

Read questions carefully to understand what is being asked. If you have doubt, feel free to ask your instructor. Use the reverse side of your answer paper as scratch. Use attached periodic table and important constants chart. (Total pts. = 52 + 36 + 12 = 100)

SHORT ANSWER: To receive full points, show appropriate set up equation, then insert the raw data in the set up equation with units before showing the calculations.

- 1) The rearrangement of methyl isonitrile to methyl nitrile has a rate constant of $5.25 \times 10^{-5} \text{ s}^{-1}$ at 198.9°C and $3.16 \times 10^{-3} \text{ s}^{-1}$ at 251.2°C . Calculate the energy of activation (E_a) of the reaction (8 pts.).

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

$$k_1 = 5.25 \times 10^{-5} \text{ s}^{-1}$$

$$T_1 = 273 + 198.9^\circ\text{C} = 471.9 \text{ K}$$

$$k_2 = 3.16 \times 10^{-3} \text{ s}^{-1}$$

$$\ln\left(\frac{3.16 \times 10^{-3} \text{ s}^{-1}}{5.25 \times 10^{-5} \text{ s}^{-1}}\right) = \frac{-E_a}{8.3145 \text{ J/K}\cdot\text{mol}} \left(\frac{1}{524.2 \text{ K}} - \frac{1}{471.9 \text{ K}}\right)$$

$T_2 = 251.2^\circ\text{C} + 273 = 524.2 \text{ K}$

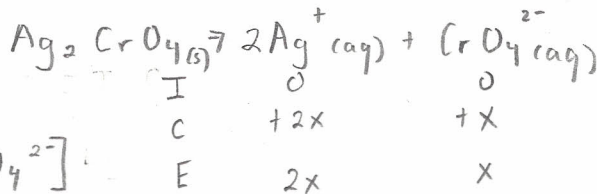
$$\ln(60.19) = \frac{-E_a}{8.3145 \frac{\text{J}}{\text{K}\cdot\text{mol}}} (-2.11 \times 10^{-4} \text{ K}^{-1})$$

$$E_a = 161,139 \text{ J/mol}$$

$$4.0975 = 2.543 \times 10^{-5} \frac{\text{mol}}{\text{J}} (E_a)$$

$$E_a = \frac{4.0975}{2.543 \times 10^{-5} \frac{\text{mol}}{\text{J}}} = 161,139 \text{ J/mol}$$

- 2) K_{sp} of Ag_2CrO_4 in water at 20°C is $1.9 \times 10^{-12} \text{ M}$. Calculate its solubility in grams per 0.1 L of solution (8 pts.).



$$K_{sp} = [\text{Ag}^+]^2 [\text{CrO}_4^{2-}]$$

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$$1.9 \times 10^{-12} = (2x)^2 (x)$$

$$1.9 \times 10^{-12} = 4x^3$$

$$\frac{4x^3}{4} = \frac{1.9 \times 10^{-12}}{4}$$

$$x^3 = 4.75 \times 10^{-13}$$

$$x = (4.75 \times 10^{-13})^{1/3}$$

$$x = 7.8 \times 10^{-5} \text{ M}$$

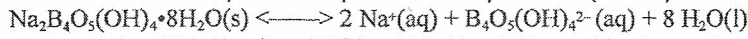
$7.8 \times 10^{-5} \text{ mol Ag}_2\text{CrO}_4$	331.736 g	$= \frac{0.0259 \text{ g}}{\text{L}}$
L	1 mol Ag_2CrO_4	

$$.1 (0.0259 \text{ g Ag}_2\text{CrO}_4) = \frac{0.00259 \text{ g}}{.1 \text{ L}}$$

$$0.00259 \text{ g of Ag}_2\text{CrO}_4 \text{ dissolves per .1 L of solution}$$

By stoichiometry, the solubility of Ag_2CrO_4 is $7.8 \times 10^{-5} \text{ M}$ (the same as $[\text{CrO}_4^{2-}]_{eq}$) since it is a 1:1 ratio. 1 mole of Ag_2CrO_4 dissolves for 1 mole of CrO_4^{2-} formed.

