KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS
CHEMISTRY DEPARTMENT
CHEM 102-111
MAJOR EXAM II

STUDENT NUMBER: _____________________________
NAME: _____________________________
SECTION NUMBER: _____________________________

INSTRUCTIONS
1. Write your student number, name, and section number on the EXAM COVER page.
2. Write your student number, section number, and your name on your EXAM ANSWER FORM.
3. Bubble in pencil your student number and your section number on the EXAM ANSWER FORM.
4. Bubble in pencil on your EXAM ANSWER FORM the correct answer to each of the questions.
   You must not give more than ONE answer per question.
5. At the end of the exam return the EXAM ANSWER FORM to the proctor.
6. The exam contains 20 multiple choice questions and the time allowed is 80 min (1 hrs and 20 min). Time will
   be announced after 40 minutes and again 10 minutes before the end of the exam.

Important constants

<table>
<thead>
<tr>
<th>Constant</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Constant (R)</td>
<td>0.0821</td>
<td>L.atm/(mol.K)</td>
</tr>
<tr>
<td></td>
<td>8.314</td>
<td>J/(mol.K)</td>
</tr>
<tr>
<td></td>
<td>8.31 x 10^7</td>
<td>g.cm²/(sec².mol.K)</td>
</tr>
<tr>
<td>Planck’s Constant (h)</td>
<td>6.626 x 10^-34</td>
<td>J.sec/particle</td>
</tr>
<tr>
<td></td>
<td>6.626 x 10^-34</td>
<td>kg.m²/(sec.particle)</td>
</tr>
<tr>
<td>Velocity of light (c)</td>
<td>2.998 x 10^8</td>
<td>m/sec</td>
</tr>
<tr>
<td>Avogadro’s number (N)</td>
<td>6.022 x 10^23</td>
<td>particles/mole</td>
</tr>
<tr>
<td>Bohr’s Constant (R_{Bohr})</td>
<td>2.179 x 10^-18</td>
<td>J/particle</td>
</tr>
<tr>
<td>Faraday (F)</td>
<td>96485</td>
<td>Coulombs</td>
</tr>
<tr>
<td>Specific heat of H₂O</td>
<td>4.18</td>
<td>J/(g.°C)</td>
</tr>
</tbody>
</table>
1. A 40.0-mL sample of 0.100 M HNO₂ is titrated with 0.200 M KOH. Calculate the pH after adding 5.00 mL of KOH (\(K_a\) for HNO₂ is 4.5 \(\times\) 10⁻⁴)

   A) 2.75  
   B) 3.75  
   C) 1.70  
   D) 3.95

2. When a strong acid is titrated with a strong base, the pH at the equivalence point is

   A) greater than 7.0  
   B) equal to 7.0  
   C) equal to the \(pK_a\) of the acid  
   D) equal to 3.5

3. The molar solubility of Ag₂SO₄ is 1.2 \(\times\) 10⁻⁵ M. What is \(K_{sp}\) for this compound?

   A) 1.7 \(\times\) 10⁻¹⁵  
   B) 1.4 \(\times\) 10⁻¹⁰  
   C) 6.9 \(\times\) 10⁻¹⁵  
   D) 2.9 \(\times\) 10⁻¹⁹

4. Methyl red is a common acid-base indicator. It has a \(K_a\) equal to 6.3 \(\times\) 10⁻⁶. Its un-ionized form is red and its anionic form is yellow. What color would a methyl red solution have at pH = 7.8?

   A) Red  
   B) Blue  
   C) Green  
   D) Yellow
5. For the process,

\[ \text{H}_3\text{PO}_4(\text{s}) \rightleftharpoons \text{H}_3\text{PO}_4(\text{l}) \]

Use the following thermodynamic data to determine at what temperature this process reaches equilibrium at 1.0 atm.

