INSTRUCTIONS:

1. This examination consists of a total of 8 different pages. The last three pages include a periodic table, a table of vapor pressures for water, a solubility table and a table of thermodynamic values. 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 6 and 8.

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.

SCORES

<table>
<thead>
<tr>
<th>Page 2</th>
<th>Page 3</th>
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<tbody>
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</table>
(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 (a)queous. Soluble ionic compounds should be written in the form of their component ions.

   a) \( \text{Fe(NO}_3\text{)}_3(aq) + \text{KSCN}(aq) \rightarrow \)

   b) \( \text{CuSO}_4(aq) + \text{NaOH}(aq) \rightarrow \)

   c) \( \text{Na}_2\text{CO}_3(s) + \text{HCl}(aq) \rightarrow \)

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

   Ionic equation

   Net Ionic equation

(9) 3. Identify the interparticle attractive force(s) present in the solids of the following substances. If more than one interparticle force, indicate which is the most important.

   a) \( \text{NF}_3 \)

   b) \( \text{CH}_3\text{NH}_2 \)

   c) \( \text{KBr} \)
(12) 4. Account for each of the following observations about pairs of substances. In your answers, use appropriate principles of intermolecular forces. In each part, your answer must include references to both substances.

a) HF has normal boiling point = 20 °C whereas HCl has a normal boiling point of –114 °C.

b) CCl₄ has normal boiling point = 76.7 °C whereas CBr₄ has a normal boiling point of 189 °C.

(6) 5. Give the name or draw the complete Lewis structure (showing all C-H bonds) for each of the following compounds.

<table>
<thead>
<tr>
<th>4-ethyl-trans-2-heptene</th>
<th>3,3-dimethyl-1-butyne</th>
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</thead>
<tbody>
<tr>
<td>![ Lewis structure 4-ethyl-trans-2-heptene ]</td>
<td>![ Lewis structure 3,3-dimethyl-1-butyne ]</td>
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</tbody>
</table>
(12) 6. Barium, Ba, crystallizes in one of the cubic unit cell systems. The edge length of its unit cell is 502 pm and the density of the metal is 3.50 g cm$^{-3}$. Determine the number of atoms in the cubic unit cell and identify the type of cubic cell.

(12) 7a. Some solutions processes are exothermic while others are endothermic. Provide an explanation for this difference.

b) A substance with the formula C$_2$H$_4$O$_2$ is very soluble in water, but insoluble in CS$_2$. Suggest a structure for this substance that supports the solubility information. Indicate the intermolecular attractive force that explains the solubility.
(36) 8. An aqueous solution of Na$_3$PO$_4$ is prepared by mixing 16.4 g Na$_3$PO$_4$ with 500 g of water.

   a) calculate the molality of the solution. (6)

   b) calculate the ideal freezing point of the solution. (6)

   c) the experimental freezing point was found to be –1.32 °C. Explain why the experimental and ideal freezing point are different. (6)
8. (Continued)
d) a new aqueous solution of sodium phosphate, Na₃PO₄, was prepared with a density of 1.05 g cm⁻³. The molality of this solution was determined to be 0.320 molal.

i) calculate the weight percent of Na₃PO₄ in this solution. (6)

ii) calculate the molarity of the solution. (6)

iii) describe how to prepare 1200 g of a 0.320 molal solution beginning with a 0.500 molal Na₃PO₄ solution and distilled water. (6)
### Periodic Table of the Elements

<table>
<thead>
<tr>
<th>IA</th>
<th>II A</th>
<th>III A</th>
<th>IVA</th>
<th>VA</th>
<th>VIA</th>
<th>VII A</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>He</td>
<td>Li</td>
<td>Be</td>
<td>B</td>
<td>C</td>
<td>N</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>1.008</td>
<td>6.94</td>
<td>9.01</td>
<td>4.08</td>
<td>10.81</td>
<td>12.01</td>
<td>14.01</td>
</tr>
</tbody>
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### Useful Information

