Recitation Worksheet 9 – Exam 3 Review

Name _____ MyID _____

Instructions:

1. This recitation worksheet is for the exam 2 review.
2. You **do not need** to submit it to GradeScope.
3. The answer key has been posted with this worksheet to eLC.
4. The **recitation session in the exam week (Mar 27-30) is still mandatory**. The attendance will be recorded.

Chapter 13 – Chemical Equilibrium

1. Chemical equilibrium is the result of

_____

A. formation of products equal in mass to the mass of the reactants.
B. all of the reactants being converted into products.
C. stoppage of further reaction.
D. opposing reactions attaining equal rates.
E. a loss of pressure in the system

2. Express the equilibrium constant for the following reaction.

$$P_4(s) + 5\,O_2(g) \rightleftharpoons P_4O_{10}(s)$$

_____

A. $K = \dfrac{[P_4][O_2]^5}{[P_4O_{10}]}$

C. $K = [O_2]^5$

B. $K = \dfrac{[P_4O_{10}]}{[P_4][O_2]^5}$

D. $K = [O_2]^{-5}$

E. $K = \dfrac{[P_4O_{10}]}{[P_4][O_2]^{1/5}}$

3. Which of the following expression is correct for K_P of the following reaction?

_____

$$4CuO\,(s) + CH_4\,(g) \rightleftharpoons CO_2\,(g) + 4Cu\,(s) + 2H_2O\,(g)$$

A. $\dfrac{P_{CH_4}}{P_{CO_2} P_{H_2}{}^2}$

D. $\dfrac{[Cu]\, P_{CO_2} P_{H_2O}{}^2}{[CuO]^4\, P_{CH_4}}$

B. $\dfrac{P_{CO_2} P_{H_2O}{}^2}{P_{CH_4}}$

E. $\dfrac{P_{CH_4}}{P_{H_2O}{}^2 P_{CO_2}}$

C. $\dfrac{P_{CO_2} P_{H_2O}{}^2}{P_{CuO}}$

4. The equilibrium constant for reaction 1 is "K". What is the equilibrium constant for reaction 2?

$SO_2\,(g) + (1/2)\,O_2\,(g) \rightleftharpoons SO_3\,(g)$ ..... Reaction 1

$2SO_3\,(g) \rightleftharpoons 2SO_2\,(g) + O_2\,(g)$ ..... Reaction 2

5. The equilibrium constant is given for two of the reactions below. Determine the value of the missing equilibrium constant.

$A\,(g) + 2B\,(g) \rightleftharpoons AB2\,(g) \quad K_c = 59$

$AB_2\,(g) + B\,(g) \rightleftharpoons AB_3\,(g) \quad K_c = ?$

$A\,(g) + 3B\,(g) \rightleftharpoons AB_3\,(g) \quad K_c = 478$

6. Determine the value of K_C for the following reaction if the equilibrium concentrations are as follows: $[N_2]eq = 3.6$ M, $[O_2]eq = 4.1$ M, $[N_2O]eq = 3.3 \times 10^{-18}$ M

$2\,N_2(g) + O_2(g) \rightleftharpoons 2\,N_2O(g)$

X 10

Recitation Worksheet 9 – Exam 3 Review

7. What is the equilibrium concentration of N_2, if $[H_2]eq = 2.0$ M and $[NH_3]eq = 0.5$ M?

[ ] M

$$\mathbf{N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)} \quad K_c = 2.$$

8. Which of the following statements is FALSE?

[ ]

A. When K >> 1, the forward reaction is favored and essentially goes tocompletion.
B. When K << 1, the reverse reaction is favored and the forward reaction doesnot proceed to a great extent.
C. When K ≈ 1, neither the forward or reverse reaction is strongly favored, andabout the same amount of reactants and products exist at equilibrium.
D. K >> 1 implies that the reaction is very fast at producing products.
E. None of the above

