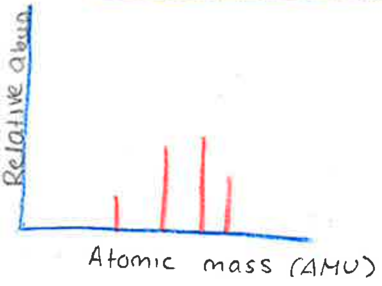
Unit 1

Mass to Moles conversion

$$\text{Moles} \cdot \frac{\text{grams}}{1\ \text{mole}} = \text{grams}$$

$$\text{grams} \cdot \frac{1\ \text{mole}}{\text{grams}} = \text{moles}$$

Mass spectra of elem.

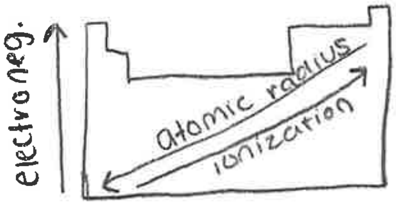


- when given an unknown element, use mass spec. + find relative amu to find element

Emperical Formula → Smallest whole # ratio

- Assume 100 g. sample
- convert percentage of, mass to moles
- Divide all moles by Smallest # of moles
- Multiply till whole.

Periodic Trends



- Elements in same column react similarily
- Effective nuclear charge → net positive charge pulling e^- to nuc.

↳ anions have less effective nuc. charge while cations have more

Molecular Formula

- Find emperical formula

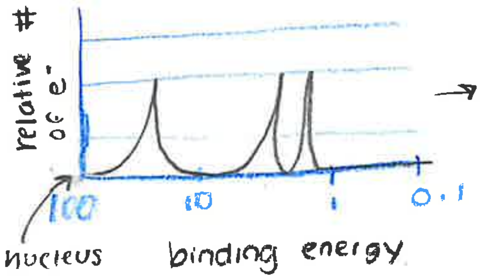
* Molecular Form = (Emperical form) × n

$$n = \frac{\text{molar mass of compound}}{\text{molar mass of emp. form.}}$$

Electron config.

Be → $1s^2 2s^2$

Photoelectron spectroscopy

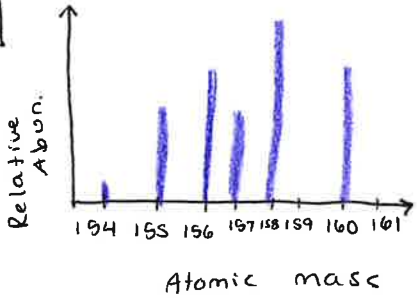


→ $1s^2 2s^2 2p^2$

- The electrons in the outermost shells (furthest right) need least energy to be removed b/c of electron shielding + Coulumb's law.
- Relative height of each peak is proportional to # of e^- in subsell

1.1 convert 5.0g of CaO to moles.

1.2



which element is the mass spectrum most consistent w/?

ⓐ Eu
ⓑ Gd
ⓒ Tb
ⓓ Dy

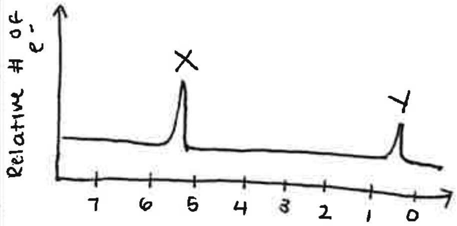
1.3 Calculate the empirical formula for a substance containing 1.11 g of Se & 1.61 g of F.

1.5

$1s^2 2s^2 2p^6 3s^2 3p^2$

Find the Element with this Electron configuration.

1.6



which peak corresponds to the 1s peak?

FRQ #1

(a) In terms of atomic structure, explain why the atomic radius of K is larger than Na.

(b) In terms of atomic structure, explain why the first-ionization energy of K is less than Ca.

(c) K forms the compound K_2O, which is an ionic compound that is brittle. Identify another element, M, that is likely to form a brittle, ionic compound with formula M_2O.

