Arrhenius Equation Chemistry Questions with Solutions

Q1: Temperature dependence of reaction rates can be studied by plotting a graph between ___________

a) Concentration of reactants and temperature
b) Concentration of products and temperature
c) Rate constant and temperature
d) Rate of catalysis and temperature

Answer: c) Rate constant and temperature

Explanation: Plotting a graph between rate constant and temperature for various reactions can demonstrate the temperature dependence of reaction rates.

Q2: According to Arrhenius equation, rate constant(k) is proportional to ___________
a) Activation Energy (E)
b) e^{E}
c) $e^{1/E}$
d) e^{-E}

Answer: d) e^{-E}

Explanation: According to the Arrhenius equation, $k = Ae^{-Ea/RT}$. So, rate constant(k) is proportional to e^{-E}.

Q3: Which of the following methods is satisfactory only for a simple homogeneous reaction?
a) Half life period method
b) Integration method
c) Graphical method
d) Ostwald's isolation method

Answer: b) Integration method

Explanation: Integration method is suitable only for simple homogeneous reactions and results in wrong conclusions for complex reactions.

Q4: Which of the following methods is used to determine the order of the reaction in which two or more reactants take part?
a) Integration method
b) Half life period method
c) Ostwald's isolation method
d) Graphical method

Answer: c) Ostwald's isolation method

Explanation: Ostwald's isolation technique is used to estimate the order of the reaction in which two or more reactants participate. The reaction order for interfacial charge recombination was determined due to the discovery of kinetic isolation conditions.

Q5: How does the half life period of a first order reaction vary with temperature?
a) It increases
b) It decreases
c) It remains the same
d) Both increases as well as decrease

Answer: a) It increases

Explanation: The rate constant is directly proportional to the half-life period of a first order reaction. As a result, as the temperature rises, it rises.

Q6: A reaction is of second order with respect to a reactant. How will the rate of reaction be affected if the concentration of this reactant is
(i) doubled, (ii) reduced to half?

Answer:

(i) If [A] = 2a then Rate = $K (2a)^2 = 4 Ka^2$
∴ Rate of reaction becomes 4 times

(ii) If [A] = a/2 then Rate = $K (a/2)^2 = Ka^2/4$
∴ Rate of reaction will be $1/4^{th}$.

Q7: The activation energy of a chemical reaction is 100 kJ/mol and its A factor is 10 $M^{-1}s^{-1}$. Find the rate constant of this equation at a temperature of 300 K.

Answer:

Given,

Ea = 100 $kJ.mol^{-1}$ = 100000 $J.mol^{-1}$

A = 10 $M^{-1}s^{-1}$, ln(A) = 2.3 (approx.)

T = 300 K

The rate constant can be calculated using the Arrhenius equation's logarithmic form, which is:

In k = In(A) – (E_a/RT)

In k = 2.3 – (100000 J.mol^{-1})/(8.314 J.mol^{-1}.K^{-1})*(300K)

In k = 2.3 – 40.1

In k = −37.8

k = 3.8341*10^{-17} M^{-1}s^{-1} (It is clear from the units of the 'A' factor that the reaction is a second-order reaction, with M^{-1}s^{-1} as the unit of k)

Therefore, the value of the rate constant for the reaction at a temperature of 300K is approximately **3.8341*10^{-17} M^{-1}s^{-1}**.

Q8: Write Arrhenius equation. Derive an expression for temperature variations.

Answer:

Arrhenius equation is ***K = A e$^{-Ea/RT}$***

K = Rate constant, A = Pre-exponential factor
E_a= Activities energy, T = Temp. (Kelvin)
R = Gas constant.

The logarithmic form of the Arrhenius equation for a chemical reaction at two different temperatures **T_1** and **T_2**, with corresponding rate constants **K_1** and **K_2**, is:

In K_1 = In(A) – E_a/RT_1

In K_2 = In(A) – E_a/RT_2

The second equation can be rearranged to get the value of In(A):

In(A) = In(K_2) + E_a/RT_2

Substituting the value of In(A) in the equation for In(K_1), the following equations can be obtained:

In(K_1) = In(K_2) + E_a/RT_2 – E_a/RT_1

Shifting In(K_2) to the LHS, the value of In(K_1) – In(K_2) becomes:

$\ln(K_1) – \ln(K_2) = E_a/RT_2 – E_a/RT_1$

The LHS of the equation is of the form ln(x) – ln(y), which can be simplified to ln(x/y). In addition, the term '**Ea/R**' is a common factor in both RHS terms. As a result, the complete equation can be reduced to the following:

$$ln(\frac{k_1}{k_2}) = \frac{-E_a}{R}(\frac{1}{T_1} - \frac{1}{T_2})$$

Q9: Give the significance of Arrhenius Equation.

