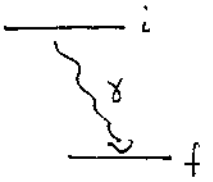


$\Delta E = \hbar\omega_\gamma$

The classic example of transitions into a continuum.

Radiative transitions

$$H_I = \int d^3x \, \mathcal{H}_I$$

$$\mathcal{H}_I = -\frac{1}{c}\vec{j}\cdot\vec{A}$$

current density (operator) of e^-

plane wave of the emitted photon.

n.b. with this norm for H_I, $\underline{e^2/\hbar c = 4\pi\alpha}$.

Actually, if this calculation is done correctly, $|i\rangle = |\text{init atomic } e^- \text{ state}\rangle \cdot \overbrace{|0\rangle}^{\text{no photons}}$

$|f\rangle = |\text{fin. atomic } e^- \text{ state}\rangle \cdot \underbrace{|\gamma_{\vec{k},\lambda}\rangle}_{1 \text{ photon}}$

and $\langle f|\mathcal{H}_I|i\rangle = \underbrace{-\frac{1}{c}\langle f_{e^-}|\vec{j}|i_{e^-}\rangle}_{e^- \text{ transition current density } j} \cdot \underbrace{\langle \gamma_{\vec{k},\lambda}|\vec{A}_{op}|0\rangle}_{\text{matrix element of the photon quantum field operator } \vec{A}_{op}(\vec{x},t).}$

(just gives the plane wave we use!)

The plane wave for an emitted photon is

$$\vec{A}(x,t) = \underbrace{\frac{\sqrt{\hbar}\, c}{\sqrt{2\omega_k V}}}_{\text{norm.}} \underbrace{\hat{\epsilon}^*_{k,\lambda}}_{\text{polarization vector}} \underbrace{e^{-i\omega_k t}\, e^{+i\vec{k}\cdot\vec{x}}}_{(+\text{-energy plane wave})}$$

$\boxed{\text{this part we already assumed \& pulled out to get Fermi's golden rule}}$ ($e^{-i\omega_k t}$)

polarization vector (unit norm $|\hat{\epsilon}|^2 = 1$, $\perp$ $\hat{\epsilon}_{k\lambda}\cdot\hat{k} = 0$)

units

$$\boxed{\begin{aligned} [j] &= e\cdot cm^{-2}\, sec^{-1} \\ [A] &= erg^{1/2}\, cm^{-1/2} \\ [e] &= erg^{1/2}\, cm^{1/2} \end{aligned}}$$

The norm is almost chosen so that the total energy in the plane wave

$$\mathcal{E} = \frac{1}{2}\int d^3x \left(\tfrac{1}{c}\dot{\vec{A}}^2 + (\vec{\nabla}\times\vec{A})^2 \right) = \frac{1}{2}\int d^3x \left(\vec{E}^2 + \vec{B}^2 \right) = \hbar\omega_{k\lambda}$$

$$= \mathcal{E}(\text{one photon})$$

(actually is an additional $\frac{1}{\sqrt{2}}$, since A has both $a_{k\lambda}$ and $a^\dagger_{k\lambda}$)

We also require the matrix element of $\vec{j}$ between initial and final atomic wfns. This is just the charge $-e$ times the probability current density,

$$\langle f_{e^-}|\vec{j}|i_{e^-}\rangle = -e\frac{\hbar}{2mi}\left[\psi_f^*\vec{\nabla}\psi_i - (\vec{\nabla}\psi_f)^*\psi_i\right] = -\frac{e}{m}\psi_f^*\vec{P}_{op}\psi_i$$

(sensible - current density is the expected $\vec{P}_{op}$ density $\cdot\frac{Q}{m}$, ~ "velocity density" $\cdot$ charge)

There is a standard simpler way to write this.

