

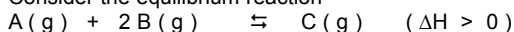


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Difficult Multiple Choice Questions (Level 5 - 7 Learners)

1.

Consider the equilibrium reaction



taking place in a closed container. The equilibrium constant for the reaction will be changed by

- (A) reducing the volume of the container
 (B) adding more of gas B
 (C) increasing the temperature
 (D) adding a suitable catalyst

2.

Which change is most likely to affect the equilibrium constant ?

- (A) pressure (B) volume
 (C) concentration (D) temperature.

3.

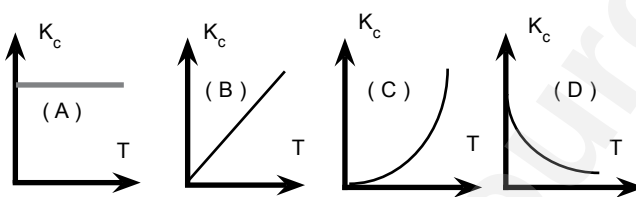
For a reaction, $K_c = 0,001$.

This means that at equilibrium

- (A) the reactions proceed at a very fast pace.
 (B) the reactions proceed at a very slow rate.
 (C) the reaction has a high concentration of products.
 (D) the reaction has a low concentration of products.

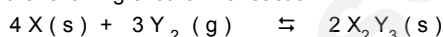
4.

Consider the following exothermic reaction

Variations in the K_c values as a function of temperature are shown by

5.

Consider the following exothermic reaction

 $K_c = 0,03$ at 313 K and $K_c = 0,02$ at 333 K.

(A) For the forward reaction $K_c = \frac{[X_2Y_3]^2}{[X]^4[Y_2]^3}$

(B) For the reverse reaction $K_c = \frac{[X]^4[Y_2]^3}{[X_2Y_3]^2}$

- (C) The forward reaction is exothermic.
 (D) The forward reaction is endothermic.

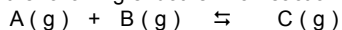
6.

The equilibrium constant only depends on

- (A) the initial concentrations of reactants and products.
 (B) the concentrations of the products that are formed at equilibrium.
 (C) the initial concentrations of the reactants and the equilibrium concentrations of the products.
 (D) the temperature at which the reaction occurs.

7.

Consider the following endothermic reaction



At equilibrium, the concentration of the product is much greater than the concentration of the reactants. Thus we conclude that K_c

(A) increases as the temperature rises.

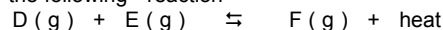
(B) increases as the temperature drops.

(C) has a value that is less than 1.

(D) increases when we add more reactants.

8.

Consider the following reaction



(a)

If the pressure is increased at constant temperature, the equilibrium and K_c will be affected as follows.

- (A) Forward reaction favoured, K_c increases.
 (B) Forward reaction favoured, K_c unchanged.
 (C) Forward reaction favoured, K_c decreases.
 (D) Reverse reaction favoured, K_c unchanged.

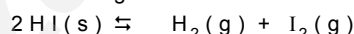
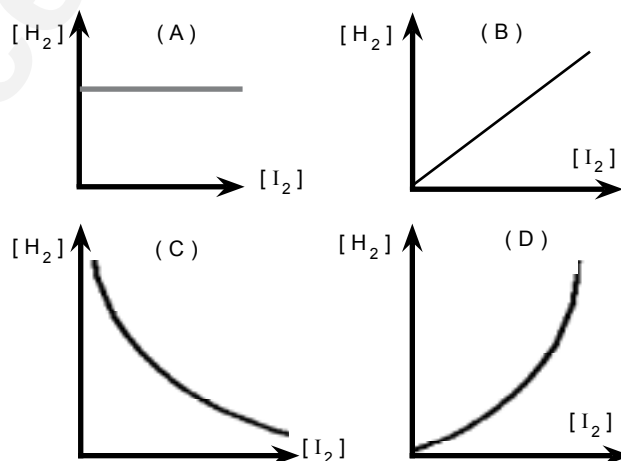
(b)

The value of the equilibrium constant is increased by

- (A) heating.
 (B) cooling.
 (C) raising the pressure.
 (D) lowering the pressure at constant temperature.

9.

