

CHEM 117 FINAL REVIEW

Monday, April 20, 2015 12:32 PM

→ Experiment 1 Conservation Laws

- Purpose: To explore/determine whether mass and volume are conserved when two substances are mixed.

- Terms to know:

1) Calibration (What did you calibrate in this lab? Volumetric pipet)

- Allows you to relate experimental parameters to some fundamental quantities

2) Control Experiments

- intended to show whether or not a result may be solely due to some experimental factor that has not been properly taken into account.

- mixing H₂O w/ H₂O in Part B represents a control in this experiment.

3) Accuracy vs. Precision

- Accuracy: Being close to the accepted results (ie. small % difference)

- Precision: Reproducibility in results (ie. small standard deviation)

- Any possible relevant calculations:

1) Averaging:
$$\bar{x} = \frac{x_1 + x_2 + x_3 + \dots}{n}$$

4. Density:

$$\rho = \frac{m}{V}$$

2) Deviation:

$$= x_i - \bar{x}$$

3) Standard Deviation
$$\sigma = \sqrt{\frac{(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + (x_3 - \bar{x})^2 + \dots}{n-1}}$$

} Don't get these mixed up, know the difference.

- Major Results:

- mass \approx volume conserved in closed system

- since $\rho = \frac{m}{V}$, the density of a liquid

will effect what the mass is for a given volume

(ie. 5mL Acetone weighed less than 5mL H₂O)

* ALSO remember to go over Sig-Fig. rules and adhere to them on the final (can do this on their own)

→ Experiment 2: Aqueous Solutions and Solution Stoichiometry

- Purpose: To examine behavior of strong, weak, and non-electrolytes by measuring electrical conductivity and to study the stages of an acid-base reaction.

- Terms to know:

1) Electrolyte vs. nonelectrolyte solutions

- Electrolytes dissociate in solution to form ions which allow the solution to conduct electricity.

- Nonelectrolytes DO NOT dissociate to form ions in solution, therefore these solutions do not conduct electricity.

2) Strong Electrolyte

- Dissociate completely into ions; no intact electrically neutral solute molecules remain

3) Weak Electrolyte

- Dissociation occurs to a limited extent and most of the solute molecules remain intact.

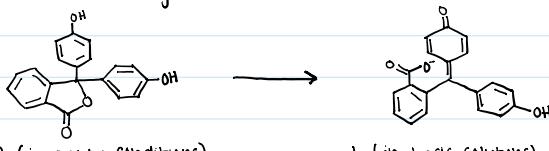
4) Acid-Base Titration

- you did this in part B. you titrated $\text{Ba}(\text{OH})_2$ of unknown [] with $\sim 0.08\text{M}$ H_2SO_4 . ($\text{Ba}(\text{OH})_2$ = base, H_2SO_4 = acid)

The goal was to reach the equivalence point in order to determine the $[\text{Ba}(\text{OH})_2]$.

5) Equivalence Point

- The point in a titration at which the species are in stoichiometrically equal amounts.
(in our experiment the reaction produced a precipitate, BaSO_4 , and water. Both are non-conducting. Therefore, the equivalence point was determined to be at the minimum conductivity).
- The equivalence point is commonly determined by an indicator.
(you used phenolphthalein; pink when basic, colorless when acidic due to structure change:



a. (in acidic conditions)

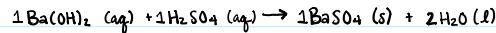
b. (in basic solutions)

Structure b has more double bond conjugation \Rightarrow absorbs in visible light region unlike structure A)

• Any relevant calculations:

1) Finding $[\text{Ba}(\text{OH})_2]$ from titration:

i) write out reaction (make sure it is balanced)



ii) find moles of H_2SO_4 @ equivalence point (b/c this is the species that you know the [] of)

How?