<table>
<thead>
<tr>
<th>Substance:</th>
<th>$\text{H}_3\text{PO}_4(\text{s})$</th>
<th>$\text{H}_3\text{PO}_4(\text{l})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta H^\circ_f$ (kJ/mol):</td>
<td>-1284.4</td>
<td>-1271.7</td>
</tr>
<tr>
<td>$\Delta G^\circ_f$ (kJ/mol):</td>
<td>-1124.3</td>
<td>-1123.6</td>
</tr>
<tr>
<td>$S^\circ$ (J/K·mol):</td>
<td>110.5</td>
<td>150.8</td>
</tr>
</tbody>
</table>

A) 286 K  
B) 305 K  
C) 315 K  
D) 347 K

6. Calculate Kp at 298 K for the reaction,

\[ \text{SO}_2(\text{g}) + \text{NO}_2(\text{g}) \rightarrow \text{SO}_3(\text{g}) + \text{NO}(\text{g}) \]

\[ \Delta G^\circ_f \]

\[ \begin{array}{l}
\text{SO}_2(\text{g}) & -300.4 \text{ kJ/mol} \\
\text{SO}_3(\text{g}) & -370.4 \text{ kJ/mol} \\
\text{NO}(\text{g}) & 86.7 \text{ kJ/mol} \\
\text{NO}_2(\text{g}) & 51.8 \text{ kJ/mol} \\
\end{array} \]

A) $6.99 \times 10^{-7}$  
B) 14.2  
C) $1.42 \times 10^6$  
D) 475
7. For the reaction,

\[
\text{AgBr (s)} \rightleftharpoons \text{Ag}^+ (\text{aq}) + \text{Br}^- (\text{aq})
\]

the equilibrium constant is the solubility product constant, \(K_{sp} = 7.7 \times 10^{-13}\) at 25°C. Calculate \(\Delta G\) when \([\text{Ag}^+] = 1.0 \times 10^{-2}\) M and \([\text{Br}^-] = 1.0 \times 10^{-3}\) M. Is the reaction spontaneous or nonspontaneous at these concentrations?

A) \(\Delta G = +69.1\) kJ/mol, nonspontaneous
B) \(\Delta G = -69.1\) kJ/mol, spontaneous
C) \(\Delta G = -40.6\) kJ/mol, spontaneous
D) \(\Delta G = +40.6\) kJ/mol, nonspontaneous

8. Which species will have the greatest absolute entropy at 25°C?

A) \(\text{Ne (g)}\)
B) \(\text{C}_4\text{H}_{10}\) (g)
C) \(\text{H}_2\text{O}\) (l)
D) \(\text{C}_2\text{H}_2\) (g)

9. Consider the figure below which shows \(\Delta G^\circ\) for a chemical process plotted against absolute temperature. From this plot, it is reasonable to conclude that:

A) \(\Delta H^\circ > 0, \Delta S^\circ > 0\)
B) \(\Delta H^\circ > 0, \Delta S^\circ < 0\)
C) \(\Delta H^\circ < 0, \Delta S^\circ > 0\)
D) \(\Delta H^\circ < 0, \Delta S^\circ < 0\)

10. For the reaction,

\[
\text{H}_2 (\text{g}) + \text{S (s)} \rightarrow \text{H}_2\text{S (g)}, \quad \Delta H^\circ = -20.2\ \text{kJ/mol and} \quad \Delta S^\circ = +43.1\ \text{J/K·mol.}
\]

Which of the following statements is TRUE?

A) The reaction is only spontaneous at low temperatures.
B) The reaction is spontaneous at all temperatures.
C) \(\Delta G^\circ\) becomes less favorable as temperature increases.
D) The reaction is spontaneous only at high temperatures.
11. Consider the following standard reduction potentials in acid solution:

\[
\begin{align*}
Cr^{3+} + 3e^- & \rightarrow Cr \quad E^\circ = -0.74 \text{ V} \\
MnO_4^- + 8H^+ + 5e^- & \rightarrow Mn^{2+} + 4H_2O \quad E^\circ = +1.51 \text{ V} \\
Co^{2+} + 2e^- & \rightarrow Co \quad E^\circ = -0.28 \text{ V}
\end{align*}
\]