Note

$$[H_{e^-}, x_i] = \left[\frac{1}{2m}\vec{P}^2, x_i\right] = \frac{1}{2m}p_j\underbrace{[p_j, x_i]}_{-i\hbar\delta_{ij}} + \frac{1}{2m}\underbrace{[p_j, x_i]}_{-i\hbar\delta_{ij}}p_j$$

$$= -\frac{i\hbar}{m}p_i$$

So $$\psi_f^*\vec{p}_{op}\psi_i = -\frac{m}{i\hbar}\psi_f^*[H_{e^-},\vec{x}]\psi_i$$

$$= -\frac{m}{i\hbar}(E_{fe^-} - E_{ie^-})\psi_f^*\vec{x}\psi_i$$

atomic e^- wfn energies, $= -\hbar\omega_\gamma$

$$= -im\omega_\gamma\underbrace{\psi_f^*\vec{x}\psi_i}$$

simpler than dealing with gradients

Collecting the pieces, for $\langle f | \mathcal{H}_I = -\frac{1}{c}\vec{j}\cdot\vec{A} \,| i\rangle$ we have

time dep $e^{-i(E_f - E_i)t/\hbar}$ already assumed & removed

$$\langle f|\mathcal{H}_I|i\rangle = \underbrace{-\frac{1}{c}\left\{\left(-\frac{e}{m}\right)\cdot\underbrace{\left(-im\omega_\gamma \psi_f^* \vec{x}\,\psi_i\right)}_{\psi_f^*\vec{p}_{op}\psi_i}\right\}}_{\langle f_{e^-}|\vec{j}|i_{e^-}\rangle \;=\; +ie\omega_\gamma\langle f|\vec{x}|i\rangle} \cdot \underbrace{\frac{\sqrt{\hbar}\,c}{\sqrt{2\omega_\gamma V}}\,\hat{\epsilon}^*_{k,\lambda}\, e^{+i\vec{k}\cdot\vec{x}}}_{\langle \gamma_{\vec{k},\lambda}|\vec{A}(\vec{x})|0\rangle}$$

1-photon plane wave, $e^{-i\omega_k t}$ time dep. already removed

$$= -\frac{ie\omega_\gamma}{\cancel{c}}\cdot\frac{\sqrt{\hbar}\,\cancel{c}}{\sqrt{2\omega_\gamma V}}\left(\psi_f^*\vec{x}\,\psi_i\right)\cdot\hat{\epsilon}^*_{k,\lambda}\,e^{+i\vec{k}\cdot\vec{x}}$$

$$\langle f|H_I|i\rangle = -\frac{ie\omega_\gamma\sqrt{\hbar}}{\sqrt{2\omega_\gamma V}}\,\hat{\epsilon}^*_{k,\lambda}\cdot\int d^3x\,\left(\psi_f^*\vec{x}\,\psi_i\right)e^{i\vec{k}\cdot\vec{x}}$$

This, when squared & multiplied by the final (photon) density of states, will give our radiative transition rate formula.

Note however that it's <u>very</u> useful to expand the exponential, because for typical radiative transitions $kR \ll 1$.

Atomic scale $R \sim 1\,\text{Å}$ $\underset{\sim\sim}{= 10^{-8}\,\text{cm}}$. $E_\gamma \sim 1\,\text{eV} = \hbar\omega_\gamma = \hbar c k = \frac{2\pi\hbar c}{\lambda} = \frac{hc}{\lambda}$,

$$\lambda = \frac{2\pi\hbar c}{E_\gamma} \sim \frac{6\cdot 10^{-27}\,\cancel{\text{erg}}\cdot\cancel{\text{sec}}\cdot 3\cdot 10^{10}\,\text{cm}\,\cancel{\text{sec}^{-1}}}{2\cdot 10^{-12}\,\cancel{\text{erg}}}$$

$$\sim 10^{-4}\,\text{cm}$$

So, typical $kR = 2\pi\frac{R}{\lambda} \sim 10^{-3}$,

<u>$kR \ll 1$.</u>

Just keeping the leading term (long-λ approx) we have

$$\langle f | H_I | i \rangle = -ie\sqrt{\frac{\hbar\omega_k}{2V}}\;\hat{\epsilon}^{k}_{k\lambda}\cdot\underbrace{\langle f|\vec{x}|i\rangle}_{\vec{x}_{fi}}$$

Note $\langle f|-e\vec{x}|i\rangle$ is just the transition dipole moment. This is called "elec. dipole" or "E1" radiation

The decay rate into $d^3k_{f\gamma}$ is (differential golden rule)

$$d\Gamma_{i\to f} = \frac{2\pi}{\hbar}\,|\langle f|H_I|i\rangle|^2\,\delta(E_f - E_i)\,\underbrace{dn}$$

$$\hookrightarrow V\frac{d^3k_\gamma}{(2\pi)^3} = \frac{V}{(2\pi)^3}k^2\,dk\,d\Omega_k$$

$$= \frac{2\pi}{\hbar}\,|\langle f|H_I|i\rangle|^2\,\frac{V}{(2\pi)^3}\,k_\gamma^2\,\delta(E_f-E_i)\frac{dE}{\hbar c}\,d\Omega_k \qquad \omega_\gamma = ck_\gamma,\quad E_\gamma = \hbar\omega_\gamma = \hbar c k_\gamma$$

