CHEMISTRY

BOOKS - CENGAGE CHEMISTRY

REACTION KINETICS AND CHEMICAL EQUILIBRIUM

Work Example

1. Rate law for a recations is $r = k[A]^2[B]^2$. If the concentration of A is halved and that of B is doubled , calculate the rate of the reactions.

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2. Calculate the active mass of 10 g hydrogen in a 10 - L vessel.

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3. An equilibrium system for the reaction between H_2 and I_2 to give HI, in a 5L flask , contains 0.4 mol of H_2 0.4 mol of I_2 and 2.4 mol of HI. Calculate the equilibrium constant .

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4. Consider $N_2 + 3H_2 \Leftrightarrow 2NH_3$

At equilibrium , it was found there were 0.25 mol/L of H_2 and 0.06 mol /L of NH_3 . Calculate the equilibrium concentration of N_2 if $k = 6.0 \times 10^{-2}$.

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Mandatory Exercise Set I

1. How would you distinguish between reactants and products.

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2. (a) What do you mean by rate of reaction? How is it expressed mathematically?

(b) Write the rate expression for the following reaction in terms of reactants and products, applying law of mass action.

$2SO_2 + O_2 \Leftrightarrow 2SO_3$

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3. Discuss the effect of concentration and temperature on the rate of reaction.

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4. Which of the following influence the rate of reaction?

A. Nature of a reactant

B. Concentration of reactant

C. Temperature

D. All of these

Answer: D

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5. For the reaction $2NO + O_2 \rightarrow 2NO_2$, $\text{rate} = k[NO]^2[O_2]$. When the volume of the reaction vessel is doubled then the rate will be

A. eight times the initial rate

B. 1/8th of its initial rate

C. four times the initial rate

D. 1/4th of its initial rate

Answer: B

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6. For the reaction $2A + B \rightarrow C + D$ which is of second order with respect to A, the active mass of B is kept constant and that of A is tripled. The rate of reaction

A. decreases by 3 times

B. decreases by 9 times

C. increases by 9 times

D. increases by 6 times

Answer: C

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7. A catalyst affects the equilibrium state by

A. increasing the concentration of products at equilibrium

B. decreasing the value of equilibrium constant

C. increasing the concentration of reactants at equilibrium

D. decreasing the time required for the attainment of equilibrium

Answer: D

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8. Molar concentration of 96 g of O_2 (in mol L^{-1}) contained in 2-L vessel is

A. 16

B. 1.5

C. 4

D. 24

Answer: B

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9. Which of the following is true statement?

A. Concentration of reactant increases with time.

B. Concentration of reactant decreases with time.

C. Concentration of reactant may increase or decreases.

D. All of these

Answer: B

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10. In which case burning of coal take place at faster rate.

A. In powder form

B. In solid state

C. In solid state containing moisture.

D. All take place at equal rate

Answer: A

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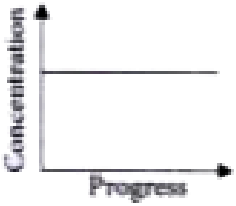
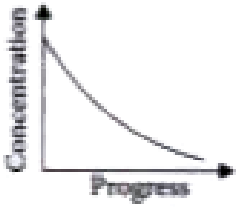
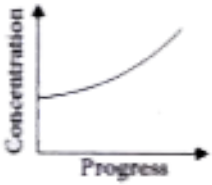
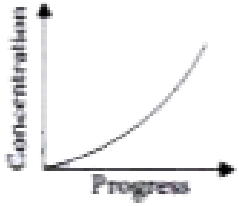
11. If reaction $x \rightarrow y$ starts with x only then which of the curve represent y (product)

A. 

B. 

C. 

D. 

