Chemistry · Chemical Equilibrium

Effect of Reactant Concentration on Reaction Rate

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questions	sets	pages

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Multiple choice questions — 26 questions

1 Which of the following shows the conditions needed to increase the rate of the reaction of magnesium with nitric acid at its start?

(A) Doubling the concentration of the acid and halving the surface area of magnesium.

(B) Doubling the concentration of the acid and doubling the surface area of magnesium.

(C) Halving the concentration of the acid and halving the surface area of magnesium.

(D) Halving the concentration of the acid and doubling the surface area of magnesium.

---

2 Four identical masses of zinc react with acids under different conditions.

Which of the following represents the reaction conditions that lead to the greatest increase in the rate of the reaction?

(form of zinc / acid used / volume of acid / concentration of acid)

(A) strips / HCl / 20 mL / 2 M

(B) powder / HCl / 20 mL / 2 M

(C) strips / H_2SO_4 / 40 mL / 1 M

(D) powder / H_2SO_4 / 20 mL / 2 M

---

3 Two cubes of calcium carbonate have the same volume. 25 mL of 1 M hydrochloric acid (at 40°C) were added to one of them.

What is the effect of adding 60 mL of 0.5 M hydrochloric acid (at 40°C) to the second cube, compared with the reaction of the first cube?

(A) The rate of reaction decreases and a larger amount is produced.

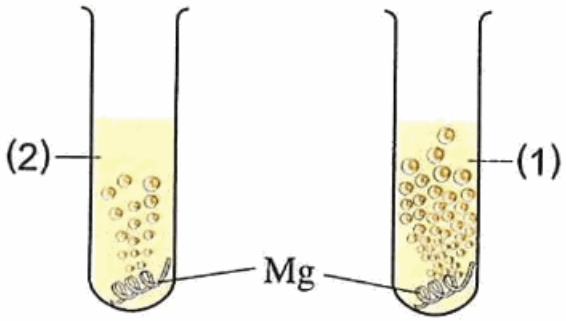
(B) The rate of reaction increases and a smaller amount is produced.

(C) The rate of reaction increases and a larger amount is produced.

(D) The rate of reaction decreases and a smaller amount is produced.

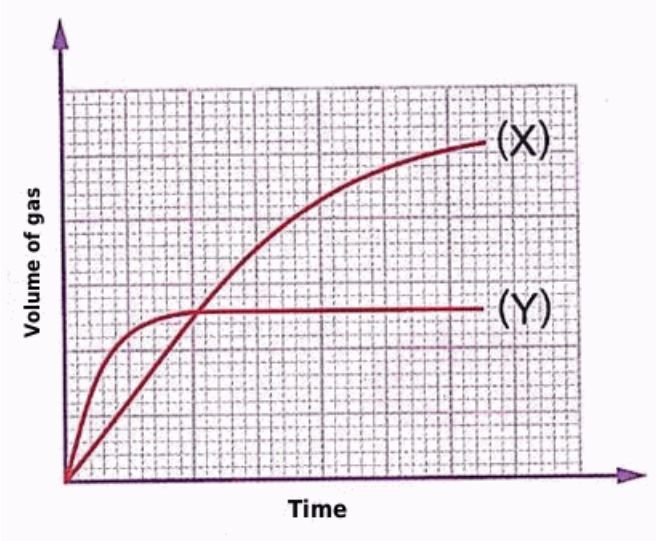
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4 The opposite figure represents two experiments at their start.
Which of the following represents each of the two acids (1) and (2)?



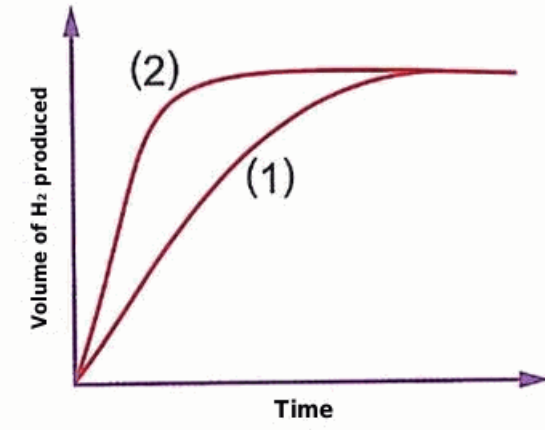
(A) (1) : 0.01 M CH_3COOH , (2) : 0.01 M H_2SO_4
(B) (1) : 0.01 M HCl , (2) : 0.1 M HCl
(C) (1) : 0.1 M CH_3COOH , (2) : 0.1 M HCl
(D) (1) : 0.1 M H_2SO_4 , (2) : 0.01 M H_2SO_4

5 Curve (X) in the opposite graph represents the volume of gas produced with time when excess calcium carbonate reacts with 100 mL of 1 M hydrochloric acid. When the reaction was repeated using the same acid with another volume and concentration under the same conditions of pressure and temperature, curve (Y) was obtained.
What are the volume and the concentration of the acid that produced curve (Y)?



(A) 50 mL , 1 mol/L (B) 25 mL , 1 mol/L (C) 50 mL , 2 mol/L (D) 25 mL , 2 mol/L

6 Curve (1) in the opposite graph represents the volume of gas given off with time when excess iron reacts with 100 mL of 0.1 M HCl acid, while curve (2) represents adding excess .....



(A) scandium to 100 mL of 0.1 M HCl acid

(B) iron to 100 mL of 0.1 M H_2SO_4 acid

(C) scandium to 100 mL of 0.2 M CH_3COOH acid

(D) iron to 100 mL of 0.2 M HCl acid

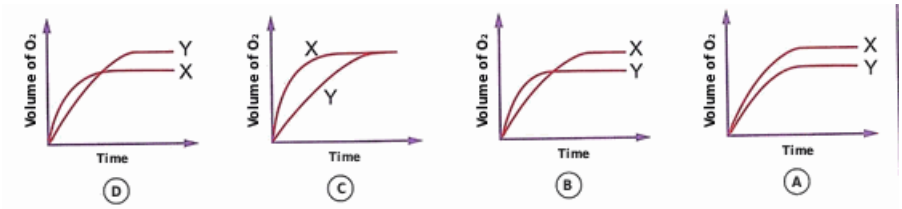
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7 Two experiments were carried out to measure the rate of oxygen gas given off from the decomposition of hydrogen peroxide under suitable conditions, as shown in the following table:

