CHEM 311 (151) **Second Major Exam** 2 HOURS

Thursday, November 19, 2015, 8:00-10:00 PM

STUDENT NAME: ....

STUDENT ID NUMBER: ....

Test Code (001)

(16 Questions)

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Dr. H. Badawi	Section 2
Dr. W. Foerner	Section 3
Dr. G. Oweimreen	Section 4

Physical constants, conversion factors, and useful equations

Physical Constants

R = 8.314 J mol^{-1} K^{-1}
= 0.08206 L atmK^{-1} mol^{-1}
= 0.08314 L bar K^{-1} mol^{-1}

N_A = 6.022 x 10^{23} mol^{-1}

k_B = 1.381 x 10^{-23} J K^{-1}

h = 6.626 x 10^{-34} J s

F = 96,500 C mol^{-1}

c = 2.998 x 10^{8} m s^{-1}

g = 9.81 m s^{-2}

B = 0.51mol$^{-1/2}$dm$^{3/2}$
(in H_2O, 25°C)

Sequential reactions:

$$A \xrightarrow{k_1} B \xrightarrow{k_2} C$$

$[B]=(k_1/(k_2-k_{-1}))\ f(t)[A]_0$

$f(t)=\exp(-k_1t)-\exp(-k_2t)$

Other Units

1dm^3 = 1 L

1dm^3 = 1000 cm^3

1 J = 1 kg m^2 s^{-2}

1 atm = 1.101325 x 10^5 Pa

1 atm = 760 mmHg

1 Torr = 1 mmHg

1 Torr = 133.322 Pa

1 bar = 10^5 Pa

1 nm = 10^{-9} m

$$\upsilon = \frac{V[S]}{K_m + [S]}$$

$$V = k_2[E]_0 \ and\ K_m = \frac{k_{-1}+k_2}{k_1}$$

Eyring equation:

$k = k_BT/(hc^0)$ x f

$f = \exp(\Delta S^{\#}/R)$ x $\exp(-\Delta H^{\#}/RT)$

Important Equations

$$k = Ae^{-E_a/RT}$$

$$k = \frac{k_BT}{h}e^{-\Delta^{\neq}G^{\circ}/RT}$$

$\Delta G = \Delta H - T\Delta S$

$E_a = \Delta^{\neq}H^o - P\Delta^{\neq}V^o + RT$ (sol)
$= \Delta^{\neq}H^o - \Sigma\nu RT + RT$ (gas)

$$\log k = \log k_o - \frac{\Delta^{\neq}V}{RT}P$$

$\Delta G^o = -RT \ln K_c$

$dP/dt = k\theta$

$\theta = KP/(1 + KP)$, at T=const

$\ln(1 - \theta) = -\theta$
if $\theta << 1$

Parallel reactions:

$\Phi_i = k_i/S$
where S is the sum of all rate constants of the paral-lel reactions

1. Find the rate law of the reaction:

6O 3N 3H

!

$$\cancel{2}3\ \cancel{3}\mathrm{HNO_2} \xrightarrow{k_{eff}} \mathrm{H_2O} + 2\mathrm{NO} + \mathrm{H^+} + \mathrm{NO_3^-}$$

If the first two of the following steps rapidly attain equilibrium and the third step is slow:

$$2\ \cancel{3}\mathrm{HNO_2} \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} \mathrm{H_2O} + \mathrm{NO} + \mathrm{NO_2}$$

4O 2

$$2\mathrm{NO_2} \underset{k_{-2}}{\overset{k_2}{\rightleftharpoons}} \mathrm{N_2O_4}$$

$$\mathrm{H_2O} + \mathrm{N_2O_4} \xrightarrow{k_3} \mathrm{HNO_2} + \mathrm{H^+} + \mathrm{NO_3^-}$$

{ Note: $k_1/k_{-1} = K_1$ and $k_2/k_{-2} = K_2$ }

A) $k_1k_2\,[\mathrm{HNO_2}]^2/[\mathrm{NO}]^2[\mathrm{H_2O}]$
B) $K_1k_3\,[\mathrm{NO}]^2[\mathrm{H_2O}]$
C) $K_1K_2k_3\,[\mathrm{HNO_2}]^4/[\mathrm{NO}]^2[\mathrm{H_2O}]$
D) $K_1K_2k_3\,[\mathrm{HNO_2}]/[\mathrm{NO}][\mathrm{H_2O}]$
E) $K_2k_3\,[\mathrm{HNO_2}]/[\mathrm{NO}]^2$

