KEY

MC, Chem1B, Fall15, Test3

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 = 56 + (18x3=)54 = 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) Benzoic acid is a monoprotic acid. A student dissolves 0.25g of benzoic acid ($C_6H_5CO_2H$) in 100.00 mL of water. The student titrates the benzoic acid solution with 0.15M NaOH solution. What is the pH of the solution at the equivalence point? (K_a = 6.4 x 10^{-5}) (10 pts.)

1) 8.23

moles of monoprotic acid = $\frac{0.25\,g}{122\,g/mol}$ = 2.049×10^{-3} mol in 100 mL H_2O

Volume of 0.15 M NaOH needed to neutralize the acid = $\frac{2.049\times10^{-3}\,mol}{0.15\,mol/L}$ = 0.0137 L

M of monoprotic acid = $\frac{2.049\times10^{-3}}{0.1\,L}$ = 0.02049 (HA)

Total volume = 0.1 + 0.0137 = 0.1137 L

Concn of salt = $\frac{2.049\times10^{-3}}{0.1137}$ = 0.018 M

100 mL NaOH [A] = $\frac{2.049\times10^{-3}\,mol}{(100+100)\times10^{-3}\,L}$ = 0.01025 M

All HA is reacted with NaOH & remaining A^- reacted with H_2O

	A^-	+ H_2O ⇌	HA	+ OH^-
I	0.018		0	0
C	−x		+x	+x
E	0.018 − x		x	x

$K_b = \frac{[HA][OH]}{[A^-]}$

$1.56\times10^{-10} = \frac{x^2}{0.018}$

$K_b = \frac{10^{-14}}{K_a} = \frac{10^{-14}}{6.4\times10^{-5}}$

$[OH^-] = \sqrt{1.56\times10^{-10}\times0.018}$

$= 1.67\times10^{-6}$

⇒ pOH = 5.77

pH = 8.23

2) The K_{sp} for $Zn(OH)_2$ is 5.0 x 10^{-17}. Determine the molar solubility of $Zn(OH)_2$ in a buffer solution with a pH of 11.5 (6 pts.).

2) 4.9×10^{-12} M

pOH = 14 − 11.5 = 2.5

$[OH^-] = 10^{-(2.5)}$ = 0.0032 M

$K_{sp} = [Zn^{2+}][OH^-]^2$

$[OH^-] = 2x + 0.0032$

$5.0\times10^{-17} = x(2x + 0.0032)^2$

$x = 4.9\times10^{-12}$ M

molar solubility = 3

1 KJ = 1000 J

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

$\Delta G^\circ =$ 3) 131.24 KJ/mol

	$CaCO_3$ (s) ---->	CaO (s) +	CO_2 (g)
ΔG_f° (kJ/mol)	-1129.16	-603.42	-394.36
ΔH_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.) .

$\Delta H^\circ = \Sigma n H^\circ_{f(products)} - \Sigma n H^\circ_{f(reactants)} = 1mol(-393.51) + 1mol(-635.09) + 1129.16$

$= 179\ KJ = +179000\ J$

$\Delta S^\circ = \Sigma n S^\circ_{f(p)} - \Sigma n S^\circ_{f(r)} = 213.74 + 38.2 - 91.7 = 160.2\ KJ = 160200\ J$

$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ = 179000J - (298K)(160.2KJ) = 131248\ J/mol = 131.24\ KJ/mol$ ✓

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

$\Delta G^\circ = \Delta H - T\Delta S^\circ$ it's favorable when ΔG° = negative

$T = \frac{\Delta H}{\Delta S^\circ} = \frac{179\ KJ}{160.24\ KJ/K.mol} \times 1000$

$= 1117.07\ K$

$= 844.07^\circ C$ ✓

favorable when > than 844.07 °C

4) A nonlinear best fit plot of Keq versus Temperature (Kelvin) of tetraborate equlilibrium: 4) 0.0697

$Na_2B_4O_5(OH)_4 \cdot 8H_2O(s) <---> 2\ Na^+(aq) + B_4O_5(OH)_4^{2-}(aq) + 8\ H_2O(l)$

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.)