Experiment (X) : 100 mL of 2 M H_2O_2 solution

Experiment (Y) : 100 mL of 2 M H_2O_2 solution + 50 mL of 1 M H_2O_2 solution

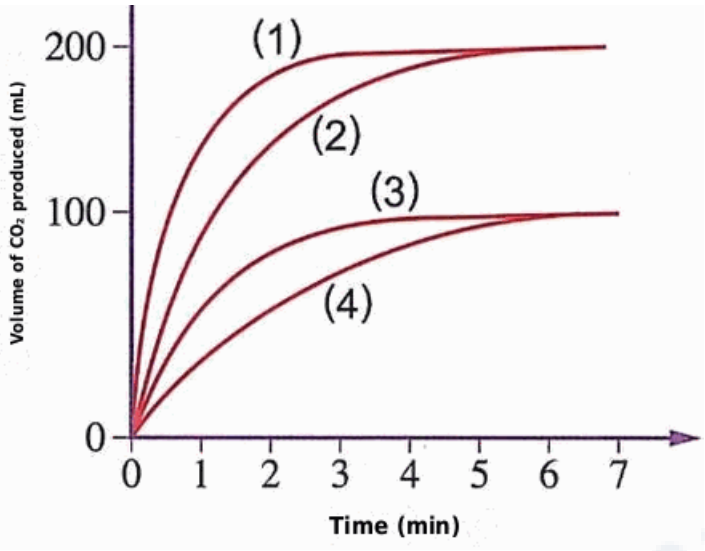
Which graph represents the results of both experiments?



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8 Four experiments (1), (2), (3) and (4) were carried out on the reaction of a fixed volume of nitric acid with identical pieces of calcium carbonate. The concentration of the acid was different from one experiment to another, and the opposite graph shows the volume of CO_2 gas produced in each experiment with time.

Which of the following can be concluded from this graph?



(A) The concentration of the acid used in experiment (3) is less than that used in experiment (1).

(B) The rate of reaction in experiment (4) is faster than in experiment (3).

(C) The concentration of the acid used in experiment (2) is greater than that used in experiment (1).

(D) The concentration of the acid used in experiment (2) is less than that used in experiment (4).

---

9 The opposite reversible reaction: $2N_2O(g) + 3O_2(g) \rightleftharpoons 4NO_2(g)$

is represented by the equilibrium constant expression .....

(A) $Kc = ([2N_2O][3O_2]) / [4NO_2]$

(B) $Kc = ([N_2O]^2[O_2]^3) / [NO_2]^4$

(C) $Kc = [4NO_2] / ([2N_2O][3O_2])$

(D) $Kc = [NO_2]^4 / ([N_2O]^2[O_2]^3)$

---

10 In the equilibrium reaction: $2KClO_3(s) \rightleftharpoons 2KCl(s) + 3O_2(g)$

Which of the following represents the equilibrium constant of this reaction?

(A) $Kc = [O_2]^3$

(B) $Kc = 1 / [O_2]^3$

(C) $Kc = [KClO_3]^2 / ([KCl]^2[O_2]^3)$

(D) $Kc = ([KCl]^2[O_2]^3) / [KClO_3]^2$

---

11 In the opposite equation: $2H_2(g) + O_2(g) \rightleftharpoons 2H_2O(v)$

Which of the following represents the rate of the forward reaction (r_1)?

(A) $r_1 = K\,[H_2O]^2$ (B) $r_1 = K\,[H_2][O_2]$

(C) $r_1 = K\,[H_2]^2[O_2]$ (D) $r_1 = K\,[H_2O]^2 / ([H_2]^2[O_2])$

12 In the equilibrium reaction: $CO_2(g) + 2H_2O(v) \rightleftharpoons CH_4(g) + 2O_2(g)$

Which of the following indicates that the reverse reaction is dominant?

(A) $r_1 < r_2$, $1 > Kc$ (B) $r_1 < r_2$, $1 < Kc$ (C) $K_1 < K_2$, $1 > Kc$ (D) $K_1 < K_2$, $1 < Kc$

13 An experiment was carried out on the reaction: $2A(g) + B(g) \rightleftharpoons C(g)$, $Kc = 1 \times 10^{-20}$

using 1 mol of each of the substances (A) and (B) in an empty 1 L vessel.

Which of the following represents the concentrations of the substances used when the state of equilibrium is reached?

(A) $[A] < [B] < [C]$ (B) $[A] > [B] > [C]$ (C) $[A] = [B] < [C]$ (D) $[B] > [A] > [C]$

14 The following reaction was carried out in a closed vessel (at STP):

$2H_2O(v) + 2Cl_2(g) \rightleftharpoons 4HCl(g) + O_2(g)$, $Kc = 5 \times 10^{-4}$

Which of the following represents the relation between the concentrations of the reaction substances when the state of equilibrium is reached?

(A) $[Cl_2]^2[H_2O]^2 < [O_2][HCl]^4$ (B) $[O_2][HCl]^4 < [H_2O]^2[Cl_2]^2$

(C) $[2Cl_2][2H_2O] < [O_2][4HCl]$ (D) $[O_2][4HCl] < [2H_2O][2Cl_2]$

15 In the opposite equilibrium reaction: $Cl_2(g) + 2NO(g) \rightleftharpoons 2NOCl(g)$, $Kc = 5$

If $[Cl_2]$ equals 1 M and [NO] equals 2 M, then [NOCl] equals .....

(A) 0.8 M (B) 0.89 M (C) 4.5 M (D) 10 M

16 0.2 mol of SO_2 gas were mixed with 0.2 mol of O_2 gas in a closed 1 L vessel, and at equilibrium the number of moles of SO_3 was 0.1 mol

What is the value of Kc for this reaction: $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$?

(A) 0.15 (B) 0.8 (C) 1.25 (D) 6.67

17 The opposite reaction was carried out in a closed 2 L vessel: $A_2(g) + B_2(g) \rightleftharpoons 2AB(g)$

At equilibrium the vessel contained:

- 0.7 mol of A_2
- 0.5 mol of B_2
- 0.2 mol of AB

What is the value of Kc for this reaction?

(A) 1.14 (B) 0.57 (C) 0.11 (D) 0.055

18 The opposite process was carried out in a closed vessel: $I_2(v) \rightleftharpoons 2I(g)$, Kc = 0.01

At equilibrium the number of moles of I_2 was 1 mol and the number of moles of I was 0.5 mol

What is the volume of the closed reaction vessel?

