Chemistry 1A
Page 1 of 14.

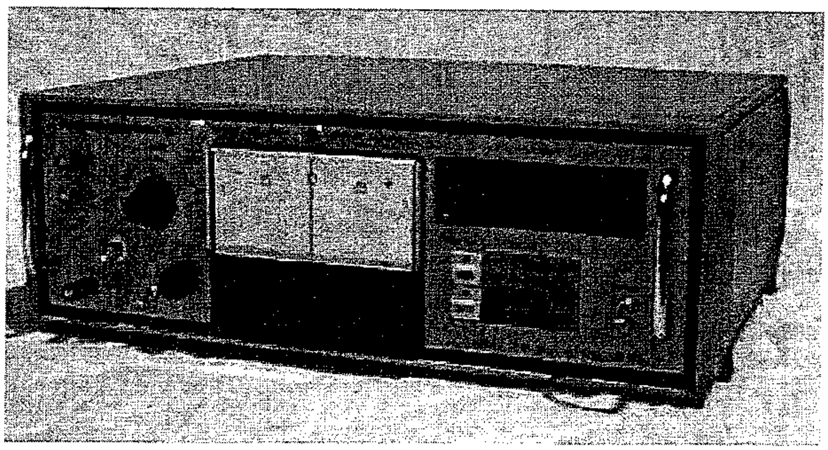
Final Exam
(Closed Book, 180 Minutes, 400 Points)

December 10, 1997
Professor Pines

Name:________________________ **TA:**________________________

SID:________________________ **Section:**________________________

Identification Sticker



Scientific instruments play an important role in research. (0 pts) Which instrument is pictured above?

Atomic Force Microscope Barometer Coulometer Diode Laser Electrochemical Cell

Test-taking strategy: PLEASE READ THIS FIRST!
Write your name on all 14 pages. This test consists of two parts: multiple choice (**answers to be circled *and* entered on the Scantron sheet**) and short answer. In order to maximize your score on the exam:

- Do the questions you know how to do first, then, go back and answer the questions you skipped.
- Budget your time carefully -- don't spend too much time on any one problem.
- Show all work for which you want credit and don't forget to include units.
- **The "tear off" back page has some useful data and equations.**

Page	Points	Page	Points	Page	Points
Multiple Choice		8		12	
5		9		13	
6		10		Total:	
7		11			

Name: ______________________________

Section 1: Multiple Choice. 20 questions, 6 points each.

Instructions: For the following questions, circle the answer on the exam sheet **and bubble in the correct answer on your Scantron sheet.** Unless you are specifically told that there might be more than one answer to a problem, assume that only one answer is correct.

1.) You are taking test version **C**. Please fill in bubble "**C**" on the Scantron sheet.

2.) Which of the following has the smallest atomic radius?

A) S^{2-} **B)** Cl^- **C)** Ar **D)** K^+ **E)** Ca^{2+}

3.) Which of the following might be the pH of a 0.1 M weak base at 25 °C?

A) 1 **B)** 4 **C)** 6 **D)** 9 **E)** 13

4.) A solution of 0.01 M $Ba(NO_3)_2$ and 0.01 M $Pb(NO_3)_2$ (both of which dissociate completely in water) is titrated with SO_4^{2-}. At the point when $PbSO_4(s)$ first begins to precipitate, what will be the concentration of Ba^{2+} in the solution? Assume a negligible change in volume. $K_{sp}(BaSO_4) = 1\times10^{-10}$; $K_{sp}(PbSO_4) = 1\times10^{-8}$.

