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How Fast a Hydrogen Atom can Move Before Its Proton and Electron Fly Apart?

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Abstract

In this paper we discussed the behavior of a hydrogen atom in moving and found there is a speed threshold for hydrogen atom. As long as the speed of hydrogen reaches or beyond its speed threshold, the proton and electron in hydrogen atom will fly apart. We also discussed the effect of the movement of hydrogen atom on its absorption spectrum which is important in spectrum analysis.

Keywords: Redshift, Blue Shift, Speed Threshold, Hydrogen Ionized, Time Travel

1. Introduction

Einstein's theories of special and general relativities change our opinion about the universe [1,2]. The new concepts such as time inflation and curved spacetime frequently appeared in scientific publications. Some idea developed from Einstein's theory even causes the imagination of the fiction novel writer and they write a lot of books regarding the time travel [3,4]. Meantime, some scientists mainly focus on how to make the time travel theoretically possible. The reason why human beings are so interested in time travel is in that based on the Einstein's theory, the people can live much longer by time travel. This dream for long life ignites the human beings' speculation on the universe we lived in.

Until now so many proposals about time travel have been published in scientific journals. Kurt Goedel pointed out the closed time like curves (CTCs) may make the time travel possible [5]. Deutsch also proposed a Hilbert-space based theory [6]. H. G. Well even designed the time machine which can be used for time travel, just like space shuttle [7]. Morris *et al.* try to develop the quantum mechanics based the closed time like curve, therefore, the concept of worm hole is proposed [8]. Even more recently, the quantum mechanics of time travel is still actively discussed in literatures [9-12].

In this paper, we will not focus on the difference among the theories regarding the time travel. Instead, we will study the behavior of a hydrogen atom in moving and its effect on the excitation spectrum of hydrogen atom, which may give us some clue about the time travel.

2. Speed Threshold for Hydrogen Atom

For a system including a free electron and proton, total energy of the system is:

$$\gamma^{'}(m_n^0 + m_e^0)c^2 \tag{1}$$

Where m_n^0 and m_e^0 are the masses of proton and electron at rest respectively. c is the speed of light in vacuum. $\gamma^{'}$ is the Lawrence factor.

When the proton and electron combined together to form a hydrogen atom, total energy of system becomes

$$\gamma\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8\varepsilon_0^2 n^2 h^2 c^2}\right)c^2 \text{, where } \mu = \frac{m_n^0 m_e^0}{m_n^0 + m_e^0} \tag{2}$$

If we accelerate the hydrogen atom, total energy of system increases. When total energy of system reaches or more than $\gamma^{'}(m_n^0 + m_e^0)c^2$, then the proton and electron in hydrogen atom will fly apart, that is,

$$\gamma\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8\varepsilon_0^2 n^2 h^2 c^2}\right)c^2 \ge \gamma^{'}(\mathrm{m_n^0} + \mathrm{m_e^0})\mathrm{c}^2 \tag{3}$$

$$\frac{\gamma}{\gamma^{'}} \ge \frac{m_n^0 + m_e^0}{m_n^0 + m_e^0 - \frac{\mu e^4}{8\varepsilon_0^2 n^2 h^2 c^2}} \tag{4}$$

$$\frac{\sqrt{1-\frac{v^{'2}}{c^2}}}{\sqrt{1-\frac{v^2}{c^2}}} \ge \left(\frac{m_n^0 + m_e^0}{m_n^0 + m_e^0 - \frac{\mu e^4}{8\varepsilon_0^2 n^2 h^2 c^2}}\right) \tag{5}$$

$$\frac{1-\frac{v'^2}{c^2}}{1-\frac{v^2}{c^2}} \geq \left(\frac{m_n^0 + m_e^0}{m_n^0 + m_e^0 - \frac{\mu e^4}{8\varepsilon_0^2 n^2 h^2 c^2}} \right)^2 \qquad (6)$$

$$1-\frac{v^2}{c^2} \leq \frac{\left(1-\frac{v'^2}{c^2}\right)\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8\varepsilon_0^2 n^2 h^2 c^2}\right)^2}{(m_n^0 + m_e^0)^2} \qquad (7)$$

$$\frac{v^2}{c^2} \geq 1-(1-\frac{v'^2}{c^2})\left[1-\frac{\mu e^4}{8\varepsilon_0^2 n^2 h^2 c^2 (m_n^0 + m_e^0)}\right]^2 \qquad (8)$$

