53−7=46 57 (103/110)

MC, Chem1B, Sp15, Lec Exam3

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 = 53 + (19x3=)57 = 110).

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) 0.25g of a monobasic acid (MW = 122 g/mol) in 100.00 mL of water is being titrated with 0.15M NaOH solution. What is the pH of the solution at the equivalence point? (K_a of the acid = 6.4 x 10^{-5}) (8 pts.) 1) ____________

moles of monobasic acid (HA) = 0.25g / 122g/mol = 2.049×10^{-3} mol in 100ml H_2O

Vol^m of 0.15M NaOH needed to neutralize the acid = 2.049×10^{-3} / 0.15 mol/L = 0.0137 L

M of monobasic acid (HA) = 2.049×10^{-3} mol / 0.1 L = 0.02049 M monobasic (HA)

Total final Vol^m = 0.1 + .0137 = 0.1137 L ; ~~Acid produced~~ Salt on neutralization. $K_b = \frac{10^{-14}}{K_a} = \frac{10^{-14}}{6.4 \times 10^{-5}}$

Conc. of salt = 2.049×10^{-3} / 0.1137 = 0.018 M

A + eq. pt = [HA] = [NaOH] 0.15M NaOH solution

100ml NaOH [A⁻] = 2.049×10^{-3} mol / total vol^m = $\frac{2.049 \times 10^{-3}}{(100+100) \times 10^{-3} L}$ = 0.01025M

$K_b = 1.56 \times 10^{-10}$

−1 At equivalence pt. = All HA is reacted with NaOH and A⁻ remaining react with H_2O

$K_a \times 10^2 < [HA]$; x ignored

$$A^- + H_2O \rightleftharpoons HA + OH^-$$

	A^-		HA	OH^-
I	~~0.01025~~ .018		0	0
C	$-x$		$+x$	$+x$
E	~~0.01025~~ .018 $-x$		x	x

−2

$K_b = \frac{[HA][OH^-]}{[A^-]}$ ✓

$1.56 \times 10^{-10} = \frac{x^2}{~~0.01025~~ .018 - x}$

∴ $[OH^-] = \sqrt{(1.56 \times 10^{-10})(~~0.01025~~ .018)}$

$= \sqrt{0.01599 \times 10^{-10}}$ = ~~1.265×10^{-6}~~ = 1.67×10^{-6}

pOH = ~~5.89~~ = 5.77

pH = ~~8.11~~ = 8.23

2) A nonlinear best fit plot of Keq versus Temperature (Kelvin) of tetraborate equilibrium: 2) ____________

$Na_2B_4O_5(OH)_4 \bullet 8H_2O(s) \rightarrow 2\,Na^+(aq) + B_4O_5(OH)_4^{2-}(aq) + 8\,H_2O(l)$

gives ΔH° = 96 kJ/mol and ΔS° = 300 J/mol. From this data calculate the K_{eq} at 25° C. Show set up, raw data and units. (8 pts.)

ΔH = 96KJ/mol

ΔS° = 300 J/mol

T = 25°C = 298 K

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

$= 96 \times 1000 \frac{J}{mol} - (298)(300\ J/mol)$

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

$\Delta G^\circ = 66{,}00$ J/mol = 6.6 KJ/mol

0.15623 1.599×10^{-12}

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

6600 J/mol = $-(8.3145 \frac{J}{mol}) \times 298K \ln K_{eq}$

$K_{eq} = e^{-2.6637}$

$K_{eq} = e^{\frac{-\Delta G^\circ}{RT}}$

$= e^{-\frac{6600}{8.3145 \times 298}}$

∴ $K_{eq} = 0.0697$ ✓

3) The following information is available for the reaction at 25°C: 3) _____

$CaCO_3$ (s) ----> CaO (s) + CO_2 (g)

$\Delta G_f°$ (kJ/mol)	-1129.16	-603.42	-394.36
$\Delta H_f°$ (kJ/mol)	-1207.6	-635.09	-393.51
$S_f°$ (J/K.mol)	91.7	38.2	213.74

(a) Calculate the Gibbs free energy change of the reaction (3pts.) .

