Chapter 19

Chemical Thermodynamics

1. The first law of thermodynamics can be given as ___A___.

A) $\Delta E = q + w$

B) $\Delta H^0_{rxn} = \sum n\Delta H^0_f\,(products) - \sum m\Delta H^0_f\,(reactants)$

C) for any spontaneous process, the entropy of the universe increases

D) the entropy of a pure crystalline substance at absolute zero is zero

E) $\Delta S = q_{rev}/T$ at constant temperature

2. Which one of the following is always positive when a spontaneous process occurs? C

A) ΔS_{system}
B) $\Delta S_{surroundings}$
C) $\Delta S_{universe}$
D) $\Delta H_{universe}$
E) $\Delta H_{surroundings}$

The second law of thermodynamics: any irreversible process results in **an increase in the entropy of the universe**, whereas any reversible process results in no change in the entropy of the universe

3. ΔS is positive for the reaction ___C___.

A) $2NO\ (g) + O_2\ (g) \rightarrow 2NO_2\ (g)$
B) $2N_2\ (g) + 3H_2\ (g) \rightarrow 2NH_3\ (g)$
C) $C_3H_8\ (g) + 5\ O_2\ (g) \rightarrow 3CO_2\ (g) + 4\ H_2O\ (g)$
D) $Mg\ (s) + Cl_2\ (g) \rightarrow MgCl_2\ (s)$
E) $C_2H_4\ (g) + H_2\ (g) \rightarrow C_2H_6\ (g)$

4. The standard Gibbs free energy of formation of __D__ is zero.

(a) H_2O (l)
(b) Fe (s)
(c) I_2 (s)

A) (a) only
B) (b) only
C) (c) only
D) (b) and (c)
E) (a), (b), and (c)

- **Standard Gibbs free energy of formation (ΔG_f^o)**: the change of Gibbs free energy that accompanies the formation of 1 mole of a substance in its standard state from its constituent elements in their standard states.

State of Matter	Standard State
Solid	Pure solid
Liquid	Pure liquid
Gas	1 atm pressure
Solution	1 *M* concentration
Element	$\Delta G_f^\circ = 0$ for element in standard state

- **The third law of thermodynamics:** the entropy of a pure, perfect crystalline substance at absolute zero is zero: S (0 K) = 0

5. For the reaction

$$2\ C_4H_{10}\ (g)\ +\ 13\ O_2\ (g) \rightarrow\ 8\ CO_2\ (g)\ +\ 10\ H_2O\ (g)$$

$\Delta H°$ is -125 kJ/mol and $\Delta S°$ is +253 J/K · mol. This reaction is __A__.

A) spontaneous at all temperatures
B) spontaneous only at high temperature
C) spontaneous only at low temperature
D) nonspontaneous at all temperatures
E) unable to determine without more information

6. Given the following table of thermodynamic data,

Substance	$\Delta H_f°$ (kJ/mol)	S° (J/mol • K)
$TiCl_4$ (g)	–763.2	354.9
$TiCl_4$ (l)	–804.2	221.9

complete the following sentence. The vaporization of $TiCl_4$ is ___C___.

A) spontaneous at all temperatures
B) spontaneous at low temperature and nonspontaneous at high temperature
C) nonspontaneous at low temperature and spontaneous at high temperature
D) nonspontaneous at all temperatures
E) not enough information given to draw a conclusion

$\Delta H_f°$ (kJ/mol)= 40.2 KJ S° (J/mol • K)= $133*10^{-3}$ KJ

7. With thermodynamics, one cannot determine ___A___.

A) the speed of a reaction
B) the direction of a spontaneous reaction
C) the extent of a reaction
D) the value of the equilibrium constant
E) the temperature at which a reaction will be spontaneous

$K = e^{-\frac{G}{RT}} =$

8. Consider the reaction:

$$FeO\,(s) + Fe\,(s) + O_2(g) \rightarrow Fe_2O_3\,(s)$$

Given the following table of thermodynamic data at 298 K:

The value K for the reaction at 25 °C is ___D___.

A) 370
B) 5.9×10^{4}
C) 3.8×10^{-14}
D) 7.1×10^{85}
E) 8.1×10^{19}

Substance	$\Delta H_f°$ (kJ/mol)	$S°$ (J/K • mol)
FeO (s)	–271.9	60.75
Fe (s)	0	27.15
O_2 (g)	0	205.0
Fe_2O_3 (s)	–822.16	89.96

$\Delta H_f°$ (kJ/mol)= -822.16+271.9 =-550.26 KJ/mol

$S°$ = 89.96-205.0-27.15-60.75 = -202.94 J/K·mol

G= -550260 +202.94*298 = $-4.89*10^5$J/mol

9. The normal boiling point of methanol is 64.7 °C and the molar enthalpy of vaporization is 71.8 kJ/mol. The value of ΔS when 1.75 mol of CH_3OH (l) vaporizes at 64.7 °C is ___C___ J/K.

A) 0.372
B) 4.24×10^7
C) 372
D) 1.94×10^3
E) 1.94