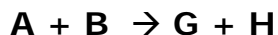


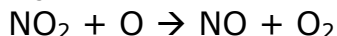
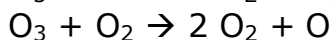
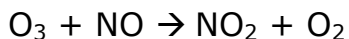
- _____ 2. In the laboratory, a student varies the concentrations of **A** & **B** in the reaction shown below while observing the absorbance of **G** (the only compound to absorb at the observed wavelength). Given the following data, determine the rate law for the reaction (recall that absorbance is directly proportional to concentration):



Trial 1: [A] = 0.5 mol•L ⁻¹ [B] = 0.5 mol•L ⁻¹		Trial 2: [A] = 0.5 mol•L ⁻¹ [B] = 1.0 mol•L ⁻¹		Trial 3: [A] = 1.0 mol•L ⁻¹ [B] = 0.5 mol•L ⁻¹	
Time (s)	Absorbance	Time (s)	Absorbance	Time (s)	Absorbance
30	0.3	30	0.6	30	0.3
60	0.4	60	1.0	60	0.4
90	0.5	90	1.4	90	0.5
120	0.6	120	1.8	120	0.6

- a. $v_0 = k[A]^1[B]^1$
 - b. $v_0 = k[A]^2[B]^1$
 - c. $v_0 = k[A]^2[B]^0$
 - d. $v_0 = k[A]^1[B]^2$
 - e. $v_0 = k[A]^0[B]^2$
- _____ 8. A reaction has an activation energy of 42.6 kJ/mol and a rate constant of 0.045 s⁻¹ at 25.0°C. At what temperature will the reaction rate quadruple?
- a. 74.2°C
 - b. 121.5°C
 - c. 51.1°C
 - d. 32.7°C
 - e. 65.3°C

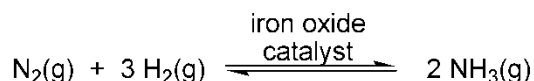
- _____ 9. Consider the following mechanism for the catalyzed decomposition of ozone to form oxygen gas ($2\text{O}_3 \rightarrow 3\text{O}_2$):



Which of the following statements about this reaction is true?

- a. O_3 is a catalyst and O_2 is an intermediate
- b. O and NO are catalysts while NO_2 is an intermediate
- c. NO_2 is a catalyst and NO is an intermediate
- d. NO and NO_2 are catalysts while O is an intermediate
- e. NO is a catalyst and NO_2 is an intermediate

15. The synthesis of ammonia in the Haber process is accelerated by a solid catalyst based on iron oxide (rust) particles. The reaction is exothermic.



If a reaction is modified simply by grinding the catalyst into much smaller particles, with reactant concentrations and pressures held constant, which of the following statements is not true?

- a. The reaction rate will increase.
- b. More heat will be generated per second.
- c. The equilibrium constant will favour more NH_3 formation.
- d. $v = -1/3 \times d[\text{H}_2]/dt$
- e. The reaction requires one or both reactants to adsorb on the surface of the catalyst.

- _____ 16. Given the following experimental data for the reduction of nitric oxide with hydrogen gas, which includes initial concentrations and rates, determine the rate law.

Experiment	[NO]	[H ₂]	Rate
1	6.4×10^{-3} M	2.2×10^{-3} M	2.6×10^{-5} M/s
2	12.8 mM	2.2×10^{-3} M	0.104 mM/s
3	6.4 mM	4.5×10^{-3} M	5.1×10^{-5} M/s

- a. $v = k[\text{NO}]^2$
- b. $v = k[\text{NO}]^2[\text{H}_2]$
- c. $v = k[\text{NO}][\text{H}_2]$
- d. $v = k[\text{NO}_2]^2[\text{H}_2]$
- e. $v = k[\text{HNO}_2]^2[\text{H}_2]$

18. A redox reaction of technetium-99m, the most widely used radionuclide in diagnostic medicine, occurs via a first order process with a rate constant of $2.0 \times 10^{-6} \text{ s}^{-1}$. How long would it take the reaction to reach 90% completion?

- a. 13.3 days
- b. 3.5 s
- c. Not enough information to answer the question.
- d. 3.2 hours
- e. 32 minutes

____ 20. In the gas phase, oxidation of nitric oxide (NO) with ozone (O₃) produces nitrogen dioxide and oxygen. The activation energy for the forward reaction is 10 kJ mol⁻¹, and it is 210 kJ mol⁻¹ for the reverse reaction. Which of the following statements is true ?