9. What is Δn for the following equation in relating K_c to K_p?

[ ]

$$\mathbf{C_3H_8(g) + 5\ O_2(g) \rightleftharpoons 3\ CO_2(g) + 4H_2O(l)}$$

Recitation Worksheet 9 – Exam 3 Review

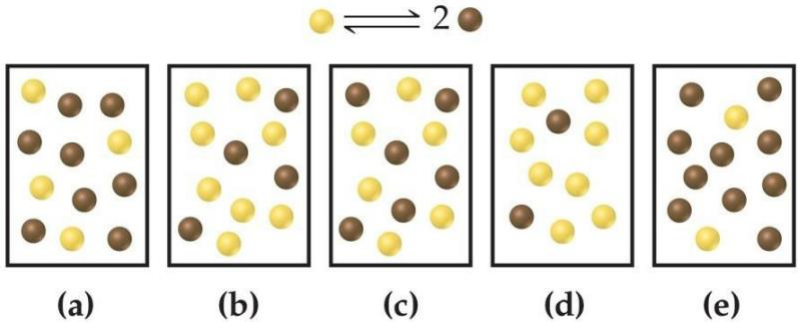
10. The reaction below has a K_p value of 3.3×10^{-5}. What is the value of K_c for this reaction at 700K?

$2\ SO_3(g) \rightleftharpoons 2\ SO_2(g) + O_2(g)$

11. The equilibrium constant for the reaction

$N_2O_4(g) \leftrightharpoons 2\ NO_2(g)$ $K_C = 6.0$ at 10 °C

If each yellow sphere represents 1 mol of N_2O_4 and each brown sphere 1 mol of NO_2 which of the following 1.0 L containers represents the equilibrium mixture at 10 °C?



12. For which of the following reactions is the ratio K_p/K_c largest at 300 K?

A. $N_2(g) + O_2(g) \leftrightharpoons 2\ NO(g)$

B. $CaCO_3(s) \leftrightharpoons CaO(s) + CO_2(g)$

C. $Ni(CO)_4(g) \leftrightharpoons Ni(s) + 4\ CO(g)$

D. $C(s) + 2\ H_2(g) \leftrightharpoons CH_4(g)$

Recitation Worksheet 9 – Exam 3 Review

13. If equilibrium is established by initially adding 0.10 mol each of A and B to a 1.00-L container, which of the following must be true once the mixture achieves equilibrium?

$A + 2\ B \leftrightharpoons 2\ C \qquad K = 320$

A. [A] = [B]
B. [A] = [B] = [C]
C. [B] = 2[C]
D. [A] > [B]
E. [A] < [B]

14. Calculate K for this reaction given the equilibrium concentrations of H_2, CO, and H_2O.

$C(s) + H_2O(g) \leftrightharpoons CO(g) + H_2(g) \qquad K=?$

Equilibrium Concentrations (M):	1.60	0.030	0.030

K=

15. What occurs when reactants are removed from a chemical reaction either in solution or the gas phase at equilibrium?

Q _____ (increases, decreases)

Equilibrium shifts _____ (left, right, no shift)

Recitation Worksheet 9 – Exam 3 Review

16. When 1.0 mole each of CO(g) and $Br_2(g)$ were placed into a 1L container and allowed to reach equilibrium, the resulting mixture contained 0.60 moles of CO(g). How many moles of $Br_2(g)$ and $C_2O_2Br_2(g)$ are present at equilibrium?

$$2\ CO(g) + Br_2(g) \rightleftharpoons C_2O_2Br_2(g)$$

Br_2 [ ] mol

$C_2O_2Br_2$ [ ] mol

17. 131 g of NOCl(g) (65.5 g/mol) was placed in a 4.00 L flask. What is the equilibrium concentration of $Cl_2(g)$ for this reaction?

$$2\ NOCl(g) \rightleftharpoons 2\ NO(g) + Cl_2(g) \qquad K_c = 3.0 \times 10^{-7}$$

$[Cl_2]$ = [ ] M

18. If you started with 0.280 mol $SbCl_3$ and 0.160 mol Cl_2, how many moles of $SbCl_5$, $SbCl_3$, and Cl_2 would be present when equilibrium is established at 248 °C in a 2.50 L flask?

$$SbCl_5(g) \rightleftharpoons SbCl_3(g) + Cl_2(g) \qquad K_c = 2.5 \times 10^{-2} \text{ at } 248\ °C$$

[ ] mol $SbCl_5$

[ ] mol $SbCl_3$

[ ] mol Cl_2

Recitation Worksheet 9 – Exam 3 Review

19. At equilibrium, a 1.0-liter container was found to contain 0.20 moles of A, 0.20 moles of B, 0.40 moles of C and 0.40 mole of D. If 0.10 moles of A and 0.10 moles of B are added to this system, what will be the new equilibrium concentration of A?