3) A nonlinear best fit plot of K_{eq} versus Temperature (Kelvin) of tetraborate equilibrium 3) _____



gives $\Delta H^\circ = 96 \text{ kJ/mol}$ and $\Delta S^\circ = 300 \text{ J/mol}$. From this data calculate the K_{eq} at 25°

C. (8 pts.)

$$T = 25 + 273 = 298 \text{ K}$$

$$\Delta_r G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$\Delta_r G^\circ = \frac{96 \text{ kJ}}{\text{mol}} \left(\frac{1000 \text{ J}}{1 \text{ kJ}} \right) - (298 \text{ K}) \left(\frac{300 \text{ J}}{\text{mol} \cdot \text{K}} \right)$$

$$\Delta_r G^\circ = 96,000 \text{ J/mol} - 89,400 \text{ J/mol}$$

$$\Delta_r G^\circ = 6600 \text{ J/mol} \cdot \text{rxn}$$

$$\Delta_r G^\circ = -RT \ln K$$

$$6600 \text{ J/mol} = -(8.3145 \frac{\text{J}}{\text{K} \cdot \text{mol}}) (298 \text{ K}) \ln K$$

$$6600 \text{ J/mol} = -2477.721 \frac{\text{J}}{\text{mol}} \ln K$$

$$\ln K = \frac{6600 \text{ J/mol}}{-2477.721 \text{ J/mol}}$$

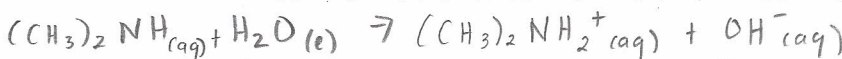
$$\ln K = -2.66$$

$$K = e^{-2.66}$$

$$K = .0697$$

$$K = .0697$$

4) Dimethylamine, $(\text{CH}_3)_2\text{NH}$, is a weak base with a $K_b = 5.9 \times 10^{-9}$. (a) Calculate, in stepwise fashion, the pH of a 0.20M solution of the base (4 pts.)? In solving this problem, show the value for (b) the $[\text{OH}^-]$ (4 pts.), (c) the pOH (2 pts.), and (d) the $[\text{H}^+]$ (2 pts.) (Total 12 pts.) 4) _____



I	.2	0	0
C	-x	+x	+x
E	.2-x	x	x

$$K_b = \frac{[(\text{CH}_3)_2\text{NH}_2^+][\text{OH}^-]}{[(\text{CH}_3)_2\text{NH}]} = \frac{(x)(x)}{.2-x} = 5.9 \times 10^{-9} \Rightarrow$$

$$\frac{x^2}{.2} = 5.9 \times 10^{-9}$$

$$x^2 = 1.18 \times 10^{-9}$$

$$x = \sqrt{1.18 \times 10^{-9}}$$

$$x = 3.44 \times 10^{-5} \text{ M}$$

b) $x = [\text{OH}^-] = 3.44 \times 10^{-5} \text{ M}$

c) $\text{pOH} = -\log[\text{OH}^-]$

$$\text{pOH} = -\log(3.44 \times 10^{-5} \text{ M}) = 4.46$$

d) $\text{pOH} + \text{pH} = 14$

$$\text{pH} = 14 - 4.46 = 9.54$$

a) $\text{pH} = 9.54$

b) $[\text{OH}^-] = 3.44 \times 10^{-5} \text{ M}$

c) $\text{pOH} = 4.46$

d) $[\text{H}_3\text{O}^+] = 2.91 \times 10^{-10} \text{ M}$

$$\text{pH} = -\log[\text{H}_3\text{O}^+]$$

$$9.54 = -\log[\text{H}_3\text{O}^+]$$

$$[\text{H}_3\text{O}^+] = 10^{-9.54} = 2.9 \times 10^{-10} \text{ M}$$

-Because this is a weak base and its initial concentration of .2 M $\gg 100(K_b)$, I can neglect x in the denominator

5) A solution of acetic acid is 2.0% dissociated at 25.0°C . What was the original concentration (in M) of the acetic acid solution? The K_a at 25.0°C for acetic acid is 1.8×10^{-5} (8 pts.)

