this reaction produces 2 moles of $2\text{NH}_3(\text{g})$ then how many moles of $\text{H}_2(\text{g})$ and $\text{N}_2(\text{g})$ were used up.
 - 4.2 If this reaction produces 6 moles of $2\text{NH}_3(\text{g})$ then how many moles of $\text{H}_2(\text{g})$ and $\text{N}_2(\text{g})$ were used up.
5.

$$\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightarrow 2\text{HI}(\text{g}) + \text{cooling}$$
 - 5.1 This reaction is (exothermic / endothermic).
 - 5.2 The reaction produces a (heating / cooling) effect as a " product ".
 - 5.3 ΔH (< 0 or > 0)
 - 5.4 If we heat a reaction it compensates by producing a (heating / cooling) effect.
 - 5.5 On a hot day you put on (warm / cool) clothes.
 - 5.6 Heating this reaction favours producing more (reactants / products) as the reaction needs to produce a cooling effect.
6. $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g}) \quad \Delta H > 0$

Write this equation to show the effect of

 - 6.1 heating the reaction
 - 6.2 cooling the reaction
7.

$$\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow 2\text{HCl}(\text{g}) + \text{warmth}$$
 - 7.1 This reaction is (exothermic / endothermic).
 - 7.2 The reaction produces a (heating / cooling) effect as a " product ".
 - 7.3 ΔH (< or >) 0
 - 7.4 If we cool a reaction it compensates by producing a (heating / cooling) effect.
 - 7.5 On a cold day you put on (warm / cool) clothes.
 - 7.6 Cooling this reaction favours producing more (reactants / products) as the reaction needs to produce warmth.
8. Must the following reactions be heated or cooled to favour a higher yield ?
 - 8.1 $\text{H}_2 + \text{I}_2 \rightarrow 2\text{HI} \quad \Delta H > 0$
 - 8.2 $2\text{KClO}_3 \rightarrow 2\text{KCl} + 3\text{O}_2 \quad \Delta H < 0$
 - 8.3 $2\text{KNO}_3 \rightarrow 2\text{KNO}_2 + \text{O}_2 \quad \Delta H < 0$
9. When working out the influence of pressure on a reaction's equilibrium, which chemicals in the balanced equation must we ignore ?
 - 9.1 solids
 - 9.2 liquids
 - 9.3 aqueous solutions of dissolved solids
 - 9.4 gases .
- 9.5 what do these symbols represent ?
 - 9.5.1 (s) 9.5.2 (l)
 - 9.5.3 (aq) 9.5.4 (g)
10. Which of the following reactions will favour the forward reaction if the pressure is increased
 - 10.1 $\text{C}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g}) \rightarrow \text{C}_2\text{H}_6(\text{g})$
 - 10.2 $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$
 - 10.3 $2\text{KClO}_3(\text{l}) \rightarrow 2\text{KCl}(\text{s}) + 3\text{O}_2(\text{g})$
 - 10.4 $\text{FeS}(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{FeCl}_2(\text{aq}) + \text{H}_2\text{S}(\text{g})$
11. What pressure will favour a higher yield ?
 - 11.1 $\text{C}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g}) \rightarrow \text{C}_2\text{H}_6(\text{g})$
 - 11.2 $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{SO}_3(\text{g})$
 - 11.3 $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$
 - 11.4 $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightarrow 2\text{HI}(\text{g})$
12.
 - 12.1 Name three factors which would influence the following equilibrium :

$$\text{NH}_4\text{Cl}(\text{s}) \rightleftharpoons \text{NH}_3(\text{g}) + \text{HCl}(\text{g}) \quad \Delta H > 0$$
 - 12.2 Explain how you can use these factors to disturb the equilibrium to favour the reverse reaction and shift the equilibrium position.
13. Dissolve some cobalt (II) chloride crystals in alcohol to get a blue colour.

$$\text{blue } \text{CoCl}_4^{2-}(\text{aq}) + 6\text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{pink or light purple } \text{Co}^{2+} \cdot 6\text{H}_2\text{O}(\text{aq}) + 4\text{Cl}^{-}(\text{aq}) \quad \Delta H < 0$$
 - Which reaction is favoured (and any colour changes) if
 - 13.1 the blue solution is cooled ?
 - 13.2 water is added to the blue solution ?
 - 13.3 AgNO_3 is added to the blue solution?
 - 13.4 the pink / purple solution is heated ?
 - 13.5 concentrated HCl is added to the purple solution ?
 - 13.6 concentrated H_2SO_4 is added to the purple solution ?
 - 13.7 the pressure on the system is increased ?
14. Dissolve some potassium dichromate crystals in water to get an orange colour.