(A) 12.5 L (B) 15 L (C) 25 L (D) 40 L

19 Given Kc for the reaction: $A(g) + 2B(g) \rightleftharpoons C(g) + \frac{5}{2} D(g)$, Kc = 4

What is the value of Kc for the opposite reaction, assuming constant concentrations: $2C(g) + 5D(g) \rightleftharpoons 2A(g) + 4B(g)$?

(A) 0.25 (B) 0.063 (C) 8 (D) 16

20 From the process: $Cl_2(g) \rightleftharpoons 2Cl(g)$, $Kc = 1.13 \times 10^{-6}$

What is the value of Kc for the reaction $2Cl(g) \rightleftharpoons Cl_2(g)$ at the same temperature?

(A) 8.85×10^{5} (B) 4.42×10^{5} (C) 2.26×10^{-6} (D) 1.13×10^{-6}

21 In the reversible reaction: $2ICl(g) \rightleftharpoons Cl_2(g) + I_2(v)$

the initial concentration of ICl gas was 0.75 M and the equilibrium constant Kc was 16

What percentage of ICl decomposed at equilibrium?

(A) 44% (B) 88% (C) 60% (D) 80%

22 Iron(III) chloride solution was added to ammonium thiocyanate solution until the system reached the state of equilibrium.

What is the effect of adding excess ammonia solution to the equilibrium system?

(A) The system is activated in the reverse direction.

(B) The equilibrium is disturbed and the reaction stops.

(C) The concentration of ammonium thiocyanate increases.

(D) The concentration of ammonium thiocyanate decreases.

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23 The following equation represents a reversible reaction in a state of equilibrium:

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$, $Kc = 1.2 \times 10^4$

What happens to the direction of the reaction and to the value of Kc when more SO_2 is added to this reaction?

(A) The reaction shifts to the left / the value of Kc decreases

(B) The reaction shifts to the right / the value of Kc increases

(C) The reaction shifts to the right / the value of Kc does not change

(D) The reaction shifts to the left / the value of Kc does not change

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24 In the reversible reaction: $Ni(s) + 4CO(g) \rightleftharpoons Ni(CO)_4(s)$

What is the effect of increasing [CO] on this equilibrium reaction?

(A) $[Ni(CO)_4]$ decreases.

(B) [Ni] decreases.

(C) The mass of Ni decreases

(D) The value of Kc increases

---

25 In the equilibrium reaction: $4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(v)$

What happens when NH_3 gas is withdrawn from the reaction vessel?

(A) The rate of the forward reaction increases.

(B) The reaction is activated to the right.

(C) The production of NO gas increases

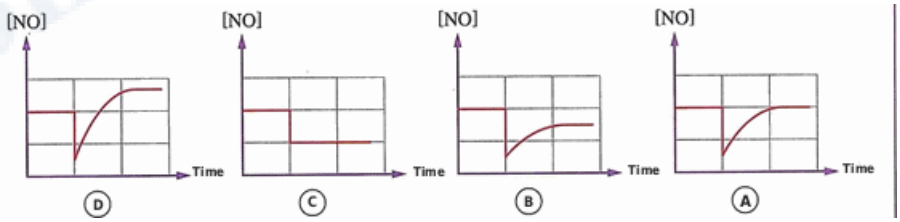
(D) The reaction is activated to the left.

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26 In the equilibrium reaction: $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$

When an amount of NO gas is removed from the reaction space,

which of the following graphs shows the system returning to the state of equilibrium at the same temperature?



Essay questions — 8 questions

1 When iron salt (X) is dissolved in water, a pale yellow solution forms:

(1) What is the colour of the precipitate formed when a strong base is added to the solution of salt (X)?

(2) What is the colour of the solution produced by adding a solution of thiocyanate ion to the solution of salt (X)?

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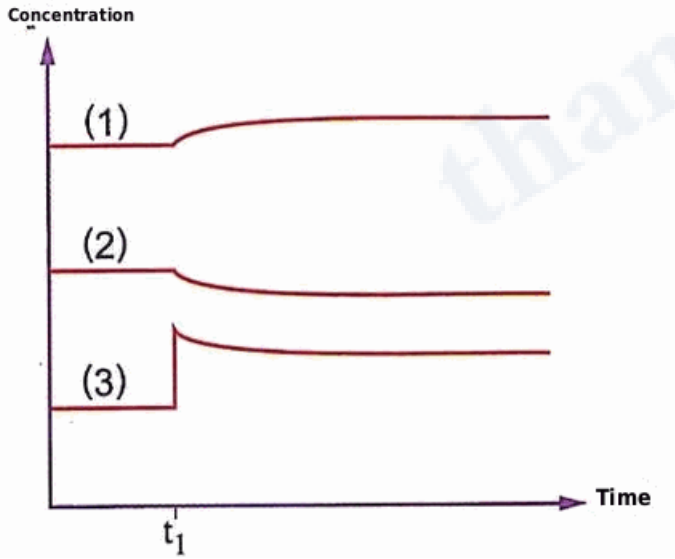
2 The opposite graph shows the effect of adding more $SCN^-(aq)$ to the following equilibrium system:

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

(Fe^{3+} : pale yellow) , (SCN^- : colourless) , ($Fe(SCN)^{2+}$: red)

(1) Replace the numbers shown on the graph with the suitable ions.

(2) Describe the change in the colour of the reaction medium after adding $SCN^-(aq)$



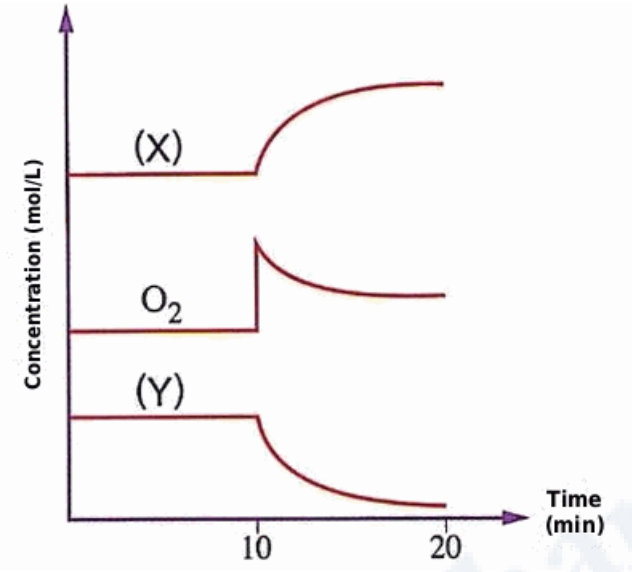
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3 The opposite graph represents the change that happened (at 10 min) in the following reversible reaction:

