CHEMISTRY

Atoms	Bonds	Stoichiometry
Elements Matter Models Trends Electrons Relations Configuration Radioactivity Half Life	Intramolecular Ionic Covalent Structure Localized Quantum Intermolecular Solids States	Stoichiometry Conservation Solutions Reactions Precipitation Oxidation Reduction Behaviour Gases Solutions

Physical	Organic	Inorganic
Kinetics Rate Laws Reaction Mechanism Equilibrium Weak Acid Buffers Precipitation Thermodynamics Heat Free Energy Electrochemistry	Structure Conformations Configurations Mechanisms Thermodynamics Kinetics Synthesis Alkanes Alkenes Alkynes Aromatics	Coordination Structure Mechanisms Solids Structure Energetics Descriptive Ideas Hydrogen Oxygen Representative

ELEMENTS

matter		
matter	pure substances	elements and compounds
	states of matter	solid liquid gas
	chemical changes	change of substance
	physical changes	no change substance
	physical properties	internal independent of amount
mixtures	mingled pure substances	homogenous same composition
	separation into pure substances	physical chemical techniques
	distillation	physical boiling point
	chromatography	physical carrier affinity
	gravimetric	chemical precipitation

models		
models	atoms	Dalton
	plum pudding	Thomson
	electron charge	Millikan
	positive core	Rutherford
	electron orbitals	Bohr
	electron cloud	Schrodinger
trends	$\mathbf{F} = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{\mathbf{r}^2}$	Coulomb
	charge effect	number of protons
	distance effect	inverse square law
	atomic radius	ionization energy
	electron affinity	electronegativity

ELECTRONS

relations		
electrons	$E = h\nu$	Planck
	$K = hf - E_0$	Einstein
	$E = -R_H\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right)$	Bohr
	$n = 1{,}2{,}3$	Lyman Balmer Paschen
photons	$E = mc^2$	Einstein
	$\lambda\nu = c$	Maxwell

configuration		
orbitals	shell	$n = 3$
	shape	$l = 1 \ldots n = spdf$
	orientation	$m_l = -l \ldots l$
	spin	$m_s = \pm 1/2$
	$3p$ 3 orbitals 6 electrons	$n = 3\ l = 1\ m_l = -1{,}0{,}1$
rules	Pauli	unique quantum numbers
	aufbau	fill in increasing energy
	Hund	unpaired then pairs
exceptions	chromium and copper	complete d before s
	ion removal	$4s$ before $3d$

RADIOACTIVITY

radioactivity		
radioactivity	nuclei decomposition	conserve mass and charge
	stability ratio	3 : 2 neutron proton
	${}^{A}_{Z}X$ nuclide	unique atom
	A nucleons atomic mass	Z protons atomic number
decay	${}^{4}_{2}He$ helium	alpha decay
	${}^{0}_{-1}e$ electron	beta decay
	${}^{0}_{0}\gamma$ photon	gamma decay
	${}^{A}_{Z-1}Y$ proton to neutron	electron capture
	${}^{0}_{+1}e$ positive charge	positron capture

half life		
half life	time to decay	to half original amount
	$\frac{dN}{dt} = -kN$	first order differential equation
	$\ln N = -kt + \ln N_0$	separation of variables
	$\ln\left(\frac{N}{N_0}\right) = -kt$	rearrange
	$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$	plug in half amount

NOMENCLATURE

compounds		
ionic	metal nonmetal	sodium chloride
	multiple oxidation	iron (II) chloride
ions	cations	sodium ion
	anions	chloride ion
covalent	nonmetal nonmetal	dinitrogen monoxide
	common names	water ammonia
acids	no oxygen	hydrofluoric acid
	oxygen	sulfuric acid

oxoacids		
oxoacids	representative of main groups	congeners all similar
	add O perchloric acid	remove O hypochlorous acid
	3A H_3BO_3	boric acid
	4A H_2CO_3	carbonic acid
	5A H_3PO_4	phosphoric acid
	5A* HNO_3	nitric acid exception
	6A H_2SO_4	sulfuric acid
	7A $HClO_3$	chloric acid
anions	oxoacid loses hydrogen	makes negative anion
	chloric acid to chlorite	chlorous acid to chlorate

INTRAMOLECULAR

intramolecular		
intramolecular	electron sharing	between atoms
	bond type depends on	electronegativity difference
energy	balance Coulomb	attraction and repulsion
	stable equilibrium	at lowest energy

ionic		
ionic	large difference	electrons transferred
	strong ionic bond	ion on ion force
	weak covalent bond	polarized electron cloud
structure	activation energy to ionize	Born-Haber
	solid crystal lattice	balance forces
	complete valence	stable low energy
ion radius	charge effect	across period smaller radius
	distance effect	down group larger radius

covalent		
polar	intermediate difference	electrons unequally shared
	weak ionic bond	partial charges
	strong covalent bond	nucleus electron attractions
covalent	small difference	electrons equally shared
	covalent bond	nucleus electron attraction
structure	complete valence	stable low energy
	simple localized model	realistic quantum orbitals

LOCALIZED

localized		
model	electrons are	localized at position
	lone pair on atom or	bonding pair in between
	complete valence	stable low energy
Lewis	skeleton of atoms	total valence electrons
	single bonds	outer then central
	double bonds	as needed for octet
resonance	multiple coexisting	valid structures
	equivalent contributions	of same bond types
	non-equivalent contributions	by octet rule formal charges
formal charge	difference from	neutral valence electrons
	bonding electrons	shared equally
	unlike oxidation states	which are too exaggerated

shape		
VSEPR	minimize	lone pair repulsion
	assume	identical angles
	nomenclature	ignore lone pairs
hybridization	methane	two s two p bonds
	identical angles	not different bonds
	sp^3 hybridization	four merged orbitals
double bonds	sp^2 hybridization	three identical orbitals
	single p orbital	left over
	$sp^2 - sp^2$ σ first bond	$p - p$ π second bond

