1. The solubility of CaSO$_4$ in pure water at 0°C is 1.14 gram(s) per liter. The value of the solubility product is
   A) $8.37 \times 10^{-3}$
   B) $1.14 \times 10^{-3}$
   C) $9.15 \times 10^{-2}$
   D) $7.01 \times 10^{-5}$
   E) none of these

2. The solubility of silver phosphate, Ag$_3$PO$_4$, at 25°C is $1.60 \times 10^{-5}$ mol/L. What is the $K_{sp}$ for the silver phosphate at 25°C?
   A) $1.11 \times 10^{-11}$
   B) $1.77 \times 10^{-18}$
   C) $7.68 \times 10^{-10}$
   D) $6.55 \times 10^{-20}$
   E) none of these

3. The correct mathematical expression for finding the molar solubility ($s$) of Sn(OH)$_2$ is:
   A) $2s^3 = K_{sp}$
   B) $2s^3 = K_{sp}$
   C) $108s^5 = K_{sp}$
   D) $4s^3 = K_{sp}$
   E) $8s^3 = K_{sp}$

4. In a solution prepared by adding excess PbI$_2$ ($K_{sp} = 1.44 \times 10^{-8}$) to water, the [I$^-$] at equilibrium is:
   A) $1.53 \times 10^{-3}$ mol/L
   B) $7.20 \times 10^{-9}$ mol/L
   C) $1.20 \times 10^{-4}$ mol/L
   D) $9.33 \times 10^{-26}$ mol/L
   E) $3.07 \times 10^{-3}$ mol/L

5. Which of the following compounds has the lowest solubility in mol/L in water?
   A) Al(OH)$_3$ $K_{sp} = 2 \times 10^{-32}$
   B) CdS $K_{sp} = 1.0 \times 10^{-28}$
   C) PbSO$_4$ $K_{sp} = 1.3 \times 10^{-8}$
   D) Sn(OH)$_2$ $K_{sp} = 3 \times 10^{-27}$
   E) MgC$_2$O$_4$ $K_{sp} = 8.6 \times 10^{-5}$

6. The $K_{sp}$ of PbSO$_4$ is $1.3 \times 10^{-8}$. Calculate the solubility (in mol/L) of PbSO$_4$ in a 0.0037 $M$ solution of Na$_2$SO$_4$.
   A) $4.8 \times 10^{-11}$ $M$
   B) $1.2 \times 10^{-11}$ $M$
   C) $3.5 \times 10^{-6}$ $M$
   D) $1.3 \times 10^{-8}$ $M$
   E) $1.9 \times 10^{-3}$ $M$

7. Given the following $K_{sp}$ values, which statement about solubility in mol/L in water is correct?

| $K_{sp}$
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>PbCrO$_4$</td>
<td>$2.0 \times 10^{-16}$</td>
</tr>
<tr>
<td>Zn(OH)$_2$</td>
<td>$4.5 \times 10^{-17}$</td>
</tr>
<tr>
<td>Pb(OH)$_2$</td>
<td>$1.2 \times 10^{-15}$</td>
</tr>
<tr>
<td>MnS</td>
<td>$2.3 \times 10^{-11}$</td>
</tr>
</tbody>
</table>

   A) PbCrO$_4$, Zn(OH)$_2$, and Pb(OH)$_2$ have equal solubilities in water.
   B) PbCrO$_4$ has the lowest solubility in water.
   C) The solubility of MnS in water will not be pH dependent.
   D) MnS has the highest molar solubility in water.
   E) A saturated PbCrO$_4$ solution will have a higher [Pb$^{2+}$] than a saturated Pb(OH)$_2$ solution.
8. Assume that the enthalpy of fusion of ice is 6020 J/mol and does not vary appreciably over the temperature range 270-290 K. If one mole of ice at 0°C is melted by heat supplied from surroundings at 276 K, what is the entropy change in the surroundings, in J/K?
A) 22.1
B) 21.8
C) 0.0
D) –21.8
E) –22.1

9. If the change in entropy of the surroundings for a process at 431 K and constant pressure is –326 J/K, what is the heat flow absorbed by for the system?
A) 326 kJ
B) 1.32 kJ
C) –141 kJ
D) 105 kJ
E) 141 kJ

