CHEMISTRY 102
Exam III

Spring 2021

1. Part of the process for the gasification of coal is:

$$2\ CO(g) + 2\ H_2(g) \rightarrow CO_2(g) + CH_4(g) \qquad \Delta H° = -247.3\ kJ$$

The standard enthalpies of formation ($\Delta H_f°$) for CO(g) and CO_2(g) are, respectively, −110.5 kJ/mol and −393.5 kJ/mol. Calculate the standard enthalpy of formation for methane (CH_4).

a) 38.0 kJ/mol b) −38.0 kJ/mol c) −74.8 kJ/mol

d) 74.8 kJ/mol e) 0 kJ/mol

2. Consider the following reaction at some temperature:

$$2\ NH_3(g) \rightleftharpoons 3\ H_2(g) + N_2(g) \qquad K_1 = 100$$

What is the value of K_2 for the following reaction at the same temperature?

$$3/2\ H_2(g) + \tfrac{1}{2}\ N_2(g) \rightleftharpoons NH_3(g) \qquad K_2 = ?$$

a) 0.005 b) 20 c) 10 d) 0.1 e) 0.02

3. Consider the reaction: $CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$. At 298 K, this reaction contains almost all product at equilibrium, with very little of the reactants present. Which of the following is the value of K for this reaction?

a) 3.7 b) 4.5×10^{9} c) 0.027 d) 6.9×10^{-12} e) 1.0

4. When a piston expands against a constant external pressure of 1.2 atm, the volume changes by 32.0 L. The change in internal energy for the expansion of the gas is −51 kJ. Calculate q for this process.

a) −36 kJ b) −13 kJ c) −47 kJ d) 24 kJ e) 56 kJ

5. A simple ionic compound, consisting of a metal and a nonmetal, forms three ions when it dissolves in water. If the solubility of the ionic compound is 1.0×10^{-4} mol/L, what is the value of K_{sp} for this ionic compound?

a) 1.0×10^{-8} b) 3.0×10^{-8} c) 1.0×10^{-12} d) 3.0×10^{-12} e) 4.0×10^{-12}

6. A 1.0 L flask is filled initially with 4.0 mol of H_2 and 6.0 mol of Cl_2. This mixture then reacts by the following equation:

$$H_2(g) + Cl_2(g) \rightleftharpoons 2\ HCl(g) \qquad K = ?$$

At equilibrium, 3.5 mol of Cl_2 remains. Calculate the value of K for the above reaction.

a) 2.0 b) 4.8 c) 0.95 d) 5.0 e) 1.2

7. The standard enthalpy of formation, $\Delta H_f°$, for hydrogen peroxide (H_2O_2) is −147.7 kJ/mol. Calculate the bond energy of the O–O single bond in hydrogen peroxide given the following bond energies:

Bond Energy	**kJ/mol**
O=O	495
H–H	432
O–H	467

H_2O_2 exists as H–O–O–H.

a) 604 kJ/mol b) 556 kJ/mol c) 278 kJ/mol

d) 141 kJ/mol e) 70. kJ/mol

8. Calculate ΔH_{vap} when 1.00 mole of a liquid is vaporized at its boiling point (80.°C) and a constant 1.00 atm pressure. ΔE for the vaporization of the liquid is 27.8 kJ/mol at 80.°C and 1.00 atm pressure.

a) 30.7 kJ b) 33.6 kJ c) −25.3 kJ

d) 24.9 kJ e) −24.9 kJ

9. The solubility of $Ce(IO_3)_3$ in a 0.20 *M* KIO_3 solution is 4.4×10^{-8} mol/L. Calculate K_{sp} for $Ce(IO_3)_3$.

a) 1.0×10^{-28} b) 8.8×10^{-9} c) 3.5×10^{-10} d) 1.9×10^{-15} e) 3.4×10^{-22}

10. Consider the following reaction:

$$Cu(OH)_2(s) + 4\ NH_3(aq) \rightleftharpoons Cu(NH_3)_4^{2+}(aq) + 2\ OH^-(aq)$$

Which of the following is the correct equilibrium constant expression for this reaction?