QUANTUM

molecular orbital		
model	quantum orbitals	complex but accurate
	distinct energy levels	even of unpaired electrons
molecular orbitals	combinations of	atomic quantum orbitals
	bonding orbitals	stable lower energy
	antibonding orbitals	unstable higher energy
stability	$\frac{\text{bonding } e^- - \text{antibonding } e^-}{2}$	bond order
	H_2 Li_2 stable	He_2 Be_2 unstable

diatomic		
$2s$ **orbitals**	σ_{2s} between atoms	bonding stable low energy
	$\sigma_{2s}{}^*$ outside atoms	antibonding unstable high energy
$2p$ **orbitals**	σ_{2p} one bonding between	$\sigma_{2p}{}^*$ one antibonding outside
	π_{2p} two bonding	$\pi_{2p}{}^*$ two antibonding
paramagnetic	molecular orbital	contains unpaired electron
	$p - s$ mixing	explains B_2 C_2 N_2
heteronuclear	adjacent atoms have	same molecular orbitals
	none adjacent atoms	have different orbitals

INTERMOLECULAR

intermolecular		
intermolecular	weaker than	intramolecular
	results in	states of matter
dipole-dipole	polar compounds	partial charges
	hydrogen bonds $FONCl$	especially strong force
	large polarity short distance	water has high boiling point
dispersion	induced dipole	partial charges
	nuclear distortion	of electron cloud
	noble gases	low freezing point
	larger atoms	more polarizable
	down group	higher melting point

solids		
solids	crystalline lattice	of repeating cells
	different nodes	and different bonds
metallic	metal atoms Cu	metallic electron sea
	conductor malleable	high melting point
network	nonmetal atoms C	covalent bonds
	insulator brittle	high melting point
ionic	ions Na^+Cl^-	ionic bonds
	insulator	high melting point
molecular	molecules SiO_4	intermolecular
	insulator	low melting point

STATES

vapor pressure		
vapor pressure	equilibrium between	evaporation and condensation
	weaker intermolecular forces	more evaporation larger pressure
temperature	higher temperature	more kinetic energy
	escape intermolecular forces	larger vapor pressure

states		
states	input energy breaks	intermolecular bonds
	substance changes state	melting point and boiling point
heating curve	input heat increase energy	solid to liquid to gas
	constant temperature until	all bonds broken state change
vapor pressure	independent for	solid and liquid states
	increase with temperature	at different rates
	equilibrium temperature	is the melting point

phase diagram		
phase diagram	the state of a substance	at given pressure volume
	for a closed system	under controlled conditions
example	thermal contact with reservoir	increase heat and tempearture
	piston moves expands volume	maintain pressure at one atm
	liquid vapor pressure	increases with temperature
	equals one atmosphere	at 100 degrees
	that is the transition point	between liquid and gas
	as progress horizontally	at one atm on pV diagram

STOICHIOMETRY

stoichiometry		
stoichiometry	balanced reactions	by conservation mass charge
	atomic mass unit	1/12 of carbon twelve
	atomic mass	isotopes nucleon mass
	molar mass	mass of one mole
	percent composition	of reactants by mass
	empirical formula	the generic reduced ratio
	molecular formula	the specific ratio
limiting	the reactant	that runs out first
	when matched	by mass conservation
yield	theoretical yield	as calculated
	percent yield	actual experimental result

solutions		
solutions	substances in water	hydration pulls apart
	how much dissolves	competing forces equilibrium
saturation	maximum dissolution	of a given solution
	concentration constant	no longer changes as add
conductivity	strong electrolytes	full dissolution into ions
	has mobile charges	is good conductor
reaction	molecular undissociated	ionic dissociated ions
	net ionic equation	cancel spectator ions
driving force	precipitation	solubility
	acid base	acid strength
	oxidation reduction	reduction potential

REACTIONS

precipitation		
precipitation	two aqueous solutions	makes solid precipitate
	competing forces	larger charge less soluble
soluble	alkali metals	Na^+ Li^+ K^+
	ammonium	NH_4^+
	halogens sulfate	Cl^- Br^- I^-
	single charge polyatomics	NO_3^- $C_2H_3O_2^-$ ClO_3^-
	sulfate	SO_4^{2-}
insoluble	single charge metal	Ag^+ Hg_2^{2+}
	double charge metals	Ba^{2+} Ca^{2+} Pb^{2+} Mg^{2+}
	multi charge polyatomics	CO_3^{2-} PO_4^{3-}

oxidation reduction		
oxidation reduction	electron transfer	by electron affinity
	use oxidation state	to track electron movement
oxidation state	ionic bonds by charge	covalent bonds wholly assign
	oxidation increase lose electron	reduction decrease gain electron
	fluorine negative one	oxygen -2 except H_2O_2
	monoatomic ion same as charge	H $+1$ covalent -1 ionic NaH
balance equation	match electron transfer	by charge conservation
	create half reactions	of oxidation reduction
	balance elements except H O	balance oxygen with H_2O
	balance hydrogen with H^+	balance charge with electrons
	equalize electron transfer	multiplication of half reactions
	combine cancel half reactions	basic add OH^- make water

GASES

ideal gas law		
ideal gas law	experimental behaviour	of all gases
	$pV = nRT$	state variables
	0 celsius 1 atm 1 mole 22.4L	all gases at standard conditions
partial pressure	total pressure	is sum of partial pressures
	$P_T = P_1 + P_2$	total is sum of partials
	colligative property	depends on number particles

kinetic molecular theory		
kinetic molecular theory	theoretical behaviour	matches experimental results
	assumptions	kinetic energy elastic collisions
	$K = \frac{3}{2}RT$	temperature is internal energy
distribution	particle energy distribution	Maxwell-Boltzmann
	reaction activation energy	higher temperature more likely
dispersion	effusion rate to vacuum	diffusion rate of mixing gases
	$\frac{E_1}{E_2} = \frac{v_1}{v_2} = \sqrt{\frac{m_2}{m_1}}$	proportional particle masses

SOLUTIONS

ideal solution law		
vapor pressure	equilibrium gas pressure	of evaporation and condensation
	non volatile solute	has no evaporation
	when replaces part of solution	decreases vapor pressure
ideal solution law	total pressure	proportional to solvent fraction
	$P = \chi_{\text{solvent}} P_{\text{solvent}}$	ratio with nonvolatile solute
	mixture of solvents	mixture of partial pressures
	$P_T = = \chi_A P_A + \chi_B P_B$	by partial pressure

colligative		
colligative	property that depends	on number of particles
	number particles variable	van't Hoff
boiling point elevation	non volatile solute	lowers vapor pressure
	needs higher temperature	to reach one atmosphere
freezing point depression	non volatile solute	lowers liquid pressure
	needs lower temperature	for equal pressure
osmotic pressure	semipermeable membrane	blocks solute passage
	solvent transfer depends	on concentration gradient
	$\Psi_s = iCRT$	lower solute more pressure