- a. The lifetime of the key intermediate is shorter than that of the preceding transition state.
- b. $\Delta H = -200 \text{ kJ mol}^{-1}$ in the forward reaction, and the reaction is exothermic.
- c. The reaction is not likely to proceed, as both ΔH and ΔS are unfavourable.
- d. The stoichiometry of the chemical reaction gives the overall reaction order.
- e. The products are less stable than the reactants.

22. For a typical reaction involving a homogenous catalyst, doubling the amount of the catalyst in a reaction will do which of the following?

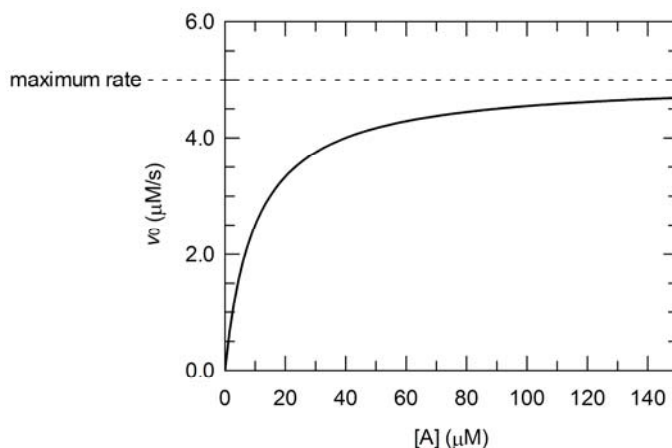
- a. Double the reaction rate.
- b. There will be no change in the reaction rate.
- c. Decrease the reaction rate because the concentration of the substrate [S] will be at the half-maximum value.
- d. Quadruple the reaction rate
- e. It will cause the activation energy to become zero and will establish a situation where $K_{eq} = 1$.

23. Which of the following statements about enzyme kinetics is/are true?

- i. At low $[S]$, doubling the substrate concentration roughly doubles the rate.
- ii. At high $[S]$, reactions are pseudo-first order with respect to $[S]$.
- iii. The value of K_M (from the steady-state approximation) is approximately equal to K_s (from the equilibrium assumption) when $k_2 \gg k_{-1}$.
- iv. $[S]_{\text{free}} \approx [S]_{\text{total}}$ when $t \approx 0$.
- v. For the equilibrium assumption, if $[S] = K_s$ then $[E \bullet S] = 0$.

- a. ii, v
- b. i, iii
- c. i, iv, v
- d. i, iv
- e. ii, iv

24. An enzyme, E, catalyzes a reaction using substrate **A**. The curve of v_0 versus $[A]$ shown below is obtained when $[E]_0 = 0.1 \mu\text{M}$. What are the values of k_{cat} and K_M for this reaction?



- | | k_{cat} | K_M |
|----|---|-------------------|
| a. | $5 \text{ M}^{-1} \bullet \text{s}^{-1}$ | $10 \mu\text{M}$ |
| b. | $50 \text{ M}^{-1} \bullet \text{s}^{-1}$ | $50 \mu\text{M}$ |
| c. | 50 s^{-1} | $10 \mu\text{M}$ |
| d. | $5 \mu\text{M} \bullet \text{s}^{-1}$ | $10 \mu\text{M}$ |
| e. | 5 s^{-1} | $150 \mu\text{M}$ |

36. An enzyme possesses a carboxylic acid functional group that must be in the protonated form (R-COOH) for the enzyme to have catalytic activity. In the deprotonated form (R-COO^-), it has no activity. If the carboxylic acid functional group has a pK_a value of 6.0, what will be the effect of changing the pH of the solution from 6.5 to 7.0?

- a. The initial velocity will not change.
- b. The initial velocity will decrease by a factor of 5.2.
- c. The initial velocity will increase by a factor of 2.6.
- d. The initial velocity will increase by a factor of 5.2.
- e. The initial velocity will decrease by a factor of 2.6.

37. The bonds in the backbone of DNA have a half-life of 140,000 years (4.4×10^{12} s). The concentration of these bonds in humans is 3×10^{-4} M, and the volume of the average person is 70 L. How many of these DNA backbone bonds break each second in the average person?