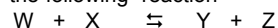
Consider the following reaction

The relationship between $[H_2]$ and $[I_2]$ at constant temperature is given by

VERY DIFFICULT PROBLEMS

10

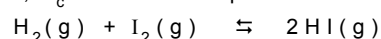
Consider the following reaction



$K_c = 1$. If 1 mole of W and 1 mole of X are put into an empty 1 litre reaction vessel, how many moles of Y form at equilibrium ?

- (A) 0,1 (B) 0,5 (C) 0,75 (D) 0,9

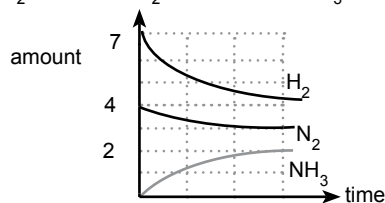
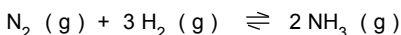
11.

At 440 °C, $K_c = 49$ for this equilibrium reaction.

If 0,2 mol H_2 and 0,2 mol I_2 are placed in an empty 1 litre reaction vessel, how many moles of HI form at equilibrium ?

- (A) 0,156 (B) 0,044 (C) 0,312 (D) 2

1.
1.1 If 4 mol N₂ and 7 mol H₂ react to form 2 mol NH₃, determine all the equilibrium concentrations in the 6 dm³ container.



- 1.2 Why do all the graphs become straight, horizontal lines after a while?
1.3 Which statement is correct?
The balanced equation tells us
(A) the starting amounts.
(B) the amount of change during the reaction.
(C) the final amounts at equilibrium.

2.
2.1 What does [CO] mean?
2.2 What is the unit for concentration?
2.3 Find the concentration if 4 mol of gas is in a 2 dm³ container.

3.
3.1 Draw a graph of K_c vs pressure.
3.2 Draw a graph of K_c vs concentration.
3.3 Draw a graph of K_c vs temperature for an
3.3.1 exothermic reaction.
3.3.2 endothermic reaction.

4.
Get an expression for K_c for each equation
4.1 CO₂(g) + H₂(g) ⇌ H₂O(g) + CO(g)
4.2 CO₂(g) + H₂(g) ⇌ H₂O(l) + CO(g)
4.3 Cl₂(g) + 2HI(g) ⇌ I₂(g) + 2HCl(g)
4.4 2Ag(s) + O₂(g) ⇌ 2AgO(s)

5.
Get an expression for K_c for each equation
5.1 MgCO₃(s) ⇌ MgO(s) + CO₂(g)
5.2 SO₂(g) + H₂O(l) ⇌ H₂SO₃(l)
5.3 NH₃(g) + HNO₃(l) ⇌ NH₄NO₃(s)
5.4 C(s) + O₂(g) ⇌ CO₂(g)
5.5 2NO₂(g) ⇌ N₂O₄(g)
5.6 2CH₄(g) + O₂(g) ⇌ 2CO(g) + 4H₂(g)

6.
2CO(g) + O₂(g) ⇌ 2CO₂(g)
2 x 10⁻² 2 x 10⁻² 4 x 10⁻³
are the equilibrium concentrations, in mol·dm⁻³, at 900 K. (ΔH < 0)

- 6.1 Calculate K_c.
6.2 Give a possible value for K_c at
6.2.1 1100 K
6.2.2 700 K.

7.
The equilibrium reaction in a 1 dm³ container is
3H₂(g) + N₂(g) ⇌ 2NH₃(g)
K_c = 0,6 at 450°C

	[H ₂]	[N ₂]	[NH ₃]
450°C:	0,15	0,75	0,039
• add	0,0435 mol hydrogen		
	0,1935		

This disturbs the equilibrium, favouring the forward reaction.

- 7.1 Determine the new value of K_c
7.2 Did the value of K_c change? Explain
7.3 Do concentration changes affect K_c?
7.4 For a given reaction, K_c can only be altered by changing the (concentrations / temperature / pressure).

8.
This equilibrium exists in a 2 dm³ sealed container at room temperature:
CaCO₃(s) ⇌ CaO(s) + CO₂(g)
ΔH > 0
At equilibrium there are 2 mol of CaCO₃, 0,25 mol of CaO and 0,25 mol of CO₂.
8.1 Calculate K_c.
8.2 Explain how to decrease the K_c value.
8.3 Is this reaction homogeneous or heterogeneous?
9.
K_c = 85 for this reaction at 460 K.
SO₂(g) + NO₂(g) ⇌ NO(g) + SO₃(g)
The reaction flask contains these gases at the following concentrations, in mol·dm⁻³

- [SO₂] = 0,0015 [NO₂] = 0,003
[NO] = 0,01 [SO₃] = 0,04
9.1 Prove that this reaction is not yet in equilibrium.
9.2 Is the forward or the reverse reaction favoured in order to reach equilibrium? Explain.