RATE LAWS

differential		
rate law	$A + B \to C$	single step reaction
	speed of reaction	rate of change substances
	rates for different reagents	related by mass conservation
differential	instantaneous rate	at specific time
	proportional to	instant concentrations
	rate $= k[A]^m[B]^n$	experimentally determined
limiting	rate $= k'[A]^m$	limiting reactants
	excess reactants	at constant concentration

integral		
integral	rate of reaction	as function of time
	solution of	differential equation
zeroth order	$\frac{d[A]}{dt} = k[A]^0 = k$	$[A] = kt + [A]_0$
	$[A]$ linear	constant rate enzyme surface
first order	$\frac{d[A]}{dt} = k[A]^1$	$\ln[A] = kt + \ln[A]_0$
	$\ln[A]$ linear	$t_{1/2} = \frac{\ln 2}{k}$
second order	$\frac{d[A]}{dt} = k[A]^1$	$\frac{1}{[A]} = kt + \frac{1}{[A]_0}$
	$\frac{1}{[A]}$ linear	half lives double previous

REACTION MECHANISM

reaction mechanism		
reaction mechanism	$A + B \rightarrow C + D \rightarrow E$	multiple step reaction
	series of steps	with intermediate products
	elementary single step	rate law by molecularity
	$aA + bB \leftrightarrow cC$	reversible or non reversible
	rate $= k[A]^a[B]^b$	collision combination
	rate determining step	is the slowest step
	intermediate products	remove by substitution
	fast reversible step	is equal forward and backward
steady state approximation	intermediate product	rate of change is zero
	simplifies gracefully	either step rate determining
	examples	surface and enzyme catalysts

collision model		
Arrhenius	reaction requires	successful collision
	$k = Ae^{-E_a/RT}$	collision model
	constant	frequency and orientation
	temperature	higher more collisions
	activation energy	lower more successful
catalyst	speed up reaction	without being consumed
	lowers reaction	activation energy
	heterogenous	different state than reactants
	holds reactant in place	absorption adsorption
	homogenous	same state as reactants
	one of unconsumed	intermediate products

EQUILIBRIUM

equilibrium		
equilibrium	reversible reactions	equilibrium equal rates
	$aA + bB \rightleftharpoons cC + dD$	equal molecularity rates
	$K = \dfrac{[C]^c[D]^d}{[A]^a[B]^b}$	law of mass action
partial pressure	pressure is proportional	to concentration
	$K_p = \dfrac{(P_A)^a(P_B)^b}{(P_C)^c(P_D)^d}$	various RT factors

Le Chatelier		
Le Chatelier	disturbed equilibrium	resists change
	reaction quotient	determines direction
changes	concentration	changes concentrations
	volume or pressure	changes moles of gas
	inert gas same total volume	no changes same partials
	temperature	heat reagent changes equilibrium

multiple equilibria		
classic	first use stoichiometry	take reaction to completion
	then use equilibrium	adjust from final state
dominant	pretent that	one reaction is dominant
	drive to completion	then check for consistency
mass charge balance	use laws of conservation	solve system of linear equations
	by numerical iterations	or ratio substitution

ACID BASE

acid base		
acids	acid base reaction	is exchange of protons
	$HA_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+{}_{(aq)} + A^-{}_{(aq)}$	
	ionization in water	water acts as base
	water and conjugate base	battle for protons
dissociation constant	$K_a = \frac{[H^+][A^-]}{[HA]}$	law of mass action
	equilibrium constant	for water ionization
	use proton for hydronium	by convention
bases	$B_{(aq)} + H_2O_{(l)} \rightleftharpoons OH^-{}_{(aq)} + BH^+{}_{(aq)}$	
	ionization in water	water acts as acid
	$K_b = \frac{[BH^+][OH^-]}{[B]}$	law of mass action

water		
water	$2H_2O_{(l)} \rightleftharpoons H_3O^+{}_{(aq)} + OH^-{}_{(aq)}$	
	amphoteric	can act as acid or base
	autoionization	acid and base with self
dissociation constant	$K_w = [H^+][OH^-]$	law of mass action
	equilibrium constant	for autoionization
	$K_w = 1.0 \times 10^{-14}$	for any solution at $25°C$
	if acidic has more protons	if basic has more hydroxides
pH	$pH = -\log[H^+]$	shorthand expression
	$pK_w = pH + pOH = 14$	substitution

WEAK ACID

weak acid		
weak acid	list all acid reactions	that produce protons
	use dominant reaction	dissociation constant
	others are not material	such as water autoionization
	determine equilibrium with	initial change equilibrium
percent dissociation	$\frac{[H^+]}{[HA]_0} \times 100\,\%$	dissociation at equilibrium
	dilute concentration has	higher percent dissociation
	because adding water	reduces all concentrations
polyprotic acids	can donate	more than one proton
	successive steps	are weaker acids
	use dominant reaction	find equilibrium concentration

characteristics		
salts	ionic compounds that	dissolve completely to ions
	solution has variable pH	acid base properties of ions
	$K_a \times K_b = K_w$	K_1 versus K_2
	first equilibrium effect	secondary cycle immaterial
structure	$H - X$ halides	bond strength and polarity
	$K_a(HX) > K_a(HF)$	close bond too strong
	$H - O - X$ oxoacids	electron withdrawing ability
	$K_a(HClO_3) > K_a(HClO)$	more withdrawing more polar

BUFFERS

common ions		
common ions	weak acid solution	with related salt
	the salt dissolves	to conjugate base
equilibrium	presence of common ions	disturbs equilibrium
	updated initial concentrations	settles to new equilibrium

buffer		
buffer	weak acid	with conjugate base
	solution resists	change in pH
	calculate buffer effects	stoichiometry then equilibrium
stoichiometry	add strong base	drives to completion
	proton and hydroxide	cancel mole for mole
equilibrium	weak acid equilibrium	updated initial concentrations
	initial change equilibrium	settles to new equilibrium
Henderson-Hasselbalch	$[H^+] = K_a \frac{[HA]}{[A^-]}$	rearrangement
	if $[HA], [A^-] > [OH^-]$	small change in pH
	$pH = pK_a + \log\left(\frac{[A^-]}{[HA]}\right)$	buffered solution pH
capacity	available amount	of buffering
	$[A^-], [HA]$	larger absorb more
	$\frac{[A^-]}{[HA]} = 1$	least change to pH
	$pH = pK_a$	optimal buffer

