Name _KEY_

Read questions **carefully** to **understand what is being asked**, before answering. No outside paper is allowed. Use the reverse side of your answer paper as scratch. Use the important equation table and periodic table provided. (Total points = 50 + (22x3=)66 = 116).

**Show your calculation first with set up equation. Then use the raw data with units in the equation in the equation and then complete the calculation.**
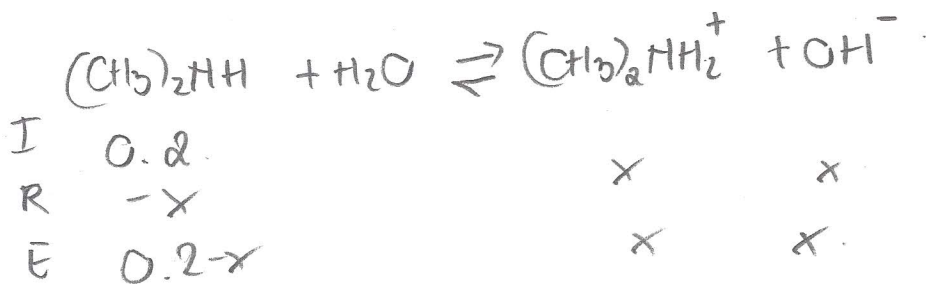
1) Calculate the pH of a solution where [H+] is 200 times the [OH- }. Given $K_W = 10^{-14}$ (6 pts.)

1) ___5.85___

$$[H^+] = 200[OH^-].$$
$$⟹ \quad [H^+][OH^-] = 10^{-14}.$$
$$(⟹ \quad 200[OH^-]^2 = 10^{-14}.$$
$$⟹ \quad [OH^-] = \sqrt{\frac{10^{-14}}{200}} = 7.07 \times 10^{-9}.$$
$$⟹ \quad pOH = -\log[OH^-] = 8.15$$
$$⟹ \quad pH = 14 - 8.15 = 5.85 \quad ✓$$

2) Dimethylamine, $(CH_3)_2NH$, is a weak base with a $K_b = 5.9 \times 10^{-9}$. (a) Calculate, in stepwise fashion, of a 0.20M solution of the base the value for (a) the [OH-] (4 pts.), (b) the pOH (2 pts.); (c) the [H+] (2 pts.) and (d) the pH (Total 12 pts.).

2) _____

$$(CH_3)_2NH + H_2O \rightleftharpoons (CH_3)_2NH_2^+ + OH^-$$

| | | | |
|---|---|---|---|
| I | 0.2 | x | x |
| R | -x | | |
| E | 0.2-x | x | x |

a) $K_b = 5.9 \times 10^{-9} = \dfrac{x^2}{0.2-x}$  ⟹ $x = 3.43 \times 10^{-5}$.

⟹ $[OH^-] = 3.43 \times 10^{-5}$.

b) ⟹ $pOH = -\log[OH^-] = 4.47$
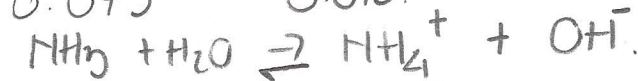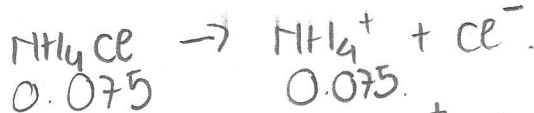
c) $[H^+] = \dfrac{10^{-14}}{[OH^-]} = 2.99 \times 10^{-10}.$

d) $pH = -\log[H^+] = 9.53$ ✓

1

3) Calculate the pH of a buffer solution that has 0.075M ammonium chloride and
   0.065M ammonia. ($K_a$ of $NH_4^+$ = 5.6 x 10-10) (Note: Check which is the acid
   here?) (6 pts.)

3) ___ 9.2 ___

$NH_4Cl$ →

$NH_3$

$NH_4Cl$ → $NH_4^+$ + $Cl^-$
0.075          0.075

$NH_3 + H_2O$ ⇌ $NH_4^+$ + $OH^-$     ⟹ $K_b = \dfrac{10^{-14}}{K_a}$

I    0.065        0.075                  $= 1.79 \times 10^{-5}$
R    -x            x          x
E    0.065-x      0.075+x     x

⟹ $K_b = 1.79 \times 10^{-5} = \dfrac{(0.075+x)x}{0.065-x}$  ⟹ $x = 1.55 \times 10^{-5}$

⟹ pOH = 4.8 ⟹ pH = 9.2 ✓

4) If $K_{sp}$ of calcium phosphate, Ca3(PO4)2 in water is 1.0 x 10- 33 , then what is its solubility
   in water in gram/L (10 pts)?