$\int dE \rightarrow$

$$d\Gamma_{i\to f} = \frac{2\pi}{\hbar}\;\frac{e^2\hbar\omega_k}{2V}\;|\hat{\epsilon}^{k}_{k\lambda}\cdot\vec{x}_{fi}|^2\cdot\frac{V}{(2\pi)^3}\;k_\gamma^2\;\frac{1}{\hbar c}\;d\Omega_k$$

$e^2 = \alpha\hbar c\cdot 4\pi$ (see p.10)

$\omega_\gamma = ck_\gamma$

$$\underline{\frac{d\Gamma_{i\to f}}{d\Omega_k} = \frac{1}{2\pi}\;\alpha c\;|\hat{\epsilon}^{k}_{k\lambda}\cdot\vec{x}_{fi}|^2\,k_\gamma^3}$$

Units? $[\text{sec}^{-1}] \overset{?}{=} [\text{cm sec}^{-1}]\cdot[\text{cm}^2]\cdot[\text{cm}^{-3}]$ ✓

$$\underline{\frac{d\Gamma^{E1}_{i\to f}}{d\Omega_f} = \frac{1}{2\pi} c\alpha\, k_\gamma^3 \left| \hat{\epsilon}^*_{k,\lambda} \cdot \vec{x}_{fi} \right|^2}$$

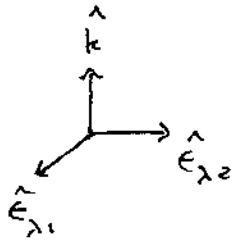
Without additional information, <u>this</u> is the <u>answer.</u> (up to overall norm - see end.)

$\vec{x}_{fi} \equiv \int d^3x\, \psi_f^*(\vec{x})\vec{x}\,\psi_i(\vec{x}) = \langle f|\vec{x}|i\rangle$

<u>Polarization sums</u>

We can simplify this result somewhat if we sum over all polarizations of the final photon. (e.g. to get <u>total</u> radiative decay rate.)

Note since $\hat{\epsilon}_{k,\lambda}\cdot\hat{k} = 0$, $\{\hat{\epsilon}_{k,1}, \hat{\epsilon}_{k2}, \hat{k}\}$ form a complete orthonormal triad.



$$\vec{A} = (\vec{A}\cdot\hat{k})\hat{k} + (\vec{A}\cdot\hat{\epsilon}^*_{\lambda,1})\hat{\epsilon}_{\lambda,1} + (\vec{A}\cdot\hat{\epsilon}^*_{\lambda,2})\hat{\epsilon}_{\lambda 2}$$

$$\text{or}\quad A_i = \underset{(\Sigma_j \text{ implicit})}{\delta_{ij} A_j} = \left(\hat{k}_i\hat{k}_j + \hat{\epsilon}_{\lambda_{1i}}\hat{\epsilon}^*_{\lambda_{1j}} + \hat{\epsilon}_{\lambda_{2i}}\hat{\epsilon}^*_{\lambda_{2j}}\right)A_j$$

$$\text{or}\quad \sum_\lambda \hat{\epsilon}^*_{k\lambda_i}\hat{\epsilon}_{k\lambda_j} = \delta_{ij} - \hat{k}_i\hat{k}_j$$

(if complex, $\hat{\epsilon}^*_{k\lambda}\cdot\hat{\epsilon}_{k\lambda'} \equiv \delta_{\lambda\lambda'}$)

Thus for any vector $\vec{A}$,

$$\sum_\lambda |\hat{\epsilon}_{k,\lambda}\cdot\vec{A}|^2 = |\vec{A}|^2 - |\hat{k}\cdot\vec{A}|^2 \quad \text{(projects out components of } \vec{A} \text{ along } \hat{k})$$

$$= (1-\cos^2\theta_{k,A})\,|\vec{A}|^2 = \sin^2\theta_{k,A}\,|\vec{A}|^2$$

and the <u>unpolarized</u> cross section is <u>a "dipole" radiation pattern, $\perp$ to $\vec{x}_{fi}$</u>

$$\sum_\lambda \frac{d\Gamma^{\epsilon}_{i\to f}}{d\Omega_k} = \frac{1}{2\pi} c\alpha k_\gamma^3 \sin^2\theta_{\hat{k},\vec{x}_{fi}} |\vec{x}_{fi}|^2 \qquad (\vec{x}_{fi} \text{ is just some fixed vector})$$

