General Chemistry I, 1st midterm exam., 2018-11-05

(Gas constant R= 0.08206 L atm $K^{-1}mol^{-1}$ or 8.31451 J K^{-1} mol^{-1}, 1 Joule= 1 kgm^2/s^2)

1. Name the following compounds in English (英文名稱) (18%)
(a) AgCl (b) NO (c) HClO (d) CO_2 (e) H_2SO_4 (f) Pb (g) Au (h) Hg (i) Al

2. What are the electronegativity values for the following atoms: (a) F (b) O (c) C (d) H (e) N (f) Na. (12%).

3. Write the English symbols of the first row transition metals from d^1 to d^{10} sequentially. (10%)

4. Balance the following equation: (10%)

$$MnO_4^-{}_{(aq)} + Fe^{2+}{}_{(aq)} \text{ -----> } Fe^{3+}{}_{(aq)} + Mn^{2+}{}_{(aq)}$$

5. There are two gases (CO_2, and H_2) in a container at 25℃ in the molar ratio of 1:1. Calculate the (a) kinetic energy, and (b) average velocity of CO_2. Also calculate the (c) expected ratio (CO_2/H_2) of effusion rates through a tiny hole. (d) In an experiment, the measured ratio (CO_2/H_2) of effusion rates is smaller than the value calculated from the Graham's law. Explain why. (molecular weight, CO_2= 44, and H_2= 2 g/mol). (20%).

6. (a) What is the Le Chatelier's principle? (4%) (b) Derive the Henderson-Hesselbalch equation from the acid equilibrium constant (5%)

7. Tris(hydroxymethyl)aminomethane, commonly called TRIS or Trizzna, is often used as a buffer in biochemical studies. Its buffering range is from pH 7 to 9, and K_b is 1.19×10^{-6} for the reaction

$$TRIS_{(aq)} + H_2O_{(l)} \rightleftharpoons TRISH^+{}_{(aq)} + OH^-{}_{(aq)}$$

a. What is the optimal (最佳的) pH for TRIS buffers?
b. Calculate the ratio (TRIS)/($TRISH^+$) at pH= 7.0
c. A buffer is prepared by diluting 50.0 g of TRIS base and 63.0 g of TRIS hydrochloride (written as TRIS·HCL) to a total volume of 2.0 L.
d. What is the pH of this buffer? What is the pH after 0.5 mL 12.0 M HCl is added to 200.0 mL portion of the buffer? (12%)
(Molecular weight, Mw, of TRIS is 121.1 g/mol; Mw of TRIS-HCl= 157.6 g/mol)

8. Solutions of sodium thiosulfate ($Na_2S_2O_3$) are used to dissolve un-exposed AgBr in the developing process for black-and-white film. What mass of AgBr can dissolve in 1.00 L of 0.5 M $Na_2S_2O_3$? Assume the overall formation constant for $Ag(S_2O_3)_2^{3-}$ is 2.9×10^{13} and K_{sp} for AgBr is 5.0×10^{-13}. (9%) (Mw of AgBr is 187.8 g/mol).

Answer To 1st midterm Exam. GChem 2013-11-11

18% 1. (a) AgCl : silver chloride (b) NO : nitrogen monoxide (or nitric oxide)

(c) HClO : hypochlorite acid, (d) CO_2 : carbon dioxide

(e) H_2SO_4 : sulfuric acid (f) Pb : lead

(g) Au : gold (h) Hg : mercury (i) Al : aluminum

12% 2. (a) F : 4.0 (b) O : 3.5 (c) C : 2.5 (d) H : 2.1

(e) N : 3.0 (f) Na : 0.9

(answer ±0.1 is considered correct)

10% 3. $d^1 \sim d^5$ transition metal elements : Sc Ti V Cr Mn

$d^6 \sim d^{10}$ " " " " : Fe Co Ni Cu Zn

10% 4. $8H^+ + MnO_4^-{}_{(aq)} + 5Fe^{2+}_{(aq)} \longrightarrow Mn^{2+}_{(aq)} + 4H_2O_{(aq)} + 5Fe^{3+}_{(aq)}$

20% 5. (a) Kinetic Energy $KE = \frac{3}{2}RT$ independent of gases

$$= \frac{3}{2}(8.3145\ J\cdot K^{-1}mol^{-1}) \times 298.5\ K$$

$$= 3722.8\ J/mol$$

or 3.72 KJ/mol for both CO_2 & H_2.

(b) $$u_{avg} = \sqrt{\frac{8RT}{\pi M}} = \sqrt{\frac{8 \times 8.3145\ J\cdot K^{-1}mol^{-1} \times 298.5\ K}{3.14159 \times 44\ g/mol}}$$

$$= \sqrt{143.6\ J/g}$$

$$= \sqrt{143.6\ (kg\cdot m^2/s^2)\cdot g^{-1}}$$

$$= \sqrt{14.36 \times 10^4\ m^2/s^2}$$

$$= 379\ m/s \text{ for } CO_2$$

5 (c) $\frac{u_{avg,CO_2}}{u_{avg,H_2}} = \sqrt{\frac{M_{H_2}}{M_{CO_2}}} = \sqrt{\frac{2}{44}} = 0.213$

(d) Since $V_{CO_2} > V_{H_2}$, CO_2 gas molecule suffers from collision with other gas molecules more than H_2.
Therefore u_{avg,CO_2} becomes smaller than theoretic value.
Consequently, the observed $\frac{u_{avg,CO_2}}{u_{avg,H_2}}$ ratio will be smaller than 0.213 (obtained from (c)).

