Recitation Worksheet (Optional Extra Practice)

Name: Key

UGA ID:

Textbook:

Chemistry & Chemical Reactivity
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Instructions:

- This recitation worksheet is optional extra practice for Ch. 2.7-2.8, 3.1-3.3.
- You **do not** need to submit it to Gradescope.
- The answer key has been posted with this worksheet to eLC.
- A periodic table and formula sheet are attached to the end of this worksheet.

1. Report the molar masses of the elements and compounds below. Report your answers in **standard notation** and **five significant figures**.

I. Elemental bromine: $\boxed{159.80}$ g/mol

Br_2

II. Copper(II) sulfate: $\boxed{159.62}$ g/mol

$CuSO_4$

III. Copper(II) sulfate pentahydrate: $\boxed{249.72}$ g/mol

$CuSO_4 \cdot 5H_2O$

2. Consider samples of three different hypothetical elements. Which of the following would you predict contain the largest number of atoms? The order of increasing atomic masses for the three elements is provided below.

Element A < Element X < Element Z

$\boxed{A}$

A. 5.00 grams of element A
B. 5.00 grams of element X
C. 5.00 grams of element Z
D. They all have the same number of atoms
E. More information is needed (i.e. the exact atomic masses of each element)

3. How many moles are present in a 10.50 g sample of ZrO_2? How many atoms? Report your answers in **scientific notation**.

I. Number of moles:

$\boxed{8.521} \times 10^{\boxed{-2}}$ moles

II. Number of atoms:

$\boxed{1.539} \times 10^{\boxed{23}}$ atoms

$10.50\ g\ ZrO_2 \times \left(\frac{mol}{123.22\ g}\ ZrO_2 \right) = 0.0852\underline{1}34\ mol$

$0.0852\underline{1}34\ mol\ ZrO_2 \times \left(\frac{6.022e23\ molecules}{1\ mol\ ZrO_2} \right) \times \left(\frac{3\ atoms}{1\ molecule} \right)$

4. Consider a 15.00 gram sample of barium phosphide. How many cations are present? How many anions? Report your answers in **scientific notation**.

I. Number of cations:

$Ba_3P_2 \rightarrow 473.93$ g/mol

$\boxed{5.718} \times 10^{\boxed{22}}$ cations

II. Number of anions:

$\boxed{3.812} \times 10^{\boxed{22}}$ anions

$$15.00 \text{ g } Ba_3P_2 \times \left(\frac{\text{mol } Ba_3P_2}{473.93 \text{ g}}\right) \times \left(\frac{6.022e23 \text{ molecules}}{1 \text{ mol } Ba_3P_2}\right) \times \left(\frac{3 \text{ cations}}{1 \text{ molecule}}\right)$$

$$15.00 \text{ g } Ba_3P_2 \times \left(\frac{\text{mol } Ba_3P_2}{473.93 \text{ g}}\right) \times \left(\frac{6.022e23 \text{ molecules}}{1 \text{ mol } Ba_3P_2}\right) \times \left(\frac{2 \text{ anions}}{1 \text{ molecule}}\right)$$

5. Consider a sample of $C_3H_8O_3$ that has a mass of 20.00 grams. How many molecules are present? How many total atoms? How many carbon atoms? Hydrogen atoms? Oxygen atoms? Report your answers in **scientific notation**.

I. Number of molecules: work on next page

$\boxed{1.308} \times 10^{\boxed{23}}$ molecules

II. Number of total atoms:

$\boxed{1.831} \times 10^{\boxed{24}}$ total atoms

III. Number of carbon atoms:

$\boxed{3.923} \times 10^{\boxed{23}}$ carbon atoms

IV. Number of hydrogen atoms:

$\boxed{1.046} \times 10^{\boxed{24}}$ hydrogen atoms

V. Number of oxygen atoms:

$\boxed{3.923} \times 10^{\boxed{23}}$ oxygen atoms

$C_3H_8O_3 \rightarrow MM = 92.11\ g/mol$

I. $20.00\ g\ C_3H_8O_3 \times \left(\frac{mol}{92.11\ g}\right) \times \left(\frac{6.022e23\ molecules}{1\ mol}\right)$

$= 1.30\underline{\underline{7}}567 \times 10^{23}$ molecules

II. $1.30\underline{\underline{7}}567 \times 10^{23}$ molecules $\times \left(\frac{14\ \text{total atoms}}{1\ \text{molecule}}\right)$