①

$$R = -\frac{d(H_2O)}{dt}$$

$$= k_3 [H_2O][N_2O_4]$$

$$K_2 = \frac{[N_2O_4]}{[NO_2]^2}$$

$$[N_2O_4] = K_2 [NO_2]^2$$

$$K_1 = \frac{[H_2O][NO][NO_2]}{[HNO_2]^2}$$

$$[NO_2] = K_1 \frac{[HNO_2]^2}{(H_2O)[NO]}$$

$$[N_2O_4] = K_2 [NO_2]^2$$

$$= K_1^2 K_2 \frac{[HNO_2]^4}{[H_2O]^2 (NO)^2}$$

$$R = k_3 (H_2O)(N_2O_4)$$

$$= K_1^2 K_2 k_3 [H_2O] \frac{[HNO_2]^4}{(H_2O)^2 (NO)^2}$$

$$= K_1^2 K_2 k_3 \frac{[HNO_2]^4}{(H_2O)[NO]^2}$$ Ⓒ

2. In a trimolecular gas-phase reaction [A(g) + B(g) + C(g) → TS(g) (TS = transition state)] the rate constant, k, is 3.44×10^5 M^{-2} s^{-1} at 55.0 °C and the entropy of activation, $\Delta S^{\neq}$, is -152 J K^{-1} mol^{-1}. What is the activation energy, E_a, according to transition state or activated complex theory?
   A) 0.152 J mol^{-1}

   B) 1.16 J mol^{-1}

   C) 4.16 kJ mol^{-1}

   D) 0.695 kJ mol^{-1}

   E) 0.695 J mol^{-1}

3. Transition state theory assumes an equilibrium between
   A) all reaction components except radicals
   B) stable intermediates
   C) activated complex and reactants
   D) reactants and products
   E) all reaction components even radicals

② tri molecular gas reactions

$$E_a = \Delta H^{\ddagger} + 3RT \qquad \Delta n_{gas} = \overset{1-3\ =\ -2}{\cancel{3 \to 2}}$$

$$\Delta U^{\ddagger} = \Delta H^{\ddagger} - \Delta n_{gas} RT$$

$$= \Delta H^{\ddagger} + 2RT$$

$$E_a = RT + \Delta U^{\ddagger} = \Delta H^{\ddagger} + 3RT$$

$$A = \frac{e^3 k_B T}{h (c^\circ)^2} e^{\Delta S^{\ddagger}/R}$$

$$\Delta S^{\ddagger}/R = -152 \frac{J}{K\,mol} \Big/ 8{,}314 \frac{J}{K\,mol} = -18{,}282$$

$$e^{\Delta S^{\ddagger}/R} = e^{-18{,}282} = 1{,}149 \cdot 10^{-8}$$

$$A = \frac{e^3 \; 1{,}381 \cdot 10^{-23}\, J/K \cdot 328{,}15\, K}{6{,}626 \cdot 10^{-34}\, Js \cdot 1\, M^2} \cdot 1{,}149 \cdot 10^{-8}$$

$$= 1.5784 \cdot 10^{6} \frac{1}{M^2 s}$$

$$k = A e^{-E_a/RT} \quad , \quad E_a = -RT \ln \frac{k}{A}$$

$$E_a = -8{,}314 \frac{J}{K\,mol} \cdot 328{,}15\, K \cdot \ln \frac{3{,}44 \cdot 10^{5} \frac{1}{M^2 s}}{1{,}5784 \cdot 10^{6} \frac{1}{M^2 s}}$$

$$= -2{,}728 \frac{kJ}{mol} \cdot \ln(0{,}2179)$$

$$= -2{,}728 \frac{kJ}{mol} \cdot (-1{,}5237)$$

$$= 4{,}15(7) \frac{kJ}{mol} = 4{,}16 \frac{kJ}{mol}$$

Ⓒ

③ condition for TS theory:

equilibrium between TS and reactants

ⓒ

4. The following free radical mechanism has been proposed for the thermal decomposition of acetaldehyde (ethanal):

$$CH_3CHO \xrightarrow{k_1} \bullet CH_3 + CHO$$

$$\bullet CH_3 + CH_3CHO \xrightarrow{k_2} CH_4 + \bullet CH_2CHO$$

$$\bullet CH_2CHO \xrightarrow{k_3} \bullet CH_3 + CO$$

$$\bullet CH_3 + \bullet CH_3 \xrightarrow{k_4} CH_3CH_3$$

Find an expression for the rate of formation of ~~m~~ethane (CH_3CH_3)

