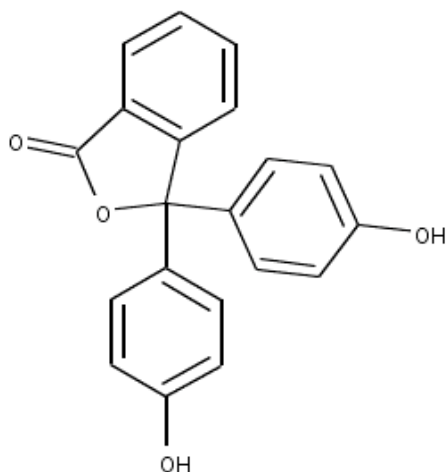


4. Indicator molecules.

Phenolphthalein:



- The structure above is that for phenolphthalein in its (a) colorless, or (b) pink form. Choose one.
- Circle the atom(s) in the structure above that take on negative charge in the other form of this indicator molecule.
- Box the atom in the structure above that undergoes a crucial hybridization change when the indicator molecule changes color.

5. Titration Curves and Buffer solutions.

- a. In the titration of a weak acid HA with the strong base NaOH, find an equation for $[A^-]$ in terms of K_a , $[HA]_{\text{init}}$, and $[H_3O^+]$. Hint: you will need to take into account mass balance and the expression for K_a .
- b. What is the charge balance equation for the system in part a ?
- c. The pH at the equivalence point for the titration in part a is (i) acidic, (ii) neutral, (iii) basic. Choose one.
- d. Estimate the initial pH of a buffer prepared with $[CH_3COOH]_{\text{init}} = 0.4 \times [CH_3COO^-]_{\text{init}}$

6. Electrochemistry.

a. The equation $\Delta G = -nFE$ is central to electrochemistry. Explain what is the physical significance of this equation. In other words, what does this equation mean?

b. Show how $\Delta G = -nFE$ can be used to derive the Nernst equation.

c. Set up but do not solve an equation for the cell potential for the cell $\text{Zn(s)}|\text{Zn}^{2+}(0.024\text{ M})||\text{Zn}^{2+}(2.4\text{ M})|\text{Zn(s)}$. What type of cell is this?

d. Consider the reaction $\text{Fe} + \text{Zn}^{2+} \rightarrow \text{Zn} + \text{Fe}^{2+}$.

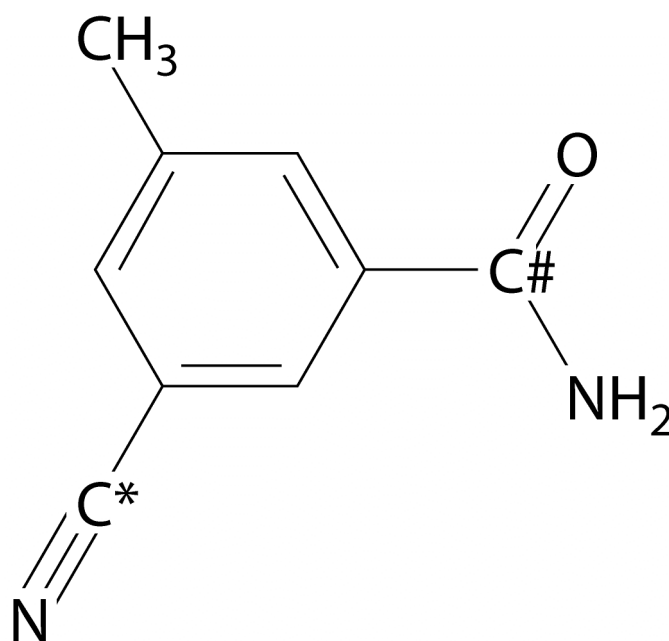
Given the following reduction potentials

Reduction Half-reaction	$^{\circ}E$
$\text{Fe}^{+2}(\text{aq}) + 2\text{e}^{-1} \rightarrow \text{Fe}(\text{s})$	-0.44 V
$\text{Zn}^{+2}(\text{aq}) + 2\text{e}^{-1} \rightarrow \text{Zn}(\text{s})$	-0.76 V

- What is the standard potential for this reaction?
- If a piece of iron is placed in a 1.0 M Zn^{2+} solution, what is the equilibrium concentration of Fe^{2+} ions?

7. VSEPR theory. Predict the shape (specified, for example, as “trigonal planar” for BH_3), and sketch the geometry of the following molecules:
- PCl_5
 - SO_3
 - $[\text{BF}_4]^-$
 - XeF_2

8. Valence bond theory.
- On the diagram below, indicate the hybridization of each carbon atom.
 - What is the % s character in each of the hybrids for the carbon atom that is marked by a *?
 - What is the % p character in each of the hybrids for the carbon atom that is marked by a #?
 - Draw an energy level diagram corresponding to the promotion and hybridization of the carbon atom marked by a *. Assume that the bonds to C* define the z axis, for purposes of labeling your diagram.