(d) The compound K_2O exists. A chemist can determine the mass of K in a sample of known mass that consists of either pure K_2O or pure K_2O_2. Can the chemist answer the question of the compound in the sample.

KEY

1.1) $\frac{5.0g}{56g/mol}$

1.2) C. Tb

1.3) SeF_6

1.5) Si

1.6) Peak X

*Frq answers in Unit 1 Progress Check Frq

Unit 2 : Compound structure and properties

Types of chemical bonds

Ionic - A bond between a metal and non-metal

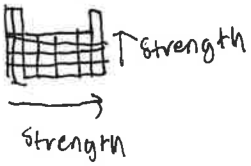
Covalent - A bond between two non-metals

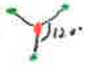
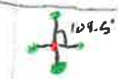
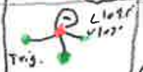
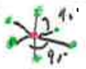
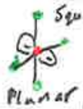
Polar covalent - high difference in electronegativity between two nonmetal

Non-Polar covalent - low difference in electronegativity between two nonmetal

metallic - Metal atoms share their outermost electrons, creating a "sea" of delocalized electrons that freely move around the positively charged metal ions, effectively holding the metal atoms together

Electronegativity increases as it goes left to right & decreases when going top to bottom on periodic table

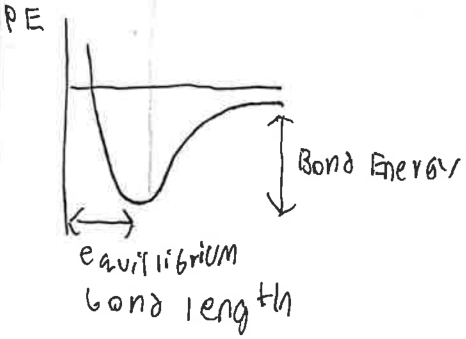


Electron-pair geometry	No lone pairs	1 lone pair	2 lone pairs	3 lone pairs	4 lone pairs
Linear					
Trig. planar		 Bent			
Tetrahedral		 Trig. Pyramidal	 Bent		
Trig. bipyramidal		 Sawhorse	 T-shaped	 Linear	
octahedral		 Square pyramidal	 Square Planar	 T-shaped	 Linear

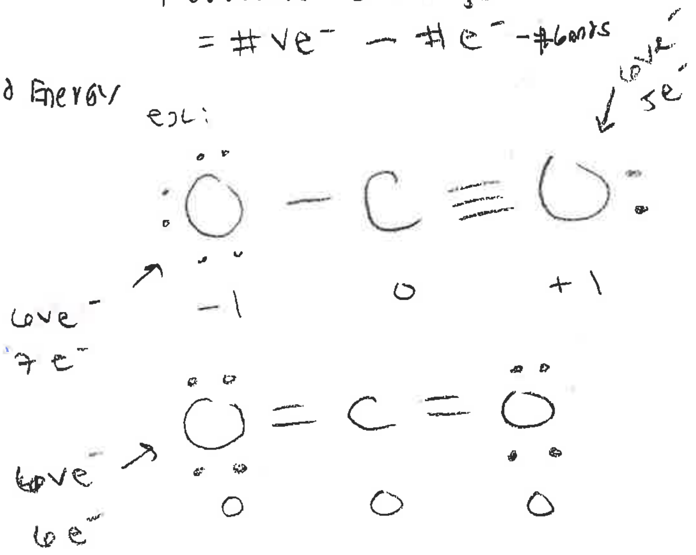
Alloys:

When two or more metals are bonded, interstitial uses smaller elements btw atoms, substitutional replaces one element with another

Electron Geometry	hybridization	σ and π bonds
tetrahedral	sp^3	σ
trig. Planar	sp^2	1σ 1π
Linear	sp	1σ 2π



Formal Charge:
$= \# ve^- - \# e^- - \# bonds$



Wonc 1234!