A) $(k_1/k_4)^{½}[CH_3CHO]^{½}$

B) $k_1k_2/k_3[CH_3CHO]^2$

C) $k_1/k_4[CH_3CHO]^{½}$

D) $k_1[CH_3CHO]$

E) $k_1[CH_3CHO]/[CH_3CH_3]$

5. What is the half-life of A in the following elementary reaction,

$$½ A \rightarrow P$$

when $[A]_o = 4.00$ M, $[P]_o = 0$ and the rate constant being $k = 1.21 \times 10^4$ $M^{1/2}$ s^{-1} ?

A) $\tau_{1/2} = 34.2$ μs

B) $\tau_{1/2} = 70.5$ μs

C) $\tau_{1/2} = 10.3$ μs

D) $\tau_{1/2} = 96.8$ μs

E) $\tau_{1/2} = 48.4$ μs

④

$$R = \frac{d[C_2H_6]}{dt} = k_4 (CH_3\cdot]^2$$

$$\frac{d[CH_3\cdot)}{dt} \overset{SSA}{=} 0 = k_1 [CH_3CHO) - k_2 [CH_3\cdot] [CH_3CHO] + k_3 [CH_2CHO\cdot] - 2k_4 [CH_3\cdot]^2 \quad (1)$$

$$\frac{d[CH_2CHO\cdot)}{dt} \overset{SSA}{=} 0 = k_2 [CH_3\cdot] [CH_3CHO) - k_3 [CH_2CHO\cdot) \quad (2)$$

(1) + (2) :

$$0 = k_1 [CH_3CHO) - 2k_4 [CH_3\cdot]^2$$

$$k_4 [CH_3\cdot]^2 = \cancel{\frac{k_4}{2k_4}}\ k_1 (CH_3CHO)$$

$$R = k_1 [CH_3CHO)$$

Ⓓ

Half-Life concept, Sections 5.2 and 5.4

5 What is the half-life of A in the following elementary reaction

½ A → P   k is the effective rate constant of the process

when $[A]_o = 4.00$ M, $[P]_o = 0$ and the rate constant being $k = 1.21 \times 10^4\ M^{1/2}\ s^{-1}$?

A) $\tau_{1/2} = 96.8\ \mu s$
B) $\tau_{1/2} = 48.4\ \mu s$
C) $\tau_{1/2} = 34.2\ \mu s$
D) $\tau_{1/2} = 70.5\ \mu s$
E) $\tau_{1/2} = 10.3\ \mu s$

rate: $\frac{1}{\nu_i}\frac{d[i]}{dt}$ $\nu_i = \frac{1}{2}$

but rate of consumption

$$v = \cancel{\frac{1}{\nu_i}} - \frac{d[A]}{dt} = k[A]^{1/2}$$

$$\frac{d[A]}{dt} = -\cancel{2}\,k[A]^{1/2} \qquad \int x^{-1/2}\,dx = 2x^{1/2} + c$$

$$\int_{[A]_o}^{[A]_o/2} \frac{d[A]}{[A]^{1/2}} = 2[A]^{1/2}\Big|_{[A]_o}^{[A]_o/2} = -\cancel{2}\,k\tau_{1/2}$$

$$\left(\frac{[A]_o}{2}\right)^{1/2} - [A]_o^{1/2} = -\frac{1}{2}k\tau_{1/2} \qquad \left(\frac{1}{\sqrt{2}} - 1\right)[A]_o^{1/2} = -\frac{1}{2}k\tau_{1/2}$$