$$v^2 \geq \left[1-(1-\frac{v'^2}{c^2})(1-\alpha)^2\right]c^2 ,$$

$$\text{where } \alpha = \frac{\mu e^4}{8\varepsilon_0^2 n^2 h^2 c^2 (m_n^0 + m_e^0)} \qquad (9)$$

$$v^2 \geq \left(2\alpha - \alpha^2 + \frac{v'^2}{c^2} - 2\alpha\frac{v'^2}{c^2} + \alpha^2\frac{v'^2}{c_2}\right)c^2 \qquad (10)$$

$$v \geq \left(2\alpha - \alpha^2 + \frac{v'^2}{c^2} - 2\alpha\frac{v'^2}{c^2} + \alpha^2\frac{v'^2}{c_2}\right)^{1/2} c \qquad (11)$$

For $n = 1$ and $v' = 0$, we got the maximum speed of a hydrogen atom can move before its proton and electron fly apart is 51 027 m/s, which is much lower than the speed of light in vacuum space.

Figure 1 shows the dependence of this speed threshold on the main quantum number. It is found that with the main quantum number increasing, the speed threshold decreases, which can be fitted as *f*~1/*n*. More generally, this dependence of speed threshold on the main quantum number can be expressed as *f*~*k*/*n*, where *k* is a constant. This result is consistent with the fact that the electron in outer shell of atom is easy to lose during the acceleration of hydrogen atom.

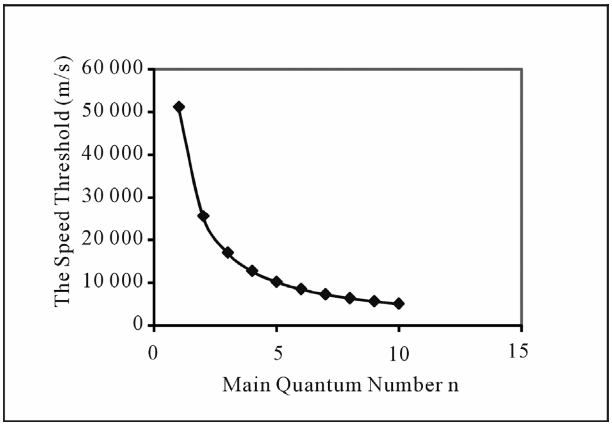

Figure 1. The dependence of the speed threshold on main quantum number.

Practically, in most cases, the *v*' can't be zero, the proton and electron will continue to move after they fly apart. **Figure 2** shows the dependence of the speed of proton and electron just after they fly apart on *v*. It is noticed that the speed of threshold doesn't increase linearly with the final speed of proton and electron but at the beginning, the speed of threshold increase very slowly when the final speed of proton and electron increase. The reason why this situation occurred is due to the fact that the electron has angular momentum when it rotates around proton called orbital angular momentum. The increase of the final speeds of proton and electron at the beginning comes from the release of the orbital angular momentum. With the main quantum number increasing, this situation becomes weaker and weaker, corresponding to the smaller and smaller the orbital angular momentum.

Our work here first time demonstrated that the atom can be broken into its parts by just accelerating it. Most of people know that the electron can be removed from atom by radiation or colliding/bombarding by atom, electron and proton, but few people know that the same process can be realized by just accelerating the atom to or above its speed threshold revealed above.

Since Einstein setup relativity theory, a lot of people dream some day they can travel with the speed of light, therefore, they can live longer. Unfortunately, our work here makes their dream broken. For example, we have two inertia frames, frame a at rest but frame b moves with speed of 0.5c. There is a hydrogen atom at rest in frame a. Now we hope to bring this hydrogen atom from frame a to frame b, then we have to accelerate this hydrogen atom at least up to 0.5c first. Based on our work here, before the hydrogen atom reaches the speed of frame b (0.5c), the hydrogen atom will be broken into proton and electron when its speed reaches 51 027 m/s, therefore, we start with a hydrogen atom from frame a but get a free proton and a free electron in frame b instead. In frame b, the proton and electron have a chance to recombine together to form a hydrogen atom, and at the same time, give up the energy in frame b. This process will be the same when we try to bring a hydrogen atom at rest in frame b to frame a. For a proton and electron to recombine into hydrogen atom, the probability of this process depends on the concentration of proton and electron, and relative speed of proton and electron. For a person, if he/she is broken into parts, the probability for him/her to be reinstalled back to him/her is definitely too low to happen. Maybe one thinks to accelerate the hydrogen atom slowly enough to avoid the proton and electron in hydrogen atom to fly apart. In fact, it is impossi ble because based on our result above, as long as the

