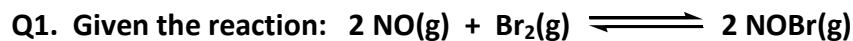


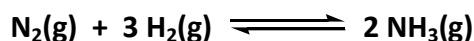
Queen's University at Kingston
Chem 112 Winter Midterm Exam
Practice Questions



At equilibrium at a certain temperature, the concentrations of $\text{NO}(g)$, $\text{Br}_2(g)$, and $\text{NOBr}(g)$ are 0.24 M, 0.36 M, and 0.66 M, respectively. The value of K_c for this reaction is

- A. 7.6
- B. 21**
- C. 0.048
- D. 5.0
- E. 32

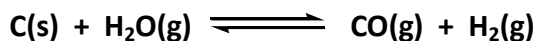
Q2. A mixture consisting of 0.250 M $\text{N}_2(g)$ and 0.500 M $\text{H}_2(g)$ reaches equilibrium according to the equation below:



At equilibrium, the concentration of ammonia is 0.150 M. Calculate the concentration of $\text{H}_2(g)$ at equilibrium.

- A. 0.0750 M
- B. 0.350 M
- C. 0.425 M
- D. 0.275 M**
- E. 0.150 M

Q3. The effect of a volume decrease on the reaction system at equilibrium is

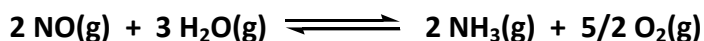


- A. that K decreases
- B. more $\text{CO}(g)$ and $\text{H}_2(g)$ are produced
- C. no change
- D. more $\text{H}_2\text{O}(g)$ is produced**
- E. that K increases

Q4. If the system $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$ is at equilibrium at constant temperature, and the number of moles of $\text{CaO}(\text{s})$ in the vessel is doubled, then

- A. the equilibrium constant, K , is doubled
- B. the equilibrium constant, K , is halved
- C. the equilibrium constant, K , remains unchanged**
- D. the number of moles of $\text{CaCO}_3(\text{s})$ in the vessel increases
- E. the number of moles of $\text{CO}_2(\text{g})$ present at equilibrium is halved

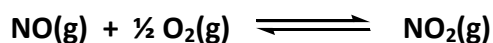
Q5. Given the reaction: $4 \text{NH}_3(\text{g}) + 5 \text{O}_2(\text{g}) \rightleftharpoons 4 \text{NO}(\text{g}) + 6 \text{H}_2\text{O}(\text{g})$ with an equilibrium constant $K (= K_p)$. The equilibrium constant for the following reaction,



is

- A. $-0.5K$
- B. $-2K$
- C. K^1
- D. $-K$
- E. $K^{-1/2}$**

Q6. Consider the reaction



If $\Delta H^\circ = -56.52 \text{ kJ}$ and $\Delta S^\circ = -72.60 \text{ J K}^{-1}$ at 298 K, what is the equilibrium constant K for the reaction at 298 K?

- A. 1.31×10^6**
- B. 7.63×10^{-7}
- C. 660
- D. 1.22×10^{14}
- E. 8.08×10^9

Q7. The equilibrium constant K for the dissociation of $\text{N}_2\text{O}_4(\text{g})$ to $\text{NO}_2(\text{g})$ is 1.70×10^3 at 500 K. For this reaction, $\Delta H^\circ = 56.8 \text{ kJ mol}^{-1}$. The value of K at 300 K is:

- A. 1.32×10^{-4}
- B. 0.188**
- C. 15.5
- D. 1.11×10^{-4}
- E. 1.54×10^7

Q8. Of the following pairs of species, which is not a Brønsted-Lowrey conjugate acid-base pair?

- A. NH_4^+ , NH_3
- B. HC_2O_4^- , $\text{C}_2\text{O}_4^{2-}$
- C. $\text{H}_2\text{C}_2\text{H}_3\text{O}_2$, $\text{HC}_2\text{H}_3\text{O}_2^-$
- D. OH^- , O^{2-}
- E. SO_3^{2-} , SO_4^{2-}**

Q9. Which of the following produces the strongest conjugate base?