TITRATION

titration		
titration	add titrant to analyte	to investigate analyte
	series of buffers	resulting pH per volume added
equivalence point	protons and hydroxide	all cancelled mole for mole
	equivalence pH by	produced conjugate equilibrium
halfway point	half weak acid cancelled	half conjugate produced
	$pH = pK_a$	Henderson-Hasselbalch
polyprotic acids	hydroxide drives	series of weak acids
	titration curve	is a staircase
indicators	choose color change	match equivalence point
	one tenth change detectable	equals pH range of one

weak acid strong base		
stoichiometry	add strong base	drive to completion
	left with remaining	weak acid conjugate base
equilibrium	weak acid equilibrium	updated initial concentrations
	determine pH	updated volume with titrant
equivalence point	strong base with weak acid	all used up mole for mole
	left with remaining	produced conjugate base
	weak base equilibrium	for hydroxide concentration
beyond equivalance	excess strong base	dominates conjugate base
	hydroxide determines pH	curve identical to strong acid
characteristics	different weak acids	same equivalence point
	amount of weak acid	is amount base required
	strength of weak acid	pH at equivalence point

PRECIPITATION

solubility		
solubility	$CaF_{2(s)} + H_2O_{(l)} \rightleftharpoons Ca^{2+}{}_{(aq)} + 2F^{-}{}_{(aq)}$	
	$s = [CaF_{2(s)}]$	dissolved solid moles
	$K_{sp} = [Ca^{2+}][F^-]^2$	law of mass action
stoichiometry	reaction quotient	sets direction
	drive to completion	mole for mole
equilibrium	then adjust	to equilibrium
	initial change equilibrium	updated initial concentrations
deviations	common ions	additional reduces solubility
	complex ions	captured increases solubility
	selective precipitation	lower threshhold goes first

qualitative		
qualitative analysis	mixture containing	all common cations
	five major groups	based on solubilities
I insoluble chlorides	add dilute HCl	Ag^+ Pb^{2+} Hg_2^{2+}
II sulfides insoluble in acid	add H_2S	Hg^{2+} Cd^{2+} Bi^{3+} Cu^{2+} Sn^{4+}
III sulfides insoluble in basic	make basic add H_2S	Co^{2+} Zn^{2+} Mn^{2+} Ni^{2+} Fe^{2+}
IV insoluble carbonates	add CO_3^{2-}	Ba^{2+} Ca^{2+} Mg^{2+}
V alkali metal ammonium	flame test on original	Mg white
	Ca Li Sr red	Fe Na yellow
	B Ba Cu green	K Rb Cs blue purple

MULTIPLE

acid base		
multiple	multiple step reaction	each with own equilibrium
	system of equations	with conservation laws
acid base	$H_2A \rightleftharpoons H^+ + HA^-$	$HA^- \rightleftharpoons H^+ + A^{2-}$
	$[A]_0 = [H_2A] + [HA^-] + [A^{2-}]$	mass conservation
	$[H^+] = [HA^-] + 2[A^{2-}]$	charge conservation
	pH overlapping bell curves	by component mole fractions
	$pH = pK_{avg}$	when equal component fractions

coordination		
coordination	step wise substitutions	first step faster more targets
	$Ag(H_2O)_6^+ + NH_3 \rightleftharpoons Ag(NH_3)(H_2O)_5^+ \quad \beta_2 = K_1K_2$	
	$Ag^+ + NH_3 \rightleftharpoons Ag(NH_3)^+$	$K_1 = \frac{[Ag(NH_3)^+]}{[Ag^+][NH_3]}$
	$Ag(NH_3)^+ + NH_3 \rightleftharpoons Ag(NH_3)_2^+$	$K_2 = \frac{[Ag(NH_3)_2^+]}{[Ag(NH_3)^+][NH_3]}$
mole fraction	$C_0 = [Ag^+] + [Ag(NH_3)^+] + [Ag(NH_3)_2^+]$	
	$C_0 = [Ag^+]\left(1 + \beta_1[NH_3] + \beta_2[NH_3]^2\right)$	
	$X(Ag^+) = \frac{[Ag^+]}{C_0} = \frac{1}{1 + \beta_1[NH_3] + \beta_2[NH_3]^2}$	
	$X(Ag(NH_3)^+) = \frac{[Ag(NH_3)^+]}{C_0} = \frac{\beta_1[Ag^+][NH_3]}{C_0}$	
	$X(Ag(NH_3)^+] = \beta_1[NH_3]X(Ag^+)$	$X(Ag(NH_3)_2^+] = \beta_2[NH_3]^2X(Ag^+)$

ENTHALPY

first law		
first law	internal energy	is heat and work
	$\Delta E = Q + W$	conservation of energy
	energy in transit	due to temperature difference
	$Q = mc\Delta T$	heat

enthalpy		
enthalpy	$H = E + PV$	a measure of heat
	$\Delta H = Q$	constant pressure substitution
	heat transfer between	system and surroundings
	endothermic positive	exothermic negative
	$\Delta H_{reaction} = H_{products} - H_{reactants}$	
	total for reaction sum of steps	Hess
	is reversible	opposite for reverse process
	is extensible	value proportional to quantity
formation	forming common compounds	at STP $25°C$ 1atm 1mol
	$\Delta H_f^\circ\text{(reaction)} = \Delta H_f^\circ\text{(products)} - \Delta H_f^\circ\text{(reactants)}$	
	elemental constituents	zero enthalpy change
	difference in bond energies	Born-Haber

ENTROPY

second law		
second law	universe entropy	always increases
	$\Delta S_{\text{univ}} = \Delta S_{\text{sys}} + \Delta S_{\text{surr}}$	spontaneous direction
system	positional entropy	of statistical distribution
	shortcut for molecules	state number complexity
surroundings	heat flow to and from	by random motion
	$-\frac{Q}{T} = -\frac{\Delta H}{T}$	impact proportional temperature
formation	reversible	extensible
	$\Delta S^\circ\,(\text{reaction}) = \Delta S^\circ\,(\text{products}) - \Delta S^\circ\,(\text{reactants})$	

free energy		
free energy	$\Delta S_{\text{univ}} = -\frac{\Delta G}{T}$	spontaneous direction
	$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$	energy available for work
	total energy in heat	minus loss in energy quality
	reversible	extensible
	$\Delta G^\circ\,(\text{reaction}) = \Delta G_f^\circ\,(\text{products}) - \Delta G_f^\circ\,(\text{reactants})$	
	free energy available	in non standard conditions
deviation	energy temperature relation	proportional to partial pressures
	$\Delta G = \Delta G^\circ + RT\,\ln(Q)$	based on reaction quotient
equilibrium	through kinetics	equal forward backward rates
	through thermodynamics	stable lowest energy
	$\Delta G^\circ = -RT\,\ln(K)$	kinetics and thermodynamics