$$\frac{1-\sqrt{2}}{\sqrt{2}}[A]_o^{1/2} = -\frac{1}{2}k\tau_{1/2} \qquad \tau_{1/2} = -2\,\frac{1-\sqrt{2}}{\sqrt{2}}\left(\frac{1}{k}\right)[A]_o^{1/2}$$

$$\tau_{1/2} = -\sqrt{2}(1-\sqrt{2})\,2\,\frac{1}{k}\sqrt{M} \qquad [A]_o = 4\,M$$

$$\tau_{1/2} = -2\sqrt{2}(1-\sqrt{2})\frac{1}{k}\sqrt{M}$$

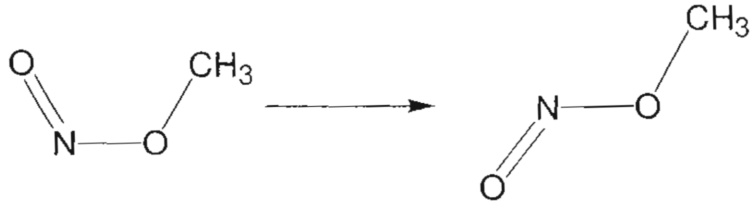
$$= 1,17157 \cdot \frac{1}{1,21 \cdot 10^4}\,s = 9,682 \cdot 10^{-5}\,s$$

$$= 96,8 \cdot 10^{-6}\,s = 96,8\,\mu s$$ Ⓐ Ⓓ in Version 1

K: effective rate constant of

$\frac{1}{2}A \rightarrow P$! $\Rightarrow$ $v = -\frac{d[A]}{dt} = k\sqrt{[A]}$

6. The compound CH_3-O-N=O has an internal rotation about the O-N bond as follows:



Cis Trans

The half-life of the first order disappearance of the cis form can be measured by NMR techniques. It is 1.00×10^{-6} sec at 25 °C. Assuming $\Delta S^{\neq} = 0$ for this reaction, calculate the height of the barrier to rotation.

A) 11.2 kJ/mol
B) -21.1 kJ/mol
C) 42.2 kJ/mol
D) 21.1 kJ/mol
E) -11.2 kJ/mol

7. For a reaction of a rate constant *k*. If all reactants have initial concentration *a* and concentration *x* at any time of an order of *n*, and its integrated rate equation is

$$\frac{1}{(n-1)\,x^{n-1}} = \frac{1}{(n-1)\,a^{n-1}} + kt$$

which of the following mathematical expression is the half-life, $t_{½}$,

A) $\frac{1}{(n-1)\,a^{n-1}}$

B) $\frac{2^{n-1}}{k\,a^{n-1}}$

C) $\frac{1}{(n-1)\,k\,a^{n-1}}$

D) $\frac{2^{n-1}-1}{(n-1)\,k}$

E) $\frac{2^{n-1}-1}{(n-1)\,k\,a^{n-1}}$

⑥ barrier height $= E_a$

1. order $\quad k = \frac{\ln 2}{\tau} = \frac{\ln 2}{1.00 \cdot 10^{-6} s} = 6,9315 \cdot 10^{5}\ s^{-1}$

$k = A\, e^{-E_a/RT} \qquad A = \frac{e k_B T}{h} \qquad \Delta S^{\ddagger} = 0$

$\Rightarrow e^{\Delta S^{\ddagger}/R} = 1$

$$A = \frac{e \cdot 1,381 \cdot 10^{-23}\ J/K \cdot 298,15\ K}{6,626 \cdot 10^{-34}\ Js} = 1,6892 \cdot 10^{13}\ \frac{1}{s}$$

$$E_a = -RT \ln \frac{k}{A} = -8,314 \frac{J}{K\ mol} \cdot 298,15\ K \ln \frac{6,9315 \cdot 10^{5}}{1,6892 \cdot 10^{13}}$$

$$= -2,4788 \frac{kJ}{mol} (-17,0115)$$

$$= 42.1(7) \frac{kJ}{mol} = 42,2 \frac{kJ}{mol}$$

Ⓒ

⑦

$$kt = \frac{1}{(n-1)x^{n-1}} - \frac{1}{(n-1)a^{n-1}}$$

$$t = t_{1/2} = \tau \implies x = \frac{a}{2}$$

$$k\tau = \frac{1}{(n-1)\left(\frac{a}{2}\right)^{n-1}} - \frac{1}{(n-1)a^{n-1}}$$

