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# Chemical Kinetics — JEE (Main) Pattern Topic Test

FREE SAMPLE TEST · CHEMISTRY · PATTERN OF JEE (MAIN)

| DURATION | MAXIMUM MARKS | QUESTIONS | NAME / ROLL NO. |
|---|---|---|---|
| 60 minutes | 100 | 25 (20 + 5) | |

## GENERAL INSTRUCTIONS

1. This question paper has two sections, A and B. All 25 questions are compulsory.
2. Section A has TWENTY (20) multiple-choice questions. Each has FOUR options, (1), (2), (3) and (4), of which ONLY ONE is correct.
3. Section B has FIVE (05) questions whose answer is a numerical value. Enter the value rounded off to the nearest integer.
4. Marking scheme for both sections: +4 for a correct answer, −1 for an incorrect answer, 0 if the question is not attempted.
5. Use of a calculator, log tables or any other aid is not allowed.
6. The answer key and worked solutions are at the end of this booklet. Attempt the paper in 60 minutes before you look at them.

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**Topics covered:** Rate of a reaction · Elementary and complex reactions · Order of a reaction · Rate constant and its units · Zero-order reactions · First-order reactions · Half-life · Effect of temperature on rate · Arrhenius equation · Activation energy · Collision theory

## SECTION A (Q1–20) · Multiple choice · +4 / 0 / −1

Each question has FOUR options. ONLY ONE of them is correct.

**1.** For the reaction $2N_2O_5(g) \rightarrow 4NO_2(g) + O_2(g)$, $N_2O_5$ is used up at a rate of 0.020 mol $L^{-1}$ $s^{-1}$ at some instant. At that instant the rates of formation of $NO_2$ and $O_2$ are, respectively,

(1) 0.040 and 0.010 mol $L^{-1}$ $s^{-1}$

(2) 0.010 and 0.040 mol $L^{-1}$ $s^{-1}$

(3) 0.040 and 0.020 mol $L^{-1}$ $s^{-1}$

(4) 0.080 and 0.020 mol $L^{-1}$ $s^{-1}$

**2.** The rate law of a reaction is rate = k[A]²[B]^(1/2). With concentrations in mol $L^{-1}$ and time in minutes, the units of k are

(1) mol^(3/2) L^(−3/2) $min^{-1}$

(2) mol^(−3/2) L^(3/2) $min^{-1}$

(3) mol^(−5/2) L^(5/2) $min^{-1}$

(4) $L^2$ $mol^{-2}$ $min^{-1}$

**3.** For a reaction A + B → products, the initial rate is $6.0 \times 10^{-4}$ mol $L^{-1}$ $s^{-1}$ when [A] = 0.20 M and [B] = 0.30 M; $1.2 \times 10^{-3}$ mol $L^{-1}$ $s^{-1}$ when [A] = 0.40 M and [B] = 0.30 M; and $4.8 \times 10^{-3}$ mol $L^{-1}$ $s^{-1}$ when [A] = 0.40 M and [B] = 0.60 M. The overall order of the reaction is

(1) 2

(2) 4

(3) 3

(4) 1

**4.** The time needed for 99.9% completion of a first-order reaction is about

(1) 3.3 half-lives

(2) 100 half-lives

(3) 6.6 half-lives

(4) 10 half-lives

**5.** A zero-order reaction A → products has $k = 1.5 \times 10^{-3}$ mol $L^{-1}$ $s^{-1}$. If $[A]_0$ = 0.30 M, the half-life of the reaction is

(1) 200 s

(2) 462 s

(3) 100 s

(4) 50 s

**6.** A first-order reaction is 87.5% complete in 45 min. Its rate constant is about

(1) 0.0462 $min^{-1}$

(2) 0.0231 $min^{-1}$

(3) 0.0100 $min^{-1}$

(4) 0.0347 $min^{-1}$

**7.** When the temperature of a reaction is raised from 280 K to 320 K, its rate constant becomes eight times as large. The activation energy of the reaction is about (R = 8.314 J/(K mol), log 2 = 0.301)