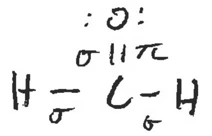
Molecular orbital Theory: describes how the orbital shapes combine when atoms combine into molecules

Orbitals always try to be in the lowest state of energy.

Bond order correlates with bond strength

More bonds = More attractive energy

① Draw Lewis Structure of CH_2O and identify electron-geometry, hybridization, and σ or π bonds.

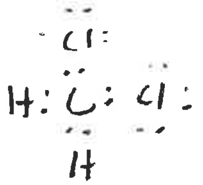


sp^2 hybridization 120°

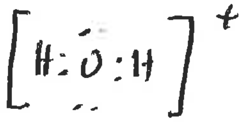
trigonal planar

② Draw Lewis Structure

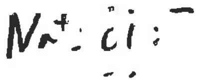
a) CH_2Cl_2



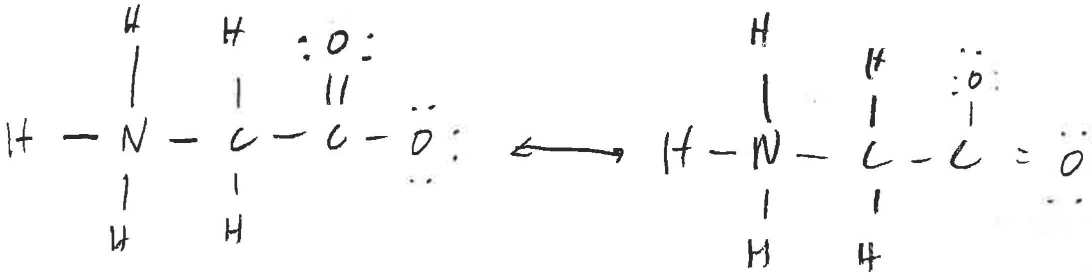
b) H_3O^+



c) NaCl



③ Based on resonance structure, explain what can be said about the bond length of the two carbon-oxygen bonds



Two carbon-oxygen bond lengths are the same → why they are interchangable

④

What has higher energy?

NaCl or MgO

⑤ predict the molecular geometry & bond angles

a. CH_4

b. BF_3

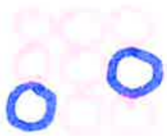
c. CH_3Cl

6) which model best represents cupro-nickel? Justify your answer.

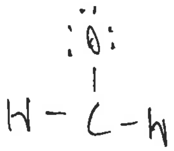
element	atomic radii
copper	128
nickel	163

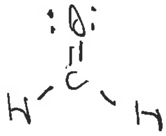
a)

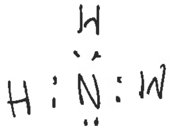
b)



7) Which of the diagrams best represent CH_2O







8. Based on the lewis diagram for NH_3, what is the bond angle?

Unit 3: properties of substances & Mixtures study Guide

Intermolecular Forces

Dispersion Bonds

- weakest force of 3
- the IMF that exist
- all types of molecules
- temporary bond
- Low boiling point
- simple attraction of atoms electrons & protons

Dipole-dipole bonds

- Attractive forces between polar molecules
  - ↳ pos. end & neg. end of 2 polar molecules.
- permenant bond
- Medium boiling pt

Hydrogen bonds

- strongest bond
  - ↳ "really strong dipole-dipole"
- Happens when hydrogen bonds w/ Florine, oxygen, or Nitrogen (FON)
- permenant bond
- High boiling pt.

solids liquids & gasses

example: H_2O

solid

- very structured
- little to no energy for molecules to move
- no macroscopic movement

liquid

- molecules somewhat close together
- some energy to flow

gas

- Bouncing & moving
- Molecules far from eachother
- no attraction bc. high energy

Molarity

*concentration of solute in solution

solute: thing being disolved

solvent: thing doing the disolving

solution: combination of both.

$$M = \frac{\text{mole soute}}{1\ \text{L soloution}}$$

solubility

*Ability of solute to disolve in solvent: to form homogeneous sltn.