$$\text{orange } \text{Cr}_2\text{O}_7^{2-}(\text{aq}) + \text{OH}^{-}(\text{aq}) \rightleftharpoons \text{yellow } 2\text{CrO}_4^{2-}(\text{aq}) + \text{H}^{+}(\text{aq})$$
 - Describe which reaction is favoured if we
 - 14.1 add a sodium hydroxide pellet to the orange solution.
 - 14.2 add concentrated sulfuric acid to the yellow solution.
15. Add methyl orange to acetic acid. It turns red.

$$\text{CH}_3\text{COOH} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COO}^{-} + \text{H}_3\text{O}^{+}$$

orange red

What happens if sodium ethanoate is added to the **red** acid solution ?
16. The equilibrium reaction is in a syringe.

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

brown colourless

$\Delta H < 0$

Describe which reaction is favoured and what colour changes occur if

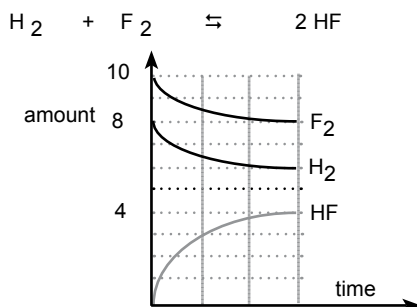
 - 16.1 the flask is cooled in a deep freeze.
 - 16.2 the colourless gas is heated in boiling water.
 - 16.3 the brown gas is put under high pressure.
17. Heating coal in steam yields a mixture called " water gas ". This is the first step in the production of synthetic fuels.

$$\text{C}(\text{s}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + \text{H}_2(\text{g}) \quad (\Delta H > 0)$$
 - 17.1 Write **three** methods to increase the **rate** of the forward reaction.
 - 17.2 Write **two** methods by which the **yield** of CO and H_2 gas can be increased.

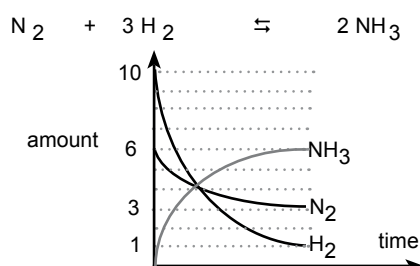
Topic : Chemical Equilibrium

Basic Activities (Level 1 and Level 2 Learners)

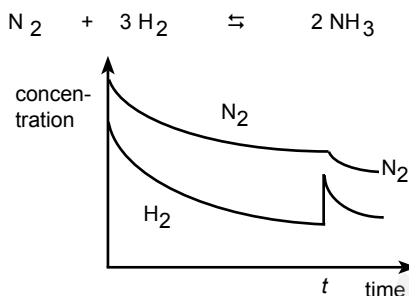
18. If 8 mol H_2 and 10 mol F_2 react to form 4 mol HF, determine all the equilibrium quantities.



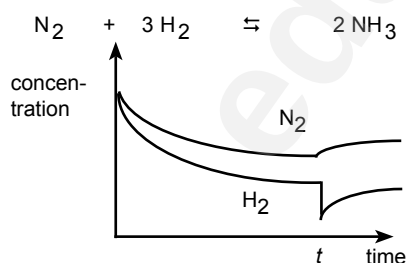
19. If 6 mol N_2 and 10 mol H_2 react leaving 3 mol N_2 at equilibrium, determine all the equilibrium quantities.



20. This reaction reaches equilibrium. What happened, as shown by the graph of the forward reaction, at t and just after t ?

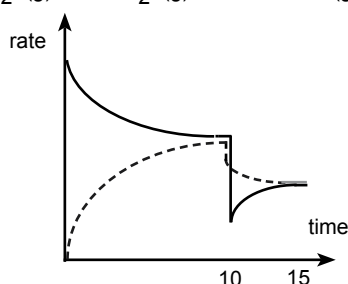


21. This reaction reaches equilibrium. What happened, as shown by the graph of the forward reaction, at t ?



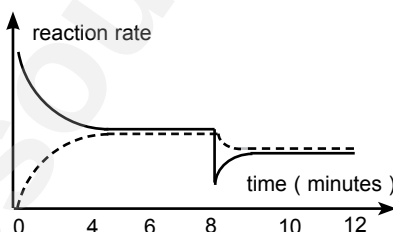
- 21.2 Draw a graph to show the reverse reaction too.
21.3 Draw a graph of reaction rate vs time.
21.4 Write an equation for the reaction just after time t .