4) 0.008 x10^{-5}
                  g/L
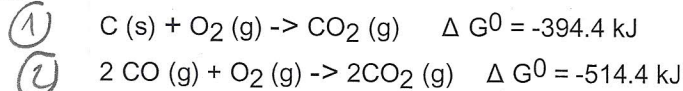
$Ca_3(PO_4)_2$ ⇌ $3Ca^{2+}$ + $2PO_4^{3-}$
                  3s          2s
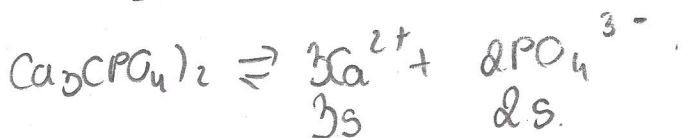
$K_{sp}$ = $[Ca^{2+}]^3 [PO_4^{3-}]^2$

= $[3s]^3 [2s]^2$

= $27s^3 \times 4s^2 = 108s^5 = 4.0 \times 10^{-33}$ ⟹ s = $9.8 \times 10^{-8}$
                                                        mol/L

⟹ s = $9.8 \times 10^{-8} \dfrac{mol}{L} \times \dfrac{310 g}{mol} = 3.038 \times 10^{-5}$ g/L ✓

2

5) Given:

(1)  $C(s) + O_2(g) \rightarrow CO_2(g)$   $\Delta G^0 = -394.4$ kJ

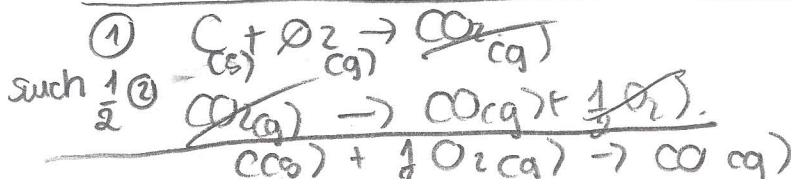(2)  $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$   $\Delta G^0 = -514.4$ kJ

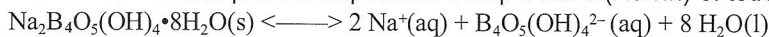Calculate the standard free energy of formation of CO (8 pts.):

   $C(s) + 1/2\ O_2(g) \rightarrow CO(g)$

5) $\underline{-137.2\ kJ}$

$\frac{1}{2}$ ②  $CO(g) + \frac{1}{2}O_{2(g)} \rightarrow CO_2(g)$   $\frac{\Delta G^\circ = -257.2\ kJ}{2}$

Swich $\frac{1}{2}$②  $\Rightarrow CO_2(g) \rightarrow CO(g) + \frac{1}{2}O_2(g)$   $-\frac{\Delta G}{2} = 257.2\ kJ$

_____

Such $\frac{1}{2}$① —  $C(s) + O_{2(g)} \rightarrow CO_{2(g)}$

Such $\frac{1}{2}$②  $CO_2(g) \rightarrow CO(g) + \frac{1}{2}O_2)$.

$C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g)$
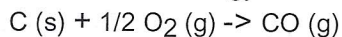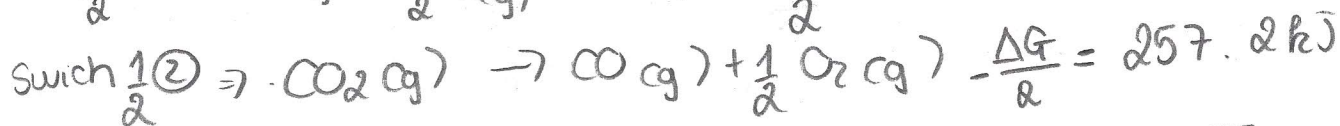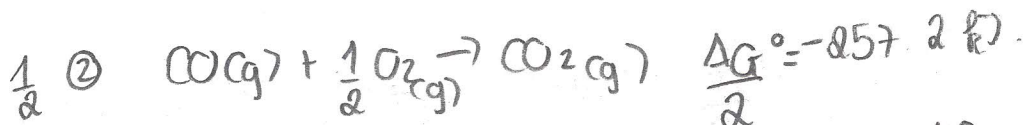
$\Rightarrow \Delta G_{0\ total} = \Delta G^\circ_1 + (-\frac{\Delta G^\circ}{2})$

