

Version A/B

Name _____

Section _____

The last two page contains potentially relevant information that may be of use to you. You are welcome to tear off and keep them.
There are 12 pages, be sure you have all pages **before** you begin.

Problems	1	2	3	4	5	6	7	8	9
Points	22	28	26	20	22	21	26	18	26

Total Points: 207 (23 pts per problem on average)

Suggestions:

- 1) Make sure you set up all calculation problems for the entire test, and then go back and finish them. You will get more points covering the full test demonstrating how the problem may be solved. (Hold off using your calculator.)
- 2) Some additional algebra, using variables rather than numbers, will save you time calculating unneeded intermediate quantities.
- 3) Be sure to show units when applicable.

Q1A) Z9.27, 10.22. (22 points) Consider 5 moles of ethane ($C_v = \frac{5}{2}R \text{ kJ/mol}\cdot\text{K}$), initially at 2 Atm. The ethane is warmed from 20°C to 80°C . Assume ethane behaves as an ideal gas.

a) Compute the heat energy, the internal energy change, the enthalpy change, the entropy change and the work required to warm the gas at constant volume. [NB: The order of the quantities may not be in the optimal order to compute them.]

$$q = \Delta E = nC_v\Delta T = 5 \cdot \frac{5}{2}R \cdot 60 = 750R = 6.2 \text{ kJ}$$

$$w = 0$$

$$\Delta E = nC_v\Delta T = 6.2 \text{ kJ}$$

$$\Delta H = nC_p\Delta T = n(C_v + R)\Delta T = \frac{7}{5}\Delta E = 8.7 \text{ kJ}$$

$$\Delta S = nC_v \ln\left(\frac{T_2}{T_1}\right) = 5 \cdot \frac{5}{2}R \ln\left\{\frac{273+80}{273+20}\right\} = \frac{25}{2} \cdot 0.2 \cdot R = 19 \text{ J/K}$$

b) Compute the same quantities but now the gas expands at constant pressure.

$$q = \Delta H = nC_p\Delta T = 5 \cdot \frac{7}{2}R \cdot 60 = 8.7 \text{ kJ}$$

$$w = \Delta E - q = 6.2 - 8.7 = -2.5 \text{ kJ}$$

$$\Delta E = nC_v\Delta T = 6.2 \text{ kJ}$$

$$\Delta H = nC_p\Delta T = 8.7 \text{ kJ}$$

$$\Delta S = nC_p \ln\left(\frac{T_2}{T_1}\right) = 5 \cdot \frac{7}{2}R \ln\left\{\frac{273+80}{273+20}\right\} = \frac{35}{2} \cdot 0.2 \cdot R = 27 \text{ J/K}$$

Q2A) Z10.16,37,41. (16points)

Predict the sign of the entropy change, and the enthalpy change for the following processes: (Answer, Pos, Neg, Zero, or Can't be Determined (CBD)).

Process	Entropy Change	Enthalpy Change
Melting of a solid	positive	positive
Sublimation	positive	positive
Freezing	negative	negative
Mixing	positive	0
$H_2O(\ell) \rightleftharpoons H_2O(g)$	positive	positive
$CO_2(g) \rightleftharpoons CO_2(s)$	negative	negative
$2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$	positive	Positive (opposite of burn)
$A_2(g) + B_2(g) \rightleftharpoons 2AB(g)$	positive	CBD

Q2B) Z10.21. (12 points) For the reaction at 298K, $2NO_2(g) \rightleftharpoons N_2O_4(g)$,

$$\Delta H_{rxn}^{\circ} = -60 \text{ kJ/mol} \text{ and } \Delta S_{rxn}^{\circ} = -150 \text{ J/K} \cdot \text{mol}.$$

a) What is ΔG_{rxn}° at 298K?

$$\begin{aligned} \Delta G_{rxn}^{\circ} &= \Delta H_{rxn}^{\circ} - T\Delta S_{rxn}^{\circ} \\ &= -60 \text{ kJ/mol} + 298 \cdot 0.15 \text{ kJ/mol} = -15 \text{ kJ/mol} \end{aligned}$$

b) At what temperature is $\Delta G_{rxn}^{\circ} = 0$ (Assuming the reaction enthalpy and entropy are independent of temperature.)

