Phyx 320
Modern Physics

April 12, 2021

Reading: 41.5-41.8

Homework #10 Due Tuesday

Electron Spin

Electrons always have angular momentum called spin

Controlled by a new set of quantum numbers: m_s, s

All fundamental particles have spin

Particles now have three properties: mass, charge, and spin

This ½ spin makes it so no two electrons can have the same quantum numbers

Leads to the Pauli Exclusion principle

$$S_z = m_s\hbar \qquad S = \sqrt{s(s+1)}\hbar$$

For electrons:

$$m_s = -\frac{1}{2}, \frac{1}{2} \qquad s = \frac{1}{2}$$

For other particles:

$$m_s = -s, -s+1, \dots s-1, s$$

$$s = \frac{1}{2}, 1, \frac{3}{2}, 2, \dots$$

Periodic Table

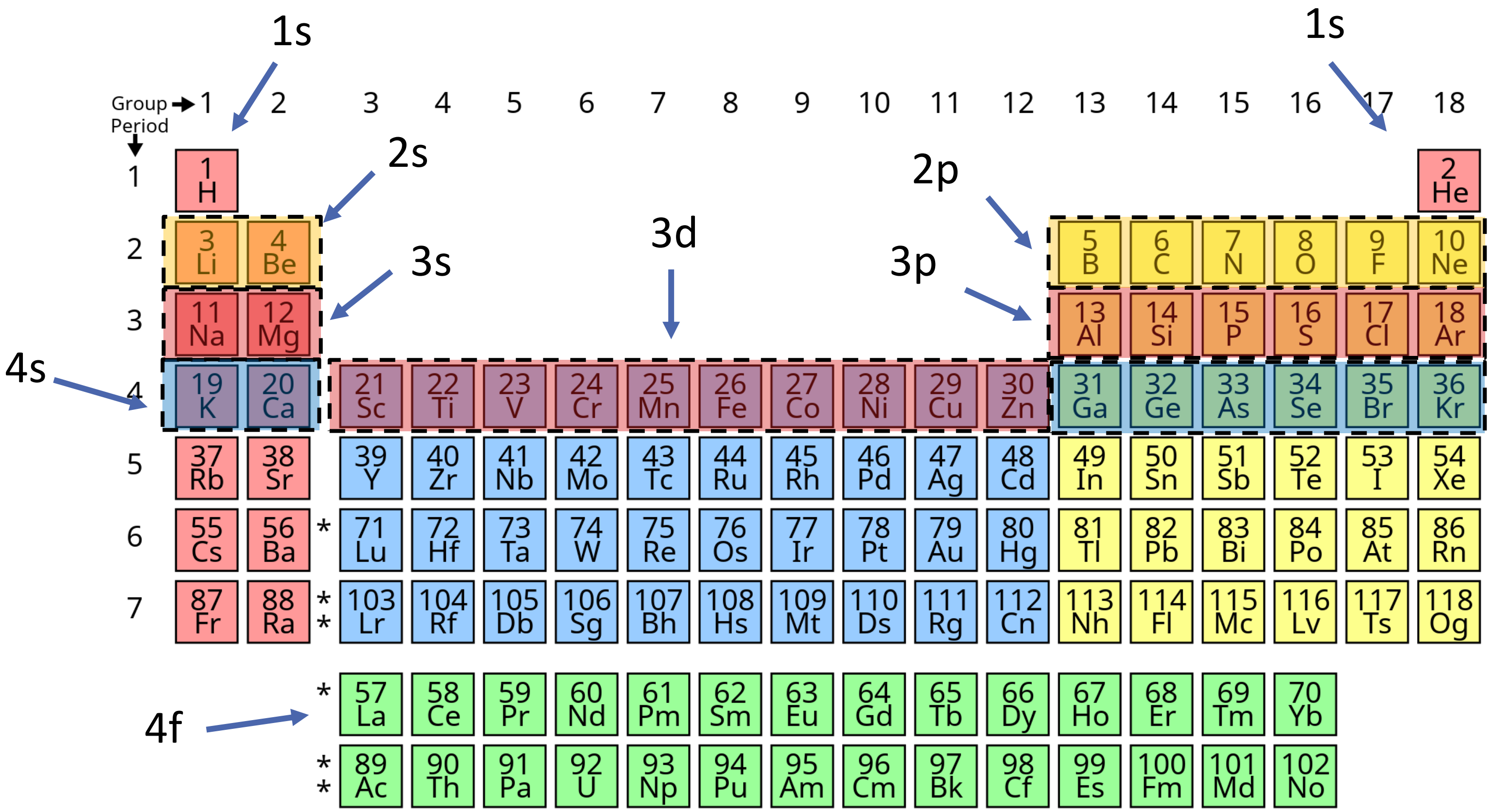
Quantum mechanics allows us to understand the layout of the periodic table

