Recitation Worksheet Eight

Name: | MyID:

Textbook:

Chemistry & Chemical Reactivity
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Instructions:

- This recitation worksheet covers Ch. 15.1-15.6, 18.5-18.7
- Please enter your first and last name as it appears on the eLC roster (do not use a nickname that is not reflected in eLC).
- Your UGA myID is a combination of letters and numbers (example: Dr. Abdelrahman's MyID is ema88805@uga.edu). **Do not use your 81x number**.
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  - You may use an app to annotate the worksheet by placing your answers in the answer boxes and showing your work when appropriate. Afterward, submit the worksheet to Gradescope. You will not need to upload anything to eLC.
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  - If you do not have access to a printer, you may type your answers directly into the worksheet PDF and then submit it to Gradescope. Write your work on separate sheets of paper, convert them to a PDF, and upload to the appropriate dropbox on eLC.
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- The following criteria **must** be met to be eligible for full credit:
  - You must make sure the pages are in the correct order and have the same layout as the original worksheet when submitting to Gradescope regardless of your submission type.
  - Answers must be written in the corresponding answer boxes.
  - You must show your work when appropriate.
- This worksheet is due no later than **12:00 PM (noon) on the Saturday, October 19th.**
- A periodic table and formula sheet are attached to the end of this worksheet. Please keep these attached to your worksheet in the correct order when submitting to Gradescope.

1. Use the equation below to answer the following questions:

$$Fe(OH)_3(s) + 3\ H^+(aq) \rightleftharpoons Fe^{3+}(aq) + 3\ H_2O(l) \quad K = 9.1 \times 10^3$$

A. The correct equilibrium constant expression for this reaction is

i. $\frac{[FeOH_3][H^+]^3}{[Fe^{3+}][H_2O]^3}$

ii. $\frac{[Fe^{3+}][H_2O]^3}{[FeOH_3][H^+]^3}$

iii. $\frac{[Fe^{3+}][H_2O]}{[FeOH_3][H^+]}$

iv. $\frac{[Fe^{3+}]}{[H^+]^3}$

v. $\frac{[FeOH_3][H^+]}{[Fe^{3+}][H_2O]}$

B. What is the equilibrium concentration for $[Fe^{3+}]$ if the equilibrium concentration for $[H^+] = 2.5 \times 10^{-8}$? Use **scientific notation** to report your answer.

x 10 M

2. Use the reaction below to answer the following questions

$$N_2(g) + O_2(g) + Cl_2(g) \rightleftharpoons 2\ NOCl(g) \quad K_p = ?$$

A. Calculate K_p at 25 °C using the set of equations provided. Use **scientific notation** to report your answer.

$\frac{1}{2} N_2(g) + O_2(g) \rightleftharpoons NO_2(g)$	$K_p = 1.0 \times 10^{-9}$
$NOCl(g) + \frac{1}{2} O_2(g) \rightleftharpoons NO_2Cl(g)$	$K_p = 1.1 \times 10^{2}$
$NO_2(g) + \frac{1}{2} Cl_2(g) \rightleftharpoons NO_2Cl(g)$	$K_p = 3.0 \times 10^{-1}$

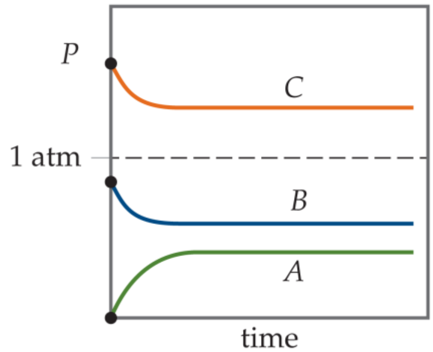
$\boxed{} \times 10^{\boxed{}}$

B. Calculate K_c for the same reaction.

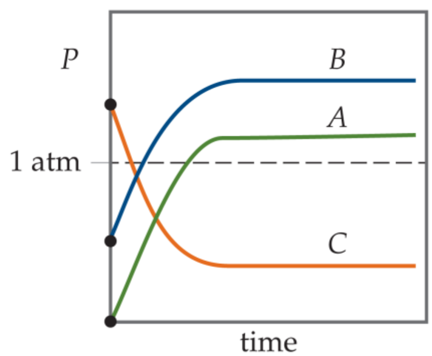
$\boxed{} \times 10^{\boxed{}}$

3. For the reaction A(g) + B(g) $\rightleftharpoons$ C(g), $K_p < 1$. Which of the following charts below describes the approach to equilibrium of a mixture of B(g) and C(g)?

