CHEM 1100 Practice Exam

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1 Multiple Choice

1. Which of the following is an example of a homogenous equilibrium?
   A. $MgCO_3(s) \leftrightharpoons MgO(s) + CO_2(g)$
   B. $NaCl(s) \leftrightharpoons Na^+(aq) + Cl^-(aq)$
   C. $3H_2(g) + N_2(g) \leftrightharpoons 2NH_3(g)$
   D. $C(s) + CO_2(g) \leftrightharpoons 2CO(G)$
   E. None of the above.

2. A system in chemical equilibrium is *not* characterized by one of the following:
   A. Dynamic interconversion between reactants and products
   B. No macroscopic changes
   C. Unaffected by changes in temperature
   D. Unaffected by addition of catalyst
   E. None of the above

3. Which is *false* about the first law of thermodynamics?
   A. All energy change in a chemical reaction is in the form of heat
   B. The enthalpy of the universe is zero
   C. $\Delta E = \Delta E_{\text{sys}} + \Delta E_{\text{sur}}$
   D. Energy cannot be created nor destroyed
   E. The combined amount of matter in the universe is constant

4. Which is *false* about the second law of thermodynamics?
   A. In any spontaneous process, entropy of the universe increases
   B. In any spontaneous process, entropy of the system increases
   C. The entropy of the surroundings can increase or decrease
   D. $\Delta S_u = \Delta S + \Delta S_s$
   E. The entropy of the universe is positive for a spontaneous process

5. If $Ba(NO_3)_2$ is added to $BaSO_4$, the solubility of the latter:
   A. is unaffected
   B. is unpredictable
   C. decreases
   D. increases

2 Short Answer

1. Calculate ΔS for the reaction $2NO_2 \rightarrow 2N_2 + O_2$. Note $\Delta S = \{240, 191.5, 205\}$, respectively.

   1. **108**

2. What is the total number of lone pairs in NCl_3?

   2. **10**

3. In manufacturing steel, carbon is likely to be a (?) impurity because it is (?) than iron.

   3. **int., smaller**

4. In the reaction $A(g) + 3B(\ell) \rightarrow 3C(g) + 7D(g)$, what are the exponents in the denominator of

the equilibrium expression?

4. **1; 0**

5. Given the heat of formation values $\{-103.8, 0, -393.5, -285.8\}$, calculate the heat of reaction for A(g) +B(g) $\rightarrow$ C(g) + D(ℓ).

5. $\mathbf{-2.22 \cdot 10^3}$

6. What is the molar solubility of CaF_2 if $K_{sp} = 3.9 \cdot 10^{-11}$?

6. $\mathbf{2.14 \cdot 10^{-4}}$

7. What is the pH of a 0.15 M NaOH solution?

7. **13.18**

8. Which type of solid is most densely packed?

8. **fcc**

9. What element (Ga, Si, Al, Ar) would be added to Ge to produce an n-type conductor?

9. **Ar**

10. The volume of a gas is 650 mL at STP. What volume will it occupy at freezing point and 950 torr?

10. **520**

11. For the reaction $H_2O(g) + CH_4(g) \leftrightharpoons CO(g) + 3H_2(g)$, if $K_c = 3.8 \cdot 10^{-3}$ at 1000 K, what is K_p?

11. **26**

12. For the reaction $PCl_5(g) \leftrightharpoons PCl_3(g) + Cl_2(g)$, the constant $K = 7.7 \cdot 10^{-3}$ at STP. Calculate $\Delta G^\ominus$.

12. **12,000 J/mol**

3 Long Answer

1. Use the Born Haber cycle to determine the lattice energy of KF (s) from the following data:

$$\Delta H_f^\ominus = -567.3 \qquad \Delta H_{sub}[K(s)] = 89.24 \qquad \Delta H_{dis}[F_2(g)] = 159$$
$$IE[K(g)] = 418.9 \qquad EA[F(g)] = -328$$

Solution: The Born Haber Cycle is given by

$$\Delta H_f^\ominus = \sum \Delta H^\ominus$$

in which the enthalpies are given by

Formation	$K(s) + \frac{1}{2}F_2(g) \rightarrow KF(s)$	$\Delta H_f^\ominus = -567.3$
Sublimation	$K(s) \rightarrow K(g)$	$\Delta H_s = 89.24$
Ionization	$K(g) \rightarrow K^+(g) + e^-$	$\Delta H_i = 418.9$
Dissociation	$\frac{1}{2}F_2(g) \rightarrow F(g)$	$\Delta H_d = 0.5 \cdot 159$
Affinity	$F(g) + e^- \rightarrow F^-(g)$	$\Delta H_e = -328$

Therefore, the cycle is

$$-567.3 = 89.24 + 418.9 + 0.5 \cdot 159 - 328 - \Delta H_l \implies \Delta H_l = 827$$

The lattice energy is thus 827 kJ/mol.