$$= \frac{2^{n-1}}{(n-1)a^{n-1}} - \frac{1}{(n-1)a^{n-1}}$$

$$= \frac{2^{n-1}-1}{(n-1)a^{n-1}}$$

$$\tau = \frac{2^{n-1}-1}{(n-1)ka^{n-1}}$$ Ⓔ

8. The thermal Decomposition of acetaldehyde vapor:

$$CH_3CHO \xrightarrow{k} CH_4 + CO$$

Is an irreversible process whose rate at 518 °C is given by the following two sets of data for pressure changes at constant temperature and volume

Initial Pressure of Acetaldehyde (mm Hg)	Total Pressure of the system after 100 sec (mm Hg)
400.0	500.0
300.0	360.0

Find the order of the decomposition process with respect to acetaldehyde.

A) 0
B) 2
C) 2.5
D) 1
E) 1.5

11. The isomerization of cyclopropane to propylene follows Lindemann kinetics:

$$A + A \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} A + A^*$$

$$A^* \xrightarrow{k_2} \text{Products}$$

so that the reaction process follow the rate law:

$$\frac{dP_A}{dt} = \frac{k_1 k_2 P_A^2}{(k_2 + k_{-1} P_A)}$$

where P_A is the reactant pressure. Calculate the ratio of the time for 1% of the propylene to isomerize at a given temperature if the initial pressure is 1 atm to the time for 1% to isomerize if the initial pressure is 1 x 10^{-2} atm. The values of k_1, k_{-1}, and k_2 are 1 x 10^{14} min^{-1} atm^{-1}, 1 x 10^{11} min^{-1} atm^{-1}, and 1 x 10^4 min^{-1}, respectively.

A) 10

B) 50

C) 100

D) 1

E) 20

$$\frac{\overset{1\%}{\cancel{\Delta P}}}{\underset{t_1}{\cancel{\Delta t}}} = \frac{k_1 k_2}{k_{-1}} P_A$$

$$\frac{t_2}{t_1} = \frac{P_{A1}}{P_{A2}} =$$

⑪ $$\frac{dP_A}{dt} = \frac{\Delta P_A}{\Delta t} = \frac{k_1 k_2 P_A^2}{k_{-1} P_A} = \frac{k_1 k_2}{k_{-1}} P_A$$

$$k_2 = 10^4\,\text{min}^{-1} << k_{-1} = 10^{11}\,\frac{1}{\text{min atm}}$$

ΔP_A is in both cases 1%

$$\Rightarrow R_1 = \frac{1\%}{\Delta t_1} \qquad R_2 = \frac{1\%}{\Delta t_2}$$

$$\frac{R_2}{R_1} = \frac{\Delta t_2}{\Delta t_1} = \frac{P_A(1)}{P_A(2)} = \frac{1\,\text{atm}}{0.01\,\text{atm}} = 100$$

Ⓔ

12. Consider the elementary reaction,

$$2A + B \xrightarrow{k} \tfrac{1}{2}Z$$

what is the rate of consumption of A, if $[A]_o = 2a_o$, $[B]_o = a_o$, $[Z]_o = 0$, and after time t, $[Z] = \tfrac{1}{2}x$?

A) $-\frac{d[A]}{dt} = -8k(a_o - x)^3$

B) $-\frac{d[A]}{dt} = 4k(a_o - x)^2$

C) $-\frac{d[A]}{dt} = 8k(a_o - x)^2$

D) $-\frac{d[A]}{dt} = 8k(a_o - x)^3$

E) $-\frac{d[A]}{dt} = 4k(a_o - x)^3$

13. Apply the steady state approximation to the intermediates B and C in the consecutive reaction sequence

$$A \xrightarrow{k_A} B \xrightarrow{k_B} C \xrightarrow{k_C} D$$

to obtain an expression for the concentration [D] as function of time, when initially $[A] = [A]_o$, and $[B]_o = [C]_o = [D]_o = 0$.