Answer: D

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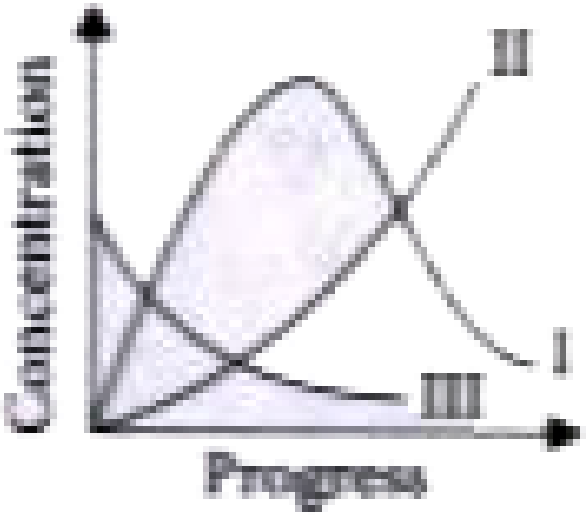
12. If reaction $x + y \Leftrightarrow z + w$ starts with x, y, z and w but net reaction proceeds in backward direction then which of the curve represent variation of concentration of z.



A. I

B. II

C. III

D. none

Answer: C

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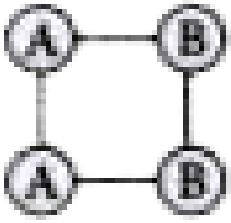
13. For the reaction $A_2(g) + B_2(g) \rightarrow 2AB(g)$

If reacting molecule have sufficient energy to cross energy barrier. i.e. reactant can converted into product. Then which collision yield maximum rate of reaction.

A. 

B. 

C. both

D. Independent of

Answer: B

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14. For differential rate law

$$\frac{+2dA}{dt} = \frac{-1}{3}\frac{dB}{dt} = \frac{+1}{4}\frac{dC}{dt} = \frac{-1}{2}\frac{dD}{dt}$$

Chemical reaction would be

A. $\frac{A}{2} + 3B \rightarrow 4C + 2D$

B. $3B + 2D \rightarrow \frac{A}{2} + 4C$

C. $2D + 3D \rightarrow 2A + 4C$

D. $2D + 3D \rightarrow 2A + 4C$

Answer: B

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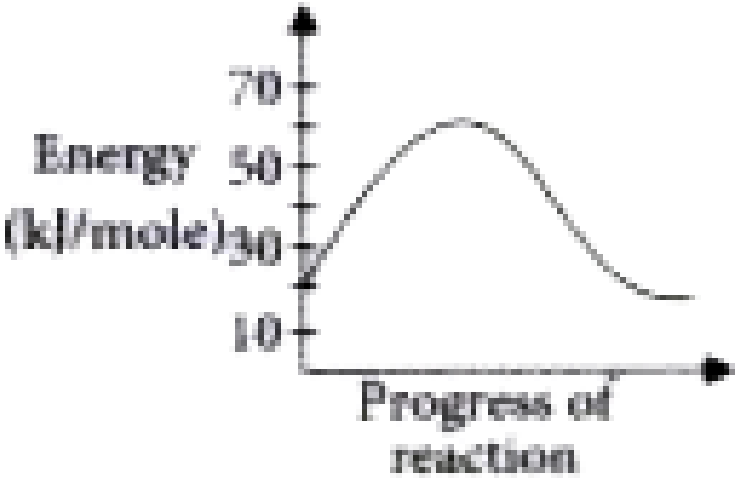
15. For the energy profile diagram



Threshold energy will be

A. 20 kJ/mole

B. 60 kJ/mole

C. 70 kJ/mole

D. 30 kJ/mole

Answer: B

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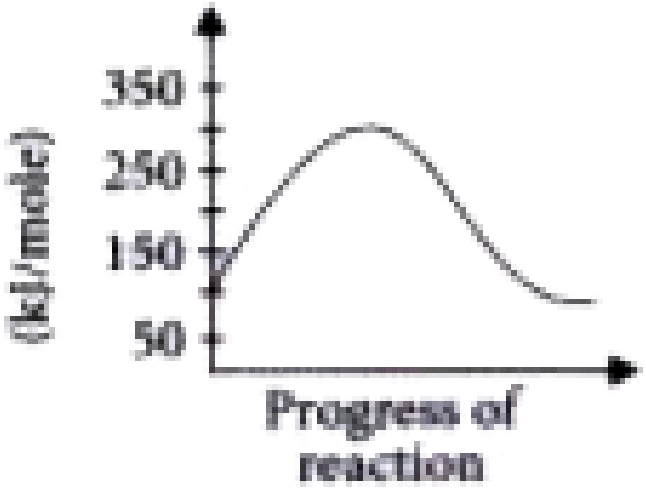
16. For the energy profile diagram