There are $2(2l+1)$ states allowed for each n, l-subshell

Except for the transition elements (columns 3-12) the row number tells you the n quantum number

Since the energy for the 4s state is lower than the 3d state it gets filled before

What is the ground state of iron (Fe)?



Ionization Energies

The fuller the shell the more stable the atom

Causes full shell atoms to have large ionization energies

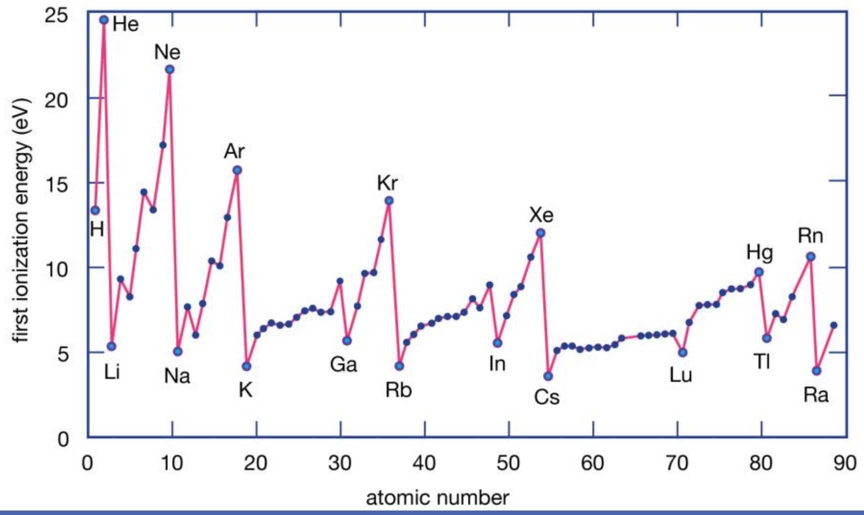
Also makes them less reactive

Noble elements (right hand column) have complete shells which makes them extremely unreactive and have high ionization energies

Alkali metals (left hand column) have a lone electron in highest shell which makes them very reactive and low ionization energies

Electrons in higher-Z elements are farther out which makes them easier to ionize

Group → / Period ↓	1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																		2 He
2	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca		21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr		39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	**	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
			*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb		
			**	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No		



Excited States

Atoms can be excited by either collisions with other atoms or absorption of a photon

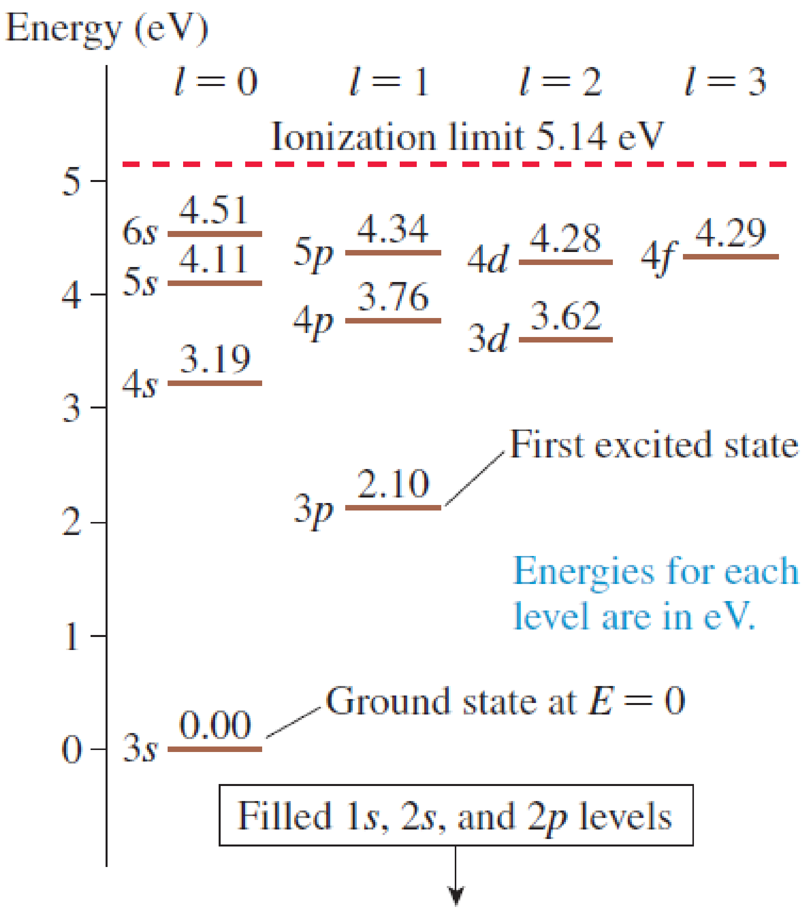
Only the valence (outer most) electron goes to a higher state