$\Delta G°_f = \Sigma n.\Delta G°_{(products)} - \Sigma n.\Delta G°_{(Reactants)}$

$= \Delta G°_{(CO_2)} + \Delta G°_{CaO} - \Delta G°_{CaCO_3}$

$= -394.36 - 603.42 - (-1129.16) = +131.38$ KJ/mol ✓

(b) Calculate the temperature in °C when the reaction will be favorable (5 pts.).

$\Delta G° = 0$ then $T = \frac{\Delta H°}{\Delta S°}$

$\Delta H°_{rxn} = \Delta H°_{CO_2} + \Delta H°_{CaO} - \Delta H°_{CaCO_3}$

$= -393.51 - 653.09 + 1207.6$

$\Delta H°_{rxn} = +179$ KJ/mol

$\Delta S° = \Delta S°_{CO_2} + \Delta S°_{CaO} - \Delta S°_{CaCO_3}$

$= 213.74 + 38.2 - 91.7$

$\Delta S° = +160.24$ J/mol.K

$\therefore T = \frac{179 \text{ KJ/mol}}{+160.24 \text{ J/mol.K}}$

$= \frac{179 \times 1000}{160.24}$ K

$T = 1117$ K ✓ $\therefore$ $T = 844°C$ ✓

@ At T=844°C Rxn will be favorable

4) For the cell reaction : 4) _____

$3\ Ni^{2+}(aq) + 2\ Cr(OH)_3(s) + 10\ OH^-(aq) \text{ ---> } 3\ Ni(s) + 2\ CrO_4^{2-}(aq) + 8\ H_2O(l)$;

Given: $CrO_4^{2-}(aq) + 4\ H_2O(l) + 3\ e^- \text{ ---> } Cr(OH)_3(s) + 5\ OH^-(aq)$ $E^0_{red} = -0.13$ V;

$Ni^{2+}(aq) + 2e^- \text{ ---> } Ni(s)$ $E^0_{red} = -0.28$ V;

(a) Calculate the E^0 at T = 298 K (4 pts.)

$E°_{cell} = E°_{(cathode)} - E°_{(anode)} = -0.28 - (-0.13) = E°_{cell} = -0.15$ V @ 298 K

$= E°_{(Ni^{2+} \to Ni)} - E°_{(CrO_4^{2-} \to Cr(OH)_3)}$

$= -0.28 + 0.13$ V

$= -0.15$ V ✓

(b) Calculate the standard free energy change ΔG^0 at T = 298 K for the above reaction (5 pts.);

Anode :- $Cr^{+3} \longrightarrow CrO_4^{2-} + 3e^- \times 2$

Cathode :- $Ni^{2+} + 2e^- \to Ni \times 2$

$\Delta G° = -nF\Delta E°_{cell}$

$= +6 \times 96485 \frac{C}{\text{mole}} \times (+0.15 V)$

$= 86836.5$ J/mol

$\Delta G° = +86.837$ KJ/mol ✓

5) The following reaction occurs spontaneously. 5) _____

$Cu^{2+}(aq) + Fe(s) \rightarrow Fe^{3+}(aq) + Cu(s)$

Write the balanced **reduction** half-reaction below. (3 pts.)

$0.N = Cu^{2+} \rightarrow Cu^{0}$ ∴

Cathode (Reduction) :- $Cu^{2+}_{(aq)} + 2e^- \longrightarrow Cu_{(s)}$ ×3

Anode (oxidation) :- $Fe_{(s)} \longrightarrow Fe^{3+}_{(aq)} + 3e^-$ ×2

Red^n half Rxn :- $Cu^{2+}_{(aq)} + 2e^- \longrightarrow Cu_{(s)}$ ✓

$3Cu^{2+} + 2Fe_{(s)} \longrightarrow 3Cu_{(s)} + 2Fe^{3+}_{(aq)}$ ← cell Reaction

6) A Voltaic cell is made up of two half cells at 298 K: Zn/Zn^{2+} half cell with $[Zn^{2+}] = 0.010$ M and H_2/H^+ half cell with $[H^+] = 2.5$ M and $P_{H2} = 0.30$ atm. Given E^0_{red} for $Zn^{2+} + 2e^- \rightarrow Zn(s) = -$[illegible] V; (Total = 14 pts.) 6) _____

-0.76

(1) Determine the cell reaction (with states) from the half cell reactions (2 pts.)

cell Rxn :- $\longrightarrow Zn_{(s)} + 2H^+_{(aq,1M)} \rightarrow Zn^{2+}_{(aq)} + H_{2(g,\,1atm)}$ ✓

Anode :- $Zn_{(s)} \longrightarrow Zn^{2+}_{(aq)} + 2e^-$

cathode :- $2H^+_{(aq)} + 2e^- \rightarrow H_{2(g)}$

(2) Calculate the E^0_{cell} (2 pts.)