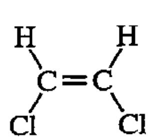
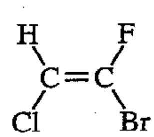
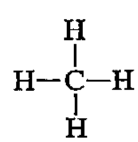
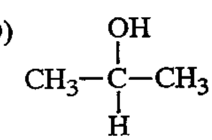
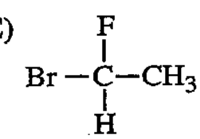
A) 1×10^{-10} M **B)** 1×10^{-8} M **C)** 1×10^{-6} M **D)** 1×10^{-4} M **E)** 1×10^{-2} M

5.) Under what conditions would the following **exothermic** reaction be spontaneous?

$$Fe(s) + CO(g) \longrightarrow FeO(s) + C(s)$$

A) At all T **B)** At no T **C)** At high T **D)** At low T **E)** At 100 °C

6.) Which of the following compounds is chiral?

A) 
B) 
C) 
D) 
E) 

7.) Which of the following can have the electron configuration $1s^22s^22p^63s^23p^64s^23d^{10}4p^66s^1$?

A) Ba^+ **B)** Cs^- **C)** Sr **D)** Rb **E)** Kr

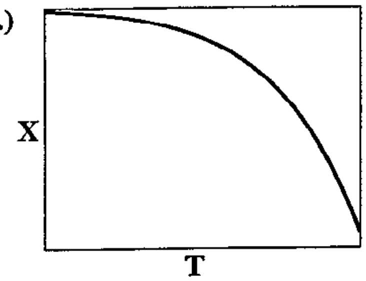
8.) For the reaction carried out at 100 °C and 1 atm: $CH_4(g) + CCl_4(g) \longrightarrow 2\,CH_2Cl_2(g)$, which of the following must be true?

A) $\Delta P > 0$ **B)** $\Delta H > 0$ **C)** $\Delta S > 0$ **D)** $\Delta G > 0$ **E)** $\Delta E > 0$

 Name: ______________________

In the following 3 problems, choose the one answer that best describes "X" in the given figures.

9.)

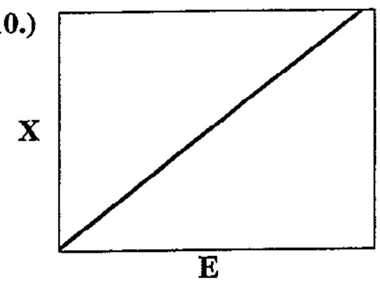


For the endothermic reaction, $SiO_2(s) \rightleftharpoons Si(s) + O_2(g)$, X=?

A) P B) mass of $SiO_2(s)$ C) K

D) Q E) total mass

10.)

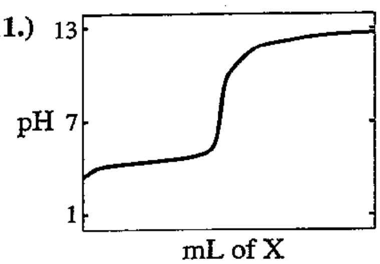


For 1 mole of an ideal gas at constant pressure, X=?

A) P/V B) u_{rms} C) 1/V

D) R E) V

11.)



For the titration curve, X=?

A) 1.0 M HCl B) 0.01 M NaOH C) 0.1 M NaOH

D) 0.1 M NH_3 E) 0.01 M NH_3

12.) A steel cylinder containing He(g) is fitted with a pressure release valve designed to open if the pressure exceeds 30 atm. If the helium has an initial pressure of 12 atm at 25 °C, to what temperature would you have to heat the gas to cause the valve to open?

A) 10 °C B) 63 °C C) 149 °C D) 400 °C E) 472 °C

13.) A mass of 2.875 g of a compound consisting of only nitrogen and oxygen is vaporized in a 1.0 L flask at 100 °C. The pressure in the flask is found to be 2.0 atm. What is the compound?

A) NO B) NO_2 C) N_2O D) N_2O_4 E) N_2O_5

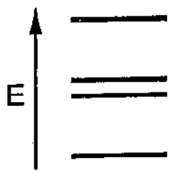
14.) Which of the following has the lowest ionization energy?