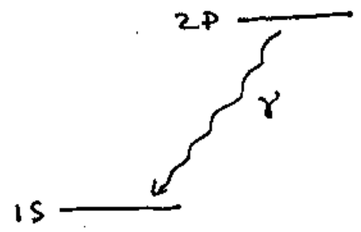
Now we can integrate over all angles of the outgoing photon, may as well use a coordinate system in which $\vec{x}_{fi} \propto \hat{z}$;

$$\int d\Omega \sin^2\theta = 2\pi \int_{-1}^{1} d\mu \left(1-\mu^2\right) = 4\pi \cdot \left(1-\frac{1}{3}\right) = \frac{8\pi}{3},$$

$$\underbrace{\Gamma^{E1}_{i\to f}} = \underbrace{\frac{4}{3} c\alpha \left|\vec{x}_{fi}\right|^2 k_\gamma^3}$$ <u>Unpolarized</u> E1 decay rate.

Explicit example of a radiative transition rate.

$$2P \to 1S + \gamma$$



$$E_{2P} = -\frac{1}{8} mc^2\alpha^2$$

$$E_{1S} = -\frac{1}{2} mc^2\alpha^2$$

$$E_\gamma = \frac{3}{8} mc^2\alpha^2 = \hbar\omega_\gamma = \hbar c k_\gamma$$

$$\therefore k_\gamma = \frac{3}{8}\,\frac{mc\alpha}{\hbar}\cdot\alpha = \frac{3}{2^3}\,\alpha a_0^{-1} \qquad \left(a_0 = \frac{\hbar}{mc\alpha}\right)$$

$$\Gamma_{A\to B\gamma} = \frac{4}{3}\alpha c\,|\vec{x}_{fi}|^2 k_\gamma^3$$

what is $\vec{x}_{fi}$? $\qquad \vec{x}_{fi} = \langle f|\vec{x}|i\rangle = \int d^3x\, \Psi_{1s}^*(\vec{x})\,\vec{x}\,\Psi_{2p}(\vec{x})$

Choose $L_z^{2P,i} = 0$:

$$\Psi_{2p}(\vec{x}) = \psi_{2p}(r)\,Y_{10}(\Omega) \qquad \psi_{2p}(r) = \eta_{2p}\, r e^{-r/2a_0}, \quad \eta_{2p} = 2^{-3/2}\,3^{-1/2}\,a_0^{-5/2}$$

$$\Psi_{1s}(\vec{x}) = \psi_{1s}(r)\,Y_{00}(\Omega) \qquad \psi_{1s}(r) = \eta_{1s}\, e^{-r/a_0}, \quad \eta_{1s} = 2a_0^{-3/2}$$

Only $\vec{x} = \underbrace{z\hat{z}} + x\hat{x} + y\hat{y}$

only will give a nonzero angular integral here.

$$\vec{x}_{fi} = \int_0^\infty r^2 dr\, \psi_{1s}(r)\psi_{2p}(r) \underbrace{\int d\Omega\, Y_{00}^*(\Omega)\, r\cos\theta\,\hat{z}\, Y_{10}(\Omega)}_{\frac{1}{\sqrt{4\pi}} r\hat{z}\int d\Omega \sqrt{\frac{4\pi}{3}}\, Y_{10}\cdot Y_{10} = \frac{1}{\sqrt{3}} r\hat{z}}$$

$$= \frac{1}{\sqrt{3}}\hat{z} \underbrace{\int_0^\infty r^3 dr\, \psi_{1s}(r)\psi_{2p}(r)}_{d}$$

$$\mathcal{I} = \eta_{1s}\,\eta_{2p} \int_0^\infty r^3 dr\, e^{-r/a_0} \cdot r e^{-2r/a_0}$$