15% 6. (a) Le Chatelier's principle: Addition of an external factor to a balanced system will trigger the balanced system shift toward a reaction direction, so that the external factor will be canceled out.

(b). $HA + OH^- \rightleftharpoons A^- + H_2O$

$$K_a = \frac{[H^+][A^-]}{[HA]} \Rightarrow [H^+] = K_a \frac{[HA]}{[A^-]}$$

$$-\log[H^+] = -\log K_a - \log\frac{[HA]}{[A^-]}$$

$$\Rightarrow pH = pK_a - \log\frac{[HA]}{[A^-]}$$

$$= pK_a + \log\frac{[A^-]}{[HA]}$$ --- Henderson-Hasselba[lch] eqn.

7 a. The optimum pH for a buffer is when pH = pK_a. At this pH a buffer will have equal neutralization capacity for both added acid and base. As shown next, because the pK_a for $TRISH^+$ is 8.1, the optimal buffer pH is about 8.1.

$$K_b = 1.19 \times 10^{-6};\ K_a = K_w/K_b = 8.40 \times 10^{-9};\ pK_a = -\log(8.40 \times 10^{-9}) = 8.076$$

b. $pH = pK_a + \log\dfrac{[TRIS]}{[TRISH^+]},\quad 7.00 = 8.076 + \log\dfrac{[TRIS]}{[TRISH^+]}$

$$\frac{[TRIS]}{[TRISH^+]} = 10^{-1.08} = 0.083 \quad (\text{at pH} = 7.00)$$

$$9.00 = 8.076 + \log\frac{[TRIS]}{[TRISH^+]},\quad \frac{[TRIS]}{[TRISH^+]} = 10^{0.92} = 8.3 \quad (\text{at pH} = 9.00)$$

c. $\dfrac{50.0\text{ g TRIS}}{2.0\text{ L}} \times \dfrac{1\text{ mol}}{121.14\text{ g}} = 0.206\ M = 0.21\ M = [TRIS]$

$$\frac{65.0\text{ g TRISHCl}}{2.0\text{ L}} \times \frac{1\text{ mol}}{157.60\text{ g}} = 0.206\ M = 0.21\ M = [TRISHCl] = [TRISH^+]$$

$$pH = pK_a + \log\frac{[TRIS]}{[TRISH^+]} = 8.076 + \log\frac{(0.21)}{(0.21)} = 8.08$$

(d) The amount of H^+ added from HCl is: $(0.50 \times 10^{-3}\text{ L}) \times 12\text{ mol/L} = 6.0 \times 10^{-3}$ mol H^+

The H^+ from HCl will convert TRIS into $TRISH^+$. The reaction is:

	TRIS	+	H^+	$\rightarrow$	$TRISH^+$	
Before	0.21 M		$\dfrac{6.0 \times 10^{-3}}{0.2005} = 0.030\ M$		0.21 M	
Change	−0.030		−0.030	$\rightarrow$	+0.030	Reacts completely
After	0.18		0		0.24	

Now use the Henderson-Hasselbalch equation to solve this buffer problem.

$$pH = 8.076 + \log\left(\frac{0.18}{0.24}\right) = 7.95$$

8.

$$\begin{array}{ll} AgBr(s) \rightleftharpoons Ag^+ + Br^- & K_{sp} = 5.0 \times 10^{-13} \\ Ag^+ + 2\,S_2O_3^{2-} \rightleftharpoons Ag(S_2O_3)_2^{3-} & K_f = 2.9 \times 10^{13} \\ \hline AgBr(s) + 2\,S_2O_3^{2-} \rightleftharpoons Ag(S_2O_3)_2^{3-} + Br^- & K = K_{sp} \times K_f = 14.5 \end{array}$$

(Carry extra sig. figs.)

	$AgBr(s)$	+	$2\,S_2O_3^{2-}$	$\rightleftharpoons$	$Ag(S_2O_3)_2^{3-}$	+	Br^-
Initial			0.500 M		0		0
	s mol/L AgBr(s) dissolves to reach equilibrium						
Change	$-s$		$-2s$	$\rightarrow$	$+s$		$+s$
Equil.			$0.500 - 2s$		s		s

$$K = \frac{s^2}{(0.500 - 2s)^2} = 14.5;\ \text{taking the square root of both sides:}$$

$$\frac{s}{0.500 - 2s} = 3.81,\ s = 1.91 - (7.62)s,\ s = 0.222\text{ mol/L}$$

$$1.00\text{ L} \times \frac{0.222\text{ mol AgBr}}{\text{L}} \times \frac{187.8\text{ g AgBr}}{\text{mol AgBr}} = 41.7\text{ g AgBr} = 42\text{ g AgBr}$$