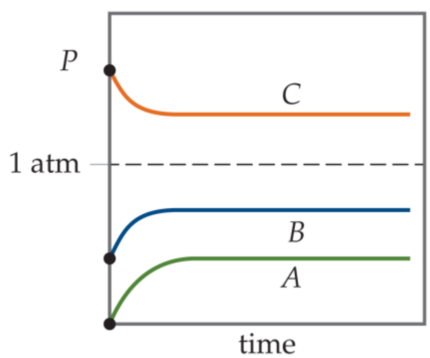
A.



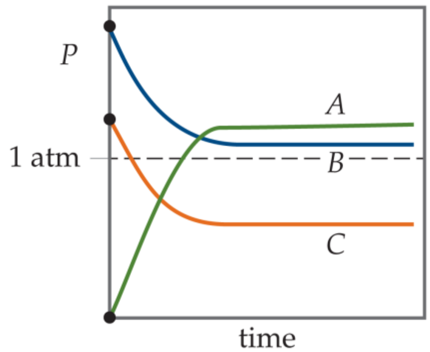
B.



C.

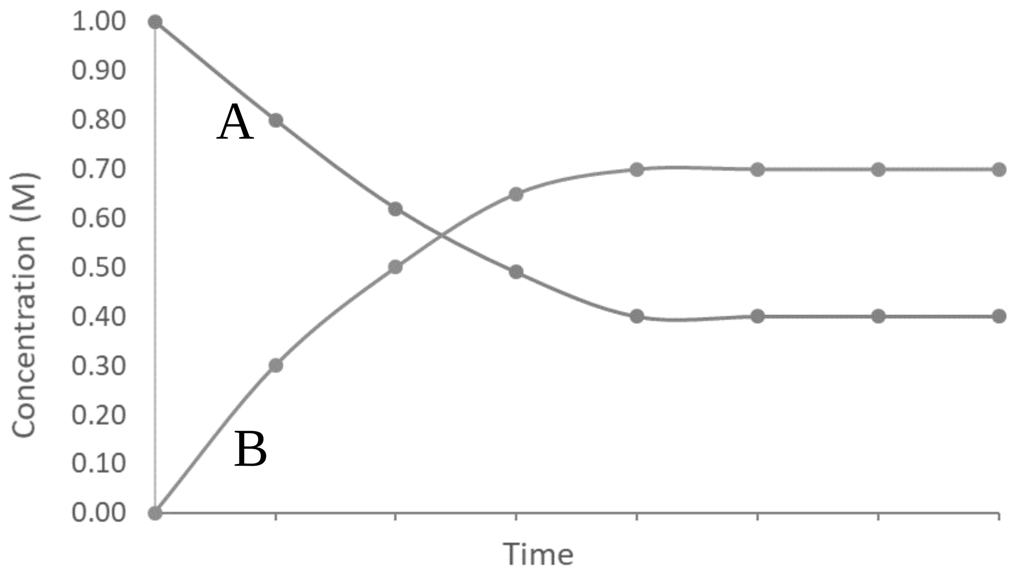


D.



4. A graph for the reaction A(g) ⇋ 2B(g) shows the change in concentration over time. What is the equilibrium constant for this reaction?

A. 1.8
B. 1.2
C. 4.4
D. 0.82
E. 0.57



5. You prepare a saturated solution of $PbBr_2$, and the equilibrium equation is written as follows:

$$PbBr_2(s) \rightleftharpoons Pb^{2+}(aq) + 2\ Br^-(aq)$$

If solid $PbBr_2$ is added to this solution, which of the following statements is **true**?