Answer:

- This equation allows for the accounting of elements that influence the rate of reaction but cannot be determined using the rate law.
- The equation aids in determining the impact of the energy barrier, frequency, temperature, collision orientation, and catalyst presence.

Q10: At a temperature of 600 K, the rate constant of a chemical reaction is $2.75*10^{-8}$ $M^{-1}s^{-1}$. When the temperature is increased to 800K, the rate constant for the same reaction is $1.95*10^{-7}M^{-1}s^{-1}$. What is the activation energy of this reaction?

Answer:

Given,

$T_1 = 600K$

$k_1 = 2.75*10^{-8}\ M^{-1}s^{-1}$.

$T_2 = 800K$

$K_2 = 1.95*10^{-7}M^{-1}s^{-1}$

The following equation is obtained when the A factor is eliminated from the Arrhenius equation:
$\ln(k_1/k_2) = (-E_a/R)(1/T_1 – 1/T_2)$

Substituting the given values in the equation, the value of E_a can be determined:

$\ln(2.75*10^{-8}/1.95*10^{-7}) = (-E_a/8.314\ J.K^{-1}.mol^{-1})*(0.00041K^{-1})$

$\ln(0.141) = (E_a)*(-0.0000493)\ J^{-1}.mol$

$E_a = (-1.958)/(-0.0000493) J.mol^{-1} = 39716\ J.mol^{-1}$

The activation energy of the reaction is approximately **39716 J.mol^{-1}**.

Q11: Define the following:
(i) Elementary step in a reaction
(ii) Rate of a reaction

Answer:

(i) Elementary step in a reaction: The reactions that occur in a single step are referred to as elementary reactions.

Example : Reaction between H_2, and I_2 to form 2HI
$H_2 + I_2 \rightarrow 2HI$

(ii) Rate of a reaction: The rate of reaction is defined as the change in concentration of any of the reactants or products per unit time.

Q12: Mention the factors that affect the rate of a chemical reaction.

Answer:

The factors that affect the rate of a chemical reaction are:
- Concentration of reactants
- Temperature
- Presence of catalysts
- Exposure to light (Radiation)
- Nature of reactants and products

Q13: A reaction is first order in A and second order in B :
(i) Write a differential rate equation.
(ii) How is the rate affected when the concentration of B is tripled?
(iii) How is the rate affected when the concentration of both A and B is doubled?

Answer:

(i) Differential rate equation for the reaction is: ***rate (r) = k*** $[A]^1 [B]^2$

(ii) Differential rate equation for the reaction is: ***rate (r') = k*** $[A]^1 [3B]^2$

$$r'/r = (k [A]^1 [3B]^2)/(k [A]^1 [B]^2) = 9 \text{ or } r' = 9r$$

Thus, the reaction rate will increase to **9** times.

(iii) Differential rate equation for the reaction is:

$$\textit{rate } (r'') = k\,[2A]^1\, 2[B]^2 \;;\; r''/r = (k\,[2A]^1\, 2[B]^2)/(k\,[A]^1\,[B]^2) = 8 \text{ or } r'' = 8r$$

Thus, the reaction rate will increase to **8** times.

Q14: In Arrhenius equation, $k = A\,e^{-Ea/RT}$. 'A' may be termed as the rate constant at very high temperature and at zero activation energy. Explain.

Answer:

All predictive formulas used to calculate reaction-rate constants are based on the Arrhenius equation, which describes the effect of temperature on the velocity of a chemical reaction. The reaction-rate constant is k, the numerical constants A and E are distinctive of the reacting elements, R is the thermodynamic gas constant, and T is the absolute temperature in the Arrhenius equation.

Arrhenius equation $k = A\,e^{-Ea/RT}$

As a result, when $T \rightarrow \infty$; k = A, the rate constant equals the frequency factor.
When the reaction's activation energy is zero, k = A, the rate becomes temperature independent.