The strongest reducing agent listed above is

A) Cr\(^{3+}\)  
B) Cr  
C) Mn\(^{2+}\)  
D) Co

12. Consider the following reaction,

\[2Fe^{2+}(aq) + Cu^{2+} \rightarrow 2Fe^{3+}(aq) + Cu.\]

When the reaction comes to equilibrium, what is the cell voltage? \((E^{\circ}_{Fe^{3+}/Fe^{2+}} = 0.77 \text{ V}, E^{\circ}_{Cu^{2+}/Cu} = 0.34 \text{ V})\)

A) 0.43 V  
B) 1.11 V  
C) 0 V  
D) −0.43 V

13. For the following Cell,

\[
Zn(s) \mid Zn^{2+}(aq) \parallel Ag^+(aq) \mid Ag(s)
\]

Calculate what \([Ag^+]\) if \([Zn^{2+}] = 0.010 \text{ M}\) and \(E_{\text{cell}} = 1.37 \text{ V}\) at 25 °C \((E^{\circ}_{Ag^+/Ag} = 0.80 \text{ V}, E^{\circ}_{Zn^{2+}/Zn} = -0.76 \text{ V})\)

A) 2.5 M  
B) 6.2 \times 10^{-3} \text{ M}  
C) 4.0 \times 10^{-9} \text{ M}  
D) 6.2 \times 10^{-5} \text{ M}
14. If a constant current of 5.0 amperes is passed through a cell containing Cr\(^{3+}\) for 1.0 hour, how many grams of Cr will plate out onto the cathode? (The atomic mass of Cr is 51.996.)

A) 0.054 g  
B) 9.7 g  
C) 3.2 g  
D) 1.6 g

15. Which of the following statements about the fuel cell is FALSE?

A) The cell reactants in a fuel cell are continuously supplied from an external source.  
B) A fuel cell is a galvanic cell.  
C) Modern fuel cells can be easily regenerated using household current.  
D) One of the reactants in a fuel cell is a traditional fuel.

16. How many electrons are transferred in the following reaction?

\[ \text{SO}_3^{2-}(aq) + \text{MnO}_4^{-}(aq) \rightarrow \text{SO}_4^{2-}(aq) + \text{Mn}^{2+}(aq) \]

A) 6  
B) 2  
C) 10  
D) 4

17. The systematic name for the compound represented below is

\[
\begin{align*}
\text{CH}_2-\text{CH}_3 \\
| \\
\text{CH}_3-\text{CH}_2-\text{CH}_2-\text{CH}-\text{CH}-\text{CH}_3 \\
| \\
\text{CH}_2 \\
| \\
\text{CH}_2-\text{CH}_3
\end{align*}
\]

A) 4,5-diethylheptane  
B) 3-propyl-4-ethylhexane  
C) 3-ethyl-4-propylhexane  
D) 3-methyl-4-propylheptane
18. Identify all the functional groups present in the following organic compound. 1) ketone, 2) aldehyde, 3) acid, 4) alcohol, 5) ether, 6) ester, 7) amine

```
O              O
CH₃COCH₂CH₂CH
```

A) 2, 6  
B) 2, 5  
C) 3, 4  
D) 1, 2, 5

19. Which of the following has a double C-O bond and a single C-O bond?

A) ketone  
B) ester  
C) alcohol  
D) aldehyde

20. Pick the optically active molecule among the following:

A)  

```
H     H
H—C—C—H
H     H
```

B)  

```
H
H—C—O—H
H
```

C)  

```
HO    H
H—C—C—H
Cl    H
```

D)  

```
HO    H
H—C—C—H
HO    H
```
Answer Key

1. A
2. B
3. C
4. D
5. C
6. C
7. D
8. B
9. A
10. B
11. B
12. C
13. D
14. C
15. C
16. C
17. D
18. A
19. B
20. C