22. The equation of the following reaction is
 $\text{I}_2(\text{g}) + \text{H}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$



- 22.1 Write down an equation for the dashed line
22.2 If the reaction is cooled after 10s the broken line is (exo / endo) thermic
22.3 Why do both graphs drop at 10 s ?
22.4 Add a catalyst after 15 s. Show how the graph changes because of the catalyst.
22.5 Does a catalyst establish a new equilibrium ?

23. Exactly 5 moles of $\text{XY}_3(\text{g})$ is placed in a 2 dm^3 container and then sealed. The following equilibrium is established at 400K
 $2\text{XY}_3(\text{g}) \rightleftharpoons 2\text{XY}_2(\text{g}) + \text{Y}_2(\text{g})$
After 8 minutes the temperature is lowered to 300 K. The graph shows the change in reaction rate for the first 12 minutes.



- 23.1 Which reaction, **forward or reverse**, is represented by the **solid line** ?
23.2 When does the reaction reach equilibrium for the first time ?
23.3 Is the reaction represented by the solid line endothermic or exothermic ? Explain your answer.
23.4 What is represented by the horizontal graphs between 10 and 12 minutes?

24. A few drops of concentrated hydrochloric acid are added to a saturated solution of sodium chloride.
24.1 Write down an equation for the equilibrium situation that exists in the saturated sodium chloride solution.
24.2 What is observed when concentrated hydrochloric acid is added to the saturated solution? Explain the observation.

- 24.3 What name is given to this phenomenon referred to in Question 24.1 ?

25. Add concentrated acetic acid to a saturated sodium acetate solution for the **common ion effect**.

- 25.1 State Le Chatelier's principle.
25.2 What is a saturated solution ?
25.3 Write an equation to show the dissociation of sodium acetate in solution.
25.4 Explain why sodium acetate crystals precipitate out when concentrated acid is added.

26. Study the following reversible reaction.
 $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$
A high temperature decreases the yield of the products at equilibrium.
26.1 Name the industrial process which uses this reaction.
26.2 Is the forward reaction exothermic or endothermic ?
26.3 How would an increase in pressure affect the yield of products ?
26.4 What catalyst is used in this process ?
26.5 Since a catalyst has no effect on the yield of products, why then use a catalyst ?

27. $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$
 $\Delta H < 0$
How is the equilibrium affected if the
27.1 pressure increases
27.2 temperature increases?
27.3 Normally the temperature is about 450°C for this reaction. Can we make ammonia profitably at 120°C ?

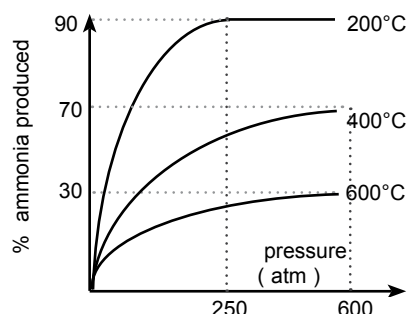
28. Consider the reversible reaction taking place in the Haber Process :
 $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$
($\Delta H < 0$)

- The **yield** of ammonia at equilibrium is favoured by a low temperature but this adversely affects the **rate** of production.
28.1 Why is this industrial reaction heated since heating lowers the reaction yield ?
28.2 Explain the meaning of the terms **yield** and **rate** when used in this context.

29. Consider this reversible reaction.
 $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$
 $\Delta H < 0$
How will the yield of SO_3 be affected if
29.1 the temperature is increased ?
29.2 the pressure is increased ?
29.3 more dioxygen is added to the reaction?
29.4 a suitable catalyst is added ?

Difficult Activities (Level 5 - 7 Learners)

30. The percentage of ammonia produced from dinitrogen and dihydrogen under certain conditions of temperature and pressure is given in the graph.



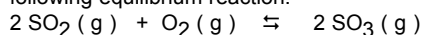
- 30.1 What happens to the % of ammonia when the temperature increases ?
 30.2 What happens to the % of ammonia when the pressure is increased ?
 30.3 Which pressure and temperature produce the highest % of ammonia ?
 30.4 Which factor in question 30.3 produces a high % of ammonia but decreases the rate of the reaction ?

The industrial preparation of NH_3 requires a high yield of ammonia to be produced under safe conditions.

- 30.5 Which values of temperature and pressure, would you recommend for the industrial preparation of NH_3 ?
 30.6 Explain the reasons for your recommendation.

31.

An important step in the industrial process to manufacture sulfuric acid is represented by the following equilibrium reaction.

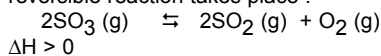


- 31.1 What do the double arrows mean in terms of the reaction rate ?
 31.2 Why is this process called "dynamic"?
 31.3 How will increasing the pressure affect the concentration of SO_3 ?
 31.4 Raising the temperature decreases the yield of SO_3 .
 What does this tell us about the reaction ?
 31.5 Name the compound SO_3 .
 31.6 Write an equation for the reaction of SO_3 with water.