A) S^{2-} B) Cl^- C) Ar D) K^+ E) Ca^{2+}

 Name: ______________________

15.) For an isothermal ($\Delta T = 0$) expansion of a monatomic ideal gas against a constant external pressure of 0.5 atm in which 4.0 L·atm of heat is absorbed by the system, what is the change in volume, ΔV?

A) -4 L B) -2 L C) 4 L D) 8 L E) Can't determine.

16.) 

Which of the following is the correct emission spectrum for the energy level diagram pictured to the left?

A) 

B) 

C) 

D) 

E) 

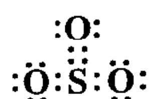
17.) What is the **approximate** $\Delta H°$ for the following reaction? Hint: there are two ways to solve this problem.

4 C-C + 3 H-H + 0.5 O=O -----> 2 C-O + 6 C-H

A) -1200 kJ B) -900 kJ C) -300 kJ D) -200 kJ E) 900 kJ

18.) For the reaction: $CO_2(g) \rightleftharpoons C(s) + O_2(g)$ at equilibrium, what happens to the reaction quotient, Q, relative to the equilibrium constant, K, if the volume is suddenly doubled without changing the temperature?

A) $Q < K$ B) $Q = K$ C) $Q > K$ D) $Q = \frac{1}{K}$ E) Can't determine.

19.) 

Pictured to the left is the Lewis electron dot structure for sulfur trioxide. What is the formal charge on the sulfur atom?

A) 2- B) 1- C) 0 D) 1+ E) 2+

20.) How many photons of yellow light ($\lambda = 600$ nm) would it take to stop a 2.0 gram bullet traveling at 55 m·sec^{-1} ($\lambda = 6x10^{-24}$ nm)?

A) 10^{-22} B) 10^{4} C) 10^{22} D) 10^{24} E) 10^{26}

21.) When mixed with excess acetic acid in a model air bag, 1.0 gram of which of the following carbonates should produce the most $CO_2(g)$?

A) $BeCO_3$ B) $MgCO_3$ C) Na_2CO_3 D) $CaCO_3$ E) K_2CO_3

 Name: ____________________

Section 2: Short Answer. 10 questions, 20 points each.

Answer the following four short answer questions. Partial credit will be given, so show your work whenever possible. Your final answers (including units where applicable) **must** be written in the boxes when provided.

1a.) (8 Points) Draw the Lewis electron dot structure for the sulfur tetrafluoride anion, SF_4^{2-}.

Lewis Dot Structure:

b.) (4 Points) What is the steric number (number of atoms and lone pairs) for the sulfur atom in SF_4^{2-}?

Steric Number =

c.) (8 Points) Draw and name the **molecular structure** (i.e. the geometric arrangement of the atoms) of SF_4^{2-}.

Molecular Structure:
Name:

 Name: ______________________

2.) Silicon nitride (Si_3N_4) is an extremely hard ceramic which has been suggested as a possible material for building a non-metal engine. Si_3N_4 can be made by reacting silicon tetrachloride ($SiCl_4$) with ammonia (NH_3).

a.) (5 points) Balance the equation for the formation of Si_3N_4.

_____ $SiCl_4$ (g) + _____ NH_3 (g) -----> _____ Si_3N_4 (s) + _____ HCl (g)

b.) (8 points) 10.0 grams of NH_3 are reacted with 10.0 grams of $SiCl_4$. Which of these reagents will be used up first?

Limiting Reagent =

c.) (7 points) If the reaction from part **b.)** is run to completion, how many moles of Si_3N_4 will be produced?

Moles of Si_3N_4 =

3.) Sulfur dioxide reacts with oxygen in the presence of a platinum catalyst to form sulfur trioxide:

$$2\,SO_2(g) + O_2(g) \longrightarrow 2\,SO_3(g)$$

a.) (8 Points) 4.0 moles of $SO_2(g)$ and 2.0 moles of $O_2(g)$ are placed in a 24.5 L sealed vessel without the catalyst (i.e. no reaction occurs) at 25 °C. What is the total pressure?