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$, $\Delta H = -192$ kJ/mol

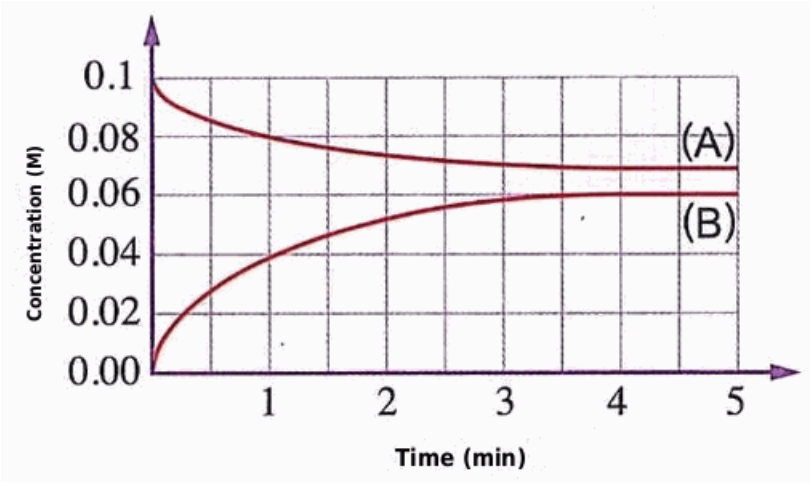
(1) What is the state of the reaction (at equilibrium or not at equilibrium) at 5 min? Explain.

(2) Which two substances are represented by the symbols (X) and (Y) on the graph when $[O_2]$ is increased at 10 min? Explain.



4 The opposite graph represents the reversible reaction: $A(g) \rightleftharpoons 2B(g)$

Calculate the equilibrium constant of this reaction.



5 A reaction was carried out between 0.5 mol of H_2 gas and 0.5 mol of I_2 vapour (at 430°C) in a closed 1 L vessel,

according to the equation: $H_2(g) + I_2(v) \rightleftharpoons 2HI(g)$, $Kc = 54.3$

At equilibrium $[H_2]$ was 0.107 M

Deduce the concentration of each of the following at equilibrium, with explanation.

(1) $[I_2]$

(2) $[HI]$

---

6 From the reversible reactions:

(1) $Cl_2(g) + 2NO(g) \rightleftharpoons 2NOCl(g)$, $Kc = 3.7 \times 10^{8}$

(2) $2HCl(g) \rightleftharpoons H_2(g) + Cl_2(g)$, $Kc = 2 \times 10^{-7}$

(1) Write the equilibrium constant expression for reaction (1).

(2) State, with explanation, which of the forward and reverse reactions is dominant in:

(a) reaction (1).

(b) reaction (2).

---

7 The following two graphs represent the rates of the forward and reverse reactions («not in order») of a reversible gaseous reaction involving the gases: O_2 , SO_2 , SO_3

Write the numbers of the two curves that represent each of the following, with explanation:

(1) the concentration of O_2 gas

(2) the concentration of SO_3 gas

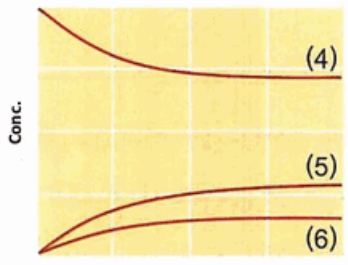


Figure (2)

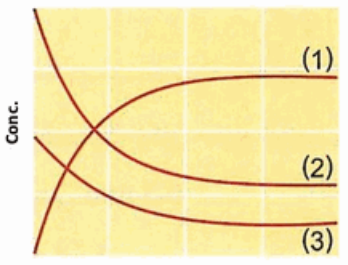


Figure (1)

8 100 mL of 0.1 M HCl acid were added to 4 g of calcium carbonate powder, and the amount of CO_2 gas given off was recorded every 30 s in the following table:

[$CaCO_3$ = 100 g/mol]

Time (s) : 30 , 60 , 90 , 120 , 150 , 180 , 210 , 240

Amount of CO_2 gas given off (mL) : 40 , 70 , 88 , 101 , 110 , 112 , 112 , 112

(1) What happens to the rate of collisions between the reactant molecules with time?

(2) Why does the reaction stop at 180 s?

Past exam questions — 24 questions

1 In the following equilibrium reaction: $Ca(OH)_2(s) \rightleftharpoons CaO(s) + H_2O(v)$

Which of the following changes leads to an increase in the mass of calcium oxide?

(A) Halving the mass of calcium oxide.

(B) Withdrawing 10 mL of water vapour.

(C) Doubling the mass of calcium hydroxide.

(D) Adding 10 mL of water vapour.

---

2 In which of the following reactions is the value of Kc equal to the concentration of the products?

(A) $C(s) + O_2(g) \rightleftharpoons CO_2(g)$

(B) $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$

(C) $H_2(g) + O_2(g) \rightleftharpoons 2H_2O(g)$

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

---

3 The following table shows the number of moles of the reactants and products at a certain temperature in the following equilibrium reaction:

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

Number of moles at equilibrium: NOCl = 3 , NO = 1.5 , Cl_2 = 3

If the value of Kc for the reaction at the same temperature = 0.25, then the volume of the reaction vessel in litres is .....

(A) 1 (B) 2 (C) 3 (D) 4

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4 One mole of each of hydrogen and iodine gases were mixed at a certain temperature, and the volume of the vessel was 2 L

At equilibrium the amount remaining of each of hydrogen and iodine was 0.3 mol

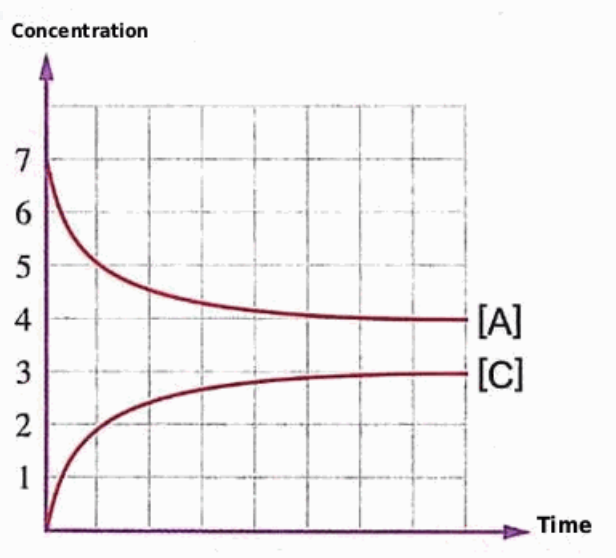
Which of the following represents the equilibrium constant of this reaction at the same temperature?