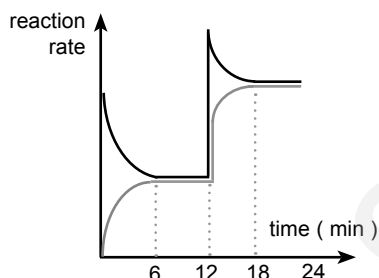
- 31.7 How would adding a catalyst change the yield ?
 31.8 What catalyst is used in industry for this process ?
 31.9 Why is this a homogenous equilibrium?
 31.10 Write down 3 ways to increase the yield of SO_3 ?
 31.11 Write down the formula for sulfuric acid.
 31.12 Where is sulfuric acid used in motor cars ?

32.

An amount of SO_3 is sealed in a container at 620°C and the following reversible reaction takes place :



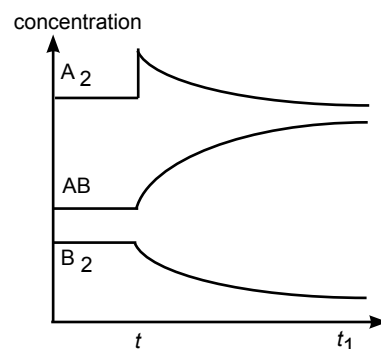
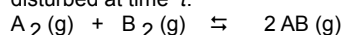
The following graph shows how the reaction rate, measured from the start of the reaction, changed with time.



- 32.1 State, giving a reason, whether the forward reaction above is homogeneous or heterogeneous.
 32.2 Write down the equation for the reaction that is indicated by the solid line.
 32.3 How long does it take for the reaction to first reach equilibrium from the start ?
 32.4 State what possibly could have happened to the system at the 12 th minute.
 32.5 Why is the horizontal part of the graph between the 18 th and 24 th minute higher than the horizontal part between the 6 th and 12 th minute?
 32.6 How will an increase in pressure affect the amount of $\text{SO}_2(\text{g})$ present in the container at equilibrium?

33.

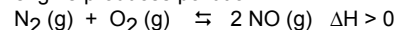
A reaction reaches equilibrium which is disturbed at time t .



- 33.1 What happened between times t and t_1 ?
 33.2 Describe the changes that occurred in the system between these two times.
 33.3 How can we tell from the graph which two lines represent the reactants ?
 33.4 Why does the product line rise more than what either reactant decreases ?

34.

The following reaction inside a motor car engine produces pollution.



- 34.1 Car engines run very hot and can reach about 2500°C . What effect does this have on the production of pollutants ?
 34.2 If you could get an engine to run cooler, what effect would this have on the environment ?

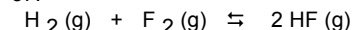
35.

$\text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}(\text{g})$ requires a very high temperature before the reaction occurs
 $2\text{NO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}_2(\text{g})$ occurs easily at room temperature.
 Explain the difference.

36.

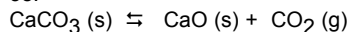
- 36.1 What is the purpose of the Ostwald process ?
 36.2 How many steps does the Ostwald process involve.
 36.3 Describe the first step in the Ostwald process.
 Explain why ammonia is used as a source of nitrogen rather than using dinitrogen gas.
 36.4 Describe the second step in the Ostwald process.
 36.5 Describe the third step in the Ostwald process.
 36.6 What are the two main uses for nitric acid.
 36.7.1 How are these two products beneficial to mankind.
 36.7.2 How are these same products detrimental to the environment ?

37.



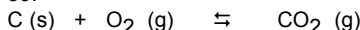
6 mol H_2 and 8 mol F_2 are put into a 1 dm^3 reaction chamber. If 6 mol HF is formed at equilibrium, determine all the equilibrium concentrations.

38.



6 mol CaCO_3 is put into a 2 dm^3 reaction chamber. If 4 mol CaO is formed at equilibrium, determine the equilibrium concentrations of all the gases present in the reaction chamber.

39.

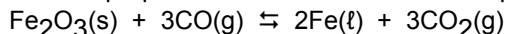


8 mol C is put into an evacuated 5 dm^3 reaction chamber with 9 mol O_2 and 3 mol CO_2 . If 4 mol C remains at equilibrium, determine the equilibrium concentrations of all the gases present in the reaction vessel.

Past Matric Papers

1.

One of the stages in the industrial preparation of iron from its ore is represented by the equation below:



The following changes are made to the system:

- (i) Fe_2O_3 is added
- (ii) CO_2 is removed
- (iii) CO is removed

Which of the changes mentioned above will favour the forward reaction?