Heat of reaction will be

A. 100 kJ/mole

B. -100 kJ/mole

C. 50 kJ/mole

D. -50 kJ/mole

Answer: D

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17. n the synthesis of ammonia by Haber process, if 60 moles of ammonia is obtained in one hour, then the rate of disappearance of nitrogen is

A. 30 mole/min

B. 6 mole/min

C. 0.5 mole/min

D. 60 mole/min

Answer: C

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18. For the reaction $Cl_2 + 2I^{\Theta} \rightarrow I_2 + 2Cl^{\Theta}$ the initial concentration of I^- was 0.20 mole L^{-1} and the concentration after 20 min was 0.18 mole L^{-1}. Then the rate of formation of I_2 in mole $L^{-1}\min^{-1}$ would be

A. 1×10^4

B. 5×10^{-4}

C. 1×10^{-3}

D. 5×10^{-3}

Answer: B

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19. The reaction $2SO_2(g) + O_2(g) \Leftrightarrow 2SO_3(g)$ is carried out in a 1 dm^3 vessel and 2 dm^3 vessel separately. The ratio of the reaction velocities will be

A. $1:8$

B. $1:4$

C. $4:1$

D. $8:1$

Answer: A

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20. For a reaction between gaseous compounds. $2A + B \rightarrow C + D$. The reaction rate = K[A][B]. If the volume of the container is made 1/4 of the initial, then what will be the rate of reaction as compared to the initial rate?

A. 16 times

B. 4 times

C. 1/8 times

D. 1/16 times

Answer: A

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21. For a reaction between A and B, the initial rate of reaction is measured for various initial concentrations of A and B. The data provided are

S. no	[A]	[B]	Initial reaction rate
1.	0.20 M	0.30 M	5×10^{-5}
2.	0.10 M	0.10 M	5×10^{-5}
3.	0.40 M	0.05 M	1×10^{-4}

The overall order of the reaction is

A. one

B. two

C. two and half

D. three

Answer: A

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22. Given the hypothetical reaction mechanism $A \xrightarrow{I} B \xrightarrow{II} C \xrightarrow{III} D \xrightarrow{IV} E$ and the rate as

Reaction step	Rate
I	0.004 mole/h
II	0.060 mole/h
III	0.015 mole/h
IV	0.615 mole/h

Rate determining step is

A. step I

B. step II

C. step III

D. step IV

Answer: A

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23. A reaction involving A, B and C as reactants is found to obey the rate law,

$\text{rate} = K[A]^x[B]^y[C]^z$. When the concentrations of A, B and C are doubled separately, the rate is also found to increases two zero and four respectively. The overall order of the reaction is

A. 1

B. 2

C. 3

D. 4

Answer: C

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Mandatory Exercise Set Ii

1. How would you distinguish between

A. reversible and irreversible reactions

B. physical and chemical equilibria

C. static and dynamic equilibria

D. velocity constant and equilibrium constant

Answer:

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2. For the reaction $N_2O_4 \Leftrightarrow 2NO_2$, the concentrations of an equilibrium mixture at 293 K are: $[N_2O_4] = 4.50 \times 10^{-2}$ mol L^{-1} and $[NO_2] = 1.61 \times 10^{-2}$ mol L^{-1}. What is the value of equilibrium constant?

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3. The equilibrium constant for the dissociation of HI $(2HI \Leftrightarrow H_2 + I_2)$ is 25. What is the equilibrium constant for the formation of HI according to the reaction, $H_2 + I_2 \Leftrightarrow 2HI$?