I	$\text{CH}_3\text{COOH}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{CH}_3\text{COO}^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$	0	0
C	-0.02x	+0.02x	+0.02x
E	x-0.02x	0.02x	0.02x

$$K_a = \frac{[\text{CH}_3\text{COO}^-][\text{H}_3\text{O}^+]}{[\text{CH}_3\text{COOH}]} = \frac{(0.02x)(0.02x)}{(x-0.02x)} = 1.8 \times 10^{-5}$$

$$\frac{.0004x^2}{.98x} = 1.8 \times 10^{-5}$$

$$4.08 \times 10^{-4} x = 1.8 \times 10^{-5}$$

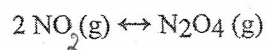
$$x = \frac{1.8 \times 10^{-5}}{4.08 \times 10^{-4}}$$

$$x = .0441 \text{ M}$$

$$[\text{CH}_3\text{COOH}]_0 = .0441 \text{ M}$$

6) At a given temperature, 0.0524 mol $\text{NO}_2(\text{g})$ is placed in a 1.00 L flask. After reaching equilibrium, the concentration of $\text{NO}_2(\text{g})$ is $3.9 \times 10^{-3} \text{ M}$. What is K_c for the reaction (8 pts.):

6) _____



	$2 \text{NO}_2(\text{g})$	\rightleftharpoons	$\text{N}_2\text{O}_4(\text{g})$
I	.0524 M		0
C	-2x		+x
E	$3.9 \times 10^{-3} \text{ M}$		x

$$K_p = \frac{P_{\text{N}_2\text{O}_4}}{(P_{\text{NO}_2})^2} \quad K_p = K_c (RT)^{\Delta n}$$

$$.0524 - 2x = 3.9 \times 10^{-3}$$

$$-2x = 3.9 \times 10^{-3} \text{ M} - .0524 \text{ M}$$

$$-2x = -.0485 \text{ M}$$

$$x = .02425 \text{ M}$$

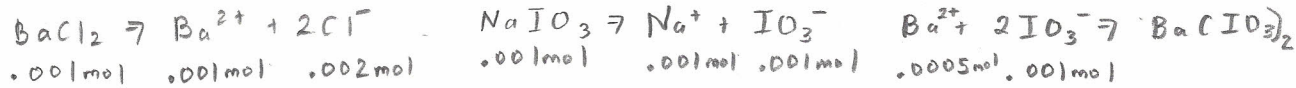
$$[\text{N}_2\text{O}_4]_{\text{eq}} = x = .02425 \text{ M}$$

$$K_c = \frac{[\text{N}_2\text{O}_4]}{[\text{NO}_2]^2}$$

$$K_c = \frac{(.02425 \text{ M})}{(3.9 \times 10^{-3} \text{ M})^2}$$

$$K_c = 1594$$

$K_c = 1594$



.001 mol .001 mol .002 mol

.001 mol .001 mol .001 mol

.0005 mol .001 mol

$$\frac{.0005 \text{ mol}}{.02 \text{ L}} =$$

MULTIPLE CHOICE. Start on line 7 of your scantron paper. Select the one alternative that best completes the statement or answers the question (4 pts each).

- 7) When 10mL of a 0.1 M BaCl₂ solution is mixed with 10mL of 0.1M NaIO₃ solution, which ion in what concentration would still be present in the equilibrium solution after precipitate of Ba(IO₃)₂ is formed? Assume K_{sp} of Ba(IO₃)₂ to be very low. 7) C
- A) 0.025 M Cl⁻ B) 0.25 M Ba²⁺ C) 0.025 M Ba²⁺ D) 0.1 M IO₃⁻

- 8) In a voltaic cell lab experiment the E_{red} of a Zn electrode was found to be -1.018 V relative to Cu, which acted as a reference cell. In this configuration, the cell has 8) A
- A) Cu cathode; Zn anode B) Zn cathode; Cu anode
C) Cu & Zn both as cathode & anode D) None of these

- 9) When balanced, the following redox reaction (in basic medium) will have coefficients: 9) D
- $$3\text{CN}^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) + 2\text{MnO}_4^-(\text{aq}) \rightarrow 3\text{CNO}^-(\text{aq}) + \text{MnO}_2(\text{s}) + 2\text{OH}^-(\text{aq})$$
- A) 3, 1, 2; 3, 2, 3 B) 2, 1, 2; 3, 2, 3 C) 1, 2, 2; 3, 2, 2 D) 3, 1, 2; 3, 2, 2