$= 1.83\underline{\underline{0}}594 \times 10^{24}$ total atoms

III. $1.30\underline{\underline{7}}567 \times 10^{23}$ molecules $\times \left(\frac{3\ C\ \text{atoms}}{1\ \text{molecule}}\right)$

$= 3.92\underline{\underline{2}}701 \times 10^{23}$ C atoms

IV. $1.30\underline{\underline{7}}567 \times 10^{23}$ molecules $\times \left(\frac{8\ H\ \text{atoms}}{1\ \text{molecule}}\right)$

$= 1.046054 \times 10^{24}$ H atoms

V. $1.30\underline{\underline{7}}567 \times 10^{23}$ molecules $\times \left(\frac{3\ O\ \text{atoms}}{1\ \text{molecule}}\right)$

$= 3.92\underline{\underline{2}}701 \times 10^{23}$ O atoms

$3.680e23$ molecules $\times \left(\frac{1 \text{ mol}}{6.022e23 \text{ molecules}} \right) = 0.6110\underline{9}27$ mol

6. Consider a hypothetical compound, $MX_?$, which contains exactly one "M" atom (atomic mass = 27.16 g/mol) and an unknown number of "X" atoms (atomic mass = 34.12 g/mol). If 100.0 grams of this hypothetical compound contains 3.680×10^{23} molecules, how many "X" atoms are present in this compound? Answer by using an integer (e.g. 0, 1, etc.).

$\boxed{4}$

molar mass = 100.0 g / $0.6110\underline{9}27$ mol = $163.\underline{6}4130$ g/mol

$163.\underline{6}4130$ g/mol $- 27.16$ g/mol $= 136.\underline{4}8130$ g/mol $\rightarrow \frac{136.\underline{4}8130 \text{ g/mol}}{34.12 \text{ g/mol}} = 4$

7. Crystals from evaporation of urine analyze to 22.6% phosphorus. Which compound is probably present?

$\boxed{A}$

A. $NaNH_4HPO_4$ $\rightarrow \frac{30.97 \text{ g/mol}}{137.02 \text{ g/mol}} \times 100$
B. $(NH_4)_3PO_4$
C. Na_3PO_4
D. H_3PO_4
E. $Ca_3(PO_4)_2$

8. Which of these could be an empirical formula?

$\boxed{A}$

A. $C_9H_8O_4$ (aspirin)
B. $C_6H_8O_6$ (vitamin C)
C. $C_8H_{10}N_4O_2$ (caffeine)
D. $C_{10}H_{14}N_2$ (nicotine)

9. Which of the following are empirical formulas? Select any that apply and answer with capital letters and no spaces (e.g. ABCDE).

AE

A. C_2H_6S
B. $C_{20}H_{24}N_2O_2$
C. $C_{10}H_{22}$
D. $C_6H_{12}N_3$
E. $C_{57}H_{110}O_6$

10. An unknown organic compound contains carbon, hydrogen, and bromine only. The mass percentages of C and H are 12.77% C and 1.60% H. The molar mass of unknown organic compound is 186.85 amu. Determine the molecular formula of the unknown. Answer by listing the chemical formula with the carbon first, then hydrogen, then bromine (e.g. $C_xH_yBr_z$).