A. The concentration of Pb^{2+} will increase more than the concentration of Br-
B. The concentration of Br^- will increase more than the concentration of Pb^{2+}
C. The concentration of Pb^{2+} and Br^- will be the same as they were before more $PbBr_2$ was added
D. The concentration of Pb^{2+} and Br^- will increase after more $PbBr_2$ was added
E. The value of K_c will decrease

6. In which of the following reactions will $K_p = K_c$? <u>Select all that apply</u>. Insert letters without spaces in the answer box, example **ABCD**.

A. $4\ KO_2(s) + 2\ CO_2(g) \rightleftharpoons 2\ K_2CO_3(s) + 3\ O_2(g)$
B. $3\ Fe(s) + 4\ H_2O(g) \rightleftharpoons Fe_3O_4(s) + 4\ H_2(g)$
C. $2\ H_2S(g) + CH_4(g) \rightleftharpoons CS_2(g) + 4\ H_2(g)$
D. $2\ HI(g) \rightleftharpoons H_2(g) + I_2(g)$
E. $4\ NH_3(g) + 5\ O_2(g) \rightleftharpoons 4\ NO(g) + 6\ H_2O(g)$

7. A mixture of 1.00 g H_2 and 1.06 g H_2S in a 0.500 L flask comes to equilibrium at 1670 K:

$$2\ H_2(g) + S_2(g) \rightleftharpoons 2\ H_2S(g)$$

The equilibrium amount of $S_2(g)$ found is 8.00×10^{-6} mol.

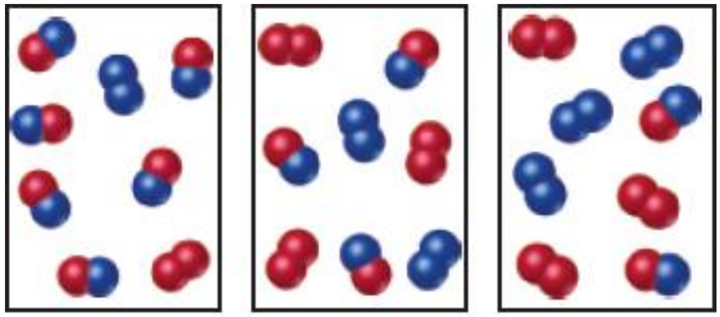
A. What is the equilibrium concentration of H_2S?

M

B. What is the value of K_c?

C. What is the value of K_p?

8. The diagram below represents the reaction between $A_2(g) + B_2(g) \rightleftharpoons 2\ AB(g)$, A_2 molecules are represented by red spheres, B_2 molecules are represented by blue spheres and the reaction has an equilibrium constant, $K_c = 1.5$. Which of the following diagrams a – c represents:



a b c

A. The reaction at equilibrium

B. $Q_c < K_c$

C. $Q_c > K_c$

9. You are a given a solution of silver sulfate and the ionization of silver sulfate in water can be represented by the equation below

$$Ag_2SO_4(s) \rightleftharpoons 2\ Ag^+(aq) + SO_4^{2-}(aq) \quad K = 1.1 \times 10^{-5} \text{ at } 298\ K$$

If the solution a 1.5 L solution contains 6.55 g Ag_2SO_4, and you attempt to dissolve additional solid silver sulfate in the solution will it dissolve?

A. Yes
B. No

10. Phosgene, a colorless toxic gas ($COCl_2$) used in the synthesis of dyes and resins can be synthesized using carbon monoxide and chorine gases represented by the equilibrium reaction below

$$CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g) \quad K_c = 1.2 \times 10^3 \text{ at } 395\ °C$$

If 4.20 g CO(g) and 10.6 g Cl_2(g) are injected in a 3.25 L flask, what is the equilibrium concentration of the species below. Use **scientific notation** to report your answer.

A. $Cl_2(g)$

$\boxed{} \times 10^{\boxed{}}$ M

B. CO(g)

$\boxed{} \times 10^{\boxed{}}$ M

C. $COCl_2(g)$

$\boxed{} \times 10^{\boxed{}}$ M

11. A mixture of 0.250 mol $H_2(g)$ and 0.250 mol $I_2(g)$ in a 4.05 L flask is represented by the reaction below

$$H_2(g) + I_2(g) \rightleftharpoons 2\ HI(g) \quad K_c = 50.2$$

Calculate the equilibrium concentrations of the species below. Use **scientific notation** to report your answer.