$A(g) + B(g) \leftrightharpoons C(g) + D(g)$

[A]= ☐ M

20. For which of these reactions would you expect the extent of the forward reaction to increase with increasing temperatures? Select all that apply.

☐

A. $NO(g) \rightleftharpoons \frac{1}{2} N_2(g) + \frac{1}{2} O_2(g)$ $\Delta_r H° = -90.2$ kJ/mol

B. $SO_3(g) \rightleftharpoons SO_2(g) + \frac{1}{2} O_2(g)$ $\Delta_r H° = +98.9$ kJ/mol

C. $N_2H_4(g) \rightleftharpoons N_2(g) + 2\ H_2(g)$ $\Delta_r H° = -95.4$ kJ/mol

D. $COCl_2(g) \rightleftharpoons CO(g) + Cl_2$ $\Delta_r H° = +108.3$ kJ/mol

21. Consider the gas-phase equilibrium system represented by the equation:

$$2\ H_2O(g) \leftrightharpoons 2\ H_2(g) + O_2(g)$$

Given that the forward reaction is **endothermic**, which of these changes will **decrease** the equilibrium amount of H_2O?

☐

A. adding more oxygen
B. adding a solid phase catalyst
C. decreasing the volume of the container (the total pressure increases)
D. increasing the temperature at constant pressure
E. adding He gas

Recitation Worksheet 9 – Exam 3 Review

22. When the system A + B ⇋ C + D is at equilibrium,

A. the sum of the concentrations of A and B must equal the sum of the concentrations of C and D
B. the forward reaction has stopped.
C. both the forward and the reverse reactions have stopped.
D. the reverse reaction has stopped.
E. neither the forward nor the reverse reactions has stopped.

23. Consider the equilibrium system:

$$2\ ICl(s) \rightleftharpoons I_2(s) + Cl_2(g)$$

Which of these changes will increase the total amount of Cl_2 that can be produced?

A. removing some of the $I_2(s)$
B. adding more ICl(s)
C. removing the Cl_2 as it is formed
D. decreasing the volume of the container
E. all of the above

24. For a specific reaction, which of these statements can be made about the equilibrium constant?

A. It always remains the same at different reaction conditions.
B. It increases if the concentration of one of the products is increased.
C. It changes with changes in the temperature.
D. It increases if the concentration of one of the reactants is increased.
E. It may be changed by the addition of a catalyst.

25. If the concentration of N_2 gas is decreased, which way will the reaction shift (right, left, no shift)?

$$N_2H_4(g) + O_2(g) \rightleftharpoons N_2(g) + 2\ H_2O(g)$$

26. Will an increase in pressure with no change in volume cause the reaction below to shift to the right or the left?

$$N_2(g) + 3\ Br_2(l) \rightleftharpoons 2\ NBr_3(s)$$

Recitation Worksheet 9 – Exam 3 Review

27. The Haber reaction to produce ammonia from nitrogen and hydrogen is:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2\ NH_3(g)$$

K_c for the Haber reaction at 472 °C is 0.105. If the reaction is setup with these starting concentrations: $N_2(g)$ = 4.27 x 10^{-3} M, $H_2(g)$ = 8.66 x 10^{-3} M, $NH_3(g)$ = 3.19 x 10^{-3} M, what will be the reaction quotient, and will more or less ammonia be present at equilibrium compared to the starting concentration?

Q_c = [ ]

(**More** or **less** NH_3) [ ]

28. In one of Haber's experiments, 2.02 x 10^{-2} M of $H_2(g)$, 9.37 x 10^{-3} M of $N_2(g)$, and 1.39 x 10^{-5} M of $NH_3(g)$ are combined at 623 °C. The mixture is allowed to come to equilibrium and the concentration of $NH_3(g)$ is observed to be 3.44 x 10^{-4} M. Calculate K_c for the Haber reaction at this temperature.