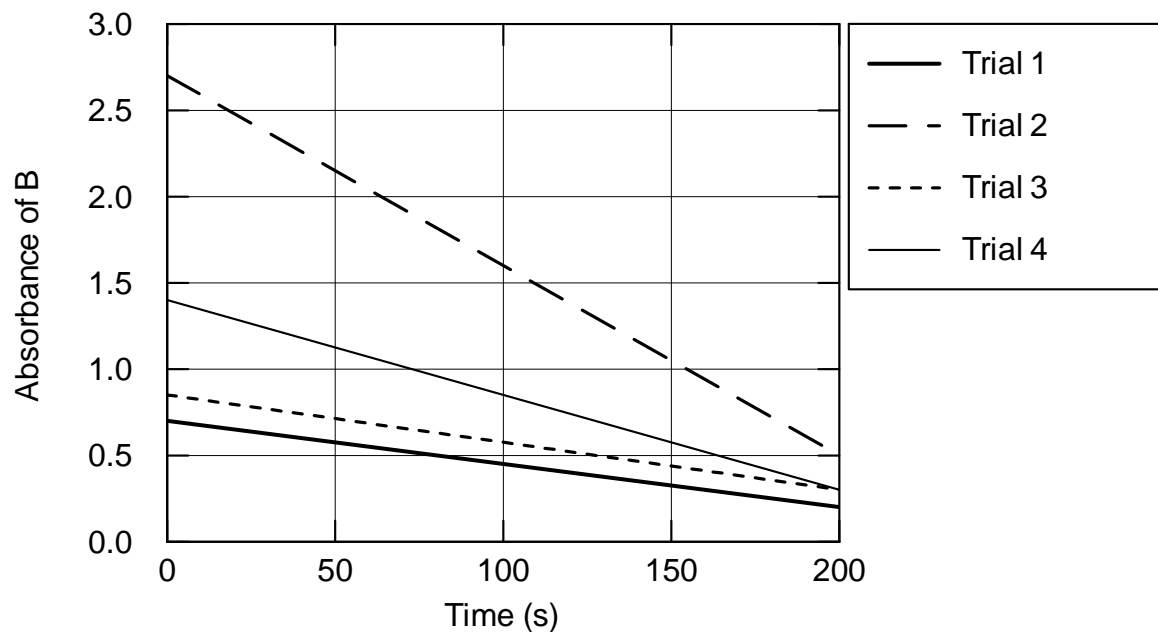
- a. 2.0×10^9 bonds/s
- b. 1.3×10^{-9} bonds/s
- c. 2.8×10^7 bonds/s
- d. 1.3×10^8 bonds/s
- e. 2.8×10^{-8} bonds/s

1. Given the following graph and data, determine the **rate law** for the following reaction



(Recall, absorbance is directly proportional to concentration)

	Trial 1	Trial 2	Trial 3	Trial 4
[A] (M)	0.2	0.4	0.2	0.2
[B] (M)	0.2	0.2	0.4	0.2
[C] (M)	0.2	0.2	0.2	0.4



- (A) $v_0 = k[\text{A}]^2[\text{B}][\text{C}]$
(B) $v_0 = k[\text{A}]^2[\text{B}][\text{C}]^2$
(C) $v_0 = k[\text{B}][\text{C}]^2$
(D) $v_0 = k[\text{A}][\text{B}][\text{C}]$
(E) $v_0 = k[\text{A}]^2[\text{C}]$

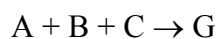
2. In the chocolate unwrapping experiment in class, one student unwrapped foil-wrapped chocolates from a pile on the table (slow step), while a second student ate the unwrapped chocolates as quickly as possible (fast step). Which of the following statements is **FALSE**?

- (A) Unwrapped chocolate is a reaction intermediate.
- (B) $[\text{unwrapped chocolate}] \approx 0$
- (C) The rate-limiting step is unwrapping the chocolate.
- (D) Doubling the number of people eating the chocolate would not change the overall rate of chocolate consumption.
- (E) Doubling the number of chocolates in the pile would double the overall rate of chocolate consumption.

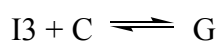
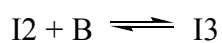
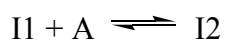
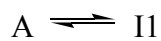
3. Which of the following statements about the Haber-Bosch reaction
 $(\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3)$ must be **TRUE**?

