



Crack the DAT

Crack Notes [General Chem 1] Atoms, Molecules & Quantum Mechanics

Atoms

- Nucleus (protons, neutrons) + electrons
- Elements written as A_ZX
 - A = mass number = protons + neutrons
 - Z = atomic number = protons
 - X = element symbol (i.e. Mg)
- Isotopes: same atomic number (same # protons), diff mass number (diff # neutrons)
- Atomic weight/molar mass: from periodic table, defined in amu or g/mol (when do we use?)
 - # moles = # grams / molecular weight
- Ion: diff # electrons than protons, so has a charge (+ cation, - anion)
- Size differences:
 - For same element: cations are smaller than neutral, anions are larger than neutral
 - For same # electrons: smaller with higher atomic number b/c of more attractive force from protons

Periodic Table

- Period: horizontal row
- Group/Family: vertical column, numbered 1-18 or IA-VIIIA, IIB-IIIB
- Types of elements
 - Metals:
 - Tend to lose electrons to form positive ions
 - Ductile, malleable, thermal/electrically conductive, luster (shiny)
 - Generally solids @ room temperature except mercury
 - Usually form ionic oxides
 - Transition metals: in the sunken area of the periodic table (section B groups)
 - Nonmetals: tend to gain electrons to form negative ions, usually form covalent oxides
 - Metalloids: between a metal and a nonmetal
- Groups/Families
 - Alkali metals (Group 1A): low melting point, form 1^+ cations, react strongly with most nonmetals including water (to form hydroxides and hydrogen gas)
 - Alkaline earth metals (Group 2A): higher melting point, less reactive than 1A, form 2^+ cations
 - Group 4A: can form four covalent bonds with nonmetals. C can form strong pi bonds, everything else can form two additional bonds for a total of 6
 - Group 5A: can form three covalent bonds. N can form strong pi bonds, everything else can form two additional bonds for a total of 5
 - Chalcogens (Group 6A): oxygen and sulfur most important, both can make strong pi bonds. Oxygen reacts with metals to form metal oxides. Pure sulfur is S_8
 - Halogens (Group 7A): F, Cl, Br, I. All exist as diatomic molecules and like to gain electrons
 - Noble gases (Group 8A): nonreactive, normally found in nature as isolated atoms
- Diatomic molecules: H, O, N, Cl, Br, I, F
- Small atoms can form pi bonds, large atoms (3rd period or above) have d orbitals so can form more than 4 bonds



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Periodic Trends

- *Ionization energy*: energy it takes to remove an electron
- *Electronegativity*: tendency to attract an electron in a bond
- *Electron affinity*: willingness of an atom to accept an additional electron
- Start with E: (energy of ionization, electron affinity, electronegativity) increase going LEFT-RIGHT, BOTTOM-TOP
- Don't start with E: (atomic radius, metallic character) increase going RIGHT-LEFT, TOP-BOTTOM

SI

- *Units*: kg, m, s, A, K, cd, mol
- *Prefixes*: mega/kilo/deci/centi/milli/micro/nano/pico/femto

Molecules: separate and distinct units made of atoms

- *Empirical formula*: relative number of atoms of one element to another
- *Molecular formula*: exact number of atoms per molecule
- Calculating percent composition by mass
 - For each atom, find weight of atom in molecule / total molecular weight
- Calculating empirical formula from percent mass
 - Assume a 100 gram sample, multiply by % masses to find # grams of each element
 - Find # moles of each element from the # grams
 - Divide by smallest # of moles to get empirical formula (might have to multiply by a factor to make all numbers integers)
 - If we want the molecular formula, have to use (given) total molecular weight

Bonds

- *Covalent bond*: shares electrons; electrons closer to more electronegative atom
- *Bond dissociation energy/bond energy*: energy it takes to break a bond
 - Higher bond energy = lower bond length
 - Double bonds have higher bond energy (lower length), triple bonds even higher/lower
- *Compound*: substance made from two or more elements

Naming compounds

- *Ionic*: cation + anion
 - Cations usually just name of element
 - Metals with more than one possible charge (i.e. copper) called copper (I) or copper (II)
 - Anions of elements end in -ide
 - Polyatomic anions containing oxygen end in -ite or -ate (also hypo- -ite and per- -ate)
- *Acids*: named after anion
 - Acids of elements = hydro- element -ic
 - Oxyacids = anion name -ic/-ous acid
- *Binary molecular compounds* (2 elements): leftmost/lowest, then other one w/ prefixes



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Chemical reactions

- *Physical vs chemical changes*: chemical when molecular structure is changed
- Remember to balance all equations!
- Limiting reagent: what will get used up first
 - Find # moles available of each reactant
 - Look at ratios between coeffs in balanced equation to find out what gets used up first
- Theoretical vs actual yield
 - Theoretical is what's predicted by equation, actual is what you get in an experiment
 - *Percent yield*: $\% \text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \cdot 100\%$
- Types of Reactions
 - *Combination*: $A + B \rightarrow C$
 - *Decomposition*: $C \rightarrow A + B$
 - *Single displacement*: $A + BC \rightarrow B + AC$
 - *Double displacement*: $AB + CD \rightarrow AD + CB$

Quantum Mechanics

- Quantum numbers
 - *Principal quantum number* n : shell level
 - *Azimuthal quantum number* l : subshell/orbital shape: s, p, d, f. Can range from 0 to $n - 1$
 - *Magnetic quantum number* m_l : which orbital; ranges from $-l$ to $+l$
 - *Electron spin quantum number* m_s : $-1/2$ or $+1/2$
- *Pauli exclusion principle*: no two electrons can have the same set of quantum numbers
- *Hund's rule*: one electron will go into each available orbital before any orbital has 2 electrons
- *Aufbau principle*: electrons look for an available orbital with the lowest energy state
 $1s \rightarrow 2s \rightarrow 2p \rightarrow 3s \rightarrow 3p \rightarrow 4s \rightarrow 3d \rightarrow 4p \rightarrow 5s \rightarrow 4d \rightarrow 5p \rightarrow 6s \rightarrow 4f \rightarrow 5d \rightarrow 6p \dots$
- *Electron configuration*:
 - $\text{Br} = 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^5 = [\text{Ar}] 4s^2 3d^{10} 4p^5$
 - Exceptions: $4s^2 3d^4 \rightarrow 4s^1 3d^5$, $4s^2 3d^9 \rightarrow 4s^1 3d^{10}$
 - For ions, make sure you have the right number of electrons
- *Heisenberg uncertainty principle*: we can never be sure about both the position and the momentum of a particle

$$\Delta x \Delta p \geq \frac{\hbar}{2}$$

Electromagnetic Energy

- *Planck's quantum theory*: electromagnetic energy is quantized in discrete increments
- For a photon, $E = hf$ and $\lambda = h/mv$
- Emission spectra:
 - Electrons have specific quantized energy levels that are unique for each atom
 - When a photon of the right wavelength hits the atom, it can excite an electron to a higher energy level
 - After a while, the electron drops from the high energy level releasing another photon
 - If you use a wide spectrum of light, you can see what wavelength of photons are released to identify the material
- Photoelectric effect:
 - Electrons can be ejected from metal by shining light on it
 - The light energy must be greater than the work function Φ of the metal
 - The kinetic energy of ejected electron = $hf - \Phi$