$= -137.2\ kJ$ ✓

6) A nonlinear best fit plot of $K_{eq}$ versus Temperature (Kelvin) of tetraborate equlilibrium:
   $Na_2B_4O_5(OH)_4 \cdot 8H_2O(s) \longleftrightarrow 2Na^+(aq) + B_4O_5(OH)_4^{2-}(aq) + 8H_2O(l)$
   gives $\Delta H° = 96$ kJ/mol and $\Delta S° = 300$ J/mol. From this data calculate the $K_{eq}$ at 25° C.
   Show set up, raw data and units. (8 pts.)

6) _____

$T = 25°C + 273 = 298\ K$.

$\Delta G° = \Delta H° - T\Delta S°$   $\Rightarrow \Delta G° = 96\ kJ/mol - 298 \cdot \frac{300\ J/mol}{1000}$ ✓

$= 6.6\ kJ/mol$.

$\Delta G = -RT\ \ell n K$.

$\Rightarrow \ell n K = \frac{-\Delta G}{RT} = \frac{-6.6\ kJ/mol \times 1000 J/1 kJ}{8.3145\ J/mol \times K \times 298 K}$ $= -2.66$

$\Rightarrow K = e^{-2.66} = 0.0699$ ✓

**MULTIPLE CHOICE.** On the scantron fill the bubble with number same as the question number. Show your work to select the one response that best completes the statement or answers the question (3 pts each).

7) Of the following acids, _____ is not a strong acid.
   A) $HClO_4$       B) $HCl$       C) $HNO_2$       D) $H_2SO_4$       E) $HNO_3$

7) $\underline{C}$

8) If the $[H^+]$ of a water sample is $1 \times 10^{-4}$ M, the $[OH^-]$ is
   A) $1 \times 10^{-14}$ M.
   B) $1 \times 10^{-4}$ M.
   C) $1 \times 10^4$ M.
   D) $1 \times 10^{-10}$ M.
   E) none of the above

8) $\underline{D}$

$\frac{10^{-14}}{10^{-4}}$

3

9) Using the data in the table, which of the conjugate acids below is the weakest acid?    9) _A_

| Base | $K_b$ |
|------|------|
| $NH_3$ | $1.8 \times 10^{-5}$ |
| $C_5H_5N$ | $1.7 \times 10^{-9}$ |
| $H_2NOH$ | $1.1 \times 10^{-8}$ |
| $NH_2CH_3$ | $4.4 \times 10^{-4}$ |

*(handwritten: $K_b$ nhỏ ⟹ $K_a$ lớn. ⟹ $K_b$ lớn ⟹ acid yếu.)*

A) $NH_3CH_3^+$

B) $NH_4^+$

C) $H_3NOH^+$

D) $C_5H_5NH^+$

E) $NH_4^+$ and $NH_3CH_3^+$

10) Which of the following aqueous solutions has the lowest [$OH^-$]?    10) _D._
   A) a $1 \times 10^{-4}$ M solution of $HNO_3$  *(pH = 4.)*  *(⟹ [biggest $H^+$].)*
   B) pure water  *(pH = 7.)*
   C) a $1 \times 10^{-3}$ M solution of $NH_4Cl$
   D) a solution with a pOH of 12.0  *(⟹ pH = 2.)*
   E) a solution with a pH of 3.0  *(⟹ pH = 3.)*

11) A 0.1 M solution of _____ has a pH of 7.0.    11) _B_
   A) $NH_4Cl$        B) $NaNO_3$        C) $Na_2S$        D) $NaF$        E) $KF$

12) Which one of the following pairs cannot be mixed together to form a buffer solution?    12) _E._
   A) KOH, HF
   B) $NaC_2H_3O_2$, HCl ($C_2H_3O_2^-$ = acetate)
   C) $NH_3$, $NH_4Cl$
   D) $H_3PO_4$, $KH_2PO_4$
   E) RbOH, HBr

*(handwritten: $CH_3COOH$ ⇌ $CH_3COO^- + H^+$)*

13) Which of the following could be added to a solution of acetic acid to prepare a buffer?    13) _A C_
   A) hydrochloric acid   *(+HCl ⟹ ↑H+)*
   B) more acetic acid
   C) sodium hydroxide   *(NaOH)*
   D) nitric acid   *(+HNO₃)*
   E) None of the above can be added to an acetic acid solution to prepare a buffer.