{ Note: $\int e^{ax}\,dx = \frac{1}{a} e^{ax} + C$, where C is the integration constant}

A) $[D] = \frac{k_A}{k_B}[A]_o(e^{-k_A t} - 1)$

B) $[D] = [A]_o(e^{-k_A t} - 1)$

C) $[D] = \frac{k_A}{k_B}[A]_o(e^{-k_B t} - e^{-k_A t})$

D) $[D] = \frac{k_A}{k_B}[A]_o(1 - e^{-k_A t})$

E) $[D] = [A]_o(1 - e^{-k_A t})$

⑫ $2A + B \rightarrow \frac{1}{2}Z$

$4A + 2B \rightarrow Z$

$$-\frac{1}{2}\frac{d[A]}{dt} = k[A^{\cancel{2}}]^2[B]$$

$$-\frac{d(A)}{dt} = 2k[A]^2[B]$$

$$\begin{array}{cccc} 4A & + \; 2B & \rightarrow & Z \\ 2a_0 - 2x & a_0 - x & & x/2 \end{array}$$

with $[A]_0 = 2a_0$, $[B]_0 = a_0$

$$-\frac{d(A)}{dt} = 2k\left[2(a_0 - x)\right]^2 (a_0 - x)$$

$$= 8k(a_0 - x)^3$$

Ⓓ

⑬

$$\frac{d[D]}{dt} = k_c [C)$$

$$\frac{d(C)}{dt} = 0 = k_B [B] - k_c [C) \rightarrow k_c [C] = k_B B$$

$$\frac{d(B)}{dt} = 0 = k_A (A) - k_B (B) \rightarrow k_B [B) = k_A (A)$$

$$\frac{d(D)}{dt} = k_A [A)$$

$$\frac{d(A)}{dt} = -k_A (A) \qquad \int_{(A)_0}^{(A)} \frac{d(A)}{[A]} = -k_A \int_0^t dt$$

$$\ln \frac{(A)}{(A)_0} = -k_A t \Rightarrow [A) = (A)_0 e^{-k_A t}$$

$$\frac{d(D)}{dt} = k_A [A]_0 e^{-k_A t}$$

$$[D] - \overset{\nearrow 0}{[D]_0} = k_A (A) \int_0^t e^{-k_A t} dt$$

$$= k_A (A)_0 \left(-\frac{1}{k_A}\right) \left(e^{-k_A t} - 1\right)$$

$$(D) = -(A)_0 \left(e^{-k_A t} - 1\right)$$

$$= (A)_0 \left(1 - e^{-k_A t}\right)$$

Ⓔ

14. The Steady State Approximation can be applied to a reaction intermediate if it reaches rapidly a concentration being constant in most of the reaction time, is much smaller than the reactant concentration, and

A) is formed slowly.
B) its concentration is constant but large compared to reactant concentrations.
C) is not reacting during the course of the reaction.
D) is consumed rapidly.
E) is present in a concentration much smaller than reactant concentrations but is not constant.

15. In an experiment (at 15 °C) on the reaction

$$NO + H_2 \longrightarrow N_2O + H_2O$$

the obtained data (v_o denotes the initial rate of consumption of NO) are

Run	$[NO]_o$ (mM)	$[H_2]_o$ (mM)	v_o (μM L^{-1} s^{-1})
1	12.8	4.4	52
2	25.6	4.4	200
3	12.8	9.0	102

What is the overall order of the reaction?

A) 2
B) 0
C) 4
D) 1
E) 3

⑭ p. 927

SSA good if intermediate decays fast Ⓓ ✓

~~and formed slowly Ⓐ~~

ERROR ~~both Ⓐ and Ⓓ are correct~~

~~B, C, E nonsense!~~

⑮ $V_0 = k[NO]^n[H_2]^m$

in 1 & 2 $(H_2)_0$ is the same

$$\rightarrow \frac{\text{Rate 1}}{\text{Rate 2}} = \frac{52}{200} = \left(\frac{12.8}{25.6}\right)^n \left(\frac{4.4}{4.4}\right)^m$$

$$0.26 = (0.5)^n$$

$$n = \frac{\ln 0.26}{\ln 0.5} = 1.94 = 2$$

$$\frac{\text{Rate 2}}{\text{Rate 3}} = \frac{200}{102} = \left(\frac{25.6}{12.8}\right)^2 \left(\frac{4.4}{9.0}\right)^m$$