- A (i), (ii) and (iii)
B (i) and (ii) only
C (ii) only
D (iii) only

2.1 Consider the following reaction which reaches equilibrium in a closed container.

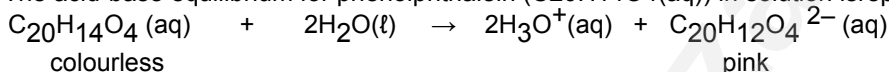


How will the amount of CO change when the following takes place?

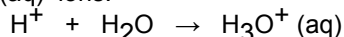
Choose from: INCREASES, DECREASES or NO CHANGE.

- 2.1.1 Temperature is decreased (2)
- 2.1.2 Volume of the container is increased at constant temperature (2)

2.2 The acid-base equilibrium for phenolphthalein ($\text{C}_{20}\text{H}_{14}\text{O}_4(\text{aq})$) in solution is represented by the equation below.



HCl is a strong acid so it ionizes almost 100% to produce H^+ ions. These H^+ ions combine with a water molecule to produce H_3O^+ (aq) ions.



Explain, using Le Chatelier's principle, why phenolphthalein is colourless when a solution of hydrochloric acid is added to it. (4)

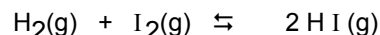
3. In which ONE of the following equilibrium reactions is the yield of products favoured by increasing the pressure of the reaction mixture?

- A $2\text{NO(g)} + \text{Cl}_2\text{(g)} \rightleftharpoons 2\text{NOCl(g)}$
- B $\text{CO(g)} + \text{H}_2\text{O(g)} \rightleftharpoons \text{CO}_2\text{(g)} + \text{H}_2\text{(g)}$
- C $2\text{SO}_3\text{(g)} \rightleftharpoons 2\text{SO}_2\text{(g)} + \text{O}_2\text{(g)}$
- D $\text{PCl}_5\text{(g)} \rightleftharpoons \text{PCl}_3\text{(g)} + \text{Cl}_2\text{(g)}$

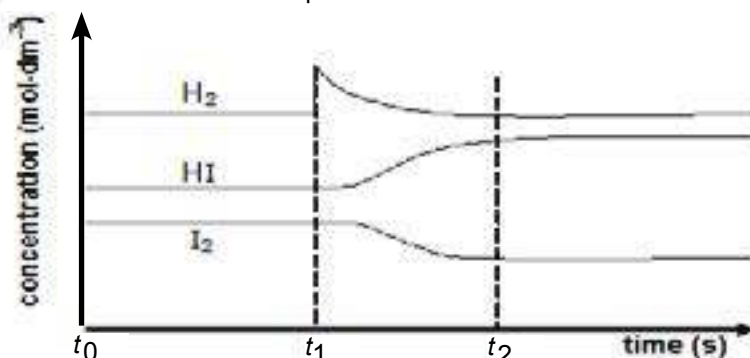
4.

4.1 Hydrogen and iodine are injected into a closed container at constant temperature.

The reaction reaches equilibrium according to the following equation:



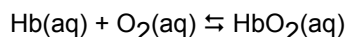
The graph below illustrates changes that were then made to the equilibrium mixture.



- 4.1.1 What information about the reaction can be obtained from the graph between times t_0 and t_1 ? (1)
- 4.1.2 Describe all the changes that occurred in the system between t_1 and t_2 . (4)

4.2 Atmospheric pressure reduces at high altitudes and consequently the amount of oxygen in the atmosphere is less than at sea level. Mountain climbers can experience hypoxia – a deficiency in oxygen. Symptoms of hypoxia include headache and nausea, and one may even slip into a coma.

The haemoglobin molecule (Hb) carries oxygen to the blood. In the process the oxygen bonds to the haemoglobin to form oxyhaemoglobin (HbO₂). A simplified equilibrium expression for the reaction is shown below.



4.2.1 What precaution must a mountain climber take in order to minimise the risk of hypoxia? (2)

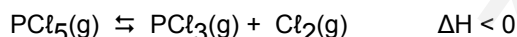
4.2.2 Refer to the above equilibrium reaction and explain why the precaution stated in QUESTION 10.2.1 is necessary. (3)

5.
Correct the following two statements :

5.1 A reaction reaches equilibrium when the concentrations of the products and reactants are equal. (2)

5.2 If sulfur dioxide reacts with oxygen in an open container, equilibrium is reached after a while. (2)

6.
A gaseous phase equilibrium is represented by the equation below.



Which ONE of the following statements regarding the equilibrium is TRUE?