$C_2H_3Br_2$

% Br = 100 − 12.77 − 1.60 = 85.63 %

$12.77 \text{ g C} \times \left(\frac{\text{mol}}{12.01 \text{ g}} \text{ C}\right) = 1.0632806 \text{ mol} / 1.0632806 \text{ mol} = 1 \times 2$

$1.60 \text{ g H} \times \left(\frac{\text{mol}}{1.01 \text{ g}} \text{ H}\right) = 1.5841584 \text{ mol} / 1.0632806 \text{ mol} = \sim 1.5 \times 2$

$85.63 \text{ g Br} \times \left(\frac{\text{mol}}{79.90 \text{ g}} \text{ Br}\right) = 1.071714 \text{ mol} / 1.0632806 \text{ mol} = \sim 1 \times 2$

$C_2H_3Br_2 \rightarrow MM = 186.85 \text{ g/mol}$

$N = 100 - 69.6 = 30.4\ \%$

11. A compound containing only sulfur and nitrogen is made up of 69.6% S by mass. The molar mass of compound is 184 g/mol. What are the empirical and molecular formulas of the compound? Answer by listing the chemical formula with the sulfur first and then nitrogen (e.g. S_xN_y).

I. Empirical formula: $\boxed{SN}$

II. Molecular formula: $\boxed{S_4N_4}$

$30.4\ g\ N \times \left(\frac{mol}{14.01\ g}\right) = 2.1698787\ mol / 2.1698787 = 1$ $\boxed{SN}$

$69.6\ g\ S \times \left(\frac{mol}{32.07\ g}\right) = 2.1702526\ mol / 2.1698787 = 1$

$SN \rightarrow MM = 46.08\ g/mol$

$$\frac{184\ g/mol}{46.08\ g/mol} = 4 \rightarrow \boxed{S_4N_4}$$

12. An unknown dye is found to be composed of 75.95 % C, 17.72 % N, and 6.33% H.

If the molar mass is determined to be 237.33 g/mol, how many nitrogen atoms are present in the molecular formula of the dye?

$\boxed{C}$

$75.95\ g\ C \times \left(\frac{mol}{12.01\ g}\right) = 6.3238968\ mol / 1.2648108\ mol = 5$

$17.72\ g\ N \times \left(\frac{mol}{14.01\ g}\right) = 1.2648108\ mol / 1.2648108\ mol = 1$

$6.33\ g\ H \times \left(\frac{mol}{1.01\ g}\right) = 6.2673267\ mol / 1.2648108\ mol = 5$

A. 1
B. 2
C. 3
D. 5
E. 15

C_5H_5N

$\downarrow$

$MM = 79.11\ g/mol$

$$\frac{237.33\ g/mol}{79.11\ g/mol} = 3 \rightarrow \boxed{C_{15}H_{15}N_3}$$

13. Which of the following statements are **true** regarding balanced chemical equations?

$\boxed{C}$

A. The coefficients in the balanced equation indicate the mass present of the reactants or products
B. The sum of the coefficients in the reactants will always equal the sum of the coefficients in the products
C. Matter is conserved in a balanced equation
D. The number of molecules in the reactants will always be the same in the products
E. More than one of the above are true

14. In the balanced equation for the combustion of benzene (C_6H_6) below, the coefficient for $O_2(g)$ is 9.

$$\left(\underline{1}\, C_6H_6\,(l) + \underline{\tfrac{15}{2}}\, O_2\,(g) \rightarrow \underline{3}\, H_2O\,(g) + \underline{6}\, CO_2\,(g) \right) \times 2$$

$$2\, C_6H_6\,(l) + 15\, O_2\,(g) \rightarrow 6\, H_2O\,(g) + 12\, CO_2\,(g)$$

$\boxed{B}$

A. True
B. False

15. Balance the equation below and list the coefficients as whole numbers with no commas or spaces (e.g. 1234).

$$\underline{2}\, H_2S\,(g) + \underline{1}\, SO_2\,(g) \rightarrow \underline{3}\, S\,(s) + \underline{2}\, H_2O\,(l)$$

$\boxed{2132}$

16. How many molecules of molecular oxygen react with four molecules of NH_3 to form four molecules of nitrogen monoxide and six molecules of water? Answer by using an integer (e.g. 0, 1, etc.).