$$1.96078 = 4 \cdot (0.4889)^m$$

$$\Rightarrow \ln 1.96078 = \ln 4 + m \ln 0.4889$$

$$m = \frac{\ln \frac{1.96078}{4}}{\ln \cancel{0.889}\ 0.4889} = 0.996 = 1$$

overall: 1 + 2 = 3 Ⓔ

16. The Pt-Catalyzed decomposition of HI obeys the following rate laws depending on the HI pressure:

$dP_{HI}/dt = k_1$, at high pressure, with $k_1 = 500$ mm Hg sec^{-1} at 100 °C,
$dP_{HI}/dt = k_2 P_{HI}$, at low pressure, with $k_2 = 50$ sec^{-1} at 100 °C.
Calculate the HI pressure at which the value of $dP_{HI}/dt = 250$ mm Hg sec^{-1}, at the same temperature.

A) 200 mm Hg
B) 0.1 mm Hg
C) 500 mm Hg
D) 50 mm Hg
E) 10 mm Hg

Langmuir $\theta = \frac{KP}{1+KP}$

$$R = \frac{dP_{HI}}{dt} = k_1 \theta \text{ at high } P$$

$$K = \left(\frac{k_1}{k_2}\right)^{-1} = \left(\frac{500 \text{ torr/s}}{50 \text{ s}^{-1}}\right)^{-1} = 10 \text{ torr}$$

$$= 0.1 \text{ torr}^{-1}$$

$$R = k_1 \frac{0.1 \text{ torr}^{-1} P}{1 + 0.1 \text{ torr}^{-1} P}$$

$$R(1 + 0.1 \text{ torr}^{-1} P) = k_1 0.1 \text{ torr}^{-1} P$$

$$(0.1 \text{ torr}^{-1} R - k_1 0.1 \text{ torr}^{-1}) P = -R$$

$$P = \frac{-250 \text{ torr/s}}{\frac{0.1}{\text{torr}} \cdot 250 \frac{\text{torr}}{\text{s}} - 500 \frac{\text{torr}}{\text{s}} \cdot 0.1 \text{ torr}^{-1}}$$

~~= 25~~

$$= \frac{-250 \text{ torr/s}}{25 \text{ 1/s} - 50 \text{ 1/s}} = 10 \text{ torr}$$ (E)

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STUDENT No. ____________________

SECTION No. ____________________

TEST ANSWER FORM

TESTING SERVICES SYSTEM

STUDENT NUMBER

SECTION NUMBER

TEST CODE No. 0 0 1

1

MARKING INSTRUCTIONS

DIRECTIONS:

Read each question and its numbered answers. When you have decided which answer is correct, blacken the corresponding oval on this form with a no. 2 pencil. Make no extra marks. They may be counted as incorrect answers. Erase incorrect answers fully before filling in correct answer.

DO NOT USE INK OR BALL POINT PEN

SAMPLE

1. RIYADH is:

A - a country *D - a city*
B - a mountain *E - a river*
C - an island

1 Ⓐ Ⓑ Ⓒ ● Ⓔ

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1 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
2 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
3 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
4 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
5 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
6 Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
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Question	Code	Answer
1	001	C ✓
2	001	C ✓
3	001	C ✓
4	001	D ✓
5	001	D ✓
6	001	C ✓
7	001	E ✓
8	001	B ✓
9	001	E ✓
10	001	E ✓
11	001	C ✓
12	001	D ✓
13	001	E ✓
14	001	D ✓
15	001	E ✓
16	001	E ✓
1	002	B
2	002	B
3	002	E
4	002	B
5	002	D
6	002	D
7	002	D
8	002	A
9	002	A
10	002	A
11	002	D
12	002	B
13	002	D
14	002	C
15	002	C
16	002	A

Question	Code	Answer
1	003	B
2	003	C
3	003	B
4	003	D
5	003	E
6	003	C
7	003	C
8	003	C
9	003	C
10	003	C
11	003	D
12	003	B
13	003	B
14	003	D
15	003	A
16	003	B
1	004	D
2	004	E
3	004	E
4	004	B
5	004	E
6	004	E
7	004	D
8	004	A
9	004	C
10	004	E
11	004	B
12	004	D
13	004	C
14	004	E
15	004	D
16	004	A