Useful Constants:

$R = 8.31451 \text{ J K}^{-1} \text{ mol}^{-1}$

$R = 0.08205 \text{ L atm K}^{-1} \text{ mol}^{-1}$

\mathcal{F} (Faraday's constant) = $96,485 \text{ C mol}^{-1}$

$c = 2.99792 \times 10^8 \text{ m s}^{-1}$

$h = 6.626076 \times 10^{-34} \text{ J s}$

$N_a = 6.022142 \times 10^{23}$

$1 \text{ L} = 10^{-3} \text{ m}^3$

$1 \text{ L atm} = 101.3253 \text{ J}$

$1 \text{ atm} = 1.013 \times 10^5 \text{ Pa}$

$1 \text{ amu} = 1.66 \times 10^{-27} \text{ kg}$

$K = 1.3807 \times 10^{-23} \text{ J K}^{-1}$

$k_w = 1.00 \times 10^{-14}$

$1 \text{ eV} = 1.602 \times 10^{-19} \text{ J}$

$1 \text{ amu} = 1.66 \times 10^{-27} \text{ kg}$

$R_H = 2.17869 \times 10^{-18} \text{ J}$

$R_H = 13.5983 \text{ eV}$

Electromagnetic Spectrum:

Violet = $4.00 \times 10^{-7} \text{ m}$

Green = $5.00 \times 10^{-7} \text{ m}$

Yellow = $6.00 \times 10^{-7} \text{ m}$

Red = $7.00 \times 10^{-7} \text{ m}$

$a_0 = 0.529 \times 10^{-10} \text{ m}$

$k = 1.3807 \times 10^{-23} \text{ J K}^{-1}$

Mass of electron

$= 9.109390 \times 10^{-31} \text{ kg}$

Charge on an e^-

$= 1.6021773 \times 10^{-19} \text{ C}$

$\epsilon_0 = 8.8541878 \times 10^{-12} \text{ C}^2 \text{ J}^{-1} \text{ m}^{-1}$

5.112 @ ESG Equation Sheet

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

$\Delta G = \Delta G^\circ + RT \ln Q$

$\Delta G = RT \ln \left(\frac{Q}{K} \right)$

$Q = I \cdot t$

$K_w = (K_a)(K_b)$

$= 1.00 \times 10^{-14}$

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

$\text{pK}_a = -\log[K_a]$

$\text{pH} \approx \text{pK}_a - \log \left(\frac{[\text{HA}]_0}{[\text{A}^-]_0} \right)$

$\Delta \mathcal{E}^\circ_{\text{net}} = \mathcal{E}^\circ_{\text{cell}} - \mathcal{E}^\circ_{\text{external}}$

$\Delta \mathcal{E}^\circ(\text{cell}) = \mathcal{E}^\circ(\text{cathode}) - \mathcal{E}^\circ(\text{anode})$

$\log K = \left(\frac{n}{0.0592 \text{ V}} \right) \Delta \mathcal{E}^\circ, \text{ at } 25^\circ \text{C}$

$\ln K = \left(\frac{n}{0.0257 \text{ V}} \right) \Delta \mathcal{E}^\circ, \text{ at } 25^\circ \text{C}$

$\Delta \mathcal{E}_{\text{cell}} = \mathcal{E}^\circ_{\text{cell}} - \left(\frac{RT}{n\mathcal{F}} \right) \ln Q$

$\Delta \text{pK} = \Delta \text{pK}_a(\text{HA}) - \Delta \text{pK}_a(\text{HB})$

Complete = $|\Delta \text{pK}| \geq 6$

$\Delta \mathcal{E}_{\text{cell}} = \mathcal{E}^\circ_{\text{cell}} - \left(\frac{0.0592 \text{ V}}{n} \right) \log Q$

$\mathcal{E}_3^\circ = \frac{[n_1 \mathcal{E}_1^\circ(\text{reduction}) - n_2 \mathcal{E}_2^\circ(\text{oxidation})]}{n_3}$

$\ln K = \left(\frac{n\mathcal{F}}{RT} \right) \Delta \mathcal{E}^\circ$

$n_3 \mathcal{E}_3^\circ = [n_1 \mathcal{E}_1^\circ + n_2 \mathcal{E}_2^\circ]$

$\Delta \mathcal{E}_{\text{cell}} = \mathcal{E}^\circ_{\text{cell}} - \left(\frac{0.0257 \text{ V}}{n} \right) \ln Q$
at 25°C

$\Delta G^\circ_{\text{cell}} = -(n)(\mathcal{F})\Delta \mathcal{E}^\circ_{\text{cell}}$

Acidity constants @ 25°C

Acid	K_a	pK_a
Hydrofluoric acid, HF	3.5×10^{-4}	3.45
Formic acid, HCOOH	1.8×10^{-4}	3.75
Acetic Acid, CH_3COOH	1.8×10^{-5}	4.75
Hypochlorous acid, HOCl	3.0×10^{-8}	7.53
Hypoiodous acid, HOI	2.3×10^{-11}	10.64