Total Pressure =

b.) (5 Points) What is the partial pressure of $SO_2(g)$ in the vessel before any reaction?

Partial Pressure =

c.) (7 Points) The platinum catalyst is added to the vessel and the reaction proceeds to completion without any change in temperature. What is the final pressure? Assume the platinum does not affect the volume.

Final Pressure =

 Name: ________________________

4a.) (10 Points) Determine ΔH_f^o in $kJ \cdot mol^{-1}$ for HCl and HF which are formed via the following exothermic reaction in which X = Cl or X = F.

$$H_2(g) \ + \ X_2(g) \ \text{----->} \ 2\,HX(g)$$

ΔH_f^o(HCl) =
ΔH_f^o(HF) =

b.) (10 Points) Which bond, H-Cl or H-F, is more polar? **In 20 words or less**, explain your choice in light of the enthalpies of formation you found in part **a.**).

Answer and Explanation:

5.) CN^- is the conjugate base to the weak acid HCN, with $K_a = 6.0 \times 10^{-10}$, $pK_a = 9.22$.

a.) (4 Points) What is K_b for CN^-?

K_b =

b.) (8 Points) What is the pH of 50 mL of a 0.1 M solution of NaCN (which dissociates completely to Na^+ and CN^-)?

pH =

c.) (8 Points) How many mL of 1.0 M HCl should be added to the solution in **b.)** in order to bring the pH to 9.22?

mL of 1.0 M HCl =

 Name: ______________________

6a.) (7 Points) The maximum wavelength of light which can eject electrons from a tungsten surface is 250 nm. What is the work function, Φ, for tungsten?

$\Phi =$

b.) (7 Points) What would be the ratio of kinetic energies of electrons ejected from a tungsten surface using 200 nm light to electrons ejected from a tungsten surface using 150 nm light?

$E_{200\ nm}/E_{150\ nm} =$

c.) (6 Points) If a photon with $\lambda = 250$ nm can eject one electron from a tungsten surface, how many electrons will a photon with $\lambda = 125$ nm eject?

of electrons =

7.) The dissolution of $NH_4NO_3(s)$ in water is an endothermic process, making it an ideal candidate for use with water in cold packs.

a.) (6 Points) What is $\Delta H°$ for the dissolution of $NH_4NO_3(s)$?

$\Delta H° =$

b.) (7 Points) If 0.50 moles of $NH_4NO_3(s)$ are dissolved in 100 mL of H_2O, what is the total amount of heat absorbed from the water?

q =

c.) (7 Points) If the water is initially at 25 °C, what will be the final temperature of the water?

T =

 Name: ____________________

8.) The famous 589 nm ($h\nu = 205$ kJ·mol^{-1}) yellow line in sodium arises from an electron initially in an excited state of sodium ([Ne]$3p^1$) falling into the ground state ([Ne]$3s^1$).

a.) (8 Points) If the ionization energy of a sodium atom in the ground state is 494 kJ·mol^{-1}, what is the ionization energy of an electron in the [Ne]$3p^1$ excited state?

$IE_{[Ne]3p1}$ =

b.) (6 Points) Would you expect the effective nuclear charge, Z_{eff}, that is felt by an electron in a 3s orbital to be higher, lower, or the same as the Z_{eff} felt by an electron in a 3p orbital? Circle your answer.

Higher Same Lower

c.) (6 Points) If sodium were ionized such that it had only one electron (Na^{10+}), what would be ΔE for the $3p^1$ ---> $3s^1$ transition?

ΔE =

9.) At 100 °C, $H_2O(\ell)$ is in equilibrium with 1.0 atm of $H_2O(g)$.

a.) (6 Points) $\Delta H°$ for the vaporization of water is +44.0 kJ·mol^{-1}. What is $\Delta S°$ for the vaporization of water at 100 °C? You will receive partial credit for the correct sign.

$\Delta S°$ =

b.) (7 Points) What is $\Delta G°$ for the vaporization of $H_2O(\ell)$ at 25 °C? You will receive partial credit for the correct sign.

