Chemistry · Chemical Equilibrium

Effect of Temperature on Reaction Rate

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Multiple choice questions — 67 questions

1 To increase the rate of a chemical reaction, it is necessary to .....

(A) decrease the rate of collisions between the molecules.

(B) increase the number of non-activated molecules.

(C) decrease the number of activated molecules.

(D) increase the percentage of activated molecules.

---

2 Which of the following explains the increase in the rate of reaction when the temperature is raised?

(energy of the reactant particles / rate of collisions of the reactant particles)

(A) stays the same / stays the same

(B) increases / increases

(C) stays the same / increases

(D) increases / stays the same

---

3 In which of the following samples do the iron atoms have the highest kinetic energy?

(A) 5 g (at 10°C)

(B) 10 g (at 25°C)

(C) 5 g (at 127°C)

(D) 10 g (at 0°C)

---

4 If the rate of a chemical reaction (at 20°C) equals 3.2×10^{-3} mol/s, then (at 30°C) it becomes .....

(A) 1.28×10^{-2} mol/s

(B) 6.4×10^{-3} mol/s

(C) 9.6×10^{-3} mol/s

(D) 3.2×10^{-4} mol/s

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5 When the temperature of a chemical reaction is raised by 50°C, its rate increases by about .....

(A) 16 times.

(B) 20 times.

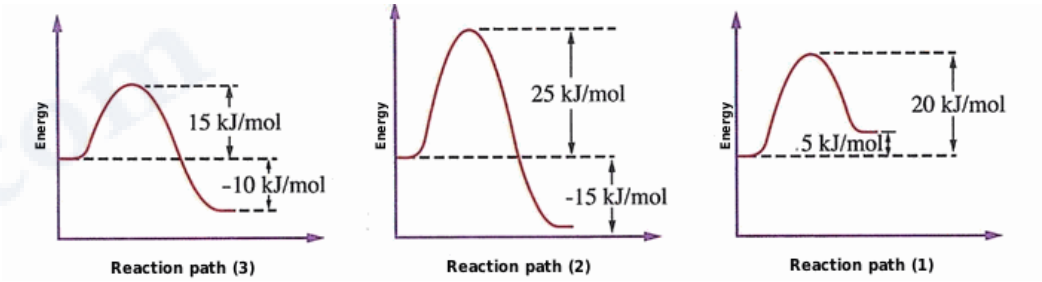
(C) 32 times.

(D) 50 times.

---

6 The following figures represent the energy diagrams of three different reactions:

Which of the following represents the order of these reactions from the slowest to the fastest?



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

---

7 A piece of a metal reacts with an acid to produce hydrogen gas.

Which of the following leads to an increase in the rate of the reaction?

(heating / grinding the piece of metal / adding water to the acid)

(A) ✓ / ✓ / ✗
(B) ✓ / ✗ / ✓
(C) ✗ / ✓ / ✓
(D) ✓ / ✓ / ✓

---

8 All of the following increase the rate of the reaction of 100 mL of 1 M HCl acid with 2 g of calcium carbonate pieces, except .....

(A) adding 50 mL of distilled water to the acid.
(B) increasing the concentration of the acid to 2 M
(C) heating the acid before adding it to the calcium carbonate.
(D) changing the calcium carbonate pieces into powder.

---

9 In the opposite reversible reaction: $\frac{1}{2}H_2(g) + \frac{1}{2}I_2(v) \rightleftharpoons HI(g)$

the activation energy of the forward reaction is 167 kJ and the activation energy of the reverse reaction is 139 kJ

What is the type of this reaction, and what is the value of its change in heat content ΔH?

(A) Exothermic / −28 kJ
(B) Exothermic / +28 kJ
(C) Endothermic / −28 kJ
(D) Endothermic / +28 kJ

---

10 In a reversible reaction, the activation energy of the endothermic forward reaction was 50 kJ and its ΔH was 20 kJ

What is the activation energy of the reverse reaction of the same reaction?

(A) 20 kJ
(B) 30 kJ
(C) 50 kJ
(D) 70 kJ

11 The following table shows the results of two experiments in which the same number of moles of zinc reacted with the same volume of hydrochloric acid:

Experiment (1) : Zn strip , temperature 10°C , [HCl] = 10 M , volume of H_2 produced 10.6 mL

Experiment (2) : Zn powder , temperature 15°C , [HCl] = 3 M , volume of H_2 produced 7.3 mL

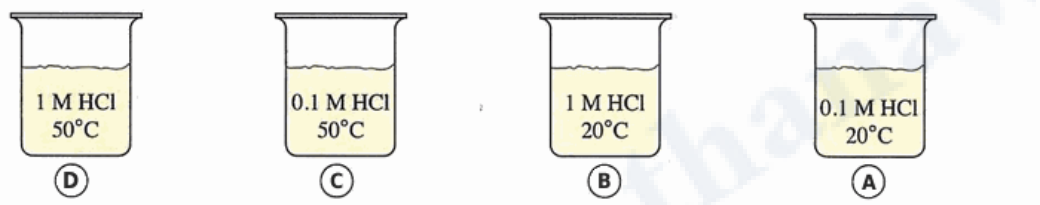
Which factor explains the difference between the volume of H_2 produced in experiment (1) and that in experiment (2)?

(A) [HCl].
(B) Temperature.
(C) Nature of the reactants.
(D) Surface area of Zn

---

12 You have 4 glass beakers, each containing 2 g of magnesium strip reacting with 100 mL of dilute hydrochloric acid under the conditions written on each beaker.

In which of the following beakers is the rate of the reaction as great as possible?



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13 The opposite table shows the conditions of two experiments.

First experiment: Fe filings with concentrated HNO_3 , at 20°C

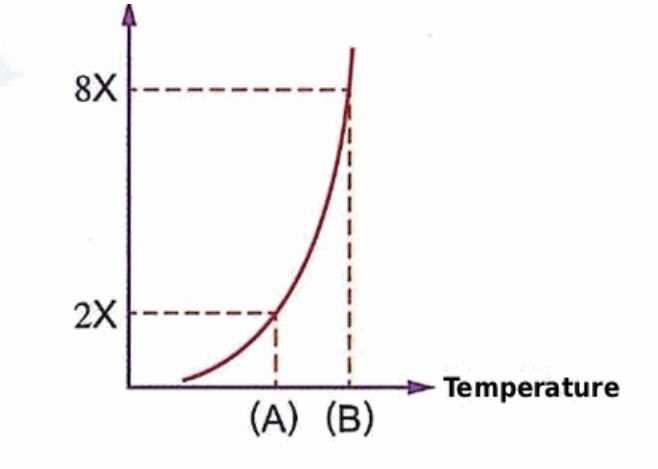
Second experiment: Fe pieces with dilute HNO_3 , at 10°C

Which experiment produces the smallest volume of gas, and what is the factor affecting that?

(A) The first experiment / nature of the reactants.
(B) The second experiment / temperature.
(C) The first experiment / concentration of the acid.
(D) The second experiment / nature of the reactants.

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14 From the opposite graph: if temperature (A) equals 40°C,
what is temperature (B)?

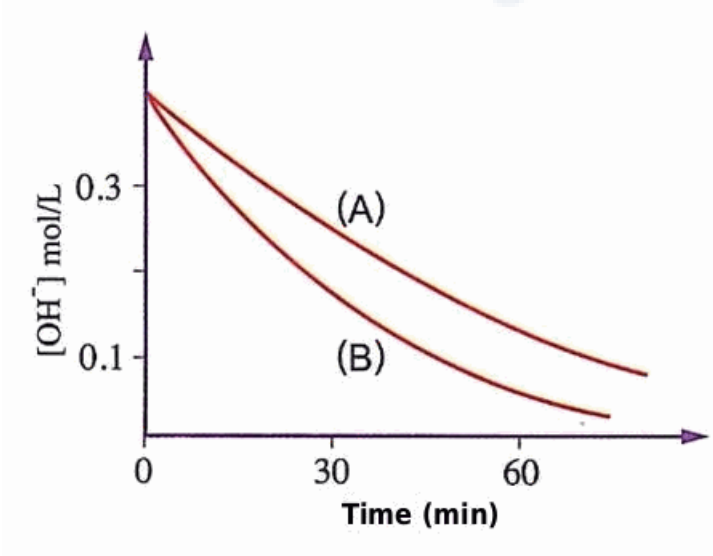


(A) 60°C (B) 70°C (C) 50°C (D) 90°C

15 The following reaction was carried out at two different temperatures without changing the concentration of the reactants:

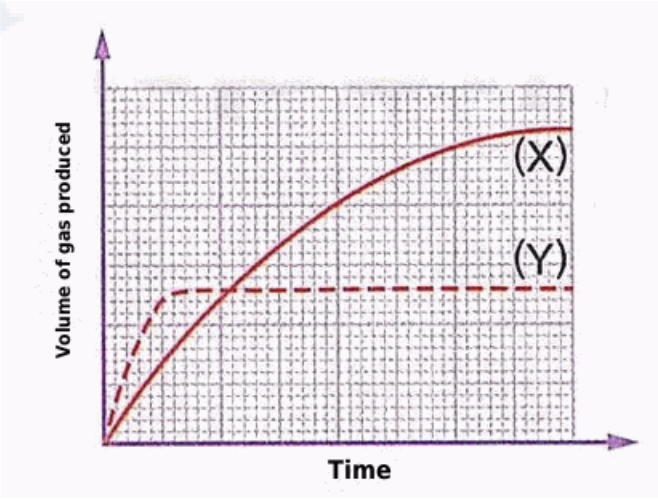
$C_2H_5Br(aq) + OH^-(aq) \rightarrow C_2H_5OH(aq) + Br^-(aq)$

From the opposite graph: which reaction has the greatest rate,
and which reaction takes place at the higher temperature?



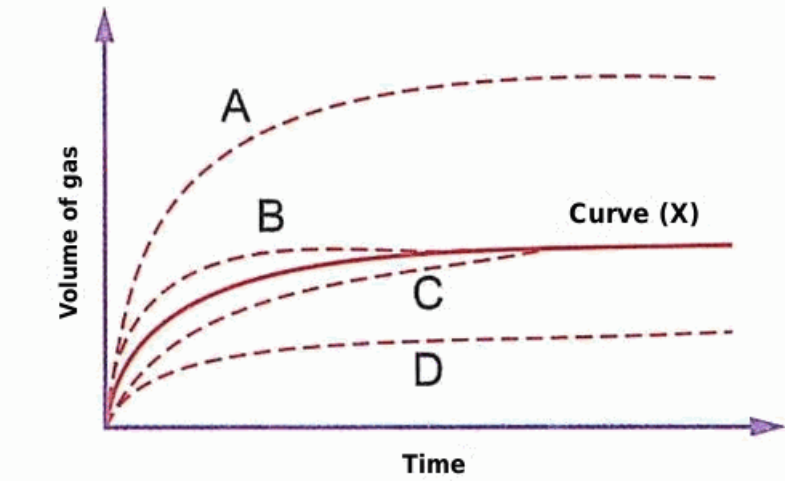
(A) (A) , (A) (B) (A) , (B) (C) (B) , (A) (D) (B) , (B)

16 In the opposite graph, curve (X) represents the volume of gas produced from the reaction between 2 g of zinc granules and excess of an acid (at 25°C).
What change leads to the formation of curve (Y) when the experiment is repeated?



(A) Using 1 g of zinc powder (at 25°C).
(B) Using 2 g of zinc powder (at 30°C).
(C) Using 1 g of zinc granules (at 25°C).
(D) Using 2 g of zinc granules (at 30°C).

17 Curve (X) in the opposite graph shows the volume of hydrogen gas given off with time when 0.01 mol of zinc powder is added to 100 mL of 0.1 M hydrochloric acid (at 25°C).
Which curve represents the volume of hydrogen gas given off with time when the previous experiment is repeated using 0.01 mol of zinc powder with 100 mL of 0.2 M hydrochloric acid (at 50°C)?