(A) 4 (B) 16 (C) 0.8711 (D) 21.78

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5 The opposite figure represents a reversible reaction.

Which of the following represents the equation of the reverse reaction of the reaction shown, and the value of its equilibrium constant?



(A) A ⇌ C , and the value of Kc = 0.75
(B) C ⇌ A , and the value of Kc = 1.33
(C) A ⇌ C , and the value of Kc = 1.33
(D) C ⇌ A , and the value of Kc = 0.75

---

6 In the equilibrium reaction: A(g) + B(g) ⇌ 2C(g)

Given that the concentrations of the reactants and products at 200°C in a 1 L vessel are:

[A] = 0.200 M , [B] = 3.00 M , [C] = 0.500 M

Which of the following represents the number of moles of A that must be added so that [C] = 0.700 M at the same temperature?

(A) 0.225 mol
(B) 0.305 mol
(C) 0.417 mol
(D) 0.610 mol

---

7 The following equilibrium reaction at a certain temperature:

2A(aq) + 3B(aq) ⇌ 2C(aq) + 3D(aq)

The concentrations of the reactants and products at equilibrium are: [A] = 1.5 M , [B] = 2.3 M , [C] = 3 M , [D] = 4.5 M

When the concentration of substance (A) was increased and the reaction reached equilibrium again at the same temperature, the concentrations at equilibrium became: [A] = 2.5 M , [C] = 4 M , [D] = 6 M

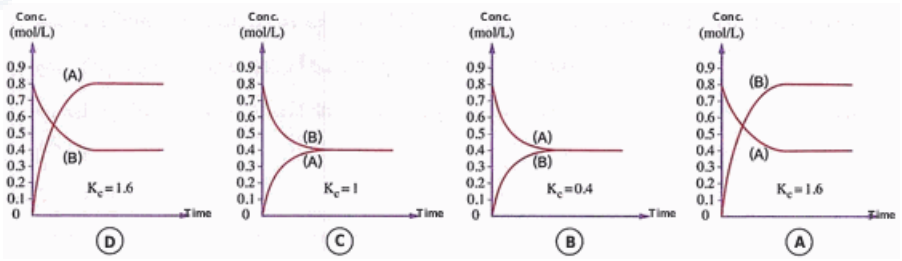
Which of the following represents the concentration of substance (B) at equilibrium?

(A) 29.96 M
(B) 6.98 M
(C) 3.83 M
(D) 2.64 M

---

8 0.8 mol of substance (A) was placed in a 1 L vessel, and when the state of equilibrium was reached according to the following equation: A(aq) ⇌ 2B(aq), it was found that 0.4 mol of substance (A) had changed into (B).

Which of the following graphs represents the state of equilibrium and the equilibrium constant of this reaction?



9 To which of the following reactions does the law of mass action apply?

(A) $HCl(aq) + KOH(aq) = KCl(aq) + H_2O(l)$ (in an open vessel)

(B) $2NaNO_3(s) = 2NaNO_2(s) + O_2(g)$ (in an open vessel)

(C) $CaCl_2(aq) + (NH_4)_2CO_3(aq) = 2NH_4Cl(aq) + CaCO_3(s)$ (in a closed vessel)

(D) $CaCO_3(s) = CaO(s) + CO_2(g)$ (in a closed vessel)

10 The following reaction: $NO + ½O_2 \rightleftharpoons NO_2$ takes place in a closed vessel at 25°C

When the state of equilibrium is reached, the value of Kc = 6.33

At a certain moment the amount of substance of NO = 0.3 mol, of O_2 = 0.3 mol and of NO_2 = 0.5 mol in a 2 L vessel at 25°C

Which of the following represents the state of the reaction at this moment?

(A) The reaction is at equilibrium and the equilibrium constant > 6.33

(B) The reaction is not at equilibrium and the equilibrium constant < 6.33

(C) The reaction is faster in the reverse direction.

(D) The reaction is faster in the forward direction.

11 In the following equilibrium reaction: $2NO + O_2 \rightleftharpoons 2NO_2$

Which of the following is correct?

(A) O_2 and NO react in equal mass ratios.

(B) The rate of formation of NO_2 equals twice the rate of consumption of O_2

(C) The rate of consumption of NO_2 equals the rate of formation of O_2

(D) The volume of the reactants equals the volume of the products.

12 The following equation represents the reaction between nitric oxide and hydrogen under certain conditions:

$2NO(g) + 2H_2(g) \rightleftharpoons N_2(g) + 2H_2O(v)$

When 0.1 mol of nitric oxide was mixed with 0.05 mol of hydrogen in a closed 1 L vessel at a certain temperature, the number of moles of nitric oxide in the vessel at equilibrium was found to be 0.062 mol

Which of the following represents the value of Kc for this reaction at the same temperature?

(A) 1.86 (B) 3.13 (C) 49.56 (D) 94.62

13 The following equilibrium reaction at a certain temperature:

$CH_3COOH(aq) + C_2H_5OH(aq) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$, $K_c = 10^{-3}$

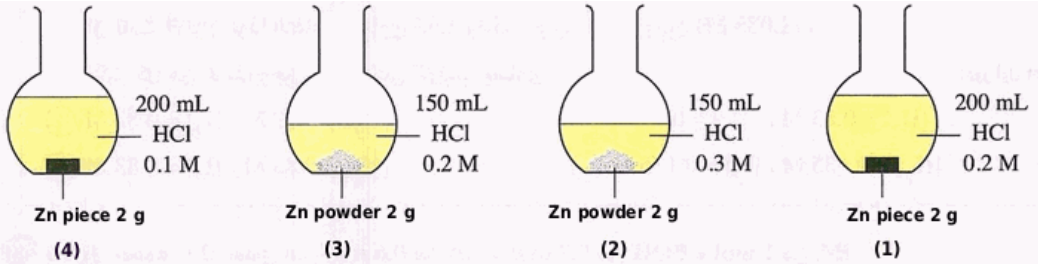
At equilibrium the concentration of acetic acid was 0.5 M and the concentration of ethyl alcohol was 0.01 M

The concentration of ethyl acetate equals .....

(A) 5×10^{-6} M (B) 1×10^{-6} M (C) 0.5×10^{-4} M (D) 5×10^{-3} M

14 Four flasks of equal volume contained the amounts shown in the following figures:

The correct order of the reactions according to their speed (the choices are in the figure) .....



