

FORMULA SHEET (tear off)

1A										8A																																			
1 H 1.01	2A										3A	4A	5A	6A	7A	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 32.07	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 65.41	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	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 95.94	43 Tc [98]	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	71 Lu 175.0	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]	103 Lr [262]	104 Rf [261]	105 Db [262]	106 Sg [266]																																								
<table border="1"> <tr> <td>57 La 138.9</td> <td>58 Ce 140.1</td> <td>59 Pr 140.9</td> <td>60 Nd 144.2</td> <td>61 Pm [145]</td> <td>62 Sm 150.4</td> <td>63 Eu 152.0</td> <td>64 Gd 157.2</td> <td>65 Tb 158.9</td> <td>66 Dy 162.5</td> <td>67 Ho 164.9</td> <td>68 Er 167.3</td> <td>69 Tm 168.9</td> <td>70 Yb 173.0</td> </tr> <tr> <td>89 Ac [227]</td> <td>90 Th 232.0</td> <td>91 Pa 231.0</td> <td>92 U 238.0</td> <td>93 Np [237]</td> <td>94 Pu [244]</td> <td>95 Am [243]</td> <td>96 Cm [247]</td> <td>97 Bk [247]</td> <td>98 Cf [251]</td> <td>99 Es [252]</td> <td>100 Fm [257]</td> <td>101 Md [258]</td> <td>102 No [259]</td> </tr> </table>																		57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm [145]	62 Sm 150.4	63 Eu 152.0	64 Gd 157.2	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	89 Ac [227]	90 Th 232.0	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]
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$$N_A = 6.022 \times 10^{23}$$

$$1 \text{ amu} = 1.661 \times 10^{-27} \text{ kg}$$

$$1 \text{ atm} = 760 \text{ torr} = 760 \text{ mm Hg}$$

$$R = 0.08206 \text{ L}\cdot\text{atm}/\text{mol}\cdot\text{K}$$

$$R = 8.314 \text{ J}/\text{mol}\cdot\text{K}$$

$$^\circ\text{C} = (5/9)(^\circ\text{F} - 32)$$

$$^\circ\text{C} = \text{K} - 273.15$$

$$1 \text{ atm} = 1.013 \text{ bar}$$

$$1 \text{ L}\cdot\text{atm} = 101.3 \text{ J}$$

$$1 \text{ J} = 1 \text{ kg}\cdot\text{m}^2/\text{s}^2$$

$$^\circ\text{F} = (9/5)(^\circ\text{C}) + 32$$

$$\text{K} = ^\circ\text{C} + 273.15$$

$$pV = nRT$$

$$p_A = X_A p_A^\circ$$

$$\Delta T_b = K_b m_B$$

$$H = U + pV$$

$$\Delta G_{\text{rxn}} = \Delta G^\circ_{\text{rxn}} + RT \ln Q$$

$$\text{If } ax^2 + bx + c = 0, \text{ then } x = \left(\frac{-b \pm [b^2 - 4ac]^{1/2}}{2a} \right)$$

$$K_a \cdot K_b = K_w$$

$$K_a \cdot K_b = 1.0 \times 10^{-14} \text{ (at } T = 25.^\circ\text{C)}$$

$$[B] = k p_B$$

$$\Delta T_f = K_f m_B$$

$$G = H - TS$$

$$\ln K = -\frac{\Delta G^\circ_{\text{rxn}}}{RT}$$

$$\Delta p_A = X_B p_A^\circ$$

$$\Pi = M_B RT$$

$$K_p = K_C (RT)^{\Delta n_g}$$

$$pH + pOH = pK_w$$

$$pH + pOH = 14.00 \text{ (at } T = 25.^\circ\text{C)}$$

**GENERAL CHEMISTRY 2
SECOND HOUR EXAM
OCTOBER 20, 2022**

Name _____ Version 3 solutions _____

Panthersoft ID _____

Signature _____

Part 1 _____ (20 points)

Part 2 _____ (44 points)

Part 3 _____ (36 points)

TOTAL _____ (100 points)

Unless otherwise stated, you may assume $T = 25.0\text{ }^{\circ}\text{C}$ in all of the problems below.

Do all of the following problems. Show your work.

Part 1. Multiple choice. Circle the letter corresponding to the correct answer. There is one and only one correct answer per problem. [4 points each]

1) Which of the following will cause a change in the numerical value for K_C ?

- a) A change in temperature
- b) A change in pressure
- A** c) A change in volume
- d) Both b and c
- e) Both a and b and c

2) Consider the following three reactions

- i. $\text{SO}_2(\text{g}) + \text{H}_2\text{O}(\ell) \rightleftharpoons \text{H}_2\text{SO}_3(\text{aq})$
- ii. $\text{Cl}_2(\text{g}) + \text{F}_2(\text{g}) \rightleftharpoons 2 \text{ClF}(\text{g})$
- iii. $\text{MgCO}_3(\text{s}) \rightleftharpoons \text{MgO}(\text{s}) + \text{CO}_2(\text{g})$

For which of these reactions is it possible to write an expression for K_p ?