18 The rate of the reaction of zinc powder with 0.1 M HCl acid is greater than the rate of the reaction of the same mass of zinc pieces with the same acid, because .....

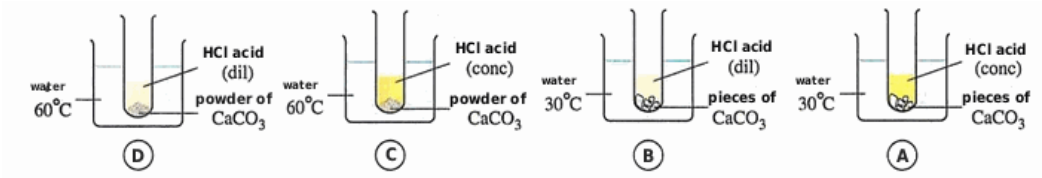
(A) its activation energy is lower.

(B) its activation energy is higher.

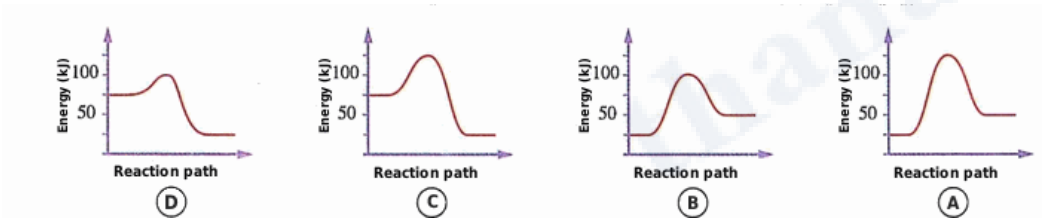
(C) the number of reacting molecules per unit time is greater.

(D) ΔH of the reaction is lower.

19 The rate of reaction is the fastest in experiment .....

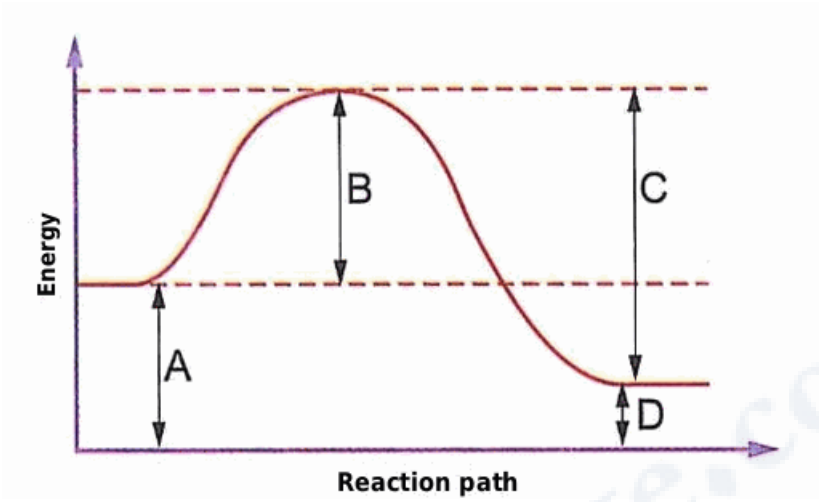


20 Which of the following graphs represents an exothermic reaction with a higher activation energy?



21 From the opposite energy diagram:

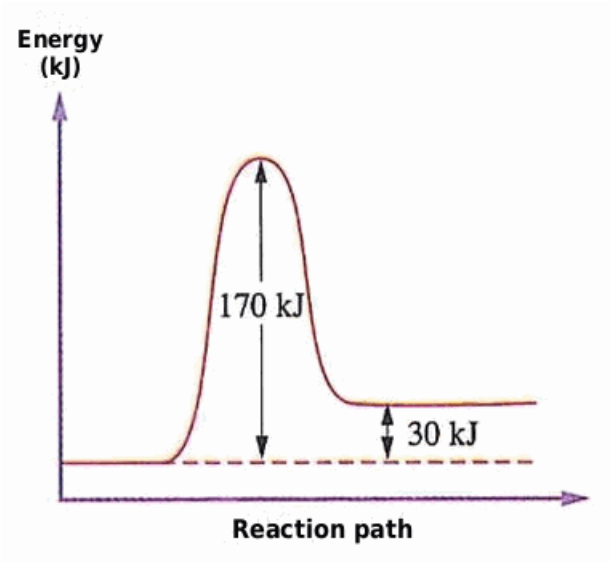
Which of the following represents the activation energy of each of the forward reaction (X) and the reverse reaction (Y)?



(A) (X) : A , (Y) : C (B) (X) : A , (Y) : D (C) (X) : B , (Y) : C (D) (X) : B , (Y) : D

22 The opposite energy diagram represents a chemical reaction.

What is the activation energy of its reverse reaction?



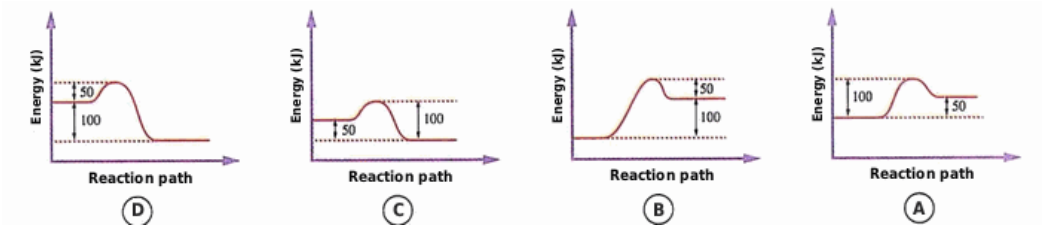
(A) 30 kJ (B) 140 kJ (C) 170 kJ (D) 200 kJ

23 A reversible chemical reaction has ΔH for its forward path = −150 kJ/mol and an activation energy of its reverse path = 350 kJ/mol

What is the activation energy of its forward path?

(A) +500 kJ/mol (B) +200 kJ/mol (C) +150 kJ/mol (D) −200 kJ/mol

24 Which figure represents the energy path of an exothermic reaction whose activation energy equals 50 kJ and whose ΔH equals −100 kJ?



25 In the opposite equilibrium reaction: $N_2O_4(g) + 58\ kJ \rightleftharpoons 2NO_2(g)$

What happens when the temperature of the system is lowered?

(A) $[NO_2]$ increases

(B) $[N_2O_4]$ decreases

(C) The intensity of the reddish-brown colour increases.

(D) The intensity of the reddish-brown colour decreases.

26 Which of the following represents the conditions that make an exothermic equilibrium reaction proceed in the direction of forming the products?
(lowering the temperature / removing one of the products)

(A) ✗ / ✓ (B) ✓ / ✓ (C) ✓ / ✗ (D) ✗ / ✗

---

27 A reversible reaction in a state of equilibrium proceeds in the reverse direction when the temperature is raised.
Which of the following describes the forward reaction?

(A) An exothermic reaction whose ΔH has a positive sign.
(B) An exothermic reaction whose ΔH has a negative sign.
(C) An endothermic reaction whose ΔH has a positive sign.
(D) An endothermic reaction whose ΔH has a negative sign.

---

28 In the equilibrium reaction: $SO_2Cl_2(g)$ + Energy ⇌ $SO_2(g)$ + $Cl_2(g)$
When the temperature is lowered, the system shifts to the .....

(A) left and $[SO_2Cl_2]$ increases.
(B) left and $[SO_2Cl_2]$ decreases.
(C) right and $[SO_2Cl_2]$ increases.
(D) right and $[SO_2Cl_2]$ decreases.

---

29 All of the following agree with Le Chatelier's principle, except .....
(type of reaction / change in temperature / effect on Kc of the reaction / the system shifts to the)

(A) endothermic / lowered / decreases / left
(B) endothermic / raised / increases / right
(C) exothermic / raised / increases / right
(D) exothermic / lowered / increases / right

---

30 In the reaction of preparing ammonia gas from its elements:
What is the effect of raising the temperature on the equilibrium system?

(A) The production of NH_3 gas decreases
(B) There is no change in the amount of NH_3 gas produced.
(C) The concentration of N_2 gas decreases
(D) There is no change in the amount of N_2 gas consumed.

---

31 In the opposite equilibrium reaction: $SO_3(g) \rightleftharpoons SO_2(g) + \frac{1}{2}O_2(g)$ $\Delta H^\circ = +43$ kJ

What is the effect of increasing the temperature of the equilibrium system?

(A) The rate of the forward reaction decreases, the rate of the reverse reaction increases and the equilibrium constant decreases.

(B) The rate of the forward reaction increases more than the rate of the reverse reaction, and the equilibrium constant does not change.

(C) The rate of the forward reaction increases more than the rate of the reverse reaction, and the equilibrium constant increases.

(D) Both the rate of the forward reaction and the rate of the reverse reaction decrease, and the equilibrium constant does not change.

---

32 Two experiments were carried out to determine the change in the value of Kc of reversible reactions with temperature, and the results were recorded in the following two tables:

Results (1) : at 25°C , Kc = 4×10^{-2} , at 127°C , Kc = 1.4 , at 227°C , Kc = 41

Results (2) : at 25°C , Kc = 4.2×10^{8} , at 127°C , Kc = 4.5×10^{4} , at 227°C , Kc = 62

Which of the following represents each of the two reactions (1) and (2)?

(A) $(1) : N_2O_4(g) \rightleftharpoons 2NO_2(g)$, $(2) : N_2H_4(g) \rightleftharpoons N_2(g) + 2H_2(g)$ $\Delta H = (-)$

(B) $(1) : N_2H_4(g) \rightleftharpoons N_2(g) + 2H_2(g)$ $\Delta H = (-)$, $(2) : N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

(C) $(1) : N_2O_4(g) \rightleftharpoons 2NO_2(g)$, $(2) : 2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$ $\Delta H = (+)$

(D) $(1) : N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$, $(2) : 2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$ $\Delta H = (+)$

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33 From the reversible reaction: $2H_2(g) + CO(g) \rightleftharpoons CH_3OH(v)$

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

(A) $Kp = (2P_H_2)^2 \times (P_CO) / (P_CH_3OH)$

(B) $Kp = (P_H_2)^2 \times (P_CO) / (P_CH_3OH)$

(C) $Kp = (P_CH_3OH) / ((P_H_2)^2 \times (P_CO))$

(D) $Kp = (P_CH_3OH) / ((2P_H_2)^2 \times (P_CO))$

---

34 In the equilibrium reaction: $2A(g) + B(g) \rightleftharpoons C(g)$ (at 392°C)

If the partial pressures of the reactants and products at equilibrium are as in the opposite table:

(A) : 6.7 atm , (B) : 10.1 atm , (C) : 3.6 atm

What is the approximate value of Kp for this reaction at equilibrium?

(A) 8×10^{-3} (B) 5.32×10^{-3} (C) 0.146 (D) 54.5

35 At the equilibrium of the reaction mixture: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ the partial pressure of N_2 gas was 18.75 pressure units, the partial pressure of H_2 gas was 2.5 pressure units, and the total pressure of the mixture was 25 pressure units. What is the value of Kp for this equilibrium system?

(A) 1.2×10^{-4} (B) 0.048 (C) 0.075 (D) 21

36 In the reaction of preparing ammonia gas from its elements, the partial pressures of nitrogen, hydrogen and ammonia at equilibrium were a , b and c respectively. Which of the following represents Kp for this reaction?