A. $H_2(g)$

$\boxed{} \times 10^{\boxed{}}$ M

B. $I_2(g)$

$\boxed{} \times 10^{\boxed{}}$ M

C. $HI(g)$

$\boxed{} \times 10^{\boxed{}}$ M

12. Which of the following statements is true regarding the equilibrium reaction $A(s) \rightleftharpoons B(s) + 2\,C(g) + \frac{1}{2}\,D(g)$ $\Delta H = 0$?

A. The addition of excess solid A(s) at equilibrium will not have any effect on the equilibrium mixture.
B. If the volume of the equilibrium mixture is decreased by doubling the pressure, the system shifts to the left to reestablish equilibrium.
C. Increasing or decreasing the temperature will not affect the equilibrium constant, Kc, for this reaction.
D. If Ne(g) is introduced to the equilibrium reaction at constant volume will .have no effect on the equilibrium position.
E. All of the statements above are true.

13. The decomposition of N_2O_4 to NO_2 is represented by the equilibrium reaction equation below

$$N_2O_4(g) \rightleftharpoons 2\,NO_2\,(g)$$

If 1.75 moles of N_2O_4 is injected in a 1.5 L vessel and at equilibrium 25% N_2O_4 is dissociated, what is the equilibrium constant for this reaction?

14. For the hypothetical equilibrium reaction

$$A(g) + B(g) \rightleftharpoons C(g) + D(g) \quad K_c = 4.0$$

If you start with 0.373 M A(g), 0.396 M B(g), 0.552 M C(g), and 3.95 M D(g), what is the equilibrium concentration of C(g) and D(g)?

A. C(g)

$\boxed{}$ M

B. D (g)

$\boxed{}$ M

15. If lead metal is added to a 0.100 M $Cr^{3+}(aq)$ solution. What are the concentrations of $Pb^{2+}(aq)$, $Cr^{2+}(aq)$, and $Cr^{3+}(aq)$ when the reaction is at equilibrium? Use **scientific notation** to report your answer.

$$Pb(s) + 2\ Cr^{3+}(aq) \rightleftharpoons Pb^{2+}(aq) + 2\ Cr^{2+}(aq) \quad K_c = 3.2 \times 10^{-10}$$

A. $Pb^{2+}(aq)$

$\boxed{} \times 10^{\boxed{}}$ M

B. $Cr^{2+}(aq)$

$\boxed{} \times 10^{\boxed{}}$ M

C. $Cr^{3+}(aq)$

$\boxed{} \times 10^{\boxed{}}$ M

16. The equilibrium mixture at 1000 K for the reaction $CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g)$ contains 0.276 M $H_2(g)$, 0.276 M $CO_2(g)$, 0.224 M $CO(g)$, and 0.224 M $H_2O(g)$. Determine the following:

A. The equilibrium constant, K_c

B. $\Delta G°_{rxn}$ at 1000 K

kJ/mol

C. Does the reaction proceed towards products or reactants at 1000 K if a mixture contains 0.0750 M $CO_2(g)$, 0.095 M $H_2(g)$, 0.0340 mol $CO(g)$, and 0.0650 mol $H_2O(g)$?

I. The reaction proceeds towards products
II. The reaction proceeds towards reactants
III. The reaction is at equilibrium

17. One of the processes used in the production of chlorine gas is the Deacon process given by the equation below

$$4\ HCl(g) + O_2(g) \rightleftharpoons 2\ H_2O(g) + 2\ Cl_2(g) \quad \Delta_r H° = -114\ kJ/mol$$

If the above mixture is brought to equilibrium at 400 °C, which of the changes below will cause the system to increase the amount of $Cl_2(g)$? <u>Select all that apply.</u> Insert letters without spaces in the answer box, example **ABCD.**

A. Cooling the reaction below 400 °C
B. Additional moles of HCl gas added to the system
C. Increasing the volume of the system
D. Increasing the pressure of the system
E. Addition of a catalyst

18. For the reaction $N_2O_4(g) \rightleftharpoons 2\ NO_2(g)$, $\Delta H° = +57.2$ kJ/mol and $K = 0.113$ at 25 °C, what is the value of