$$\begin{aligned} \Delta G_{rxn}^{\circ} = 0 &= \Delta H_{rxn}^{\circ} - T\Delta S_{rxn}^{\circ} \Rightarrow T = \frac{\Delta H_{rxn}^{\circ}}{\Delta S_{rxn}^{\circ}} \\ T &= \frac{-60}{-0.15} \text{ K} = 400 \text{ K} \end{aligned}$$

c) If the system is at 1 Atmosphere when $\Delta G_{rxn}^{\circ} = 0$ (at the temperature of part b) what is the composition of the gas? (i.e. What are partial pressures of each of the two species in the gas?)

$$\begin{aligned} \Delta G_{rxn}^{\circ} = 0 &= -RT \ln K \Rightarrow K = 1 = \frac{P_{N_2O_4}}{P_{NO_2}^2} \\ 1 &= P_{N_2O_4} + P_{NO_2} \text{ and } P_{NO_2}^2 = P_{N_2O_4} \end{aligned}$$

The two equations and two unknowns, show the reactant is greater than $\frac{1}{2}$ and the product is less than $\frac{1}{2}$ Atm. $P_{NO_2} \approx 0.62 \approx \frac{1}{2} + \frac{1}{8} \text{ Atm}$ and $P_{N_2O_4} \approx 0.38 \text{ Atm}$

d) Is ΔG_{rxn}° negative above or below this temperature (of part b)? At lower temperatures the enthalpy dominates so ΔG_{rxn}° is negative below this temperature, and the reaction is favored, spontaneous. [At higher temperature entropy dominates, so ΔG_{rxn}° is positive, meaning reactants dominate.]

Q3) Z12.49, 50,54 (26 points)

a) Which of the following orbital designations are allowed or unallowed:

1s allowed	7d allowed
1p not allowed	3f unallowed
3s allowed	2d unallowed

b) How many 4d orbitals are there?

D corresponds to $l=2$, so there are 5 orbitals with the 4d designation.

c) Which atom has 1 (and only one) electron in a 4d orbital in its ground state? (give the symbol or atomic number). From the periodic table, the element has $EC=[\text{core}] 5s^2 4d^1$. Element 39, or Y, or yttrium.

d) How do the 2p orbitals differ from each other? (Include the number of them in your explanation.) There are 3 orbitals each designated as 2p. Each one points along a different axis, such as x, y or z, so they are the 2p_x, 2p_y and 2p_z orbitals. They differ by orientation in space. Otherwise they look identical.

e) How do the 2p orbitals differ from the 3p orbitals? (Include a comparison of the number of 2p and 3p orbitals in your explanation.)

Each set of orbitals has 3 orbitals, and the orientation of the 2p and 3p are the same. For example the 2p_x and 3p_x both point along x. However, the 3p_x has a more complicated structure, there is a place out from the center where the orbital, (wave function or probability) goes to zero. This does not happen with the 2p_x orbital. When going along the x axis there is a place on the +x and the -x axis where this happens, because there is radial node that cuts through the 3p orbital everywhere in space at a fixed distance out that does not happen to the 2p orbital.

f) Draw a picture of a 2p_z orbital (include labeled axes). Show a dumbbell or bowling pin pointing along the z axis, and label x,y,z, the xy plane should have no orbital there.

Q4) Z11.81,Z11.55 (20 points) Consider a battery (@ T=298K) composed of two beakers each with a Ni electrode (a concentration cell) and each containing 2 liters of solution. In the solution in beaker A the $[Ni^{2+}] = 1.0M$, and in beaker B

the $[Ni^{2+}] = 4 \cdot 10^{-3}M$. [There is also a salt bridge to allow counter ion conduction.]

a) Compute the cell potential.

$$E_{Cell} = E_{Cell}^{\circ} - \frac{RT}{nF} \ln Q = 0 - \frac{25.7}{2} \ln \left(\frac{4 \cdot 10^{-3}}{1} \right) = 70mV = 0.07V$$

b) Explain which way the electrons flow (e.g. from beaker A to B) and why.