The correct order of the reactions according to their speed is ..... (1st session 2022)

(A) (2) > (1) > (3) > (4) (B) (3) > (2) > (4) > (1)

(C) (2) > (3) > (1) > (4) (D) (4) > (1) > (2) > (3)

15 In the equilibrium reaction: $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

Given that the numbers of moles of PCl_5 , PCl_3 and Cl_2 at equilibrium are $(0.008 , 0.0114 , 0.0114)$ respectively

and the volume of the vessel = 10 L, then the value of the equilibrium constant Kc is .....

(A) 615.5 (B) 1.62×10^{-3} (C) 16.24×10^{-3} (D) 61.55

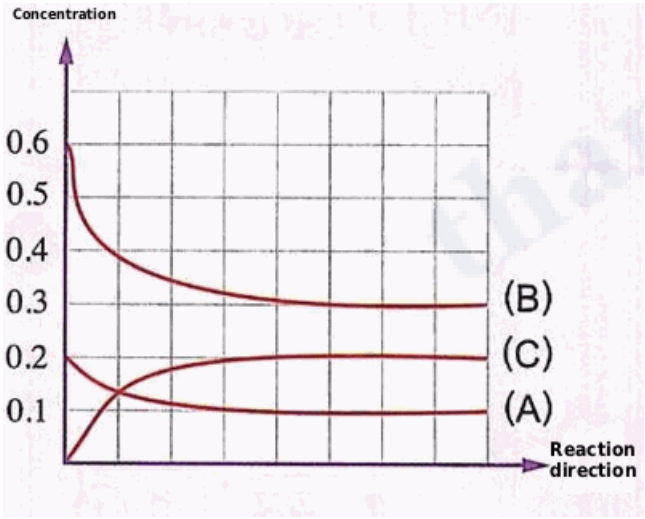
16 When ammonia gas was prepared from its elements at a certain temperature, it was found at equilibrium that: $[N_2] = 0.5$ M , $[H_2] = 0.7$ M , $Kc = 3.7 \times 10^{-4}$ so $[NH_3]$ = ...

(A) 7.97×10^{-3} M (B) 63.36×10^{-6} M (C) 3.9×10^{-2} M (D) 7.8×10^{-4} M

17 When equal concentrations of H_2 and A_2 were mixed, the following equilibrium took place: $H_2(g) + A_2(g) \rightleftharpoons 2HA(g)$
If [HA] equals 1.563 M at equilibrium and the equilibrium constant equals 40, then $[A_2]$ equals .....

(A) 0.247 M (B) 0.039 M (C) 62.52 M (D) 42.52 M

18 The opposite graph represents the equilibrium state $A + 3B \rightleftharpoons 2C$ so the value of Kc equals .....



(A) 6.66 (B) 14.81 (C) 0.9 (D) 15.49

19 In the reaction: $I_2(g) + H_2(g) \rightleftharpoons 2HI(g)$
If the equilibrium constant of this reaction equals 1.55 and the concentration of hydrogen iodide is (1.035 M), then the concentrations of hydrogen and iodine respectively are .....

(A) $[H_2] = 0.79$ M , $[I_2] = 0.83$ M (B) $[H_2] = 0.83$ M , $[I_2] = 0.79$ M
(C) $[H_2] = 0.83$ M , $[I_2] = 0.83$ M (D) $[H_2] = 0.135$ M , $[I_2] = 0.135$ M

20 A 2 L solution contains 0.6 mol of HA, 0.7 mol of BOH, 1 mol of BA and 100 mol of water:

$HA(aq) + BOH(aq) \rightleftharpoons BA(aq) + H_2O(l)$

The value of the equilibrium constant of the previous reaction is .....

(A) 238 (B) 476 (C) 2.38 (D) 4.76

21 When a solution of substance (Y) is added to a pale yellow solution of substance (X), a solution of a certain colour forms,

and when more of the solution of substance (Y) is added to the same reaction, the colour produced becomes deeper.

The two substances (X) and (Y) are .....

(A) (X) : $FeCl_3$, (Y) : NH_4SCN

(B) (X) : NH_4SCN , (Y) : $FeCl_3$

(C) (X) : NH_4OH , (Y) : $FeCl_3$

(D) (X) : $FeCl_3$, (Y) : NH_4OH

22 In the reaction: $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

(N_2O_4 : colourless) , (NO_2 : reddish brown)

When more N_2O_4 gas is added, ...

(A) the colour increases and the value of Kc stays constant.

(B) the colour increases and the value of Kc increases

(C) the colour decreases and the value of Kc stays constant.

(D) the colour decreases and the value of Kc decreases

23 In the opposite equilibrium reaction: $4NH_3(g) + 3O_2(g) \rightleftharpoons 2N_2(g) + 6H_2O(v)$

When a little of the mixture ($O_2 + 2N_2(g)$) is added to the previous reaction, it is activated in the .....

(A) forward direction and $[NH_3]$ increases.

(B) reverse direction and $[O_2]$ decreases.

(C) reverse direction and $[NH_3]$ increases.

(D) forward direction and $[N_2]$ decreases.

24 In the two opposite equilibrium reactions:

(1) $N_2O_4(g) \rightleftharpoons 2NO_2(g)$, Kc_1

(2) $2NO_2(g) \rightleftharpoons N_2O_4(g)$, Kc_2

the mathematical relation between the equilibrium constants is .....

(A) $Kc_1 + Kc_2 = 1$ (B) $Kc_1 \times Kc_2 = 1$ (C) $Kc_1 \div Kc_2 = 1$ (D) $Kc_1 - Kc_2 = 1$

Answer key and solutions

Multiple choice questions

1	2	3	4	5	6	7	8	9	10
B	D	A	D	D	A	D	A	D	A
11	12	13	14	15	16	17	18	19	20
C	C	D	B	C	D	C	C	B	A
21	22	23	24	25	26				
B	B	C	C	D	B				

1 **Answer (B)**

The rate of reaction increases as the concentration of the acid increases.

It also increases as the surface area of the metal increases.

2 **Answer (D)**

The highest rate is with the powder, because its surface area is larger.

And with the acid that has the highest concentration of H^+, which is 2 M H_2SO_4

3 **Answer (A)**

The concentration of the new acid $(0.5\ M)$ is lower, so the rate of reaction decreases.

Number of moles of the first acid = $1 \times 0.025 = 0.025$ mol

Number of moles of the second acid = $0.5 \times 0.06 = 0.03$ mol

So a larger amount of gas is produced.