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4. The rate constants of forward and backward reactions in a reversible reaction are 3.6×10^{-4} and 6.2×10^{-6}, respectively. Calculate the equilibrium constant of reaction.

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5. One mol each of nitrogen and oxygen are heated in a 2 dm^3 vessel. At equilibrium, one mol of nitric oxide is formed. Calculate the equilibrium constant for the reaction $N_2 + O_2 \Leftrightarrow 2NO$.

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6. How much PCl_3 must be added to a one litre vessel at 250° C in order to obtain a concentration of 0.1 mol dm^{-3} of chlorine after re establishment of equilibrium? K_c for the reaction $PCl_3 \Leftrightarrow PCl_3 + Cl_2$ is 0.044.

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7. How is the dynamic nature of equilibrium explained?

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8. Mention the conditions necessary to attain a state of equilibrium.

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9. (a) State the law of chemical equilibrium.

(b) Write the expressions for equilibrium constants

for the following pairs of reactions and establish the relation between them.

I. $H_2 + I_2 \Leftrightarrow 2HI$

$HI \Leftrightarrow \frac{1}{2}H_2 + \frac{1}{2}I_2$

II. $2NH_3 \Leftrightarrow N_2 + 3H_2$

$\frac{1}{2}N_2 + \frac{3}{2}H_2 \Leftrightarrow NH_3$

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10. At 448°C, the equilibrium constant for the reaction, $H_2 + I_2 \Leftrightarrow 2HI$ is 50.5. Predict the direction in which the reaction will proceed to reach equilibrium at 448°C, if we start with 2.0×10^2 mol

of HI, 1.0×10^2 mol of H_2 and 3.0×10^{-2} mol of I_2 in a 2-L container.

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11. An equilibrium mixture contains 6.4 g of sulphur dioxide, 9.6 g of oxygen and 24 g of sulphur trioxide in 1 L flask. Calculate the equilibrium constant for the reaction.

$2SO_2 + O_2 \Leftrightarrow 2SO_3$

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12. The rate constant of backward reaction is 2×10^{-6}. If the equilibrium constant is 4, calculate the rate constant of the forward reaction.

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13. $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$ is an irreversible reaction because

A. NaCl is soluble in water

B. $AgNO_3$ and $NaCl$ are completely ionized

C. AgCl is insoluble

D. None of these

Answer: C

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14. The unit of equilibrium constant for the reaction

$H_2 + I_2 \Leftrightarrow 2HI$ is

A. $mol^{-1}L$

B. $mol^{-2}L$

C. mol L^{-1}

D. None of these

Answer: D

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15. The equilibrium constant of a system is

A. temperature dependent

B. temperature independent

C. dependent on concentration of reactants

D. dependent on concentration of catalyst

Answer: A

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16. The equilibrium constant of the reaction $A + B \Leftrightarrow C + D$ is 10. If the rate constant of forward reaction is 203, the rate constant for backward reaction is

A. 20.3

B. 10.3

C. 2.03

D. 203

Answer: A

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17. 4 moles of A are mixed with 4 moles of B initially. At equilibrium, 2 moles of C are formed according to the reaction $A + B \Leftrightarrow C + D$. The equilibrium constant is

A. 4

B. 1

C. $\sqrt{2}$

D. $\sqrt{4}$

Answer: B

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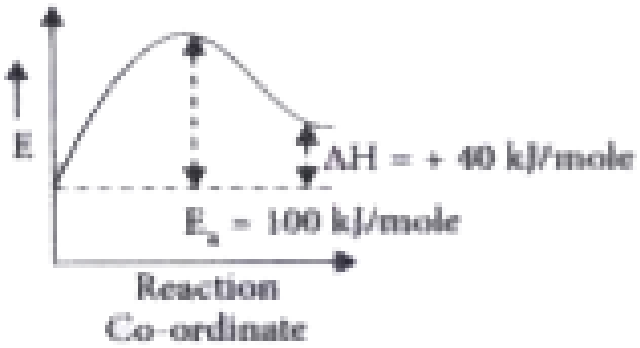
18. In the given graph the activation energy, E_a for the reverse reaction will be



