PART 1

1&2. Which is the correct $K_c$ expression for the equilibrium: $2C(s) + O_2(g) \rightleftharpoons 2CO(g)$?

(a) $K_c = \frac{2[CO]}{[C][O_2]}$  
(b) $K_c = \frac{[C]^2[O_2]}{[CO]^2}$  
(c) $K_c = \frac{[CO]^2}{[C]^2[O_2]}$  
(d) $K_c = \frac{[CO]^2}{[O_2]}$  
(e) $K_c = \frac{[O_2]}{[CO]^2}$

3&4. Consider the following rate law expression for the reaction: $X + 2Y \rightarrow 2Z$

$\text{Rate} = k[X]^2[Y]$  

The reaction is

(a) first order with respect to $X$, first order with respect to $Y$ and second order overall.  
(b) second order with respect to $X$, first order with respect to $Y$ and third order overall.  
(c) second order with respect to $X$, second order with respect to $Y$ and second order overall.  
(d) first order with respect to $X$, second order with respect to $Y$ and third order overall.  
(e) It is impossible to determine the order of the reaction from the information given.

5&6. The units of the specific rate constant for a reaction that is second order overall is _________.

(a) $M^{-3}\text{ s}^{-1}$  
(b) $M^{-2}\text{ s}^{-1}$  
(c) $M^{-1}\text{ s}^{-1}$  
(d) $\text{ s}^{-1}$  
(e) $M\text{ s}^{-1}$
The equilibrium constant for the gas phase reaction \( A ightleftharpoons B \) is \( 4.0 \times 10^{-13} \).

Which of the following is TRUE?

(a) If only A is added to a container, most of it will convert to B.
(b) Adding a catalyst will increase the value of the equilibrium constant.
(c) Adding more A will increase the value of the equilibrium constant.
(d) Changing the temperature will change the value of the energy of activation for the forward reaction.
(e) The equilibrium concentration of A is greater than that of B.

Consider the gaseous system: \( 2CO + O_2 \rightleftharpoons 2CO_2 \) with \( K_c = 3.0 \times 10^3 \)

What is the value of \( K_c \) for \( 4CO_2 \rightleftharpoons 4CO + 2O_2 \) at the same temperature?

(a) \( 3.0 \times 10^3 \)  (b) 11  (c) 0.54  (d) \( 3.3 \times 10^{-4} \)  (e) \( 1.1 \times 10^{-7} \)

Consider the gaseous system: \( 2CO + O_2 \rightleftharpoons 2CO_2 \) with \( \Delta H^0 = -599 \text{ kJ/mol rxn} \)

Which of the following will cause an increase in the number of moles of CO?

(a) Decreasing the volume of the system at constant temperature.
(b) Adding more oxygen gas to the system.
(c) Removing carbon dioxide from the system as it is formed.
(d) Increasing the temperature of the system.
(e) Adding a catalyst.
13&14. The **principal** reason for the increase in reaction rate with increasing temperature is:

(a) the pressure exerted by reactant molecules increases with increasing temperature.
(b) the activation energy increases with increasing temperature.
(c) the fraction of high energy molecules increases with increasing temperature.
(d) molecules increase in size at high temperatures.
(e) the activation energy decreases with increasing temperature.

15&16. Rate data were collected for the following reaction at a particular temperature. What is the value of the specific rate constant?

\[
\text{NO}_2(g) + \text{CO}(g) \rightarrow \text{NO}(g) + \text{CO}_2(g)
\]

<table>
<thead>
<tr>
<th>Experiment</th>
<th>[NO\textsubscript{2}]\text{initial}</th>
<th>[CO]\text{initial}</th>
<th>Initial Rate of Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.10 M</td>
<td>0.10 M</td>
<td>0.0050 M/s</td>
</tr>
<tr>
<td>2</td>
<td>0.40 M</td>
<td>0.10 M</td>
<td>0.080 M/s</td>
</tr>
<tr>
<td>3</td>
<td>0.10 M</td>
<td>0.20 M</td>
<td>0.0050 M/s</td>
</tr>
</tbody>
</table>

(a) 0.50 M\textsuperscript{-1}\cdot s\textsuperscript{-1} (b) 0.0050 M\textsuperscript{-1}\cdot s\textsuperscript{-1} (c) 0.055 s\textsuperscript{-1}
(d) 50. M\textsuperscript{2}\cdot s\textsuperscript{-1} (e) 5.0 M\textsuperscript{-1}\cdot s\textsuperscript{-1}
17&18. Consider this equilibrium at a temperature in which the $K_c = 25$.

$$H_2(g) + I_2(g) \rightleftharpoons 2 \text{HI}(g)$$

Initially in the container there is 0.40 M of HI. At equilibrium, what is the concentration of $H_2$?