2) volume @ equiv. pt. \rightarrow moles using []

$$28.85 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 0.02885 \text{ L} \quad (\text{since } [\text{C}] = \frac{\text{mol}}{\text{L}})$$

$$\Rightarrow 0.02885 \text{ L H}_2\text{SO}_4 \times \frac{0.0803 \text{ mol H}_2\text{SO}_4}{1 \text{ L}} = 0.0232 \text{ mol H}_2\text{SO}_4$$

iii) find moles $\text{Ba}(\text{OH})_2$ @ equivalence point.

How?

a) stoichiometric ratio given by chemical reaction

$$0.0232 \text{ moles H}_2\text{SO}_4 \times \frac{1 \text{ mole Ba}(\text{OH})_2}{1 \text{ mole H}_2\text{SO}_4} = 0.0232 \text{ mol Ba}(\text{OH})_2$$

iv) find concentration of $\text{Ba}(\text{OH})_2$

How?

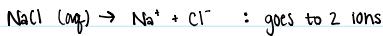
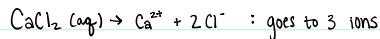
a) use volume of $\text{Ba}(\text{OH})_2$ you titrated

$$0.0232 \text{ mol Ba}(\text{OH})_2 \times \frac{1}{0.050 \text{ L Ba}(\text{OH})_2} = 0.464 \frac{\text{mol}}{\text{L}} \text{ Ba}(\text{OH})_2$$

• Major Results / things to understand:

- Strong electrolytes: NaCl , CaCl_2 , HCl

- weak electrolytes: CH_3COOH , tap H_2O
 - non electrolytes: $\text{C}_2\text{H}_5\text{OH}$, distilled H_2O
- * CaCl_2 would give higher conductivity than NaCl solution of the same concentration because:



- the more ions there are dissolved in solution the greater the electrical conductivity.

- know what is happening at a molecular level at each step of the titration.

1) Before the addition of H_2SO_4 :

- the beaker only contains Ba(OH)_2 which dissociates completely to $\text{Ba}^{2+} + 2\text{OH}^-$ ions
 \Rightarrow Conductivity is high

2) As H_2SO_4 is added, before equiv. pt. is reached:

- the H_2SO_4 reacts with Ba(OH)_2 to form solid $\text{Ba}(\text{SO}_4)$ and H_2O . Since the products formed do not dissociate in the solution the conductivity decreases as H_2SO_4 is added (because the amount of free ions in solution is decreasing)

3) At the equivalence point

- stoichiometrically equal amounts of $\text{H}_2\text{SO}_4 \equiv \text{Ba(OH)}_2$ in beaker \Rightarrow no excess ions in solution because all have reacted to form BaSO_4 precipitate $\not\equiv \text{H}_2\text{O}$
 \Rightarrow the conductivity is at a minimum

4) After the equivalence point

- All of the Ba(OH)_2 has reacted so H_2SO_4 is in excess ($\not\equiv$ unreacted) so it dissociates into ions which increases the conductivity

* Know how to read a buret

→ Experiment 3: Pressure, Volume & Temperature

- Purpose: to determine the relationships that exist among the pressure, volume and temperature of a sample of gas.

- Major results:

- Pressure-Volume Relationship: (done in Part A)

- Inversely proportional \Rightarrow as one increases the other decreases

- Can be written as $K = P \cdot V$

- Pressure-temperature Relationship:

- Directly Proportional \Rightarrow increase or decrease together

- Can be written as $\frac{P}{T} = K$

- Absolute zero:

- found by using linear regression of Pressure vs. temp ($^\circ\text{C}$) graph. y-int. represented temp in $^\circ\text{C}$ @ absolute zero.

- Explanation of Pressure-temperature Relationship using Kinetic Theory:

- Increasing the temperature increases the kinetic energy of the molecules which increases the number of collisions against the walls of the container. Since pressure is the measure of collisions against the container's walls, the increased kinetic energy increases the pressure.

* remember ideal gas law: $PV = nRT$ (using pure Nitrogen would not improve results b/c ideal gas law is independent of identity of a gas)

→ Experiment 5: Preparation and Optical Properties of Silver Nanoparticles

- Purpose: to introduce nanomaterials, spectrophotometry and Beer's law.