A. K at 0 °C (report your answer using **scientific notation**)

x

B. At what temperature will $K = 1.00$?

K

19. In the Ostwald process for oxidizing ammonia, a variety of products is possible – N_2, N_2O, NO, and NO_2 – depending on the conditions. One possibility is:

$$NH_3(g) + \frac{5}{4} O_2(g) \rightleftharpoons NO(g) + \frac{3}{2} H_2O\ (g) \quad K_p = 2.11 \times 10^{19} \text{ at 700 K}$$

For the decomposition of NO_2 at 700 K,

$$NO_2(g) \rightleftharpoons NO(g) + \frac{1}{2} O_2(g) \quad K_p = 0.524 \text{ at 700 K}$$

What is K_p for the oxidation of $NH_3(g)$ to $NO_2(g)$?

$\square \times 10^{\square}$

20. The equilibrium reaction for the synthesis of 1,2 dichloroethane is given below

$$C_2H_4(g) + Cl_2(g) \rightleftharpoons C_2H_4Cl_2(g) \quad \Delta H = -1244 \text{ kJ/mol}$$

To maximize the amount of $C_2H_4Cl_2(g)$ produced, which of the following strategies might be applied? Assume the reaction is at equilibrium. Select all that apply. Insert letters without spaces in the answer box, example **ABCD.**

A. Increasing the reaction volume
B. Removing $C_2H_4Cl_2(g)$ from the reaction mixture as it forms
C. Adding $Cl_2(g)$
D. Lowering the reaction temperature
E. None of the choice above will increase the amount of $C_2H_4Cl_2(g)$ produced

21. The free energy change of the reaction A(g) ⟶ B(g) is zero under certain conditions. The standard free energy of the reaction is -42.5 kJ. Which statement is true about the reaction? Select all that apply. Insert letters without spaces in the answer box, example **ABCD.**

A. The concentration of the product is greater than the concentration of the reactant.
B. The reaction is at equilibrium.
C. The concentration of the reactant is greater than the concentration of the product.
D. None of the above statements is correct

22. You are given the information below for the equilibrium reaction between sulfur dioxide and oxygen to produce sulfur trioxide at 25 °C

	$2\ SO_2(g)$	$+\ O_2(g)$	$\rightleftharpoons 2\ SO_3(g)$
$\Delta G°_f$ (kJ/mol)	-300.2	0.0	-371.1

If $SO_2(g)$ has a partial pressure is 1.0×10^{-4} atm, $O_2(g)$ is 0.20 atm, and $SO_3(g)$ is 0.10 atm, calculate **ΔG_{rxn}.**

kJ/mol

Extra Practice Questions: these questions will not be graded

1. You are given two elementary reactions below which are the reverse of one another and the reaction rates for elementary reaction are provided as well. Which of the following statements about an equilibrium mixture of X, Y, and Z is **false**?

$$X + Y \longrightarrow Z + Z \qquad \text{Rate} = k_1[X][Y]$$
$$Z + Z \longrightarrow X + Y \qquad \text{Rate} = k_2[Z]^2$$

A. At equilibrium, k_1 and k_2 can have different values
B. At equilibrium, $k_1[X][Y] = k_2[Z]^2$
C. At equilibrium, X and Y still react to form Z
D. At equilibrium, the concentrations of X and Y must be the same
E. At equilibrium, $\frac{[X][Y]}{[Z]^2}$ is a constant

2. For the reaction,

$$2\ SO_2\ (g) + O_2(g) \rightleftharpoons 2\ SO_3(g) \qquad K_c = 2.8 \times 10^2 \text{ at } 25\ °C$$

If a mixture contains 0.455 mol of SO_2, 0.183 mol of O_2, and 0.568 mol SO_3, are introduced into a 1.90 L vessel at 727 K. Which of the following statements is true?