ELECTROCHEMISTRY

galvanic cell		
electrochemistry	oxidation reduction reaction	is the flow of electrons
	energy transformation	chemical to electrical
galvanic cell	if direct exchange	then charge build up stops flow
	so use indirect exchange	to maintain electron flow
	electrode metal conductors	are sites of electron transfer
	if reactant is not solid	use surface of inert platinum
cell potential	reactants pull electrons	called electromotive force
	standard reduction potential	pull strength vs hydrogen gas
	$\varepsilon°(\text{cell}) = \varepsilon°(\text{cathode}) - \varepsilon°(\text{anode})$	
	reversible but not extensive	strength not depend on quantity
free energy	$\Delta G° = -nF\varepsilon°$	from $V = \dfrac{U}{Q}$
	$F = \dfrac{Q}{n} = 96{,}485\ \dfrac{C}{\text{mol}}$	charge of 1 mole of electrons
electrolytic cell	supply energy	to force reverse reaction
	amount of product	by mole ratio with electrons

equilibrium		
deviation	concentration but not quantity	directly affects potential
	$\varepsilon = \varepsilon° - \dfrac{RT}{nF}\ln(Q)$	Nernst
equilibrium	as reaction progresses	concentrations are updated
	$\varepsilon° = \dfrac{RT}{nF}\ln(K)$	$Q = K \quad \Delta G = 0 \quad \varepsilon = 0$

STRUCTURE

organic chemistry		
organic chemistry	(Z) 2-chloro pent 2-en 1-ol	
	stereoisomerism substituents parent unsaturation functional	
	are all redox reactions	sterics geometric inhibition
	regiochemsitry reaction location	stereochemistry configurations
line drawings	draw formal charges	do not draw lone pairs
	resonance structures	lone pair pi bond conversions
	bad tail never break single bond	bad head never exceed octet

conformations		
conformations	bond twistable positions	Newman
	staggered anti stable	eclipsed gauche steric
ring	flipped bond twisting	into chair conformation
	equatorial stable roomy	axial steric bumpy

configurations		
configurations	left and right handedness	optical stereoisomers
	chiral center	four different bonds
	rank four bonds	by list of attached atoms
	R, S chiral carbon	E, Z double bond
compounds	enantiomers	mirror image
	diastereomeers	not mirror image
	meso compound	self mirror image

MECHANISMS

mechanisms		
mechanisms	all organic chemistry reactions	composed of four mechanisms
	nucleophile attacks electrophile	base removes a proton
	loss of a leaving group	carbocation rearrangement
carbocation	more stable with	tertiary or resonance
	rearrangement through	methyl shift or hydride shift

thermodynamics		
equilibrium	reaction direction	depends on charge stability
	ability of the conjugate base	to absorb negative charge
charge stability	atom	electronegativity polarizability
	resonance	delocalize the charge
	induction	delocalize the charge
	orbitals	closer to nucleus more stable
	solvating by solvent	nonsteric more stable

kinetics		
kinetics	speed of reaction	depends on nucleophile strength
	on the polarizability	of the negative charge
	strong nucleophile	concerted one step reaction
	weak nucleophile	slower two step reaction
nucleophile strength	same row atoms	strength parallel to basicity
	same column atoms	strength opposite to basicity

ALKANES

alkanes		
mechanism	saturated hydrocarbons	substitution or elimination
	leaving group weakens carbon	reagent attacks electrophile
	attacks carbon is substitution	attacks proton is elimination
	determination depends upon	reagent function substrate degree
strong nucleophile	halides sulfur $X^- RS^-$	all substitution
	kinetics	tertiary steric two step
	regiochemistry	two step may rearrange
	stereochemistry	one step is inverted
strong base	hydride steric t-BuOK LDA	all one step elimination
	regiochemistry	Zaitsev unless tertiary or steric
	stereospecific	sole proton antiperiplanar
	stereoselective	racemic trans
strong nucleophile base	hydroxide alkoxides $HO^- RO^-$	one step competition
	primary substitution	secondary tertiary elimination
weak nucleophile base	water alcohol ROH	two step competition
	reaction too slow not practical	leaving group stable all possible
	conc sulfuric acid H_2SO_4	two step elimination

substitution		
kinetics	electrophile degree	tertiatry steric unreactive
	nucleophile strength	more polarizable more reactive
	leaving group charge stability	more stable more reactive
	polar aprotic solvent $DMSO$	no solvent shell reactive

ALKENES

alkenes		
alkenes	unsaturated double bonds	addition reactions
	regiochemistry Markovnikov	syn or anti with enantiomers
hydrogenation	H_2 / Pt	metal surface catalyst
	no regiochemistry	syn held by catalyst
hydrohalogenation	HX	carbocation rearrangement
	Markovnikov more substituted	syn and anti
hydrobromination	$HBr / ROOR$	light or heat makes radical
	anti Markovnikov	syn and anti
hydration	H_2O / [dilute H_2SO_4]	reverse of alcohol elimination
	Markovnikov	syn and anti
	$BH_3 THF / H_2O_2 NaOH$	hydroboration oxidation
	anti Markovnikov	syn

synthesis		
alkene	create $Br_2 hv / NaOEt$	radical bromination elimination
	cleave O_3 / DMS	ozonolysis to $C = O$
halogenation	Br_2 adds $Br Br$	via bromonium bridge
	none	anti
halohydrin	Br_2 / H_2O adds $Br OH$	via bromonium bridge
	Markovnikov for alcohol	anti
dihydroxylation	add $OH OH$	via epoxide
	RCO_3H or MCPBA / H_3O^+	none and anti
	OsO_4 / H_2O_2 or $KMnO_4 / NaOH$	none and syn

