INSTRUCTIONS:

1. This examination consists of a total of 10 different pages. The last three pages include a periodic table; useful mathematical equations and constants, a table of equilibrium constants; a solubility table; and an activity series. All work should be done in this booklet.

2. PRINT your name, TA's name and your lab section number now in the space at the top of this sheet. DO NOT SEPARATE THESE PAGES.

3. Answer all questions that you can and whenever called for show your work clearly. Your method of solving problems should pattern the approach used in lecture. You do not have to show your work for the multiple choice or short answer questions.

4. No credit will be awarded if your work is not shown in 3, 4b, and 5c.

5. Point values are shown next to the problem number.

6. Budget your time for each of the questions. Some problems may have a low point value yet be very challenging. If you do not recognize the solution to a question quickly, skip it, and return to the question after completing the easier problems.

7. Look through the exam before beginning; plan your work; then begin.

8. Relax and do well.
(9) 1. Write the chemical formula(s) of the product(s) and balance the following reactions. Identify all products phases as either (g)as, (l)iquid, (s)olid or (aq)ueous. Soluble ionic compounds should be written in the form of their component ions.

a) $\text{HBr}(aq) + \text{NH}_3(aq) \rightarrow$

b) $\text{HC}_9\text{H}_7\text{O}_4(aq) + \text{NaOH}(aq) \rightarrow$

c) $\text{Al}(s) + \text{Ni(NO}_3)_2(aq) \rightarrow$

(4) 2a. Write the ionic and net ionic chemical equation for 1a, 1b or 1c).

Ionic equation

Net Ionic equation

(30) 3. Calculate the pH for each of the following solutions.

a) 0.00350 M $\text{HClO}_4$
3. (CONTINUED)

b) 0.520 M $\text{C}_6\text{H}_5\text{NH}_2$ (aniline)

c) 0.250 M $\text{HC}_7\text{H}_5\text{O}_2$ (benzoic acid)
4. In petroleum refining longer chain hydrocarbons are 'cracked' into smaller hydrocarbons. One such reaction is

\[ \text{C}_4\text{H}_{10}(g) \rightleftharpoons \text{C}_2\text{H}_6(g) + \text{C}_2\text{H}_4(g) \]

a) write the equilibrium constant expression for \( K_P \) for the chemical reaction. (3)

b) When 50.0 atm of butane are placed into a closed container at 500 \(^\circ\)C and allowed to reach equilibrium according to the equation above, the partial pressure of ethane is found to be 19.2 atm. Calculate the equilibrium partial pressures of the remaining substances and \( K_P \) for the reaction. (8)

c) Suppose after equilibrium is attained in part b) half of the ethane is removed from the reaction container. Which direction will the reaction proceed to re-establish equilibrium, L to R or R to L. Support your prediction with a short explanation. (6)
d) The $\Delta H^\circ$ for the reaction above is $+158$ kJ mol$^{-1}$. Under what conditions of temperature (high T or low T) will the reaction above produce the most amount of product? Explain. (5)

4. (CONTINUED)

e) Under what conditions of pressure (high P or low P) will the reaction above produce the most amount of product? Explain. (5)

(18) 5. Complete the following short answer questions:

a) Given the following substance behaves as an acid, write the formula of its conjugate base. (2)

\[
\text{HC}_3\text{H}_5\text{O}_2 \quad \rightarrow \quad \text{Acid} \quad \text{conjugate base}
\]

b) Write a balanced chemical equation showing how the substance you identified as a base in 6a behaves as a base when added to water. (4)

c) The value of K for the reaction

\[
\text{NH}_4{^+}(aq) + \text{NO}_2^{-}(aq) \rightarrow \text{NH}_3(aq) + \text{HNO}_2(aq)
\]

is less than one. Write the formula for the strongest acid and strongest base in the reaction. (4)
c) A particular solution has a $[\text{OH}^-] = 7.00 \times 10^{-9}$ M. Calculate $[\text{H}^+]$, pH and pOH of this solution. Is this solution acid or basic? (8)
Multiple Choice: (12 points)

Print the letter (A, B, C, D) which corresponds to the answer selected.

10. _______  11. _______  12. _______

ONLY THE ANSWERS IN THE AREA ABOVE WILL BE GRADED. Select the most correct answer for each question. Each question is worth 3 points.

11. The following diagram represents a reaction chamber

where the chemical reaction,

\[ \text{O} + \text{●} \leftrightarrow \text{●} \]

is at equilibrium

If nine units of

are added to the reaction chamber, which of the following best represents the system when it reestablishes equilibrium?
12. Consider the following hypothetical reaction:

\[ A_2(g) + 4B_2(g) \rightleftharpoons 2AB_4(g) \]

Initially 3 molecules of \( A_2 \) and 7 molecules of \( B_2 \) are placed in a reaction vessel. After a period of time 2 molecules of \( AB_4 \) are found in the vessel. Which of the following diagrams represents this final state?