- (A) $3 \Delta[\text{H}_2]/\Delta t = 2 \Delta[\text{NH}_3]/\Delta t$
- (B) $2 \Delta[\text{H}_2]/\Delta t = 3 \Delta[\text{NH}_3]/\Delta t$
- (C) $v_0 = k[\text{N}_2][\text{H}_2]^3$
- (D) $v_0 = -d[\text{N}_2]/dt$
- (E) $v_0 = d[\text{NH}_3]^2/dt$

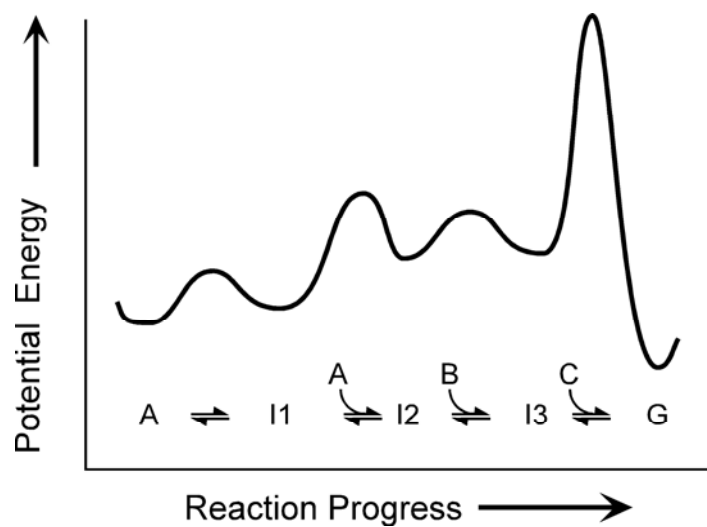
4. The reaction profile shown below is for the overall reaction:



There are several steps in the reaction:

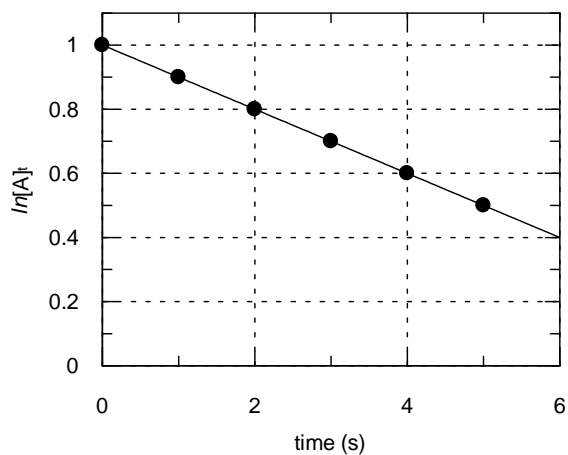


What is the **overall rate equation** for this reaction?



- (A) $v_0 = k[A]$
- (B) $v_0 = k[A]^2[B]$
- (C) $v_0 = k[A][B][C]$
- (D) $v_0 = k[A]^2[B][C]$
- (E) $v_0 = k[C]$

5. The graph below is for a first order reaction. What is the **value of k** ?



- (A) -0.4 s^{-1}
- (B) 0.4 s^{-1}
- (C) 0.15 s^{-1}
- (D) 0.1 Ms^{-1}
- (E) 0.1 s^{-1}

6. The first hydrogen bomb was exploded in 1952, releasing tritium (^3H) into the atmosphere. The half-life for the radioactive decay of ^3H is $t_{1/2} = 3.9 \times 10^8 \text{ s}^{-1}$. **What percentage** of the ^3H from the 1952 explosion has not yet decayed?

- (A) $1.0 \times 10^{-4} \%$
- (B) 0.0040%
- (C) 1.0%
- (D) 4.0%
- (E) 10%

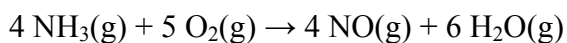
7. For a reaction involving reactants A and B, the rate data in the table below were obtained.

What is the **reaction rate** when $[A] = 0.300\text{ M}$ and $[B] = 0.400\text{ M}$?

Expt. #	[A] (M)	[B] (M)	d[A]/dt (M/s)
1	0.20	0.30	0.24
2	0.40	0.60	1.92
3	0.20	0.60	0.48
4	0.40	0.30	0.96

- (A) 0.56 M/s
- (B) 0.72 M/s
- (C) 0.28 M/s
- (D) 1.4 M/s
- (E) 0.68 M/s

8. In the following reaction, $\Delta[\text{O}_2]/\Delta t = -0.45\text{ M/s}$ over the first 10 s of the reaction. What is the **average reaction rate in that time**?