$\boxed{5}$

$5O_2 + 4NH_3 \rightarrow 4NO + 6H_2O$

17. Which of the following statements is **false**?

$\boxed{B}$

A. When dynamic equilibrium is reached, the rate of the forward reaction is equal to the rate of the reverse reaction

→ not true, can be reactant favored

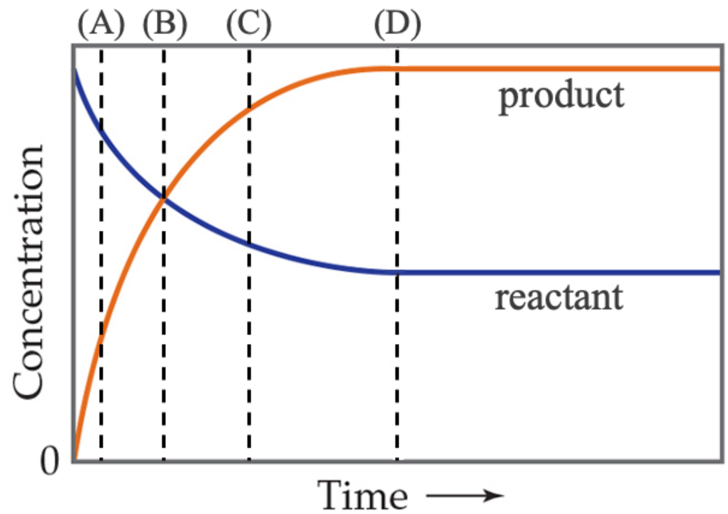
B. All chemical reactions are product favored at equilibrium (versus reactant favored), which is indicated by the forward arrow symbol (→) that is often used in chemical reactions

C. In a hypothetical, product favored equilibrium equation, A + B ⇆ C + D, the reactants 'A' and 'B' are predicted to largely convert to the products 'C' and 'D' once equilibrium is established

D. Chemical equilibrium is reached when the concentrations of both the reactants and products do not change

E. None of the above are false

18. In the graph below, a singular reactant converts to a singular product as illustrated by the two solid lines. Which vertical dashed line in the graph shows equilibrium being established?



D

A. Line A
B. Line B
C. Line C
D. Line D
E. Equilibrium is not established in this graph

Additional Practice Questions:

1. A block of Cu contains 3.439×10^{24} atoms. If the density of Cu is 8.96 g/cm^3, what is the volume of the block in liters? Report your answer in **standard notation**.

$\boxed{0.0405}$ L

$$3.439e24 \text{ atoms} \times \left(\frac{1 \text{ mol}}{6.022e23 \text{ atoms}}\right) \times \left(\frac{63.55 \text{ g}}{1 \text{ mol}}\right) \times \left(\frac{\text{cm}^3}{8.96 \text{ g}}\right) \times \left(\frac{1 \text{ mL}}{1 \text{ cm}^3}\right) \times \left(\frac{1 \text{ L}}{1000 \text{ mL}}\right)$$

2. Exactly 50.00 grams of an element contains 3.8128×10^{23} atoms. What is the identity of the element? Write the chemical symbol in the box below (e.g. H, Br, etc.).

$\boxed{\text{Se}}$

$$3.8128 \times 10^{23} \text{ atoms} \times \left(\frac{1 \text{ mol}}{6.022e23 \text{ atoms}}\right) = 0.6331451 \text{ mol}$$

molar mass = 50.00 g / 0.6331451 mol = 78.97084 g/mol → selenium

3. How many atoms of rubidium-85 are in 87.2 g of rubidium? Rubidium-85 is 72.2% abundant. Report your answer in **scientific notation**.