10. The enthalpy of vaporization of ammonia is 23.35 kJ/mol at its boiling point (–33.4°C). Calculate the value of \( \Delta S_{\text{surr}} \) when 1.00 mole of ammonia is vaporized at –33.4°C and 1.00 atm.
A) 0
B) –6.99 \times 10^2 J/K mol
C) 9.74 \times 10^1 J/K mol
D) –9.74 \times 10^1 J/K mol
E) 6.99 \times 10^2 J/K mol

11. Given that \( \Delta H_{\text{vap}} \) is 58.2 kJ/mol, and the boiling point is 83.4°C, 1 atm, if one mole of this substance is vaporized at 1 atm, calculate \( \Delta S_{\text{surr}} \).
A) –163 J/K mol
B) 163 J/K mol
C) 698 J/K mol
D) –698 J/K mol
E) 0

12. Substance X has a heat of vaporization of 55.9 kJ/mol at its normal boiling point (423°C). For the process \( X(l) \rightarrow X(g) \) at 1 atm and 423°C calculate the value of \( \Delta S_{\text{surr}} \).
A) 0
B) 80.3 J/K mol
C) 132 J/K mol
D) –80.3 J/K mol
E) –132 J/K mol

13. For a particular chemical reaction \( \Delta H = 4.3 \text{ kJ} \) and \( \Delta S = –19 \text{ J/K} \). Under what temperature condition is the reaction spontaneous?
A) When \( T < –226 \text{ K} \).
B) When \( T > 226 \text{ K} \).
C) The reaction is spontaneous at all temperatures.
D) The reaction is not spontaneous at any temperature.
E) When \( T > 226 \text{ K} \).

14. Consider the freezing of liquid water at –10°C. For this process what are the signs for \( \Delta H, \Delta S, \) and \( \Delta G \)?
\[
\begin{array}{ccc}
\Delta H & \Delta S & \Delta G \\
A) & + & – & 0 \\
B) & + & – & – \\
C) & – & + & 0 \\
D) & – & + & – \\
E) & – & – & – \\
\end{array}
\]
15. For which of the following processes would $\Delta S^\circ$ be expected to be most positive?

A) $\text{O}_2(g) + 2\text{H}_2(g) \rightarrow 2\text{H}_2\text{O}(g)$
B) $\text{H}_2\text{O}(l) \rightarrow \text{H}_2\text{O}(s)$
C) $\text{NH}_3(g) + \text{HCl}(g) \rightarrow \text{NH}_4\text{Cl}(g)$
D) $2\text{NH}_3\text{NO}_3(s) \rightarrow 2\text{N}_2(g) + \text{O}_2(g) + 4\text{H}_2\text{O}(g)$
E) $\text{N}_2\text{O}_4(g) \rightarrow 2\text{NO}_2(g)$

The following questions refer to the following reaction at constant 25°C and 1 atm.

$2\text{Fe}(s) + (3/2)\text{O}_2(g) + 3\text{H}_2\text{O}(l) \rightarrow 2\text{Fe(OH)}_3(s)$  \[ \Delta H = -789 \text{ kJ/mol} \]

<table>
<thead>
<tr>
<th>Substance</th>
<th>$S^\circ$ (J/mol K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Fe(OH)}_3(s)$</td>
<td>107</td>
</tr>
<tr>
<td>$\text{Fe}(s)$</td>
<td>27</td>
</tr>
<tr>
<td>$\text{O}_2(g)$</td>
<td>205</td>
</tr>
<tr>
<td>$\text{H}_2\text{O}(l)$</td>
<td>70</td>
</tr>
</tbody>
</table>

16. Determine $\Delta S_{\text{surr}}$ for the reaction (in kJ/mol K)

A) 3.14
B) 0.937
C) 0.378
D) 1.31
E) 2.65

17. Determine $\Delta S_{\text{univ}}$ for the reaction (in kJ/mol K)

A) 0.23
B) 2.3
C) 0.36
D) 2.8
E) 3.6

18. What must be true about $\Delta G$ for this reaction?

A) $\Delta G = \Delta H$
B) $\Delta G = 0$
C) $\Delta G > 0$
D) $\Delta G < 0$
E) $\Delta G = \Delta S_{\text{univ}}$

ANSWERS:

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