(a) 0.032 M (b) 0.057 M (c) 0.071 M (d) 0.015 M (e) 0.048 M

19&20. Calculate $\Delta G^0$ for the reaction at 25°C if the value of the thermodynamic equilibrium constant, $K_{\text{thermo}}$ is $2.47 \times 10^{-29}$.

$$\frac{3}{2} \text{O}_2(g) \rightleftharpoons \text{O}_3(g)$$

$R = 8.314 \text{ J/mol} \cdot \text{K}$

(a) +163 kJ/mol rxn (b) −163 kJ/mol rxn (c) −13.7 kJ/mol rxn (d) +13.7 kJ/mol rxn (e) +1.61 kJ/mol rxn
21&22. What is the half-life of the following reaction if after 6.00 days only 2.50 g of a 50.0 g sample of CS$_2$ remains at a certain temperature? The decomposition reaction is first order.

$$\text{CS}_2 \rightarrow \text{CS} + \text{S}$$

(a) 0.223 d  (b) 1.39 d  (c) 0.785 d  (d) 0.174 d  (e) 1.48 d

23&24. Consider the gas phase equilibrium system: $\text{C} \rightleftharpoons \text{D} + 2\text{X}$. Initially in the 10.0 L container we have 1.00 mole of C, D and X. When the system is at equilibrium, there are 2.00 moles of X in the container. Calculate $K_c$.

(a) 0.33  (b) 2.7  (c) 0.67  (d) 1.3  (e) 0.12
PART 2

Please read and sign: “On my honor, as an Aggie, I have neither given nor received unauthorized aid on this exam.”

(1 pt) **25.** I want my OWL to count _____% of an exam grade (Choose any number between 20% and 100%). (extra credit)

(3 pts) **26.** (a) Consider this system at equilibrium: \(2A(g) \rightleftharpoons B(g)\). Write the \(K_c\) expression.

(1 pt) (b) Suppose that the value of \(K_c \gg 1\), will there be a lot more products or reactants at equilibrium?

(3 pts) (c) Sketch a picture of the final equilibrium mixture when \(K_c \gg 1\) when A is represented by \(\bigcirc\) and B is represented by \(\bullet\).
27. Consider the following 2 step mechanism for a gas phase reaction. In the first step, a molecule of X collides with a molecule of Y to form a molecule of A. In the second step, a molecule of A collides with a molecule of Y to form a molecule of X and a molecule of B.

(a) Write out the mechanism and the overall reaction.

(b) Identify the catalyst (if any): _______
   Identify the intermediate (if any): _______

(c) Write the rate law expression for this mechanism if the first step is the slow step.

(d) Write the rate law expression for this mechanism if the first step is a fast equilibrium step and the second step is the slow step. (Remember: show all your work to get full credit.)
28. (a) Consider the reaction: \( A \rightarrow B \). What is the activation energy for the forward reaction (in kJ) when the rate constant at 20°C is 0.0850 min\(^{-1}\) and the rate constant at 50°C is 1.34 min\(^{-1}\)?

\[
\log \left( \frac{k_2}{k_1} \right) = \frac{E_a}{2.303R} \left( \frac{T_2 - T_1}{T_1 T_2} \right)
\]

or

\[
\ln \left( \frac{k_2}{k_1} \right) = \frac{E_a}{R} \left( \frac{T_2 - T_1}{T_1 T_2} \right)
\]

\( R = 8.314 \text{ J/mol} \cdot \text{K} \)

(b) The \( \Delta H = \Delta E \) for this reaction is \(-40.0 \text{ kJ}\). Draw the potential energy diagram for this reaction using the answer for part (a). If you were unable to do the calculation, assume that the activation energy for the forward reaction is 150. kJ. Label the axes correctly.

(c) Determine the activation energy for the reverse reaction.
29. Consider the gas phase equilibrium system: \( 2X \rightleftharpoons Y \) in a 1.00 L container at 250°C. The equilibrium concentrations were determined to be:

\[
\begin{align*}
[X]_{eq} &= 0.10 \text{ M} \\
[Y]_{eq} &= 0.40 \text{ M}
\end{align*}
\]

(a) Calculate \( K_c \) for the equilibrium.

(b) How many moles of \( Y \) must be added to the container to increase the concentration of \( X \) to 0.12 M?

30. Consider the following one-step reaction: \( \text{SO} + \text{CO} \rightarrow \text{S} + \text{CO}_2 \), in which all the molecules are linear. What is necessary to have an effective collision? Illustrate your answer with a drawing.