10.
For the following equilibrium reaction
N₂(g) + 3H₂(g) ⇌ 2NH₃(g)
ΔH < 0
9 mol of N₂ and 15 mol of H₂ are put into a 1 dm³ container at room temperature. The temperature of the gas mixture is now raised to 405°C resulting in 8 mol NH₃ being present at equilibrium.

- 10.1 Calculate the value of K_c at 405°C.
10.2 Low temperatures favour a high yield. But this Haber process is run at high temperatures. Why?

11.
This reaction is in equilibrium
2H₂(g) + O₂(g) ⇌ 2H₂O(g)
3 mol H₂O,
6 g of H₂ and
2,4 x 10²⁴ molecules of O₂
are found at equilibrium in the 2 dm³ container. Equilibrium is established at 310K. Calculate the equilibrium constant at 310 K.

12.
In the equilibrium system at 1100 K
A(g) + 2B(g) + 3C(g) ⇌ 4D(g)
A 5 dm³ reaction vessel contains 1 mol A, 2 mol B, 3 mol C and 4 mol D at equilibrium.
12.1 Calculate the value of K_c at 1100 K.
12.2 How many moles of A will be in equilibrium with 1 mol B, 1 mol C and 1 mol D in the reaction vessel at 1100 K?

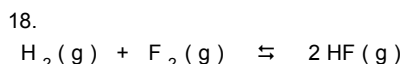
13.
H₂(g) + I₂(g) ⇌ 2HI(g)
(ΔH is positive)
Dihydrogen gas and diiodine gas are placed in a 1 dm³ container.
1 g of H₂ and 254 g of I₂ remain when equilibrium is reached at 750 K.
If K_c = 50 then calculate the equilibrium mass of HI.

14.
H₂(g) + I₂(g) ⇌ 2HI(g)
(ΔH is positive)
4 mol of H₂ and 4 mol of I₂ are mixed in a 1 litre reaction chamber which is kept at a constant temperature.
If K_c = 36 then calculate all the equilibrium concentrations.

15.
I₂(g) + H₂(g) ⇌ 2HI(g)
ΔH > 0
2 mol of H₂ and 2 mol of I₂ are mixed in a 1 litre reaction chamber which is kept at a constant temperature of 210°C.
If K_c = 1 at 210°C then calculate all the equilibrium concentrations.

16.
Consider the following reaction in a closed 1 dm³ container at constant temperature.
N₂O₄(g) ⇌ 2NO₂(g) (ΔH > 0)
Initially put 1 mol N₂O₄(g) in the container.
Calculate the equilibrium concentration of NO₂(g) if K_c = 0,9 at this temperature.

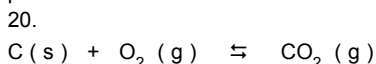
17.
O₂(g) + 2NO(g) ⇌ 2NO₂(g)
2 mol of NO₂ is placed in a 500 cm³ container with 2,5 mol O₂ and 4 mol NO.
Calculate K_c if the equilibrium amount of NO₂ in the container is 3 mol at 100°C.



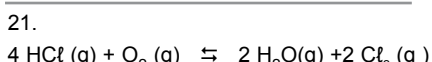
6 mol H_2 and 8 mol F_2 are put into a 1 dm³ reaction chamber. If 6 mol HF is formed at equilibrium, determine all the equilibrium concentrations.



6 mol CaCO_3 is put into a 2 dm³ reaction chamber. If 4 mol CaO is formed at equilibrium, determine the equilibrium concentrations of all the gases present in the reaction chamber.



8 mol C is put into a 5 dm³ 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.



12 mol HCl and 5 mol O_2 is added to a 10 dm³ reaction chamber containing 2 mol H_2O and 1 mol Cl_2 . If there is 5 mol Cl_2 at equilibrium, determine the equilibrium concentrations of all the gases present.

22.
 (a) Changing a large container's volume has (some / no) effect upon a small solid or a little liquid that is in the container.

(b) (Gases / liquids / solids) immediately fill the entire container when placed inside a container.

(c) The volume of a reaction chamber only affects the concentration of a substance in the reaction chamber if the substance (fills / partly fills) the container.