- (A) 0.09 M/s
- (B) 0.09 s^{-1}
- (C) -0.45 M/s
- (D) 0.45 M/s
- (E) 0.85 M/s

9. If $E_a = 48 \text{ kJ}\cdot\text{mol}^{-1}$ for a reaction, **at what temperature** would the reaction have to run in order to double the rate observed at 100°C ? (Assume A is constant).

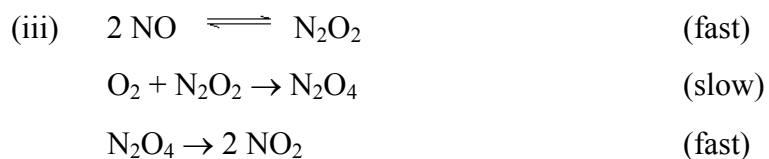
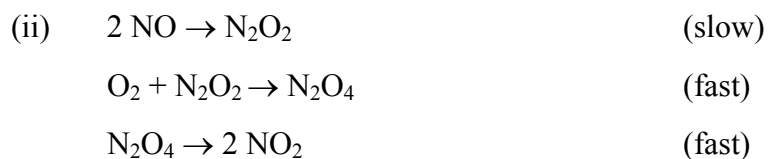
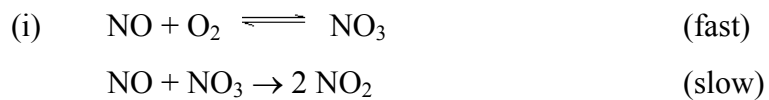
- (A) 106°C
- (B) 111°C
- (C) 117°C
- (D) 122°C
- (E) 128°C

10. The activation energy for the decomposition of HI (g) into $\text{H}_2 \text{ (g)}$ and $\text{I}_2 \text{ (g)}$ at 300°C is $183 \text{ kJ}\cdot\text{mol}^{-1}$. A metallic rhodium catalyst lowers the activation energy to $55 \text{ kJ}\cdot\text{mol}^{-1}$. By **what factor would the reaction rate increase** in the presence of this catalyst? (Assume A is constant).

- (A) 1.09
- (B) 1.98×10^{29}
- (C) 5.94×10^8
- (D) 3.18×10^{14}
- (E) 4.67×10^{11}

11. For the reaction: $2 \text{NO} (\text{g}) + \text{O}_2 (\text{g}) \rightarrow 2 \text{NO}_2 (\text{g})$,

the rate doubles when the O_2 concentration is doubled, but it increases by a factor of 4 when the NO concentration is doubled. Which of the following mechanisms **is/are consistent with this**?



- (A) i
(B) ii
(C) i, ii
(D) i, iii
(E) i, ii, iii

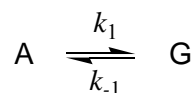
12. β -Lactamase is an enzyme that destroys penicillin-type antibiotics and makes bacteria antibiotic resistant. The steady state kinetic parameters with one particular β -lactamase were determined for several antibiotics.

- (i) amoxicillin: $k_{\text{cat}} = 10 \text{ s}^{-1}$, $K_{\text{M}} = 2.0 \times 10^{-4} \text{ M}$
- (ii) ampicillin: $k_{\text{cat}} = 30 \text{ s}^{-1}$, $K_{\text{M}} = 6.0 \times 10^{-4} \text{ M}$
- (iii) penicillin G: $K_{\text{M}} = 1.0 \times 10^{-5} \text{ M}$, $v_0 = 1.6 \times 10^{-5} \text{ M/s}$ when $[\beta\text{-lactamase}] = 2 \text{ }\mu\text{M}$ and $[\text{penicillin G}] \gg K_{\text{M}}$

Which antibiotic would be destroyed at the highest rate if they were all present at a concentration of $1.0 \times 10^{-4} \text{ M}$?

- (A) amoxicillin
- (B) ampicillin
- (C) penicillin G
- (D) amoxicillin & ampicillin will be destroyed at the same rate
- (E) all three antibiotics will be destroyed at the same rate

13. In the reaction of A to G, $k_1 = 12 \text{ s}^{-1}$ at 25°C . The overall enthalpy of reaction, $\Delta H = 10 \text{ kJ}\cdot\text{mol}^{-1}$. What is the **rate constant for the reverse reaction, k_{-1}** ?