$E^\circ_{cell} = E^\circ_{(cathode)} - E^\circ_{(anode)}$

$= E^\circ_{(2H^+ \rightarrow H_2)} - E^\circ_{(Zn^{2+} \rightarrow Zn)}$

$= 0 - (-0.76)V$ ✓

$\therefore E^\circ_{cell} = +0.76V$

(3) Calculate the molarity of H_2 (g) given PV = n RT (3 pts.)

Molarity of $H_{2(g)} = \frac{n}{V} = \frac{P}{RT} = \frac{0.30\,atm}{0.082\,atm/mol.K \times 298} = 0.01228\ M$

(4) Calculate the Quotient Q for the cell reaction (3 pts.)

$Q = \frac{[Zn^{2+}] \times [H_2]}{[H^+]^2} = \frac{0.010\,M}{(0.01228)^2} = 66.3137$

$= \frac{(.01)(.01228)}{(2.5)^2} = 1.96 \times 10^{-5}$

−3

(5) Using the above values calculate the E_{cell} using Nersnt Eqn. (4 pts.)

$E_{cell} = E^\circ_{cell} - \frac{0.0259}{n} \ln Q$

$= 0.76 - \frac{0.0259}{2} \ln 66.3137 \quad 1.96 \times 10^{-5}$

$= 0.76 - 0.01295 (-10.84)$

$= 0.90V$

$\therefore E_{cell} = 0.7057\ V = 0.90V$

−1

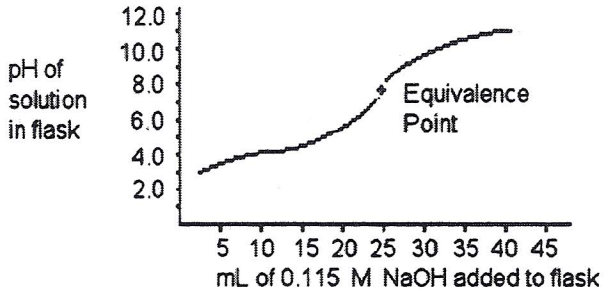
7) In the formula $\Delta G = -nFE$, F is the _____. (3 pts.) 7) _____

In Formula $\Delta G = -nFE$

F = Faraday's constant ✓

$F = 96485 \frac{Coulomb}{mol.\ electron}$

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



8) A 25.0 mL sample of a solution of an unknown compound is titrated with a 0.115 M NaOH solution. The titration curve above was obtained. The unknown compound is _____. 8) A

A) a weak acid
B) a strong base
C) a strong acid
D) a weak base
E) neither an acid nor a base

9) For which salt should the aqueous solubility be most sensitive to pH? 9) C

A) $Ca(NO_3)_2$ B) CaI_2 C) CaF_2 D) $CaBr_2$ E) $CaCl_2$

10) What is the oxidation number of nitrogen in the HNO_3? $+1+N-6 = -5+N = 0 \quad \therefore N=+5$ 10) C

A) +1 B) +7 C) +3 D) +5 E) -1

11) Which transformation could take place at the anode of an electrochemical cell? 11) E

A) O_2 to H_2O $0 \rightarrow -2$
B) $Cr_2O_7^{2-} \rightarrow Cr^{2+}$
C) $HAsO_2$ to As
D) F_2 to F^-
E) None of the above could take place at the anode.