- 1 pm = 10^{-12} m
- R = 0.0821 [L·atm·mol⁻¹·K⁻¹] = 8.314 [J·mol⁻¹·K⁻¹] = 6.02 \times 10^{23}
- P_{solution} = \chi_{solvent}P^*_{solvent}
- \rho_{H_2O} = 1.00 \text{ g cm}^{-3}
- \Delta T = \Delta T_{km} = 1.86 \text{ °C m}^{-1}
- k_f(H_2O) = 0.512 \text{ °C m}^{-1}
- k_b(H_2O) = 1.00 \text{ °C m}^{-1}
- \text{edge length (l) = 2r}
- \text{edge length (l) = } 2\sqrt{2} \cdot r
- \text{edge length (l) = } \frac{4r}{\sqrt{3}}
- \Delta G^\circ = \Delta H^\circ - T\Delta S^\circ

Lanthanides:

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</thead>
<tbody>
<tr>
<td>Ce</td>
<td>Pr</td>
<td>Nd</td>
<td>Sm</td>
<td>Eu</td>
<td>Gd</td>
<td>Tb</td>
<td>Dy</td>
</tr>
<tr>
<td>140.1</td>
<td>144.2</td>
<td>150.4</td>
<td>157.2</td>
<td>158.9</td>
<td>162.5</td>
<td>164.9</td>
<td>167.3</td>
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</table>

Actinides:

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</tr>
</thead>
<tbody>
<tr>
<td>Th</td>
<td>Pa</td>
<td>U</td>
<td>Pu</td>
<td>Am</td>
<td>Cm</td>
<td>Bk</td>
<td>Cf</td>
</tr>
<tr>
<td>232.0</td>
<td>231.0</td>
<td>238.0</td>
<td>244.0</td>
<td>243.0</td>
<td>247.0</td>
<td>247.0</td>
<td>251.0</td>
</tr>
</tbody>
</table>

R}_{\text{at}} = \text{density of } H_2O = 1.00 \text{ g cm}^{-3}
Temperature (°C) | Vapor Pressure (mmHg) | Temperature (°C) | Vapor Pressure (mmHg)
---|---|---|---
-5 | 3.2 | 50 | 92.5
0 | 4.6 | 55 | 118.0
5 | 6.52 | 60 | 149.4
10 | 9.20 | 65 | 187.5
15 | 12.8 | 70 | 233.7
20 | 17.5 | 75 | 289.1
25 | 23.8 | 80 | 355.1
30 | 31.8 | 85 | 433.6
35 | 42.1 | 90 | 525.8
40 | 55.3 | 95 | 633.9
45 | 71.9 | 100 | 760

Solubility Table

<table>
<thead>
<tr>
<th>Ion</th>
<th>Solubility</th>
<th>Exceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO₃⁻</td>
<td>soluble</td>
<td>none</td>
</tr>
<tr>
<td>ClO₄⁻</td>
<td>soluble</td>
<td>none</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>soluble</td>
<td>except Ag⁺, Hg₂²⁺, *Pb²⁺</td>
</tr>
<tr>
<td>I⁻</td>
<td>soluble</td>
<td>except Ag⁺, Hg₂²⁺, Pb²⁺</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>soluble</td>
<td>except Ca²⁺, Ba²⁺, Sr²⁺, Hg²⁺, Pb²⁺, Ag⁺</td>
</tr>
<tr>
<td>CO₃²⁻</td>
<td>insoluble</td>
<td>except Group IA and NH₄⁺</td>
</tr>
<tr>
<td>PO₄³⁻</td>
<td>insoluble</td>
<td>except Group IA and NH₄⁺</td>
</tr>
<tr>
<td>OH⁻</td>
<td>insoluble</td>
<td>except Group IA, *Ca²⁺, Ba²⁺, Sr²⁺</td>
</tr>
<tr>
<td>S²⁻</td>
<td>insoluble</td>
<td>except Group IA, IIA and NH₄⁺</td>
</tr>
<tr>
<td>Na⁺</td>
<td>soluble</td>
<td>none</td>
</tr>
<tr>
<td>NH₄⁺</td>
<td>soluble</td>
<td>none</td>
</tr>
<tr>
<td>K⁺</td>
<td>soluble</td>
<td>none</td>
</tr>
</tbody>
</table>

*slightly soluble