Chemical Kinetics

Standard difficulty · 20 questions · 40 marks · Time: 42 minutes

Name: _____ Date: _____ Score: ____ / 40

Show your working for Sections B and C. Answers are on the last page — try every question first!

Section A — Choose the correct answer 8 × 1 = 8 marks

1. The rate of a zero-order reaction:

(a) is proportional to the square of concentration

(b) is always zero

(c) is proportional to concentration

(d) does not depend on the concentration of the reactant

2. For rate = $k[A][B]^2$, the overall order of the reaction is:

(a) 3 **(b)** 1 **(c)** 2 **(d)** 4

3. The unit of the rate constant of a third-order reaction, with time in seconds, is:

(a) s^{-1} **(b)** mol L^{-1} s^{-1} **(c)** L mol^{-1} s^{-1} **(d)** L^2 mol^{-2} s^{-1}

4. A first-order reaction has k = 0.013 s^{-1}. Its half-life is:

(a) 53.31 s **(b)** 0.009009 s **(c)** 106.62 s **(d)** 76.92 s

5. A zero-order reaction has $[A]_0$ = 0.7 mol/L and k = 0.007 mol L^{-1} s^{-1}. Its half-life is:

(a) 50 s **(b)** 0.02 s **(c)** 99 s **(d)** 100 s

6. A first-order reaction has a half-life of 48 min. The time for it to be 93.75% complete is:

(a) 384 min **(b)** 240 min **(c)** 48 min **(d)** 192 min

7. For a reaction that is of order 0 in A, the concentration of A is made 4 times. The rate becomes:

(a) unchanged **(b)** 16 times **(c)** 4 times **(d)** 8 times

8. Assertion (A): A first-order reaction with k = 0.019 min^{-1} has the same half-life when it starts at 5 mol/L as at 8 mol/L.
Reason (R): The half-life of a first-order reaction, 0.693/k, does not depend on the initial concentration.

(a) Both A and R are true, and R is the correct explanation of A.

(b) Both A and R are true, but R is not the correct explanation of A.

(c) A is true, but R is false.

(d) A is false, but R is true.

Section B — Short answer 8 × 2 = 16 marks

9. Distinguish between order and molecularity of a reaction.

10. For $N_2 + 3H_2 \rightarrow 2NH_3$, H_2 is used up at 0.024 mol L^{-1} s^{-1}. Find the rate of formation of NH_3 and the rate of the reaction.

11. In a first-order reaction the concentration of the reactant falls to 1/10 of its initial value in 30 min. Find the rate constant. (log 2 = 0.3010)

12. The half-life of a first-order reaction is 26 min. How long does it take for 1/64 of the reactant to remain? What fraction is left after 130 min?

13. For A + B → products, initial rates are: [A] = 0.1, [B] = 0.1: 2×10^{-3}; [A] = 0.3, [B] = 0.1: 0.018; [A] = 0.1, [B] = 0.3: 6×10^{-3} (concentrations in mol/L, rates in mol L^{-1} s^{-1}). Find the order with respect to A and B.

14. A zero-order reaction has k = 0.09 mol L^{-1} min^{-1} and starts at 1.7 mol/L. Find the concentration after 5 min, and the half-life.

15. The rate constant of a reaction becomes 4 times larger when the temperature rises from 310 K to 330 K. Find the activation energy. (R = 8.314 J mol^{-1} K^{-1}, log 2 = 0.3010)

16. A first-order reaction has k = 0.074 s^{-1}. How long does it take for 50% of the reactant to react?

Section C — Word problems — 4 × 4 = 16 marks

17. Derive the integrated rate equation for a first-order reaction and show that its half-life does not depend on the initial concentration.

18. For $2A + B \rightarrow C$, the initial rates were: experiment 1: [A] = 0.1, [B] = 0.1 mol/L, rate = 0.01 mol L^{-1} s^{-1}; experiment 2: [A] = 0.2, [B] = 0.1 mol/L, rate = 0.01 mol L^{-1} s^{-1}; experiment 3: [A] = 0.1, [B] = 0.2 mol/L, rate = 0.02 mol L^{-1} s^{-1}. Find the order with respect to each reactant, write the rate law, and find k.

19. A first-order reaction has a half-life of 46 min. Find (a) the rate constant, (b) the time for 93.75% completion, (c) the time for the concentration to fall to 1/10 of its initial value. (log 10 = 1)

20. The rate constant of a reaction is k at 310 K and 10k at 330 K. Find its activation energy, and explain why a small rise in temperature can increase the rate so much. ($R = 8.314$ J mol^{-1} K^{-1}, log 2 = 0.3010)

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Answer key

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Q	Answer	Working
1	**(d) does not depend on the concentration of the reactant**	—
2	**(a) 3**	add the powers
3	**(d) $L^2\ mol^{-2}\ s^{-1}$**	$(mol\ L^{-1})^{(1-n)}\ s^{-1}$ with n = 3
4	**(a) 53.31 s**	$t_{1/2} = 0.693/k$
5	**(a) 50 s**	$t_{1/2} = [A]_0/(2k)$
6	**(d) 192 min**	6.25% left = 4 half-lives
7	**(a) unchanged**	rate $\propto [A]^0$: $4^0 = 1$
8	**(a) Both A and R are true, and R is the correct explanation of A.**	A is true: $t_{1/2} = 0.693/k = 36.47$ min for any starting concentration. R is true and explains A.
9	**Order is the sum of the powers of concentrations in the experimental rate law; it can be zero or a fraction. Molecularity is the number of species colliding in an elementary step; it is a whole number (1, 2 or 3).**	—
10	**0.016 mol $L^{-1}\ s^{-1}$; rate of reaction 0.008 mol $L^{-1}\ s^{-1}$**	rate $= -(1/3)\ d[H_2]/dt = (1/2)\ d[NH_3]/dt$
11	**0.0768 min^{-1}**	$k = (2.303/t)\ \log(10) = (2.303/30) \times 1$
12	**156 min; 1/32**	each half-life halves it; $1/64 = (1/2)^6$
13	**order 2 in A, 1 in B; overall 3**	[A] × 3 changes the rate × 9; [B] × 3 changes it × 3
14	**1.25 mol/L; 9.44 min**	$[A] = [A]_0 - kt$; $t_{1/2} = [A]_0/2k$
15	**59 kJ/mol**	$\log(k_2/k_1) = (Ea/2.303R)(1/T_1 - 1/T_2)$
16	**9.36 s**	50% reacted = 1 half-life; $t_{1/2} = 0.693/k$
17	**$-d[R]/dt = k[R] \Rightarrow d[R]/[R] = -k\ dt \Rightarrow \ln[R] = -kt + \ln[R]_0 \Rightarrow k = (2.303/t)\ \log([R]_0/[R])$. At $t_{1/2}$, $[R] = [R]_0/2$, so $k = (2.303/t_{1/2})\ \log 2 \Rightarrow t_{1/2} = 0.693/k$, which contains no concentration term.**	—
18	**order 0 in A, 1 in B; rate = k[B]; k = 0.1 s^{-1}**	compare experiments 1 and 2 for A, 1 and 3 for B
19	**(a) 0.0151 min^{-1}; (b) 184 min; (c) 153 min**	$k = 0.693/t_{1/2}$; $t = (2.303/k)\ \log([A]_0/[A])$
20	**97.9 kJ/mol; the fraction of molecules with energy above Ea rises sharply with temperature**	$Ea = 2.303R\ \log(k_2/k_1) \times T_1T_2/(T_2 - T_1)$

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