$\boxed{4.44} \times 10^{\boxed{23}}$ atoms

$$87.2 \text{ g Rb} \times \left(\frac{\text{mol}}{85.47 \text{ g Rb}}\right) \times \left(\frac{6.022e23 \text{ atoms}}{1 \text{ mol}}\right) = 6.143891e23 \text{ atoms}$$

$$6.143891e23 \text{ atoms} \times 0.722 = 4.43589 \times 10^{23} \text{ atoms}$$

$$6.17 \times 10^{22} \text{ molecules} \times \left(\frac{1 \text{ mol}}{6.022e23 \text{ molecules}}\right) = \underline{0.102458} \text{ mol}$$

4. A student goes to the lab and finds a container of an organic compound, $C_{14}H_{10}$, which in total contains 6.17×10^{22} molecules. If this compound has a density of 1.25 g/cm^3, and has a molar mass of 178.24 g/mol, what volume (in mL) does $C_{14}H_{10}$ occupy in this container?

$\boxed{C}$

$$\underline{0.102458} \text{ mol} \times \left(\frac{178.24 \text{ g}}{\text{mol}}\right) = \underline{18.26205} \text{ g}$$

A. 22.8 mL
B. 1.39×10^3 mL
C. 14.6 mL
D. 9.76 mL
E. 18.3 mL

$$d = m/V$$

$$1.25 \text{ g/cm}^3 = \frac{18.26205 \text{ g}}{V} \rightarrow 14.6 \text{ cm}^3 =$$

$$14.6 \text{ mL}$$

5. A compound composed of sulfur and fluorine is found to contain 25.24% by mass of sulfur. If the molar mass of the compound is 254.11 g/mol, what is its molecular formula? What is its empirical formula? Answer by listing the chemical formula with the sulfur first and then fluorine (e.g. S_xF_y).

I. Molecular formula: $\boxed{S_2F_{10}}$

II. Empirical formula: $\boxed{SF_5}$

$$25.24 \text{ g S} \times \left(\frac{\text{mol}}{32.07 \text{ g}}\right) = 0.787028 \text{ mol} \;/\; 0.787028 \text{ mol} = 1$$

$$74.76 \text{ g F} \times \left(\frac{\text{mol}}{19.00 \text{ g}}\right) = 3.934737 \text{ mol} \;/\; 0.787028 \text{ mol} = 5$$

$\boxed{SF_5}$

$$SF_5 \rightarrow MM = 127.07 \text{ g/mol}$$

$$\frac{254.11 \text{ g/mol}}{127.07 \text{ g/mol}} = 2 \rightarrow \boxed{S_2F_{10}}$$

6. Balance the equation:

$$\_\_\_B_2O_3\text{ (s)} + \_\_\_HF\text{ (l)} \rightarrow \_\_\_BF_3\text{ (g)} + \_\_\_H_2O\text{ (l)}$$

A

A. B_2O_3 (s) + 6 HF (l) → 2 BF_3 (g) + 3 H_2O (l)
B. B_2O_3 (s) + H_6F_6 (l) → B_2F_6 (g) + H_6O_3 (l)
C. B_2O_3 (s) + 2 HF (l) → 2 BF_3 (g) + H_2O (l)
D. B_2O_3 (s) + 3 HF (l) → 2 BF_3 (g) + 3 H_2O (l)
E. B_2O_3 (s) + 6 HF (l) → 2 BF_3 (g) + 6 H_2O (l)

7. What is the stoichiometric coefficient of HCl once the equation below is fully balanced?

$$\underline{2}\,Al\text{ (s)} + \underline{6}\,HCl\text{ (aq)} \rightarrow \underline{2}\,AlCl_3\text{ (aq)} + \underline{3}\,H_2\text{ (l)}$$

F

A. 1
B. 2
C. 3
D. 4
E. 5
F. 6

Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** 1.01																	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.63	33 **As** 74.92	34 **Se** 78.97	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.95	43 **Tc** [97]	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
37 **Cs** 132.91	56 **Ba** 137.33		72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** [209]	85 **At** [210]	86 **Rn** [222]
87 **Fr** [223]	88 **Ra** [226]		104 **Rf** [267]	105 **Db** [268]	106 **Sg** [269]	107 **Bh** [270]	108 **Hs** [269]	109 **Mt** [277]	110 **Ds** [281]	111 **Rg** [282]	112 **Cn** [285]	113 **Nh** [286]	114 **Fl** [290]	115 **Mc** [290]	116 **Lv** [293]	117 **Ts** [294]	118 **Og** [294]