- A. HCN ($\text{p}K_a = 9.21$)**
- B. HClO ($\text{p}K_a = 7.54$)
- C. HIO_3 ($\text{p}K_a = 0.80$)
- D. HNO_2 ($\text{p}K_a = 3.14$)
- E. CH_3COOH ($\text{p}K_a = 4.75$)

Q10. Which of the following is the strongest acid?

- A. CH_2FCOOH
- B. CH_3OH
- C. CCl_3COOH
- D. CHCl_2COOH
- E. CF_3COOH**

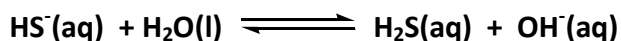
Q11. What is the $[H_3O^+]$ for a solution labeled "0.10 M $H_3PO_3(aq)$ " if $pK_{a1} = 2.00$ and $pK_{a2} = 6.59$?

- A. 0.027 M
- B. 0.054 M
- C. 0.20 M
- D. 0.015 M
- E. 0.15 M

Q12. What is the pH of a 0.10 M solution of NaCN (K_b for $CN^- = 4.9 \times 10^{-10}$)?

- A. 8.85
- B. 5.15
- C. 10.31
- D. 3.69
- E. -9.31

Q13. Calculate the equilibrium constant for the reaction,



given that $K_{a1} = 1.3 \times 10^{-7}$ and $K_{a2} = 7.1 \times 10^{-15}$ for H_2S .

- A. 9.2×10^{-22}
- B. 1.3×10^7
- C. 7.7×10^{-8}
- D. 5.5×10^{-8}
- E. 7.1×10^{-1}

Q14. What is the value of K_b for the fluoride ion, $F^-(aq)$, given that the K_a of $HF(aq)$ is 3.5×10^{-4} ?

- A. 3.46
- B. 3.5×10^{-4}
- C. 2.9×10^{-11}
- D. 10.54
- E. 1.2×10^{-7}

Q15. A buffer solution containing $\text{NH}_3(\text{aq})$ and $\text{NH}_4\text{Cl}(\text{aq})$ has a pH of 8.90. What is the $[\text{NH}_3]/[\text{NH}_4^+]$ ratio in this solution? (K_b for NH_3 is 1.8×10^{-5})

- A. 0.44
- B. 1.0
- C. 0.36
- D. -0.36
- E. 2.3

Q16. A 1.00 L buffer solution contains 0.75 mol $\text{KH}_2\text{PO}_4(\text{aq})$ and 0.75 mol $\text{K}_2\text{HPO}_4(\text{aq})$. What is the pH after 0.10 mol $\text{KOH}(\text{s})$ is added to this buffer solution (assume no change in the volume). The $\text{p}K_a$ of H_2PO_4^- is 7.21.

- A. 6.91
- B. 7.16
- C. 7.33
- D. 7.26
- E. 7.09

Q17. What is the pH at the stoichiometric (equivalence) point for the titration of 0.100 M $\text{CH}_3\text{COOH}(\text{aq})$ with 0.100 M $\text{Ca}(\text{OH})_2(\text{aq})$? The value of K_a for acetic acid is 1.8×10^{-5} .

- A. 9.56
- B. 8.88
- C. 9.26
- D. 7.00
- E. 8.79

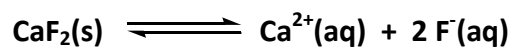
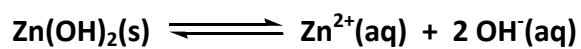
Q18. The molar solubility of $\text{Ca}_3(\text{PO}_4)_2(\text{s})$ is 3.2×10^{-6} M. The K_{sp} for $\text{Ca}_3(\text{PO}_4)_2(\text{s})$ is:

- A. 1.3×10^{-16}
- B. 3.6×10^{-26}
- C. 3.3×10^{-17}
- D. 3.4×10^{-28}
- E. 1.0×10^{-11}

Q19. The solubility product of $\text{BaF}_2(\text{s})$ is 1.7×10^{-6} at 25 °C. How many grams of $\text{BaF}_2(\text{g})$ will dissolve in 1.00 L of water at 25 °C?