A. The reaction is at equilibrium because $Q_c = K_c$
B. The reaction will proceed towards the reactants because $Q_c < K_c$
C. The reaction will proceed towards the products because $Q_c > K_c$
D. Not enough information is provided in the question

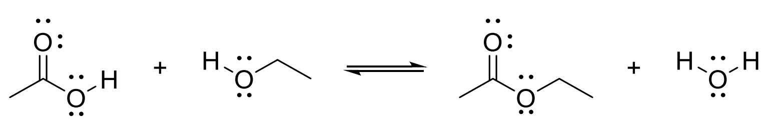
3. Two equations can be written for the dissolution of $Mg(OH)_2(s)$ in acidic solution

$$\textbf{Equation 1: } Mg(OH)_2(s) + 2\,H^+(aq) \rightleftharpoons Mg^{2+}(aq) + 2\,H_2O(l)$$
$$\textbf{Equation 2: } \frac{1}{2}\,Mg(OH)_2(s) + H^+(aq) \rightleftharpoons \frac{1}{2}\,Mg^{2+}(aq) + H_2O(l)$$

Which of the statements below is/are correct regarding the relationship between the two equations? <u>Select all that apply.</u> Insert letters without spaces in the answer box, example **ABCD.**

A. If ΔG°_{rxn} for equation 1 is −95.5 kJ/mol therefore ΔG°_{rxn} for equation 2 will be −47.8 kJ/mol
B. If ΔG°_{rxn} for equation 1 is −95.5 kJ/mol therefore ΔG°_{rxn} for equation 2 will be 9120 kJ/mol
C. K_1, the equilibrium constant for equation 1 is the square of K_2, the equilibrium constant for equation 2
D. K_1, the equilibrium constant for equation 1 is the square root of K_2, the equilibrium constant for equation 2
E. None of the above statements is/are correct

4. The following shows an example of an organic chemistry equilibrium reaction known as the Fisher Esterification.



Which of the following would correctly predict the effect of adding an acid catalyst to this reaction?

A. The reaction equilibrium would change from favoring the products to favoring the reactants
B. The reaction equilibrium would change from favoring the reactants to favoring the products
C. The reaction equilibrium would have a higher concentration of products than without the catalyst
D. The reaction equilibrium would have a higher concentration of reactants than without the catalyst
E. The reaction would reach a state of equilibrium faster but the equilibrium concentrations would not change
F. There is not enough information to determine how a catalyst would affect the reaction

5. The Citric acid cycle is a metabolic pathway that connects carbohydrate, fat, and protein metabolism. One important reaction in the Citric acid cycle is:

$$\text{Citrate(aq)} \rightleftharpoons \text{aconitate (aq)} + H_2O(l) \quad K = 3.1 \times 10^2 \quad \Delta H = +6.7 \text{ kJ/mol}$$

Which of the statements regarding the equilibrium reaction is **<u>true</u>**? <u>Select all that apply.</u>

A. The equilibrium reaction favors the formation of aconitate.
B. If the enzyme catalyst, aconitase is added the equilibrium concentration of aconitate increases.
C. If the reaction is heated at 40 °C, the concentration of aconitate increases.
D. Adding more $H_2O(l)$ has no effect on the equilibrium position.

6. Which of the following statements are **false** regarding the following reaction, given the equilibrium constant shown?

$$A(g) \leftrightharpoons B(g) \quad K_c = 10$$

A. At equilibrium, the reaction is product favored
B. If [A] = 1.0 M and [B] = 1.0 M, then the reaction is not at equilibrium; the concentration of [B] will increase as the reaction moves toward equilibrium
C. If [A] = 0.1 M and [B] = 1.0 M, then the reaction is already at equilibrium, and the concentrations of products and reactants will not change
D. If [A] = 1.0 M and [B] = 1.0 M, then the reaction is not at equilibrium; the concentration of [A] will increase as the reaction moves toward equilibrium

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

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

A. 4
B. 3
C. -2
D. 1
E. 0

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

$A(g) + 2\ B(g) \rightleftharpoons AB_2(g)$	$K_c = 59$
$AB_2(g) + B(g) \rightleftharpoons AB_3(g)$	$K_c = ?$
$A(g) + 3\ B(g) \rightleftharpoons AB_3(g)$	$K_c = 478$

A. 3.5×10^{-5}
B. 2.8×10^{4}
C. 8.1
D. 0.12
E. 89

9. Choose the correct statement about the equilibrium:

$N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)$, $K_p = 1 \times 10^{-4}$

A. The rate constant for the forward reaction is greater than that of the reverse reaction.
B. Since the reaction has a high activation energy, a catalyst is not needed.
C. The equilibrium constant is given by $K_p = [N_2][H_2]^3/[NH_3]^2$.
D. Conducting the reaction under high pressures will increase the yield of ammonia.
E. The K_p is independent of temperature.