The high concentration of Ni ion is in A, this must go down. Therefore in beaker A the reaction is $Ni^{2+} + 2e^{-} \rightarrow Ni^{\circ}$, which needs electrons, so the electrons must flow from B to A. In beaker B the opposite reaction is going on and the nickel ion concentration increases as the battery runs. [In battery terminology, beaker A is positive, reduction is occurring and it is the cathode.]

c) Assuming the voltage does not change significantly during the operation of the battery, how much work (as the "maximum work") will you obtain from the battery if 10% of the Nickel is consumed?

From part b) $n = 2$

$$X = \Delta n_{Ni} = V \Delta [Ni^{2+}] = 2 \cdot 0.1M - \ell = 0.2moles$$

$$w_{rev}^{elect} = \Delta G = X \cdot \Delta G_{rxn} = -n \cdot X \cdot F \cdot E_{Cell} = -2 \cdot 0.2 \cdot 96 \cdot 10^3 \cdot 0.07J = -2.7kJ$$

d) What is the cell potential when the solution in both beakers is

$$[Ni^{2+}] = 0.5M \quad E_{Cell} = \frac{RT}{nF} \ln \left(\frac{.5}{.5} \right) = 0V \quad \text{The battery is dead.}$$

Q5A) Z11.39 (22 points)

a) Combine the equations $\Delta G_{rxn}^{\circ} = -nFE_{Cell}^{\circ}$ and $\Delta G_{rxn}^{\circ} = \Delta H_{rxn}^{\circ} - T\Delta S_{rxn}^{\circ}$ to derive an expression for E_{Cell}° as a function of the temperature.

$$E_{Cell}^{\circ} = T \frac{\Delta S_{rxn}^{\circ}}{nF} - \frac{\Delta H_{rxn}^{\circ}}{nF}$$

b) From the measurement of E_{Cell}° at two different temperatures, called

$E_{Cell}^{\circ}(T_1)$ and $E_{Cell}^{\circ}(T_2)$ at the two different temperatures.. Assume ΔH_{rxn}° and ΔS_{rxn}° are independent of temperature.

Explain how you would determine ΔH_{rxn}° . This is determined from the T=0 intercept,

need the entropy term first. $E_{Cell}^{\circ}(T_1) = T_1 \frac{\Delta S_{rxn}^{\circ}}{nF} - \frac{\Delta H_{rxn}^{\circ}}{nF}$ and $\Delta H_{rxn}^{\circ} = T_1 \Delta S_{rxn}^{\circ} - nFE_{Cell}^{\circ}(T_1)$

c) Explain how you would determine ΔS_{rxn}° . This is determined from the slope.

$$E_{Cell}^{\circ}(T_2) - E_{Cell}^{\circ}(T_1) = (T_2 - T_1) \frac{\Delta S_{rxn}^{\circ}}{nF} \text{ and } \Delta S_{rxn}^{\circ} = nF \cdot \frac{E_{Cell}^{\circ}(T_2) - E_{Cell}^{\circ}(T_1)}{(T_2 - T_1)}$$

Q5B) Z11.53,39

The lead acid (car) battery, under standard conditions, is a 2Volt battery. However the voltage does change with temperature. At $-30^{\circ}C$ the battery voltage is 1.8V. (All chemical species comprising the battery are at 1M at both temperatures.)

a) Determine ΔH_{rxn}° for the chemical reaction: $PbO_2 + 4H^+ + Pb^{\circ} \rightarrow 2Pb^{2+} + 2H_2O$

For this reaction, from the two half reactions: $n = 2 \text{ moles} - \text{elec} / \text{mole} - \text{rxn}$

$$\Delta H_{rxn}^{\circ} = T_1 \Delta S_{rxn}^{\circ} - nFE_{Cell}^{\circ}(T_1) = 298 \cdot 702 - 2 \cdot 96500 \cdot 2 = -177 \text{ kJ/mol}$$

b) Determine ΔS_{rxn}° for this reaction:

$$\Delta S_{rxn}^{\circ} = nF \cdot \frac{E_{Cell}^{\circ}(T_2) - E_{Cell}^{\circ}(T_1)}{(T_2 - T_1)} = 2 \frac{96500}{-30 - 25} (1.8 - 2) = 702 \text{ J/mol} \cdot K$$

Q6) Z12.44,45,114 (21 points)

a) Discuss what happens to the energy levels for a particle (obeying quantum mechanical principles) in a one-dimensional box as the length of the box increases? (Assume the particle stays in the same quantum states, ie. n does not change).