- a) Reaction i.
- b) Reaction ii.
- D** c) Reaction iii.
- d) Both reaction ii. and reaction iii.
- e) Both reaction i. and reaction ii. and reaction iii.

3) An Arrhenius acid

- a) forms $\text{H}^+(\text{aq})$ when added to liquid water
- b) forms $\text{OH}^-(\text{aq})$ when added to liquid water
- A** c) donates a proton in an acid-base reaction
- d) accepts a proton in an acid-base reaction
- e) is an electron pair donor

4) Which of the following solids is a strong soluble base?

- a) $\text{AgOH}(\text{s})$
- b) $\text{Sr}(\text{OH})_2(\text{s})$
- B** c) $\text{Fe}(\text{OH})_3(\text{s})$
- d) Both b and c
- e) Both a and b and c

5) The numerical value for the equilibrium constant for the autoionization reaction of water is $K_w = 5.5 \times 10^{-14}$, at $T = 50.^\circ\text{C}$. What is the value for pH for a neutral aqueous solution at this temperature?

- a) 14.00
- b) 13.26
- D** c) 7.00
- d) 6.63
- e) Cannot tell from the information given

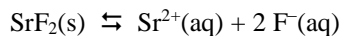
Version 1: C, D, B, C, D

Version 2: B, D, E, B, A

Version 4: B, D, D, C, A

Part 2. Short answer.

1) For the chemical reaction



$$\Delta H^{\circ}_{\text{rxn}} = + 5.3 \text{ kJ/mol}$$

$$\Delta S^{\circ}_{\text{rxn}} = - 142.3 \text{ J/mol}\cdot\text{K}$$

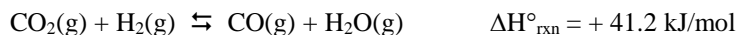
$$\Delta G^{\circ}_{\text{rxn}} = + 47.7 \text{ kJ/mol}$$

Based on the above information, find the numerical value for K for the above reaction. Assume T = 25. °C. [8 points]

$$\ln K = - \frac{\Delta G^{\circ}_{\text{rxn}}}{RT} = - \frac{(47.7 \text{ kJ/mol}) (1000 \text{ J/kJ})}{(8.314 \text{ J/mol}\cdot\text{K}) (298. \text{ K})} = - 19.25$$

$$\text{So } K = e^{-19.25} = 4.4 \times 10^{-9}$$

2) Consider the following chemical reaction



A system containing CO(g), CO₂(g), H₂(g), and H₂O(g) in a container of fixed volume is initially at equilibrium at T = 25. °C. For each of the following changes, indicate whether the moles of CO(g) will increase, stay the same, or decrease when equilibrium is reestablished. [4 points each]

a) Add 0.0200 moles of H₂ to the system.

moles CO(g) will increase

moles CO(g) will stay the same

moles CO(g) will decrease

b) Increase the volume of the container.

moles CO(g) will increase

moles CO(g) will stay the same

moles CO(g) will decrease

c) Change the temperature of the system to T = 60. °C while keeping volume constant.

moles CO(g) will increase

moles CO(g) will stay the same

moles CO(g) will decrease

3) An aqueous solution has $\text{pH} = 9.46$. Based on this, find the values for $[\text{H}_3\text{O}^+]$ and $[\text{OH}^-]$ for the solution. [4 points each]

$$[\text{H}_3\text{O}^+] = \underline{3.5 \times 10^{-10} \text{ M}} \qquad [\text{OH}^-] = \underline{2.9 \times 10^{-5} \text{ M}}$$

$$\text{pH} + \text{pOH} = 14.00 \text{ and so } \text{pOH} = 14.00 - \text{pH} = 14.00 - 9.46 = 4.54$$

$$[\text{H}_3\text{O}^+] = 10^{-\text{pH}} = 10^{-9.46} = 3.5 \times 10^{-10} \text{ M} \qquad [\text{OH}^-] = 10^{-\text{pOH}} = 10^{-4.54} = 2.9 \times 10^{-5} \text{ M}$$

Version 1: $[\text{H}_3\text{O}^+] = 8.3 \times 10^{-10} \text{ M}$ **Version 2:** $[\text{H}_3\text{O}^+] = 2.3 \times 10^{-10} \text{ M}$ **Version 4:** $[\text{H}_3\text{O}^+] = 1.5 \times 10^{-10} \text{ M}$
 $[\text{OH}^-] = 1.2 \times 10^{-5} \text{ M}$ $[\text{OH}^-] = 14.3 \times 10^{-5} \text{ M}$ $[\text{OH}^-] = 6.5 \times 10^{-5} \text{ M}$

4) For each of the following questions circle the correct answer. There is only one correct answer per problem. [4 points each]

a) The strongest acid.



b) A monoprotic strong acid



c) The pH of a 0.040 M aqueous solution of barium nitrite, $\text{Sr}(\text{NO}_2)_2$, the salt of a weak acid and a strong soluble base.

$\text{pH} < 7.0$

$\text{pH} = 7.0$

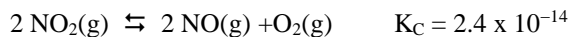
$\text{pH} > 7.0$

d) The oxide compound expected to form a base when added to water



Part 3. Problems.