[N_2] at equilibrium [ ] M

[H_2] at equilibrium [ ] M

K_c = [ ]

29. For the simple equilibrium reaction A ⇌ B, the forward rate constant is known to be 4.87 x 10^3 Ms^{-1}, and the reverse rate constant is 5.01 x 10^{-5} M s^{-1}. For a reaction at equilibrium, the concentration of A is observed to be 2.93 x 10^{-2} M. What is the concentration of B at equilibrium?

[B] = [ ] M

Recitation Worksheet 9 – Exam 3 Review

30. Calculate the equilibrium constant, K_C, for the reaction:

$$2\ SO_3(g) \leftrightharpoons 2\ SO_2(g) + O_2(g)$$

Initial concentration of $[SO_3(g)]$ = 1.32 M, $[SO_2(g)]$ = 0.282 M, $[O_2(g)]$ = 0.127 M

Equilibrium concentration of $SO_3(g)$ = 0.287 M

K_C = ☐

31. For the reaction, write how the each of the changes will affect the indicated quantity, assuming a container of a fixed size. Use an **"up" arrow** to indicate an increase, and a **"down" arrow"** to indicate a decrease.) (For a chemical added, write how it would respond AFTER the addition.)

$$H_2(g) + Br_2(g) \leftrightharpoons 2HBr(g) \quad \Delta H^o = -103.7kJ$$

Change	[H2]	[Br2]	[HBr]	K value
1. H_2 added				
2. HBr added				
3. H_2 removed				
4. HBr removed				
5. The temperature is increased				
6. The temperature is decreased				
7. Pressure is increased and thecontainer volume decreased				

32. Do you expect **products or reactants** to dominate at equilibrium in a reaction for which ΔG° is equal to

☐ A. 1.4 kJ/mol?

☐ B. 105 kJ/mol?

☐ C. −34 kJ/mol?

Recitation Worksheet 9 – Exam 3 Review

33. Carbon monoxide, a toxic product from the incomplete combustion of fossil fuels, reacts with water to form CO_2 and H_2, as shown in the equation

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

for which $\Delta H° = -41.0$ kJ/mol and $\Delta S° = -42.3$ J/(mol·K) at 25 °C and 1 atm.

A. What is the K_p for this reaction?

B. What is ΔG if the gases have the following partial pressures: $P_{CO} = 1.3$ atm, $P_{H_2O} = 0.8$, atm, $P_{CO_2} = 2.0$ atm, and $P_{H_2} = 1.3$ atm?

kJ/mol

C. What is $\Delta G°$ if the temperature is increased to 150 °C assuming no change in pressure? kJ/mol

34. Which of the following is NOT true? <u>Select all that apply.</u>

A. If $\Delta G°_{rxn} > 0$, the reaction is spontaneous in the forward direction.
B. If $Q = 1$, then $\Delta G_{rxn} = \Delta G°_{rxn}$.
C. If $\Delta G°_{rxn} > 0$, the reaction is spontaneous in the reverse direction.
D. Under equilibrium conditions, $\Delta G_{rxn} = 0$.
E. If $K > 1$, the reaction is spontaneous in the reverse direction.

Recitation Worksheet 9 – Exam 3 Review

35. Which of the following reactions will have the largest equilibrium constant (K) at 298 K?

A. $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ $\Delta G° = +131.1$ kJ
B. $2\ Hg(g) + O_2(g) \rightarrow 2\ HgO(s)$ $\Delta G° = -180.8$ kJ
C. $3\ O_2(g) \rightarrow 2\ O_3(g)$ $\Delta G° = +326$ kJ
D. $Fe_2O_3(s) + 3\ CO(g) \rightarrow 2\ Fe(s) + 3\ CO_2(g)$ $\Delta G° = -28.0$ kJ
E. It is not possible to determine without more information.

36. Calculate the equilibrium constant for the following reaction,

$$ClO(g) + O_3(g) \rightarrow Cl(g) + 2\ O_2(g)$$

$2\ O_3(g) \rightarrow 3\ O_2(g)$ $\Delta G°_{rxn} = +489.6$kJ
$Cl(g) + O_3(g) \rightarrow ClO(g) + O_2(g)$ $\Delta G°_{rxn} = -34.5$ kJ

37. Consider the reaction:

$N_2(g) + 3\ F_2(g) \rightarrow 2\ NF_3(g)$ $\Delta H° = -253$ kJ and $\Delta S° = -264$ J/K at 31 °C

Calculate $\Delta G°$ and state whether the equilibrium composition should favor reactants or products at standard conditions.