(1) 16.8 kJ/mol

(2) 38.7 kJ/mol

(3) 77.5 kJ/mol

(4) 19.4 kJ/mol

**8.** At 400 K, a catalyst increases the rate of a reaction 1000 times, the pre-exponential factor being unchanged. The catalyst lowers the activation energy by about (2.303RT = 7.66 kJ/mol at 400 K)

(1) 7.7 kJ/mol

(2) 2.3 kJ/mol

(3) 23.0 kJ/mol

(4) 69.0 kJ/mol

**9.** The elementary reaction $2NO(g) + Cl_2(g) \rightarrow 2NOCl(g)$ takes place in a closed vessel. If the concentration of NO is doubled and that of $Cl_2$ is halved, the rate of the reaction becomes

(1) 4 times

(2) 8 times

(3) the same

(4) 2 times

**10.** For a first-order reaction, a graph of $\ln([A]_0/[A])$ against time t is a straight line through the origin with slope $0.0231\ min^{-1}$. The time taken for [A] to fall to one-eighth of $[A]_0$ is about

(1) 30 min

(2) 60 min

(3) 270 min

(4) 90 min

**11.** In a first-order reaction, 60% of the reactant is left after 20 min. The percentage left after 60 min is

(1) 20%

(2) 36%

(3) 21.6%

(4) 6.4%

**12.** The activation energy of a reaction is 34.47 kJ/mol. When the temperature is raised from 300 K to 600 K, the fraction of collisions with energy at least equal to the activation energy increases by a factor of about (2.303R × 600 K = 11.49 kJ/mol)

(1) 2

(2) 30

(3) 100

(4) 1000

**13.** The rate of a reaction doubles for every 10 K rise in temperature. When the temperature is raised from 300 K to 350 K, the rate increases by a factor of

(1) 10

(2) 32

(3) 25

(4) 5

**14.** A first-order reaction is 20% complete in 10 min. The time needed for 75% completion is about (log 2 = 0.301, log 1.25 = 0.097)

(1) 37.5 min

(2) 31.0 min

(3) 82.3 min

(4) 62.1 min

**15.** The decomposition $2O_3 \rightarrow 3O_2$ is thought to occur by a fast equilibrium $O_3 \rightleftharpoons O_2 + O$ followed by a slow step $O + O_3 \rightarrow 2O_2$. The rate law predicted by this mechanism is

(1) rate = $k[O_3]$

(2) rate = $k[O_3]^2$

(3) rate = $k[O_3]^2/[O_2]$

(4) rate = $k[O_3][O_2]$

**16.** Two reactions have the same pre-exponential factor, and activation energies of 40.0 kJ/mol and 80.0 kJ/mol. At 300 K, the ratio of the rate constant of the first reaction to that of the second is about (2.303RT = 5.744 kJ/mol at 300 K)

(1) 2

(2) $1 \times 10^7$

(3) $1 \times 10^3$

(4) $1 \times 10^{14}$

**17.** Statement I: The half-life of a zero-order reaction is directly proportional to the initial concentration of the reactant.
Statement II: The half-life of a first-order reaction does not depend on the initial concentration of the reactant.
In the light of the above statements, choose the correct answer from the options given below:

(1) Both Statement I and Statement II are true

(2) Statement I is true but Statement II is false

(3) Statement I is false but Statement II is true

(4) Both Statement I and Statement II are false

**18.** The first-order gas-phase reaction $2A(g) \rightarrow B(g)$ is started with pure A at 0.60 atm in a closed vessel at constant temperature. After 20 min the total pressure is 0.45 atm. The rate constant (for the loss of A) is about

(1) 0.0144 $min^{-1}$

(2) 0.0347 $min^{-1}$

(3) 0.0693 $min^{-1}$

(4) 0.0173 $min^{-1}$

**19.** For an endothermic reaction, $\Delta H = +25$ kJ/mol and the activation energy of the backward reaction is 35 kJ/mol. The activation energy of the forward reaction is

(1) 10 kJ/mol

(2) 35 kJ/mol

(3) 25 kJ/mol

(4) 60 kJ/mol

**20.** The rate constant of a reaction is $2.0 \times 10^{-3}$ L mol$^{-1}$ s$^{-1}$. The order of the reaction is

(1) 0

(2) 1

(3) 3

(4) 2

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**SECTION B (Q21–25) · Numerical value · +4 / 0 / −1**

The answer to each question is a NUMERICAL VALUE. Enter it rounded off to the nearest integer.