A. 

B. 

C. 

D. 

E. 

13. The following diagram represents a hypothetical chemical reaction
At time 2 a change takes place in the reaction. Which of the following statements about this chemical system is false?

A) At time 3 the system is at equilibrium.
B) At time 2 the concentration of D was increased
C) The change at time 2 caused more C to be formed.
D) The diagram is an illustration of the effect that changing the concentration has on a reaction at equilibrium
E) D and A are on opposite sides of the equation representing the reaction
### Periodic Table of the Elements

<table>
<thead>
<tr>
<th>IA</th>
<th>IIA</th>
<th>IIIIB</th>
<th>IIIA</th>
<th>IVB</th>
<th>VIB</th>
<th>VIIA</th>
<th>VA</th>
<th>VIA</th>
<th>VIIIA</th>
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<td>C</td>
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<tr>
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<td>C</td>
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</table>

**Useful Information**

\[ PV = nRT \]

\[ R = 0.0821 \text{ L·atm mol}^{-1} \text{K}^{-1} = 8.314 \text{ J mol}^{-1} \text{K}^{-1} \]

\[ 6.02 \times 10^{23} \]

Density of \( \text{H}_2\text{O} = 1.00 \frac{\text{g}}{\text{cm}^3} \)

\[ \text{pH} = -\log[\text{H}^+] \]

\[ \text{pOH} = -\log[\text{OH}^-] \]

\[ \text{pH} + \text{pOH} = 14 \]

\[ K_w = 1.00 \times 10^{-14} \]

\[ K_p = K_c(RT)^\Delta n \]

\[ x_{1,2} = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \] for \( ax^2 + bx + c = 0 \)
<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
<th>$K_{a1}$</th>
<th>$K_{a2}$</th>
<th>$K_{a3}$</th>
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<td>Hydrochlohydr</td>
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<td>Pyrophosphoric</td>
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**E.2 DISSOCIATION CONSTANTS FOR BASES AT 25°C**

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<th>$K_b$</th>
<th>Name</th>
<th>Formula</th>
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<tr>
<td>Ammonia</td>
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<td>Hydroxylamine</td>
<td>HONH$_2$</td>
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<td>C$_6$H$_5$NH$_2$</td>
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<td>Trimethylamine</td>
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### Solubility Table

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<td>NO$_3^-$</td>
<td>soluble</td>
<td>none</td>
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<tr>
<td>ClO$_4^-$</td>
<td>soluble</td>
<td>none</td>
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<tr>
<td>Cl$^-$</td>
<td>soluble</td>
<td>except Ag$^+$, Hg$_2^{2+}$, *Pb$^{2+}$</td>
</tr>
<tr>
<td>I$^-$</td>
<td>soluble</td>
<td>except Ag$^+$, Hg$_2^{2+}$, Pb$^{2+}$</td>
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<tr>
<td>SO$_4^{2-}$</td>
<td>soluble</td>
<td>except Ca$^{2+}$, Ba$^{2+}$, Sr$^{2+}$, Hg$^{2+}$, Pb$^{2+}$, Ag$^+$</td>
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<td>CO$_3^{2-}$</td>
<td>insoluble</td>
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<tr>
<td>PO$_4^{3-}$</td>
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<td>except Group IA and NH$_4^+$</td>
</tr>
<tr>
<td>-OH</td>
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<tr>
<td>S$^{2-}$</td>
<td>insoluble</td>
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<td>K$^+$</td>
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*slightly soluble

### Activity Series

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<th>Metal</th>
<th>Half-Reaction Reaction</th>
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<td>Gold</td>
<td>Au$^{3+}$ + 3e$^-$$\rightarrow$ Au</td>
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<td>Platinum</td>
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<td>Mercury</td>
<td>Hg$^{2+}$ + 2e$^-$$\rightarrow$ Hg</td>
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<tr>
<td>Silver</td>
<td>Ag$^+$ + e$^-$$\rightarrow$ Ag</td>
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<td>Copper</td>
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<td>2H$^+$ + 2e$^-$$\rightarrow$ H$_2$</td>
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<td>Tin</td>
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<td>Nickel</td>
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<td>Cobalt</td>
<td>Co$^{2+}$ + 2e$^-$$\rightarrow$ Co</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe$^{2+}$ + 2e$^-$$\rightarrow$ Fe</td>
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<tr>
<td>Chromium</td>
<td>Cr$^{3+}$ + 3e$^-$$\rightarrow$ Cr</td>
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<td>Potassium</td>
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<tr>
<td>Lithium</td>
<td>Li$^+$ + e$^-$$\rightarrow$ Li</td>
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