A. $\Delta G° = -333$ kJ; the equilibrium composition should favor products.
B. $\Delta G° = -333$ kJ; the equilibrium composition should favor reactants.
C. $\Delta G° = -173$ kJ; the equilibrium composition should favor products.
D. $\Delta G° = -173$ kJ; the equilibrium composition should favor reactants.

Acids and Bases

38. Solutions of each of the hypothetical acids in the following table are prepared with an initial concentration of 0.100 M. Which of the four solutions will have the lowest pH and be most acidic?

Acid	pKa
HA	4.00
HB	7.00
HC	10.00
HD	11.00

Recitation Worksheet 9 – Exam 3 Review

39. In the equation: $HF + H_2O \leftrightharpoons H_3O^+ + F^-$

A. H_2O is a base and HF is its conjugate acid.
B. H_2O is an acid and HF is the conjugate base.
C. HF is an acid and F^- is its conjugate base.
D. HF is a base and H_3O^+ is its conjugate acid.
E. HF is a base and F^- is its conjugate acid.

40. Which of the following species is amphoteric?

A. CO_3^{2-}
B. HF
C. NH_4^+
D. HPO_4^{2-}
E. None of the above is amphoteric

41. What is the conjugate base of $H_2PO_4^-$?

A. HPO_4^{2-}
B. PO_4^{3-}
C. H_3PO_4
D. H_3O^+
E. OH^-

42. What is the pH and pOH of a 2.77×10^{-3} M aqueous solution of HI?

pH =

pOH =

43. Hypochlorous acid (HOCl) has a $K_a = 2.90 \times 10^{-8}$. What is the pH of a 0.187 M aqueous solution?

Recitation Worksheet 9 – Exam 3 Review

44. What is the pH and pOH of an aqueous solution of 3.22×10^{-5} M HCl?

pH = ☐

pOH = ☐

45. Hydrofluoric acid has a $K_a = 6.60 \times 10^{-4}$. What is the pH of a 0.257 M aqueous solution of hydrofluoric acid?

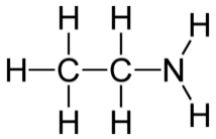
pH = ☐

46. An aqueous solution of a monoprotic weak acid has a pH = 3.22. If the concentration of the weak acid initially added to the water was 0.108 M what is the K_a for this weak acid?

K_a = ☐

Recitation Worksheet 9 – Exam 3 Review

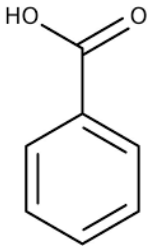
47. The K_b of ethylamine is 4.30×10^{-4}. What is the pH of a 0.0847 M aqueous solution of ethylamine?



$$CH_3CH_2NH_2(aq) + H_2O(l) \leftrightharpoons CH_3CH_2NH_3^+(aq) + OH^-(aq)$$

pH = [ ]

48. Benzoic acid (C_6H_5COOH) is a monoprotic acid with $K_a = 6.30 \times 10^{-5}$. What is the pH of a solution of benzoic acid that is 0.559 M in benzoic acid?



pH = [ ]

49. The $[H_3O^+]$ and pH of 0.021 M HNO_3 are:

$[H_3O^+]$ = [ ]

pH = [ ]

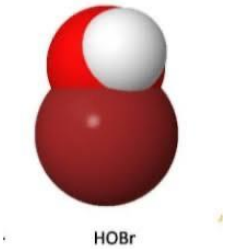
Recitation Worksheet 9 – Exam 3 Review

50. Calculate the hydronium ion concentration in a 0.012 M aqueous solution of NaOH.

$[H_3O^+]$ = ☐

51. A 0.55 M solution of the weak acid HBrO has a pH of 4.48. What is the value of K_a for HBrO?

K_a = ☐

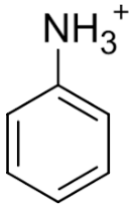


52. Vinegar is a 5.0% solution by weight acetic acid (CH_3CO_2H) in water. Given that $K_a = 1.8 \times 10^{-5}$ for acetic acid and assuming the density is 1.00 g/cm^3, what is the pH of the vinegar solution?

