$\qquad$

Directions: (1) Put your name on PART 1 and PART 2 of the exam where indicated.
(2) Sign the Aggie Code on PART 2 of this exam.
(3) Each multiple choice question is actually 2 questions on your scanning sheet. If you are sure of an answer, put the same answer down for both questions for 5 pts. If you cannot decide between two answers, put your best answer down for the first (odd) question and the other answer down for the second (even) question. If you get the first one correct you'll get 3 pts; if you get the second one correct you'll get 2 pts. If there is an ambiguous multiple choice question, use the last page to explain your answer.
(4) Do NOT write on the envelope.
(5) When finished, put everything in the envelope and wait to be excused. At the table, take everything out of the envelope. You can pick up the multiple choice part with the answers outside my office after 3 pm .
(6) There are a total of 35 questions (19 actual questions).

## PART 1

1\&2. Which is the correct $K_{\mathrm{c}}$ expression for the equilibrium: $\left.\mathrm{CH}_{4}(\mathrm{~g}) \underset{\mathrm{C}}{\leftarrow} \mathrm{s}\right)+2 \mathrm{H}_{2}(\mathrm{~g})$ ?
(a) $K_{\mathrm{C}}=\frac{\left[\mathrm{H}_{2}\right]^{2}}{\left[\mathrm{CH}_{4}\right]}$
(b) $K_{\mathrm{c}}=\frac{[\mathrm{C}]\left[\mathrm{H}_{2}\right]^{2}}{\left[\mathrm{CH}_{4}\right]}$
(c) $K_{\mathrm{c}}=\frac{[\mathrm{C}]\left[2 \mathrm{H}_{2}\right]^{2}}{\left[\mathrm{CH}_{4}\right]}$
(d) $K_{\mathrm{c}}=\frac{2\left[\mathrm{H}_{2}\right]}{\left[\mathrm{CH}_{4}\right]}$
(e) $\frac{[\mathrm{C}] 2\left[\mathrm{H}_{2}\right]}{\left[\mathrm{CH}_{4}\right]}$

3\&4. This sketch represents which of the following situations where $: \quad$ is $A$ and $O$ is $B$.
(a) $2 \mathrm{~A} \underset{\leftarrow}{\rightleftarrows} \mathrm{~B}$
K >> 1
(b) $\mathrm{B}_{2} \underset{\leftarrow}{\leftarrow} \mathrm{~A}$
$K \ll 1$
(c) $B \underset{\leftarrow}{\rightleftarrows} A_{2}$
K >> 1
(d) $A_{2} \underset{ }{\leftarrow} B$
K <<1
(e) $A \stackrel{B}{\leftarrow} B_{2}$
$K \ll 1$


5\&6. The rate law for the chemical reaction, $5 \mathrm{Br}^{-}+\mathrm{BrO}_{3}^{-}+6 \mathrm{H}^{+} \rightarrow 3 \mathrm{Br}_{2}+3 \mathrm{H}_{2} \mathrm{O}$ has been determined experimentally to be:

$$
\frac{-\Delta\left[\mathrm{BrO}_{3}^{-}\right]}{\Delta \mathrm{t}}=\mathrm{k}\left[\mathrm{Br}^{-}\right]\left[\mathrm{BrO}_{3}^{-}\right]\left[\mathrm{H}^{+}\right]^{2}
$$

The reaction order with respect to the bromide ion is
(a) 1
(b) 2
(c) 6
(d) $\mathrm{k}\left[\mathrm{H}^{+}\right]^{2}$
(e) $\mathrm{k}\left[\mathrm{Br}^{-}\right]\left[\mathrm{BrO}_{3}^{-}\right]\left[\mathrm{H}^{+}\right]^{2}$

7\&8. If a reaction has a slightly negative $\Delta \mathrm{G}$, like $\Delta \mathrm{G}=-50 \mathrm{~J}$, the reaction will occur:
(a) slowly.
(b) rapidly.
(c) with a high activation energy.
(d) with a low activation energy.
(e) It is impossible to know from the $\Delta \mathrm{G}$ information.

9\&10. The principal reason for the increase in reaction rate with increasing temperature is:
(a) the activation energy increases with increasing temperature.
(b) molecules increase in size at high temperature.
(c) the activation energy decreases with increasing temperature.
(d) the fraction of high energy molecules increases with increasing temperature.
(e) the pressure exerted by reactant molecules increases with increasing temperature.