- A. 0.20 grams
- B. 19 grams
- C. 0.23 grams
- D. 2.1 grams
- E. 0.00030 grams

Q20. Consider the following two equilibria:



Which of the following statements is correct when acid is added?

- A. The $\text{Zn(OH)}_2(\text{s})$ and $\text{CaF}_2(\text{s})$ equilibria both shift to the left
- B. The $\text{Zn(OH)}_2(\text{s})$ and $\text{CaF}_2(\text{s})$ equilibria both shift to the right**
- C. The $\text{Zn(OH)}_2(\text{s})$ equilibrium shifts to the left but the $\text{CaF}_2(\text{s})$ equilibrium shifts to the right
- D. The $\text{Zn(OH)}_2(\text{s})$ equilibrium shifts to the right but the $\text{CaF}_2(\text{s})$ equilibrium shifts to the left
- E. Adding acid has not effect on either equilibrium.

Symbol	Value
R	$8.31451 \text{ J K}^{-1} \text{ mol}^{-1}$ $0.08206 \text{ L} \cdot \text{atm mol}^{-1} \text{ K}^{-1}$ $8.3145 \times 10^{-2} \text{ L bar mol}^{-1} \text{ K}^{-1}$
K_b	$1.3807 \times 10^{-23} \text{ J K}^{-1}$
N_A	$6.0221 \times 10^{23} \text{ mol}^{-1}$
F	$96485. \text{ C mol}^{-1}$
e	$1.6022 \times 10^{-19} \text{ C}$
h	$6.6261 \times 10^{-34} \text{ J s}$
m_p	$1.6726 \times 10^{-27} \text{ kg}$
m_e	$9.1094 \times 10^{-31} \text{ kg}$
R_H	$2.179 \times 10^{-18} \text{ J}$
c	$2.9979 \times 10^8 \text{ m s}^{-1}$

Data/Formula Sheet

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1A	2A	3B	4B	5B	6B	7B	8B	8B	1B	2B	3A	4A	5A	6A	7A	8A	
1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 18.99	10 Ne 20.18
11 Na 22.99	12 Mg 24.30											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.1	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 55.84	27 Co 58.99	28 Ni 58.94	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.8
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc 99	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57 La 138.9	72 Hf 178.5	73 Ta 181.0	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po 209	85 At 210	86 Rn 222
87 Fr 223	88 Ra 226	89 Ac 227															
		6	58 Ce 140	59 Pr 141	60 Nd 144	61 Pm 145	62 Sm 150	63 Eu 152.0	64 Gd 157	65 Tb 159	66 Dy 163	67 Ho 165	68 Er 167	69 Tm 169	70 Yb 173.0	71 Lu 175.0	
		7	90 Th 232	91 Pa 231.0	92 U 238.0	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	

1atm = 101.325 kPa = 760 mm Hg = 760 torr 1L = 1 dm³ 0°C = 273.15 K
1 bar = 10⁵ Pa

$$E = h\nu \quad c = \lambda\nu \quad \lambda = \frac{h}{m\nu} \quad u_{rms} = \sqrt{\frac{3RT}{M}} \quad f(u) = 4\pi \left(\frac{m}{2\pi k_B T} \right)^{3/2} u^2 e^{-\frac{mu^2}{2k_B T}} \quad \Delta x \Delta p \geq \frac{h}{4\pi}$$

$$w(A) = \frac{m(A)}{m(A) + m(B) + \dots} \quad w(A) + w(B) + \dots = 1 \quad x(A) = \frac{n(A)}{n(A) + n(B) + \dots} \quad \Delta H = \sum_{broken} BE - \sum_{formed} BE$$

$$b(A) = \frac{n(A)}{m(S)} \quad c(A) = \frac{n(A)}{V} \quad \text{density} = m/V \quad \Delta E = h\nu = R_H \left[\frac{1}{n_1^2} - \frac{1}{n_2^2} \right] \quad x(A) + x(B) + \dots = 1 \quad \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$P_1 V_1 = P_2 V_2 \quad PV = nRT \quad w = -P_e \Delta V = -\Delta n_{gas} RT \quad \Delta U = q + w \quad \Delta U = q_v \quad \Delta H = q_p \quad \Pi V = nRT$$