ALKYNES

alkynes		
alkynes	unsaturated triple bonds	addition reactions
	location of triple bond	terminal or internal
deprotonation	terminal alkyne is weak acid	strong orbital effect
	$NaNH_2$ or NaH removes H^+	terminal alkyne stable conjugate

synthesis		
create	$XR-RX$ dihalide	strong base eliminations
	$2 \times NaNH_2$	create internal alkyne
	$3 \times NaNH_2 / H_2O$	create terminal alkyne
cleave	O_3 / H_2O	ozonolysis of triple bond
	internal to carboxylic acid	terminal also carbon dioxide
alkylation	attach alkyle MeX or EtX	to terminal alkyne
	$NaNH_2 / MeX$	one step substitution
	two independent steps	if attach at both ends
conversion	convert saturation	alkyne to alkene or alkane
	H_2 / Pt	reduce to alkane
	H_2, / Lindlar's catalyst	cis alkene
	Na / NH_3	trans alkene
hydration	add HOH to terminal alkyne	similar processes as alkene
	result is alkene and alcohol	this enol is unstable
	enol ketone tautomerization	converted constitutional isomers
	$H_2O / [H_2SO_4]\ [HgSO_4]$	makes enol then ketone
	$R_2BH / H_2O_2\ NaOH$	makes enol then aldehyde

SYNTHESIS

alcohols		
alcohols	amphiphatic with both	hydrophobic hydrophillic areas
	solubility depends on areas	only if less than five C per OH
	acidity depends on	stability of conjugate base
create by conversion	substitution of alkanes	fast and slow nucleophillic attack
	addition to alkenes	hydration hydrohalogenation
create by reduction	oxidation state of carbon	increase $C-O$ bonds
	alkane to alcohol to aldehyde	reduce carbonyl to alcohol
	$LiAlH_4/H_3O^+$ $NaBH_4/MeOH$	hydride H^- attack carbonyl
	$RMgX/H_3O^+$ Grignard	carbanion RC^- attack carbonyl

ethers		
ethers	$R-O-R$ excellent solvents	unreactive dissolve low boiling
	crown ring ethers	solvate metal for fluoride ions
create	alcohol with $NaH/R'X$	Williamson
cleavage	excess HX / heat in strong acid	makes $R-X$ $X-R$ H_2O
epoxides	create with alkene MCPBA	reactive three member ring ether
	cleave with Nuc / H_2O	nucleophillic attack relieve stress

synthesis		
synthesis	change carbon skeleton	Grignard alkylation cleavage
	change functional group	substitution elimination addition
	use retrosynthetic analysis	work from last step backwards

AROMATICS

aromatics		
nomenclature	stereoisomerism substituents < parent unsaturation functional >	
	methylbenzene or toluene	name as single functional group
	location of substituents	ortho meta para
aromatics	stable ring not just benzene	as long as meet two criteria
	has continuous p orbitals	else nonaromatic
	has odd number of π pairs	else antiaromatic unstable
reactions	aromatics stable unreactive	reaction must be forced
	strengthen nucleophile	or strengthen electrophile

reactions		
electrophilic	strengthen electrophile substrate	for ring π nucleophiles to attack
	$X_2 / AlBr_3$ Lewis acid helps	substitution not addition install X
	HNO_3 / H_2SO_4	nitration install NO_2
	$RX / AlCl_3$ $Zn(Hg) / HCl$ heat	Friedel-Crafts install acyl alkyl
	conc. fuming H_2SO_4	sulfonation install SO_3H
directing	strengthen aromatic nucleophile	substituent activate or deactivate
	activators direct to ortho para	deactivators direct meta except X
	ortho para > meta directors	strong > weak activators
nucleophillic	weaken aromatic to electrophile	requires specific conditions
	substituent electron withdrawing	leaving group in ortho or para
	$X -$ ◯ $- NO_2$ Nuc replace X	not S_N1 or S_N2 but S_NAr
	$NaOH / H_3O^+$	addition elimination S_NAr
	$X -$ ◯ Nuc replace X	no withdrawing substituent
	$NaOH$ $350\,^{\circ}C / H_3O^+$	elimination addition

SPECTROSCOPY

IR		
IR	functional groups	stretch and bend energies
	$\tilde{\nu} = \frac{\nu}{c}$ 4000 − 400 cm^{-1}	wavenumber form of frequency
	diagnostic region 1500+	H triple double stretch only
	fingerprint region 1500−	unique pattern stretch and bend
location	$C \equiv C_{sp} - H$ 3300	$C = C_{sp^2} - H$ 3100
	$C = O$ 1700	conjugated resonance weaker
intensity	$C - H$ ~ 3000 dominant	larger dipole stronger
	$C = O^{\delta}$ strong $C = C^{\delta}$ weak	symmetric $C = C$ no signal
shape	$O - H$ 3600	no hydrogen bonding narrow
	$O - H^{\delta}$ 3200+	distribution hydrogen broad
	carboxylic acid broad	double hydrogen exaggerated
	CH_3 NH_2 multiple signals	symmetric asymmetric stretch

NMR		
NMR	carbon and hydrogen	proton field altered by electrons
	equivalent by symmetry	CH_2 no chiral CH_3 chiral
location	chemical shift 10 − 0 ppm	downfield unshielded protons
	deshielding by induction	cumulative and tapers off
area	relative number protons	integration of signals
shape	number neighbour protons	equivalent protons do not split
	complex splitting subgroups	no splitting alcohol aldehyde
analysis	hydrogen deficiency index	degree unsaturation rings π
	^{13}C NMR only uses location	number of groups of similars

COORDINATION

structure		
structure	ligands around central metal	coordinate covalent bond
	primary valence oxidation state	secondary valence coordination
	some partners double duty	secondary valence not ionizable
	tetraaminechromium(III)-μ-amido-μ-hydroxobis(en)iron(III) sulfate	
ligands	monodentate one bite	amine NH_3 $M \longleftarrow$:L
	chelating multi bite claw ring	enthylenediamine (2) EDTA (6)
	ambidentate two donors :AB:	bridging $M \longleftarrow$:L: $\longrightarrow M$
coordination	metal coordination sphere	coordination number of ligands
	six ligands octahedral	four square planar tetrahedral
	isomers same atoms	with different properties
	structural different bonds	stereoisomers same bonds

isomers		
structural	coordination interchange ligands	between coordination spheres
	ionization interchange groups	coordination sphere counterions
	linkage ambidentate ligand	switches coordinating atom
stereo	geometric	different spatial arrangement
	optical handedness	plane of symmetry nonchiral
six	MA_5B no geometric no optical	MA_4B_2 cis trans geometric
	MA_3B_3 fac mer geometric	$MA_2B_2C_2$ five geo cises chiral
	bidentate $M(A-A)_2B_2$	two geometric cises chiral
four	square planar two geometric	asymmetric chelating chiral
	tetrahedral no geometric	different or asymmetric chiral

