Hisenberg uncertainty principle:

1. Cheat sheet.
2. Pulses:
   1. Superposition of different psi functions
3. Plane waves vs. Wave packets
4. MOA (find energy): determine range of x (based on constraints of particles in the system), determine range of momentum based on HUP [ Pf-Pi=dP. Set Pi = 0], find E=KE with p^2/2m.
5. Spread= range of V (rV).
6. rV vs V
   1. rV
      1. High rV 🡪 high rP 🡪 low rX
      2. Same r = same r everywhere.
   2. V
      1. Higher V = high f = high p = high KE = low wavelength = high quantum state.

Electron in metal wire

1. Graph
   1. E = K + U = constant energy line.
   2. U = potential energy curve as a function of time.
   3. K = gap in between energy line and potential energy curve
   4. When E = U onwards (K < or = 0)🡪 classically forbidden region.
   5. COPY
2. Relation of KE to x
   1. deBroglie wavelength: high KE 🡪 high p 🡪 low wavelength of psi 🡪 high wave number.
3. Schrodinger equation -> COPY
4. ISOLATED Electron metal wire:
   1. Definition:
      1. Assume Total E = thermal energy of electron, kT -> constant.
         1. WHY: Since it is quantized, when measuring one electron -> measuring one value of k from the superposition of wave functions (SCHRODINGER)-> one particular quantum number -> one value of energy = constant.
         2. Low energy spacing = easy to shift quantum states = easier to achieve different values for energy -> behaviors in solids.
      2. 0<x<L : Electrons able to freely move in wire -> High KE, low U
      3. x<0, x>L: Electron needed to overcome V = work function of the metal (if KE of electron in wire =thermal energy of electron in wire <<< work function, then low chance to find electron = psi^2 🡪 0. Assume V= INFINITY 🡪 classically forbidden area = no chance to find electron psi^2=0) -> low KE (or zero KE), high U (or INFINITY U)
   2. Schrodinger Equation (time to solve):
      1. Conditions:
         1. Continuous function (so if psi = 0 when x>L, then psi = 0 x=L)
         2. Psi = 0 -> classically forbidden region.
         3. Psi -> 0 as x🡪 + - infinity.
         4. Psi is a normalized function.
      2. Solving:
         1. Define region BC (X problem: psi(0)=?, psi(L)=?)
         2. Define V in that region.
         3. Solve for X problem form.
         4. Use BC and normalization (psi^2 = 1) to solve for constants.
         5. Multiply time dependence psi = e^(-iEt/h)
   3. Compare psi graph with energy graph.
      1. On psi: High n 🡪 high number of peaks 🡪 high f 🡪 high total energy 🡪 high number of oscillations.
      2. Infinite square well: n = number of peaks.
   4. Solutions for Schrodinger equation
      1. Psi
      2. Relation of beta= npi/L=k=2pi/lambda=substitution of root (blah)
         1. E as a function of quantum states, n and L
         2. E as a function of quantum states, n
            1. Spacing increases with energy level
         3. E as a function of wavelength (confirm with deBroglie wavelength and p)
         4. E here denotes total E= kT of electron = constant
      3. Classically vs. quantum.
         1. Any energy vs specific energy (based on schro solutions with quantum states)
         2. Localized vs. delocalized (probability)
         3. Quantum: lowest energy state= ground state = zero-point motion > 0. WHY: HUP. If there is zero energy, then it is sitting motionless at the bottom of potential well -> range of x = 0 and range of p = 0 🡪 NOT POSSIBLE. IT must a have a range of x and a range of 🡪 energy greater than the minimum of the potential well.
         4. Correspondence principle: Average behavior of quantum system = classical solution as n🡪infinity.
            1. HOW:

Classical solution: probability density = constant.

Quantum solution: As high n🡪 high number of peaks -> high number of waves within same range 🡪 AVERAGE = same probability density and classical.

Square well and superposition principle:

1. Determining ease of electron motion in metal
   1. How does it make a transition?
      1. Ratio = dE (gap energy)/ kT
         1. kT> dE : classical. Jump with thermal energy.
         2. kT< dE: quantum. Transition through quantum means.
   2. Determine relation for individual metal.
      1. Relation of dE with L (based on reference L of metal )
         1. Generally, high L = low dE.
      2. Relation of thermal energy kT with T (based on reference T of metal)
         1. Generally, high T = high kT
      3. FOR WHAT: Helps determine how easy or difficult to transition quantum states in metals + through what means.
         1. Low dE: easy to transition.
         2. High dE: difficult to transition.
         3. Look above to determine what means.
2. Energy eigenstates:
   1. Definition: different psi values = different n values = different energy levels = different eigenstates.
3. Superposition principle:
   1. Definition: Psi solution for SAME electron = apsi1+bpsi2+….
      1. Different psi values = different n values = different energy eigenstates = possibility of measuring any of those energy levels.
   2. Psi(x,t) = psi(x)e(-iEnt/hbar)
   3. Examples:
      1. Wave packet -> superposition of plane waves (fourier series).
      2. Double slit interference:
         1. MOA
            1. ADD: Psi= Psi1+psi2
            2. NORMALIZE: (psi)^2 =(psi1 + psi 2)^2 = psi1^2 + psi2^2 + 2 psi1psi2.
            3. Mixed term = Interference term= oscillatory term = time dependence = 2psi1psi2
   4. Time dependence of psi^2, probability density.
      1. Condition: If there is a mixed term (complex term) following normalization -> oscillatory term -> time dependence.
      2. 1 eigenstate (no superposition):
         1. Psi has time dependence.
         2. Normalization: Psi^2 = Psi \*Psi (complex conjugate) = psi(x)^2 -> real amplitudes + time independent.
      3. Several eigenstates (superposition):
         1. Psi = psi1+psi2 has time dependence.
         2. Normalization: Psi^2 = blah + mixed term 🡪 mixed term has complex components = oscillatory term 🡪 complex amplitudes + time dependence.
         3. Mixed term = interference term = constructive or destructive (depending on time)
   5. Measurements:
      1. Context: Discontinuous process. Schro eqn: before, after; not moment of measurement. Measure energy/positon, energy/position eigenstate.
         1. Changes system.
      2. Measurement of position then momentum:
         1. Collapsing/localizing of wave function to SINGLE value of x -> Extremely low dX.
         2. Superposition principle and math denotes that spike= addition of a higher range of frequencies to system 🡪 high dP.
         3. Measurement of momentum 🡪 inclusion of all addition frequencies 🡪 no. of possible P (or E) > solved initial solution.
         4. Relation to spread: high range of frequencies 🡪 high range of n 🡪 high range of energy levels 🡪 higher range of v 🡪 MORE SPREAD.
      3. Measure of momentum:

Measurement of momentum directly 🡪no. of possible P (or E) = solved initial solution.

STM:

Purpose: Using tunneling 🡪 to measure surface profile of conductive surface (accuracy of atoms).

Measure change in tunneling electrons (current) 🡪 from changes in distance due to presence of atoms.

Process:

1. Conducting tip brought close to metal surface.
2. Small positive voltage at tip + negative voltage at metal 🡪 higher potential at tip + lower potential at metal = biased tunneling into surface.
3. Measure of current: tunneling rate. Changes in distance (measure): number of surface atoms.
4. Based on need to maintain measure of current (and tunneling rate) 🡪 STM measures own vertical distance 🡪 deduce different number of surface atoms = profile of surface.
5. Piezoelectric actuator: precise control.

Radioactive decay:

Review:

1. Unstable nucleus (usually large with many protons, neutrons) -> emit particles.
2. Alpha decay: Emission of alpha particles (2 neutrons, 2 protons).

2 forces:

1. Coulomb forces: Electrostatic forces through interaction of charges. Nucleus 🡪 protons close together 🡪 high repulsion form electrostatic forces 🡪 high V (high peak) . (usually acting when external particles brought together or internal of VERY LARGE atoms ; usually requiring energy to push 🡪 POSITIVE INCREASE OF V)
2. Nuclear forces. Strong force through interaction of neutron, proton. Nucleus 🡪 neutron, proton close together 🡪 high attraction from nuclear forces 🡪 low V (deep valley). (only act when internal; requiring energy to pull apart 🡪 NEGATIVE V)

Radioactive decay:

1. Definition: Emission of alpha-particle (2n,2p).
2. With n>p in all particles, ratio of neutron: proton increase 🡪 decrease proportion of protons (positive charges)🡪 decrease effects of coulomb forces 🡪 decrease repulsion 🡪 allow remaining nuclei to be closer 🡪 increase nuclear force 🡪 increase attraction 🡪 DOUBLE WHAMMY of decrease V 🡪 MORE STABLE.
3. WHY NUCLEAR FORCE SO STRONG LA? Just look at force equation. Since internal r (between particles) in nucleus <<<<<< external r (between nucleus and alpha particle) outside nucleus 🡪 MUCH HIGHER LA.
4. Size of nuclei vs. forces.
   1. High protons and neutron in nucleus 🡪 higher particles close together 🡪 high internal nuclear force 🡪 high attraction 🡪 STEEP dip in low V.
   2. High protons and neutron in nucleus 🡪 high internal (nuclei) coulomb forces 🡪 high repulsion 🡪 STEEP increase in high V.
   3. If too high protons and neutrons🡪 high size in nucleus 🡪 more spaced out 🡪 less particles closer together 🡪
      1. In spaced out regions of nuclei: lower internal nuclear force < high internal coulomb forces. 🡪 attraction <repulsion 🡪 higher V.
      2. Lower proportion of internal nuclear attraction force + higher proportion of internal coulomb repulsion force = high peak + shallow valley.
5. Energy well.
   1. Different regions, see KE and PE.
   2. Same amount of protons = same peak height for potential well.
   3. Probability to tunnel: High Etotal electron = KE of electron 🡪 low alpha 🡪 high depth, don’t decay as much🡪 more probable.
6. Isotopes => same protons, different neutrons.
   1. Different isotopes 🡪 different neutrons 🡪 different internal nuclear attraction force 🡪 different depth of potential well 🡪 different number of bounded energy states 🡪 alpha particle leave with different amount of energy in accordance to energy states.
   2. Higher energy alpha particles 🡪 shorter lifetimes.
7. Radioactive decay-fission:
   1. Definition:
      1. Emission of neutrons towards parent nucleus 🡪 sufficient energy + collision = excitation of nucleus to peak of potential well + splitting into 2 excited smaller nuclei, more neutrons.
      2. Excited smaller nuclei: Transition back to ground state 🡪 release gamma rays = photons. + repulsion away from peak.
      3. Neutrons: Coulomb repulsion forces 🡪 pushed at high speeds 🡪 collide with other nuclei 🡪 CHAIN REACTION.
      4. CHAIN REACTION: reusing of neutrons.
   2. Requires:
      1. Atoms with low nuclear attraction force + high coulomb repulsion force 🡪 less neutrons closer together 🡪 shallow potential well.
      2. Neutron producing fissionable material.
      3. Remove all ‘impurities’ that absorb neutrons (atoms with high nuclear attraction force)
      4. Fast enough🡪 supercritical mass. 🡪 Enough neutrons for prolong chain reaction.