Because $E_n = +\frac{h^2 n^2}{8m L^2}$, as L gets larger E_n get smaller. The actual internal energy of the particle decreases as the length increases. The particle is doing adiabatic work as the wall moves to give a longer length.

b) Assume the particle, which has the mass of an electron, is in a one dimensional box of length $L = 1 \cdot 10^{-6} m$, is in the $n = 1000$ state. How much work will the particle do if the box increases in length by 10%, and n does not change. (Assume that the wall of the box moves adiabatically.)

$$w = \Delta E_n$$

$$\Delta E_n = E_n(L \cdot 1.1) - E_n(L) = \frac{h^2 n^2}{8m L^2} \left(\frac{1}{1.1^2} - 1 \right) = \left(\frac{6.6 \cdot 10^{-34} \cdot 10^3}{10^{-6}} \right)^2 \frac{1}{8 \cdot 9 \cdot 10^{-31}} (-0.17) = -1 \cdot 10^{-20} J$$

c) A microwave oven produces photons with a wavelength of 9cm. How many photons must be absorbed for a cup of water to be heated from $25^\circ C$ to boiling? The cup has 50grams of water and the heat capacity of water is $C_p = 4.18 J/gm \cdot ^\circ C$

$$q = \Delta E_{water} = N \cdot \Delta E_{photons}$$

$$\Delta E_{water} = m C_p \Delta T = 50 \cdot 4.18 \cdot (100 - 25) = 16 kJ$$

$$\Delta E_{photons} = h\nu = \frac{hc}{\lambda} = \frac{6.6 \cdot 10^{-34} \cdot 3 \cdot 10^8}{9 \cdot 10^{-2}} = 2.2 \cdot 10^{-24} J / photon$$

$$N = \frac{\Delta E_{water}}{\Delta E_{photons}} = \frac{16 \cdot 10^3}{2.2 \cdot 10^{-24}} = 7 \cdot 10^{27} photons$$

In short, about 10^{27} photons to heat 3 moles of water. But the point is heat is generated in a classical system by quantum processes.

Q7A) Z12.94 (10 points) The Electron Affinity of the elements Al to Cl are -44, -120, -74, -200, and -350 kJ/mol, respectively. Rationalize the trend in these values.

In general, moving from Al to Cl the EA should become more negative (more favorable) until Cl where one electron added to Cl gives Cl^- which is isoelectronic with a noble gas (Ar). There is one bump in this trend and that is Si is anomalously low. That is because the silicon anion is isoelectronic with P, which is half filled. So P is stable as is, so adding an electron to P is harder than expected, therefore its EA is more positive than the rest of the trend, but still less than Al so it is in the right order but quantitatively very high (i.e. not as negative as it should be.)

In summary, the trend is right but half-filled stability shifts Si and P EAs, in opposite directions for the same root reason.

Q7B) Z13.13,14 (16 points)

A) Using the periodic table: of the following elements: **B, O, Ga,**

a) Which has the largest electronegativity? O	b) Which has the smallest electronegativity? Ga
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B) Using the periodic table: of the following elements: **B, O, Ga,**

a) Largest Ionization Potential? O	b) Smallest Ionization Potential? Ga
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C) Using the periodic table: of the following elements: **B, O, Ga,**

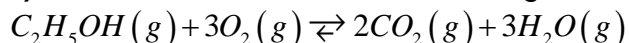
a) Largest atomic radius? Ga	b) Smallest atomic radius? O
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D) Using the periodic table: of the following molecules: **Ti-Cl, Si-Cl, Ge-Cl**

a) Which bond the most polar? Ti-Cl	b) Which bond the least polar? Si-Cl
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Q8A) Z13.34 (10 points)

a) Estimate ΔH for the reaction, using bond energies (from this table):



Bond	Energy (kJ / mol)	Bond	Energy (kJ / mol)	Bond	Energy (kJ / mol)
C - H	413	C = C	614	C = O	750
C - C	350	C \equiv C	840	O - O	150
C - O	360	O = O	500	O - H	465

$$\begin{aligned} \Delta H &= 5(C-H) + (C-C) + (C-O) + (O-H) + 3(O=O) - \{4(C=O) + 6(O-H)\} \\ &= 5(C-H) + (C-C) + (C-O) + 3(O=O) - \{4(C=O) + 5(O-H)\} \\ &= 5 \cdot 413 + 350 + 360 + 3 \cdot 500 - \{4 \cdot 750 + 5 \cdot 465\} = -1 \text{ MJ/mol} \end{aligned}$$

b) Explain how the bond energies, for this reaction may be inexact. Would you expect the enthalpy predicted by this reaction to be too high or too low?