CRYSTAL FIELD

splitting		
crystal field	metal is Lewis acid	electron pair acceptor
	match next noble gas	effective atomic number
	effect of field of ligands	on energies of $n\,d$ orbitals
	six dependent orbitals	any one combo of other pair
	five independent orbitals	combine dependent pair to d_{z^2}
octohedral	two of six ligands along axis	two of five orbitals along axis
	$3\left(\frac{2}{5}\Delta_o\right) = 2\left(\frac{3}{5}\Delta_o\right)$	ligand and orbital repulsion
	$d_{z^2}\ \ d_{x^2-y^2} > d_{xy}\ \ d_{yz}\ \ d_{xz}$	two z orbitals higher energy
	tetragonally elongated	z ligands pushed further
	square planar d^8 metals	z ligands completely removed
tetrahedral	no orbital points at ligand	differ by repulsion distance
	$d_{z^2}\ \ d_{x^2-y^2} < d_{xy}\ \ d_{yz}\ \ d_{xz}$	$\Delta_t \approx \frac{4}{9}\Delta_o$

stabilization		
stabilization	Δ vs P split vs pairing	Aufbau pairs or split electrons
	strong field low spin Aufbau	weak field high spin split
	$d^4\ \ t_{2g}^3 e_g^1\ \ \frac{3}{5}\Delta_o\ \ t_{2g}^4\ \ \frac{8}{5}\Delta_o - P$	energy relative to unsplit state
factors	$\Delta_t < P$ tetrahedral	always weak field high spin
	metal larger charge or size	stronger field splitting effects
	ligand smaller size	less steric stronger field
	ligand covalent π direction	$Cl^- < H_2O < NH_3 <$ en $< CN^-$
	different cyrstal field splittings	different absorbed energy colors

MECHANISMS

merchanisms		
mechanisms	coordination reactions	changes to metal or ligands
	most common is substitution	octohedral or square planar
octohedral	first row metals labile	Cr^{3+} Co^{3+} other rows inert
	dissociation not association	evidenced by reaction rates
	larger charge size less steric	stronger $M-L$ bonds
	intermediate five coordinate	negative $\Delta CFSE$ more E_A
redox	electron transfer	from one metal to other
	outer sphere coordinations intact	$M-L$ distance difference
	inner sphere bridging complex	larger halide more polarizable
square planar	association not dissociation	readily attack above below
	kinetic trans effect	more polarizable trans directing
	$CN^- > I^- > Br^- > Cl^- > NH_3 > H_2O$	

applications		
stability	hard soft acid base	empirical hard hard soft soft
	chelate effect stability	multidentate increasing entropy
hemoglobin	four octohedral heme groups	coordinate transport oxygen
	prefer carbon monoxide cyanide	asphyxiation lack of oxygen
metals	soft sulfur atoms	easily coordinate with metals
	lead arsenic poisoning	EDTA BAL DMSA
tumors	cisplatin platinum coordination	slow cell division side effects
	platinum ruthenium metals	coordinate DNA cell destruction

SOLIDS

unit cells		
A **type**	crystal lattice of spheres	spheres are same size
	simple cubic 52 %	touching 6 containing 1
	body centered cubic 68 %	touching 8 containing 2
	face centered cubic 74 %	touching 12 containing 4
	cubic close packed ABC	rotated face centered cubic
	hexagonal close packed $ABAB$	touching 12 containing 6
holes	spheres are two sizes	smaller in holes of larger
	simple cubic A type	1 cubic hole per sphere
	close packed A type	1 octahedral 2 tetrahedral holes
AB_n **type**	structure of AB_n solids	depend on ratio of ionic radii
	cubic hole	max touch 8 ratio 73 % +
	octahedral hole	max touch 6 ratio 41 % +
	tetrahedral hole	max touch 4 ratio 23 % +

energetics		
energetics	lattice energy change	gas ions form ionic solid
	$E_{attraction} = \frac{kqq}{r}\left(6 - \frac{12}{\sqrt{2}}\ldots\right)$	potential energy infinite series
	$E_{repulsion} = \frac{B}{r^n}$	valence electron cloud repulsion
	$U = 1389\frac{kqqM}{r_0}\left(1 - \frac{1}{n}\right)$	theoretical Born-Lande
	thermodynamic Hess buildup	experimental Born-Haber

IDEAS

ideas		
periodic	effective nuclear charge	$Z_{eff} = Z - \sigma$
	approximate is group number	Slater proportional shielding
unique	first elements different	from group congeners
	small size more covalent	charge density polarizing power
	more π bonding overlap	no d orbitals expanded octets
diagonal	three diagonals similar	ionic size lattice replace
	charge density electronegativity	similar covalent bonds
inert pair	shielding effect minimal	from filled d and f orbitals
	hard to remove $5s^2\,6s^2$	2 less Pb (II) not Pb (IV)
metal line	metals lose electrons cations	conductors sea of electrons
	nonmetals gain anions	chains and rings covalent

additional		
anhydrides	anhydrides are oxides that	make acid or base in water
	oxide in water $E - O - H$	different $E - O$ polarity
	metal oxides make bases	nonmetal oxides make acids
potential	tendency to gain electron	thermodynamic determination
	across period increase	down group constant
	$Li^+_{(aq)} + e^- \rightarrow Li_{(s)}$ easiest to oxidize best reducing agent	
$d\pi - p\pi$	second period small $C\ O$	readily form $p\pi - p\pi$ bonds
	second filled p third empty d	dative $d\pi - p\pi$ bonds
	strengthens single bond $Si - O$	eventually double bond $P = O$