(d) When working with equilibrium concentrations we (can / cannot) ignore all solids.

(e) When working with equilibrium concentrations we (can / cannot) ignore all liquids.

(f) When working with equilibrium concentrations we (can / cannot) ignore all gases.

(g) Why do all the amount vs time graphs become straight, horizontal lines after a while?

(h) Which statement is correct?

The balanced equation tells us

(i) the starting amounts.

(ii) the amount of change during the reaction.

(iii) the final amounts at equilibrium.

23.

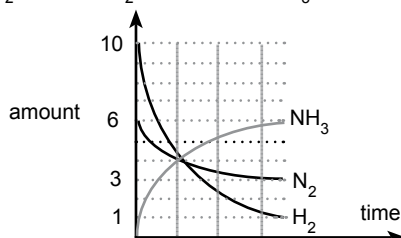
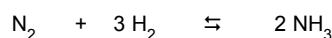
(a) If the yield increases,
 K_c (increases / decreases).

(b) If the yield decreases,
 K_c (increases / decreases).

(c) Heat an exothermic reaction :
 the yield (increases / decreases)
 and K_c (increases / decreases).

24.

If 6 mol N_2 and 10 mol H_2 react leaving 3 mol N_2 at equilibrium, find all the equilibrium concentrations if the reaction occurs in a sealed 10 dm³ container



25.

(a) What are the units of the equilibrium constant?

(b) What is the symbol of the equilibrium constant?

(c) The equilibrium constant only deals with (mass / amount / concentration).

(d) The equilibrium constant only deals with (solids / liquids / gases).

(e) The equilibrium constant is only affected by (pressure / temperature / concentration) changes.

(f) Every K_c value (is / is not) linked to a specific temperature.

(g) The K_c value for a specific reaction at 60°C is $K_c = 0,4$.

How can we change the K_c value?

26.



The mixture of gases is compressed in 4 stages.

stage	pressure	volume dm ³	moles NO ₂	moles N ₂ O ₄	total moles
1	p	10	1,19	0,4	1,59
2	2 p	5	0,96	0,52	?
3	3 p	2	0,68	0,66	?
4	4 p	1	0,52	0,77	?

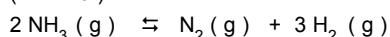
(a) What happens to the total number of moles as the pressure increases?

(b) If a new equilibrium was established at each stage, find the value of K_c for each stage.

27.

0,5 mol NH_3 is placed in a 1 dm³ vessel and only 0,3 mol remains at equilibrium.

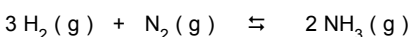
($\Delta H > 0$)



(a) Calculate the equilibrium constant at this temperature.

(b) How does K_c change if the temperature drops?

28.

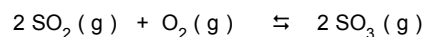


3 mol N_2 and 8 mol H_2 react at 720 K in a 1 litre container.

4 mol NH_3 is present at equilibrium.

Calculate K_c .

29.



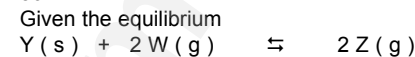
4,5 x 10⁻² ? 1,5 x 10⁻²

are the equilibrium concentrations, in mol·dm⁻³, at 600 K. ($\Delta H < 0$)

Calculate $[\text{O}_2]$ if $K_c = 4$.

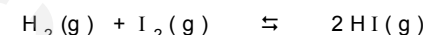
$[\text{O}_2]$ means the concentration of $\text{O}_2(\text{g})$.

30.



If $K_c = 0,64$ then calculate the concentration of Z in equilibrium with 1 mol Y and 0,5 mol W, if the reaction vessel is 1 dm³.

31.



Equilibrium concentrations :

1,14 1,14 8,41

(a) If the concentrations are measured in mol·dm⁻³, calculate K_c at this temperature of 800 K.

(b) Equal molar amounts of both H_2 and I_2 were pumped into the reaction vessel, raising their concentrations to 1,34 mol·dm⁻³ at 800 K.

What is the new concentration of HI?

(c) If the temperature is raised to 860 K and the equilibrium concentrations of

H_2 , I_2 and HI are 0,0862, 0,263 and 1,02 mol·dm⁻³ respectively.

(i) Calculate the new K_c value.

(ii) Is the reaction endo - or exothermic?

32.



$\Delta H > 0$

The reaction shown above takes place in a sealed container.

When equilibrium is established, the volume is then decreased.