- A. Adding a catalyst speeds up the rate at which equilibrium is reached and the forward reaction is favoured.
- B. Increasing the temperature has no effect on the yield of products.
- C. Increasing the concentration of PCl₅(g) causes the system to reach an equilibrium which has more products.
- D. Increasing the temperature causes the value of the equilibrium constant to increase.

7.
Many industries use ammonia as a coolant in their plants. Ammonia is also used in the fertiliser industry. The ammonia is manufactured by the Haber process in the presence of a catalyst at a temperature of 500 °C. The equilibrium process may be represented by the equation below.



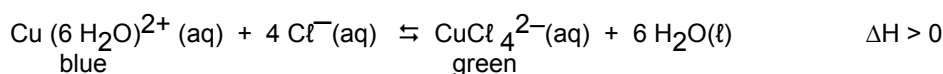
The temperature is now decreased to 100 °C.

Explain whether or not the ammonia can now be produced profitably. (3)

8.
8.1 Name the type of equilibrium in which the macroscopic properties (those visible to the naked eye) of the reaction mixture remain unchanged.

8.2 Name the type of equilibria where all the reagents are in the same phase.

8.3 When the solution in equilibrium represented below is heated, it turns green.



Is this statement true or false?

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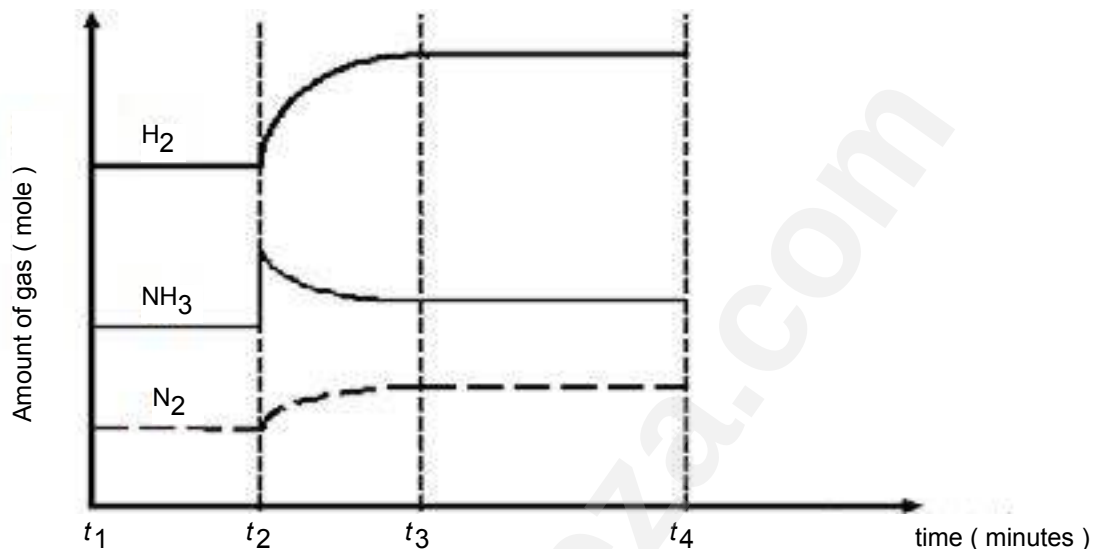
9.

The following equation represents a reversible reaction that has reached equilibrium at 470 °C in a closed container:



A change was then made to the NH_3 in the equilibrium mixture at t_2 . A graph showing the effect of this change is drawn below. (The graph is not drawn to scale.)

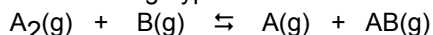
Graph of amount of gas versus time



- 9.1 What is the meaning of the horizontal lines between t_1 and t_2 ? (1)
- 9.2 State the change that was made to the NH_3 in the mixture at time t_2 . (1)
- 9.3 Explain how the change mentioned in QUESTION 9.3, affected the concentration of H_2 and N_2 gases as shown in the graph. (3)

10.

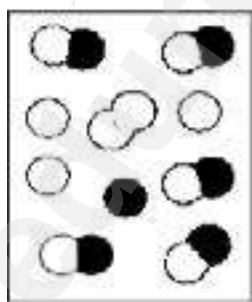
The following hypothetical reaction is at equilibrium at 300 K:



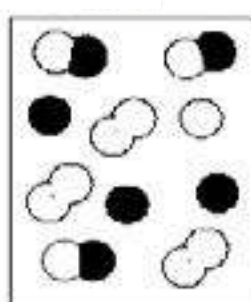
The diagram below shows the molecules involved in this chemical equilibrium at 300 K.

The white circles represent atoms of A, the black circles represent atoms of B.

300 K



500 K



The temperature is increased to 500 K.