All bond energies are approximate, as they represent averaged values. So the result should be no better than 5%. The reaction should be very exothermic, because water and carbon dioxide are extremely stable. The CO₂ bond is especially strong, and anomalous, so one would expect this estimate to be too high.

Q8B) Z13.22 (8 points) The radii of the ions Na⁺, F⁻, Cl⁻, in picometers are:

95, 136, 181 pm, respectively.

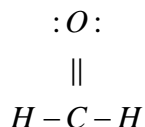
a) On this basis which would have the larger stabilizing lattice energy? NaCl, or NaF. Explain. The Fluoride ion is smaller than the Chloride ion so NaF has a closer ionic contact distance. Therefore its lattice energy should be a number with a large magnitude, so the NaF should have a larger stabilizing lattice energy (which is negative).

b) Predict the ratio of the lattice energy of the NaCl solid to the NaF solid, as

$$\frac{V_{le}(NaCl)}{V_{le}(NaF)}$$

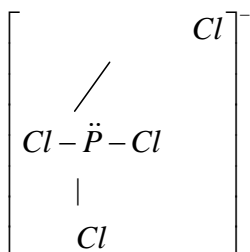
$$\frac{V_{le}(NaCl)}{V_{le}(NaF)} = \frac{r_{NaF}}{r_{NaCl}} = \frac{95 + 136}{95 + 181} = 0.84$$

Q9A) Z13.47 (8 points) a) Write the best Lewis structure for H_2CO



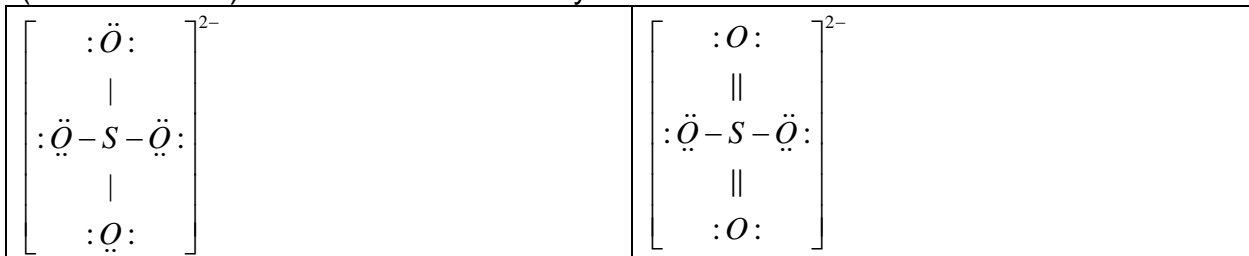
b) Predict the molecular structure for this molecule Trigonal Planar	c) Predict the \widehat{HCO} bond angle for this structure. The bond angle is ~120 degrees.
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Q9B) Z13.48 (8 points) Write the best Lewis structure for $[PCl_4]^-$



b) Predict the molecular structure for this molecule See Saw	c) Predict the \widehat{ClPCl} bond angles for this structure. a) <90 and b) <120 degrees
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Q9C) Z13.48 (10 points) a) Write two possible, distinct Lewis structures for SO_4^{2-} (the sulfate ion) which are not related by resonance.



b) Show the formal charges on each atom on your structures in part a). Summarize (in words) the formal charges on the two structures.

The S has +2 FC in the first structure and each of the Os has -1 FC. In the second structure only two of the Os have -1FC, and the other Os and the S are 0 FC.

c) Which structure is preferred based on the formal charges? Explain.

The second structure is preferred because there are fewer formal charges.