- Key concepts and terms

1) "nano"

- denotes factor of 10^{-9}
- Nanoparticles exhibit different properties by getting them so small by altering their sizes. They exhibit atom-like behavior. (change in color due to change in absorption λ b/c changing the size of the nano particles changes the Energy gap for transitions. behaves like particle in a box model)

2) Reducing Agent:

- In the lab NaBH_4 was the Reducing Agent
- The reducing Agent reduces the Silver from $\text{Ag}(\text{NO}_3)_2$ (this means that the reducing agent, NaBH_4 , itself is oxidized)
- Reduction step expressed as:



3) Oxidizing agent:

- The oxidizing Agent used in the experiment was H_2O_2 (The NaBH_4 and H_2O_2 are NOT reacting w/ each other)

4) Spectrophotometry:

- Visible light range $400\text{nm} - 700\text{nm}$



if a solution looks blue
it is really absorbing orange

light @ $590\text{nm} - 620\text{nm}$

$$\% \text{ Transmittance} = \frac{I}{I_0} \times 100$$

$$A = -\log(T)$$

5) Beer's law:

$$A = \epsilon b c$$

A = Absorbance

ϵ = molar absorptivity

b = path length (1cm b/c length of cuvette)

c = molar concentration of sample

- During the experiment, etc:

1) What each chemical did:

- AgNO_3 was reduced to silver metal particles
- NaBH_4 was the reducing Agent that was used to reduce the silver ions.

- H_2O_2 was an oxidizing agent used to etch the silver nanoprisms
- Sodium citrate created a buffer to resist changes in pH of the system
- NaBr would bind to the surface of the nanoparticles and restrict the particle growth

- Relevant calculations:

1) concentrations

$$M = n/V$$

2) dilutions

$$M_1 V_1 = M_2 V_2$$

$$\left(\frac{\text{mol}}{\text{L}}\right)(\text{L}) = \left(\frac{\text{mol}}{\text{L}}\right)(\text{L})$$

3) % transmittance:

$$T = \frac{I}{I_0}$$

$$\% = \frac{I}{I_0} \times 100$$

$$A = -\log T = -\log \frac{I}{I_0} = \log \frac{I_0}{I}$$

$$= \log \frac{1}{T} \quad \left\{ \frac{1}{T} = \frac{100}{\%T} \right\}$$

$$= \log \frac{100}{\%T}$$

$$= \log 100 - \log \%T$$

$\Rightarrow A = 2 - \log \%T$ (\leftarrow this is why you used this formula in the DRA)

4) The calculation that everyone missed:

to calculate ϵ :

1st calculate [nanoprisms]

$$\text{"moles" Ag Nanoprisms} = \frac{\text{moles of Ag}}{(\text{volume of prism}) (\text{density of Ag}) \left(\frac{\text{MW of silver}}{\text{mol}} \right) \left(\frac{6.022 \times 10^{23}}{\text{atoms/mol}} \right)}$$

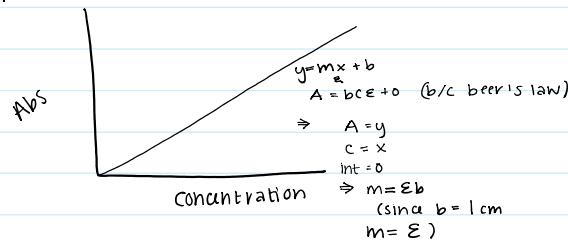
$$\Rightarrow \text{"moles" Ag Nanoprisms} = \frac{1.88 \times 10^{-6} \text{ moles Ag}}{(9400 \times 10^{-21} \text{ cm}^3) (10.5 \text{ g/cm}^3) \left(\frac{107.87 \text{ g/mol}}{1 \text{ mol}} \right) (6.022 \times 10^{23})} = X$$

↑ in unit conversion
must cube number too

$$\Rightarrow [\text{nanoprisms}] = \frac{X}{0.0145 \text{ L}}$$

↑ volume in vial

then plot:



- Major Results:

- Do NaBH_4 (reducing Agent) & H_2O_2 (oxidizing agent) react w/ each other?