The second diagram represents the same equilibrium mixture at 500 K.

Which ONE of the following statements is CORRECT?

- A. The forward reaction is exothermic.
- B. The concentration of AB is lower at a lower temperature.
- C. The forward reaction is endothermic.
- D. The concentration of B is higher at a lower temperature.

11.

Smog refers to a very unpleasant condition of pollution in certain urban environments. It is produced largely by the action of sunlight on car exhaust gases. Two groups of compounds emitted from car exhausts, that contribute to the formation of smog, are nitrogen oxides and unburned hydrocarbons.

Nitric oxide (NO(g)) forms in internal combustion engines by the direct combination of nitrogen and oxygen according to the following reversible reaction:



In air, nitric oxide is rapidly oxidised to nitrogen dioxide (NO₂(g)) that initiates the reactions responsible for the formation of smog. Nitrogen dioxide acts as catalyst for the formation of ozone, a key component of smog.

Although an essential UV screen in the upper atmosphere, ozone is an undesirable pollutant in the lower atmosphere. It is extremely reactive and toxic, and breathing air containing appreciable amounts of ozone can be dangerous for asthma sufferers, sports people and the elderly.

11.1 Explain why the formation of NO(g) is favoured in internal combustion engines where temperatures are as high as 2 400 K. (2)

11.2 How will the amount of NO(g) at equilibrium be affected if:

11.2.1 The pressure is increased by decreasing the volume (2)

11.2.2 A catalyst is added (1)

12.

Combustion in air at high temperatures produces oxides of nitrogen of which nitrogen dioxide (NO₂(g)), is the most common. Natural sources of nitrogen dioxide include lightning and the activity of some soil bacteria.

These natural sources are small compared to emissions caused by human activity.

NO₂ can irritate the lungs and cause respiratory infection. When NO₂(g) dissolves in rainwater in air it forms nitric acid which contributes to acid rain.

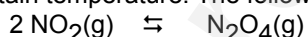
12.1 State TWO human activities that contribute to high nitrogen dioxide levels in the atmosphere. (2)

12.2 Write a balanced equation to show how nitric acid forms from nitrogen dioxide in air. (3)

12.3 High levels of nitrogen dioxide in the atmosphere can result in damage to crops and eventually food shortages. Briefly state how high levels of nitrogen dioxide can damage crops. (1)

12.4 Nitric acid can cause corrosion of copper cables whilst hydrochloric acid does no harm to copper cables. Refer to the relative strengths of the oxidising agents involved to explain this phenomenon. (3)

12.5 2 mol of NO₂(g) and an unknown amount of N₂O₄(g) are sealed in a 2 dm³ container, that is fitted with a plunger, at a certain temperature. The following reaction takes place:



At equilibrium it is found that the NO₂ concentration is 0,4 mol·dm⁻³.

The equilibrium constant at this temperature is 2.

12.5.1 Calculate the initial amount (in mol) of N₂O₄(g) that was sealed in the container. (9)

The plunger is now pushed into the container causing the pressure of the enclosed gas to increase by decreasing the volume.

12.5.2 How will this change influence the amount of nitrogen dioxide at equilibrium?

Only write down INCREASES, DECREASES or REMAINS THE SAME. (1)

12.5.3 Use Le Chatelier's principle to explain your answer to QUESTION 8.5.2. (2)

13. Name the stage in a reversible reaction when the rate of the forward reaction equals the rate of the reverse reaction.

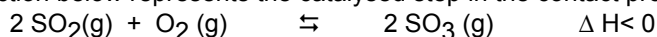
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14. The reaction represented by the equation below reaches equilibrium.
- $$\underset{\text{Pink}}{\text{Co (H}_2\text{O)}_6^{2+}(\text{aq})} + 4 \text{Cl}^-(\text{aq}) \rightleftharpoons \underset{\text{blue}}{\text{CoCl}_4^{2-}(\text{aq})} + 6 \text{H}_2\text{O}(\text{l}) \quad \Delta H > 0$$

Which ONE of the following changes to the reaction mixture will change its colour from blue to pink?

- A Add a catalyst.
- B Place the reaction mixture in a container with hot water.
- C Add a few drops of concentrated hydrochloric acid to the reaction mixture.
- D Add water to the reaction mixture.

15. The reaction below represents the catalysed step in the contact process:



The reaction takes place in a closed container and reaches equilibrium at 427°C.

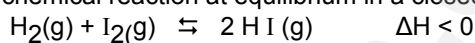
How will a HIGHER temperature affect each of the following?

Write down only INCREASES, DECREASES or REMAINS THE SAME.