10. Choose the INCORRECT statement.

A. The van't Hoff equation is $\ln \frac{K2}{K1} = \frac{\Delta_r H^\circ}{R}\left(\frac{1}{T1} - \frac{1}{T2}\right)$.
B. K_{eq} is independent of temperature.
C. In a thermodynamic equilibrium constant expression, the activity of a gas is replaced by its partial pressure in atmosphere.
D. In a K_{eq} expression, the activity of an aqueous species can be approximated by the numerical value of its molarity.
E. If $\Delta G = 0$, the process is at equilibrium.

11. For the reaction: $CO(g) + 2\ H_2(g) \rightarrow CH_3OH(g)$

$K_p = 91.4$ at 350 K and $K_p = 2.05 \times 10^{-4}$ at 298 K.

What is the value of ΔH°_{rxn}?

A. 49.9 kJ/mol
B. 2.08×10^{3} kJ/mol
C. 3.74×10^{-2} kJ/mol
D. 217 kJ/mol
E. 446 kJ/mol

12. At a certain temperature the equilibrium constant, K_C, equals 0.11 for the reaction:

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

What is the equilibrium concentration of ICl if 0.45 mol of I_2 and 0.45 mol of Cl_2 are initially mixed in a 2.0 L flask?

A. 0.14 mol/L
B. 0.17 mol/L
C. 0.27 mol/L
D. 0.34 mol/L

Formula Sheet

Length
1 kilometer = 0.62137 mile
1 inch = 2.54 centimeters (exactly)
1 Ångstrom = 1×10^{-10} meter

Energy
1 joule = 1 $kg \cdot m^2/s^2$
1 calorie = 4.184 joules
1 Calorie = 1 kilocalorie = 1000 calories
1 L·atm = 101.325 joules

Pressure
1 pascal = 1 N/m^3 = 1 $kg/m \cdot s^2$
1 atmosphere = 101.325 kilopascals = 760 mm Hg = 760 torr = 14.70 lb/in^2
1 bar = 1×10^5 Pa (exactly)

Temperature
0 K = −273.15°C
K = °C + 273.15
°C = (5/9)(°F − 32)

Mass
1 kg = 2.205 lbs

Volume
1 mL = 1 cm^3 = 1 cc

Constants
$c = 2.998 \times 10^8$ m/sec
$h = 6.626 \times 10^{-34}$ $J \cdot sec^{-1}$
R = 0.08206 L·atm/mol·K = 8.314 J/mol·K
Specific heat of water = 4.184 J/g·K
Mass of an electron: 9.109×10^{-31} kg
Mass of a proton: 1.673×10^{-27} kg
RH = 2.18×10^{-18} J
Specific heat of water = 4.184 J/g·K
STP = 273.15 K and 1 atm
Avogadro's number: 6.022×10^{23}

Equations
d (density) = m/V
$P_1V_1=P_2V_2$
$V_1/T_1=V_2/T_2$
$P_1V_1/n_1T_1=P_2V_2/n_2T_2$
$PV=nRT$
$(P + a(n^2/V^2))\cdot(V - nb) = nRT$
molar mass (M) = mRT/PV
density (d) = MP/RT
$x_A = n_A/n_{tot} = P_A/P_{tot} = V_A/V_{tot}$
$P_{tot} = P_A + P_B + \ldots$
$n_{tot} = n_A + n_B + \ldots$

$$\mu_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\frac{Rate\ of\ effusion\ A}{Rate\ of\ effusion\ B} = \sqrt{\frac{MW_B}{MW_A}}$$