All other electrons (core) stay in their ground state configurations, so we ignore them when looking at excited states

The core electrons restrict the lowest state the valence electron can go

Energy states are ordered by energy not quantum number

Sodium (Na) Energy Diagram



Excitation

Photons are spin-1 particles, $s = 1$, which means each photon that is absorbed or emitted shifts l by one, $\Delta l = 1$

This makes it so atoms must be excited diagonally when absorbing a photon

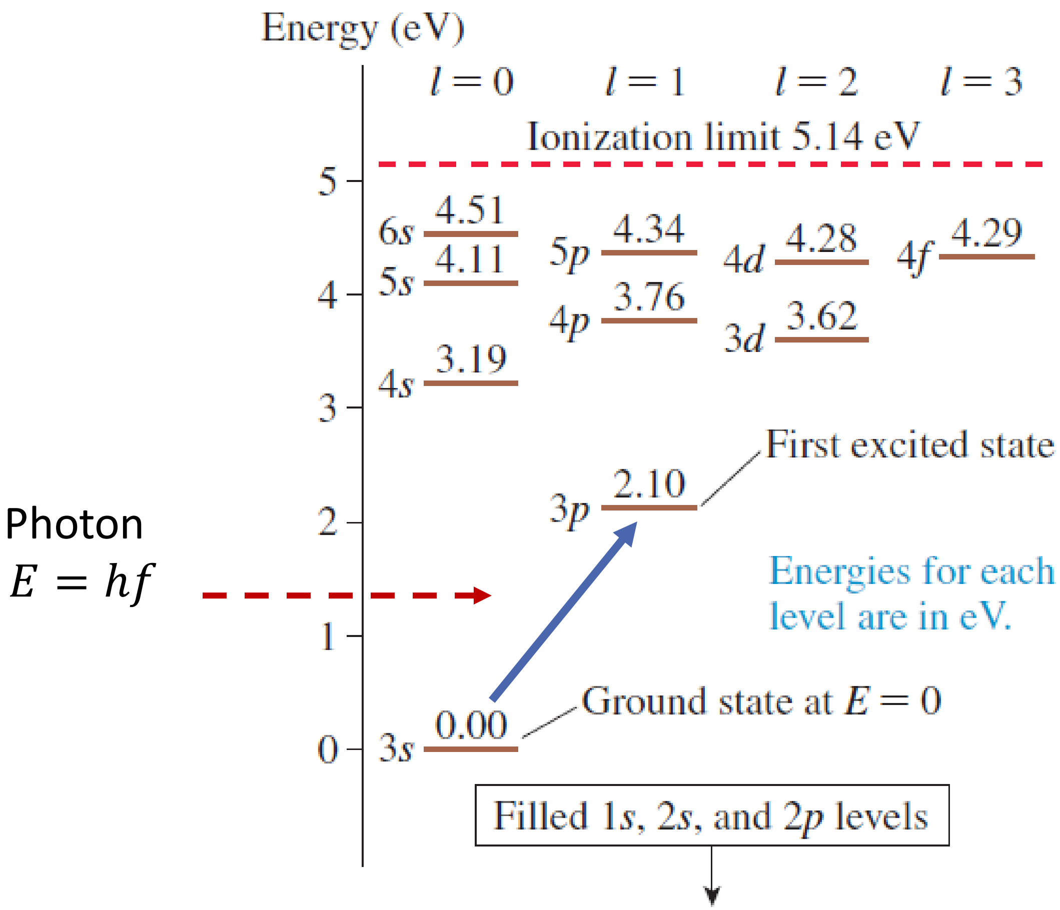
Photon is completely absorbed by atom, so its entire energy goes into excited state

