Directions: (1) Put your name (neatly) and signature on both parts of the exam where indicated. (2) 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 one answer down for one question and the other answer down for the other question. If you get one correct you’ll get half credit for 2.5 pts. If there is an ambiguous multiple choice question, use the last page to explain your answer. (3) Do NOT write on the envelope. (4) When finished, put both parts of the exam in the envelope with the scanning sheet. You can leave during announced times. You can pick up your multiple choice and answers outside my office after the exam. (5) There are a total of 54 questions (29 actual questions).

**PART 1**

**1&2.** Which is the correct $K_c$ expression for the equilibrium: $[\text{Co(CO)}_4]_2(\text{s}) \rightleftharpoons 2\text{Co(s)} + 8\text{CO(g)}$?

(a) $K_c = [\text{CO}]^8$  
(b) $K_c = \frac{[\text{Co(CO)}_4]_2}{[\text{Co}]^2[\text{CO}]^8}$  
(c) $K_c = \frac{[\text{CO}]^8}{[\text{Co(CO)}_4]_2}$

(d) $K_c = \frac{2[\text{Co}] + 8[\text{CO}]}{[\text{Co(CO)}_4]_2}$  
(e) $K_c = \frac{[\text{Co}]^2[\text{CO}]^8}{[\text{Co(CO)}_4]_2}$

**3&4.** Which of the following elemental formulas could be the one for 2,3-dimethylpentane?

(a) $\text{C}_5\text{H}_{12}$  
(b) $\text{C}_6\text{H}_{12}$  
(c) $\text{C}_6\text{H}_{14}$  
(d) $\text{C}_7\text{H}_{14}$  
(e) $\text{C}_7\text{H}_{16}$

**5&6.** Which of the following salts is the MOST soluble?

(a) $\text{CdCO}_3$  
(b) $\text{CoCO}_3$  
(c) $\text{AgCl}$  
(d) $\text{PbCrO}_4$  
(e) $\text{ZnCO}_3$
7&8. Which of the following statements is FALSE?

(a) $\Delta H$ is a state function.
(b) Some spontaneous processes are endothermic.
(c) Exothermic processes are those with $\Delta H < 0$.
(d) $\Delta G$ represents the free energy change for a process.
(e) Entropy alone determines the spontaneity of a reaction.

9&10. Consider the conversion of a substance between solid and liquid: solid $\leftrightarrow$ liquid.
When the two phases are in equilibrium at one atmosphere pressure and at the melting point of the substance,

(a) $\Delta H = 0$ for the process.
(b) $\Delta E = 0$ for the process.
(c) $\Delta S = 0$ for the process.
(d) $\Delta G = 0$ for the process.
(e) both (a) and (b)

11&12. Which functional group is NOT present in this compound?

(a) alcohol  (b) ether  (c) amide  (d) ketone  (e) aldehyde

13&14. Consider the gas-phase equilibrium system represented by the equation:

$$2 \text{CO} + \text{O}_2 \rightleftharpoons 2 \text{CO}_2$$

Given that the conversion of reactants to products is exothermic, as written, which of the following changes will increase the equilibrium amount of CO$_2$?

(a) decreasing the pressure (increasing the volume) at constant temperature
(b) cooling the system at constant pressure
(c) removing oxygen
(d) adding a catalyst
(e) none of these
15&16. Of the following species, which is the STRONGEST reducing agent?

(a) V  (b) Sn^{2+}  (c) Au^{3+}  (d) Cu  (e) Co^{2+}

17&18. For electrolysis of molten calcium chloride with the following observations, which of the following statements is incorrect?

Observation #1: Bubbles of pale green chlorine gas are produced at one electrode
Observation #2: Silvery while molten calcium metal is produced at the other electrode.

(a) The chlorine gas is produced at the electrode where oxidation is occurring.
(b) Electrons will flow through the external circuit from the anode to the cathode.
(c) Reduction occurs at the electrode where Ca metal is being produced.
(d) The electrode where chlorine gas is produced is negatively charged.
(e) Reaction at the anode: \( \text{Ca} \rightarrow \text{Ca}^{2+} + 2e^- \).