↳ temp. affects solubility: more temp → more KE → more energy to break bonds.

*Aqueous solvents made of water. → naturally polar because of Hydrogen bonds

*non aqueous solvents are nonpolar. → ex: oil, held together by despersion forces.

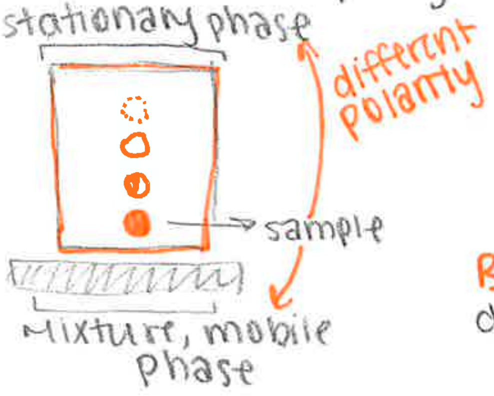
*"Likes disolve likes"

polar molecules will disolve in aqueous solutions. non polar molecules will disolve in non aqueous solutrons.

↳ Basically, poles have to be similar in order for the pull on bonds to be strong enough to break & ∴ disolve.

chromatography

there are varying degrees of polarity. chromatography uses this (competing IMFs) to seperate mixtures.



- depending on if the sample's polarity is more similar to the stationary or mobile phase, it will travel up more or less, seperating itself.

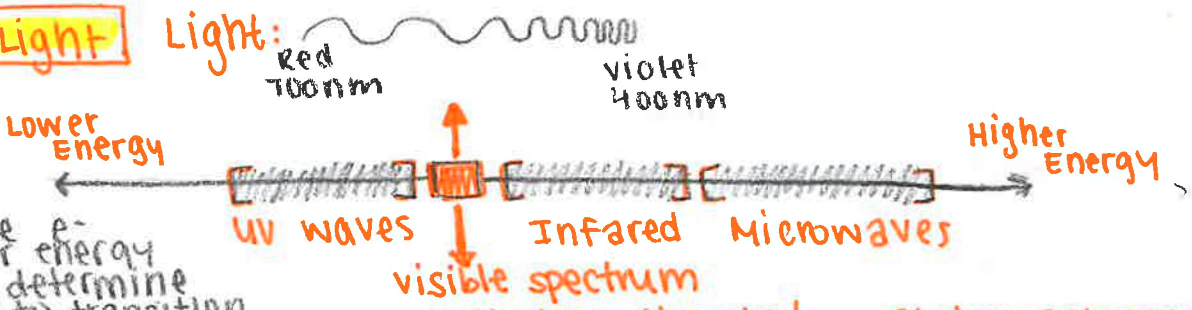
↳ seperation occours due to differences in polarity, solubility, or molecular size.

Retention Factor

distance sample moved : distance solvent moved :)

Waves and Light

Light:



UV waves: make e- move to higher energy level. Helps to determine energy required to transition energy levels.

Infared waves: Make bonds vibrate. Helps to determine bond strength.

Microwaves: Make Molecules rotate. can det. shape + distance of atoms

*** photon Absorbed**

energy brings e- to higher energy level.
↳ endothermic.

photon Released

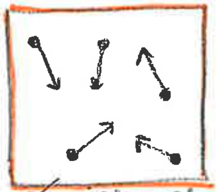
e- goes back to original energy level + emits colored light.
↳ exothermic

Ideal gas law

$PV = nRT$

- works when particle voloume is negligible to vol. of container
- workes with High KE so that temperature is high enough for no intermolecular interaction

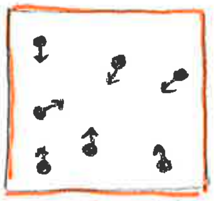
* works at STP



$$P = \frac{nRT}{V}$$

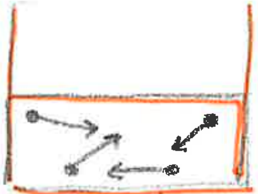
☑ High vol.
☑ High temp

when ideal gas law fails



high vol.
Low temp

Bc. of low temp, the particles have less KE to overcome IMF. attraction so they stick together + hit walls less. this lowers preassure. The IGL would predict that less temp = less preassure but dosent predict why.



low vol.
High temp.

since preassure + vol. are inverse, the IGL would predict that less vol = more preassure. But, since the vol. is less, particle size is no longer negligible + actually take up lots of space so hit walls more often. The preassure becomes higher than predicted.