(A) $c^2 / (a^3b)$ (B) a^3b / c^2 (C) ab^3 / c^2 (D) $c^2 / (ab^3)$

37 Which of the following describes the following reaction: $2H_2(g) + O_2(g) \rightleftharpoons 2H_2O(v)$?

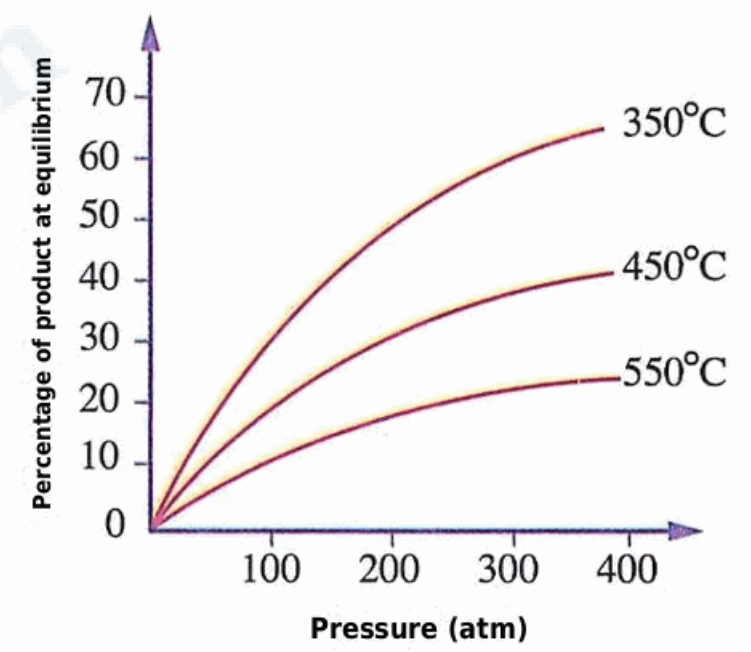
(A) All collisions between H_2 and O_2 molecules lead to the formation of H_2O

(B) The total pressure of the reaction equals the sum of the partial pressures of the gases H_2 , O_2 and H_2O at equilibrium.

(C) The rate of formation of H_2O equals the rate of consumption of O_2

(D) The value of Kp is constant when the temperature is raised.

38 The opposite graph shows the percentage of the product under different conditions for the forward direction of a reaction that is .....



(A) exothermic, and the number of moles of its products is less than the number of moles of the reactants.

(B) exothermic, and the number of moles of its products is greater than the number of moles of the reactants.

(C) endothermic, and the number of moles of its products is less than the number of moles of the reactants.

(D) endothermic, and the number of moles of its products is greater than the number of moles of the reactants.

---

39 In which of the following reactions does the product of the forward reaction increase by increasing the temperature and lowering the pressure?

(A) $CH_4(g) + H_2O(v) \rightleftharpoons 3H_2(g) + CO(g)$ $\Delta H = +206$ kJ

(B) $4NH_3(g) + 3O_2(g) \rightleftharpoons 2N_2(g) + 6H_2O(v)$ $\Delta H = -227$ kJ

(C) $2NO_2(g) \rightleftharpoons N_2O_4(g)$ $\Delta H = -58$ kJ

(D) $3O_2(g) \rightleftharpoons 2O_3(g)$ $\Delta H = +143$ kJ

---

40 Which of the following reactions is activated in the forward direction when the pressure is increased?

(A) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$
(B) $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$
(C) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$
(D) $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

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41 From the reaction: $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g) + Heat$
its speed can be increased by .....

(A) increasing the pressure.
(B) lowering the pressure.
(C) raising the temperature.
(D) lowering the temperature.

---

42 In the equilibrium process: $N_2O_4(g) + 58\ kJ \rightleftharpoons 2NO_2(g)$
the reaction shifts to the right when .....

(A) NO_2 is added
(B) N_2O_4 is removed
(C) the temperature is lowered.
(D) the volume of the system is increased.

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43 From the opposite equation: $2H_2O(v) \rightleftharpoons 2H_2(g) + O_2(g)\ \Delta H = +484\ kJ$
Which of the following leads to an increase in the volume of hydrogen gas produced?

(A) Raising the temperature.
(B) Lowering the temperature.
(C) Increasing the pressure.
(D) Adding more O_2 gas

---

44 Kp for the following equilibrium reaction: $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ (at 444°C , 1 atm) equals 50
What is the value of Kp for the same reaction (at 444°C , 2 atm)?

(A) 25 (B) 50 (C) 100 (D) 200

---

45 The compound PCl_5 decomposes in a closed vessel according to the equation: $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ Kp = 16
What is the value of Kp for this reaction when the volume of the reaction vessel is halved?

(A) 8 (B) 16 (C) 32 (D) 64

---

46 The opposite reversible reaction was carried out in a closed vessel at constant temperature:
$AX_3(g) + X_2(g) \rightleftharpoons AX_5(g)$
All of the following are correct when the system is at equilibrium, except .....

(A) The rate of formation of X_2 equals the rate of formation of AX_3

(B) Increasing the volume of the vessel leads to producing more AX_5

(C) Increasing the pressure leads to producing more AX_5

(D) The compound AX_3 remains present in the reaction space.

---

47 In the opposite equilibrium reaction the temperature was raised: $H_2(g) + I_2(v) \rightleftharpoons 2HI(g) - Heat$
What is the effect of that on the value of Kp of the reaction and on the position of equilibrium?

(A) The value of Kp decreases and the position of equilibrium shifts to the left.

(B) The value of Kp increases and the position of equilibrium shifts to the right.

(C) The value of Kp does not change and the position of equilibrium shifts to the left.

(D) The value of Kp decreases and the position of equilibrium does not change.

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48 The following reaction was carried out at normal atmospheric pressure: $X(g) + 3Y(g) \rightleftharpoons 2Z(g)$
At temperature T_1, Kp for the reaction was 2
At a higher temperature T_2, the partial pressures of the reactants and products at equilibrium were as in the opposite table: (X) : 2 atm , (Y) : 3 atm , (Z) : 5 atm
What is the value of Kp at temperature T_2, and what is the type of the forward reaction?

(A) 54/25 / endothermic.

(B) 54/25 / exothermic.

(C) 25/54 / endothermic.

(D) 25/54 / exothermic.

---

49 What role does the catalyst play in a chemical reaction?

(A) It increases the amount of the products.

(B) It decreases the activation energy needed for the reaction.

(C) It increases the kinetic energy of the molecules.

(D) It decreases the internal energy of the products.

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50 A catalyst is a chemical substance that .....

(A) increases the concentration of the products at equilibrium.

(B) changes the equilibrium constant of the chemical reaction.

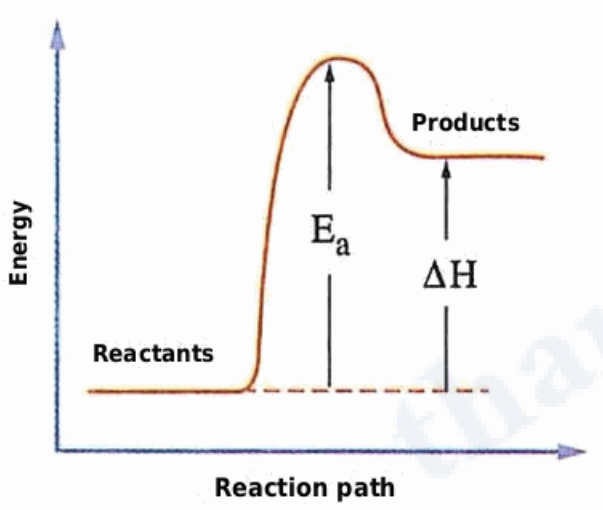
(C) decreases the time needed to reach the state of equilibrium.

(D) supplies the chemical reaction with energy.

---

51 The opposite energy diagram is for a chemical reaction.

What is the effect of adding a catalyst on the values of both the activation energy Ea and the enthalpy of the reaction ΔH?



(A) Ea : decreases , ΔH : decreases.

(B) Ea : decreases , ΔH : does not change.

(C) Ea : does not change , ΔH : decreases.

(D) Ea : decreases , ΔH : increases.

---

52 Adding vanadium pentoxide to the mixture of O_2 and SO_2 during the preparation of sulphuric acid leads to .....

(A) changing the path of the reaction while lowering the activation energy of the reaction.

(B) changing the path of the reaction while increasing the activation energy of the reaction.

(C) the reaction proceeding along the same path while increasing the activation energy of the reaction.

(D) the reaction proceeding along the same path while lowering the activation energy of the reaction.

---

53 Which of the following describes a catalyst?

(A) It changes the path of the reaction by increasing the activation energy.

(B) It increases the rate of reaction by lowering its value of ΔH.

(C) It increases the percentage of particles that have the minimum energy needed for the reaction.

(D) It changes the amount of the products at the end of the reaction.

---

54 The compound MnO_2 is used as a catalyst in the decomposition of hydrogen peroxide, and the rate of the reaction decreases with time, because .....

(A) MnO_2 is consumed.

(B) the reaction absorbs energy from the surroundings.

(C) the surface area of MnO_2 decreases.

(D) the hydrogen peroxide becomes dilute.

---

55 From the opposite reaction: $2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$

Which of the following represents the type of this reaction and where it takes place?

(A) Neutralization reaction / in the blast furnace.

(B) Oxidation-reduction reaction / in the catalytic converter.

(C) Neutralization reaction / in the catalytic converter.

(D) Oxidation-reduction reaction / in the blast furnace.

---

56 In the reversible reaction: $Cl(g) + O(g) + O_3(g) \rightleftharpoons 2O_2(g) + Cl(g)$

What is the catalyst used in this reaction, and what role does it play?

(A) O / increasing the rate of the forward reaction only.

(B) Cl / increasing the rate of the forward reaction only.

(C) O / increasing the rates of both the forward and reverse reactions.

(D) Cl / increasing the rates of both the forward and reverse reactions.

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57 A reaction takes place in two steps, as follows:

(1) $S_2O_8^{2-}(aq) + 2I^-(aq) + 2Fe^{2+}(aq) \rightarrow 2SO_4^{2-}(aq) + 2I^-(aq) + 2Fe^{3+}(aq)$

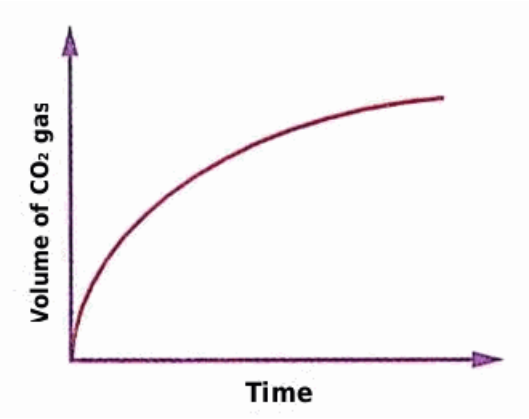
(2) $2SO_4^{2-}(aq) + 2I^-(aq) + 2Fe^{3+}(aq) \rightarrow 2SO_4^{2-}(aq) + I_2(aq) + 2Fe^{2+}(aq)$

Which ion acts as the catalyst in this reaction?

(A) $Fe^{2+}(aq)$ (B) $I^-(aq)$ (C) $SO_4^{2-}(aq)$ (D) $S_2O_8^{2-}(aq)$

58 The opposite graph represents the reaction of excess $CaCO_3$ with HCl acid

Which of the following represents the change in the rate of the reaction with time?



(A) It decreases, because the concentration of the acid decreases.

(B) It decreases, because the concentration of $CaCO_3$ decreases.

(C) It increases, because the temperature rises.

(D) It increases, because the CO_2 produced acts as a catalyst.

---

59 What is the effect of a catalyst on the activation energy of a reversible reaction?

(A) It decreases the activation energy of the forward reaction only.

(B) It decreases the activation energy of the reverse reaction only.

(C) It decreases the activation energy of both the forward and reverse reactions.

(D) It decreases the activation energy of the forward reaction and increases the activation energy of the reverse reaction.

---

60 When a suitable catalyst is added to hydrogen peroxide, it decomposes according to the following equation: $2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$

All of the following describe the rate of this reaction, except .....

