

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 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 ΔS 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 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 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 ΔG^\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 ΔG_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 ΔG_{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 C_8H_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 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:

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

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

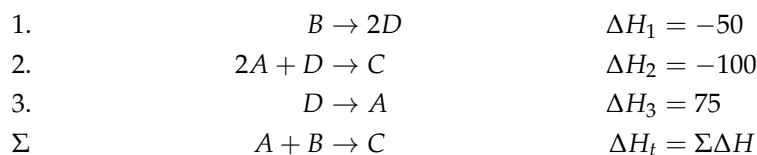
$$-mC_{Ti}\Delta T_{31} = VC\Delta T_{32} \implies C_{Ti} = 0.52$$

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 $r = 138 \text{ pm}$.