$$= 2a_0^{-3/2} \cdot 2^{-3/2}\, 3^{-1/2}\, a_0^{-5/2} \cdot \underbrace{\int_0^\infty r^4 e^{-\frac{3}{2a_0}r} dr}_{\frac{4!}{\left(\frac{3a_0}{2a_0}\right)^5} = \frac{2^5}{3^5} a_0^{-5} \cdot 2^3 \cdot 3 = 2^8 3^{-4} a_0^{-5}}$$

$$= 2^{15/2}\, 3^{-9/2}\, a_0$$

$$\therefore \quad \vec{x}_{fi} = 2^{15/2}\, 3^{-5}\, a_0 \hat{z} \qquad\qquad |\vec{x}_{fi}|^2 = \frac{2^{15}}{3^{10}} a_0^2$$

decay rate

$$\underline{\Gamma_{2P\to 1S+\gamma}} = \frac{4}{3}\alpha c\, |\vec{x}_{fi}|^2 k_\gamma^3$$

$$= \frac{4}{3}\alpha c \cdot \frac{2^{15}}{3^{10}} a_0^2 \cdot \frac{3^3}{2^9} \frac{\alpha^3}{a_0^3}$$

$$= \underline{\frac{2^8}{3^8}} \cdot \underbrace{\underline{\frac{c}{a_0}\alpha^4}}_{\underline{\frac{mc^2}{\hbar}\alpha^5}} = \underline{1.606 \cdot 10^{10}\ [\text{sec}^{-1}]}$$

(all these E1 rates come out as this)

With the coeff $\frac{2^8}{3^8} = \frac{256}{6561}$, final result is

$$\underline{\Gamma^{E1}_{2P\to 1S+\gamma}} = \underline{6.266 \cdot 10^8\ [\text{sec}^{-1}]} \quad \checkmark$$

(NIST data sheet has $\underline{6.265 \cdot 10^8\ [\text{sec}^{-1}]}$) thy, not expt!

expt ref: W.S. Bickel + A.S. Goodman, pr 148, 1 (1966).

quote thy. numbers!

(list some expt refs.)

Nist Atomic Physics Database

(2J_i+1) (2J_k+1)

trans	λ [Å]	E_i [cm^{-1}]	E_k [cm^{-1}]	$g_i - g_k$	A_{ki} [10^8 sec^{-1}]
1s – 2p	1215.670	0	–82 259.165	2–6	$6.265 \cdot 10^{0}$
2p – 3s	6562.857	82 259.165	–97 492.2235	6 – 2	$6.313 \cdot 10^{-2}$
2p – 3d	6562.805	82 259.165	–97 492.343	6 – 10	$6.465 \cdot 10^{-1}$

c/o Jeffrey R. Fuhr, NIST
(301 · 975 · 3204)

www.nist.gov

physics.nist.gov/asd

DATA — INFORMATION

NIST Atomic Spectra Database Lines Data (Multiplet Ordered)
H I 308 Lines of Data Found (page 1 of 4)

Wavelength units: vac Å < 2000 Å < air Å < 10,000 Å < vac cm^{-1}

Allowed Transitions

Mult. No.	Configurations	Terms	Wavelength	E_i (cm^{-1})	E_k (cm^{-1})	g_i-g_k	A_{ki} ($10^8\ s^{-1}$)	Acc.
1	1*s*–2*p*	^2S–$^2P^o$	*1 215.670*	0.	– *82 259.165*	2–6	6.265e+0	AA
			1 215.6682	0.	– 82 259.2865	2–4	6.265e+0	AA’
			1 215.6736	0.	– 82 258.9206	2–2	6.265e+0	AA’
2	1*s*–3*p*	^2S–$^2P^o$	*1 025.722*	0.	– *97 492.285*	2–6	1.672e+0	AA
			1 025.7218	0.	– 97 492.3214	2–4	1.672e+0	AA’
			1 025.7229	0.	– 97 492.2130	2–2	1.672e+0	AA’
3	1*s*–4*p*	^2S–$^2P^o$	*972.537*	0.	– *102 823.881*	2–6	6.818e-1	AA
			972.5366	0.	– 102 823.8962	2–4	6.818e-1	AA’
			972.5370	0.	– 102 823.8505	2–2	6.818e-1	AA’
4	1*s*–5*p*	^2S–$^2P^o$	*949.743*	0.	– *105 291.646*	2–6	3.437e-1	AA