(A) The rate of decomposition of H_2O_2 equals the rate of formation of H_2O

(B) Lowering $[H_2O_2]$ decreases the rate of formation of O_2

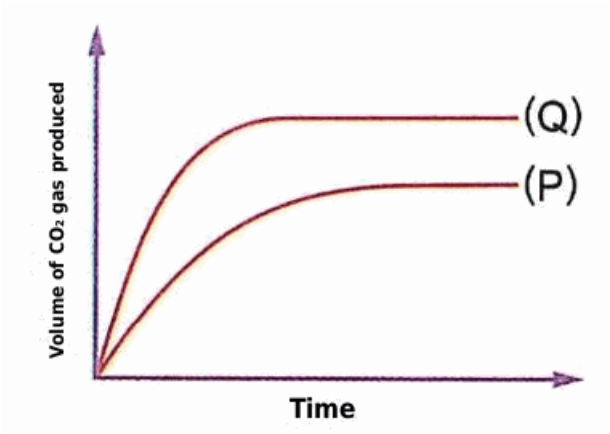
(C) Raising the temperature increases the rate of formation of O_2

(D) Increasing the amount of the catalyst decreases the rate of formation of O_2

---

61 Two experiments were carried out to measure the rate of the reaction of excess copper(II) carbonate with 20 mL of nitric acid, as shown in the opposite graph.

What change was made to the experiment represented by curve (P) that led to the results represented by curve (Q)?



(A) Using a catalyst.

(B) Adding more copper(II) carbonate.

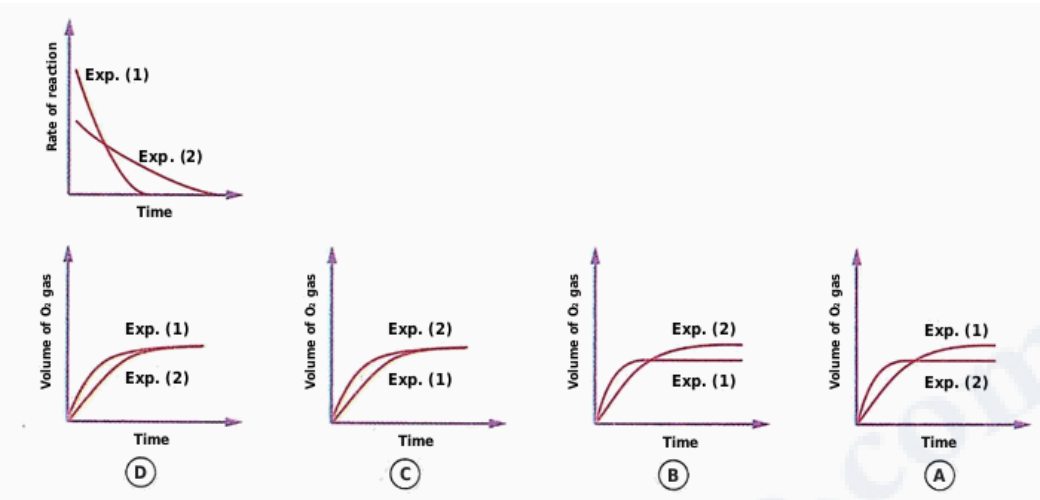
(C) Using 20 mL of nitric acid of a higher concentration.

(D) Raising the temperature.

---

62 Two experiments were carried out on the decomposition of 100 mL of 1 M hydrogen peroxide using two different catalysts, and the opposite graph shows the relation between the rate of reaction and time for each experiment.

Which of the following shows the relation between the volume of oxygen gas produced and time for each of the two experiments?



---

63 Which of the following shows the effect of adding a catalyst to a system in a state of dynamic equilibrium?

(the rate of the forward reaction increases by the same amount as the rate of the reverse reaction / no change happens in the concentration of any of the reactants or products / the value of Kc of the reaction increases)

(A) ✓ / ✓ / ✓ (B) ✓ / ✓ / ✗ (C) ✗ / ✓ / ✓ (D) ✓ / ✗ / ✗

64 The reaction of iron with steam in a closed vessel is a reversible reaction.

Which of the following leads to a change in the mass of iron in the equilibrium reaction?

(adding steam / increasing the pressure / adding a catalyst)

(A) ✓ / ✗ / ✓ (B) ✗ / ✓ / ✗ (C) ✓ / ✗ / ✗ (D) ✗ / ✓ / ✓

65 The following two equations represent one reaction under different conditions:

(1) $A + B \rightarrow (\Delta, \text{cat})\ 2D$

(2) $A + B \rightarrow (\Delta)\ 2D$

Which of the following describes reaction (2) compared with reaction (1)?

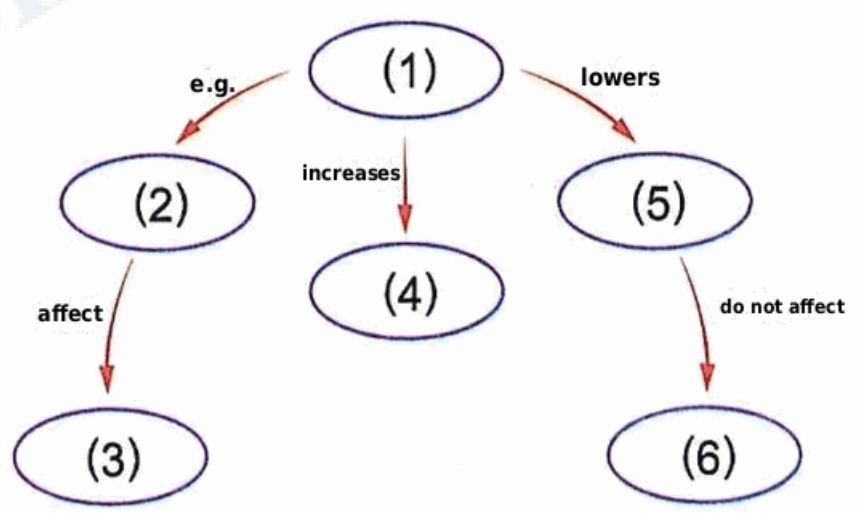
(A) It takes place at a lower temperature and its activation energy is lower.

(B) It takes place at a higher temperature and its activation energy is lower.

(C) It takes place at a higher temperature and its activation energy is greater.

(D) It takes place at a lower temperature and its activation energy is greater.

66 The following terms represent the numbers (1) to (6) in the opposite chart «not in order»:
(enzymes / rate of reaction / catalyst / position of equilibrium / biological reactions / activation energy)
Which of the following represents correct data?



(A) (1) : catalyst , (2) : enzymes , (4) : position of equilibrium.
(B) (3) : biological reactions , (5) : position of equilibrium , (6) : activation energy.
(C) (1) : catalyst , (3) : biological reactions , (6) : position of equilibrium.
(D) (2) : enzymes , (4) : activation energy , (5) : rate of reaction.

---

67 The solid substance (A) dissolves in water forming a solution that reacts instantly with NaCl(aq) forming a white precipitate, and it also reacts with the solution of substance (B) forming substance (C), which is used in the gelatinous layer of photographic films.
Which of the following is correct?

(A) (A) : $AgNO_3$, (B) : NaBr , (C) : AgBr
(B) (A) : AgCl , (B) : NaCl , (C) : AgCl
(C) (A) : $AgNO_3$, (B) : NaBr , (C) : AgCl
(D) (A) : AgCl , (B) : NaBr , (C) : AgBr

Essay questions — 13 questions

1 The opposite table shows the results of two experiments:

Experiment (1) : initial concentration $[NO_2]$ = 0.03 M , $[N_2O_4]$ = 0.5 M , concentration at equilibrium $[NO_2]$ = 0.0475 M , $[N_2O_4]$ = 0.491 M

Experiment (2) : initial concentration $[NO_2]$ = 0.04 M , $[N_2O_4]$ = 0.6 M , concentration at equilibrium $[NO_2]$ = 0.0523 M , $[N_2O_4]$ = 0.594 M

(1) Write the equation of the chemical reaction taking place, including the value of Kc

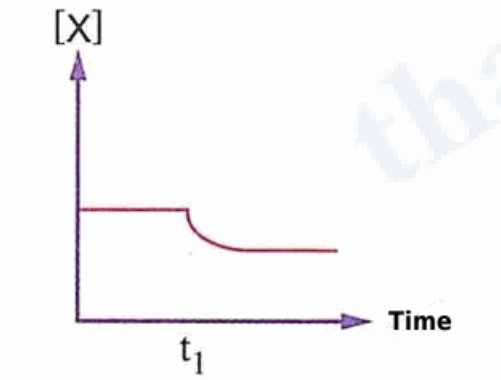
(2) Were the two experiments (1) and (2) carried out at the same temperature? Explain.

2 The opposite graph shows the change in [X] when the temperature of the following reaction is lowered starting from time t_1 :

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

(1) What is substance (X)? Explain.

(2) Is the reaction exothermic or endothermic? Explain.



3 Name three external factors that shift an exothermic gaseous equilibrium reaction in the direction of forming the reactants.

4 Calculate the partial pressure of each of $CO_2(g)$ and $H_2O(v)$ in the following equilibrium reaction:

$2NaHCO_3(s) \rightleftharpoons Na_2CO_3(s) + CO_2(g) + H_2O(v)$ Kp = 2.6×10^3

5 From the equilibrium reaction: $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$ $\Delta H = -124$ kJ/mol

(1) Explain the effect of increasing the pressure on this reaction.

(2) Explain the effect of lowering the temperature on this reaction.

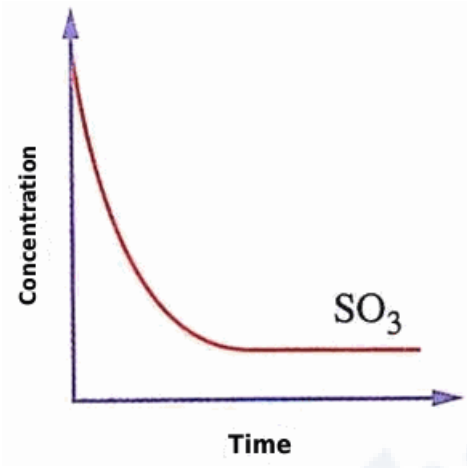
6 Ammonia gas is prepared in industry from its elements.

Suggest two different ways to increase the $[NH_3]$ produced without adding more reactants.

7 The position of equilibrium of the following reaction changes when the concentration of the reactants changes: $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

(1) Name two other factors that can affect the position of equilibrium of this reaction.

(2) How can you tell from the opposite graph that the reaction has reached the state of equilibrium?



8 In the opposite equilibrium reaction: $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

What is the effect of adding V_2O_5 on each of:

(1) the concentration of SO_3

(2) the value of Kc of the reaction.

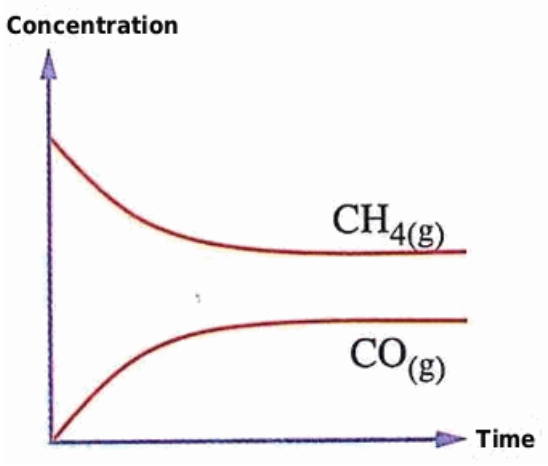
9 The opposite figure shows the change in [CO] and [CH_4] with time in the reaction:

$CH_4(g) + H_2O(v) \rightleftharpoons CO(g) + 3H_2(g)$ $\Delta H = +206$ kJ/mol

Draw on the opposite graph a curve that shows the change in:

(1) [H_2] with time.