*(handwritten: Add ~½ the amt. of NaOH as the acetic acid. That makes Na-acetate or $CH_3CO_2^-$ ion around ~½ of acetic acid. So soln will now have acetic acid (½) & $CH_3CO_2$ (½) making buffer. $CH_3COO + H$)*

14) In which of the following aqueous solutions would you expect $PbCl_2$ to have the lowest solubility?    14) _D_
   A) 0.015 M NaCl
   B) 0.020 M $BaCl_2$
   C) pure water
   D) 0.015 M $PbNO_3$
   E) 0.020 M KCl

15) Which below best describe(s) the behavior of an amphoteric hydroxide in water?    15) _E_
    A) With conc. aq. HCl, its suspension dissolves.
    B) With conc. aq. HCl, its clear solution forms a precipitate.
    C) With conc. aq. NaOH, its clear solution forms a precipitate.
    D) With conc. aq. NaOH, its suspension dissolves.
    E) With both conc. aq. NaOH and conc. aq. HCl, its suspension dissolves.

16) A reversible process is one that _____.    16) _D_
    A) is spontaneous in both directions
    B) must be carried out at high temperature
    C) happens spontaneously
    D) can be reversed with no net change in either system or surroundings
    E) must be carried out at low temperature

17) Which one of the following is always positive when a spontaneous process occurs?    17) _D_
    A) $\Delta H_{universe}$
    B) $\Delta H_{surroundings}$
    C) $\Delta S_{system}$
    D) $\Delta S_{universe}$
    E) $\Delta S_{surroundings}$

4.19 kJ / mol.

18) The normal boiling point of $C_2Cl_3F_3$ is 47.6°C and its molar enthalpy of vaporization is 27.49    18) _B_
    kJ/mol. What is the change in entropy in the system in J/K when 28.6 grams of $C_2Cl_3F_3$ vaporizes
    to a gas at the normal boiling point?
    A) 4.19        B) 13.1        C) 27.5        D) - 4.19        E) - 13.1

19) Which one of the following processes produces a decrease in the entropy of the system?    19) _C_
    A) boiling water to form steam
    B) melting ice to form water
    C) freezing water to form ice
    D) dissolution of solid KCl in water
    E) mixing of two gases into one container

20) Of the following, the entropy of gaseous _____ is the largest at 25°C and 1 atm.    20) _B_
    A) $H_2$        B) $C_2H_6$        C) $CH_4$        D) $C_2H_4$        E) $C_2H_2$

21) The standard Gibbs free energy of formation of _____ is zero.    21) _D_ C

Elements in their natural state has φ free energy of formation

    (a) $H_2O$ (l)
    (b) O (g)
    (c) $H_2$ (g)

    A) (a) only
    B) (b) only
    C) (c) only
    D) (b) and (c)
    E) (a), (b), and (c)

22) For the reaction

$$C_2H_6 (g) \rightarrow C_2H_4 (g) + H_2 (g)$$

$\Delta H > 0 \quad \Delta S > 0$
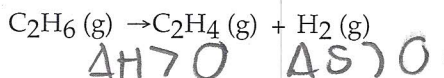
$\Delta H°$ is +137 kJ/mol and $\Delta S°$ is +120 J/K · mol. This reaction is _____.
A) spontaneous only at high temperature      B) spontaneous at all temperatures
C) spontaneous only at low temperature      D) nonspontaneous at all temperatures

22)  __A__

**TRUE/FALSE. Select A in the scantron if the statement is TRUE and B if the statement is FALSE (3 pts).**

23) $H^+$ is called the hydronium ion.   $H_3O^+$ is hydronium ion. Not $H^+$   ~~T~~ or (F)

24) A 100 mL sample of 4.0 M $H_2SO_4$ could be neutralized by 100 mL of 4.0 M $NH_3$.   T or (F)

$0.8[H^+]$                              $0.4$

25) A neutral solution does not contain any $H^+$ or $OH^-$.   T or (F)

26) The extent of ionization of a weak electrolyte is increased by adding to the solution a strong electrolyte   T or (F)
that has an ion in common with the weak electrolyte.   $\cap$

27) The solubility of slightly soluble salts containing basic anions is proportional to the pH of the solution.   T or (F)

28) The more negative $\Delta G°$ is for a given reaction, the larger the value of the corresponding equilibrium   (T) or F
constant, K.

$CH_3COOH \rightarrow CH_3COO^- + H^+$
$\leftarrow$
$COOH a.$

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