- 15.1 The rate of production of $\text{SO}_3(\text{g})$ (2)
- 15.2 The yield of $\text{SO}_3(\text{g})$ (2)

16.

The equation below represents a chemical reaction at equilibrium in a closed container.



Which ONE of the following changes will increase the yield of $\text{HI}(\text{g})$ in the above reaction?

- A. Increase the temperature
- B. Decrease the temperature
- C. Increase the pressure by decreasing the volume
- D. Decrease the pressure by increasing the volume

17.

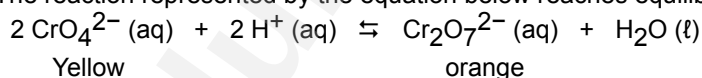
17.1

A chemical reaction reaches equilibrium. Which ONE of the following statements regarding this equilibrium is TRUE?

- A. The concentrations of the individual reactants and products are constant.
- B. The concentrations of the individual reactants and products are equal.
- C. The concentrations of the individual reactants are zero.
- D. The concentrations of the individual products increase until the reaction stops.

- 17.2 What is the name of the stage reached in a reversible chemical reaction when the rate of the forward reaction is equal to the rate of the reverse reaction.

- 17.3 The reaction represented by the equation below reaches equilibrium.



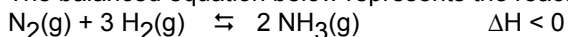
Which ONE of the following changes to the reaction mixture will change its colour from yellow to orange?

- A Add a catalyst.
- B Add water to the reaction mixture.
- C Add a few drops of sodium hydroxide solution to the reaction mixture.
- D Add a few drops of concentrated hydrochloric acid to the reaction mixture.

18.

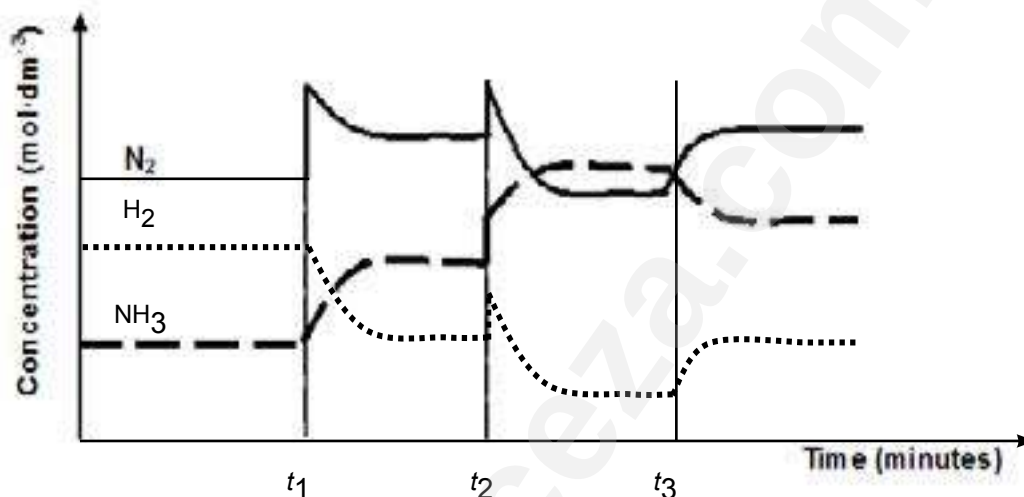
A fertiliser company produces ammonia on a large scale at a temperature of 450 °C.

The balanced equation below represents the reaction that takes place in a sealed container.



To meet an increased demand for fertiliser, the management of the company instructs their engineer to make the necessary adjustments to increase the yield of ammonia.

In a trial run on a small scale in the laboratory, the engineer makes adjustments to the TEMPERATURE, PRESSURE and CONCENTRATION of the equilibrium mixture. The graphs below represent the results obtained.



Identify the changes made to the equilibrium mixture at each of the following times:

18.1 t_1 (2)

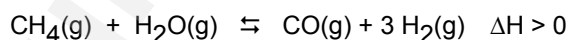
18.2 t_2 (2)

18.3 t_3 (2)

18.4 At which of the above time(s) did the change made to the reaction mixture lead to a higher yield of ammonia? Write down only t_1 and/or t_2 and/or t_3 . (2)

19.

The industrial preparation of hydrogen gas is represented by the equation below.



The reaction reaches equilibrium at 1 000 °C in a closed container.

19.1 State Le Chatelier's principle. (3)

19.2

How will an increase in pressure at 1 000 °C (by decreasing the volume) affect the yield of hydrogen gas? Write down only INCREASES, DECREASES OR NO EFFECT. Explain the answer. (3)

19.3 Write down TWO reasons why high temperatures are used for this reaction. (2)