$\Delta H = \Delta H_{rxn} \Delta X$ $\Delta G = \Delta H - T \Delta S$ $aA + bB \rightleftharpoons cC + dD$ $K = \frac{[C]^c [D]^d}{[A]^a [B]^b}$ $\Delta G_{rxn} = \Delta G_{rxn}^o + RT \ln Q$ $\ln K = -\frac{\Delta G_{rxn}^o}{RT}$ $\ln K = -\frac{\Delta H_{rxn}^o}{RT} + \frac{\Delta S_{rxn}^o}{R}$ $w_{rev}^{elect} = \Delta G = X \cdot \Delta G_{rxn}$ $\Delta G_{rxn} = -nFE_{Cell}$ $E_{Cell} = E_{Cell}^o - \frac{RT}{nF} \ln Q$ $E_{Cell}^o = \frac{RT}{nF} \ln K$	$K.E. = \frac{1}{2}mv^2$ $P.E. = mgh$ $P.E._{Coul} = -\frac{Ze^2}{r}$ $E = cp = h\nu_{Photon}$ $c = \lambda\nu$ $h\nu = \frac{1}{2}mv^2 + \Phi$ $\nu = R_y \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$ $\lambda = \frac{h}{p} \quad p = \frac{h}{\lambda}$ $\Delta x \Delta p \geq \frac{\hbar}{2}$ $E_n = +\frac{h^2 n^2}{8m L^2}$ $E_n = -2.178 \cdot 10^{-18} \left(\frac{Z^2}{n^2} \right) J$	<table border="1"> <thead> <tr> <th>Constant</th> <th>Value</th> </tr> </thead> <tbody> <tr> <td>Avagdro's #</td> <td>$N_A = 6.022 \cdot 10^{23} mol^{-1}$</td> </tr> <tr> <td>Bohr Radius</td> <td>$a_o = 5.3 \cdot 10^{-11} m$</td> </tr> <tr> <td>Boltzmann</td> <td>$k_B = 1.38 \cdot 10^{-23} J / K$</td> </tr> <tr> <td>e Charge</td> <td>$e^- = 1.6 \cdot 10^{-19} C$</td> </tr> <tr> <td>Faraday</td> <td>$F = 96,485 C mol^{-1}$</td> </tr> <tr> <td>Gas Cnst</td> <td>$R = 8.314 JK^{-1} mol^{-1}$</td> </tr> <tr> <td>mass elec</td> <td>$m_e = 9.1 \cdot 10^{-31} kg$</td> </tr> <tr> <td>mass prot</td> <td>$m_p = 1.67 \cdot 10^{-27} kg$</td> </tr> <tr> <td>Planck</td> <td>$h = 6.626 \cdot 10^{-34} J \cdot s$</td> </tr> <tr> <td>light speed</td> <td>$c = 2.99 \cdot 10^8 ms^{-1}$</td> </tr> <tr> <td>Gas Cnst</td> <td>$R = 0.082 l - Atm K^{-1} mol^{-1}$</td> </tr> <tr> <td>Gravity</td> <td>$g = 9.8 m \cdot s^{-2}$</td> </tr> <tr> <td>Rydberg</td> <td>$R_y = 3.29 \cdot 10^{15} Hz$</td> </tr> <tr> <td colspan="2">$RT = 2.48 kJ/mol \quad \frac{RT}{F} = 25.7 mV/mol$</td> </tr> <tr> <td colspan="2">$V = \frac{Q_1 Q_2}{r} \cdot 2.3 \cdot 10^{-19} J - nm$</td> </tr> <tr> <td colspan="2">$\mu = 0.48 \cdot QR \text{ Debye} / nm$</td> </tr> <tr> <td colspan="2">$\mu_{AB} \approx E.N.(A) - E.N.