			949.7429	0.	– 105 291.6540	2–4	3.437e-1	AA'
			949.7431	0.	– 105 291.6306	2–2	3.437e-1	AA'
5	1*s*–6*p*	^{2}S–^{2}P°	*937.803*	0.	– *106 632.160*	2–6	1.973e-1	AA
			937.8033	0.	– 106 632.1640	2–4	1.973e-1	AA'
			937.8035	0.	– 106 632.1505	2–2	1.973e-1	AA'
6	2*p*–3*s*	^{2}P°–^{2}S	*6 562.857*	*82 259.165*	– 97 492.2235	6–2	6.313e-2	AA
			6 562.9093	82 259.2865	– 97 492.2235	4–2	4.209e-2	AA'
			6 562.7517	82 258.9206	– 97 492.2235	2–2	2.104e-2	AA'
7	2*p*–4*s*	^{2}P°–^{2}S	*4 861.346*	*82 259.165*	– 102 823.8549	6–2	2.578e-2	AA
			4 861.3748	82 259.2865	– 102 823.8549	4–2	1.719e-2	AA'
			4 861.2883	82 258.9206	– 102 823.8549	2–2	8.593e-3	AA'
8	2*p*–5*s*	^{2}P°–^{2}S	*4 340.477*	*82 259.165*	– 105 291.6329	6–2	1.289e-2	AA
			4 340.4998	82 259.2865	– 105 291.6329	4–2	8.593e-3	AA'
			4 340.4308	82 258.9206	– 105 291.6329	2–2	4.297e-3	AA'
9	2*p*–6*s*	^{2}P°–^{2}S	*4 101.745*	*82 259.165*	– 106 632.1518	6–2	7.350e-3	AA
			4 101.7658	82 259.2865	– 106 632.1518	4–2	4.900e-3	AA'
			4 101.7043	82 258.9206	– 106 632.1518	2–2	2.450e-3	AA'
10	2*s*–3*p*	^{2}S–^{2}P°	*6 562.740*	82 258.9559	– *97 492.285*	2–6	2.245e-1	AA

			6 562.7247	82 258.9559 - 97 492.3214	2–4	2.245e-1	AA'
			6 562.7714	82 258.9559 - 97 492.2130	2–2	2.245e-1	AA'
11	2*s*–4*p*	$^2S-^2P^\circ$	*4 861.290*	82 258.9559 - *102 823.881*	2–6	9.668e-2	AA
			4 861.2869	82 258.9559 - 102 823.8962	2–4	9.668e-2	AA'
			4 861.2977	82 258.9559 - 102 823.8505	2–2	9.668e-2	AA'
12	2*s*–5*p*	$^2S-^2P^\circ$	*4 340.435*	82 258.9559 - *105 291.646*	2–6	4.948e-2	AA
			4 340.4335	82 258.9559 - 105 291.6540	2–4	4.948e-2	AA'
			4 340.4379	82 258.9559 - 105 291.6306	2–2	4.948e-2	AA'
13	2*s*–6*p*	$^2S-^2P^\circ$	*4 101.709*	82 258.9559 - *106 632.160*	2–6	2.858e-2	AA
			4 101.7081	82 258.9559 - 106 632.1640	2–4	2.858e-2	AA'
			4 101.7104	82 258.9559 - 106 632.1505	2–2	2.858e-2	AA'
14	2*p*–3*d*	$^2P^\circ-^2D$	*6 562.805*	*82 259.165* - *97 492.343*	6–10	6.465e-1	AA
			6 562.8516	82 259.2865 - 97 492.3574	4–6	6.465e-1	AA'
			6 562.7096	82 258.9206 - 97 492.3212	2–4	5.388e-1	AA'
			6 562.8672	82 259.2865 - 97 492.3212	4–4	1.078e-1	AA'
15	2*p*–4*d*	$^2P^\circ-^2D$	*4 861.334*	*82 259.165* - *102 823.905*	6–10	2.062e-1	AA
			4 861.3614	82 259.2865 - 102 823.9114	4–6	2.062e-1	AA'
			4 861.2785	82 258.9206 - 102 823.8961	2–4	1.718e-1	AA'
			4 861.3650	82 259.2865 - 102 823.8961	4–4	3.437e-2	AA'