4 **Answer (D)**

Tube (1) has more bubbles, so its rate of reaction is greater.

That is, its acid has a higher concentration than the acid of tube (2), of the same type.

5 **Answer (D)**

The rate of reaction in (Y) is greater, so the concentration of its acid is greater.

Number of moles of acid (X) = $0.1 \times 1 = 0.1$ mol

The volume of gas in (Y) is half its volume in (X), so the number of moles of its acid = 0.05 mol

Volume of acid (Y) = $0.05 \div 2 = 0.025$ L = 25 mL

6 **Answer (A)**

The final volume of gas is equal, so the number of moles of acid is equal.

The rate is greater because scandium is more active than iron.

7 **Answer (D)**

Number of moles of H_2O_2 in (X) = 0.2 mol

Number of moles of H_2O_2 in (Y) = 0.05 + 0.2 = 0.25 mol

So the volume of O_2 produced in (Y) is larger.

The concentration of (Y) is lower than (X), so its rate of reaction is slower.

8 **Answer (A)**

The volume of the acid is constant, and the final volume of gas in (3) = 100 mL is less than in (1) = 200 mL.

So the concentration of the acid in (3) is less than in (1).

9 **Answer (D)**

Kc = [products] ÷ [reactants], each raised to the power of its coefficient.

$Kc = [NO_2]^4 / ([N_2O]^2[O_2]^3)$

10 **Answer (A)**

Solids do not appear in the equilibrium constant.

$Kc = [O_2]^3$

11 **Answer (C)**

The rate of the forward reaction is proportional to the product of the concentrations of the reactants, each raised to the power of its coefficient.

$r_1 = K\,[H_2]^2\,[O_2]$

12 **Answer (C)**

The reverse reaction being dominant means that the concentration of the products is less than that of the reactants.

That is, Kc is less than 1

13 **Answer (D)**

Kc is very small, so the reverse reaction is dominant and [C] is very small.

Every 2 mol of A react with 1 mol of B.

So at equilibrium [A] < [B]

14 **Answer (B)**

$Kc = 5 \times 10^{-4}$ is less than 1

So the product of the concentrations of the products is less than the product of the concentrations of the reactants.

$[O_2][HCl]^4 < [H_2O]^2[Cl_2]^2$

15 **Answer (C)**

$Kc = [NOCl]^2 / ([Cl_2][NO]^2) = 5$

$[NOCl]^2 = 5 \times 1 \times 2^2 = 20$

$[NOCl] = 4.5$ M

16 **Answer (D)**

Remaining $SO_2 = 0.2 - 0.1 = 0.1$ mol

Remaining $O_2 = 0.2 - 0.05 = 0.15$ mol

$SO_3 = 0.1$ mol, and the volume is 1 L, so the concentration = the number of moles.

$Kc = (0.1)^2 / ((0.1)^2 \times 0.15) = 6.67$

17 **Answer (C)**

Concentration = number of moles ÷ 2 L

$[A_2] = 0.35$ M , $[B_2] = 0.25$ M , $[AB] = 0.1$ M

$Kc = (0.1)^2 / (0.35 \times 0.25) = 0.11$

18 **Answer (C)**

$Kc = [I]^2 / [I_2]$

$0.01 = (0.5 \div V)^2 / (1 \div V)$

$V = (0.5)^2 \div 0.01 = 25$ L

19 **Answer (B)**

The required reaction is the reverse of the given reaction multiplied by 2

$Kc = (1 \div 4)^2 = 0.0625 \approx 0.063$

20 **Answer (A)**

The required reaction is the reverse of the given reaction.

$Kc = 1 \div (1.13 \times 10^{-6}) = 8.85 \times 10^5$

21 **Answer (B)**

Let the concentration of Cl_2 = the concentration of I_2 = x

$16 = x^2 / (0.75 - 2x)^2$

$4 = x / (0.75 - 2x)$

$x = 0.33$ M

ICl decomposed = $2x = 0.66$ M

Percentage = $0.66 \div 0.75 \times 100 = 88\%$

22 **Answer (B)**

23 **Answer (C)**

Adding SO_2 (a reactant) shifts the reaction to the right.

The value of Kc changes only with temperature, so it does not change.

24 **Answer (C)**

Ni is a solid, so its concentration does not change.

Increasing [CO] shifts the reaction to the right.

So part of the Ni changes into $Ni(CO)_4$ and the mass of Ni decreases

25 **Answer (D)**

Withdrawing NH_3 (a reactant) decreases its concentration.

So the reaction is activated to the left to make up for the decrease.

26 **Answer (B)**

Removing an amount of NO suddenly decreases its concentration.

The rate of the forward reaction increases, so the concentration of NO increases gradually until equilibrium.

But to a concentration lower than the initial concentration.

Essay questions

1 **Model answer**

(1) Reddish brown.

(2) Blood red.

2 **Model answer**

(1) (1) : $Fe(SCN)^{2+}(aq)$, (2) : $Fe^{3+}(aq)$, (3) : $SCN^{-}(aq)$

(2) The red colour becomes deeper.

3 **Model answer**

(1) The reaction is in a state of equilibrium, because the concentrations of both the reactants and the products are constant.

(2) (X) : $SO_3(g)$, (Y) : $SO_2(g)$

Because increasing $[O_2]$ makes the system proceed in the direction of forming SO_3 by consuming more SO_2

4 **Model answer**

$Kc = [B]^2 / [A] = (0.06)^2 / (0.07) = 0.05$

5 **Model answer**

(1) Number of moles of H_2 = number of moles of I_2, and the volume of the vessel is 1 L

$\therefore [I_2] = [H_2]$ at the start of the reaction.

$\therefore [I_2] = [H_2] = 0.107$ M at equilibrium, because their numbers of moles in the balanced equation are equal.

(2) $Kc = [HI]^2 / ([H_2][I_2])$

$\therefore [HI] = \sqrt{(54.3 \times 0.107 \times 0.107)} = 0.788$ M

6 **Model answer**

(1) $Kc = [NOCl]^2 / ([Cl_2][NO]^2)$

(2) (a) The direct combination reaction (the forward reaction) is dominant / because its value of Kc is greater than one.

(b) The direct combination reaction (the reverse reaction) is dominant / because the value of Kc for the decomposition reaction is less than one.

7 **Model answer**

Graph (1) represents the rate of the reaction: $2SO_2 + O_2 \rightarrow 2SO_3$, while graph (2) represents the rate of the reaction: $2SO_3 \rightarrow 2SO_2 + O_2$

(1) In graph (1) the reactants are represented by the two curves (2) and (3), because their concentrations are as large as possible at the start of the reaction.