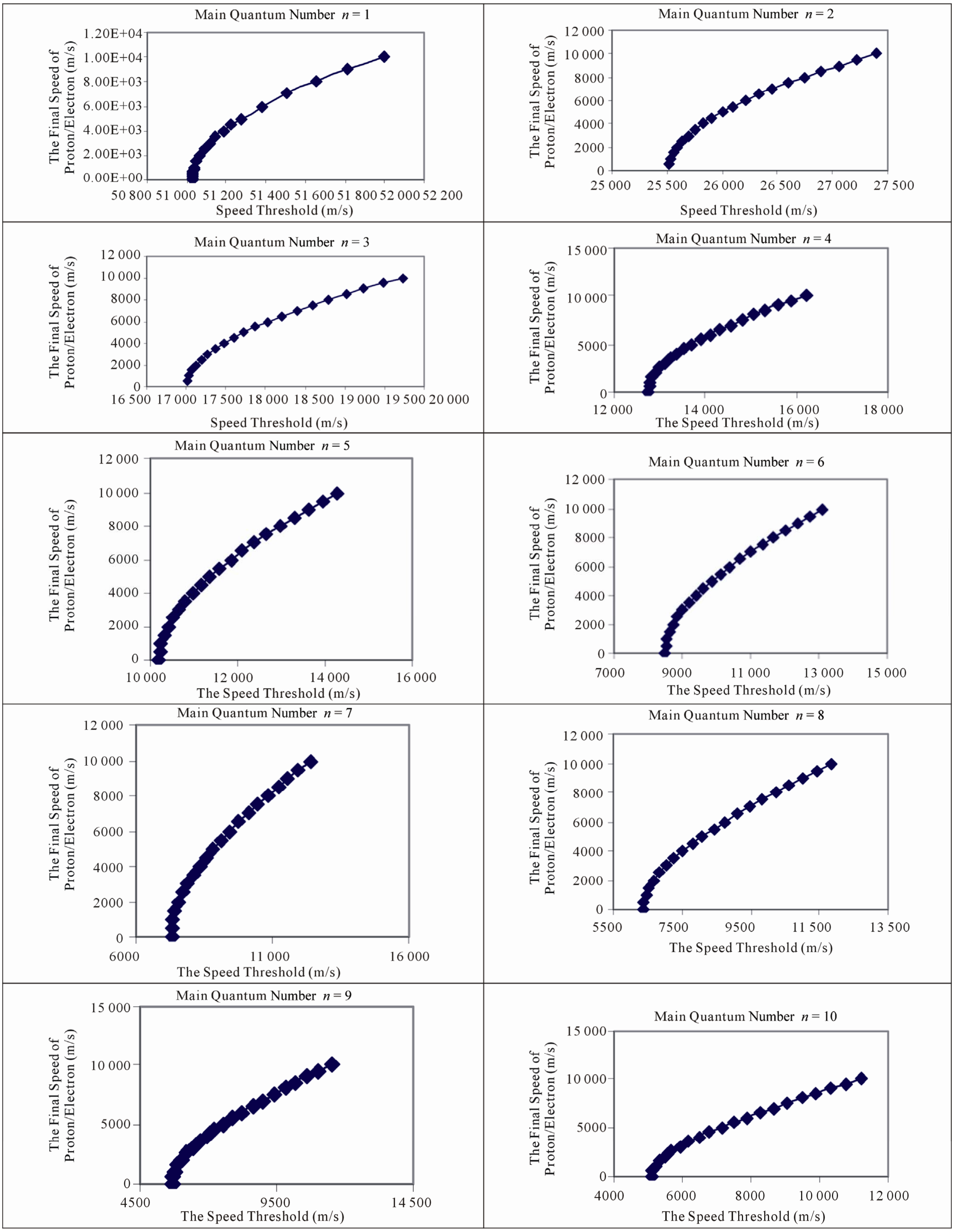

Figure 2. The dependence of the speed threshold on the final speed of proton/electron (just flying apart; main quantum number 1 - 10).

speed of hydrogen atom reaches the speed threshold, the proton and electron in hydrogen atom will fly apart (**Figure 3** the velocity corresponding to different acceleration). Lawrence invariance of transformation law is still valid and all physical laws are kept the same in both frames but the process from the frame a to the frame b is not always invariance except that the difference in speed between frame a and frame b is much lower than the speed threshold. Our work here really a bad news for those to dream some day they can make a time travel and live longer but it is good news for us to develop new technology to study the structure of matter based on our work here. Our work also opens a way to calculate the activation energy for the molecules in chemical reaction and predict the reaction mechanism.