a) $K = \dfrac{[Cu(NH_3)_4^{2+}][OH^-]}{[Cu(OH)_2][NH_3]}$

b) $K = \dfrac{[Cu(NH_3)_4^{2+}][OH^-]^2}{[Cu(OH)_2][NH_3]^4}$

c) $K = [Cu(NH_3)_4^{2+}][OH^-]^2$

d) $K = \dfrac{[OH^-]^2}{[NH_3]^4}$

e) $K = \dfrac{[Cu(NH_3)_4^{2+}][OH^-]^2}{[NH_3]^4}$

11. At 35 °C, $K = 1.6 \times 10^{-5}$ for the reaction:

$$2\ NOCl(g) \rightleftharpoons 2\ NO(g) + Cl_2(g)$$

If 2.0 mol of NOCl are placed into a 4.0 L evacuated container at 35°C, what is the equilibrium concentration of NO?

a) 0.010 *M* b) 0.020 *M* c) 0.50 *M* d) 0.016 *M* e) 0.032 *M*

12. When 2.000 g of $NaHCO_3$ (molar mass = 84.01 g/mol) is reacted with 50.0 mL of 1.00 *M* HCl, the temperature of a coffee cup calorimeter decreases from 28.1°C to 24.8°C. Assuming the 50.0 mL of 1.00 *M* HCl has a mass of 50.0 g and assuming the heat capacity of the solution is 4.184 J/°C•g, calculate ΔH for the following reaction:

$$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + CO_2(g) + H_2O(l) \qquad \Delta H = ?$$

a) 30.2 kJ/mol b) 60.3 kJ/mol c) −30.2 kJ/mol

d) −60.3 kJ/mol e) 15.1 kJ/mol

13. An equilibrium mixture for the reaction:

$$2\ NO_2(g) \rightleftharpoons 2\ NO(g) + O_2(g) \qquad K = ?$$

contains 4.0 mol of NO_2, 6.0 mol of NO, and 8.0 mol of O_2, all in a 2.0 L container at a certain temperature. Calculate the value of K for this reaction at this temperature.

a) 3.0 b) 18 c) 9.0 d) 6.0 e) 12

14. At a certain temperature, K = 320. for the following reaction:

$$H_2(g) + F_2(g) \rightleftharpoons 2\,HF(g) \qquad K = 320.$$

Initially, 0.0500 *M* of H_2, 0.0500 *M* of F_2, and 0.400 *M* of HF are all reacted together. After equilibrium is established, calculate the equilibrium HF concentration ($[HF]_e$ = ?).

a) 0.325 *M* b) 0.350 *M* c) 0.400 *M*

d) 0.425 *M* e) 0.450 *M*

15. Consider a cyclic process (one that has the same initial and final state). How many of the following equalities (I - V) must be true for a cyclic process?

I. $\Delta E = 0$; II. $\Delta H = 0$; III. $\Delta P = 0$; IV. $\Delta V = 0$; V. $w = 0$;

a) 1 b) 2 c) 3 d) 4

e) 5 (All of these must be true for a cyclic process.)

16. Consider the following reaction at 25°C:

$$B_2O_3(s) + 3\,H_2O(g) \rightleftharpoons B_2H_6(g) + 3\,O_2(g) \qquad \Delta H° = 2035\ kJ;\ K = 4.8 \times 10^{-2}$$

Assuming the reaction is initially at equilibrium, which of the following statements is **true** regarding the reaction?

a) Raising the temperature will cause the value of K to decrease for this reaction.
b) Adding more $B_2O_3(s)$ will cause the reaction to shift to the right to reestablish equilibrium.
c) If the container volume is cut in half, the reaction will shift to the left to reestablish equilibrium.
d) Removing some $B_2H_6(g)$ will cause the reaction to shift to the left to reestablish equilibrium.
e) Adding more $O_2(g)$ will cause the value of K to decrease for this reaction.

Consider the following data for the next two questions:

Specific heat capacity of ice = 2.03 J/°C•g;
Specific heat capacity of water = 4.18 J/°C•g;
Specific heat capacity of steam = 2.02 J/°C•g

ΔH_{fusion} = 6.02 kJ/mol;
$\Delta H_{vaporization}$ = 40.7 kJ/mol;

17. A 100.0 g sample of water at 50.0°C is heated to steam at 150.0°C. If heat is added at a constant rate of 10.0 kJ/min, how long will it take the water to be heated from 50.0 to 150.0°C?

a) 13.0 min b) 16.3 min c) 28.8 min d) 3.10 min e) 25.7 min

18. A coffee cup calorimeter is filled with some water initially at 60.0°C. When 36.0 g of ice at 0.0°C is added to the calorimeter contents, the temperature decreased to 22.1°C. Calculate the mass of water (at 60.0°C) initially present in the calorimeter assuming no heat loss to the surroundings or to the calorimeter.

a) 97.0 g b) 36.0 g c) 76.0 g d) 21.0 g e) 42.9 g

19. Which of the following statements (a-d) is **true** for a process in which one mole of a gas is expanded from 1.0 L to 2.0 L?

a) When the gas expands from 1.0 L to 2.0 L, the surroundings are doing work on the system.
b) The work done in the process will be the same regardless of the path in going from the initial to the final state.
c) It is not possible to have more than one pathway to go from the initial to the final state.
d) The amount of heat exchanged in the process will not depend on the path taken.
e) None of these statements (a-d) is true.