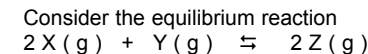
How does this affect

(a) the value of K_c ?

(b) the amount of B_2 in the container?

(c) the concentration of AB_3 in the container?

33.



4 mol of Z are pumped into a 5 dm³ container at 650 K. After a short time equilibrium is established with 0,5 mol of Y being present.

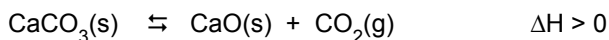
(a) Calculate the value of K_c at 650 K.

(b) If at 700 K the K_c value increases, then what can be said about the forward reaction?

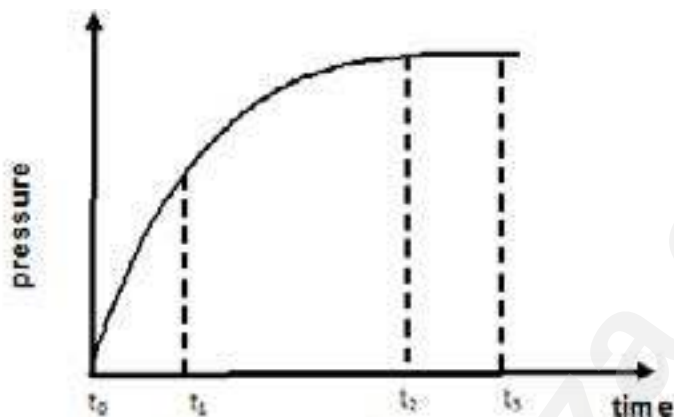
Past Matric Papers

1.

William wants to determine the equilibrium constant for the decomposition of calcium carbonate (CaCO_3). He seals 2,0 g of CaCO_3 in an evacuated 1,0 dm³ metal flask and connects a pressure gauge to the flask. The flask is placed in an oven and heated to a temperature of 800 °C at which equilibrium was reached according to the following equation:



The graph obtained for pressure versus time for the decomposition of calcium carbonate is shown below.



- 1.1 How does the rate of the reverse reaction change from t_0 to t_1 ? (2)
- 1.2 What is the reason for the horizontal line between t_2 and t_3 ? (1)
- 1.3 Draw a sketch graph to show how the mass of CaCO_3 changes for the period t_0 to t_3 . (4)
- 1.4 During a power failure the temperature of the oven drops to 500°C. What effect (only write down INCREASES, DECREASES or STAYS THE SAME) does this decrease in temperature have on the following:
- 1.4.1 The rate of the forward reaction (1)
- 1.4.2 The concentration of CO_2 (1)
- 1.4.3 The value of K_c (1)
- 1.5 Give a reason for your answer to QUESTION 1.4.3. (4)
- 1.6 When equilibrium was established at 800°C, the concentration of CO_2 present in the flask was $1,4 \times 10^{-2} \text{ mol} \cdot \text{dm}^{-3}$. Calculate the equilibrium constant (K_c) at 800°C for this reaction. (2)

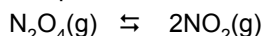
- 2.1 A hypothetical reaction represented by the equation below has reached equilibrium in a closed container. The K_c value is 4×10^{-2} at a certain temperature.



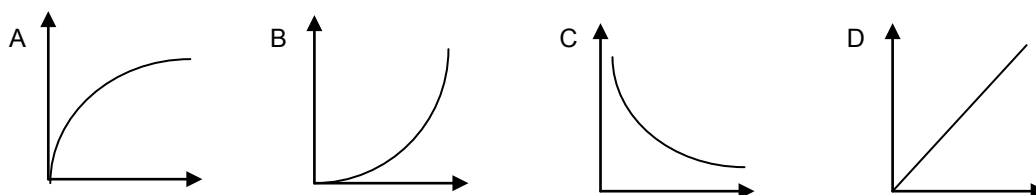
Which one of the following factors will cause the K_c value to change to 4×10^{-1} after equilibrium is re-established?

- A Adding more $\text{R}_2(\text{g})$
- B Decreasing the temperature
- C Increasing the temperature
- D Increasing the pressure by decreasing the volume

- 2.2 The following chemical reaction has reached equilibrium in a closed container.



Which one of the graphs below is the best representation of the relationship between the $[\text{N}_2\text{O}_4(\text{g})]$ on the y-axis and $[\text{NO}_2(\text{g})]$ on the x-axis at equilibrium?