No, otherwise you'd get no nanoparticles to form

- What does NaBr do?

NaBr controls size

\Rightarrow increasing $[\text{NaBr}]$ gives smaller

nanoparticles.

40 μL of NaBr produced

yellow solution \Rightarrow absorbed

@ 380 nm - 450 nm

This was the shortest wavelength.

Decreasing size increases ϵ gap for transitions

\Rightarrow absorption λ corresponds to ϵ gap

$$\epsilon = h\nu = \frac{hc}{\lambda}$$

$\Rightarrow \downarrow \lambda = \uparrow \epsilon = \downarrow$ nanopartical size

- Why must trendline for Beer's law plot be forced through origin?

$A = \epsilon bc$ which corresponds to $y = mx + b$ when $A=y$ & $c=x$

when $c=0$ there should be zero Absorbance of 0 b/c there are no particles present to block the light

$$\Rightarrow 0 = \epsilon b(0) \quad \& \quad 0 = m(0) + b$$

$\Rightarrow b$ must = 0 @ $(A, c) = (0, 0)$ to obey beer's law

* just adding point $(0,0)$ is not same as forcing trend through origin.

→ Experiment 7: From Atoms to Molecules - Theory & Models

- Drawing Lewis dot structures

1) e⁻ needed to fill all octets

2) e⁻ available (if the molecule has overall charge: negative \rightarrow Add charge value; positive \rightarrow subtract charge value)

3) how many e⁻ must be shared to fill octets (DRAW SKELETON & EVALUATE after this step)

4) lone pairs (how many available e⁻ that are not being shared)

example H₂SO₄

1) e⁻ needed

$$2(2) + 1(8) + 4(8) = 44e^-$$

2) e⁻ available (get from periodic table; group #)

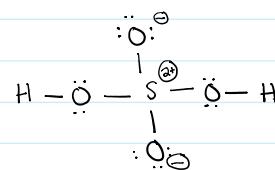
$$2(1) + 1(6) + 4(6) = 32e^-$$

$$3) 44e^- - 32e^- = 12e^- \quad (\frac{12e^- \text{ shared}}{2e^- \text{ / bond}} = 6 \text{ bonds})$$

{ Draw skeleton

{ the least electronegative atom is center;

{ it is also usually species w/ fewest atoms present }



H often goes to terminal O.

H is never central atom.

(note: this works out, but sometimes)

you have to go back & recalculate steps 1-3

incorporating an expanded octet. i.e. in

step one S would need 12 not 8 if step

2 does not change)

$$4) 32e^- - 12e^- = 20e^-$$

\Rightarrow 10 Lonepairs

Step one S would need 12 not 8 if step

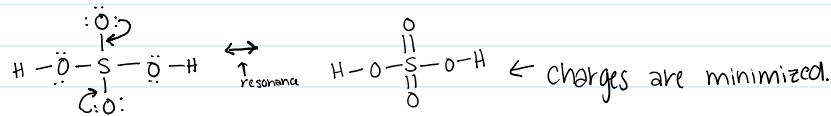
2 does not change)

* Once lone pairs have been added check for charges

& filled octets

- to count for charge bonds count as 1 & each \cdot as 1

- to count for octet bonds count as 2 & each • still 1
- * if the molecule has charges that can be minimized by double bonds
minimize the charges

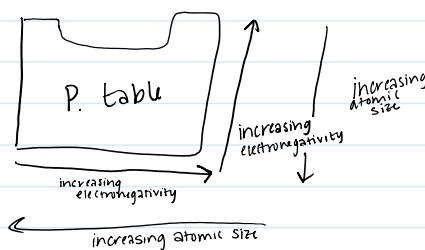


this could be done b/c S has d orbital (period 3 on)

so it can expand its octet

⇒ drawn as is it has an octet rule violator

- Polarity ↗ Periodic trends



Electronegativity is an atoms affinity towards the gain of e^-

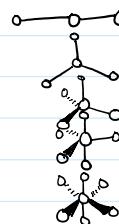
• bonds:

- ionic if $\Delta EN > 2.0$
- polar covalent if $1.6 > \Delta EN > 0.4$
- nonpolar covalent if $\Delta EN < 0.4$

- VSEPR

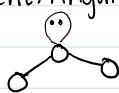
- Valence Shell Electron Pair Repulsion
 - used to show 3-D structure
- Electronic Geometries (no lone pair e- on central atom)

- Linear	180°
- Trigonal Planar	120°
- Tetrahedral	109.5°
- Trigonal Bipyramidal	$90^\circ, 120^\circ, 180^\circ$
- Octahedral	$90^\circ, 180^\circ$



• Molecular Geometries (e-pairs on central atom)

Bent/Angular



2 Bonded 1 LP
 $< 120^\circ$

T-shaped



3 B, 2 LP
 $< 90^\circ$

Trigonal Planar



3 Bonded 1 LP
 $< 109.5^\circ$

Linear



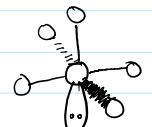
2 B, 3 LP
 $= 180^\circ$

Bent/Angular



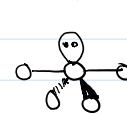
2 B, 2 LP
 $< 109.5^\circ$

Square Pyramidal



5 B, 1 LP
 $< 90^\circ$

See-Saw



4 B, 1 LP
 $< 120^\circ \approx < 90^\circ$

Square Planar



4 B, 2 LP
 $= 90^\circ$

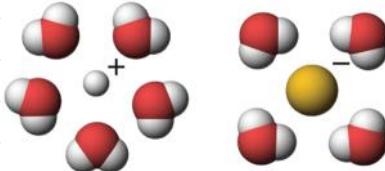
→ Experiment 9: Intermolecular forces

- Purpose: To learn how the strength of the intermolecular forces varies with molecular size & structure

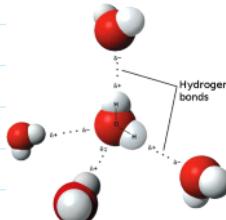
- Key points / terms:

- 1) Intermolecular forces (strongest → weakest)

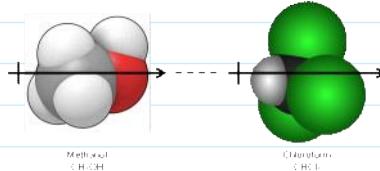
- Ionic dipole:



- Hydrogen bonding (H bound to terminal O, N or F)



- Van der Waals forces (permanent Dipole-Dipole)



- Ion induced dipole

- permanent dipole induced dipole

- Relevant calculations

- 1) calculating vapor pressure (Part B)

first find corrected air pressure:

$$\frac{\text{Corrected air pressure}}{\text{temperature of water/ice bath}} = \frac{P_2}{T_2} = \frac{P_1}{T_1} \leftarrow \begin{array}{l} \text{atmospheric pressure} \\ \text{room temp (K)} \end{array}$$

then

$$\text{vapor pressure} = \text{measured} - \text{corrected}$$

- Major Results

- 1) Alcohols have stronger IMFs than alkanes due to the presence of hydrogen bonding in the alcohols.

Alkanes do not experience hydrogen bonding because they lack the Electronegative N, O, or F to do so.

→ Seen in data by small ΔT for alcohols & large ΔT for alkanes

- 2) In addition to molecular structure, molecular size affects strength of IMFs. Increasing molecular size increases the strength of the IMFs.

→ Seen in data b/c butanol (largest of alcohols) had the smallest ΔT and methanol (smallest of the alcohols) had the

largest ΔT of the alcohols.

Same trend seen between hexane & pentane

- 3) Methanol has the larger vapor pressure compared to Ethanol
b/c its IMFs are weaker.