- (A) 0.012 s^{-1}
- (B) 0.16 s^{-1}
- (C) 0.21 s^{-1}
- (D) 1.6 s^{-1}
- (E) 21 s^{-1}

14. For a certain reaction, the rate constant, k , was measured at several temperatures. A plot of $\ln(k)$ vs. $1/T$ gave a straight line of the following form:

$$\ln(k) = -(8.15 \times 10^3)/T + 8.3$$

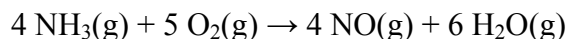
Calculate the activation energy, E_a , in $\text{kJ}\cdot\text{mol}^{-1}$, for the reaction.

- (A) 3.85
- (B) 22.0
- (C) 50.1
- (D) 67.8
- (E) 244

15. A certain overall reaction occurs in two elementary steps. The first step has an activation energy, E_a , of $38 \text{ kJ}\cdot\text{mol}^{-1}$ and is endothermic by $25 \text{ kJ}\cdot\text{mol}^{-1}$. The overall forward reaction is exothermic by $11 \text{ kJ}\cdot\text{mol}^{-1}$. If E_a of the first step of the *reverse* reaction is $64 \text{ kJ}\cdot\text{mol}^{-1}$, what is the **E_a of the second step of the forward reaction**, in $\text{kJ}\cdot\text{mol}^{-1}$?

- (A) 6
- (B) 28
- (C) 37
- (D) 53
- (E) 62

1. In the following reaction, $\Delta[\text{O}_2]/\Delta t = -0.45 \text{ M/s}$ over the first 10 s of the reaction. What is the **average reaction rate in that time**?



- (A) 0.09 M/s
- (B) 0.09 s^{-1}
- (C) -0.45 M/s
- (D) 0.45 M/s
- (E) 0.85 M/s

2. During experiment # 8, the absorbance of Br_2 (which is directly proportional to $[\text{Br}_2]$) was measured as a method to determine the rate of the following reaction:



Determine the **TRUE** statement regarding this process.

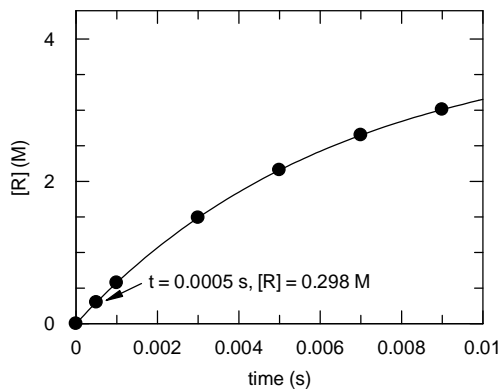
- (A) The slope of the absorbance versus time graph can be considered to be the rate of the reaction.
- (B) The absorbance of Br_2 increased as the reaction proceeded.
- (C) Assuming a rate law of $v = k[\text{Br}]^2[(\text{CH}_3)_2\text{CO}]^1$, doubling the concentration of Br_2 while keeping the concentration of acetone the same would double the rate.
- (D) At time = 0 (once everything is mixed), absorbance of $\text{Br}_2 = 0$.
- (E) The rate constant, k , changes depending on the relative concentrations of each reactant.

3. For the reaction $A + B \rightarrow G + H$, the data in the table below were obtained. What is the **reaction rate** when $[A] = 0.300 \text{ M}$ and $[B] = 0.400 \text{ M}$?

Expt. #	[A] (M)	[B] (M)	d[A]/dt (M/s)
1	0.200	0.300	0.144
2	0.400	0.600	1.152
3	0.200	0.600	0.288
4	0.400	0.300	0.576

- (A) 0.576 M/s
 (B) 0.432 M/s
 (C) 0.288 M/s
 (D) 1.44 M/s
 (E) 0.628 M/s

4. The graph below shows $[R]$ for the reaction: $3 \text{RX}_3 \rightarrow \text{R} + \text{R}_2\text{X}_3 + 3 \text{X}_2$. What is the **initial instantaneous rate** (v_0) of this reaction?



- (A) 557 M/s
 (B) 1671 M/s
 (C) 459 M/s
 (D) 1860 M/s
 (E) 620 M/s

1. ^{11}C is a radioactive isotope of carbon. Its radioactive decay was followed by plotting $\ln([^{11}\text{C}])$ versus t , which gave a slope of -0.034 min^{-1} . If the radioactivity in a ^{11}C sample was initially $2.2 \times 10^6 \text{ dpm}$ (disintegrations per minute), **how long would it take to decay to $2.2 \times 10^5 \text{ dpm}$?**

- (A) 68 min
- (B) 6.8 min
- (C) 61 min
- (D) 0.015 min
- (E) 29 min

2. **By what factor does the rate of a reaction increase** if its activation energy is 50. kJ/mol and the temperature is increased from 300 K to 320 K?