11\&12. Which CANNOT be true for the 1 step reaction: $\mathrm{N}=\mathrm{O}+\mathrm{N}=\mathrm{N}=\mathrm{O} \rightarrow \mathrm{O}=\mathrm{N}-\mathrm{O}+\mathrm{N} \equiv \mathrm{N}$ ?
(a) Rate $=\mathrm{k}[\mathrm{NO}]\left[\mathrm{N}_{2} \mathrm{O}\right]$
(b) The rate determining step is a bimolecular collision.
(c) The oxygen atom in NO must collide with the N in $\mathrm{N}_{2} \mathrm{O}$ for an effective collision.
(d) As temperature increases, the rate of the reaction increases.
(e) All the statements are true.

13\&14. Which of the following statements is/are TRUE concerning the action of catalysts?
(1) Catalysts participate in the reaction.
(2) Their presence do not change the mechanism of the reaction.
(3) The activation energy of the rate-determining step is raised and the reaction speeds up.
(a) 1,2
(b) 1 only
(c) 1,3
(d) 1,2,3
(e) none of these

15\&16. The $\Delta \mathrm{H}(=\Delta \mathrm{E})$ for a reaction is -55 kJ . The activation energy for the reverse reaction is 200 kJ . What is the activation energy for the forward reaction? It might be helpful to sketch the potential energy diagram.
(a) +145 kJ
(b) +255 kJ
(c) -255 kJ
(d) -145 kJ
(e) +55 kJ

17\&18. Rate data were collected for the following reaction at a particular temperature. What is rate law expression?

$$
\mathrm{A}(\mathrm{~g})+2 \mathrm{~B}(\mathrm{~g}) \rightarrow \mathrm{C}(\mathrm{~g})+2 \mathrm{D}(\mathrm{~g})
$$

| Experiment | $[\mathrm{A}]_{\text {jintial }}$ | $[\mathrm{B}]_{\text {linitial }}$ | Initial Rate of Reaction |
| :---: | :---: | :---: | :---: |
| 1 | 0.10 M | 0.10 M | $0.020 \mathrm{M} / \mathrm{s}$ |
| 2 | 0.20 M | 0.10 M | $0.080 \mathrm{M} / \mathrm{s}$ |
| 3 | 0.20 M | 0.20 M | $0.160 \mathrm{M} / \mathrm{s}$ |

(a) Rate $=k[A][B]$
(b) Rate $=k[A]^{2}[B]^{2}$
(c) Rate $=\mathrm{k}[\mathrm{A}][\mathrm{B}]^{2}$
(d) Rate $=k[A]^{2}[B]^{3}$
(e) Rate $=k[A]^{2}[B]$

19\&20. At $445^{\circ} \mathrm{C}$, the value for $\mathrm{K}_{\mathrm{c}}$ for the following reaction is $49: \mathrm{H}_{2}(\mathrm{~g})+\mathrm{I}_{2}(\mathrm{~g}) \underset{\mathrm{H}}{\rightleftarrows} \mathrm{HI}(\mathrm{g})$ A mixture of $\mathrm{H}_{2}, \mathrm{I}_{2}$ and HI in a vessel has the following concentrations:

$$
\left[\mathrm{H}_{2}\right]=0.10 \mathrm{M} \quad\left[\mathrm{I}_{2}\right]=0.010 \mathrm{M} \quad[\mathrm{HI}]=0.50 \mathrm{M}
$$

Which one of the following statements concerning the reaction quotient, $Q_{c}$, is TRUE for the above system?
(a) $Q_{c}=K_{c}$; and the system is at equilibrium.
(b) $\mathrm{Q}_{\mathrm{c}}=0.0040$; more HI will be produced as the system proceeds to equilibrium.
(c) $Q_{c}=0.0040$; more $\mathrm{H}_{2}$ and $\mathrm{I}_{2}$ will be produced as the system proceeds to equilibrium.
(d) $Q_{c}=250$; more HI will be produced as the system proceeds to equilibrium.
(e) $Q_{c}=250$; more $H_{2}$ and $I_{2}$ will be produced as the system proceeds to equilibrium

21\&22. Cyclobutane, $\mathrm{C}_{4} \mathrm{H}_{8}$, converts to ethylene, $\mathrm{C}_{2} \mathrm{H}_{4}$, by first order kinetics with half-life of $1.33 \times 10^{-4} \mathrm{~min}$ at $1000^{\circ} \mathrm{C}$. What percentage of cyclobutane will be converted to products after 0.035 s ?