→ Experiment 14: Electroplating

- Purpose: To use electrolysis to plate tin onto copper & to calculate Avogadro's #

- Key terms / concepts:

- 1) oxidation / reduction Reactions:

O IL R I G

Oxidation Is Loss of Electrons Reduction Is Gain of Electrons

- 2) Electrochemical Cell:

- Apparatus where electrochemical reactions occur

- 2 types:

1) voltaic cells → spontaneous chemical rxns; produce electricity

2) electrolytic cells → nonspontaneous; use electrical energy

↑ you used this type in the lab.

- 3) Electrodes:

Cathode vs. Anode

Remember:

RED CAT & AN OX

reduction occurs @ the cathode

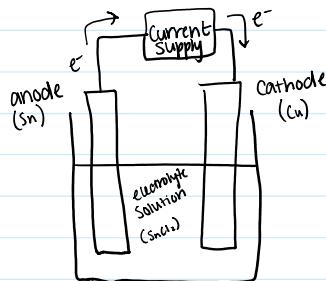
(Cu in Experiment)

oxidation occurs @ the anode

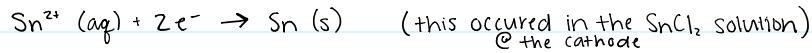
(Sn in Experiment)

- Experimental Stuff to know

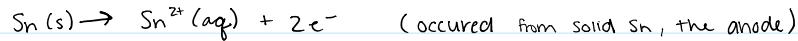
- 1) Set up:



- 2) Reduction Step:



- 3) Oxidation Step:



- Relevant Calculations:

- 1) Calculating Charge:

$$C = I \cdot S \leftarrow \text{time (s)}$$

\uparrow Charge (Coulombs) \downarrow Current (Amps; C/s)

- 2) Calculating # e⁻ transferred

$$C \cdot \frac{1 e^-}{1.602 \times 10^{-19} C} = \# e^- \text{ transferred}$$

\uparrow the charge of one electron.

- 3) Calculating # atoms plated

$$\# \text{ atoms} = \frac{\# e^-}{2 e^- \text{ per Sn Atom}}$$

(b/c Reduction step: $Sn^{2+} + 2 e^- \rightarrow Sn (s)$)

- 4) Avogadro's #

$$= \frac{\text{# atoms}}{\text{moles Sn plated}}$$

- Major Results

- Calculated Avogadro's # (6.022 E 23)
(w/o a flaw in the experiment b/c MW of Sn
is found from ^{12}C scale & doesn't depend on
Avogadro's #)

→ Experiment 10: Calorimetry & Hess's law

- Purpose: Use an indirect method to calculate the Heat of combustion of Magnesium based on Hess's law.
- Key terms / concepts

1) First law of thermodynamics

- States that the energy of a closed system is constant unless changed by work or heat.
 $(U = q + w)$

2) Hess's law:

- the overall enthalpy of reaction is equal to the sum of the enthalpies of the individual reactions into which it may be divided
 - ΔH is a state function & independent of path.
- * Know how to rearrange equations in order to calculate enthalpy from other reactions.

- Relevant Calculations / Equations:

$$1) q_f = m C \Delta T$$

$\xrightarrow{\text{mass}}$ $\xrightarrow{\text{specific heat}}$ $\xrightarrow{\text{change in temp}}$
 (g) heat of water $(^{\circ}\text{C})$
 $(\text{J/g} \cdot ^{\circ}\text{C})$

$$2) q_{\text{cal}} = C_{\text{cal}} \Delta T$$

\uparrow
calorimetric constant (J/C)

$$3) q_{\text{surr}} = m C \Delta T + C_{\text{cal}} \Delta T$$

$$4) H = q$$

5) Molar enthalpy change.

$$\Delta H^\circ = q_r / n$$

\uparrow
moles of Limiting Agent.

- Major Results:

- 1) Endothermic vs. Exothermic

↑ ↑
heat absorbed by rxn heat released by rxn.

2) Hess's law

- Change in Enthalpy is independent of path

→ Experiment 12: Chemical kinetics of the iodine clock reaction.