12) Which transformation could take place at the cathode of an electrochemical cell? 12) D

Red'n

A) $Mn^{2+} \rightarrow MnO_4^-$ oxid'n
B) $MnO_2 \rightarrow MnO_4^-$ oxid'n
C) $Br_2 \rightarrow BrO_3^-$ oxid'n
D) $HSO_4^- \rightarrow H_2SO_3$
E) $NO \rightarrow HNO_2$ (+2 → +3)

Table 20.2

Half-reaction	E° (V)
$Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$	-0.74
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	-0.440
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(s)$	+0.771
$Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$	+0.154

13) Which of the following reactions will occur spontaneously as written? 13) A

A) $3Sn^{4+}(aq) + 2Cr(s) \rightarrow 2Cr^{3+}(aq) + 3Sn^{2+}(aq)$

B) $3Fe(s) + 2Cr^{3+}(aq) \rightarrow 2Cr(s) + 3Fe^{2+}(aq)$

C) $3Fe^{2+}(aq) \rightarrow Fe(s) + 2Fe^{3+}(aq)$

D) $Sn^{4+}(aq) + Fe^{3+}(aq) \rightarrow Sn^{2+}(aq) + Fe^{2+}(aq)$

E) $Sn^{4+}(aq) + Fe^{2+}(aq) \rightarrow Sn^{2+}(aq) + Fe(s)$

14) The standard cell potential ($E°_{cell}$) for the voltaic cell based on the reaction below is _____ V. 14) B

$$Sn^{2+}(aq) + 2Fe^{3+}(aq) \rightarrow 2Fe^{2+}(aq) + Sn^{4+}(aq)$$

A) +1.21 B) +0.617 C) +0.46 D) +1.39 E) -0.46

15) The reduction half reaction occurring in the standard hydrogen electrode is _____. 15) D

A) $H_2(g, 1\ atm) \rightarrow 2H^+(aq, 1M) + 2e^-$

B) $2H^+(aq) + 2OH^- \rightarrow H_2O(l)$

C) $2H^+(aq, 1M) + Cl_2(aq) \rightarrow 2HCl(aq)$

D) $2H^+(aq, 1M) + 2e^- \rightarrow H_2(g, 1\ atm)$

E) $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$

16) The standard cell potential ($E°_{cell}$) for the reaction below is +1.10 V. The cell potential for this reaction is _____ V when the concentration of $[Cu^{2+}] = 1.0 \times 10^{-5}$ M and $[Zn^{2+}] = 1.0$ M. 16) A

$$Zn(s) + Cu^{2+}(aq) \rightarrow Cu(s) + Zn^{2+}(aq)$$

A) 0.95 B) 0.80 C) 1.25 D) 1.10 E) 1.40

17) The thermodynamic quantity that expresses the degree of disorder in a system is _____. 17) B

A) bond energy
B) entropy
C) internal energy
D) enthalpy
E) heat flow

18) The normal boiling point of water is 100.0°C and its molar enthalpy of vaporization is 40.67 kJ/mol. What is the change in entropy in the system in J/K when 39.3 grams of steam at 1 atm condenses to a liquid at the normal boiling point? 18) E

A) 373 B) 88.8 C) -40.7 D) -88.8 E) -238

19) ΔS is positive for the reaction _____. 19) C

A) $2NO_2(g) \rightarrow N_2O_4(g)$ (−)

B) $2Hg(l) + O_2(g) \rightarrow 2HgO(s)$ (−)

C) $BaF_2(s) \rightarrow Ba^{2+}(aq) + 2F^-(aq)$ (+)

D) $CO_2(g) \rightarrow CO_2(s)$ (−)

E) $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ (−)

20) Of the following, the entropy of _____ is the largest. 20) E

A) HCl (s) B) HCl (g) C) HCl (l) D) HBr (g) E) HI (g)

Highest m.w in gas

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

21) The quantity of energy gained by a system equals the quantity of energy gained by its surroundings. T or F

lost

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

$\Delta G^\circ < 0$, $K > 0$

23) The vaporization of a substance at its boiling point is an isothermal process T or F

24) The entropy of a pure crystalline substance at 0°C is zero. T or F

ok

25) The electrode where reduction occurs is called the anode. T or F

cathode

26) The standard reduction potential of X is 1.23 V and that of Y is -0.44 V therefore X is oxidized by Y. T or F

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

27) **EXTRA POINT QUESTION:** 27) E

In which one of the following solutions is silver chloride the most soluble?

A) 0.181 M HCl

B) 0.181 M NaCl

C) 0.744 M $LiNO_3$

D) pure water

E) 0.0176 M NH_3