FOUNDATION

hydrides		
hydrogen	strong $H-H$ not reactive	requires catalyst to react
	borderline electronegativity	forms hydrides with all
covalent	hydrogen as metal HCl	formal oxidation state $+1$
	H high ionization energy	extreme charge density
	molecular units H_2O NH_3	with all nonmetals
	polymeric e^- deficient BeH_2	with beryllium and 3A
ionic	hydrogen as nonmetal LiH	formal oxidation state -1
	H^- low electron affinity	strong electron repulsion
	salt compounds	with alkali and alkaline
	white gray solids	drying reducing bases
metallic	nonstoichiometric $PdH_{0-0.7}$	with transition metals
	interstitial crystals	store purify hydrogen

anhydrides		
oxygen	extremely reactive	forms oxides with most
	solid ionic oxides Li_2O	gas covalent oxides CO_2
anhydrides	anhydrides are oxides that	make acid or base in water
	oxide in water $E-O-H$	different $E-O$ polarity
metal	$M-O$ more polar or ionic	O^{2-} reactive makes OH^-
	$Na_2O_{(s)} + H_2O \rightarrow NaOH_{(aq)} \rightarrow Na^+ + OH^-$	
nonmetal	$O-H$ more polar	proton attacked by water
	$NM-O_{(g)} + H_2O \rightarrow NM-(OH)_2 \rightarrow NMO_2^{2-} + H_3O^+$	
semimetal	$E-O-H$ same polarity	amphoteric by circumstance
	semimetal oxides Al_2O_3	usually water insoluble

ALKALI

alkali		
alkali	ashes of plants	soft highly reactive metals
	$NaCl_{(l)} \xrightarrow{\text{electrolysis}} Na_{(l)} + Cl_{2(g)}$	$KCl_{(l)} + Na_{(g)} \xrightarrow{\text{reduce}} K_{(g)} + NaCl_{(s)}$
ideas	unique Li	covalent salts less soluble
	diagonal Mg	salt hydration is hygroscopic
	inert pair	ionization energy K to Rb
	metals	ionic hydrides oxides halides
	anhydrides	oxide makes base in water

reduction potential		
potential	tendency to gain electron	thermodynamic determination
	free energy enthalpy change	ionization vs hydration energies
	$Li^+_{(aq)} + e^- \rightarrow Li_{(s)}$	$E^\circ = -3.05V$
trends	easy to oxidize lose electron	strongest reducing agents
	Li unique small size	charge density strong hydration
	Na representative larger	lower ionization and hydration
	K Rb Cs congeners	balanced energies same potential

peroxides		
peroxides	expected Li_2O unexpected peroxide Na_2O_2 superoxide KO_2	
	$Na_2O_{2(s)} + H_2O \rightarrow H_2O_2 + NaOH$	
	$H_2O_2 \xrightarrow{heat} H_2O + O_2$	disproportionate oxide reduce
	peroxides bleaching drying	superoxide rebreathers

BONDS

alkaline		
alkaline	ashes of plants	whose oxides do not melt
	$MgCl_{2(s)} + K_{(s)} \xrightarrow{\text{reduce}} Mg_{(s)} + KCl_{(s)}$	$CaCl_{(l)} \xrightarrow{\text{electrolysis}} Ca_{(l)} + Cl_{2(g)}$
deficient	BeX_2 electron deficient	excellent Lewis acid
	$BeX_2 + 2X^- \rightarrow BeX_4^{2-}$	complete octet

3A		
3A	not as chemically similar	metal to nonmetal range
	$Al^{3+} + C_{(s)} + O^{2-} \xrightarrow{\text{electrolysis}} Al_{(s)} + CO_2$ Hall-Heroult	
banana	metal compound less octet	beryllium and 3A hydrides
	three center two electron	not two center two electron
	$(BeH_2)_n$ polymeric chains	$B2H_6$ diborane banana bonds

4A		
4A	increasingly wide variety	carbon concatenation
	$SiO_{2(s)} + C_{(s)} \xrightarrow{\text{electrolysis}} Si_{(s)} + CO$	
$d\pi - p\pi$	second period small C O	readily form $p\pi - p\pi$ bonds
	second filled p third empty d	dative $d\pi - p\pi$ bonds
	contributes to single bond	unusual strong $Si - O$
	$Si - N$ especially strong	$N(SiH_3)_3$ not Lewis base
	eventually even stronger	full double bond $S = O$

REPRESENTATIVE

pnicogens		
pnicogens	choking producers	more uniform properties
	$N_{2(g)} + H_{2(g)} \xrightarrow{\text{heat pressure}} NH_{3(g)}$ Haber	
	N stable π triple bonds	varied oxidation -3 to $+5$
	H_3PO_4 phosphoric acid	formal double bond $P = O$

chalcogens		
chalcogens	copper producers	polymeric catenations
	$H_2O_{(l)} \xrightarrow[H_2SO_4]{\text{electrolysis}} H_{2(g)} + O_{2(g)}$	
	sulfur nitrogen compounds	formal double bond $S = N$
	tho is S replaces an O	alcohol to thiol $-SH$

noble		
noble	complete valence inert	krypton xenon fluorides
	$Xe_{(g)} + F_{2(g)} \xrightarrow[\text{6 atm}]{\text{heat}} XeF_{4(s)}$	
	He α radiation natural gas	escapes Earth gravity
	Rn radiation soil seep	basement air flow

HALOGENS

halogens		
halogens	salt producers	striking similarities
	$F^{+}_{2(g)} + e^{-} \rightarrow F^{-}_{(aq)}$	$E^{\circ} = +2.87V$
	easy to reduce gain electron	strongest oxidizing agent
	$F-F$ repulsion small ionization	F^{-} dense large hydration
interhalogens	XX'_n larger center	smaller surroundings BF_3
	halogenation reactions	aprotic self ionizing solvent

halides		
halides	ionic nonvolatiles	molecular volatiles
	direct reaction	explosive if too strong
	basic anhydrides	with hydrogen halides
	acidic anhydrides	exchange covalent halides
	pseudohalides N_3^{-} CN^{-} OCN^{-} SCN^{-} $SeCN^{-}$ $TeCN^{-}$	

oxoacids		
oxoacids	multiple oxidation states	expect variety of oxoacids
	3A 4A single H_3BO_3 H_2CO_3	5A 6A two H_3PO_3 H_3PO_4
	halogens four oxoacids $HOCl$ $HOClO$ $HOClO_2$ $HOClO_3$	
characteristics	fluorine no oxoacids	most electronegative element
	various oxoacids	not polyprotic acids
	hypohalous HOX single O	weak acid strong oxidizer
	reduction potential	oxoacid larger than oxoanion