Kinetic Molecular theory

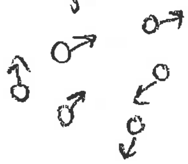
* uses kinetic energy to predict the behaivor of Matter

	Macro properties	Micro properties
Solid	- low KE - not compressable - Holds shape	- Slow moving particles - strong IMF
Liquid	- Medium KE - some compress. - fluid shape	- some moving particles - Medium IMF
Gas	- High KE - yes compress. - Moving	- Fast moving particles - weak IMF

solid

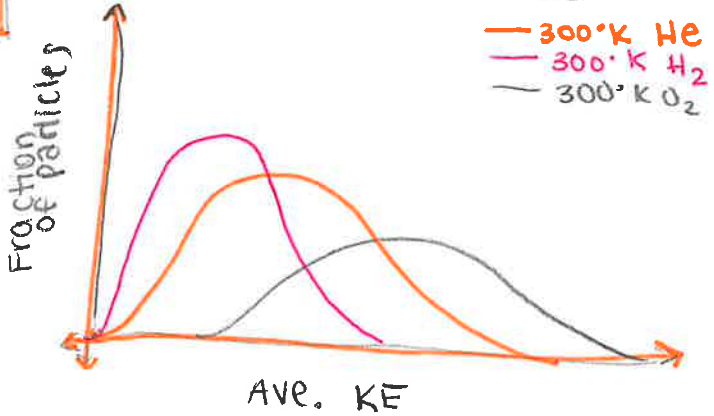
liquid

gas



Maxwell Boltzman distribution

Temp. ∝ Ave KE
↳ Temp. ∝ $\frac{1}{2}mv^2$
↳ stays constant ∴ KE must stay constant.
- if a particle is heavier, the velocity must be less to compensate + vice. versa



Practice Problems Unit 3

1. Determine the molarity of a solution formed by dissolving 7.45g of potassium chloride in 500mL of water.

2. The solubility of NaCl in water is 36g per 100g of water at 20°C. How many grams of NaCl can dissolve in 250g of water at the same temperature?

3. Which element does Hydrogen interact with to become a Hydrogen Bond?

4. What intermolecular bond occurs when two polar molecules are attracted towards each other?

5. Which phase of matter would occur when hydrogen is at absolute zero?

6. Which state of matter takes on the shape, but not the volume, of its container?

7. If $T \propto KE$ & T is constant, then what happens to the velocity of a particle if its mass increases?

⑧ If a sample of a polar substance was placed in a chromatography mechanism with an aqueous solution as the mobile phase & non polar stationary phase, how would it act.

⑨ how do each, uv, infared, & microwaves affect molecules

⑩ what is one scinario where the ideal gas law is wrong?

Chemical Reactions

UNIT 4

MEMORIZE

Sodium Na^+
Potassium K^+
Ammonia NH_4^+
Nitrate NO_3^-

All Soluble

$M_a V_a = M_B V_B$

$(M_{acid}) \cdot (V_{acid}) = (M_{Base}) \cdot (V_{Base})$

Physical Vs. Chemical changes

Physical	Chemical
- Melting	- Combustion
- Freezing	- Rusting
- Boiling	- irreversible
- Reversible	- New product
- Cutting	- Breaking bonds
- $H_2O(s)$ + Heat -> $H_2O(l)$	- $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

