

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? ($K_a = 6.4 \times 10^{-5}$) (10 pts.)

1) 8.23

mole of monoprotic acid = $\frac{0.25g}{122g/mol} = 2.049 \times 10^{-3} \text{ mol}$ in 100ml H_2O

Volume of 0.15M NaOH needed to neutralize the acid = $\frac{2.049 \times 10^{-3} \text{ mol}}{0.15 \text{ mol/L}} = 0.0137 \text{ L}$

M of monoprotic acid = $\frac{2.049 \times 10^{-3}}{0.11} = 0.02049 \text{ (HA)}$

Total volume = $0.1 + 0.0137 = 0.1137 \text{ L}$

Conc of salt = $\frac{2.049 \times 10^{-3}}{0.1137} = 0.018 \text{ M}$

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

All HA is reacted with NaOH & remaining A⁻ reacted with H₂O

	$A^- + H_2O \rightleftharpoons HA + OH^-$		
I	0.018	0	0
C	-x	+x	+x
E	0.018 - x	x	x

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

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

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

$[OH^-] = \sqrt{1.56 \times 10^{-10} \times 0.018}$

$= 1.67 \times 10^{-6}$

$\Rightarrow pOH = 5.77$

$pH = 8.23$

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

2) $4.9 \times 10^{-12} \text{ M}$

$pOH = 14 - 11.5 = 2.5$

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

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

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

$5.0 \times 10^{-17} = x(2x + 0.0032)^2$

$x = 4.9 \times 10^{-12} \text{ M}$

molar solubility \rightarrow ✓

105-1000 J

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

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

	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.).

$$\Delta H^\circ = \sum \Delta H_f^\circ(\text{products}) - \sum \Delta H_f^\circ(\text{reactants}) = 1\text{mol}(-393.51) + 1\text{mol}(-635.09) + 1129.16$$

$$= 179\text{ kJ} = 179000\text{ J}$$

$$\Delta S^\circ = \sum \Delta S_f^\circ(\text{products}) - \sum \Delta S_f^\circ(\text{reactants}) = 213.74 + 38.2 - 91.7 = 160.2\text{ kJ} = 160200\text{ J}$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ = 179000\text{ J} - (298\text{ K})(160200\text{ J}) = 131248\text{ J/mol} = \underline{131.24\text{ kJ/mol}}$$

(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 $\Delta G^\circ = \text{negative}$

$$T = \frac{\Delta H}{\Delta S} = \frac{179\text{ kJ} \times 1000}{160.24\text{ kJ/K.mol}}$$

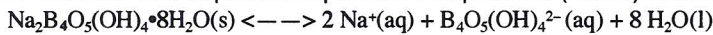
$$= 1117.07\text{ K}$$

$$= 844.07^\circ\text{C}$$

favorable when > than 844.07°C

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

4) 0.0697



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

Show set up, raw data and units. (8 pts.)

$$\Delta H = 96\text{ kJ/mol} \quad \Delta S^\circ = 300\text{ J/mol} \quad \text{Keq at } 25^\circ\text{C}$$

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

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

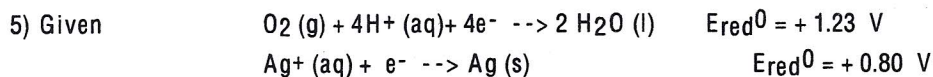
$$\Delta G^\circ = 96000 - 89400\text{ J/mol}$$

$$= 6600\text{ J/mol} = 6.6\text{ kJ/mol}$$

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

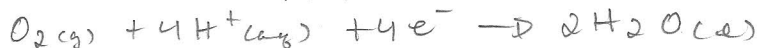
$$6600\text{ J/mol} = (8.3145\text{ J/mol}) \times 298\text{ K} \ln K$$

$$\text{Keq} = e^{(-\Delta G^\circ/RT)} = e^{(-\frac{6600\text{ J/mol}}{8.3145(298)})} = \underline{0.0697}$$

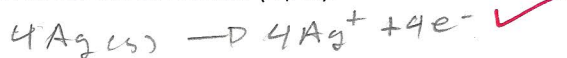


For redox reaction: $4Ag(s) + O_2(g) + 4H^+(aq) \rightarrow 4Ag^+(aq) + 2H_2O(l)$

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



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



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

$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$
 $4Ag(s) \rightarrow 4Ag^+(aq) + 4e^-$
 $E_{cell}^0 = 1.23V - 0.80V = 0.43V$ ✓
 $\Delta G^0 = -nFE^0 = -(4)(96,480 J/V mol)(+0.43V)$
 $-166 kJ/mol$ ✓

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

-7

$\Delta G^0 = -RT \ln K$ or $K = e^{\frac{-\Delta G^0}{RT}} = e^{\frac{-(-166 kJ) \times \frac{1000 J}{kJ}}{8.31 \frac{J}{K \cdot mol} \times 298K}}$
 $\Delta G^0 = - (4)(96,480 J/V mol)(+0.43V) = -166 kJ/mol$
 $K = 1.27 \times 10^{+29}$