3. Light Absorption of Hydrogen Atom in Moving

For the light absorption of hydrogen atom in moving, we consider two processes here.

Process a.

hν ~~~~≻ +*atom* ~~~~~≻⇒ *atom* ~~~~≻

$(v \to)$ $(v' \to)$

The momentum conservation:

$$\gamma\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8n_1^2h^2c^2\varepsilon_0^2}\right)v + \frac{h\nu}{c} = \gamma'\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8n_2^2h^2c^2\varepsilon_0^2}\right)v' \tag{12}$$

The energy conservation:

$$\gamma\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8n_1^2h^2c^2\varepsilon_0^2}\right)c^2 + h\nu = \gamma'\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8n_2^2h^2c^2\varepsilon_0^2}\right)c^2 \tag{13}$$

$(13) \div c$

$$\gamma\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8n_1^2h^2c^2\varepsilon_0^2}\right)c + \frac{h\nu}{c} = \gamma'\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8n_2^2h^2c^2\varepsilon_0^2}\right)c \tag{14}$$

(12) − (14)

$$\gamma\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8n_1^2h^2c^2\varepsilon_0^2}\right)(v-c) = \gamma'\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8n_2^2h^2c^2\varepsilon_0^2}\right)(v'-c) \tag{15}$$

$(15) \div c$

$$\gamma\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8n_1^2h^2c^2\varepsilon_0^2}\right)\left(\frac{v}{c}-1\right) = \gamma'\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8n_2^2h^2c^2\varepsilon_0^2}\right)\left(\frac{v'}{c}-1\right) \tag{16}$$

$$\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8n_1^2h^2c^2\varepsilon_0^2}\right)\left(\frac{v}{c}-1\right) = \frac{1}{\sqrt{1-\frac{v'^2}{c^2}}}\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8n_2^2h^2c^2\varepsilon_0^2}\right)\left(\frac{v'}{c}-1\right) \tag{17}$$

$$\frac{1}{\sqrt{(1+\frac{v}{c})(1-\frac{v}{c})}}\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8n_1^2h^2c^2\varepsilon_0^2}\right)\left(\frac{v}{c}-1\right) = \frac{1}{\sqrt{(1+\frac{v'}{c})(1-\frac{v'}{c})}}\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8n_2^2h^2c^2\varepsilon_0^2}\right)\left(\frac{v'}{c}-1\right) \tag{18}$$

$$\frac{\sqrt{1-\frac{v}{c}}}{\sqrt{1+\frac{v}{c}}}\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8n_1^2h^2c^2\varepsilon_0^2}\right) = \frac{\sqrt{1-\frac{v'}{c}}}{\sqrt{1+\frac{v'}{c}}}\left(m_n^0 + m_e^0 - \frac{\mu e^4}{8n_2^2h^2c^2\varepsilon_0^2}\right) \tag{19}$$

$$\sqrt{\frac{1-\frac{v}{c}}{1+\frac{v}{c}}}Q_1 = \sqrt{\frac{1-\frac{v'}{c}}{1+\frac{v'}{c}}}Q_2\text{, where } Q_1 = \left(m_n^0 + m_e^0 - \frac{\mu e^4}{8n_1^2h^2c^2\varepsilon_0^2}\right) \text{ and } Q_2 = \left(m_n^0 + m_e^0 - \frac{\mu e^4}{8n_2^2h^2c^2\varepsilon_0^2}\right) \tag{20}$$

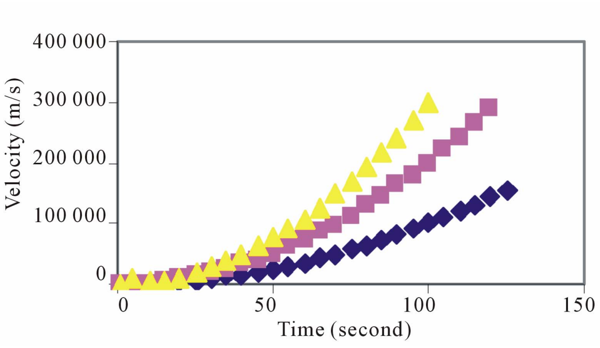

Figure 3. Velocity corresponding on different acceleration (a : 10; 20; 30 meter per square second).