No change in bonds

Types of Reactions

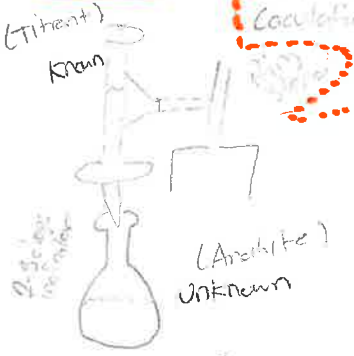
Percipitation: 2 Reactants in aqueous solution form percipitate (insoluble solid)
Ex: $Ag_2NO_{3(aq)} + NaCl_{(aq)} \rightarrow AgCl_{(s)} + NaNO_3(aq)$

Acid-Base: Occur between acid (H^+) and base (OH^-)
Ex: $HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O(l)$

Redox: Transfer of electrons from Reactant to Reactant
Ex: $Zn_{(s)} + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$ (Zn = oxidation, Cu = reduction)

Titrations

A solution of known concentration is added drop by drop to a solution of unknown concentration until chemical reaction is complete, allowing a calculation of unknown solution, by measuring how much known solution was needed.



(Acid + Base)

Ex:

Trys to find concentration of

Acid Base Titration

Problem:
$HCl_{(aq)} + KOH_{(aq)} \rightarrow H_2O(l) + KCl(aq)$

HCl is in 1:1 ratio

Given:
- HCl: 15mL M?
- KOH: 18.5mL 0.75 M

$0.0185L\ KOH \times \frac{0.75\ mol\ KOH}{1L\ KOH} = 0.013875\ mol\ KOH$

$\frac{0.013875\ mol\ HCl}{0.01500L\ HCl} = \boxed{0.93M}$ (HCl)

Balancing Redox Reactions

1) Assign oxidation numbers (oxidation loses electrons)
2) Separate half reactions
3) Balance atoms (excluding H and O)
4) Balance oxygen by adding H_2O
5) Balance hydrogen by adding H^+
6) Balance charge by adding electrons
7) Equalize electrons by common factor
8) Combine half reactions
9) Cancel out stuff on both side

IF BASIC SOLUTION DO THESE

10) Add OH^- to cancel out H^+ by creating H_2O
11) Equalize the new H_2O

Examples

1) $H_2Se(g) + 4O_2F_2(g) \rightarrow SeF_6(g) + 2HF(g) + 4O_2(g)$

Which of the following is true?

A Oxidation # of O doesn't change.

B ox # of H goes from -1 to +1

C ox # of F goes from +1 to -1

D ox # of Se goes from -2 to +6

2) Which of the following is reduction

A $Ca(s) \rightarrow Ca^{2+}(aq)$

B $Fe^{2+}(aq) \rightarrow Fe^{3+}(aq)$

C $NO_3^-(aq) \rightarrow NO(g)$

D $SO_3^{2-}(aq) \rightarrow SO_4^{2-}(aq)$

Example Problems (Unit 4)

1) $H_2Se(g) + 4O_2F_2(g) \rightarrow SeF_6(g) + 2HF(g) + 4O_2(g)$

Which of the following is true?

A oxidation # of O doesn't change

B ox # of H goes from -1 to 1

C ox # of F goes from -2 to +6

2) Which is reduction?

A $Ca(s) \rightarrow Ca^{2+}(aq)$

B $Fe^{2+}(aq) \rightarrow Fe^{3+}(aq)$

C $NO_3^-(aq) \rightarrow NO(g)$

D $SO_3^{2-}(aq) \rightarrow SO_4^{2-}(aq)$

3) Balance each equation according to half reaction method:

a) $MnO_4^-(aq) + NO_2^-(aq) \rightarrow MnO_2(s) + NO_3^-(aq)$ (in base)

b) $MnO_4^{2-}(aq) \rightarrow MnO_4^-(aq) + MnO_2(s)$ (in base)

c) $Br_2(l) + SO_2(g) \rightarrow Br^-(aq) + SO_4^{2-}(aq)$ (in acid)

4) $2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$

The exothermic process above is best classified as:

A physical change because a new phase appears in products

B Physical change because $O_2(g)$ that was dissolved comes out of solution

C chemical change because entropy increases as process proceeds

D Chemical change because covalent bonds are broken and new covalent bonds are formed.

unit 5: kinetics

key concepts

- focus on understanding the concepts behind rate laws, mechanisms, and factors effecting rates
- practice graph interpretation (zero, first, second)

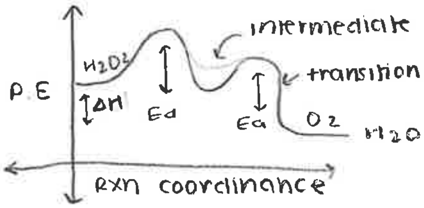
Reaction Mechanism | Elementary step

- Elementary steps → reaction can occur in multiple steps. Rate law written directly from its molecularity.
  - unimolecular: one reactant
  - Biomolecular: two reactants
  - termolecular: three reactants (rare)
- Homo vs. Hetero Reactions
  - Homo: all reactants same phase
  - Hetero: different phases

Transition State Theory

How to increase likelihood of rxn?

- ↓ volume
- ↓ time
- + catalyst
- ↑ reacting substance
- ↑ surface Area : volume ratio



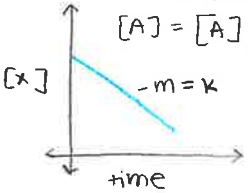
Graph explained:
- y-axis is the potential energy
- x-axis is the reaction coordinate (used to present progress of the chemical rxn)
  - Activated complex / first transition state is the energy required for the reactant to produce
  - After first dip, an intermediate may be formed.
  - The activated complex 2 show the activation energy needed for the second transition Stat
  - If final P.E lower mean the reaction loses energy (exo)
- If final P.E level is higher, reaction gains energy (endothermic.
- The lower the activation energy, the rxn is more likely to occur.

Reaction Rate laws

Zero-order

$$Rate = k$$

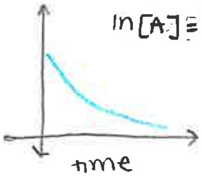
$$[A] = [A]_0 - kt$$



first-order

$$Rate = k[A]$$

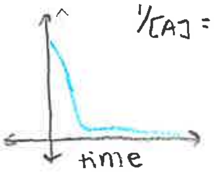
$$\ln[A] = \ln[A]_0 - kt$$



second-order

$$Rate = k[A]^2$$

$$1/[A] = 1/[A]_0 + kt$$



$m = \frac{\Delta C}{\Delta t}$ rate $= k[A]^m[B]^n$ [A] and [B] are concentrations of rxns

Rate law Determination

- Data used to determine → observing how rate changes as the concentration of one reactant is varied while keeping the others constant.
  - First order: Rate is directly proportional to concentration of one reactant.
  - Second order: Rate proportional to the square of the concentration

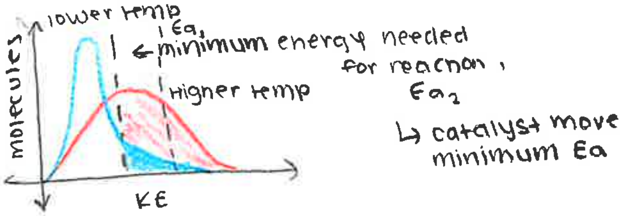
Collision Theory

- intermediates = species that are produced in one step and consumed in subsequent steps
- catalyst: substance that increases the rate of a chem. rxn w/o itself undergoing permenant chemical change. Appears at beginning and end.
- collision theory.
  - Reactants must collide
  - Molecules must have sufficient activation energy
  - Molecules must be in proper orientation
- Activation Energy (Ea): minimum energy required to initiate reaction.
- Transition state: highest energy configuration along reaction path, where bonds are breaking and forming.
- Factors affecting rate:
  - Temp: increasing temp increases the rate of rxn by increasing the frequency of collisions and energy of collisions (more molecules have energy equal to or greater than Ea
  - concentration: increasing the concentration of reactants increases number of collisions, thus increasing the rate.
  - surface Area: increased surface Area allows more collisions and thus increases the rate (impt. for heterogenous rxns)
  - catalyst: provide an alternate rxn pathway with a lower activation energy, increasing the rxn rate.