$$
\mathrm{C}_{4} \mathrm{H}_{8} \rightarrow 2 \mathrm{C}_{2} \mathrm{H}_{4}
$$

(a) $31 \%$
(b) $8.1 \%$
(c) $4.3 \%$
(d) $95.2 \%$
(e) $92.1 \%$

23\&24. Consider the following equilibrium at $200^{\circ} \mathrm{C}: X+Y \underset{\leftarrow}{\rightleftarrows} 2 Z$, with a $\mathrm{K}_{\mathrm{c}}$ of 0.16 . Initially, there is 3.00 M of $Z$ in the container. What is the concentration of $Z$ in the container after the system has reached equilibrium?
(a) 0.10 M
(b) 1.20 M
(c) 0.50 M
(d) 0.30 M
(e) 2.80 M

25\&26. Consider the reaction: $X \rightarrow Y$. What is the activation energy for the forward reaction (in $k J$ ) when the rate constant at $10^{\circ} \mathrm{C}$ is $0.125 \mathrm{~min}^{-1}$ and the rate constant at $60^{\circ} \mathrm{C}$ is $2.11 \mathrm{~min}^{-1}$ ?
$\ln \left(\frac{k_{2}}{k_{1}}\right)=-\frac{E_{a}}{R}\left(\frac{1}{T_{2}}-\frac{1}{T_{1}}\right) \quad$ or $\ln \left(\frac{k_{2}}{k_{1}}\right)=\frac{E_{a}}{R}\left(\frac{T_{2}-T_{1}}{T_{1} T_{2}}\right) \quad$ or $\ln \left(\frac{k_{2}}{k_{1}}\right)=\frac{E_{a}}{R}\left(\frac{1}{T_{1}}-\frac{1}{T_{2}}\right) \quad R=8.314 \mathrm{~J} / \mathrm{mol} \cdot \mathrm{K}$
(a) 2.1 kJ
(b) 15.9 kJ
(c) 30.7 kJ
(d) 42.9 kJ
(e) 51.8 kJ

27\&28. Estimate the sublimation temperature of solid sodium, Na , given the following data from thermodynamic tables. Assume that $\Delta H_{\mathrm{f} 298}^{\circ}$ and $S^{\circ}$ do not change with temperature:

$$
\mathrm{Na}(\mathrm{~s}) \stackrel{\mathrm{Na}(\mathrm{~g})}{\leftarrow}
$$

|  | $\Delta H_{\mathrm{f} 298}^{\circ}(\mathrm{kJ} / \mathrm{mol})$ | $S^{o}(\mathrm{~J} / \mathrm{mol} \cdot \mathrm{K})$ | $\Delta G_{\mathrm{f} 298}^{\circ}(\mathrm{kJ} / \mathrm{mol})$ |
| :---: | :---: | :---: | :---: |
| $\mathrm{Na}(\mathrm{s})$ | 0 | 51.5 | 0 |
| $\mathrm{Na}(\mathrm{g})$ | 107.3 | 153.8 | 76.8 |

(a) $335^{\circ} \mathrm{C}$
(b) $776^{\circ} \mathrm{C}$
(c) $515^{\circ} \mathrm{C}$
(d) $1^{\circ} \mathrm{C}$
(e) $495^{\circ} \mathrm{C}$

29\&30. Calculate $\Delta \mathrm{G}^{\circ}$ for the following reaction at $25^{\circ} \mathrm{C}$ in kJ :

$$
\begin{gathered}
\mathrm{N}_{2}(\mathrm{~g})+\mathrm{O}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{NO}(\mathrm{~g}) \\
\text { at } 25^{\circ} \mathrm{C}, \Delta \mathrm{H}_{\mathrm{rxn}}{ }^{\circ}=+180.5 \mathrm{~kJ} \text { and } \Delta \mathrm{S}_{\mathrm{rxn}}{ }^{\circ}=+24.9 \mathrm{~J} / \mathrm{K}
\end{gathered}
$$