(B)$</td> </tr> <tr> <td colspan="2">$I.C._{AB} \approx \frac{\mu_{AB}^2}{3 + \mu_{AB}^2}$</td> </tr> </tbody> </table>	Constant	Value	Avagdro's #	$N_A = 6.022 \cdot 10^{23} mol^{-1}$	Bohr Radius	$a_o = 5.3 \cdot 10^{-11} m$	Boltzmann	$k_B = 1.38 \cdot 10^{-23} J / K$	e Charge	$e^- = 1.6 \cdot 10^{-19} C$	Faraday	$F = 96,485 C mol^{-1}$	Gas Cnst	$R = 8.314 JK^{-1} mol^{-1}$	mass elec	$m_e = 9.1 \cdot 10^{-31} kg$	mass prot	$m_p = 1.67 \cdot 10^{-27} kg$	Planck	$h = 6.626 \cdot 10^{-34} J \cdot s$	light speed	$c = 2.99 \cdot 10^8 ms^{-1}$	Gas Cnst	$R = 0.082 l - Atm K^{-1} mol^{-1}$	Gravity	$g = 9.8 m \cdot s^{-2}$	Rydberg	$R_y = 3.29 \cdot 10^{15} Hz$	$RT = 2.48 kJ/mol \quad \frac{RT}{F} = 25.7 mV/mol$		$V = \frac{Q_1 Q_2}{r} \cdot 2.3 \cdot 10^{-19} J - nm$		$\mu = 0.48 \cdot QR \text{ Debye} / nm$		$\mu_{AB} \approx E.N.(A) - E.N.(B) $		$I.C._{AB} \approx \frac{\mu_{AB}^2}{3 + \mu_{AB}^2}$	
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$\Delta E = nC_V \Delta T$ $(I.G.) \quad C_p = C_v + R$ $\Delta S = \frac{q_{ev}}{T}$ $w_{rev} = -nRT \ln \frac{V_f}{V_i}$ $\Delta S = nR \ln \frac{V_f}{V_i}$ $\Delta S = nC_v \ln \frac{T_f}{T_i}$	<p>Standard Reduction potentials for Half-Reactions in Volts:</p> <table border="1"> <tbody> <tr> <td>$F_2 + 2e^- \rightarrow 2F^-$</td> <td>2.87</td> <td>$Cu^{2+} + 2e^- \rightarrow Cu^o$</td> <td>0.34</td> </tr> <tr> <td>$Ag^{2+} + e^- \rightarrow Ag^+$</td> <td>1.99</td> <td>$2H^+ + 2e^- \rightarrow H_2$</td> <td>0.00</td> </tr> <tr> <td>$PbO_2 + 4H^+ + 2e^- \rightarrow Pb^{2+} + 2H_2O$</td> <td>1.46</td> <td>$Pb^{2+} + 2e^- \rightarrow Pb^o$</td> <td>-0.13</td> </tr> <tr> <td>$Cl_2 + 2e^- \rightarrow 2Cl^-$</td> <td>1.36</td> <td>$Ni^{2+} + 2e^- \rightarrow Ni^o$</td> <td>-0.23</td> </tr> <tr> <td>$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$</td> <td>1.23</td> <td>$Al^{3+} + 3e^- \rightarrow Al^o$</td> <td>-1.66</td> </tr> <tr> <td>$Br_2 + 2e^- \rightarrow 2Br^-$</td> <td>1.09</td> <td>$Na^+ + e^- \rightarrow Na^o$</td> <td>-2.71</td> </tr> <tr> <td>$Ag^+ + e^- \rightarrow Ag^o$</td> <td>0.80</td> <td>$Li^+ + e^- \rightarrow Li^o$</td> <td>-3.05</td> </tr> </tbody> </table>	$F_2 + 2e^- \rightarrow 2F^-$	2.87	$Cu^{2+} + 2e^- \rightarrow Cu^o$	0.34	$Ag^{2+} + e^- \rightarrow Ag^+$	1.99	$2H^+ + 2e^- \rightarrow H_2$	0.00	$PbO_2 + 4H^+ + 2e^- \rightarrow Pb^{2+} + 2H_2O$	1.46	$Pb^{2+} + 2e^- \rightarrow Pb^o$	-0.13	$Cl_2 + 2e^- \rightarrow 2Cl^-$	1.36	$Ni^{2+} + 2e^- \rightarrow Ni^o$	-0.23	$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	1.23	$Al^{3+} + 3e^- \rightarrow Al^o$	-1.66	$Br_2 + 2e^- \rightarrow 2Br^-$	1.09	$Na^+ + e^- \rightarrow Na^o$	-2.71	$Ag^+ + e^- \rightarrow Ag^o$	0.80	$Li^+ + e^- \rightarrow Li^o$	-3.05
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