$Q = C \times \Delta T = c_{specific} \times m \times \Delta T$
$Q = n \times \Delta H$ (kJ/mol) $= m \times \Delta H$ (kJ/g)
$w = -P\Delta V$
$\Delta E = q + w$
$\Delta H° = \Sigma n\Delta Hf°$(products) $- \Sigma n\Delta Hf°$(reactants)
$\Delta H° = \Sigma n\Delta H°$(bonds broken) $- \Sigma n\Delta H°$(bonds formed)
$E=h\nu$
$c=\lambda\nu$
$\lambda = h/mv$

$$\Delta E = -2.18 \times 10^{-18} J(\frac{1}{n_f^2} - \frac{1}{n_i^2})$$

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_{vap}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$C_g = kP_g$
$P_{solution}=P_{solvent}\, X_{solvent}$
$P_{solution}=\sum P_j=\sum P_jX_j$
$\Delta T_b = K_b m i$
$\Delta T_f = K_f m i$
$\pi = MRTi$

<u>Thermodynamic and Electrochemistry</u>

$S = k_b \times \ln(W)$
$k_b = 1.381 \times 10^{-23}$ J/K
$\Delta S = q_{rev}/T$
$\Delta S_{surr} = q_{surr}/T = -q_{rev}/T$
$\Delta S_{univ} = \Delta S_{sys} + \Delta S_{surr}$
$\Delta S°_{rxn} = \Sigma \nu S°_{products} - \Sigma \nu S°_{reactants}$
$\Delta H°_{rxn} = \Sigma \nu H°_{products} - \Sigma \nu H°_{reactants}$
$\Delta G°_{rxn} = \Sigma \nu G°_{products} - \Sigma \nu G°_{reactants}$
$\Delta G = \Delta H - T\Delta S$
$\Delta G = \Delta G° + RT \cdot \ln Q$
$R=8.314$ J/mol.K
$\Delta G° = -RT \cdot \ln K$
$\Delta G = -nFE_{cell}$
$F = 96485$ J/(V·mol e^-)
$E°_{cell} = RT/nF \ln K$
$E°_{cell} = (0.0257/n) \ln K = (0.0592/n) \log K$
$E_{cell} = E°_{cell} - (RT/nF) \ln Q$
$E_{cell} = E°_{cell} - (0.0257/n) \ln Q$
Electrolysis: Q (total charge) $= I \times t = n \times F$

<u>Integrated Rate Laws & half-life</u>

$$\ln \frac{[A]}{[A]_0} = -kt$$

$$\frac{1}{[A]} = kt + \frac{1}{[A]_0}$$

$$[A] = -kt + [A]_0$$

$$t_{1/2} = \frac{[A]_0}{2k}$$

$$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$$

$$t_{1/2} = \frac{1}{k[A]_0}$$

$$ln \frac{k_2}{k_1} = -\frac{\mathrm{E_a}}{\mathrm{R}}\left(\frac{1}{\mathrm{T_2}} - \frac{1}{\mathrm{T_1}}\right)$$

<u>Equilibrium and Acid / Base</u>

$K_P = K_c \times (RT)^{\Delta n}$
pH = $-\log[H_3O^+]$
$K_w = 1.0 \times 10^{-14}$ at 25 °C
$K_w = [H_3O^+] \times [OH^-]$
$K_w = K_a \times K_b$
$pK_a = -\log[K_a]$
Buffer: pH = $pK_a + \log \frac{[A^-]}{[HA]}$

$$ln \frac{K_2}{K_1} = \frac{\Delta H^\circ_{rxn}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.01																	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.63	33 **As** 74.92	34 **Se** 78.97	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.95	43 **Tc** [97]	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
37 **Cs** 132.91	56 **Ba** 137.33		72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** [209]	85 **At** [210]	86 **Rn** [222]
87 **Fr** [223]	88 **Ra** [226]		104 **Rf** [267]	105 **Db** [268]	106 **Sg** [269]	107 **Bh** [270]	108 **Hs** [269]	109 **Mt** [277]	110 **Ds** [281]	111 **Rg** [282]	112 **Cn** [285]	113 **Nh** [286]	114 **Fl** [290]	115 **Mc** [290]	116 **Lv** [293]	117 **Ts** [294]	118 **Og** [294]

57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** [145]	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05	71 **Lu** 174.97
89 **Ac** [227]	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** [237]	94 **Pu** [244]	95 **Am** [243]	96 **Cm** [247]	97 **Bk** [247]	98 **Cf** [251]	99 **Es** [252]	100 **Fm** [257]	101 **Md** [258]	102 **No** [259]	103 **Lr** [262]