$$\Delta E = hf = \frac{hc}{\lambda}$$

Atoms can also be excited by collisions

No restrictions on amount of energy or angular momentum change

Sodium (Na) Energy Diagram



Emission Spectra

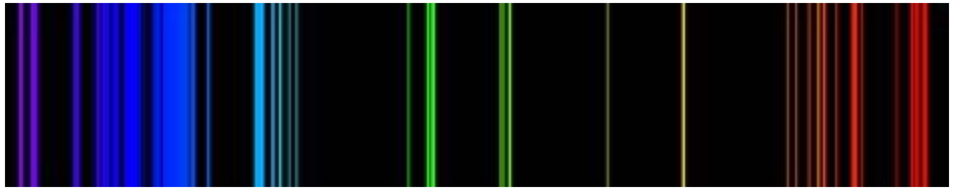
Excited atoms can emit a photon and fall down to lower energy state (time reverse of absorption)

Just like absorption, $\Delta l = 1$ so the atom can only transition diagonally

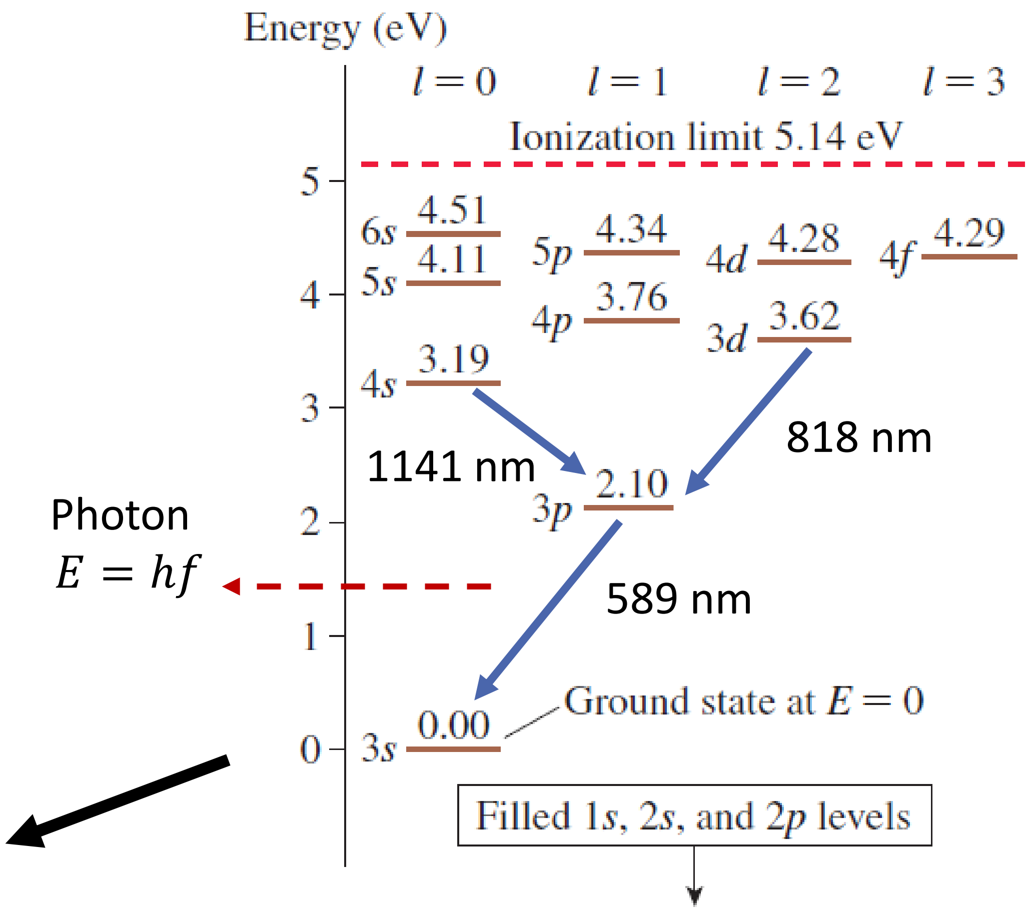
Entire energy difference between states goes into one photon