$$p_B = x_B K_H \quad p_A + p_B + \dots = P \quad y_A = \frac{p_A}{p_A + p_B} = \frac{x_A P_A^*}{x_A P_A^* + (1 - x_A) P_B^*} \quad y_B = \frac{p_B}{p_A + p_B} = \frac{(1 - x_A) P_B^*}{x_A P_A^* + (1 - x_A) P_B^*}$$

$$\Delta H = \Delta U + P \Delta V \quad C = \frac{q}{\Delta T} \quad C_V = \frac{\Delta U}{\Delta T} \quad C_P = \frac{\Delta H}{\Delta T} \quad C_P - C_V = R \quad p_A = x_A P_A^*$$

$$\left(P + \frac{a}{V_m^2} \right) (V_m - b) = RT \quad a = \frac{27R^2 T_C^2}{64P_C} \quad b = \frac{RT}{8P_C} \quad \ln \left(\frac{P_2^*}{P_1^*} \right) = -\frac{\Delta H_{vap}}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right) \quad [H^+] = \frac{-K_a + \sqrt{K_a^2 + 4K_a C_a}}{2} \quad K = (RT)^{\Delta n} K_c$$

$$\Delta S^\circ = \sum S^\circ(P) - \sum S^\circ(R) \quad \Delta H_T^\circ = \Delta H_{298}^\circ + \Delta C_P (T - 298) \quad \Delta H^\circ = \sum \Delta H_f^\circ(P) - \sum \Delta H_f^\circ(R)$$

$$\ln \left(\frac{K_2}{K_1} \right) = \frac{-\Delta H^\circ}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right) \quad [H^+] = \sqrt{K_a C_a} \quad [OH^-] = \sqrt{K_b C_b} \quad pH = (pK_a + pC_a)/2 \quad pOH = (pK_b + pC_b)/2$$

$$[OH^-] = \frac{-K_b + \sqrt{K_b^2 + 4K_b C_b}}{2} \quad pH = pK_a + \log \frac{[base]}{[acid]} \quad \frac{(U_{rms})_A}{(U_{rms})_B} = \sqrt{\frac{M_B}{M_A}} \quad \Delta S = \frac{q_{rev}}{T} \quad \Delta S = \frac{\Delta H}{T}$$

$$\Delta S = \frac{C \Delta T}{T} \quad \text{or} \quad \Delta S = C \ln \frac{T_2}{T_1} \quad \Delta S = R \ln \frac{V_2}{V_1} = -R \ln \frac{P_2}{P_1} \quad \ln \left(\frac{k_2}{k_1} \right) = -\frac{E_a}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right) \quad G = H - TS$$

$$\Delta G^\circ = \Delta H^\circ - T \Delta S^\circ \quad \Delta G = \Delta G^\circ + RT \ln Q \quad \Delta G^\circ = -RT \ln K \quad S_{universe} = S_{system} + S_{surroundings}$$

$$KE = \frac{1}{2} m v^2 \quad h\nu = KE + \phi \quad M = m/n \quad \Delta G^\circ = \sum \Delta G_f^\circ(P) - \sum \Delta G_f^\circ(R) \quad w' = -nFE$$

$$E = E^\circ - \frac{RT}{nF} \ln Q \quad \Delta G^\circ = -nFE^\circ \quad K = \exp \left(\frac{nFE^\circ}{RT} \right) \quad E_{cell} = E_{ox} + E_{red} \quad Q = nF \quad Q = It$$

$$[A]_t = -kt + [A]_0 \quad \ln[A]_t = -kt + \ln[A]_0 \quad \frac{1}{[A]_t} = \frac{1}{[A]_0} + kt \quad t_{1/2} = \frac{\ln 2}{k} \quad k = A \exp\{-E_a/RT\}$$

$$2r = L = a \quad 4r = \sqrt{2}L = \sqrt{2}a \quad 4r = \sqrt{3}L = \sqrt{3}a \quad b = \sqrt{2}a \quad c = \sqrt{3}a$$