Chemistry 112, Spring 2007 Prof. Metz Exam 2 Practice

Use the following information to answer questions 1 through 3

A proposed mechanism for the decomposition of hydrogen peroxide by iodide ion is:

$$H_2O_2 + I^- \rightarrow H_2O + OI^- \quad \text{slow}$$
$$H_2O_2 + OI^- \rightarrow H_2O + O_2 + I^- \quad \text{fast}$$

1. The rate law consistent with this mechanism is:

(A) $R = k[H_2O_2]^2$
(B) $R = k[H_2O_2][I^-]$
(C) $R = k[H_2O][OI^-]$
(D) $R = k[H_2O_2]^2[I^-]/[H_2O]$
(E) $R = k[H_2O][OI^-]/[H_2O_2][I^-]$

2. A catalyst in this mechanism is:

(A) I^-
(B) OI^-
(C) O_2
(D) H_2O
(E) there is none

3. An intermediate in this mechanism is:

(A) I^-
(B) OI^-
(C) O_2
(D) H_2O
(E) there is none

4. Methanogens are a class of bacteria that metabolize methane. They have an enzyme that allows them to convert methane to methanol. A very simplified mechanism has two steps: First, oxygen binds to the enzyme (E) to produce an enzyme-O_2 complex ($E{\bullet}O_2$), then methane reacts with the $E{\bullet}O_2$ complex to produce methanol:

$$O_2 + E \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} E{\bullet}O_2 \quad \text{fast, equilibrium}$$

$$E{\bullet}O_2 + 2\,CH_4 \xrightarrow{k_2} E + 2\,CH_3OH \quad \text{slow}$$

What is the rate law for this reaction ? (Note: k is a combination of k_1, k_{-1} and k_2)

(A) Rate = $k[O_2][CH_4][E]$
(B) Rate = $k[O_2][CH_4]^2[E]$
(C) Rate = $k[O_2][E]$
(D) Rate = $k[E][CH_4]^2$
(E) Rate = $k[CH_4]^2$

5. A reaction with an activation energy of E_a=100 kJ/mol has a rate constant k=10 s^{-1} at a temperature of 20 °C. What is the rate of this reaction (in s^{-1}) at 50 °C ?

(A) 7.1 (B) 10.0 (C) 14.0 (D)450 (E) 3300

6. Predict the sign of ΔS^o_{rxn} for the three reactions below:

I. $2NO_2$ (g) → N_2O_4 (liq)
II. NH_4NO_3 (s) → N_2O (g) + $2H_2O$ (g)
III. B (s) + $^3/_2F_2$ (g) → BF_3 (g)

	I	II	III		I	II	III
(A)	+	+	+	(D)	-	-	+
(B)	-	+	-	(E)	+	-	+
(C)	+	+	-				

7. Under what circumstances will ΔG for a chemical reaction always be positive?

(A) An endothermic reaction that generates fewer moles of gaseous products than gaseous reactants.

(B) An exothermic reaction that generates solids from liquid reactants.

(C) An exothermic reaction that generates fewer moles of gaseous products than gaseous reactants.

(D) An endothermic reaction that generates more moles of gaseous products than gaseous reactant.

(E) both (B) and (C) above.

For questions 8 and 9 use the thermodynamic data at 298 K given below and the following reaction.

$$Mg\ (s) + \frac{1}{2} O_2\ (g) \rightarrow MgO\ (s)$$

	ΔH^o_f (kJ/mol)	ΔG^o_f (kJ/mol)	S^o (J/mol K)
Mg (s)	0	0	33
O_2 (g)	0	0	205
MgO (s)	-602	-569	27

8. What is ΔS^o_{rxn} in J/mol K?

(A) -175 (C) -27 (E) -108
(B) 27 (D) 108

9. If magnesium metal is ignited in an oxygen atmosphere in an isolated system at 300 K:
   (A) no reaction will take place because ΔS^o_{rxn} is negative.
   (B) no reaction will take place because $\Delta S_{surroundings} = 0$.
   (C) a reaction will take place because $\Delta S_{universe}$ is positive.
   (D) no reaction will take place because $\Delta G^o_{reaction}$ is positive.
   (E) a reaction will take place because $\Delta S_{surroundings}$ is negative.

Questions 10 and 11 refer to the reaction

$$NO\ (g) + \frac{1}{2} O_2\ (g) \rightarrow NO_2\ (g)$$

for which ΔH_{rxn} = -57 kJ/mol and ΔS_{rxn} = -73 J/(mol K) at 298 K.

10. What is ΔG_{rxn} in kJ/mol at 25 °C for this reaction?

    (A) -35 (B) -79 (C) -22 (D) 68 (E) 85

11. What is the temperature in °C above/below which this reaction would have K_p greater than one?

    (A) below 508 °C
    (B) above 508 °C
    (C) below 128 °C
    (D) above 128 °C
    (E) There is none.