57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** [145]	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05	71 **Lu** 174.97
89 **Ac** [227]	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** [237]	94 **Pu** [244]	95 **Am** [243]	96 **Cm** [247]	97 **Bk** [247]	98 **Cf** [251]	99 **Es** [252]	100 **Fm** [257]	101 **Md** [258]	102 **No** [259]	103 **Lr** [262]

Formula Sheet

Length
1 kilometer = 0.62137 mile
1 inch = 2.54 centimeters (exactly)
1 Ångstrom = 1×10^{-10} meter

Energy
1 joule = 1 $kg \cdot m^2/s^2$
1 calorie = 4.184 joules
1 Calorie = 1 kilocalorie = 1000 calories
1 L·atm = 101.325 joules

Pressure
1 pascal = 1 N/m^3 = 1 $kg/m \cdot s^2$
1 atmosphere = 101.325 kilopascals = 760 mm Hg = 760 torr = 14.70 lb/in^2
1 bar = 1×10^5 Pa (exactly)

Temperature
0 K = −273.15°C
K = °C + 273.15
°C = (5/9)(°F − 32)

Mass
1 kg = 2.205 lbs

Volume
1 mL = 1 cm^3 = 1 cc

Constants
c = 2.998×10^8 m/sec
h = 6.626×10^{-34} J·sec
R = 0.08206 L·atm/mol·K = 8.314 J/mol·K
Specific heat of water = 4.184 J/g·K
Mass of an electron: 9.109×10^{-31} kg
Mass of a proton: 1.673×10^{-27} kg
RH = 2.18×10^{-18} J
Specific heat of water = 4.184 J/g·K
Avogadro's number: 6.022×10^{23}
F = 96485 J/(V·mol e^-)
$K_w = 1.0 \times 10^{-14}$ at 25 °C
$k_b = 1.381 \times 10^{-23}$ J/K

Equations
$(P + a(n^2/V^2))\cdot(V - nb) = nRT$
molar mass (M) = mRT/PV
density (d) = MP/RT

$$KE = \frac{3}{2}RT$$

$$\mu_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\frac{Rate\ of\ effusion\ A}{Rate\ of\ effusion\ B} = \sqrt{\frac{MW_B}{MW_A}}$$

$$\Delta E = -2.18 \times 10^{-18} J\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_{vap}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$C_g = kP_g$
$P_{solution} = P_{solvent}\, X_{solvent}$
$P_{solution} = \sum P_j = \sum P_j X_j$
$\pi = MRTi$

Thermodynamic and Electrochemistry

$S = k_b \times \ln(W)$
$\Delta S = q_{rev}/T$
$\Delta G = \Delta G° + RT \cdot \ln Q$
R=8.314 J/mol.K
$\Delta G° = -RT \cdot \ln K$
$\Delta G = -nFE_{cell}$
$E°_{cell} = RT/nF \ln K$
$E°_{cell} = (0.0257/n) \ln K = (0.0592/n) \log K$
$E_{cell} = E°_{cell} - (RT/nF) \ln Q$
$E_{cell} = E°_{cell} - (0.0257/n) \ln Q$
Electrolysis: Q (total charge) = I × t = n × F

Integrated Rate Laws & half-life

$$\ln\frac{[A]}{[A]_0} = -kt$$

$$\frac{1}{[A]} = kt + \frac{1}{[A]_0}$$

$$[A] = -kt + [A]_0$$

$$t_{1/2} = \frac{[A]_0}{2k}$$

$$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$$

$$t_{1/2} = \frac{1}{k[A]_0}$$

$$ln\frac{k_2}{k_1} = -\frac{E_a}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

Equilibrium and Acid / Base

$K_P = K_c \times (RT)^{\Delta n}$

$$ln\frac{K_2}{K_1} = \frac{\Delta H^{\circ}_{rxn}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$