$$\Delta E = hf = \frac{hc}{\lambda}$$

This means each allowed transition corresponds to a unique wavelength of light



Sodium (Na) Energy Diagram



Stimulated Emission

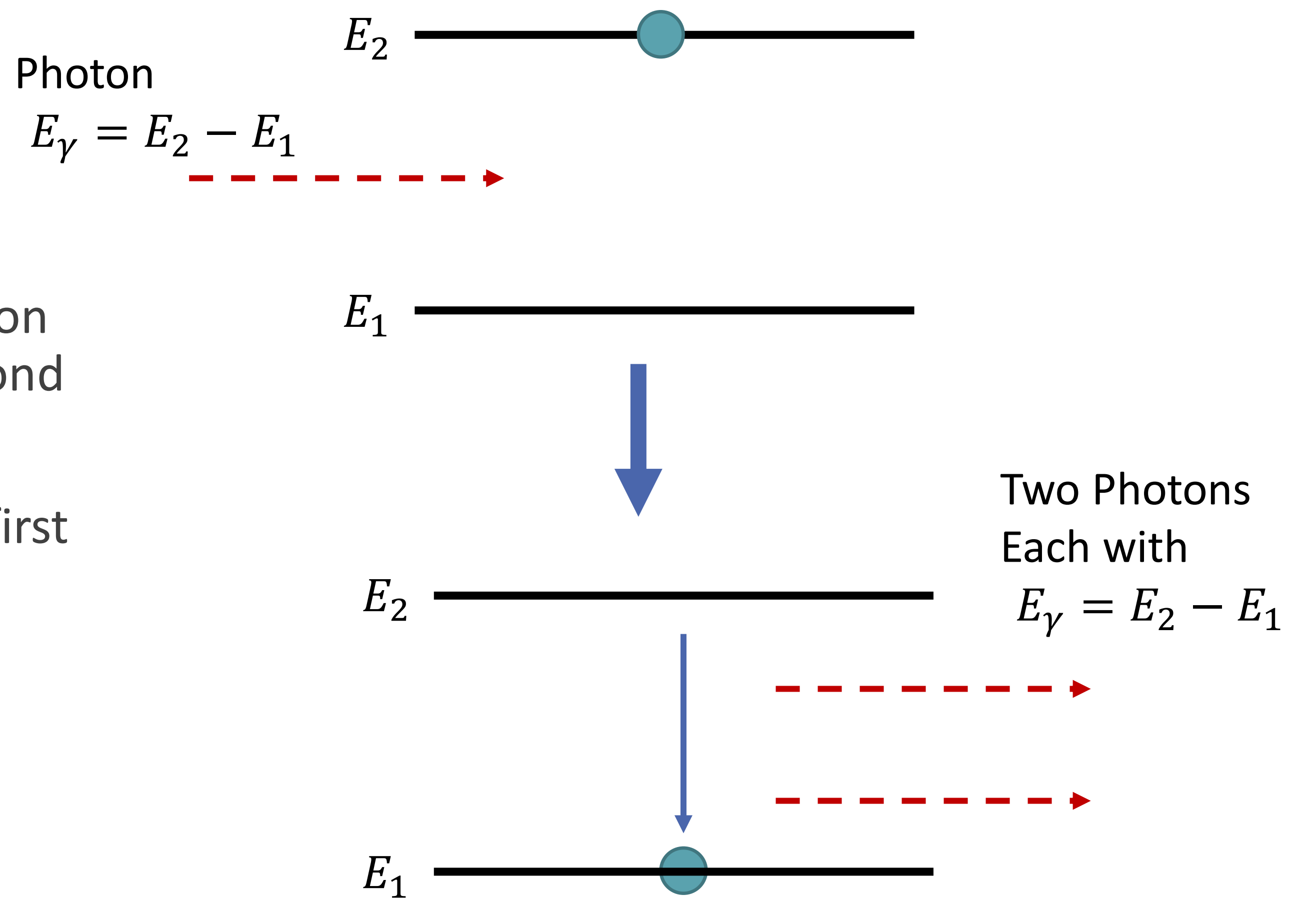
So far, we've been only talking about spontaneous emission

But atoms can also undergo stimulated emission

When an atom is in an excited state, a photon can come in and make the atom emit a second photon