- (A) 3.5
- (B) 5.0
- (C) 0.5
- (D) 7.1
- (E) 1.25

3. Pepsin ($k_{\text{cat}} = 23 \text{ s}^{-1}$) is the enzyme in your stomach that digests proteins by hydrolyzing amide bonds. Trypsin ($k_{\text{cat}} = 124 \text{ s}^{-1}$) does the same job in your intestines. The uncatalyzed rate constant for amide bond hydrolysis is $5.5 \times 10^{-11} \text{ s}^{-1}$. **How much lower** is the **activation energy** for the **trypsin-catalyzed reaction** at body temperature, 37°C ?

- (A) 4.3 J/mol
- (B) 1.3 kJ/mol
- (C) 2.3 kJ/mol
- (D) 4.3 kJ/mol
- (E) 7.3 kJ/mol

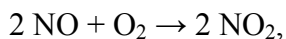
4. The reaction $2\text{NOCl(g)} \rightarrow 2\text{NO(g)} + \text{Cl}_2\text{(g)}$ has an activation energy of 100. kJ/mol and a rate constant of $8.0 \times 10^{-6} \text{ mol}^{-1}\text{Ls}^{-1}$ at 350K. **What is the value of the rate constant at 400 K?**

- (A) $5.9 \times 10^{-4} \text{ mol}^{-1}\text{Ls}^{-1}$
- (B) $9.5 \times 10^{-4} \text{ mol}^{-1}\text{Ls}^{-1}$
- (C) $1.18 \times 10^{-3} \text{ mol}^{-1}\text{Ls}^{-1}$
- (D) $2.95 \times 10^{-3} \text{ mol}^{-1}\text{Ls}^{-1}$
- (E) $9.5 \times 10^{-4} \text{ mol}^1\text{L}^{-1}\text{s}^1$

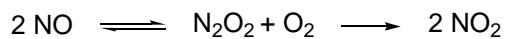
5. Which of the following statements about the steady state approximation is **not true**?

- (A) $d[E\cdot S]/dt = 0$
- (B) k_{-1} can be much greater than k_2
- (C) k_2 is rate-limiting
- (D) rate of $[E\cdot S]$ formation = $k_2[E\cdot S]$
- (E) k_{-1} can be less than k_2

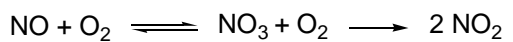
6. For the overall reaction:



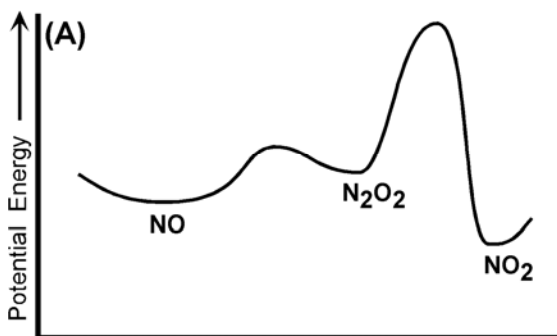
the experimental kinetic data are consistent with two possible mechanisms having a fast equilibrium step followed by a slow step:



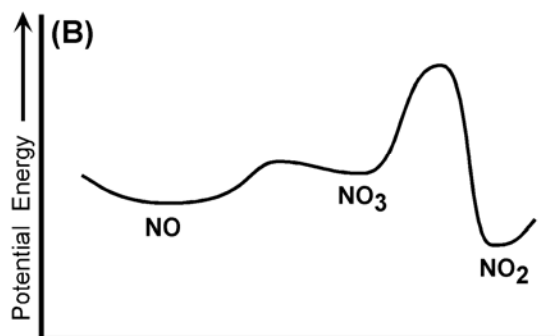
OR



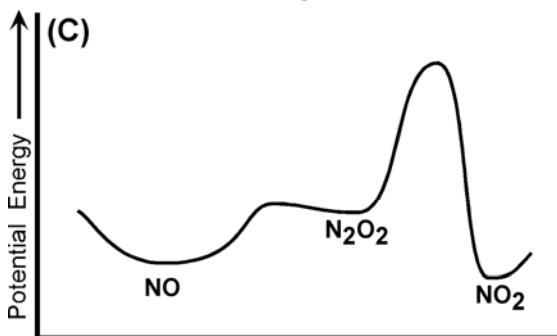
Which of the following reaction profiles is **not** consistent with the experimental data for the overall reaction?