19&20. Consider 0.1 M solutions of the following weak acids:

\[
\begin{align*}
\text{CH}_3\text{COOH} & \quad K_a = 1.8 \times 10^{-5} \\
\text{HCN} & \quad K_a = 4.0 \times 10^{-10}
\end{align*}
\]

Which of the following statements is NOT correct?

(a) Acetic acid is a stronger acid than hydrocyanic acid.
(b) \([\text{CN}^-]\) in HCN solution > \([\text{CH}_3\text{COO}^-]\) in CH\(_3\)COOH solution.
(c) The concentration of OH\(^-\) ions is greater in the HCN solution.
(d) The pH of the CH\(_3\)COOH solution is lower than the pH of the HCN solution.
(e) \([\text{H}^+]\) in CH\(_3\)COOH solution > \([\text{H}^+]\) in HCN solution.
21&22. A particular reaction \( A + 2B \rightarrow C + 3D \) absorbs 45 kJ of heat and has an activation energy for the forward reaction of 60 kJ. Sketch a potential energy diagram for this reaction. What is the activation energy for the reverse reaction?.

(a) 45 kJ  (b) 30 kJ  (c) 15 kJ  (d) 60 kJ  (e) 105 kJ

23&24. Consider the gas phase reaction: \( 2C + D \rightarrow C_2D \), which occurs by the following mechanism:

<table>
<thead>
<tr>
<th>Step</th>
<th>Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>( C + C \rightarrow C_2 ) (slow)</td>
</tr>
<tr>
<td>2</td>
<td>( C_2 + D \rightarrow C_2D ) (fast)</td>
</tr>
<tr>
<td>Overall</td>
<td>( 2C + D \rightarrow C_2D )</td>
</tr>
</tbody>
</table>

The rate law expression must be \( \text{Rate} = \underline{\text{_______}} \).

(a) \( k[D] \)  (b) \( k[C]^2[D] \)  (c) \( k[C][D] \)  (d) \( k[C]^2 \)  (e) \( k[C] \)

25&26. What is the pH of a \( 3.1 \times 10^{-3} \) M HCl?

(a) 2.35  (b) 2.51  (c) 2.72  (d) 3.01  (e) 3.17

27&28. What is the enthalpy change of the reaction below at 298 K and 1 atm pressure?

\[
\begin{array}{cccccc}
\text{CO}_2(g) & + & 2\text{H}_2\text{S}(g) & \rightarrow & \text{CS}_2(l) & + & 2\text{H}_2\text{O}(l) \\
\Delta H_{f298} ^o \text{(kJ/mol)} & & -394.0 & -20.2 & +89.5 & & -286.0 \\
\end{array}
\]

(a) \(-472.5 \) kJ  (b) \(-68.3 \) kJ  (c) \(-896.7 \) kJ  (d) \(-264.1 \) kJ  (e) \(-48.1 \) kJ

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29&30. Rate data were collected for the following reaction at a particular temperature. What is the correct rate law expression?

\[ A + 2B \rightarrow C + 3D \]

<table>
<thead>
<tr>
<th>Experiment</th>
<th>([A]_{\text{initial}})</th>
<th>([B]_{\text{initial}})</th>
<th>Initial Rate of Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.10 M</td>
<td>0.40 M</td>
<td>0.0090 M/min</td>
</tr>
<tr>
<td>2</td>
<td>0.20 M</td>
<td>0.40 M</td>
<td>0.036 M/min</td>
</tr>
<tr>
<td>3</td>
<td>0.10 M</td>
<td>0.20 M</td>
<td>0.0045 M/min</td>
</tr>
</tbody>
</table>

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

31&32. Consider the equilibrium at a certain temperature: \(H_2(g) + I_2(g) \rightleftharpoons 2HI(g)\) \(K_c = 63.0\)

If 2.00 mol of HI are placed in a 1.00 L container, what is the concentration of HI at equilibrium?

(a) 1.60 M  
(b) 1.86 M  
(c) 0.85 M  
(d) 0.27 M  
(e) 0.51 M
33&34. How many grams of iron can be plated out at the cathode if a solution of FeSO₄ is electrolyzed by a current of 1.00 amp for 30.0 minutes, if the electrode efficiency is only 75.0%?

