

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 homogeneous equilibrium?
  - A.  $\text{MgCO}_3(\text{s}) \rightleftharpoons \text{MgO}(\text{s}) + \text{CO}_2(\text{g})$
  - B.  $\text{NaCl}(\text{s}) \rightleftharpoons \text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq})$
  - C.  $3\text{H}_2(\text{g}) + \text{N}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$
  - D.  $\text{C}(\text{s}) + \text{CO}_2(\text{g}) \rightleftharpoons 2\text{CO}(\text{g})$
  - 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.  $\Delta S_{\text{u}} = \Delta S + \Delta S_{\text{s}}$
  - E. The entropy of the universe is positive for a spontaneous process
5. If  $\text{Ba}(\text{NO}_3)_2$  is added to  $\text{BaSO}_4$ , 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)

- Calculate  $\Delta S$  for the reaction  $2\text{NO}_2 \rightarrow 2\text{N}_2 + \text{O}_2$ .  
Note  $\Delta S = \{240, 191.5, 205\}$ , respectively.  
1. 108
- What is the total number of lone pairs in  $\text{NCl}_3$ ?  
2. 10
- In manufacturing steel, carbon is likely to be a (?) impurity because it is (?) than iron.  
3. int., smaller
- In the reaction  $\text{A(g)} + 3\text{B(l)} \rightarrow 3\text{C(g)} + 7\text{D(g)}$ , what are the exponents in the denominator of the equilibrium expression?  
4. 1; 0
- Given the heat of formation values  $\{-103.8, 0, -393.5, -285.8\}$ , calculate the heat of reaction for  $\text{A(g)} + \text{B(g)} \rightarrow \text{C(g)} + \text{D(l)}$ .  
5.  $-2.22 \cdot 10^3$
- What is the molar solubility of  $\text{CaF}_2$  if  $K_{sp} = 3.9 \cdot 10^{-11}$ ?  
6.  $2.14 \cdot 10^{-4}$
- What is the pH of a 0.15 M NaOH solution?  
7. 13.18
- Which type of solid is most densely packed?  
8. fcc
- What element (Ga, Si, Al, Ar) would be added to Ge to produce an  $n$ -type conductor?  
9. Ar
- The volume of a gas is 650 mL at STP. What volume will it occupy at freezing point and 950 torr?  
10. 520
- For the reaction  $\text{H}_2\text{O(g)} + \text{CH}_4\text{(g)} \rightleftharpoons \text{CO(g)} + 3\text{H}_2\text{(g)}$ , if  $K_c = 3.8 \cdot 10^{-3}$  at 1000 K, what is  $K_p$ ?  
11. 26
- For the reaction  $\text{PCl}_5\text{(g)} \rightleftharpoons \text{PCl}_3\text{(g)} + \text{Cl}_2\text{(g)}$ , the constant  $K = 7.7 \cdot 10^{-3}$  at STP. Calculate  $\Delta G^\ominus$ .  
12. 12,000 J/mol
- Predict whether the entropy change is positive or negative for the following processes:  
(a)  $\text{CH}_3\text{OH(l)} + 3/2\text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)} + 2\text{H}_2\text{O}$   
(a) Positive  
(b)  $\text{Na(s)} + 1/2\text{F}_2\text{(g)} \rightarrow \text{NaF(s)}$   
(b) Negative  
(c) Compressing gas from 0.5 to 1.5 atm.  
(c) Negative  
(d) Heating copper by 20 K  
(d) Positive
- If  $\Delta G_f^\ominus$  for  $\text{CO}, \text{H}_2, \text{CH}_4, \text{H}_2\text{O}$  are  $-137.2, 0, -50.75, -228.6$ , calculate  $\Delta G_{rxn}^\ominus$  for  $\text{CH}_4 + \text{H}_2\text{O} \rightarrow \text{CO} + 3\text{H}_2$ .  
14. 142.2 kJ
- 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
- What is the DP for  $\text{C}_8\text{H}_8$  with a molecular weight of 100,000 g/mol?  
16. 960
- Give an example of a ceramic.  
17. CSi
- For the reaction  $2\text{H}_2\text{SO}_4 + \text{Cu} \rightarrow \text{CuSO}_4 + 2\text{H}_2\text{O} + \text{SO}_2$ , how much  $\text{SO}_2$  is produced from 14.2g Cu and 18g  $\text{H}_2\text{SO}_4$ ?  
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:

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

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

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  $N_2 + 3H_2 \rightleftharpoons 2NH_3$ . Is such mixture at equilibrium? If not, what is the direction of the net reaction?

**Solution:** The initial concentrations are given by

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

The reaction quotient is thus

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

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  $T_1 = 99.5^\circ$ , 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

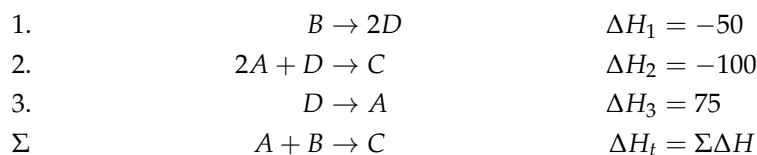
$$-mC_{Ti}\Delta T_{31} = VC\Delta T_{32} \implies C_{Ti} = 0.52$$

Therefore, the specific heat of titanium is  $0.52 \text{ J/g } ^\circ\text{C}$ .

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



**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  $B \rightarrow 2D$  and  $\Delta H = -50$ . Adding this to the remaining two sub-reactions yields:



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

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

- In which structures are the chains connected by non bonding interactions and covalent bonds?
- Which structure more easily forms a crystal? Explain.
- Which structure can be recycled?
- If a compound burns and does not melt, what type of structure is it?

**Solution:**

- Linear and branched polymers are connected by nonbonding interactions, whereas crosslinked polymers are connected by covalent bonds.
- Linear forms crystals more easily as there are no branches.
- Linear and branched polymers can be recycled as their interactions are broken when melted.
- 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  $r = 138 \text{ pm}$ .