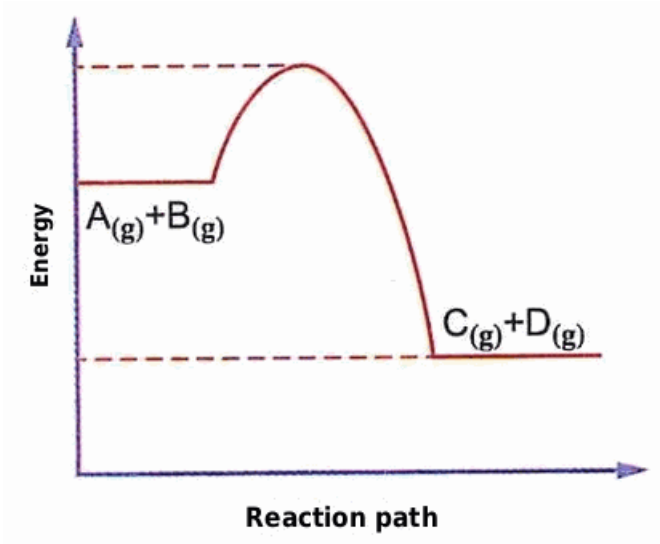
(2) [CO] only, when a suitable catalyst is used.



10 The opposite graph represents the forward reaction of a reversible reaction.

(1) Explain the change in the concentration of each of: (A) (A) when the temperature of the equilibrium reaction is raised. (B) (C) when the external pressure on the equilibrium reaction is increased.

(2) What is the effect of adding a catalyst to the reaction mixture on each of: (A) the activation energy of the reaction. (B) ΔH of the reaction.



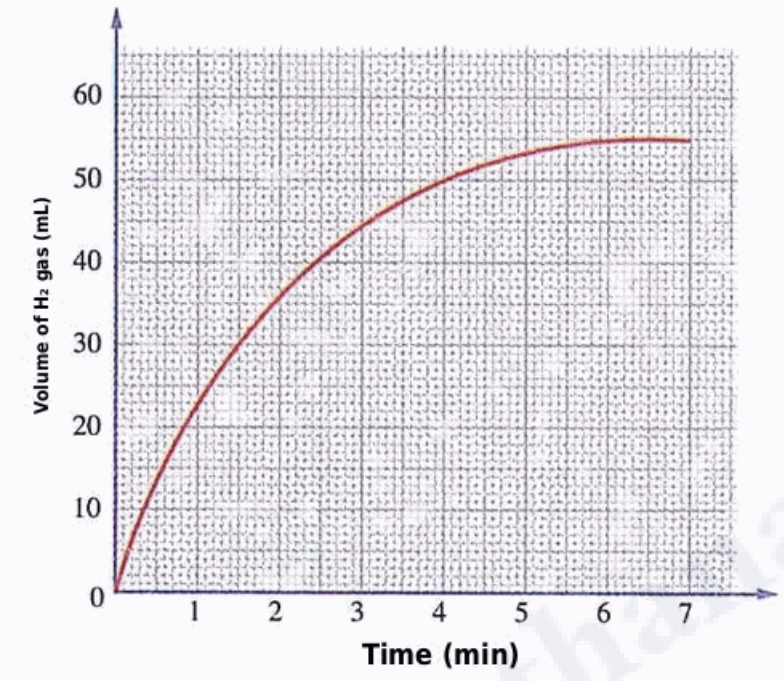
11 What are the two factors that do not change the position of equilibrium of the following reversible reaction? Explain:

$SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g) + Energy$

12 The opposite graph shows the volume of hydrogen gas given off from the reaction of zinc powder with excess hydrochloric acid:

(1) Why does the volume of gas stay constant 6 min after the start of the reaction?

(2) Draw on the same opposite graph a curve that shows the rate of reaction when the mixture of reactants is heated.



13 Explain the following in the light of the collision theory:

(1) A mixture of natural gas and air reacts at a high temperature, while an explosion happens in the same mixture at a lower temperature when a piece of platinum is added to it.

(2) A piece of coal does not react with oxygen at room temperature.

Past exam questions — 48 questions

1 In the following equilibrium reaction: $C(s) + CO_2(g) \rightleftharpoons 2CO(g)$

If the total pressure of this system at equilibrium is 40 atm and the partial pressure of carbon monoxide gas is 31.6 atm, then the value of Kp for this system equals .....

(A) 8.487 (B) 3.760 (C) 118.87 (D) 131.98

---

2 From the following equilibrium reaction: $2X_2(g) + Y_2(g) \rightleftharpoons 2X_2Y(g) - Heat$

Which of the following is correct regarding its effect on this reaction?

(A) Adding X_2 increases the concentration of the products and increases the amount of energy released.

(B) Adding Y_2 increases the concentration of the products and increases the amount of energy absorbed.

(C) Removing heat from the reaction space increases the value of the equilibrium constant.

(D) Increasing the heat in the reaction space decreases the value of the equilibrium constant.

---

3 Which of the following reactions is the fastest?

(A) A magnesium strip of mass 10 g with 25 mL of 0.2 M H_2SO_4 at room temperature.

(B) A magnesium strip of mass 5 g with 50 mL of 0.1 M H_2SO_4 at 35°C

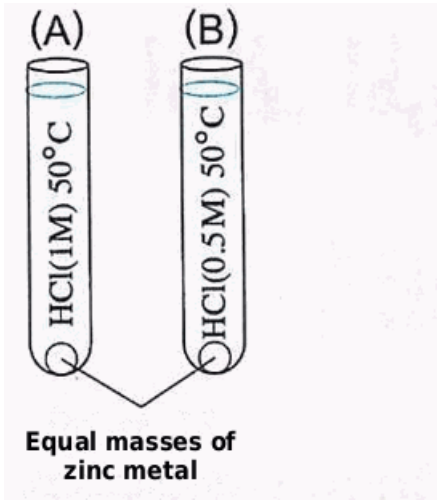
(C) Magnesium powder of mass 10 g with 50 mL of 0.1 M H_2SO_4 at room temperature.

(D) Magnesium powder of mass 5 g with 25 mL of 0.2 M H_2SO_4 at 35°C

---

4 Study the two tubes (A , B) in the shown figure:

Which of the following describes the result of the reaction in each of the two tubes?



(A) The rate of disappearance of the zinc piece in tube (A) is greater than its rate of disappearance in (B).

(B) The rate of disappearance of the zinc piece in tube (B) is greater than its rate of disappearance in (A).

(C) The amount of hydrogen gas produced in (B) is greater than in (A) when the zinc dissolves completely.

(D) The amount of hydrogen gas produced in (B) is less than in (A) when the zinc dissolves completely.

---

5 Which of the following expresses the effect of heat on a system in a state of equilibrium?

(A) Lowering the temperature decreases the value of Kc in exothermic reactions.

(B) Raising the temperature increases the value of Kc in exothermic reactions.

(C) Lowering the temperature decreases the value of Kc in endothermic reactions.

(D) Raising the temperature decreases the value of Kc in endothermic reactions.

---

6 In the following equilibrium system: $2H_2O(l) \rightleftharpoons 2H_2(g) + O_2(g)$, $\Delta H = +286$ kJ

Which of the following choices is correct when the temperature is lowered?

(A) The value of the equilibrium constant Kc increases and the rate of dissociation of water decreases.

(B) The value of the equilibrium constant Kc increases and the rate of formation of water decreases.

(C) The value of the equilibrium constant Kc decreases and the rate of dissociation of water decreases.

(D) The value of the equilibrium constant Kc decreases and the rate of formation of water decreases.

---

7 The following reaction is in a state of equilibrium at a certain temperature: $2HI(g) \rightleftharpoons H_2(g) + I_2(g)$

If the total pressure at equilibrium = 2 atm, and the partial pressure of each of H_2 and I_2 is: ($P_H_2 = P_I_2 = 0.4$ atm)

Which of the following represents the value of Kp when the volume of the vessel is halved?

(A) 0.05 (B) 0.11 (C) 0.25 (D) 0.40

---

8 In the following equilibrium reaction: $2NO_2(g) \rightleftharpoons N_2(g) + 2O_2(g)$

the total pressure at equilibrium is 3.2 atm, the partial pressure of NO_2 gas is 2 atm and the partial pressure of O_2 gas is 1 atm

Which of the following expresses the value of Kp for the reaction?

(A) 0.1 (B) 0.2 (C) 0.05 (D) 5

---

9 Which of the following expresses one of the reasons for using nickel as a catalyst in the hydrogenation of oils?

(A) It increases the surface area of the reactants.

(B) It decreases the chances of collision between the molecules of the reactants.

(C) The 4s and 3d electrons take part in increasing the concentration of the reactants on its surface.

(D) It increases the activation energy of the molecules of the reactants.

---

10 Which of the following does not express a reversible reaction?

(A) Preparing ammonia gas from its elements in a closed vessel.

(B) Adding acetic acid to ethyl alcohol.

(C) Adding magnesium sulphate solution to sodium carbonate solution.

(D) Adding iron(III) chloride solution to ammonium thiocyanate solution.

11 In which of the following equilibrium reactions is the equilibrium activated in the forward direction when the volume of the reaction vessel is increased?

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

(B) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

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

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

12 Two tubes (A , B) each contain equal masses of an active metal and the same acid. The reaction in tube (B) ended in less time than in (A).

Which of the following is a reason for the difference in the time of the two reactions?

(A) Dividing the metal into small pieces in tube (A).

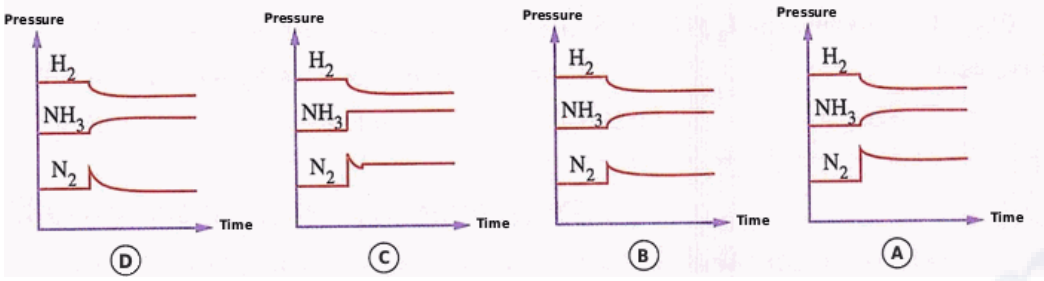
(B) Adding a catalyst to tube (A).

(C) Raising the temperature of tube (B).

(D) Adding water to tube (B).

13 Ammonia is prepared in industry by the Haber-Bosch reaction, according to the equation:
$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

Which of the following figures expresses the effect of increasing the partial pressure of nitrogen gas on the previous equilibrium?



14 According to the following equilibrium reaction: $COCl_2(g) \rightleftharpoons CO(g) + Cl_2(g)$

When an amount of $COCl_2(g)$ is placed in a closed vessel of volume 1 L, at equilibrium the pressure of $Cl_2(g)$ equals 0.3 atm and the total pressure at equilibrium equals 0.8 atm then the value of Kp equals .....

(A) 0.3 (B) 2.22 (C) 0.45 (D) 1.5

15 The following equation expresses a hypothetical reaction in a closed vessel at the state of equilibrium: $A(s) + B(l) \rightleftharpoons C(g) + D(g)$, $\Delta H = 84.3$ kJ

Which of the following factors decreases the number of moles of substance (C)?

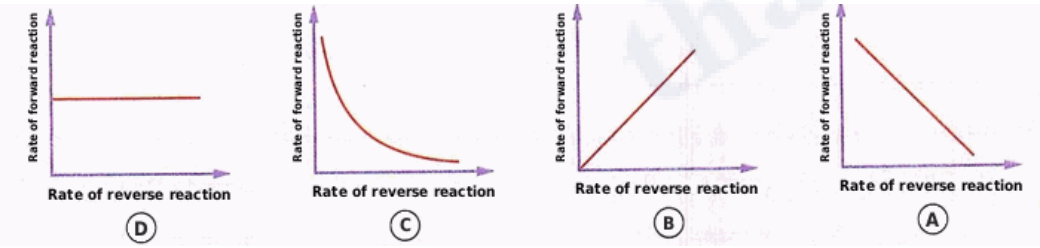
(A) Adding a little of substance (A) to the reaction medium.