1) In the presence of molecular oxygen (O₂) nitrogen monoxide and nitrogen dioxide will establish an equilibrium by the process



A system initially has [NO₂] = 6.1 x 10⁻³ M and [O₂] = 0.52 M. There is initially no NO(g) in the system.

a) Give an appropriate ICE table for the above system. [8 points]

$$K_C = \frac{[\text{NO}]^2 [\text{O}_2]}{[\text{NO}_2]^2} = 2.4 \times 10^{-14}$$

	Initial	Change	Equilibrium
NO	0	2x	2x
O ₂	0.52	x	0.52 + x
NO ₂	6.1 x 10 ⁻³	- 2x	6.1 x 10 ⁻³ - 2x

b) What is the [NO], the concentration of NO(g), when the above system reaches equilibrium. [8 points]

Based on the ICE table and the expression for K_C

$$\frac{(2x)^2 (0.52 + x)}{(6.1 \times 10^{-3} - 2x)^2} = 2.4 \times 10^{-14} \quad \text{Assume } x \ll 6.1 \times 10^{-3}$$

$$\text{Then } \frac{(4x^2)(0.52)}{(6.1 \times 10^{-3})^2} = 2.4 \times 10^{-14}$$

$$x^2 = \frac{(2.4 \times 10^{-14})(6.1 \times 10^{-3})^2}{4(0.52)} = 4.29 \times 10^{-19}$$

$$x = (4.29 \times 10^{-19})^{1/2} = 6.55 \times 10^{-10} \quad \text{Our assumption that } x \ll 6.1 \times 10^{-3} \text{ was good}$$

$$\text{So } [\text{NO}] = 2x = 1.3 \times 10^{-9} \text{ M}$$

Version 1: 1.3 x 10⁻⁹ M

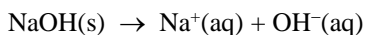
Version 2: 6.3 x 10⁻¹⁰ M

Version 4: 8.0 x 10⁻¹⁰ M

2) Find the pH for the following

a) A 0.026 M solution of sodium hydroxide (NaOH, MW = 40.00 g/mol), a strong soluble base.
[8 points]

NaOH is a strong soluble base, and reacts by the process



Since the base is soluble and strong the reaction goes to completion.

$$\text{Therefore} \quad [\text{OH}^{\text{-}}] = \frac{0.026 \text{ mol NaOH}}{\text{L soln}} \frac{1 \text{ mol OH}^{\text{-}}}{1 \text{ mol NaOH}} = \frac{0.026 \text{ mol OH}^{\text{-}}}{\text{L soln}}$$

$$\text{pOH} = -\log_{10}[\text{OH}^{\text{-}}] = -\log_{10}(0.026) = 1.59$$

$$\text{pH} + \text{pOH} = 14.00 \text{ and so } \text{pH} = 14.00 - \text{pOH} = 14.00 - 1.59 = 12.41$$

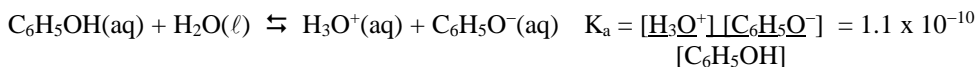
Version 1: pH = 12.81

Version 2: pH = 12.62

Version 4: pH = 12.95

b) A 3.6×10^{-2} M solution of phenol ($\text{C}_6\text{H}_5\text{OH}$, MW = 94.11 g/mol). Phenol is a weak monoprotic acid, with $K_a = 1.1 \times 10^{-10}$ [12 points]

$\text{C}_6\text{H}_5\text{OH}$ is a weak monoprotic acid, so



Now we need the ICE table

	Initial	Change	Equilibrium
$\text{C}_6\text{H}_5\text{O}^{\text{-}}$	0	x	x
$\text{H}_3\text{O}^{\text{+}}$	0	x	x
$\text{C}_6\text{H}_5\text{OH}$	1.6×10^{-2}	-x	$3.6 \times 10^{-2} - x$

And so $\frac{(x)(x)}{(3.6 \times 10^{-2} - x)} = 1.1 \times 10^{-10}$ Assume $x \ll 3.6 \times 10^{-2}$

Then $\frac{x^2}{(3.6 \times 10^{-2})} = 1.1 \times 10^{-10}$ $x^2 = (1.1 \times 10^{-10})(3.6 \times 10^{-2}) = 3.96 \times 10^{-12}$
 $x = (3.96 \times 10^{-12})^{1/2} = 1.99 \times 10^{-6}$ Our assumption that $x \ll 3.6 \times 10^{-2}$ was good

So $[\text{H}_3\text{O}^{\text{+}}] = 1.99 \times 10^{-6}$ M $\text{pH} = -\log_{10}[\text{H}_3\text{O}^{\text{+}}] = -\log_{10}(1.99 \times 10^{-6}) = 5.70$

Version 1: pH = 5.49

Version 2: pH = 5.59

Version 4: pH = 5.55