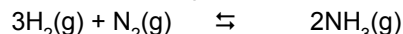


Topic : Equilibrium Constant

Past Matric Papers

3.

At a certain temperature the gases N_2 , H_2 and NH_3 , each with a concentration of $0,50 \text{ mol} \cdot \text{dm}^{-3}$, are placed in a sealed 1 dm^3 container. At equilibrium the concentration of N_2 is $0,40 \text{ mol} \cdot \text{dm}^{-3}$. The equation for the reaction at equilibrium is:



Calculate the equilibrium constant for the reaction at this temperature.

Round off all calculations to 3 decimal places.

(8)

4.

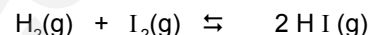
When the reaction $CuO(s) + H_2(g) \rightleftharpoons Cu(s) + H_2O(g)$ is in equilibrium, then $K_c = \frac{[CuO][H_2]}{[Cu][H_2O]}$

Correct this statement.

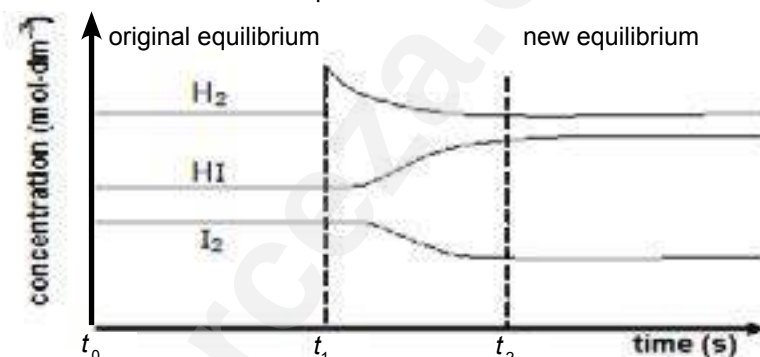
5.

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.



Initially, at t_0 , $0,3 \text{ mol}$ of H_2 and $0,3 \text{ mol}$ of I_2 is injected into the closed container of volume 2 dm^3 .

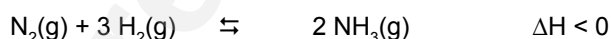
Equilibrium is established at 448°C . The equilibrium constant (K_c) for the reaction at 448°C is $50,5$.

Calculate the number of moles of HI produced at the original equilibrium.

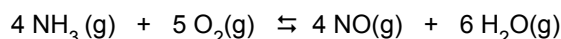
(8)

6.

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.



Ammonia is used in the industrial preparation of nitric acid. One of the reactions in this process, shown below, reached equilibrium in a closed container.



The initial concentrations of $NH_3(g)$ and $O_2(g)$ were both equal to $1 \text{ mol} \cdot \text{dm}^{-3}$.

At equilibrium it is found that the concentration of $NH_3(g)$ has changed by $0,25 \text{ mol} \cdot \text{dm}^{-3}$.

6.1 Calculate the value of the equilibrium constant (K_c) at the given temperature.

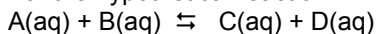
(9)

6.2 Is the yield of NO high or low at this temperature? Give a reason for your answer.

(3)

7.

For the hypothetical reaction:



If at equilibrium $K_c = 10^{-4}$, then $[A][B] < [C][D]$.

**Topic : Equilibrium Constant
Past Matric Papers**

8.

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



1,5 mol of $\text{N}_2(\text{g})$ and 2 mol $\text{H}_2(\text{g})$ were injected into a 0,5 dm³ closed reaction vessel and allowed to reach equilibrium at 470 °C. When equilibrium was reached it was found that 1 mol of $\text{NH}_3(\text{g})$ was present.

8.1 Calculate the equilibrium constant (K_c) at 470 °C. Show ALL your calculations. (8)

8.2 The temperature is now increased to 800 °C.

8.2.1 How will the value of K_c be affected if the temperature is increased to 800°C?
Write down only INCREASES or DECREASES or REMAINS THE SAME. (1)

8.2.2 Explain your answer to QUESTION 8.2.1. (2)

9.

The equilibrium constant for an exothermic reaction decreases with increase in temperature.
Is this statement true or false?

10.

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



During a research experiment carried out by initially adding 1 mol of $\text{O}_2(\text{g})$ and 1 mol of $\text{N}_2(\text{g})$ in a 2 dm³ closed container at 300 K, it was found that the concentration of the $\text{NO}(\text{g})$ present in the container at equilibrium was 0,1 mol·dm⁻³.