Activation energy for the reverse reaction will be

A. 100 kJ/mole

B. 140 kJ/mole

C. 60 kJ/mole

D. 40 kJ/mole

Answer: C

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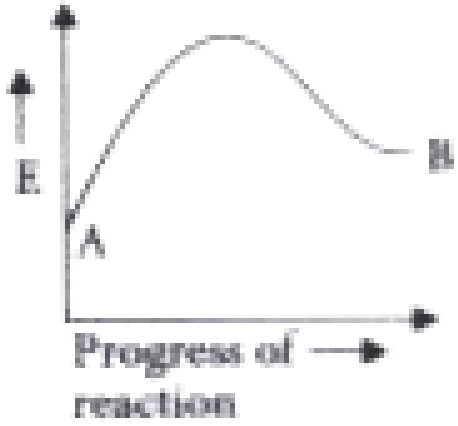
19. For a reversible reaction $A \Leftrightarrow B$ which one of the statements is wrong from the given energy profile



A. Activation energy of forward reaction is greater than backward reaction.

B. Forward reaction is endothermic.

C. The threshold energy is less than that of activation energy

D. The energy of activation of forward reaction is equal to the sum of heat of reaction and the energy of activation of backward reaction.

Answer: C

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20. A chemical reaction proceeds following formula rate $= p.z.e^{-E_a/RT}$. Which of the following process will increase the rate of reaction?

A. Lowering of E_a

B. Lowering of P

C. Lowering of z

D. Independent of all the above factor

Answer: A

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21. Consider an endothermic reaction $A \rightarrow B$ with the activation energies E_a and E_b for the forward and backward reactions respectively. In general

A. $E_a = E_b$

B. $E_a > E_b$

C. $E_a < E_b$

D. none

Answer: B

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22. Which of the following is reversible process

I. Dissociation of HCl in water

II. Dissociation of Ethyl alcohol in water

III. Dissociation of $CaCO_3(s)$ in open container

IV. Dissociation of $CaCO_3(s)$ in close container

A. I, II

B. II, IV

C. I, III

D. II, III

Answer: B

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23. Which of the following represent chemical equilibrium?

A. $Au(s) \Leftrightarrow Au(l)$

B. $H_2O(l) \Leftrightarrow H_2O(g)$

C. $N_2(g) + 3H_2(g) \Leftrightarrow 2NH_3(g)$

D. $Br_2(g) \Leftrightarrow Br_2(l)$

Answer: C

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24. Which of the following represent physical equilibrium?

A. $H_2(g) + Cl_2(g) \Leftrightarrow 2HCl(g)$

B. $CaCO_3(s) \Leftrightarrow CaO(s) + CO_2(g)$

C. $Ice(s) \Leftrightarrow$ liquid water.

D. $N_2O_4(g) \Leftrightarrow 2NO_2(g)$

Answer: C

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25. For the homogenous reaction

$4NH_3 + 5O_2 \Leftrightarrow 4NO + 6H_2O$ the equilibrium constant Kc has the units

A. $(\text{concentration})^{10}$

B. $(\text{concentration})^{+1}$

C. $(\text{concentration})^{-1}$

D. Dimension less

Answer: B

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26. A reaction chemical reaction is having two species in equilibrium. If the concentration of the both species are doubled then the equilibrium constant will

A. be doubled

B. becomes one fourth

C. be halved

D. Remain the same

Answer: D

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27. Which of the following is a wrong statement about equilibrium state?

A. Rate of forward reaction = rate of backward reaction

B. Equilibrium is dynamic

C. Catalysts increase value of equilibrium constant

D. Catalysts decreases time to acquire equilibrium state

Answer: C

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28. Which of the following is not a physical equilibrium?