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**21.** The half-life of a first-order reaction is 12 min. The time (in min) needed for 87.5% of the reactant to react is _____.

Answer: _____

**22.** The rate constant of a reaction becomes ten times as large when the temperature is raised from 300 K to 330 K. The activation energy (in kJ/mol) is _____ (to the nearest integer; R = 8.314 J/(K mol)).

Answer: _____

**23.** A zero-order reaction has $k = 2.5 \times 10^{-3}$ mol L$^{-1}$ min$^{-1}$. The time (in min) taken for the concentration of the reactant to fall from 0.40 M to 0.15 M is _____.

Answer: _____

**24.** In the reaction $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$, ammonia is formed at 0.060 mol L$^{-1}$ s$^{-1}$ at some instant. The rate at which hydrogen is used up is $x \times 10^{-3}$ mol L$^{-1}$ s$^{-1}$. The value of x is _____.

Answer: _____

**25.** A first-order reaction has rate constant $1.155 \times 10^{-2}$ min$^{-1}$. The time (in min) for the reactant concentration to fall from 0.80 M to 0.10 M is _____.

Answer: _____

**END OF THE QUESTION PAPER**

## ANSWER KEY

| Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 |
|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (3) | (1) | (2) | (3) | (4) | (4) |

| Q11 | Q12 | Q13 | Q14 | Q15 | Q16 | Q17 | Q18 | Q19 | Q20 |
|---|---|---|---|---|---|---|---|---|---|
| (3) | (4) | (2) | (4) | (3) | (2) | (1) | (2) | (4) | (4) |

| Q21 | Q22 | Q23 | Q24 | Q25 |
|---|---|---|---|---|
| 36 | 63 | 100 | 90 | 180 |

## WORKED SOLUTIONS

**Q1. Answer (1).** Rate = −½ d[$N_2O_5$]/dt = ¼ d[$NO_2$]/dt = d[$O_2$]/dt = 0.010 mol $L^{-1}$ $s^{-1}$. So d[$NO_2$]/dt = 0.040 and d[$O_2$]/dt = 0.010 mol $L^{-1}$ $s^{-1}$.

**Q2. Answer (2).** The overall order is 2 + ½ = 5/2, and k has units (mol $L^{-1}$)^(1−n) $min^{-1}$ = (mol $L^{-1}$)^(−3/2) $min^{-1}$ = mol^(−3/2) L^(3/2) $min^{-1}$.

**Q3. Answer (3).** Doubling [A] doubles the rate: first order in A. Doubling [B] (at [A] = 0.40 M) multiplies the rate by 4 = $2^2$: second order in B. Overall order 3 (rate = k[A][B]²).

**Q4. Answer (4).** t = (2.303/k) log(1000) = 3 × 2.303/k, and t½ = 0.693/k. Ratio = 6.909/0.693 ≈ 10 half-lives (each halving leaves $(½)^{10}$ ≈ 1/1024).

**Q5. Answer (3).** For zero order [A] = $[A]_0$ − kt, so t½ = $[A]_0$/(2k) = 0.30/(2 × 1.5 × $10^{-3}$) = 100 s. (462 s would be 0.693/k, which applies only to first order.)

**Q6. Answer (1).** 87.5% complete leaves one-eighth = three half-lives, so t½ = 15 min and k = 0.693/15 ≈ 0.0462 $min^{-1}$. (Taking 45 min as two half-lives gives 0.0308; as one gives 0.0154.)

**Q7. Answer (2).** log($k_2/k_1$) = (Ea/2.303R)($T_2$ − $T_1$)/($T_1T_2$) with log 8 = 3 × 0.301 = 0.903: 0.903 = Ea × 40/(2.303 × 8.314 × 280 × 320), Ea ≈ 38.7 kJ/mol. (Leaving out the 2.303 gives 16.8.)