Calculate the equilibrium constant (K_c) for the reaction at this temperature. (7)

11.

For the heterogeneous equilibrium $\text{NH}_4\text{Cl}(\text{s}) \rightleftharpoons \text{NH}_3(\text{g}) + \text{HCl}(\text{g})$,

$$K_c = \frac{[\text{NH}_3(\text{g})][\text{HCl}(\text{g})]}{[\text{NH}_4\text{Cl}(\text{s})]}$$

Is this the correct formula for K_c ?

12.

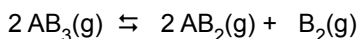
When the equilibrium constant of a reversible reaction has a value much greater than 1 ($K_c > 1$), it indicates that ...

- A a higher concentration of products than reactants will be formed.
- B a lower concentration of products than reactants will be formed.
- C the reaction will reach equilibrium quickly.
- D the reaction will take a long time to reach equilibrium.

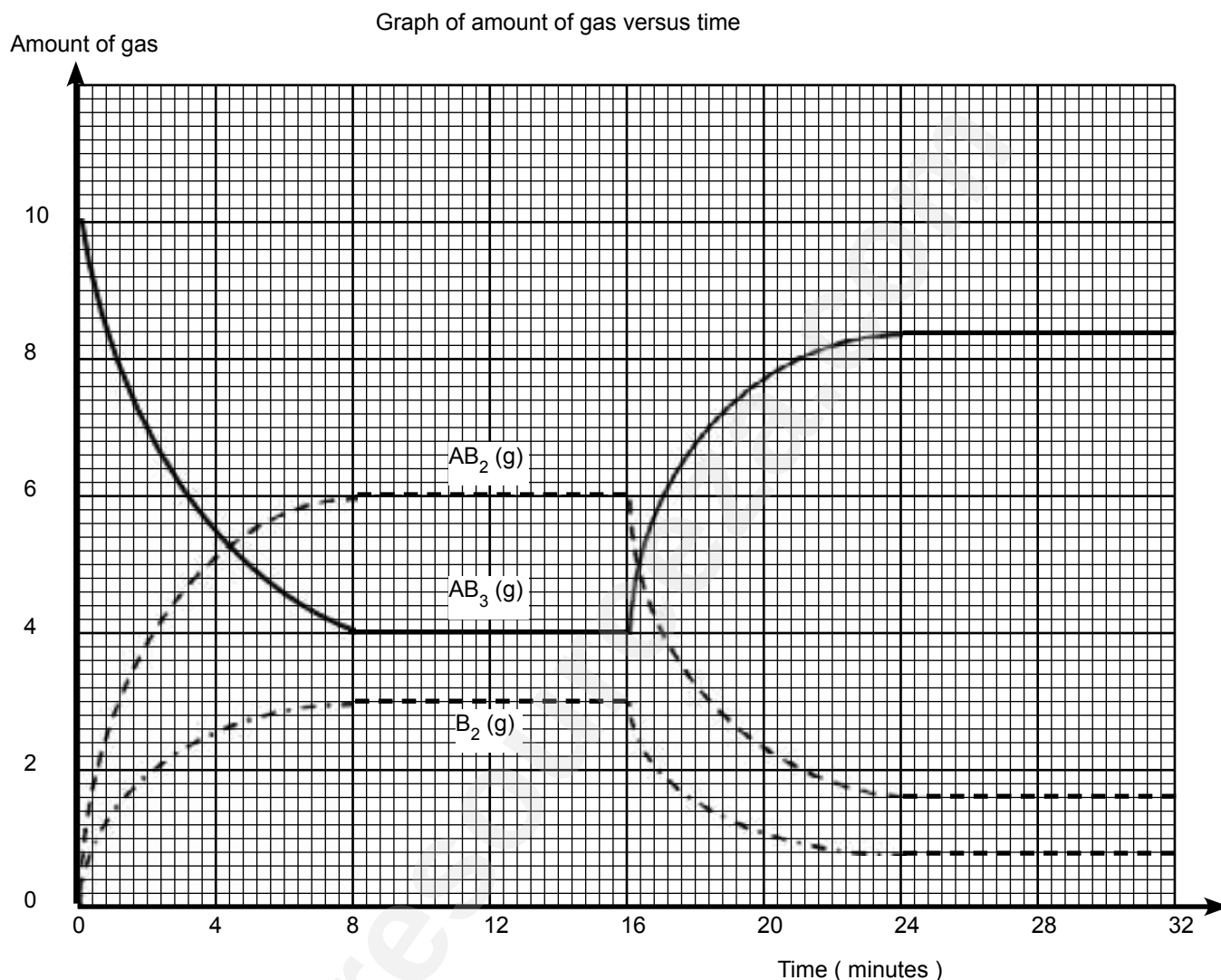
Topic: Equilibrium Constant
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13.