☐

53. The basicity constant K_b for $C_6H_5NH_2 = 4.3 \times 10^{-10}$. Calculate the pH of a 0.15 M solution of $C_6H_5NH_3^+$ in water.

pH = ☐



Recitation Worksheet 9 – Exam 3 Review

54. Which one of these is the strongest acid?

A. CH_3COOH ($K_a = 1.8 \times 10^{-5}$)
B. $HCOOH$ ($K_a = 1.0 \times 10^{-4}$)
C. $HClO$ ($K_a = 3.0 \times 10^{-8}$)
D. HF ($K_a = 6.8 \times 10^{-4}$)

55. What is the conjugate acid of $C_4H_7NH_2$?

56. Given the K_a values shown, which of the following acids would have the strongest conjugate base?

A. CH_3COOH ($K_a = 1.8 \times 10^{-5}$)
B. $HCOOH$ ($K_a = 1.0 \times 10^{-4}$)
C. $HClO$ ($K_a = 3.0 \times 10^{-8}$)
D. HF ($K_a = 6.8 \times 10^{-4}$)

57. A saturated aqueous solution of calcium hydroxide has a pH of 12.25. What is the concentration of calcium hydroxide in such a solution?

58. If the pH of a solution increases by 2 units (e.g., from 1 to 3), then the ratio of the new to the original hydronium ion concentration is _____

A. 2/1
B. 1/100
C. 100/1
D. 1/1, unchanged
E. ½

Recitation Worksheet 9 – Exam 3 Review

59. When $[H_3O^+] = 1.0 \times 10^{-7}$ M in water at 25 °C, then _____

A. pH = 1

B. $[OH^-] = 1.0 \times 10^{7}$ M

C. pH = 10^{-7}

D. $[OH^-] = 0$ M

E. $[OH^-] = 1.0 \times 10^{-7}$ M

60. A solution with a pH of 9.50 has a pOH of _____ .

61. The first disinfectant used by Joseph Lister was called carbolic acid. This substance now is known as phenol, C_6H_5OH (pK_a = 10.0). What is the pH of a 0.10 M solution of phenol?

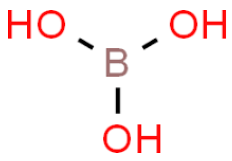
pH =

62. The pH of a popular soft drink is 3.4; what is its hydronium ion concentration?

$[H_3O^+]$ = M

63. Boric acid frequently is used as an eyewash to treat eye infections. The pH of a 0.050 M solution of boric acid is 5.28. What is the value of the boric acid ionization constant, K_a?

K_a =



Recitation Worksheet 9 – Exam 3 Review

64. The acidic ingredient in vinegar is acetic acid. The pH of vinegar is around 2.4, and the molar concentration of acetic acid in vinegar is around 0.85 M. Based on this information, determine the value of the acid ionization constant for acetic acid.

$K_a =$ ☐

65. For the reaction

$$CdO(s) + SO_3(g) \rightarrow CdSO_4(s) \quad \Delta H = -279.4 \text{ kJ/mol, and } \Delta S = -118.4 \text{ J/mol} \cdot \text{K}.$$

What is the temperature, in Celsius, at which K_{eq} is 1.0×10^4?

☐ °C

66. The equilibrium constant for the reaction $\frac{1}{2} Cl_2(g) + \frac{1}{2} F_2(g) \rightleftharpoons ClF(g)$ is measured to be 9.3×10^9 at 298 K and 3.3×10^7 at 398 K. Calculate:

A. $\Delta G°_{rxn}$ at 298 K for the reaction in kJ/mol.

☐ kJ/mol

B. $\Delta H°$ between 298 K and 398 K. Keep your answer to three sig figs.
kJ/mol

67. For the hypothetical reaction A(g) + B(g) ⇌ C(g) + D(g), $\Delta H°$ = -25.8 kJ/mol and K = 1.4 x 10^3 at 25 °C. What is the value of K at 382 °C? Keep your answer to two sig figs.