A. $\text{Ice} \Leftrightarrow \text{water}$

B. $I_2(s) \Leftrightarrow I_2(g)$

C. $S(e) \Leftrightarrow S(g)$

D. $3O_2 \Leftrightarrow 2O_3$

Answer: D

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29. For an equilibrium reaction if the value of $K_c > > 1$, then the reaction favoured more towards

A. backward

B. forward

C. equilibrium will be obtained

D. reaction will stop

Answer: B

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30. For $PCl_5(g) \Leftrightarrow PCl_3(g) + Cl_2(g)$. Initial concentration of each reactant and product is 1 M. If $K_{ea} = 0.41$, then

A. more PCl_3 will form

B. more Cl_2 will form

C. more PCl_5 will form

D. no change

Answer: C

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31. The reaction $2SO_2(g) + O_2(g) \Leftrightarrow 2SO_3(g) + heat.$ The equilibrium reaction proceeds in forward direction by

A. addition of O_2

B. removal of O_2

C. Increase in temperature

D. decrease in pressure

Answer: A

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32. When pressure is applied to the equilibrium system Ice $\Leftrightarrow$ water. Which of the following phenomenon will happen?

A. more Ice will be formed

B. water will evaporate

C. more water will be formed

D. equilibrium will not be disturbed

Answer: C

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33. For the gaseous reaction $C_2H_4(g) + H_2(g) \Leftrightarrow C_2H_6(g), \Delta H = -130kJmol^{-1}$ carried in a closed vessel, the equilibrium

concentration of the C_2H_6 can definitely be increased by

A. Increasing temperature and decreasing pressure

B. Decreasing temperature and increasing pressure

C. Increasing temperature and pressure both

D. Decreasing temperature and pressure both

Answer: B

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Consolidated Exercise

1. State Le Chatelier's principle.

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2. The following reaction represents a gaseous system at equilibrium:

$2SO_{2(g)} + O_{2(g)} \Leftrightarrow 2SO_{3(g)} + heat$

Indicate the direction in which the equilibrium will shift when the following change are made:

(a) Temperature of the system is decreased

(b) Total pressure is decreased

(c) Volume of the container is increased

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3. What will be the effect of increased pressure on the following equilibria?

(a) $H_{2(g)} + I_{2(g)} \Leftrightarrow 2HI_g$

(b) $N_{2(g)} + 3H_{2(g)} \Leftrightarrow 2NH_{3(g)}$

(c) $2SO_{2(g)} + O_{2(g)} \Leftrightarrow 2SO_{3(g)}$

(d) $2O_{3(g)} \Leftrightarrow 3O_{2(g)}$

(e) $N_2O_4 \Leftrightarrow 2NO_{2(g)}$

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4. Match the following:

Column A	Column B
(1) Rate of a reaction	(a) Rate $= k[A]^2[B]^3$
(2) Molar concentration	(b) $K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$
(3) Law of mass action for $2A + 3B \rightarrow$ products	(c) $\frac{\text{Mass}}{\text{Gram molecular mass}} \times \frac{1}{\text{Volume}\,(dm^3)}$
(4) $N_2 + 3H_2 \rightleftharpoons 2NH_3$	(d) $\frac{\text{Mass}}{\text{Equilibrium mass}} \times \frac{1}{\text{Volume}\,(dm^3)}$
	(e) Rate $= \frac{\text{Change in concentration of reactants or products}}{\text{Time taken}}$

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Multiple Choice Questions With One Or More Than One Correct Answer

1. For the reaction $2N_2O_5 \rightarrow 4NO_2 + O_2$, the rate of the reaction can be given by

A. $\frac{d[N_2O_5]}{dt}$

B. $-\frac{1}{2}\frac{d[N_2O_5]}{dt}$

C. $+\frac{1}{4}\frac{d[NO_2]}{dt}$

D. $-\frac{4d[NO_2]}{dt}$

Answer: A::B::C::D

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2. Chemical equilibrium is characterised by

A. the concentration of each of the reactants and products being constant after the attainment of equilibrium

B. the rate of forward reaction being double the rate of backward reaction

C. chemical equilibrium being established when the gaseous products are allowed to escape

D. attainment of chemical equilibrium in either direction

Answer: A::D

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3. Which of the following statements is/are true for he equilibrium constant?