(a) 0.391 g  (b)  1.04 g  (c)  0.535 g  (d)  838 g  (e)  16.6 g

35&36. For the following reaction at 25°C, \( \Delta H^\circ = -35.9 \text{ kJ} \) and \( \Delta S^\circ = +446 \text{ J/K} \).
Calculate \( \Delta G^\circ \) for the reaction at 25°C in kJ.

\[
\text{NH}_4\text{NO}_3(s) \rightarrow \text{N}_2\text{O(g)} + 2 \text{H}_2\text{O(g)}
\]

(a) −169 kJ  (b) +97. kJ  (c) −24.8 kJ  (d) +10.7 kJ  (e) +47.1 kJ
37&38. Calculate the pH after 135 mL of 0.100 M HCl has been added to 100.0 mL of 0.200 M methylamine.

(a) 10.12  (b) 9.53  (c) 10.38  (d) 8.63  (e) 10.70

39&40. What concentration of Pb\(^{2+}\) will initiate precipitation in a solution that is 0.10 M NaCl?

(a) \(1.7 \times 10^{-2}\) M  (b) \(1.7 \times 10^{-5}\) M  (c) \(1.7 \times 10^{-7}\) M

(d) \(1.7 \times 10^{-3}\) M  (e) \(1.7 \times 10^{-4}\) M
41&42. What is the pH of a 0.20 M KCN solution?
   (a) 2.81    (b) 7.00    (c) 11.34    (d) 9.13    (e) 10.64

43&44. Calculate the concentration of Au$^{3+}$ in a saturated solution of AuI$_3$, prepared by mixing solid AuI$_3$ in 1.00 L of water until equilibrium is reached.
   (a) $2.1 \times 10^{-8}$ M    (b) $1.0 \times 10^{-46}$ M    (c) $6.5 \times 10^{-11}$ M
   (d) $1.4 \times 10^{-12}$ M    (e) $1.8 \times 10^{-10}$ M

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45&46. Consider the equilibrium at a certain temperature: \[ C \rightleftharpoons 3A + B \]

A reaction begins with 4.0 moles of C in a 2.0 L container. When the system reaches equilibrium, there are 2.0 moles of B present. What is the value of the equilibrium constant, \( K_c \)?

(a) 0.081  (b) 0.11  (c) 6.0  (d) 0.037  (e) 27

47&48. A 0.40 M solution of a monoprotic acid is 1.7% ionized. What is the \( K_a \) for this weak acid?

(a) \( 1.3 \times 10^{-3} \)  (b) \( 3.7 \times 10^{-4} \)  (c) \( 1.2 \times 10^{-4} \)  (d) \( 2.9 \times 10^{-5} \)  (e) \( 3.2 \times 10^{-6} \)
49&50. Which answer best represents the species present for the equilibrium $A \rightleftharpoons 2B$ when $K_c = 0.001$, where

- $\bigcirc = A$ and $\bullet = B$?

(a)  
(b)  
(c)  
(d)  
(e)  

51. Take the on-line questionnaire on our course (5 pts) - see your neo account.
(7 pts) 52. (a) Draw the voltaic cell that results when the following two half-cells are connected:

(1) a gold electrode is inserted into a solution of 0.00010 M Au^{3+} ions.
(2) a silver electrode is inserted into a solution of 0.010 M Ag^{+} ions.

Which is the anode and what is the anodic reaction?
Which is the cathode and what is the cathodic reaction?
What is the sign on each electrode?
Show the direction of the electron flow.
What is the overall reaction?

(3 pts) (b) Write the shorthand notation for this cell.

(5 pts) (c) Calculate the equilibrium constant for the overall reaction.
(5 pts) (d) Calculate the potential for this non-standard cell

53. (a) Name this compound:
   (include cis or trans)

(b) Define what an isomer is.

(c) Draw and name a CYCLIC isomer of the compound given in (a).
(6 pts) 54. Roughly sketch two graphs with pH on the y axis and volume of titrant added on the x axis for:
   (a) The titration of methylamine with hydrochloric acid
   (b) The titration of sodium hydroxide with hydrochloric acid.
   Note where pH = 7 on each graph.