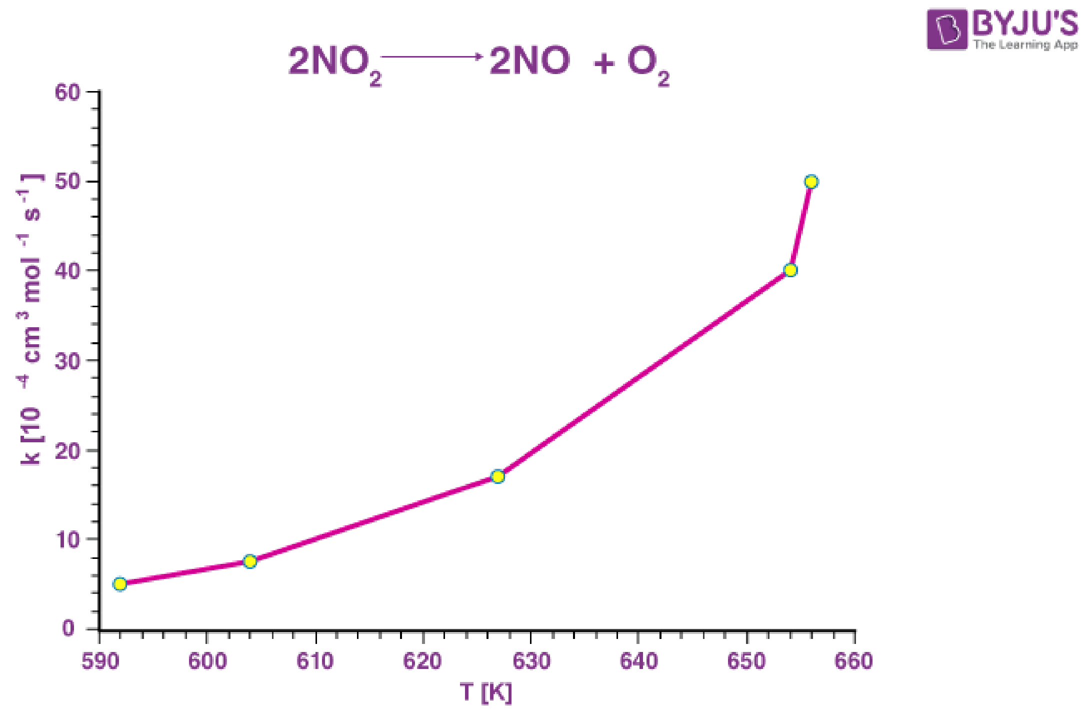
The lower the rate constant, the higher the activation energy of the reaction.
The larger the activation energy of a reaction, the greater the effect of temperature change on the rate constant.

When the temperature is raised in the lower temperature range, the value of 'k' changes more than when the temperature is raised in the higher temperature range.

Q15: Explain Arrhenius Plot.

Answer:

A graph with the rate constant (k) on the Y-axis and the absolute temperature (T) on the X-axis is presented below for the decomposition reaction of nitrogen dioxide (given by $2NO_2 \rightarrow 2NO + O_2$). Observe that the rate of the reaction increases as the temperature increases.



The Arrhenius equation can be expressed as follows when logarithms are used on both sides of the equation:

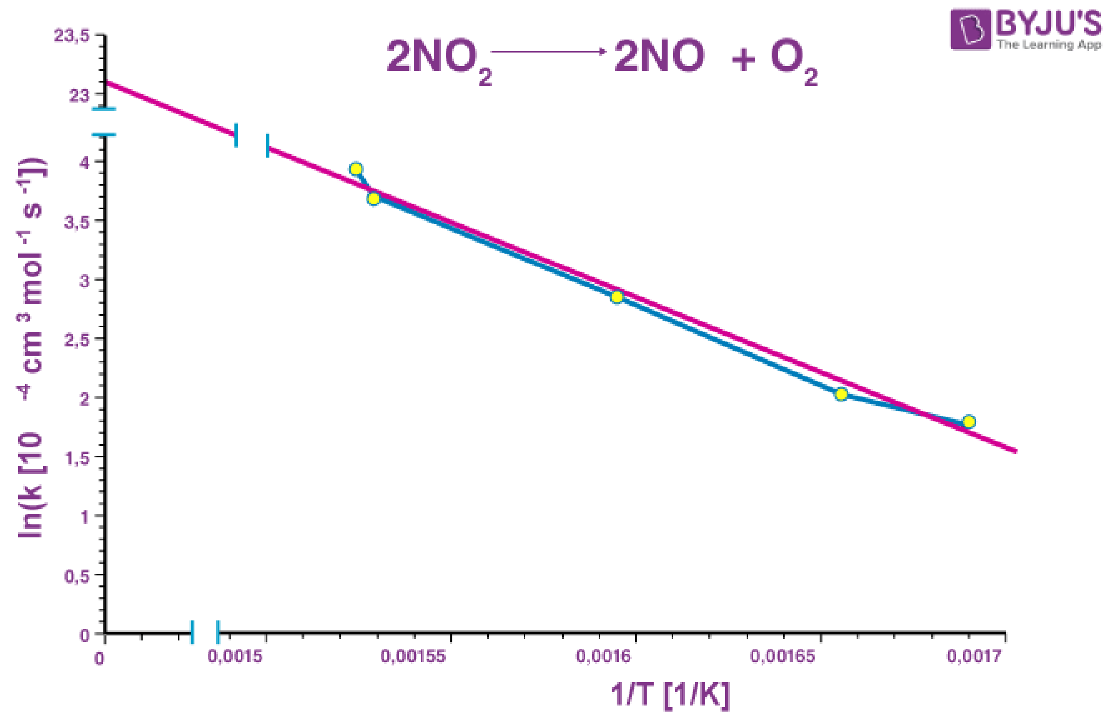
$\ln k = \ln(Ae^{-Ea/RT})$

Solving the equation further:

$\ln k = \ln(A) + \ln(e^{-Ea/RT})$

$\ln k = \ln(A) + (-E_a/RT) = \ln(A) - (E_a/R)(1/T)$

The equation corresponds to a straight line (y = mx + c) with a slope (m) of $-E_a/R$ because ln(A) is a constant. The Arrhenius plot is obtained when the logarithm of the rate constant (ln K) is plotted on the Y-axis and the inverse of the absolute temperature (1/T) is plotted on the X-axis.



The Arrhenius plot for nitrogen dioxide decomposition is depicted above.

Practise Questions on Arrhenius Equation

Q1: What will be the effect of temperature on rate constant?

Answer:

The rate constant of a reaction approximately doubles with a 10° rise in temperature. The Arrhenius equation, $k = A\, e^{-Ea/RT}$, describes the relationship between rate constant and temperature, where A is the Arrhenius constant and Ea is the reaction's activation energy.

Q2: Distinguish between 'rate expression' and 'rate constant' of a reaction.

Answer:

Rate expression: An expression that expresses the rate of reaction in terms of the reactants' molar concentrations, with each term raised to its power, which may or may not be the same as stoichiometric coefficient of that reactant in the balanced equation.

Rate constant: When the molar concentrations of each reactant are assumed to be equal, the rate constant is one.

Q3: What is ***E*** in the Arrhenius equation?

Answer:

E in the Arrhenius equation, $k = A\, e^{-Ea/RT}$, is the energy below which colliding molecules will not react.

E stands for activation energy, which is the energy below which colliding molecules would not react.

The Arrhenius equation describes the relationship between the absolute temperature T (in Kelvin) and the rate constant k of a chemical reaction, where A is the pre-exponential factor (or simply the prefactor), E_a is the activation energy, and R is the Universal gas constant: By Arrhenius equation, $\boldsymbol{k = A\, e^{-Ea/RT}}$

Q4: The ratio of the rate constant of a reaction at two temperatures differing by __________°C is called temperature coefficient of reaction.
a) 2
b) 10
c) 50
d) 100

Answer: b) 10

Explanation: The temperature coefficient of reaction is the ratio of a reaction's rate constant at two temperatures separated by 10°C.

Q5: How many times the rate of reaction increases at 20°C for a reaction having the activation energies in the presence and absence of a catalyst as 50 kJ/mol and 75 kJ/mol?
a) 50000
b) 30000
c) 10000
d) 1000

Answer: b) 30000

Explanation: The reaction rate will increase 30,000 times, or 28,592 times.