A. Equilibrium constant has constant value at a given temperature.

B. If $K > 1$, forward reaction is favoured at equilibrium.

C. Value of K depends upon the initial concentration of the reactants.

D. If $K < 1$, backward reaction is favoured at equilibrium.

Answer: A::B::D

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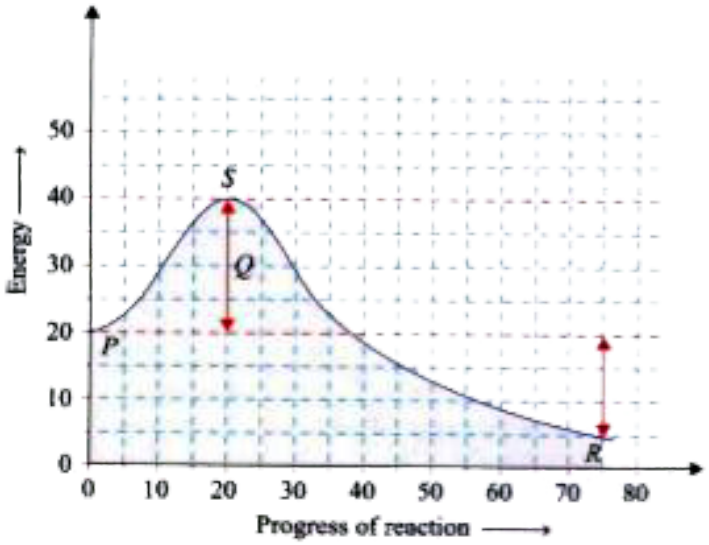
4. For a chemical reaction, a plot of energy versus the progress of reaction can be represented as shown in the figure.



The following are true:

A. $P = E_R$, Q = threshold energy

B. $P = E_R$, Q = activation energy

C. $R = E_p$, S = activation energy

D. $R = E_p$, S = threshold energy

Answer: A::B::D

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5. A catalyst

A. participates in the chemical reaction as oneof the reactants and so gets consumed.

B. may undergo a permanent chemical change during the reaction.

C. may undergo a physical change during the reaction.

D. in a small amount is sufficient to catalyse areaction.

Answer: A::C::D

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Challenging Exercise

1. One mol each of A and B are heated in a 2-dm^3 container. At equilibrium 0.5 mol of A was found to

remain in the equilibrium mixture. Calculate the equilibrium constant for the reaction

$A + B \rightarrow 2C + 3D$

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2. One mol of PCl_5 is heated in a 2-dm^3 container. At equilibrium, 40% of PCl_5 was dissociated. Calculate the equilibrium constant.

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3. $2A + B + C \rightarrow A_2B + C$

rate = k[A][B] with $k = 2.0 \times 10^{-6} mol^{-2} s^{-1}$

(a) Calculate the initial rate of the reaction when

[A] = 0.1 M [B] = 0.2 M [C] = 0.8 M

(b) Calculate the rate of reaction after [A] is reduced to 0.06 M.

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4. 2 mol of hydrogen iodide are heated in a 2-dm^3 container. At equilibrium 50% of hydrogen iodide is dissociated. Calculate the equilibrium constant for the reaction: $2HI \Leftrightarrow H_2 + I_2$

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5. 0.087 mol of NO and 0.0437 mol of Br_2 are mixed in a closed container at constant temperature. 0.0518 mol of NOBr is obtained at equilibrium. Calculate the equilibrium concentration of NO and Br_2 for the reaction: $2NO + Br_2 \Leftrightarrow 2NOBr$.

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Olympiad And Ntse Level Exercises

1.