$\Delta G°$ =

c.) (7 Points) What is the equilibrium partial pressure of $H_2O(g)$ at 25 °C?

Pressure =

 Name: ____________________

10.) A student uses the method we used in the spectroscopy lab to determined that the masses of chlorophyll A and B in a 1.25 mg sample of lettuce are 6.5×10^{-3} mg and 3.0×10^{-3} mg, repectively.

Species	Specific absorbance ($L \cdot cm \cdot mg^{-1}$) at 425 nm in ethanol
Chlorophyll A	81
Chlorophyll B	55
Carotene	60

a.) (8 Points) If the 1.25 mg of lettuce is dissolved in 1.0 L of ethanol, what would be the individual absorbances of chlorophyll A and B in the sample at 425 nm? The path length is 1.0 cm.

$A_{\text{chlorophyll A}} =$

$A_{\text{chlorophyll B}} =$

b.) (4 Points) When the absorbance of the 1.25 mg sample of lettuce in 1.0 L of ethanol is measured, the value of 0.825 suggests that a third compound is contributing to the total absorbance. If this is true, what is be the absorbance of the third compound at 425 nm?

$A_{\text{3rd component}} =$

c.) (8 Points) The assumption is made that the mystery third component of the absorbance is carotene, whose specific absorbance is given in the table above. If this assumption is correct, what would be the weight percent of carotene in lettuce? The path length is 1.0 cm.

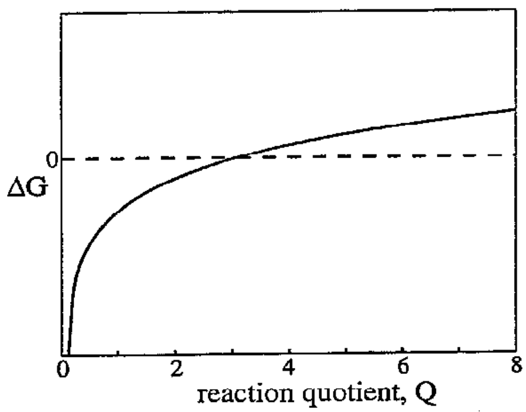
Weight Percent =

 Name: ____________________

Section 3: Finish the Picture. 8 questions, 10 points each.

For each question in this section, provide the sketch required on the same graph and, if you wish, explain your answer **in 20 words or less** in the box provided. Your explanation might allow partial credit to be assigned, but may also cost you points if it is incorrect.

1.) Shown below is a plot of ΔG as a function of the reaction quotient, Q, for a process in which the equilibrium constant, K, is equal to 3.0. Draw a plot of ΔG versus Q for a process in which K = 5.0.

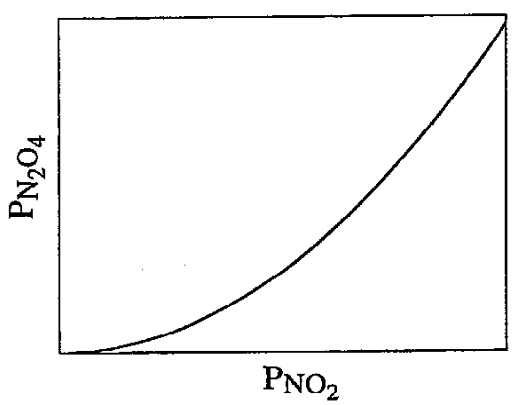


Explanation:

2.) Shown below is a plot of the partial pressure of N_2O_4 versus the partial pressure of NO_2 for the following exothermic process at equilibrium with the temperature held at 25 °C:

$$2\,NO_2(g) \rightleftharpoons N_2O_4\,(g)$$

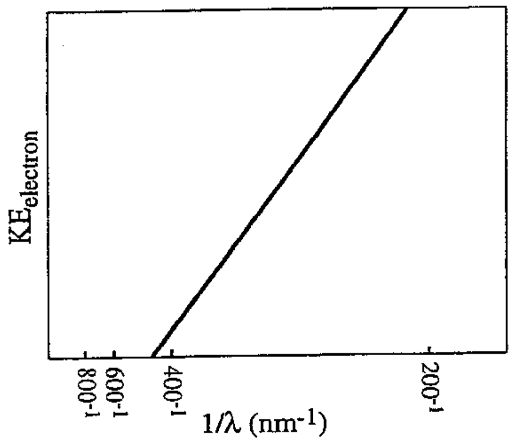
Draw a plot of $P_{N_2O_4}$ versus P_{NO_2} at equilibrium at a higher temperature.



Explanation:

 Name: ______________________

3.) Shown below is a plot of $KE_{electron}$ versus λ^{-1} (where λ is the wavelength of the light) for an electron which can be ejected by blue light but not by green light ($\lambda = 500$ nm). Draw a plot of $KE_{electron}$ versus λ^{-1} for an electron which can be ejected by green light, but not red light.



Explanation:

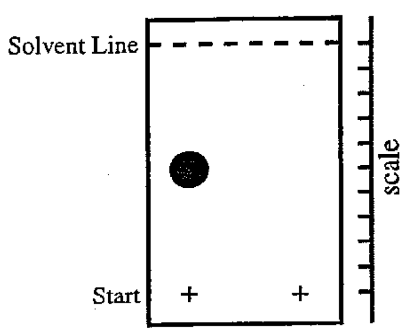
4.) Fill in the electron dots for the Lewis electron dot structure of phosphorus trifluoride, PF_3.

F

F **P** **F**

Explanation:

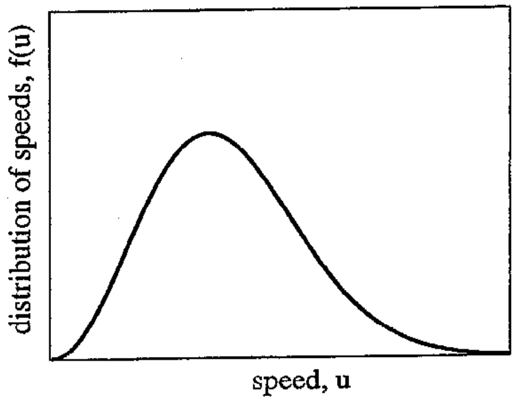
5.) Shown below is chromatogram of a compound with an R_f value of 0.5. Draw a spot at the correct location for a compound with an $R_f = 0.3$.



Explanation:

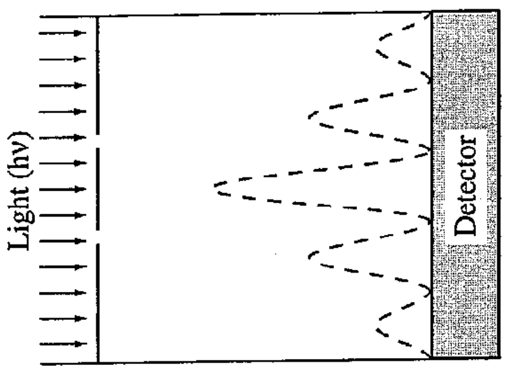
 Name: ______________________

6.) Shown below is a plot of the distribution of speeds of the molecules in an ideal gas at 25 °C. Draw a plot showing the distribution of speeds of the molecules for the same gas **at a** temperature lower than 25°C.



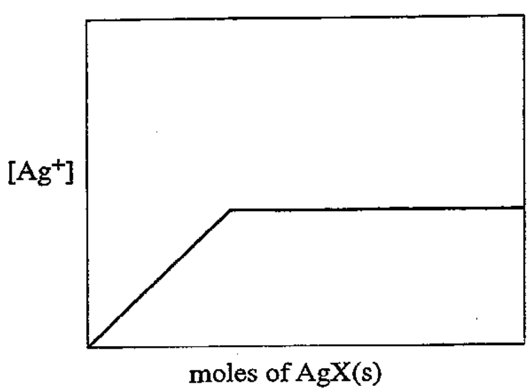
Explanation:

7.) Shown below is the interference pattern created when red light is diffracted through two slits. Sketch an interference pattern for green light diffracted through the same two slits.