Determining the Rate Determining step (RDS)

- identify the slowest step in proposed rxn mechanism
- Step with highest Activation Energy

Bolman Distribution



↳ catalyst moves minimum Ea

PRACTICE EXERCISES

MCQ (pg 333 Barons book)

1. why does an increase in temperature increase the rate of a rxn?

Ⓐ Ea increases

Ⓑ Temp. acts as a catalyst

Ⓒ more collisions / sec that will have proper energy to exceed Ea

Ⓓ Greater proportion of collisions w/ correct orientation to be effective

SOLUTION: C

Questions 2 + 3 refer to the following proposed mechanism:

$Cl_2(g) \rightarrow 2Cl(g)$ FAST

$Cl(g) + CHCl_3(g) \rightarrow CCl_3(g) + HCl(g)$ SLOW

$CCl_3(g) + Cl(g) \rightarrow CCl_4(g)$ FAST

2. what is the overall rxn equation for this mechanism?

Ⓐ $Cl(g) + CHCl_3(g) \rightarrow CCl_3(g) + HCl(g)$

Ⓑ $Cl_2(g) + CHCl_3(g) \rightarrow HCl(g) + CCl_4(g)$

Ⓒ $CCl_3(g) + Cl(g) \rightarrow CCl_4(g)$

Ⓓ $Cl_2(g) + CHCl_3(g) + CCl_3(g) \rightarrow HCl(g) + CCl_4(g)$

SOLUTION: B

3. which of the following rate laws is consistent w/ the proposed mechanism?

Ⓐ rate = k $[CHCl_3][Cl]$

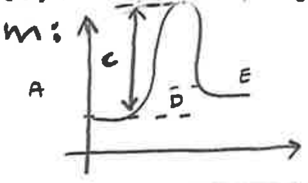
Ⓑ rate = k $[CCl_3][Cl]$

Ⓒ rate = k $[Cl_2]$

Ⓓ rate = k $[Cl_2][CHCl_3]$

SOLUTION: A

Questions 4 + 5 refer to the following diagram:



5. addition of a catalyst to the rxn affects only:

[✓ Ⓐ A.] Ⓒ C.

Ⓑ B. Ⓓ D.

4. in the rxn profile A, B, + C should be labeled as shown in:

	A	B	C
Ⓐ	PE	rxn coordinate	Ea
Ⓑ	heat of rxn	rxn coord.	PE
Ⓒ	PE	rxn coord.	heat of rxn
Ⓓ	heat of rxn	PE	Ea

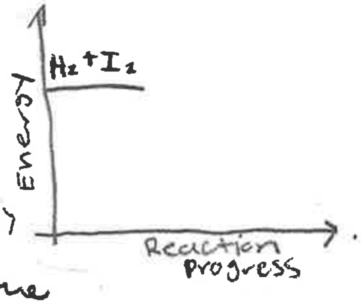
SOLUTION: A

FRQ #1

$H_{2(g)} + I_{2(g)} \rightarrow 2HI_{(g)}$

$\Delta H^\circ_{rxn} = -9.5$ kJ/mol rxn

Shown below is an incomplete energy diagram for the reaction. The PE of the reactants is indicated on the diagram:



A: complete the energy diagram by drawing a curve that shows the progress of the reaction. Begin at the reactants, move through the transition state, and end at the final products. Use an energy level that is appropriate to the energy level of the reactants

B: on energy diagram, draw a dashed curve to show reaction progress from reactants to products in the presence of a catalyst

C: Draw a vertical line segment with a length that corresponds to the activation energy for the reverse uncatalyzed reaction:

$2HI_{(g)} \rightarrow H_{2(g)} + I_{2(g)}$