(B) Removing a little of substance (D) from the reaction medium.

(C) Decreasing the volume of the vessel.

(D) Increasing the temperature.

16 Which of the following graphs expresses the effect of a catalyst on a reaction in a state of equilibrium?



17 When 0.2 mol of hydrazine gas is placed in a closed vessel of volume one litre, the equilibrium expressed by the following equation took place: $N_2H_4(g) \rightleftharpoons N_2(g) + 2H_2(g)$, $\Delta H < 0$

At equilibrium, the concentration of hydrogen gas was $[H_2] = 0.2$ M. When the temperature of the system is raised and the state of equilibrium is reached again, the concentration of nitrogen gas $[N_2]$ becomes .....

(A) 0.08 M (B) 0.20 M (C) 0.30 M (D) 0.10 M

18 The following equilibrium reaction is in a closed vessel: $ICl(g) + Cl_2(g) \rightleftharpoons ICl_3(g)$ (ICl : dark brown , ICl_3 : yellow)

When the vessel is placed in a basin of hot water, the colour of the mixture becomes dark brown.

Which of the following expresses the type of the reaction (exothermic or endothermic) and the change that leads to decreasing the intensity of the brown colour?

(A) Exothermic – decreasing the pressure.

(B) Endothermic – increasing the pressure.

(C) Exothermic – decreasing the volume of the vessel.

(D) Endothermic – increasing the volume of the vessel.

---

19 When light falls on a sensitive photographic film,

which of the following describes the chemical change taking place?

(A) Silver ions gain electrons from bromide ions.

(B) Bromide ions gain electrons from silver ions.

(C) Silver is oxidized to silver ions.

(D) Bromide ions are reduced to bromine.

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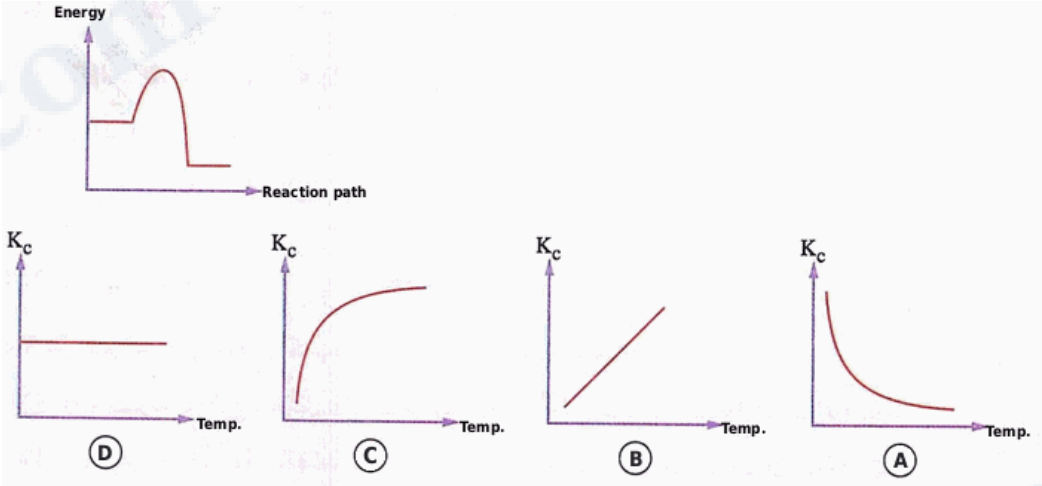
20 In the following equilibrium reaction: $2NO_2(g) \rightleftharpoons N_2O_4(g)$, Kp = 6.15

At equilibrium, the partial pressure of (NO_2) gas in the vessel was $(0.15$ atm), so the value of the partial pressure of (N_2O_4) gas equals .....

(A) 0.0225 atm (B) 0.1383 atm (C) 0.2767 atm (D) 0.9225 atm

---

21 The opposite figure shows the energy diagram of a reversible reaction at equilibrium:
Which of the following graphs expresses the relation between Kc and temperature for this reaction?



22 When equal masses of zinc react with excess hydrochloric acid,
which of the following choices expresses the reaction that produces the same volume of hydrogen gas in the least possible time (given that the masses of zinc are equal)?

(A) A zinc strip with an acid of concentration 0.1 M at 25°C
(B) Zinc powder with an acid of concentration 1 M at 50°C
(C) Zinc powder with an acid of concentration 0.1 M at 25°C
(D) A piece of zinc with an acid of concentration 1 M at 50°C

23 The following equilibrium reaction is in a closed vessel: $2A_2X(g) + XY_2(g) \rightleftharpoons 3X(s) + 2A_2Y(g)$, $\Delta H < 0$ (X(s) : yellow in colour)
Which of the following is correct?

(A) Adding more of substance (X) shifts the equilibrium in the reverse direction.
(B) When the vessel is placed in a cooling mixture, the partial pressure of XY_2 gas increases
(C) The mass of the precipitate increases as the pressure increases.
(D) The volume of A_2Y decreases when the volume of the vessel is decreased.

24 In the opposite equilibrium reaction: Heat + $2AB(g) \rightleftharpoons A_2(g) + B_2(g)$, $(Kc = 80)$
If you know that: $[A_2] = 2$ M , $[B_2] = 2$ M
Which of the following represents the possible [AB] when the temperature is raised?

(A) 0.500 M (B) 0.100 M (C) 0.223 M (D) 0.300 M

25 In the opposite equilibrium reaction: $A_2(g) + 3B_2(g) \rightleftharpoons 2AB_3(g)$, $\Delta H < 0$

Which of the following changes increases the rate of the reverse reaction?

(A) Lowering the pressure with cooling.

(B) Lowering the pressure with heating.

(C) Using a catalyst with cooling.

(D) Decreasing the volume of the vessel with heating.

---

26 In the opposite equilibrium reaction: $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

Which of the following expresses the role of vanadium pentoxide as a catalyst for this reaction?

(A) It increases the number of molecules that react on collision.

(B) It increases the activation energy of the reactants.

(C) It decreases the concentration of the products only.

(D) It increases the rate of decomposition of SO_3 only.

---

27 $N_2H_4(g) \rightleftharpoons N_2(g) + 2H_2(g)$, $\Delta H = (+)$

Which of the following choices is correct when the volume of the vessel is decreased?

(A) The partial pressure of hydrazine decreases.

(B) The partial pressure of hydrogen gas increases.

(C) The value of the equilibrium constant increases.

(D) The rate of dissociation of hydrazine decreases.

---

28 In the opposite reaction: $Cu(s) + 4HNO_3(l) \rightarrow^{(conc\ ,\ \Delta)} Cu(NO_3)_2(aq) + 2H_2O(l) + 2NO_2(g)$

Which of the following choices decreases the rate of the reaction?

(A) Increasing the temperature.

(B) Increasing the surface area of the reactants.

(C) Adding water to the reaction medium.

(D) Adding drops of $Cu(NO_3)_2$ solution

---

29 In the opposite reaction: $Zn(s) + 2HCl(aq) \rightarrow (dil.)\ ZnCl_2(aq) + H_2(g)$

The amount of hydrogen gas produced from the previous reaction per unit time can be increased by .....

(A) placing the vessel in a cooling mixture.

(B) adding a little water to the reaction medium.

(C) increasing the volume of the vessel.

(D) increasing the number of moles of HCl per unit volume.

---

30 In the opposite reaction: $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$

Which of the following factors increases the rate of the reaction?

(A) Grinding the magnesium.

(B) Decreasing the concentration of HCl(aq)

(C) Cooling.

(D) Increasing the volume of the reaction vessel.

---

31 When an active metal (X) reacts with a strong mineral acid (Y),

what modification can be made so that this reaction takes place in less time?

(A) Dividing the metal into small pieces.

(B) Decreasing the volume of the acid.

(C) Lowering the temperature of the reaction.

(D) Increasing the pressure.

---

32 In the opposite equilibrium reaction: $A_2(g) + B_2(g) \rightleftharpoons 2AB(g)$

If the rate of formation of AB gas (at 25°C) equals (3 L/sec), when the temperature of the reaction is raised to (45°C), the rate of formation of AB gas equals .....

(A) 12 L/sec (B) 6 L/sec (C) 5.4 L/sec (D) 9 L/sec

---

33 In the opposite reaction: $\frac{1}{2}N_2(g) + \frac{1}{2}O_2(g) + E \rightleftharpoons NO(g)$

The rate of decomposition of nitric oxide can be increased by .....

(A) removing nitrogen, and raising the temperature.

(B) adding oxygen, and increasing the pressure.

(C) removing nitrogen, and lowering the temperature.

(D) adding oxygen, and lowering the pressure.

34 In the opposite reaction: $H_2(g) + I_2(g) \rightleftharpoons 2HI(g) - Heat$

the value of Kc increases when .....

(A) the temperature is lowered.

(B) the concentration of H_2 gas is increased

(C) the concentration of H_2 gas is decreased

(D) the temperature is increased.

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35 In the equilibrium reaction: $2NO_2(g) \rightleftharpoons N_2O_4(g) + Heat$

the value of the equilibrium constant of this reaction changes with the change of .....

(A) pressure and the catalyst.

(B) temperature only.

(C) concentration and the catalyst.

(D) pressure only.

---

36 In the reaction: $H_2N - NH_2(g) \rightleftharpoons N_2(g) + 2H_2(g)$, $\Delta H = (-)$

the amount of hydrogen given off can be increased by .....

(A) increasing the temperature.

(B) increasing the volume of the vessel.

(C) adding more N_2 to the reaction medium.

(D) adding a catalyst to the reaction medium.

---

37 In the equilibrium reaction: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$, $\Delta H = -92$ kJ

the reaction shifts in the direction of forming ammonia gas when .....

(A) more nitrogen gas is added and the temperature is lowered.

(B) nitrogen gas is removed and the pressure is increased.

(C) more hydrogen gas is added and the temperature is raised.

(D) hydrogen gas is removed and the pressure is decreased.

---

38 In the following equilibrium reaction: $A_2(g) + 3B_2(g) \rightleftharpoons 2AB_3(g)$, $\Delta H < 0$

Which of the following factors leads to an increase in the rate of the forward reaction?

(A) Increasing the pressure and cooling.

(B) Increasing the pressure and the heat.

(C) Using a catalyst and cooling.

(D) Using a catalyst and increasing the volume of the vessel.

39 If the value of the equilibrium constant of the reaction: $H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$ is $Kc = 4.4 \times 10^{32}$

then the value of Kc of the reaction: $\frac{1}{2}H_2(g) + \frac{1}{2}Cl_2(g) \rightleftharpoons HCl(g)$ equals .....

(A) 2.2×10^{32} (B) 4.4×10^{32} (C) 2.1×10^{16} (D) 1.1×10^{16}

40 In the opposite equilibrium reaction: $N_2H_4(g) \rightleftharpoons N_2(g) + 2H_2(g) + Heat$, $Kc = 0.04$

If you know that: $[N_2H_4] = 0.1$ M , $[H_2] = 0.2$ M

then $[N_2]$ when the temperature is raised equals .....

(A) 0.08 M (B) 0.2 M (C) 0.3 M (D) 0.1 M

41 The following relation is used to calculate Kp for a reaction: $Kp = 1 / ([X_2]^2 [Y_2])$

Which of the following equations expresses this reaction?

(A) $2X_2(l) + Y_2(g) \rightleftharpoons 2X_2Y(g)$ (B) $2X_2(g) + Y_2(g) \rightleftharpoons 2X_2Y(l)$

(C) $2X_2(g) + Y_2(s) \rightleftharpoons 2X_2Y(aq)$ (D) $2X_2(g) + Y_2(s) \rightleftharpoons 2X_2Y(l)$

42 In the opposite reaction: $CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$

An amount of $CO(g)$ and $Cl_2(g)$ was placed in a flask, and at the state of equilibrium the pressure inside the flask was (1.2 atm). If you know that the partial pressures of the three gases are equal, then Kp equals .....