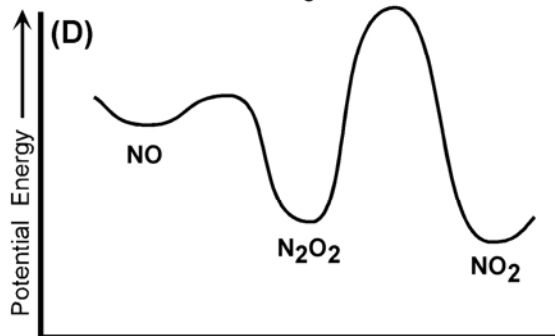
Reaction Progress →



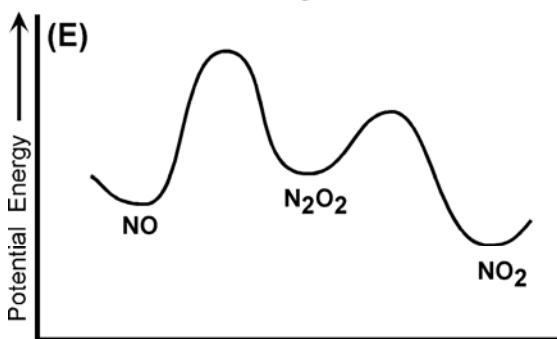
Reaction Progress →



Reaction Progress →



Reaction Progress →



Reaction Progress →

7. Zyprexa Adhera is a slow-release anti-schizophrenia drug. It is injected once per month and quickly reaches a constant concentration in the blood. Its release into the blood is zero-order, with $k = 5 \mu\text{M}/\text{day}$. It is destroyed by the body in process that follows first order kinetics, with $k = 2 \text{ day}^{-1}$. What is the **Zyprexa Adhera concentration in the blood**?

- (A) $1 \mu\text{M}$
- (B) $2 \mu\text{M}$
- (C) $2.5 \mu\text{M}$
- (D) $5 \mu\text{M}$
- (E) $10 \mu\text{M}$

1. Ozone (O_3) decomposes in the stratosphere, giving molecular oxygen (O_2) as the product. The same reaction was run in the lab, with a initial partial pressure of O_3 of 1.0 kPa . The reaction reached 75% completion in 17 min. What was the **partial pressure of O_2 at $t = 17 \text{ min}$** ?

- (A) 2.0 kPa
- (B) 1.5 kPa
- (C) 1.1 kPa
- (D) 0.50 kPa
- (E) 0.11 kPa

2. Derive k and $t_{1/2}$ for a first order reaction that gives the following results.

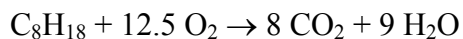
time (s)	[A] (M)
0	0.500
20	0.184
40	0.068
60	0.025
80	0.009

	$k \text{ (s}^{-1}\text{)}$	$t_{1/2} \text{ (s)}$
(A)	2.0×10^{-4}	43
(B)	0.016	43
(C)	0.05	14
(D)	0.05	20
(E)	0.5	1.4

3. Radioactive decay is a first order process, and the half-life of ^{18}F is 110 min. If ^{18}F -FDG synthesis takes 52 min., **how much of the original radioactivity would remain at the end of the synthesis** (ignoring any losses from incomplete reactions or purification)?

- (A) 40 %
- (B) 72 %
- (C) 47 %
- (D) 78 %
- (E) 50 %

4. Combustion of octane in the gas phase is described by the equation:



If the rate of production of CO_2 is $4.3 \text{ mol}\cdot\text{L}^{-1}\cdot\text{s}^{-1}$, which of the following statements is **not true**?

- (A) The rate of oxygen consumption is $6.7 \text{ mol}\cdot\text{L}^{-1}\cdot\text{s}^{-1}$.
- (B) Carbon dioxide production is $189 \text{ g}\cdot\text{L}^{-1}\cdot\text{s}^{-1}$.
- (C) Octane production is $0.54 \text{ mol}\cdot\text{L}^{-1}\cdot\text{s}^{-1}$.
- (D) $-\text{d}[\text{C}_8\text{H}_{18}]/\text{dt} = \frac{1}{8} \text{d}[\text{CO}_2]/\text{dt}$.
- (E) $\text{d}[\text{H}_2\text{O}]/\text{dt} = 3.8 \text{ mol}\cdot\text{L}^{-1}\cdot\text{s}^{-1}$.