$\Delta H = 96\ KJ/mol \quad \Delta S^\circ = 300\ J/mol \quad K_{eq}$ at 25°C

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

$= 96\ KJ/mol \times 1000\ J - 298(300\ J/mol)$

$\Delta G^\circ = 96000 - 89400\ J/mol$

$= 6600\ J/mol = 6.6\ KJ/mol$

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

$6600\ J/mol = (8.3145\ J/mol) \times 298\ K \ln K$

$K_{eq} = e^{(-\Delta G^\circ/RT)} = e^{\left(\frac{-6600\ J/mol}{8.3145(298)}\right)} = 0.0697$ ✓

5) Given $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$ $E_{red}^0 = +1.23$ V

$Ag^+(aq) + e^- \rightarrow Ag(s)$ $E_{red}^0 = +0.80$ V

5) _____

For redox reaction: $4Ag(s) + O_2(g) + 4H^+(aq) \rightarrow 4Ag^+(aq) + 2H_2O(l)$

(i) Write the cathode reaction (2 pts.):

$O_{2(g)} + 4H^+_{(aq)} + 4e^- \rightarrow 2H_2O_{(l)}$ ✓

(ii) Write the anode reaction (2 pts.):

$4Ag_{(s)} \rightarrow 4Ag^+ + 4e^-$ ✓

iii) Show set up and all your work to calculate the standard free energy change for the reaction at 25°C (4 pts.)

$O_{2(g)} + 4H^+_{(aq)} + 4e^- \rightarrow 2H_2O_{(l)}$

$4Ag_{(s)} \rightarrow 4Ag^+_{(aq)} + 4e^-$ ✓

$E^\circ_{cell} = 1.23V - 0.80V = 0.43V$

$\Delta G^\circ = -nFE^\circ = -(4)(96,480\ J/V\,mol)(+0.43V)$

$= -166\ kJ/mol$ ✓

(iv) Show set up and all your work to calculate the equilibrium constant for the reaction at 25°C (8 pts.)

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~~$\Delta G^\circ = -(2)(96,480\ J/V\,mol)(+0.43V) = -83kJ/mol$~~ ?

$\Delta G^\circ = -RT\ln K$ or $K = e^{\frac{-\Delta G^\circ}{RT}} = e^{\frac{-(-166\ kJ)\times\frac{1000J}{1kJ}}{8.31\frac{J}{K\cdot mol}\times 298K}}$

or $K = e^{+\frac{166000}{2476.38}}$ or $K = 1.27\times10^{+29}$

6) How many seconds are required to produce 4.00 g of aluminum metal from the electrolysis of molten $AlCl_3$ with an electrical current of 12.0 A? Show set up and all your work. (8 pts.)

6) 3.577×10^3 s

$n_{Al} = \frac{4.00\ g}{26.98\ g/mol} = 0.1483\ mol$ ✓

$Al^{3+} + 3e^- \rightarrow Al_{(s)}$

$n_{e^-} = 3n_{Al} = 3\times0.1483\ mol = 0.4449\ mol$ ✓

$C = 0.4449\ mol \times 96485\ C/mol$

$= 4.293\times10^4\ C$

$I = Q/t = \frac{4.293\times10^4\ C}{t} = 12.0\ A$

$t = 3.577\times10^3\ s$ ✓

MULTIPLE CHOICE. Show your work to select the one response that best completes the statement or answers the question (3 pts each).

7) In which of the following aqueous solutions would you expect $PbCl_2$ to have the lowest solubility? 7) ~~D~~ B

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

8) Which below best describe(s) the behavior of an amphoteric hydroxide in water? 8) ~~A~~ 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.

9) What is the oxidation number of sulfur in the HSO_4^- ion? 9) C

A) +2 B) +4 C) +6 D) +1 E) -2

10) Which transformation could take place at the anode of an electrochemical cell? 10) ~~C~~ D

A) $O_2 \rightarrow H_2O_2$
B) $H_2AsO_4 \rightarrow H_3AsO_3$
C) $VO_2^+ \rightarrow VO^{2+}$
D) $NO \rightarrow NO_3^-$
E) $CO_2 \rightarrow C_2O_4^{2-}$

11) Which transformation could take place at the cathode of an electrochemical cell? 11) ~~A~~ D

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

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

12) Which of the following reactions will occur spontaneously as written? 12) 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) $Sn^{4+}(aq) + Fe^{2+}(aq) \rightarrow Sn^{2+}(aq) + Fe(s)$

13) The standard cell potential ($E°_{cell}$) for the voltaic cell based on the reaction below is _____ V. 13) 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

14) The reduction half reaction occurring in the standard hydrogen electrode is _____. 14) 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) $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$

15) 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. 15) 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

16) The thermodynamic quantity that expresses the degree of disorder in a system is _____. 16) B

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

17) 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? 17) E

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

18) ΔS is positive for the reaction _____. 18) 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) $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$

19) Of the following, the entropy of _____ is the largest. 19) E

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

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

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

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

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

23) The standard reduction potential, $E°_{red}$, is proportional to the stoichiometric coefficient. T or F

24) 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. Show your work to select the one response that best completes the statement or answers the question (3 pts each).

25) **EXTRA POINT QUESTION** The standard Gibbs free energy of formation of _____ is zero. 25) D

(a) $H_2O(l)$
(b) $Na(s)$
(c) $H_2(g)$

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