This second photon is an exact copy of the first

Incoming photon must have $E_\gamma = \Delta E_{atom}$



Laser

With the right conditions, simulated emission can lead to a chain reaction

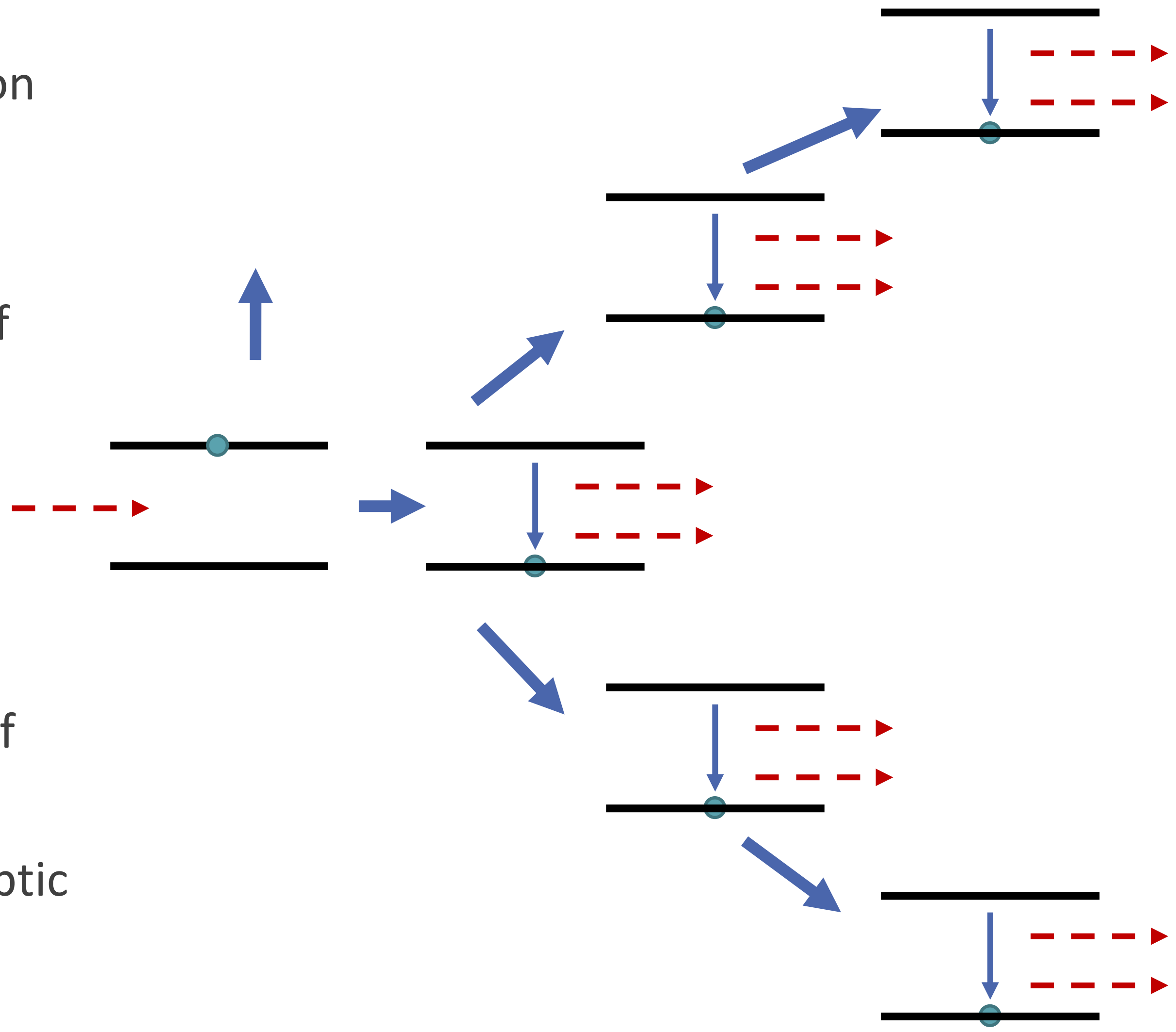
This is what's done inside a laser

Hard part is maintaining a large collection of atoms in the excited state (population inversion)

Then once one decays, it causes another to decay, which causes another two to decay, onwards

This make a higher power, coherent beam of photons at a specific frequency

Used in many technologies from the fiber optic backbone of the internet to surgery and medical imaging



Homework Questions

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