The following equation represents a hypothetical reaction that reaches equilibrium in a 2 dm^3 closed container at 500°C after 8 minutes.



The course of the reaction is illustrated by the graph below.

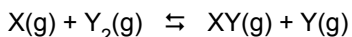


- 13.1 Use the information in the graph to calculate the value of the equilibrium constant at 500°C . (7)
- 13.2 The temperature is increased to 600°C at the 16th minute.
- 13.2.1 Is the forward reaction endothermic or exothermic?
Use Le Chatelier's principle to explain your answer. (3)
- 13.2.2 How does the equilibrium constant between $t = 8$ minutes and $t = 16$ minutes compare to that between $t = 24$ minutes and $t = 32$ minutes?
Write down only GREATER THAN, SMALLER THAN or EQUAL TO. (1)
- 13.3 The volume of the container is decreased from 2 dm^3 to 1 dm^3 after 32 minutes, while keeping the temperature constant at 600°C . How will each of the following be affected?
- 13.3.1 The value of K_c (1)
- 13.3.2 The number of moles of $\text{AB}_3(\text{g})$. Use Le Chatelier's principle to explain your answer. (4)

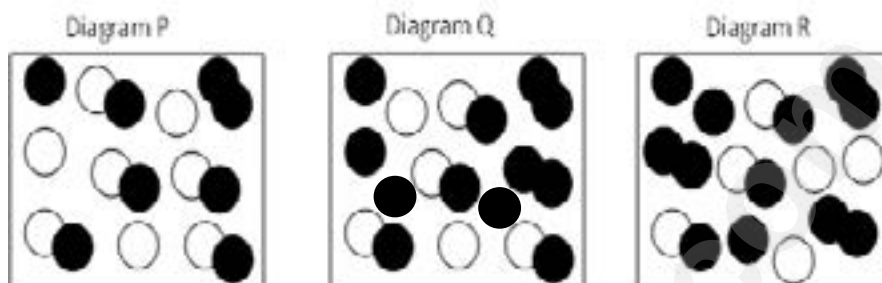
Topic: Equilibrium Constant
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14.

Diagrams P, Q and R represent different reaction mixtures of the following hypothetical reaction that is at equilibrium in a closed container at a certain temperature.



$$\Delta H > 0$$

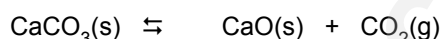


If at equilibrium $K_c = 2$, which diagram(s) correctly represent(s) the mixture at equilibrium?

- A. P only B. Q only C. R only D. P, R and Q

15.

The thermal decomposition of calcium carbonate (CaCO_3) is an example of a heterogeneous equilibrium. The decomposition that takes place in a closed container can be represented by the following equation:



Initially 5 g of $\text{CaCO}_3(s)$ is placed in a closed 500 cm^3 container and then heated. Equilibrium is reached at 900°C .

- 15.1 Why is the above decomposition referred to as a heterogeneous equilibrium? (1)
- 15.2 Calculate the mass of unreacted $\text{CaCO}_3(s)$ that remains in the container at equilibrium if K_c for the reaction is 0,0108 at 900°C . (9)
- 15.3 It is found that the value of K_c increases when the container is heated to a higher temperature. Is the forward reaction exothermic or endothermic? Use Le Chatelier's principle to explain your answer. (3)
- 15.4 The volume of the container is now decreased to 250 cm^3 while the temperature is kept constant. How will each of the following be affected? Write down only INCREASES, DECREASES or REMAINS THE SAME.
- 15.4.1 The value of K_c (1)
- 15.4.2 The number of moles of $\text{CaCO}_3(s)$ present in the equilibrium mixture (1)
- 15.4.3 The concentration of $\text{CO}_2(g)$ at the new equilibrium (1)
- 15.5 More $\text{CaCO}_3(s)$ is now added to the equilibrium mixture in the 500 cm^3 container. How will this change influence the number of moles of $\text{CO}_2(g)$? Write down only INCREASES, DECREASES or REMAINS THE SAME. (1)