Explanation:

8.) Shown below is a plot of $[Ag^+]$ as a function of the moles of AgX(s) added to 1.0 L of water where $X = Br^-$. Draw a plot of $[Ag^+]$ versus AgX(s) added when $X = Cl^-$. Note: the K_{sp} for AgCl is 1.6×10^{-10} and the K_{sp} for AgBr is 7.7×10^{-13}.



Explanation:

Name: ____________________

Ideal Gas:

PV=nRT

$R = 8.3145\ J{\cdot}mol^{-1}{\cdot}K^{-1}$

$R = 0.08206\ L{\cdot}atm{\cdot}mol^{-1}{\cdot}K^{-1}$

$E = \frac{3}{2}nRT$

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

Acids and Bases:

$K_w = [H_3O^+][OH^-] = K_aK_b$

$K_w = 1.0x10^{-14}$ at 25°C

$pH = -\log[H_3O^+]$

$pH = pK_a - \log\left(\frac{[HA]}{[A^-]}\right)$

Thermodynamics:

$\Delta E_{sys} = q + w$

$w = -P_{ext}\Delta V$

$\Delta E_{univ} = 0$

$\Delta S_{univ} \geq 0$

$\Delta G° = \Delta H° - T\Delta S°$

$\Delta G° = -RT\ln K$

$\Delta G = \Delta G° + RT\ln Q$

$\ln K = -\frac{\Delta H°}{R}\left(\frac{1}{T}\right) + \frac{\Delta S°}{R}$

$q = mC_p\Delta T$, $C_p = 4.18\ J{\cdot}g^{-1}{\cdot}K^{-1}$

$\Delta S^o = \sum S_f^o(prod) - \sum S_f^o(react)$

$\Delta H^o = \sum \Delta H_f^o(prod) - \sum \Delta H_f^o(react)$

$\Delta G^o = \sum \Delta G_f^o(prod) - \sum \Delta G_f^o(react)$

Quantum

$E_{photon} = h\nu = \frac{hc}{\lambda}$

$h = 6.626x10^{-34}\ J{\cdot}s$

$mu = p = \frac{h}{\lambda}$

$c = 3.00x10^8\ m{\cdot}s^{-1}$

$E_n = -\frac{Z^2}{n^2}R_y$

$R_y = 1312\ kJ{\cdot}mol^{-1}$

$KE_{electron} = h\nu - \Phi$

$\Delta E_n = -Z^2\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)R_y$

$IE = \frac{Z_{eff}^2}{n^2}R_y$

$1\ nm = 1x10^{-9}\ m$

$A = \varepsilon bc$

Standard Thermodynamic Parameters (25 °C)

Substance	ΔH_f^o ($kJ \cdot mol^{-1}$)	S_f^o ($J \cdot K^{-1} \cdot mol^{-1}$)	ΔG_f^o ($kJ \cdot mol^{-1}$)
$H_2O(\ell)$	-286		-237
$H_2O(g)$	-242		-228
$NH_4NO_3(s)$	-366	151	-184
$NH_4^+(aq)$	-133	113	-79
$NO_3^-(aq)$	-205	146	-109
$C_2H_6(g)$	-85	229	-33
$CH_3OCH_3(g)$	-184	266	-113
$C_2H_5OH(\ell)$	-278	161	-175

Bond Enthalpies (25 °C)

Bond	BE ($kJ \cdot mol^{-1}$)
C-C	350
C-O	350
O-O	140
H-H	450
C-H	410
O=O	500
H-F	560
H-Cl	430
Cl-Cl	240
F-F	160