Comprehensive practice exam for CHEM 1100. All questions based on previous assessment and thus contains $> 90\%$ of the actual exam.

1 Multiple Choice (1)

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

6. Will Cu have a higher conductivity at 200° than 100°?
   A. Yes **B. No**

7. Will Si have a higher conductivity at 25 K than 75 K?
   A. Yes **B. No**

8. In an n-type semiconductor, does it take less energy for an electron to jump from the donor level or valence band to the conduction band?
   A. Donor B. Valence

9. Will an undoped semiconductor have a higher conductivity than an n-type semiconductor?
   A. Yes **B. No**

2 Short Answer (2)

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 $A(g) + B(g) \rightarrow C(g) + D(\ell)$.

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

    11. **26**

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

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

13. Predict whether the entropy change is positive or negative for the following processes:

    (a) $CH_3OH(l) + 3/2O_2(g) \rightarrow CO_2(g) + 2H_2O$

    (a) **Positive**

    (b) $Na(s) + 1/2F_2(g) \rightarrow NaF(s)$

    (b) **Negative**

    (c) Compressing gas from 0.5 to 1.5 atm.

    (c) **Negative**

    (d) Heating copper by 20 K

    (d) **Positive**

14. If $\Delta G_f^{\ominus}$ for CO, H_2, CH_4, H_2O are $-137.2, 0, -50.75, -228.6$, calculate $\Delta G_{rxn}^{\ominus}$ for $CH_4 + H_2O \rightarrow CO + 3H_2$.

    14. **142.2 kJ**

15. For a sample which is 15 mol % polymer with a molecular weight $M = 500{,}000$ g/mol and 85 mol % with $M = 150{,}000$, what is the number average molecular weight?

    15. **202,500**

16. What is the DP for C_8H_8 with a molecular weight of 100,000 g/mol?

    16. **960**

17. Give an example of a ceramic.

    17. **CSi**

18. For the reaction $2H_2SO_4 + Cu \rightarrow CuSO_4 + 2H_2O + SO_2$, how much SO_2 is produced from 14.2g Cu and 18g H_2SO_4?

    18. **5.88g**

3 Long Answer (6)

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

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 $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$, 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:

	H_2	I_2	$2HI$
R			
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 $4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$
   (b) The formation of $N_2(g) + 3/2H_2(g) \rightarrow NH_3(g)$
   (c) The formation of $2Na(s) + O(g) \rightarrow Na_2O(s)$

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 $T_1 = 99.5°$, then dropped into a calorimeter containing $V = 75$ mL of water at $T_2 = 21.7°$. When equilibrium is reached, the temperature is $T_3 = 24.3°$. Calculate the specific heat of titanium.

Solution: The heats are related via

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

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

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

$$2D \rightarrow B \quad \Delta H = 50, \qquad 2A + D \rightarrow C \quad \Delta H = -100, \qquad D \rightarrow A \quad \Delta H = 75$$

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.

7. A metal has a cubic structure with density $\rho = 1.892$ g/cm^3, an atomic weight $M = 132.91$ g/mol, and a lattice parameter $a = 6.13 \cdot 10^{-8}$ cm. Determine the crystal structure of the metal.

Solution: The number of atoms per cell n is given by

$$\rho = \frac{nM}{a^3 N_a} \implies n = \frac{\rho a^3 N_a}{M} = 2$$

Therefore, the structure is a body centered cubic as the number of atoms per cell is 2.

8. List and explain two factors that affect the conductivity of semiconductors.

Solution: Temperature and the number of impurities is proportional to conductivity in semiconductors, and opposite in conductors.

9. There are three types of polymer molecular structures.
   (a) In which structures are the chains connected by non bonding interactions and covalent bonds?
   (b) Which structure more easily forms a crystal? Explain.
   (c) Which structure can be recycled?
   (d) If a compound burns and does not melt, what type of structure is it?

Solution:
(a) Linear and branched polymers are connected by nonbonding interactions, whereas crosslinked polymers are connected by covalent bonds.
(b) Linear forms crystals more easily as there are no branches.
(c) Linear and branched polymers can be recycled as their interactions are broken when melted.
(d) It is either network or crosslinked.

10. Calculate the radius of a Pd atom in picometers, given $\rho = 12.02$ and such atom is an fcc unit cell.

Solution: The lattice parameter a can be found via

$$a = \sqrt[3]{V} = \sqrt[3]{m/\rho} \quad \text{for} \quad m = nM/N_a$$

Therefore, $a = 3.89 \cdot 10^{-8}$. Because the unit cell is fcc,

$$r = a/2\sqrt{2} = 1.376 \cdot 10^{-8} \text{ cm}$$

Converting to picometers from centimetres yields

$$1.376 \cdot 10^{-8} \cdot 10^{8} \cdot 10^{2} = 138 \text{ pm}$$

Therefore the radius is $r = 138$ pm.