- 10) Consider an electrochemical cell based on the reaction: 10) D
- $$2\text{H}^+(\text{aq}) + \text{Sn}(\text{s}) \rightarrow \text{Sn}^{2+}(\text{aq}) + \text{H}_2(\text{g})$$
- Handwritten notes:
 $\text{CN}^- \rightarrow \text{CN}^{3-} + 4e^- \quad \times 3$
 $\text{Mn}^{+7} + 3e^- \rightarrow \text{Mn}^{+4} \quad \times 4$
 $3\text{CN}^- + \text{H}_2\text{O} + 4\text{MnO}_4^- \rightarrow 3\text{CNO}^- + 4\text{MnO}_2 + \text{OH}^-$

Which of the following actions would not change the measured cell potential? $E^\circ = E^\circ_{\text{red}}(\text{cathode}) - E^\circ_{\text{red}}(\text{anode})$

- A) lowering the pH in the cathode compartment
 B) increasing the tin (II) ion concentration in the anode compartment
 C) increasing the pressure of hydrogen gas in the cathode compartment
 D) addition of more tin metal to the anode compartment
 E) Any of the above will change the measured cell potential.
- Handwritten notes:
 $2\text{H}^+ + 2e^- \rightarrow \text{H}_2 \text{ cathode}$
 $\text{Sn} \rightarrow \text{Sn}^{2+} + 2e^- \text{ anode}$

- 11) What is the concentration (in M) of hydroxide ions in a solution at 25.0 °C with pH = 4.282? 11) B
- A) 5.22×10^{-5}
 B) 1.91×10^{-10}
 C) 1.66×10^4
 D) 9.72
 E) 4.28

- 12) HZ is a weak acid. An aqueous solution of HZ is prepared by dissolving 0.020 mol of HZ in sufficient water to yield 1.0 L of solution. The pH of the solution was 4.93 at 25.0°C. The K_a of HZ is _____ 12) D
- Handwritten notes:
 $\text{pH} = \text{pK}_a + \frac{[\text{con base}]}{[\text{acid}]}$
 $4.93 = \text{pK}_a +$
 $x = 1.17 \times 10^{-5} \text{ M}$
 $\text{HZ} + \text{H}_2\text{O} \rightleftharpoons \text{Z}^- + \text{H}_3\text{O}^+$

0.02 M	0	0
-x	+x	+x
0.02 - x	x	1.17 x 10 ⁻⁵
0.01999 M	1.17 x 10 ⁻⁵ M	1.17 x 10 ⁻⁵ M

13) The equilibrium constant for a reaction is 0.48 at 25°C. What is the value of ΔG° (kJ/mol) at this temperature? 13) A

A) 1.8

B) -4.2

C) 4.2

D) 1.5×10^2

E) More information is needed.

$$\Delta_r G = -RT \ln K$$

$$\left(\frac{-8.3145 \text{ J}}{\text{K} \cdot \text{mol}} \right) (298 \text{ K}) \ln 0.48 \left(\frac{1 \text{ kJ}}{1000 \text{ J}} \right)$$

14) ΔS is negative for the reaction _____.

A) $\text{NH}_4\text{Cl}(\text{s}) \rightarrow \text{NH}_3(\text{g}) + \text{HCl}(\text{g})$

B) $\text{PbCl}_2(\text{s}) \rightarrow \text{Pb}^{2+}(\text{aq}) + 2\text{Cl}^-(\text{aq})$

C) $2\text{C}(\text{s}) + \text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g})$

D) $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{O}(\text{g})$

E) $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{SO}_3(\text{g})$

entropy ↓

14) E

15) Of the following, the entropy of gaseous _____ is the largest at 25°C and 1 atm.

A) H_2

B) C_2H_4

C) CH_4

D) C_2H_6

E) C_2H_2

15) D

TRUE/FALSE. On your scantron, fill bubble A if the statement is true or bubble B if it is false (4 pts. each).

16) The extent of ionization of a weak electrolyte is increased by adding to the solution a strong electrolyte that has an ion in common with the weak electrolyte.

16) B

17) The standard reduction potential, E°_{red} , is proportional to the stoichiometric coefficient.

17) B

18) To titrate 1.0 g of ascorbic acid (MW 176 g/mole), one needs 45.0 mL of a NaOH solution. The strength of the NaOH solution is 0.252 M.

18) B

1g	1mol
	176g

0.252 M