(A) 1 (B) 2.5 (C) 0.4 (D) 0.16

43 In the opposite equilibrium reaction: $Br_2(g) + H_2(g) \rightleftharpoons 2HBr(g)$

If the partial pressures of bromine, hydrogen and hydrogen bromide gases are 0.5 atm , 1 atm and 1.5 atm respectively,

then the equilibrium constant of the dissociation of hydrogen bromide into its elements equals .....

(A) 2.2 (B) 0.22 (C) 0.45 (D) 4.5

44 In the opposite reaction: $A(g) \rightleftharpoons 2B(g)$

When the partial pressures at equilibrium are as follows: A = 0.213 atm , B = 0.213 atm

then the value of the equilibrium constant of the reaction equals .....

(A) 0.213 (B) 4.69 (C) 0.426 (D) 0.1065

45 In the opposite equilibrium reaction: $2NO_2(g) \rightleftharpoons N_2O_4(g)$, $(Kp = 20)$
then the value of Kp for the dissociation of 2 mol of N_2O_4 equals .....

(A) 40 (B) 25×10^{-3} (C) 2.5×10^{-3} (D) 400

46 In the opposite reaction: $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$, $(Kp_1 = 0.013)$
then the value of Kp_2 of the reaction: $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ equals .....

(A) 76.92 (B) 67.29 (C) 61.79 (D) 82.6

47 In the opposite reaction: $2H_2O(l) + O_2(g) \rightleftharpoons 2H_2O_2(l)$, $(Kp = 0.2)$
then the value of the partial pressure of oxygen equals .....

(A) 0.2 atm (B) 0.02 atm (C) 5 atm (D) 0.5 atm

48 From the opposite reaction: $4NH_3(g) + 3O_2(g) \rightleftharpoons 2N_2(g) + 6H_2O(v)$, $(Kp = 15.47)$
If the partial pressures are: ammonia 1.5 atm , oxygen 1.16 atm , water vapour 2.4 atm
then the partial pressure of nitrogen equals .....

(A) 2.4 atm (B) 1.6 atm (C) 0.8 atm (D) 0.64 atm

Answer key and solutions

Multiple choice questions

1 D	2 B	3 C	4 B	5 C	6 D	7 A	8 A	9 D	10 B
11 A	12 D	13 C	14 A	15 D	16 A	17 A	18 C	19 C	20 C
21 C	22 B	23 B	24 D	25 D	26 B	27 B	28 A	29 C	30 A
31 C	32 A	33 C	34 A	35 B	36 D	37 B	38 A	39 A	40 D
41 C	42 D	43 A	44 B	45 B	46 B	47 B	48 D	49 B	50 C
51 B	52 A	53 C	54 D	55 B	56 D	57 A	58 A	59 C	60 D
61 C	62 D	63 B	64 C	65 C	66 C	67 A			

1 **Answer (D)**

Increasing the percentage of activated molecules increases the effective collisions, so the rate of reaction increases.

2 **Answer (B)**

When the temperature is raised, the energy of the reactant particles increases.

So the rate of their collisions increases.

3 **Answer (C)**

Kinetic energy increases as the temperature rises.

The highest temperature is 127°C, and the mass has no effect.

4 **Answer (B)**

Every rise of 10°C doubles the rate of reaction.

Rate = $3.2 \times 10^{-3} \times 2 = 6.4 \times 10^{-3}$ mol/s

5 **Answer (C)**

50°C = 5 × 10°C

The rate increases $2^5 = 32$ times.

6 **Answer (D)**

The greater the activation energy, the lower the rate of reaction.

Activation energy: $(1) = 20$, $(2) = 25$, $(3) = 15$ kJ/mol

Order from the slowest to the fastest: $(2) \rightarrow (1) \rightarrow (3)$

7 **Answer (A)**

Heating and grinding the metal increase the rate of reaction.

Adding water dilutes the acid, so the rate decreases.

8 **Answer (A)**

Adding distilled water dilutes the acid, so the rate decreases.

The other choices increase the rate of reaction.

9 **Answer (D)**

The activation energy of the forward reaction is greater than that of the reverse reaction, so the reaction is endothermic.

$\Delta H = 167 - 139 = +28$ kJ

10 **Answer (B)**

ΔH = activation energy of the forward reaction − activation energy of the reverse reaction

$20 = 50 -$ activation energy of the reverse reaction

Activation energy of the reverse reaction = 30 kJ

11 **Answer (A)**

The volume of the acid is the same, so the difference in the volume of gas is due to the difference in its concentration.

12 **Answer (D)**

The highest rate is at the highest concentration of the acid and the highest temperature.

It is the 1 M beaker at 50°C

13 **Answer (C)**

Iron does not react easily with concentrated nitric acid.

So the volume of gas produced in the first experiment is smaller.

The affecting factor is the concentration of the acid.

14 **Answer (A)**

From the graph, the rate increased from 2X to 8X, i.e. 4 times.

Doubling twice means a rise in temperature of 20°C

(B) = 40 + 20 = 60°C

15 **Answer (D)**

In (B) the concentration of OH^- decreases faster, so the rate of reaction is greater.

The greater rate is at the higher temperature.

16 **Answer (A)**

Curve (Y) is faster but its final volume of gas is smaller.

So the change is a smaller mass and a larger surface area.

That is 1 g of zinc powder at the same temperature.

17 **Answer (A)**

Number of moles of acid in the original experiment = 0.1 × 0.1 = 0.01 mol

Number of moles of acid when repeated = 0.2 × 0.1 = 0.02 mol

So the volume of gas doubles, and the rate increases because of the higher concentration and temperature.

18 **Answer (C)**

The powder has a larger surface area than the pieces.

So the number of reacting molecules per unit time increases.

19 **Answer (C)**

The fastest reaction is with the concentrated acid and the powder at the highest temperature.

20 **Answer (C)**

In an exothermic reaction the products have less energy than the reactants.

And the higher activation energy has the highest peak above the level of the reactants.

21 **Answer (C)**

The activation energy of the forward reaction is from the level of the reactants to the peak (B).

The activation energy of the reverse reaction is from the level of the products to the peak (C).

22 **Answer (B)**

Activation energy of the reverse reaction = activation energy of the forward reaction − ΔH

= 170 − 30 = 140 kJ

23 **Answer (B)**

Activation energy of the forward reaction = activation energy of the reverse reaction + ΔH

$= 350 + (-150) = 200$ kJ/mol

24 **Answer (D)**

The reaction is exothermic, so the level of the products is 100 kJ lower.

And the height of the peak above the reactants is 50 kJ

25 **Answer (D)**

The reaction is endothermic, so lowering the temperature shifts the equilibrium to the left.

So $[N_2O_4]$ increases and $[NO_2]$ decreases

And the intensity of the reddish-brown colour decreases.

26 **Answer (B)**

The reaction is exothermic, so lowering the temperature activates the forward direction.

And removing one of the products also activates the forward direction.

27 **Answer (B)**

The forward reaction is exothermic, so it is the one that decreases when the temperature is raised.

So its ΔH is negative.

28 **Answer (A)**

The forward reaction is endothermic.

Lowering the temperature shifts the equilibrium to the left, so $[SO_2Cl_2]$ increases

29 **Answer (C)**

In an exothermic reaction, raising the temperature activates the reverse direction.

So Kc decreases and the system shifts to the left.

30 **Answer (A)**

The reaction is exothermic, so raising the temperature shifts the equilibrium to the left.

So the production of NH_3 decreases

31 **Answer (C)**

The reaction is endothermic, so raising the temperature increases the rates of both reactions.

The forward one increases more, so Kc increases

32 **Answer (A)**

In reaction (1) Kc increases with temperature, so it is endothermic: $N_2O_4 \rightleftharpoons 2NO_2$

In reaction (2) Kc decreases with temperature, so it is exothermic: $N_2H_4 \rightleftharpoons N_2 + 2H_2$ $\Delta H = (-)$

33 **Answer (C)**

Kp = pressure of the products ÷ pressure of the reactants, each raised to the power of its coefficient.

$Kp = P_CH_3OH / ((P_H_2)^2 \times P_CO)$

34 **Answer (A)**

$Kp = P_C / ((P_A)^2 \times P_B)$

$Kp = 3.6 / ((6.7)^2 \times 10.1) = 7.9 \times 10^{-3} \approx 8 \times 10^{-3}$

35 **Answer (B)**

$P_NH_3 = 25 - 18.75 - 2.5 = 3.75$

$Kp = (3.75)^2 / (18.75 \times (2.5)^3) = 0.048$

36 **Answer (D)**

$Kp = (P_NH_3)^2 / (P_N_2 \times (P_H_2)^3)$

$Kp = c^2 / (a \times b^3)$

37 **Answer (B)**

The total pressure equals the sum of the partial pressures of the gases.

38 **Answer (A)**

The product increases when the temperature is lowered, so the reaction is exothermic.

And the product increases as the pressure increases, so the number of moles of the products is smaller.

39 **Answer (A)**

Increasing the temperature activates the forward reaction in an endothermic reaction.

And lowering the pressure activates the side with more moles of gas.

That is the first reaction.

40 **Answer (D)**

Increasing the pressure activates the side with fewer moles of gas.

$2SO_2 + O_2 \rightleftharpoons 2SO_3$: the number of moles of the reactants is 3 and of the products 2

41 **Answer (C)**

This reaction is not at equilibrium, and raising the temperature increases its speed.

Pressure has no effect because the reactants are not gases.

42 **Answer (D)**

Increasing the volume of the system lowers the pressure.

So the direction that forms a larger number of moles of gas is activated.

That is the forward direction.

43 **Answer (A)**

The forward reaction is endothermic.

Raising the temperature activates the forward direction, so H_2 increases

44 **Answer (B)**

Kp changes only when the temperature changes.

So its value stays 50

45 **Answer (B)**

Kp does not change with pressure or volume.

So its value stays 16

46 **Answer (B)**

Increasing the volume of the vessel lowers the pressure, so the side with more moles of gas is activated.

So the equilibrium shifts in the reverse direction and AX_5 decreases

47 **Answer (B)**

The equation is endothermic, so raising the temperature activates the forward direction.

So Kp increases and the equilibrium shifts to the right.

48 **Answer (D)**

$Kp = (P_Z)^2 / (P_X \times (P_Y)^3) = 25 / (2 \times 27) = 25/54$

Kp at T_2 (0.46) is less than Kp at T_1 (2), although the temperature increased.

So the forward reaction is exothermic.

49 **Answer (B)**

The catalyst decreases the activation energy needed for the reaction.

50 **Answer (C)**

The catalyst decreases the time needed to reach equilibrium.

And it does not change the concentration of the products at equilibrium.

51 **Answer (B)**

The catalyst decreases the activation energy.

And it does not change ΔH

52 **Answer (A)**

The catalyst changes the reaction path to an alternative path with a lower activation energy.

53 **Answer (C)**

The catalyst increases the percentage of particles that have the minimum energy needed for the reaction.

54 **Answer (D)**

The catalyst is not consumed.

The rate decreases because the concentration of hydrogen peroxide decreases with time.

55 **Answer (B)**

CO is oxidized and NO is reduced, so it is an oxidation-reduction reaction.

And it takes place in the catalytic converter of cars.

56 **Answer (D)**

Cl takes part in the reaction and then forms again, so it is the catalyst.

And it increases the rates of both the forward and reverse reactions.

57 **Answer (A)**

Fe^{2+} is consumed in the first step and forms again in the second step.

So it is the catalyst.

58 **Answer (A)**

The slope of the curve decreases with time, so the rate of reaction decreases.

That is because the concentration of the acid decreases (excess $CaCO_3$)

59 **Answer (C)**

The catalyst decreases the activation energy of both the forward and reverse reactions.