Thermodynamic values for Problems 12 and 13:

Species	**ΔH_f^0(298 K) kJ/mol**	**S^0(298 K) J/(K mol)**	**ΔG_f^0(298 K) kJ/mol**
C(s, graphite)	0	5.6	0
CH_4(g)	-74.87	186.26	-50.8
C_2H_4(g)	52.47	219.36	68.35
C_2H_6(g)	-83.85	229.2	-31.89
CO(g)	-110.53	197.67	-137.17
CO_2(g)	-393.51	213.74	-394.36
H_2(g)	0	130.7	0
H_2O(g)	-241.83	188.84	-228.59
H_2O(l)	-285.83	69.95	-237.15
NO(g)	90.29	210.76	86.58
NO_2(g)	33.1	240.04	51.23
O_2(g)	0	205.07	0

12. Use the thermodynamic values above to calculate ΔG_{rxn} in kJ/mol **at a temperature of 500 K** for the reaction

$$CH_4\,(g) + {}^3/_2\,O_2\,(g) \rightarrow CO\,(g) + 2\,H_2O\,(g)$$

(A) –275 (B) –280 (C) –479 (D) –544 (E) –560

13. Use the thermodynamic values at the top of this page to calculate the equilibrium constant K_p at 298 K for the reaction

$$O_2\,(g) + 2\,NO\,(g) \rightarrow 2\,NO_2\,(g)$$

(A) 4.0×10^{-13} (B) 6.4×10^{-7} (C) 4.8×10^{-4} (D) 1.6×10^{6} (E) 2.5×10^{12}

14. The equilibrium constant K_c for the reaction

$U_{(s)} + 3\,F_{2(g)} \rightleftharpoons UF_{6(g)}$ is

(A) $K_c = \dfrac{[UF_6]}{[U][F_2]}$

(B) $K_c = \dfrac{[UF_6]}{[U][3F_2]}$

(C) $K_c = \dfrac{[UF_6]}{[U][F_2]^3}$

(D) $K_c = \dfrac{[UF_6]}{[F_2]}$

(E) $K_c = \dfrac{[UF_6]}{[F_2]^3}$

15. At a particular temperature, an equilibrium mixture contains the following concentrations of gases: $[NO_2] = 0.32$ M, $[NO] = 10^{-4}$ M, $[O_2] = 0.045$ M.
What is the equilibrium constant K_c for the reaction

$$2\ NO_{2(g)} \rightleftharpoons 2\ NO_{(g)} + O_{2(g)}$$

(A) 4.5×10^{-10}
(B) 1.4×10^{-9}
(C) 4.4×10^{-9}
(D) 1.4×10^{-5}
(E) 4.5×10^{-5}

16. The reaction

$$H_{2(g)} + I_{2(g)} \rightleftharpoons 2\ HI_{(g)}$$ has K_c=56 at 300 K.

A 1 liter flask is filled with 0.2 moles of H_2, 0.2 moles of I_2 and 0.4 moles of HI.
Will any reaction occur ? If so, is HI produced or consumed ?

(A) No reaction will occur
(B) A reaction will occur; HI will be produced
(C) A reaction will occur; HI will be consumed

17. 2 moles of $NH_4Cl_{(s)}$ are put into an evacuated 1 liter container at 550 K, and the following reaction occurs:

$$NH_4Cl_{(s)} \rightleftharpoons NH_{3(g)} + HCl_{(g)}$$

At equilibrium, $[NH_{3(g)}] = 2.2 \times 10^{-3}$ M. What is K_c for the reaction ?

(A) 2.2×10^{-3} (B) 2.4×10^{-6} (C) 4.8×10^{-6} (D) 9.6×10^{-6} (E) 1.9×10^{-5}

18. 0.1 moles of $NOCl_{(g)}$ are placed in a 1 liter container at 372 K. The following reaction occurs:

$$2\ NOCl_{(g)} \rightleftharpoons 2\ NO_{(g)} + Cl_{2(g)} \qquad K_c = 1.78 \times 10^{-9}$$

What is the Cl_2 concentration at equilibrium ?
(Hint: K_c is so small that very little of the NOCl decomposes)

(A) 6.67×10^{-6}
(B) 1.33×10^{-5}
(C) 2.66×10^{-5}
(D) 1.64×10^{-4}
(E) 3.28×10^{-4}

19. At high temperatures, graphite reacts with CO_2 to produce CO:

$$C_{(s)} + CO_{2(g)} \rightleftharpoons 2\ CO_{(g)} \qquad K_c = 0.10$$

If 0.07 moles of CO_2 are placed in a 1 liter container, what is the CO concentration at equilibrium?
(Note: K_c is fairly large, so a significant amount of the CO_2 reacts)

(A) 0.022 M
(B) 0.031 M
(C) 0.043 M
(D) 0.062 M
(E) 0.13 M

Questions 20 through 22 refer to the following gas phase equilibrium for which K_c = 12 at 1100K and $\Delta H°$ = -198 kJ/mol.

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$$

20. Increasing the concentration (the pressure) on an equilibrium mixture by decreasing the volume at constant temperature would cause:

(A) K to decrease and the amount of $O_{2(g)}$ to increase.
(B) K to decrease and the amount of $O_{2(g)}$ to decrease.
(C) K to increase and the amount of $O_{2(g)}$ to decrease.
(D) no change in K but an increase in the amount of $O_{2(g)}$.
(E) no change in K but a decrease in the amount of $O_{2(g)}$.

21. Addition of $SO_{3\ (g)}$ to an equilibrium mixture of the three gases at constant volume and temperature
would cause:

(A) K to decrease and the amount of $O_{2\ (g)}$ to increase.
(B) K to decrease and the amount of $O_{2\ (g)}$ to decrease.
(C) K to increase and the amount of $O_{2\ (g)}$ to decrease.
(D) no change in K but an increase in the amount of $O_{2(g)}$.
(E) no change in K but a decrease in the amount of $O_{2\ (g)}$.

22. An equilibrium mixture of the three gases is initially at 1100K. The temperature is increased to 1300K, at constant volume. This would cause:

(A) K to decrease and the amount of $O_{2\ (g)}$ to increase.
(B) K to decrease and the amount of $O_{2\ (g)}$ to decrease.
(C) K to increase and the amount of $O_{2\ (g)}$ to decrease.
(D) no change in K but an increase in the amount of $O_{2(g)}$.
(E) no change in K but a decrease in the amount of $O_{2\ (g)}$.