2. For the reaction $H_2(g) + I_2(g) \leftrightharpoons 2HI(g)$, the constant $K = 57$ at 700K. If 1 mol H_2 reacts with 1 mol I_2 in a 10L vessel at 700K, what is the molar composition at equilibrium?

Solution: The initial concentrations are given by $[H_2] = [I_2] = n/V = 0.1$ M. An ICE table is next constructed to determine the concentrations at equilibrium:

R	H_2	I_2	$2HI$
I	0.100	0.100	0
C	$-x$	$-x$	$+2x$
E	$0.100 - x$	$0.100 - x$	$2x$

The change in concentration is therefore given by

$$K_c = 57 = \frac{(2x)^2}{(0.1-x)(0.1-x)} \implies x = \begin{cases} 0.0791 \text{ M} \\ 0.136 \text{ M} \end{cases}$$

Thus, the valid solution is $x = 0.0791$ so the concentrations at equilibrium are

$$[H_2]_{eq} = [I_2]_{eq} = 0.1 - x = 0.0209 \text{ M} \quad \text{and} \quad [HI]_{eq} = 2x = 0.1582 \text{ M}$$

3. A mixture of 1.57 mol N_2, 1.92 mol H_2, and 8.13 mol NH_3 is mixed in a 20L vessel at 500K. At this temperature, $K_c = 1.7 \cdot 10^2$ for $N_2 + 3H_2 \leftrightharpoons 2NH_3$. Is such mixture at equilibrium? If not, what is the direction of the net reaction?

Solution: The initial concentrations are given by

$$[N_2] = 0.0785 \qquad [H_2] = 0.0960 \qquad [NH_3] = 0.406$$

The reaction quotient is thus

$$Q = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{(0.406)^3}{(0.0785)(0.0960)^3} = 2.37 \cdot 10^3$$

Therefore, $Q > K$ so the mixture is not at equilibrium and the net reaction will proceed leftwards, decreasing the NH_3 concentration.

4. Define a formation reaction, and explain why the each equation is not correct:
   (a) The formation of $4\text{Al(s)} + 3\text{O}_2\text{(g)} \rightarrow 2\text{Al}_2\text{O}_3\text{(s)}$
   (b) The formation of $\text{N}_2\text{(g)} + 3/2\text{H}_2\text{(g)} \rightarrow \text{NH}_3\text{(g)}$
   (c) The formation of $2\text{Na(s)} + \text{O(g)} \rightarrow \text{Na}_2\text{O(s)}$

Solution: A formation reaction is that of a compound from its standard state elements.

1. Two moles of the compound is formed, not one.
2. It is not correctly balanced.
3. Oxygen is not in its standard state.

5. A piece of Ti with mass $m = 20.8$ g is heated in boiling water to $T_1 = 99.5^\circ$, then dropped into a calorimeter containing $V = 75$ mL of water at $T_2 = 21.7^\circ$. When equilibrium is reached, the temperature is $T_3 = 24.3^\circ$. Calculate the specific heat of titanium.

Solution: The heats are related via

$$-mC_{Ti}\Delta T_{31} = VC\Delta T_{32} \implies C_{Ti} = 0.52 \tag{1}$$

Therefore, the specific heat of titanium is 0.52 J/g °C.

6. Using Hess' Law, calculate the heat of reaction for $A + B \to C$ given:

$$2D \to B \quad \Delta H = 50, \qquad 2A + D \to C \quad \Delta H = -100, \qquad D \to A \quad \Delta H = 75 \tag{2}$$

Solution: The net sum of the sub-reactions must be equal to the overall reaction. To achieve this, the first reaction is reversed such that $B \to 2D$ and $\Delta H = -50$. Adding this to the remaining two sub-reactions yields:

1.	$B \to 2D$	$\Delta H_1 = -50$
2.	$2A + D \to C$	$\Delta H_2 = -100$
3.	$D \to A$	$\Delta H_3 = 75$
Σ	$A + B \to C$	$\Delta H_t = \Sigma\Delta H$

Therefore, the total enthalpy $\Delta H_{rxn} = \sum \Delta H = -75$ kJ / mol.