(a) -173.1 kJ
(b) +173.1 kJ
(c) +155.3 kJ
(d) -78.3 kJ
(e) +30.4 kJ

31\&32. For the reaction: $\mathrm{N}_{2}(\mathrm{~g})+\mathrm{O}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{NO}(\mathrm{g}) \quad$ at $25^{\circ} \mathrm{C}, \Delta \mathrm{H}_{\mathrm{rxn}}{ }^{\circ}=+180.5 \mathrm{~kJ}$ and $\Delta \mathrm{S}_{\mathrm{rxn}}{ }^{\circ}=+24.9 \mathrm{~J} / \mathrm{K}$ Which of the following statements is TRUE? The reaction
(a) is spontaneous at all temperatures.
(b) is nonspontaneous at all temperatures.
(c) will become spontaneous at higher temperatures.
(d) will become spontaneous at lower temperatures.
(e) Nothing can be said about the spontaneity of a reaction from the values of $\Delta \mathrm{H}^{\circ}$ and $\Delta \mathrm{S}^{\circ}$ only.

CHEMISTRY 102
EXAM 2

FALL 2010
Section 501

NAME $\qquad$
(Please Block Print)

Form B

## PART 2

Please read and sign: "On my honor, as an Aggie, I have neither given nor received unauthorized aid on this exam."
33. Consider the following gas phase reaction: $2 \mathrm{C}+\mathrm{D} \rightarrow \mathrm{G}$.

The experimentally-derived rate-law expression is: Rate $=k[D]^{2}$.
For each mechanism below, write the rate-law expression that fits it and state whether or not that mechanism could be the correct one. Show your work for Part (c) - I want to know that you understand how the equilibrium constant works into the problem.
(2 pts)
(a) Step $1 \quad 2 \mathrm{D} \rightarrow \mathrm{X} \quad$ slow

Step $2 \quad X+C \rightarrow Y+D$ fast
Step $3 \quad Y+C \rightarrow G \quad$ fast
Overall $\quad 2 \mathrm{C}+\mathrm{D} \rightarrow \mathrm{G}$
(2 pts)
(b) Step $1 \quad \mathrm{C}+\mathrm{D} \rightarrow \mathrm{F}$ slow

Step $2 \quad \mathrm{~F}+\mathrm{C} \rightarrow \mathrm{G}$ fast
Overall $\quad 2 \mathrm{C}+\mathrm{D} \rightarrow \mathrm{G}$
(4 pts)
(c) Step $1 \quad \mathrm{D}+\mathrm{X} \underset{\leftarrow}{\rightleftarrows} \quad$ fast equilibrium

Step $2 \quad \mathrm{Y}+\mathrm{C} \rightarrow \mathrm{Z}$ slow
Step $3 \quad Z+C \rightarrow G+X$ fast
Overall $\quad 2 \mathrm{C}+\mathrm{D} \rightarrow \mathrm{G}$
(1 pt) (d) In mechanism (c), what is/are the intermediate(s) (if any): $\qquad$
(1 pt) In mechanism (c), what is the catalyst (if any): $\qquad$
OVER $\Rightarrow$
(3 pts) 34. Consider the equilibrium: $2 \mathrm{~A}(\mathrm{~g}) \underset{\mathrm{l}}{\rightleftarrows} 4 \mathrm{~B}(\mathrm{~g})$ with $\mathrm{K}_{\mathrm{c}}=9$.
Calculate the equilibrium constant for $2 \mathrm{~B}(\mathrm{~g}) \stackrel{\mathrm{A}(\mathrm{g})}{\rightleftarrows}$
(4 pts) 35. Consider the equilibrium: $\mathrm{W}(\mathrm{g}) \stackrel{\mathrm{Y}}{\mathrm{g}} \mathrm{g})+2 \mathrm{Z}(\mathrm{g})$
The reaction as written is strongly endothermic. Predict how the following changes will affect the moles of $Y$ at equilibrium,
The possible answers are: increase (I), decrease (D), or remain unchanged (U)

|  | Moles of $\mathbf{Y}$ |
| :--- | :--- |
| (a) The concentration of $\mathbf{Z}$ is increased. |  |
| (b) The temperature is decreased. |  |
| (c) $A$ catalyst is introduced. |  |
| (d) The volume of the container is halved. |  |

(3 pt) Explain briefly how changing temperature will affect the value of $\mathrm{K}_{\mathrm{c}}$ for this reaction?

## SCRAP PAPER OR COMMENTS ON EXAM

| CHEMISTRY 102 | Fall 2010 | NAME |  |
| :--- | :--- | :--- | :--- |
| EXAM 2 | Form B | S 501 |  |