$\because$ the number of moles of SO_2 is twice the number of moles of O_2 $\therefore [O_2]$ is represented by the two curves (3) and (6).

(2) $\because$ SO_3 in graph (1) represents the product and in graph (2) represents the reactant $\therefore [SO_3]$ is represented by the two curves (4) and (1).

8 **Model answer**

(1) The rate of the reaction decreases with time, ∴ the rate of collisions between the reactant molecules decreases with time.

(2) All the HCl acid is consumed

Past exam questions

1	2	3	4	5	6	7	8	9	10
B	B	C	D	B	B	D	A	D	D
11	12	13	14	15	16	17	18	19	20
B	C	A	C	B	A	A	B	C	D
21	22	23	24						
A	A	C	B						

1 **Answer (B)**

Withdrawing water vapour (a product) shifts the reaction to the right.

So the mass of CaO increases

Changing the masses of solids does not affect the equilibrium.

2 **Answer (B)**

$Kc = [CO_2]$

Solids do not appear in the equilibrium constant.

3 **Answer (C)**

$Kc = [NO]^2 [Cl_2] / [NOCl]^2$

Concentration = number of moles ÷ V

$0.25 = (1.5)^2 \times 3 / (3^2 \times V) = 0.75 \div V$

V = 3 L

4 **Answer (D)**

Remaining H_2 = 0.3 mol, so 0.7 mol of each reacted.

HI formed = 2 × 0.7 = 1.4 mol

$[HI] = 0.7$ M , $[H_2] = [I_2] = 0.15$ M

$Kc = (0.7)^2 / (0.15)^2 = 21.78$

5 **Answer (B)**

From the figure: [A] = 4 , [C] = 3 at equilibrium.

For the reaction A ⇌ C : Kc = 3 ÷ 4 = 0.75

For the reverse reaction C ⇌ A : Kc = 1 ÷ 0.75 = 1.33

6 **Answer (B)**

$Kc = [C]^2 / ([A][B]) = (0.5)^2 / (0.2 \times 3) = 0.4167$

At [C] = 0.7 M, 0.1 mol of each of A and B react, so [B] = 2.9 M

$[A] = (0.7)^2 / (0.4167 \times 2.9) = 0.405$ M

Amount added = 0.405 − 0.2 + 0.1 = 0.305 mol

7 **Answer (D)**

Kc is constant at the same temperature.

$Kc = [C]^2 [D]^3 / ([A]^2 [B]^3) = 3^2 \times 4.5^3 / (1.5^2 \times 2.3^3) = 29.96$

$29.96 = 4^2 \times 6^3 / (2.5^2 \times [B]^3)$

$[B]^3 = 18.46$

[B] = 2.64 M

8 **Answer (A)**

At equilibrium: [A] = 0.8 − 0.4 = 0.4 M

[B] = 2 × 0.4 = 0.8 M

$Kc = (0.8)^2 / 0.4 = 1.6$

9 **Answer (D)**

The law of mass action applies to reversible reactions in a closed vessel.

The decomposition of $CaCO_3$ in a closed vessel reaches a state of equilibrium.

10 **Answer (D)**

$Q = [NO_2] / ([NO]\,[O_2]^{\wedge}½) = 0.25 / (0.15 \times 0.387) = 4.3$

Q is less than Kc = 6.33

So the reaction is not at equilibrium and proceeds in the forward direction.

11 **Answer (B)**

$2NO + O_2 \rightarrow 2NO_2$

Rate of formation of NO_2 = 2 × rate of consumption of O_2

12 **Answer (C)**

NO reacted = 0.1 − 0.062 = 0.038 mol

Remaining H_2 = 0.05 − 0.038 = 0.012 mol

N_2 = 0.019 mol , H_2O = 0.038 mol

Kc = $(0.019)(0.038)^2 / ((0.062)^2 (0.012)^2)$ = 49.56

13 **Answer (A)**

Kc = $[CH_3COOC_2H_5] / ([CH_3COOH][C_2H_5OH])$

[ester] = $10^{-3} \times 0.5 \times 0.01 = 5 \times 10^{-6}$ M

14 **Answer (C)**

A powder is faster than a piece, and a greater concentration is faster.

(2) is a powder with a concentration of 0.3 M, so it is the fastest.

(3) is a powder with a concentration of 0.2 M, then (1) is a piece with a concentration of 0.2 M

(4) is a piece with a concentration of 0.1 M, so it is the slowest.

15 **Answer (B)**

Concentration = number of moles ÷ 10 L

$[PCl_5]$ = 0.0008 M , $[PCl_3] = [Cl_2]$ = 0.00114 M

Kc = $(0.00114)^2 / 0.0008 = 1.62 \times 10^{-3}$

16 **Answer (A)**

Kc = $[NH_3]^2 / ([N_2][H_2]^3)$

$3.7 \times 10^{-4} = [NH_3]^2 / (0.5 \times 0.7^3)$

$[NH_3] = 7.97 \times 10^{-3}$ M

17 **Answer (A)**

$[H_2] = [A_2] = x$

$40 = (1.563)^2 / x^2$

x = 0.247 M

18 **Answer (B)**

From the graph: [A] = 0.1 M , [B] = 0.3 M , [C] = 0.2 M

Kc = $[C]^2 / ([A][B]^3) = (0.2)^2 / (0.1 \times 0.3^3) = 14.81$

19 **Answer (C)**

$[H_2] = [I_2] = x$

$1.55 = (1.035)^2 / x^2$

$x = 0.83$ M

20 **Answer (D)**

Concentration = number of moles ÷ 2 L

[HA] = 0.3 M , [BOH] = 0.35 M , [BA] = 0.5 M

Water is a liquid, so it does not appear in the equilibrium constant.

$Kc = 0.5 / (0.3 \times 0.35) = 4.76$

21 **Answer (A)**

Ammonium thiocyanate is colourless and iron(III) chloride is pale yellow.

$Fe^{3+} + SCN^- \rightleftharpoons Fe(SCN)^{2+}$ forms a blood-red colour.

Increasing one of the reactants deepens the red colour.

22 **Answer (A)**

Increasing the concentration of N_2O_4 shifts the reaction to the right.

So the reddish-brown NO_2 increases and the colour increases.

The value of Kc changes only with temperature.

23 **Answer (C)**

24 **Answer (B)**

The two reactions are reverse of each other, so $Kc_1 = 1 \div Kc_2$

$Kc_1 \times Kc_2 = 1$