20. 1.0×10^3 g of solid $NaHCO_3$ are placed into an evacuated reaction container at 125°C. The $NaHCO_3$ then reacts to reach equilibrium by the following reaction:

$$2\ NaHCO_3(s) \rightleftharpoons Na_2CO_3(s) + CO_2(g) + H_2O(g) \qquad K = 0.25$$

Which of the following statements concerning this experiment is **false**?

a) For this reaction, $K = [CO_2][H_2O]$.

b) At equilibrium, the concentrations of CO_2 and H_2O in this experiment will be equal to each other ($[CO_2] = [H_2O]$ at equilibrium).

c) If 2.0×10^3 g of solid $NaHCO_3$ were initially reacted at the same temperature (instead of 1.0×10^3 g), the value of K would remain constant ($K = 0.25$).

d) If 2.0×10^3 g of solid $NaHCO_3$ were initially reacted at the same temperature (instead of 1.0×10^3 g), the amount of CO_2 and H_2O produced at equilibrium would increase.

e) For this reaction, $K \neq K_p$.

21. Consider the following solubilities of silver chromate:

I. solubility of $Ag_2CrO_4(s)$ in water
II. solubility of $Ag_2CrO_4(s)$ in 0.10 *M* $AgNO_3$.
III. solubility of $Ag_2CrO_4(s)$ in 0.10 *M* K_2CrO_4.

Which of the above solubilities (I-III) is largest (in mol/L)?

a) I b) II c) III d) All of these solubilities are the same.

22. The energy of combustion of benzoic acid ($HC_7H_5O_2$) is -25 kJ/g and the energy of combustion of vanillin ($C_8H_8O_3$) is -20. kJ/g. When 1.0 g of benzoic acid is combusted in a bomb calorimeter, the temperature increases by 5.0°C. What will be the temperature increase (ΔT = ?) when 2.0 g of vanillin is combusted in the same bomb calorimeter?

a) 2.0°C b) 4.0°C c) 6.0°C

d) 8.0°C e) 10.0°C

23. Diborane (B_2H_6) is a highly reactive substance and was once considered as a possible rocket fuel. Using the following data:

	$\Delta H°$
$2\ B(s) + 3/2\ O_2(g) \rightarrow B_2O_3(s)$	−1273 kJ
$B_2H_6(g) + 3\ O_2(g) \rightarrow B_2O_3(s) + 3\ H_2O(g)$	−2035 kJ
$H_2O(l) \rightarrow H_2(g) + 1/2\ O_2(g)$	286 kJ
$H_2O(l) \rightarrow H_2O(g)$	44 kJ

calculate $\Delta H°$ for the following reaction:

$2\ B(s) + 3\ H_2(g) \rightarrow B_2H_6(g)$ $\quad \Delta H° = ?$

a) −96 kJ b) −52 kJ c) 36 kJ

d) 520. kJ e) 2582 kJ

24. In each of the following pairs of substances (I and II), which compound in each pair is most soluble (in mol/liter)?

I. Bi_2S_3 ($K_{sp} = 1.1 \times 10^{-73}$) vs. CuS ($K_{sp} = 8.5 \times 10^{-45}$)

II. Ag_2SO_4 ($K_{sp} = 1.2 \times 10^{-5}$) vs. $PbBr_2$ ($K_{sp} = 4.6 \times 10^{-6}$)

a) $Bi_2S_3(s)$ and $Ag_2SO_4(s)$ are the most soluble in each pair.
b) $Bi_2S_3(s)$ and $PbBr_2(s)$ are the most soluble in each pair.
c) CuS and $Ag_2SO_4(s)$ are most soluble in each pair.
d) CuS and $PbBr_2(s)$ are most soluble in each pair.

25. How many of the following three reactions (I – III) are endothermic at constant pressure?

I. $H{-}H(g) \rightarrow 2\ H(g)$
II. $O{=}O(g) \rightarrow 2\ O(g)$
III. $N{\equiv}N(g) \rightarrow 2\ N(g)$

a) 0 (none) b) 1 c) 2 d) 3 (All are endothermic reactions.)