16	$2p$–$5d$	$^2P^\circ$–^2D	*4 340.472*	*82 259.165 – 105 291.659*	6–10	9.425e-2	AA
			4 340.4943	82 259.2865 – 105 291.6618	4–6	9.425e-2	AA'
			4 340.4268	82 258.9206 – 105 291.6540	2–4	7.854e-2	AA'
			4 340.4958	82 259.2865 – 105 291.6540	4–4	1.571e-2	AA'
17	$2p$–$6d$	$^2P^\circ$–^2D	*4 101.743*	*82 259.165 – 106 632.167*	6–10	5.145e-2	AA
			4 101.7630	82 259.2865 – 106 632.1685	4–6	5.145e-2	AA'
			4 101.7022	82 258.9206 – 106 632.1640	2–4	4.288e-2	AA'
			4 101.7638	82 259.2865 – 106 632.1640	4–4	8.575e-3	AA'
18	$3s$–$4p$	^2S–$^2P^\circ$	*5 331.658 cm^{-1}*	97 492.2235 – *102 823.881*	2–6	3.065e-2	AA
			5 331.6727 cm^{-1}	97 492.2235 – 102 823.8962	2–4	3.065e-2	AA'
			5 331.6270 cm^{-1}	97 492.2235 – 102 823.8505	2–2	3.065e-2	AA'
19	$3s$–$5p$	^2S–$^2P^\circ$	*7 799.423 cm^{-1}*	97 492.2235 – *105 291.646*	2–6	1.638e-2	AA
			7 799.4305 cm^{-1}	97 492.2235 – 105 291.6540	2–4	1.638e-2	AA'
			7 799.4071 cm^{-1}	97 492.2235 – 105 291.6306	2–2	1.638e-2	AA'

- **Page 1** - Next 100 lines of output

NIST atomic database

Return to main page

Publications on Atomic Transition Probabilities

Method(s): lifetime

that include atomic number(s) Z = 1

that include stage(s) I

12 references found:

Emission of the H-α and H-β lines excited by electron impact on H_2,
M. Ortiz, J. Campos,
J. Chem. Phys. **72**, 5635 (1980).

Lifetimes and initial populations of foil-excited hydrogen and lithium states,
H. H. Bukow, H. v. Buttlar, D. Haas, P. H. Heckmann, M. Holl, W. Schlagheck, D. Schürmann, R. Tielert, and R. Woodruff,
Nucl. Instrum. Methods **110**, 89 (1973).

A correlated-fit method including cascade corrections in beam-foil experiments on hydrogen,
R. Tielert and H. H. Bukow,
Z. Phys. **264**, 119 (1973) (Ger.).

Hydrogen Balmer lifetimes,
R. A. Mickish and R. G. Fowler,
Bull. Am. Phys. Soc. **16**, 205 (1971).

Lifetimes and relative initial state populations of some hydrogen atomic states using beam-foil spectroscopy,
D. Schürmann, W. Schlagheck, P. H. Heckmann, H. H. Bukow, and H. v. Buttlar,
Z. Phys. **246**, 239 (1971) (Ger.).

Lifetimes of 3p, 4p, and 5p states in atomic hydrogen,
R. C. Etherton, L. M. Beyer, W. E. Maddox, and L. B. Bridwell,
Phys. Rev. A **2**, 2177 (1970).

Radiative mean life measurements of some atomic-hydrogen excited states using beam-foil excitation,
E. L. Chupp, L. W. Dotchin, and D. J. Pegg,
Phys. Rev. **175**, 44 (1968).

Mean lifetimes of excited states of hydrogen and their influence on the intensity distribution of the hydrogen Stark effect. Application of Wien's intensity decay experiment to the Stark-effect components,

R. Gebauer and H. Jäger,
Acta Phys. Austriaca **26**, 123 (1967) (Ger.).

Mean lives of the 2p and 3p levels in atomic hydrogen,
W. S. Bickel and A. S. Goodman,
Phys. Rev. **148**, 1 (1966).

Mean lives of some states in atomic hydrogen,
A. S. Goodman and D. J. Donahue,
Phys. Rev. **141**, 1 (1966).

Measurement of the lifetimes of the n=3 states of H by electron capture during fast H^+ impact on gases,
R. H. Hughes, H. R. Dawson, and B. M. Doughty,
J. Opt. Soc. Am. **56**, 830 (1966).

Measurement of lifetimes of excited states of the hydrogen atom,
V. A. Ankudinov, S. V. Bobashev, and E. P. Andreev,
Sov. Phys.--JETP **21**, 26 (1965).

Return to main page