60 **Answer (D)**

Statement (D) is wrong.

Increasing the amount of the catalyst does not decrease the rate of formation of O_2; it increases it.

61 **Answer (C)**

Curve (Q) is faster and its volume of gas is larger.

The acid is the limiting substance of the reaction, and a more concentrated acid gives more gas at a greater rate.

62 **Answer (D)**

The rate of reaction of experiment (1) is greater, so it finishes in less time.

The amount of hydrogen peroxide is constant, so the final volume of O_2 is the same.

63 **Answer (B)**

The catalyst increases the rates of both the forward and reverse reactions by the same amount.

And it changes neither the concentrations at equilibrium nor the value of Kc

64 **Answer (C)**

$Fe + H_2O \rightleftharpoons Fe_3O_4 + H_2$

Adding steam changes the position of equilibrium, so the mass of iron changes.

Pressure has no effect because the numbers of moles of the gases are equal, and the catalyst does not affect the equilibrium.

65 **Answer (C)**

Reaction (2) is without a catalyst, so its activation energy is greater.

And it needs a higher temperature.

66 **Answer (C)**

(1) catalyst , (2) enzymes , (3) biological reactions.

(4) rate of reaction , (5) activation energy , (6) position of equilibrium.

67 **Answer (A)**

$AgNO_3$ reacts with NaCl forming a white precipitate of AgCl.

And it reacts with NaBr forming AgBr, which is used in photographic films.

Essay questions

1 **Model answer**

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

$Kc = [NO_2]^2 / [N_2O_4]$

Experiment (1) : $Kc = (0.0475)^2 / 0.491 = 4.6 \times 10^{-3}$

Experiment (2) : $Kc = (0.0523)^2 / 0.594 = 4.6 \times 10^{-3}$

(2) Yes, the two experiments were carried out at the same temperature, because the value of Kc is equal for both.

2 **Model answer**

(1) Substance (X) : $CO_2(g)$, because it is the only substance of the reaction whose concentration can change.

(2) The reaction is endothermic, because at t_1, lowering the temperature activates the reaction in the reverse direction and the concentration of substance (X) decreases.

3 **Model answer**

Raising the temperature.

Increasing the concentration of one of the products.

Removing one of the reactants from the reaction space.

4 **Model answer**

$Kp = (P_CO_2) \times (P_H_2O)$

The number of moles of CO_2 equals the number of moles of H_2O in the balanced equation.

$(P_CO_2) = (P_H_2O) = \sqrt{(2.6 \times 10^3)} = 50.99$ atm

5 **Model answer**

(1) The reaction is activated in the forward direction (the direction that forms the smaller number of moles of gases).

(2) The reaction is activated in the forward direction.

6 **Model answer**

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H = -92$ kJ

The first way : lowering the temperature of the equilibrium reaction.

The second way : increasing the pressure on the equilibrium reaction.

7 **Model answer**

(1) Temperature , pressure.

(2) When the concentration of SO_3 stays constant with time.

8 **Model answer**

(1) The concentration of SO_3 does not change

(2) The value of Kc of the reaction does not change.

9 **Model answer**

(1) The $[H_2]$ curve starts from zero and increases gradually until it becomes constant at equilibrium, and it is higher than the CO curve (three times the increase in [CO]).

(2) The [CO] curve rises faster and becomes constant at the same level (the same equilibrium concentration), because the catalyst does not change the position of equilibrium.

10 **Model answer**

(1) (A) [A] increases, because the reaction is activated in the reverse direction.

(B) [C] is not affected, because the number of moles of the reactants equals the number of moles of the products.

(2) (A) The activation energy of the reaction decreases.

(B) The value of ΔH of the reaction does not change.

11 **Model answer**

Pressure / because the number of moles of the reactants equals the number of moles of the products.

Catalyst / because it increases the rates of the forward and reverse reactions by the same amount.

12 **Model answer**

(1) Because the reaction ended when all the zinc powder was consumed.

(2) A curve with a steeper slope than the original curve (it reaches the maximum volume in less time) and it becomes constant at the same final volume (about 55 mL).

13 **Model answer**

(1) Because the piece of platinum acts as a catalyst that lowers the activation energy, so the collisions between the molecules lead to the reaction at a lower temperature, as the molecules reach the activation energy needed for the reaction.

(2) Because the kinetic energy of the molecules is less than the activation energy needed for the reaction when the molecules collide, so the chemical reaction does not take place.

Past exam questions

1 C	2 B	3 D	4 A	5 C	6 C	7 B	8 C	9 C	10 C
11 A	12 C	13 A	14 C	15 C	16 B	17 A	18 C	19 A	20 B
21 A	22 B	23 C	24 B	25 B	26 A	27 D	28 C	29 D	30 A
31 A	32 A	33 C	34 D	35 B	36 B	37 A	38 A	39 C	40 A
41 B	42 B	43 B	44 A	45 C	46 A	47 C	48 C		

1 **Answer (C)**

$P_CO_2 = 40 - 31.6 = 8.4$ atm

$Kp = (31.6)^2 / 8.4 = 118.87$

2 **Answer (B)**

The forward direction is endothermic.

Adding Y_2 activates the forward direction, so the product increases and the energy absorbed increases.

3 **Answer (D)**

The fastest is magnesium powder with the highest concentration of the acid and the highest temperature.

4 **Answer (A)**

The concentration of the acid in (A) is higher, so the zinc piece disappears faster.

The mass of zinc is the same, so the final volume of gas is the same.

5 **Answer (C)**

In an endothermic reaction, lowering the temperature decreases the value of Kc

6 **Answer (C)**

The reaction is endothermic, so lowering the temperature decreases the value of Kc

And the rates of both reactions decrease, including the dissociation of water.

7 **Answer (B)**

Kp does not change when the volume changes.

$P_HI = 2 - 0.8 = 1.2$ atm

$Kp = (0.4)^2 / (1.2)^2 = 0.11$

8 **Answer (C)**

$P_N_2 = 3.2 - 2 - 1 = 0.2$ atm

$Kp = 0.2 \times (1)^2 / (2)^2 = 0.05$

9 **Answer (C)**

The reactants are adsorbed on the surface of nickel by the 4s and 3d electrons.

So the concentration of the reactants on its surface increases.

10 **Answer (C)**

The reaction of magnesium sulphate with sodium carbonate forms a precipitate, so it is not reversible.

11 **Answer (A)**

Increasing the volume lowers the pressure, so the side with more moles of gas is activated.

$N_2O_4 \rightleftharpoons 2NO_2$: the forward direction.

12 **Answer (C)**

Raising the temperature of tube (B) increases the rate of reaction.

So the reaction ends in less time.

13 **Answer (A)**

Increasing the partial pressure of N_2 activates the forward direction.

So P_N_2 rises suddenly and then decreases gradually, P_H_2 decreases and P_NH_3 increases

14 **Answer (C)**

$P_CO = P_Cl_2 = 0.3$ atm

$P_COCl_2 = 0.8 - 0.6 = 0.2$ atm

$Kp = (0.3)^2 / 0.2 = 0.45$

15 **Answer (C)**

Increasing the pressure activates the side with fewer moles of gas, which is the reverse direction.

So the number of moles of C decreases

16 **Answer (B)**

The catalyst increases the rates of both the forward and reverse reactions by the same amount.

So the relation between them is direct, a straight line.

17 **Answer (A)**

At equilibrium $[N_2]$ = 0.1 M because $[H_2]$ = 0.2 M

The reaction is exothermic, so raising the temperature shifts the equilibrium to the left.

So $[N_2]$ becomes less than 0.1 M, i.e. 0.08 M

18 **Answer (C)**

On heating, the brown colour increases, so the equilibrium shifts to the left.

So the forward reaction is exothermic.

To decrease the brown colour, we shift the equilibrium to the right by decreasing the volume of the vessel.

19 **Answer (A)**

When light falls, silver ions gain electrons from bromide ions.

20 **Answer (B)**

$Kp = P_N_2O_4 / (P_NO_2)^2$

$P_N_2O_4 = 6.15 \times (0.15)^2 = 0.1383$ atm

21 **Answer (A)**

The level of the products is lower than that of the reactants, so the reaction is exothermic.

Raising the temperature decreases the value of Kc

22 **Answer (B)**

The fastest reaction is the powder with the highest concentration and the highest temperature.

23 **Answer (C)**

The number of moles of gas in the reactants is 3 and in the products 2

Increasing the pressure activates the forward direction, so the mass of the precipitate increases.

24 **Answer (B)**

$Kc = [A_2][B_2] / [AB]^2$

$80 = 4 / [AB]^2$

$[AB] = 0.223$ M

Raising the temperature (endothermic reaction) increases Kc, so [AB] becomes less than 0.223, i.e. 0.100 M

25 **Answer (B)**

26 **Answer (A)**

The catalyst decreases the activation energy.

So the number of molecules that react on collision increases.

27 **Answer (D)**

28 **Answer (C)**

Adding water decreases the concentration of the acid, so the rate of reaction decreases.

29 **Answer (D)**

Increasing the number of moles of HCl per unit volume increases the concentration.

So the amount of hydrogen produced per unit time increases.

30 **Answer (A)**

Grinding the magnesium increases its surface area, so the rate of reaction increases.

31 **Answer (A)**

Dividing the metal into small pieces increases its surface area, so the time of the reaction decreases.

32 **Answer (A)**

A rise of 20°C doubles the rate twice.

Rate = 3 × 2 × 2 = 12 L/sec

33 **Answer (C)**

34 **Answer (D)**

Kc changes only when the temperature changes.

The reaction is endothermic, so Kc increases as the temperature increases.

35 **Answer (B)**

The value of the equilibrium constant changes only with the change of temperature.

36 **Answer (B)**

The forward reaction increases the number of moles of gas.

Increasing the volume of the vessel activates this direction, so the hydrogen increases.

37 **Answer (A)**

The forward reaction is exothermic and the number of moles of the products is smaller.

Adding N_2 and lowering the temperature both activate the forward direction.

38 **Answer (A)**

39 **Answer (C)**

The new equation is half of the first equation.

The new Kc = $\sqrt{(4.4 \times 10^{32})} = 2.1 \times 10^{16}$

40 **Answer (A)**

$[N_2]$ = Kc $[N_2H_4] / [H_2]^2 = 0.04 \times 0.1 / (0.2)^2 = 0.1$ M

The reaction is exothermic, so raising the temperature shifts the equilibrium to the left.

So $[N_2]$ becomes less than 0.1 M, i.e. 0.08 M

41 **Answer (B)**

Kp does not contain the products, so they are liquid.

And the two reactants are both gases.

42 **Answer (B)**

The total pressure is 1.2 atm and the pressures are equal, so each of them is 0.4 atm

Kp = $0.4 / (0.4 \times 0.4) = 2.5$

43 **Answer (B)**

Kp of formation = $(1.5)^2 / (0.5 \times 1) = 4.5$

Dissociation constant = $1 \div 4.5 = 0.22$

44 **Answer (A)**

Kp = $(P_B)^2 / P_A = (0.213)^2 / 0.213 = 0.213$

45 **Answer (C)**

Dissociation is the reverse of formation, so for one mole Kp = 1 ÷ 20 = 0.05

For 2 mol (the equation multiplied by 2) : Kp = $(0.05)^2 = 2.5 \times 10^{-3}$

46 **Answer (A)**

The second reaction is the reverse of the first.

$Kp_2 = 1 \div 0.013 = 76.92$

47 **Answer (C)**

Kp = 1 / P_O_2 because the rest of the substances are liquids.

$P_O_2 = 1 \div 0.2 = 5$ atm

48 **Answer (C)**

$Kp = (P_N_2)^2 (P_H_2O)^6 / ((P_NH_3)^4 (P_O_2)^3)$

$15.47 = (P_N_2)^2 \times (2.4)^6 / ((1.5)^4 \times (1.16)^3)$

$P_N_2 = 0.8$ atm