**Q8. Answer (3).** $k_c$at/k = e^(ΔEa/RT), so log 1000 = ΔEa/(2.303RT): ΔEa = 3 × 7.66 ≈ 23.0 kJ/mol.

**Q9. Answer (4).** For an elementary reaction the rate law follows the equation: rate = k[NO]²[$Cl_2$]. New rate = k(2[NO])²([$Cl_2$]/2) = 2 × old rate.

**Q10. Answer (4).** ln($[A]_0$/[A]) = kt, so k = 0.0231 $min^{-1}$ and t½ = 0.693/0.0231 = 30 min. One-eighth is three half-lives: 90 min.

**Q11. Answer (3).** In equal times a first-order reaction leaves the same fraction: each 20 min leaves 0.6 of what was there. After 60 min, $0.6^3$ = 0.216 = 21.6%.

**Q12. Answer (4).** The fraction is e^(−Ea/RT). Ratio = e^((Ea/R)(1/300 − 1/600)) = e^(Ea/(R × 600)), so its log is 34.47/11.49 = 3: a factor of about 1000, although the temperature only doubles.

**Q13. Answer (2).** Five steps of 10 K: $2^5$ = 32.

**Q14. Answer (4).** k = (2.303/10) log(1/0.8) = (2.303/10) log 1.25. For 75%, t = (2.303/k) log 4 = 10 × 0.602/0.097 ≈ 62.1 min.

**Q15. Answer (3).** Rate = $k_2$[O][$O_3$] from the slow step. From the fast equilibrium, [O] = K[$O_3$]/[$O_2$], so rate = $k_2$K[$O_3$]²/[$O_2$]: oxygen, a product, slows the reaction (order −1 in $O_2$).

**Q16. Answer (2).** $k_1/k_2 = e^{((Ea_2 - Ea_1)/RT)}$: $\log(k_1/k_2) = 40.0/5.744 \approx 6.96$, so the ratio is about $9 \times 10^6 \approx 10^7$. Doubling Ea does not halve k; it lowers it by a huge factor.

**Q17. Answer (1).** Zero order: $t_{½} = [A]_0/(2k)$. First order: $t_{½} = 0.693/k$. Both statements are true.

**Q18. Answer (2).** If B rises by x, A falls by 2x and the total is $0.60 - x = 0.45$, so $x = 0.15$ and $p(A) = 0.60 - 0.30 = 0.30$ atm: one half-life in 20 min. $k = 0.693/20 \approx 0.0347\ min^{-1}$.

**Q19. Answer (4).** $\Delta H = Ea(forward) - Ea(backward)$, so $Ea(forward) = 25 + 35 = 60$ kJ/mol. For an endothermic reaction the forward barrier is always the higher one.

**Q20. Answer (4).** Units $(mol\ L^{-1})^{(1-n)}\ s^{-1}$ equal $L\ mol^{-1}\ s^{-1}$ when $1 - n = -1$, so $n = 2$.

**Q21. Answer 36.** 12.5% left = $(½)^3$: three half-lives, 36 min.

**Q22. Answer 63.** $\log 10 = 1 = Ea \times 30/(2.303 \times 8.314 \times 300 \times 330)$. $Ea = 2.303 \times 8.314 \times 3300 \approx 63.2$ kJ/mol, i.e. 63.

**Q23. Answer 100.** For zero order the concentration falls by k each minute: $t = (0.40 - 0.15)/(2.5 \times 10^{-3}) = 100$ min.

**Q24. Answer 90.** $-⅓\ d[H_2]/dt = ½\ d[NH_3]/dt$, so $-d[H_2]/dt = (3/2) \times 0.060 = 0.090 = 90 \times 10^{-3}\ mol\ L^{-1}\ s^{-1}$.

**Q25. Answer 180.** $t_{½} = 0.693/k = 0.693/0.01155 = 60$ min. $0.80 \rightarrow 0.10$ M is a fall to one-eighth, three half-lives: $3 \times 60 = 180$ min (directly, $t = (2.303/k) \log 8 = 180$ min).

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All questions are original and © Master Testing Agency. Free to download and use for personal practice; not for resale. Every answer in this paper was checked independently by computer: concentrations were found by integrating the rate laws step by step, orders by fitting logarithms of the rate data, and Arrhenius quantities by evaluating $k = A\ e^{(-Ea/RT)}$ at both temperatures.