Column I (Rate law)	Column II (Order)
(A) Rate = $k \times$ Intensity of light	(P) Second order
(B) Rate = $k\,[A]^1[B]^1$	(Q) Zero order
(C) Rate = $k\,[A]^{3/2}\,[B]^{1/2}$	(R) First order when A is in excess
(D) Rate = $k\,[A]^2[B]^1$	(S) Second order when B is in excess

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2. $A \rightarrow$ Product, $[A]_0 = 2M$. After 10 min reaction is 10% completed. If $\frac{d[A]}{dt} = k[A]$, then $t_{1/2}$ is approximately

A. 0.693 min

B. 69.3 min

C. 66.0 min

D. 0.0693 min

Answer: C

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3. The rate of a chemical reaction generally increases rapidly even for small temperature increase because of a rapid increase in

A. Collision frequency

B. Fraction of molecules with energies in excess of the activation energy

C. Activation energy

D. Average kinetic energy of molecules

Answer: B

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4. Select the law that corresponds to data shown for the following reaction $A + B \rightarrow$ Products

Exp	$[A]$	$[B]$	Initial rate
1	0.012	0.035	0.1
2	0.024	0.070	0.8
3	0.024	0.035	0.1
4	0.012	0.070	0.8

A. $\text{Rate} = k[B]^3$

B. $\text{Rate} = k[B]^4$

C. $\text{Rate} = k[A][B]^3$

D. $\text{Rate} = k[A]^2[B]^2$

Answer: A

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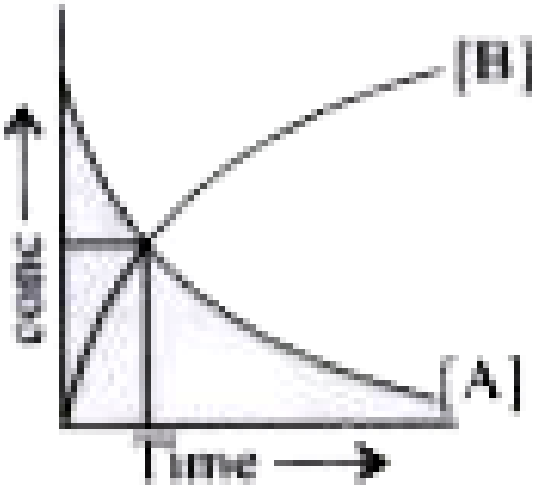
5. The accompanying figure depicts a change in concentration of species A and B for the reaction $A \rightarrow B$, as a function of time. The point of inter section of the two curves represents



A. $t_{1/2}$

B. $t_{3/4}$

C. $t_{2/3}$

D. Data insufficient to predict

Answer: A

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6. The rate equation for the reaction $2A + B \rightarrow C$ is found to be: rate = k[A][B]. The correct statement in relation of this reaction is that

A. The value of k is independent of the initial concentration of A and B.

B. $t_{1/2}$ is a constant.

C. The rate of formation of C is twice the rate of disappearance of A.

D. The unit of k must be s^{-1}.

Answer: A

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7. The activation energy for a simple chemicalreaction $A \rightarrow B$ is E_a in the forward reaction. The activation energy of the reverse reaction

A. Is negative of E_a

B. Is always less than E_a

C. Can be less than or more than E_a

D. Is always double of E_a

Answer: C

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8. Collision theory is applicable to

A. First order reactions

B. Zero order reactions

C. Bimolecular reactions

D. Intermolecular reactions

Answer: C

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9. Given the following two mechanisms, one with catalyst and the other without catalyst.

(i) $A + B \rightarrow C$ (slow)

(ii) $C + B \rightarrow F + A$ (fast)

(iii) $B + B \rightarrow F$ (slow)

Which mechanism uses the catalyst and what is it?

A. Step (i), A

B. Step (ii), B

C. (c) Step (iii), F

D. Steps (i) and (ii), C

Answer: A

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10. Burning of coal is represented as $C(s) + O_2(g) \rightarrow CO_2(g)$. The rate of this reaction is increased by

A. Decrease in the concentration of oxygen

B. Powdering the lumps of coal

C. Decreasing the temperature of coal

D. Providing inert atmosphere

Answer: B

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