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) $3.577 \times 10^3 s$

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



$n_{e^-} = 3n_{Al} = 3 \times 0.1483 mol = 0.4449 mol$ ✓

$Q = 0.4449 mol \times 96485 C/mol$
 $= 4.293 \times 10^4 C =$

$I = Q/t = \frac{4.293 \times 10^4 C}{t} = 12.0 A$

$t = 3.577 \times 10^3 s$ ✓

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) ~~A~~ 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) e
- A) +2
 - B) +4
 - C) +6
 - D) +1
 - E) -2
- 10) Which transformation could take place at the anode of an electrochemical cell? 10) ~~e~~ D
- A) $\text{O}_2 \rightarrow \text{H}_2\text{O}_2$
 - B) $\text{H}_2\text{AsO}_4 \rightarrow \text{H}_3\text{AsO}_3$
 - C) $\text{VO}_2^+ \rightarrow \text{VO}_2^+$
 - D) $\text{NO} \rightarrow \text{NO}_3^-$
 - E) $\text{CO}_2 \rightarrow \text{C}_2\text{O}_4^{2-}$
- 11) Which transformation could take place at the cathode of an electrochemical cell? 11) ~~A~~ D
- A) $\text{Mn}^{2+} \rightarrow \text{MnO}_4^-$
 - B) $\text{MnO}_2 \rightarrow \text{MnO}_4^-$
 - C) $\text{Br}_2 \rightarrow \text{BrO}_3^-$
 - D) $\text{HSO}_4^- \rightarrow \text{H}_2\text{SO}_3$
 - E) $\text{NO} \rightarrow \text{HNO}_2$

Table 20.2

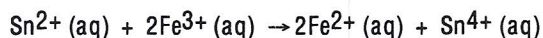
Half-reaction	E° (V)
$\text{Cr}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Cr}(\text{s})$	-0.74
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Fe}(\text{s})$	-0.440
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Fe}^{2+}(\text{s})$	+0.771
$\text{Sn}^{4+}(\text{aq}) + 2\text{e}^-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

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

12) A

- A) $3\text{Sn}^{4+}(\text{aq}) + 2\text{Cr}(\text{s}) \rightarrow 2\text{Cr}^{3+}(\text{aq}) + 3\text{Sn}^{2+}(\text{aq})$ ✓
 B) $3\text{Fe}(\text{s}) + 2\text{Cr}^{3+}(\text{aq}) \rightarrow 2\text{Cr}(\text{s}) + 3\text{Fe}^{2+}(\text{aq})$
 C) $3\text{Fe}^{2+}(\text{aq}) \rightarrow \text{Fe}(\text{s}) + 2\text{Fe}^{3+}(\text{aq})$
 D) $\text{Sn}^{4+}(\text{aq}) + \text{Fe}^{3+}(\text{aq}) \rightarrow \text{Sn}^{2+}(\text{aq}) + \text{Fe}^{2+}(\text{aq})$
 E) $\text{Sn}^{4+}(\text{aq}) + \text{Fe}^{2+}(\text{aq}) \rightarrow \text{Sn}^{2+}(\text{aq}) + \text{Fe}(\text{s})$

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

13) B

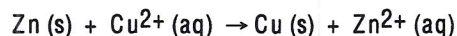
- A) +1.21 B) +0.617 C) +0.46 D) +1.39 E) -0.46

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

14) D

- A) $\text{H}_2(\text{g}, 1 \text{ atm}) \rightarrow 2\text{H}^+(\text{aq}, 1\text{M}) + 2\text{e}^-$
 B) $2\text{H}^+(\text{aq}) + 2\text{OH}^- \rightarrow \text{H}_2\text{O}(\text{l})$
 C) $2\text{H}^+(\text{aq}, 1\text{M}) + \text{Cl}_2(\text{aq}) \rightarrow 2\text{HCl}(\text{aq})$
 D) $2\text{H}^+(\text{aq}, 1\text{M}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g}, 1 \text{ atm})$ ✓
 E) $\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}(\text{l})$

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 $[\text{Cu}^{2+}] = 1.0 \times 10^{-5} \text{ M}$ and $[\text{Zn}^{2+}] = 1.0 \text{ M}$.

15) A

- 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 _____.

- A) $2\text{NO}_2(\text{g}) \rightarrow \text{N}_2\text{O}_4(\text{g})$
B) $2\text{Hg}(\text{l}) + \text{O}_2(\text{g}) \rightarrow 2\text{HgO}(\text{s})$
C) $\text{BaF}_2(\text{s}) \rightarrow \text{Ba}^{2+}(\text{aq}) + 2\text{F}^{-}(\text{aq})$
D) $\text{CO}_2(\text{g}) \rightarrow \text{CO}_2(\text{s})$
E) $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{g})$

18) C

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

- A) $\text{HCl}(\text{s})$ B) $\text{HCl}(\text{g})$ C) $\text{HCl}(\text{l})$ D) $\text{HBr}(\text{g})$ E) $\text{HI}(\text{g})$

19) E

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) $\text{H}_2\text{O}(\text{l})$

(b) $\text{Na}(\text{s})$

(c) $\text{H}_2(\text{g})$

A) (a) only

B) (b) only

C) (c) only

D) (b) and (c)

E) (a), (b), and (c)