- Purpose: To explore how reaction rates can be affected by Temperature, concentration, and presence of a catalyst.

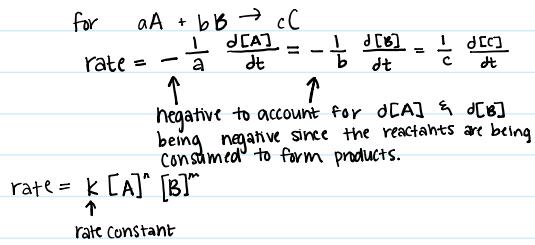
- Key terms / concepts:

1) rate expressions:

$$\text{for } aA + bB \rightarrow cC$$

$$\text{rate} = -\frac{1}{a} \frac{d[A]}{dt} = -\frac{1}{b} \frac{d[B]}{dt} = \frac{1}{c} \frac{d[C]}{dt}$$

\uparrow \uparrow



$n \neq m$ are the reaction order w/ respect to A & B

- i.e. if $[A]$ doubles and the reaction w/ respect to A
- does not change \rightarrow zeroth order
 - doubles \rightarrow first order
 - quadruples \rightarrow second order

$$n+m = \text{the overall rxn order}$$

2) Catalyst

- a substance that increases the reaction rate by creating a new reaction pathway

3) Some factors affecting reaction rates are:

- Concentrations of reactants
- Temperature
- Catalyst
- Surface area of solid reactants or catalyst
- **Collision Theory** – Not all molecular collisions result in a chemical reaction. Molecules must collide with a certain minimum energy in order to break existing bonds and form new ones. This activation energy, E_a , is affected by the factors above.

— Relevant Equations / Calculations

$$1) K = A e^{-E_a/RT} \quad \leftarrow \text{Arrhenius Equation}$$

↑
Experimentally determined pre-exponential factor

$$2) \ln(k) = -\frac{E_a}{RT} + \ln(A)$$

$$3) E_a = R \ln\left(\frac{k_2}{k_1}\right) \cdot \left(\frac{T_2 - T_1}{T_2 + T_1}\right)$$

— Major results:

- 1) Catalyst increases rxn rate
- 2) increasing temp. increases rxn rate
- 3) increasing concentration increases rxn rate

→ Experiment 13: Chemical Equilibrium

- Purpose: Calculate an equilibrium constant (K_{eq}) and

observe the effects of Le Chatelier's Principle.

- Key terms / concepts:

- 1) \rightleftharpoons denotes an equilibrium reaction
equilibrium is reached when the rate of the forward reaction is equal to the rate of the reverse rxn.

$$\text{i.e. } K_{\text{forward}} [A]_{eq} [B]_{eq} = K_{\text{reverse}} [C]_{eq}$$

- 2) For $aA + bB \rightleftharpoons cC$

$$K_{eq} = \frac{[C]^c}{[A]^a [B]^b}$$

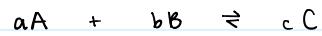
↑
equilibrium constant

$$K_{eq} = \frac{[C]^c}{[A]^a [B]^b} = \frac{K_{fwd}}{K_{rev.}}$$

↑ equilibrium constant
↑ these concentrations must be the concentrations at equilibrium.

- 3) to figure out equilibrium concentrations:

- USE ICE table



Initial	$[A]_i$	$[B]_i$	0	$\leftarrow b/c$ no product is formed before reaction progresses
Change	$-ax$	$-bx$	$+cx$	
Equilibrium Expression	$[A]_i - ax$	$[B]_i - bx$	cx	

$$\Rightarrow K_{eq} = \frac{(cx)^c}{([A]_i - ax)^a ([B]_i - bx)^b}$$

- Major results:

1) K_{eq} values constant at given temperature

2) Le Chatelier's Principle

- States that if a system at equilibrium is disturbed it will respond in a manner that minimizes the effects of the disturbance

(ie. \uparrow [reactants] will drive rxn to product formation
thus \uparrow [products], etc.)