Make rearrangement, we get,

$$\frac{v}{c}=\frac{Q_1^2\left(1+\frac{v'}{c}\right)-Q_2^2\left(1-\frac{v'}{c}\right)}{Q_1^2\left(1+\frac{v'}{c}\right)+Q_2^2\left(1-\frac{v'}{c}\right)} \quad (21)$$

Generally, v' increases with v (**Figure 4**). but if we check $\Delta v = v' - v$, it is found that Δv exhibits up and down dependence on v'or v. This up and down variation of Δv comes from the electron orbital angular momentum release during the excitation. This fact tells us that when we accelerate the hydrogen atom, the hydrogen atom speed can't linearly increase or decrease. This result is consistent with the discussion about the dependence of the speed threshold on the main quantum number in previous paragraph.

From Equation (13), we can get,

$$\nu=\left(\gamma' Q_2-\gamma Q_1\right)\frac{c^2}{h} \quad (22)$$

In fact, we can simplify the Equation (22) by taking

$$\gamma' \approx 1+\frac{v'^2}{2c^2} \quad \text{and} \quad \gamma \approx 1+\frac{v^2}{2c^2} \quad (23)$$

We get,

$$\nu=(Q_2-Q_1)\frac{c^2}{h}+\frac{1}{2h}(Q_2 v'^2-Q_1 v^2) \quad (24)$$

First term in Equation (24) is the fundamental frequency during excitation. The second term in Equation (24) is the frequency shift due to the movement of hydrogen atom during the excitation. It is obvious that this frequency shift depends on both the speed of v and v'. here exists the possibility that in some case, if initial state of hydrogen atom or final state of hydrogen atom involved in some other process, such as chemical reaction or just collision and therefore, the v and v' be changed, then the frequency shift term in Equation (24) may change sign, that is, may change from blue shift to red shit or vice versa. If this situation really happened in our universe, then the red shift observation from the sky is not enough for us to conclude our universe in expansion, at least we have to make clear no other process involved in this red shift as we discussed above.

Table 1 lists the frequency shift (blue shift) for process a. This blue shift increases with the speed of v and v'. But we do find if $v' = 0$, then we observed the red shift instead of blue shift.

Process b:

$$\underset{(v\rightarrow)}{atom \sim\sim\sim\sim\succ} + \prec\sim\sim\sim\sim\sim h\nu \Rightarrow \underset{(v'\rightarrow)}{atom \sim\sim\sim\sim\sim\succ}$$

Now we consider the process b. Based on the similar procedure above, we get,

$$\frac{v}{c}=\frac{\left(1+\frac{v'}{c}\right)Q_2^2-\left(1-\frac{v'}{c}\right)Q_1^2}{\left(1+\frac{v'}{c}\right)Q_2^2+\left(1-\frac{v'}{c}\right)Q_1^2} \quad (25)$$

For the process b, it is different from the process a in that the v' is always smaller than v, not like in process a, v' always higher than v. But the $\Delta = v' - v$ dependence on v or v' is also up and down (**Figure 5**). The reason for $\Delta v = v' - v$ up and down with v or v' is the same as in the process a (**Figure 4**).

Similarly, we can get the frequency for the process b,

$$\nu=\left(Q_2-Q_1\right)\frac{c^2}{h}+\frac{1}{2h}\left(Q_2 v'^2-Q_1 v^2\right) \quad (26)$$

The first term in Equation (26) is the fundamental frequency, the second term determines the frequency shift (**Table 2**). As in process a, this frequency shift for process b also depends on both v and v'. That means if the initial or final state of hydrogen atom during excitation involved in different process which causes the v or v'

Table 1. The frequency shift for process a (n_1---->n_2; fundamental frequency: 2.441 506 795 × 10^{15} s^{-1})

V(m/s)	V′ (m/s)	Frequency Shift (s^{-1})
–3.22	0	–13 130 646
46.84	50	386 41 422
96.90	100	769 398 085
196.88	200	1 560 293 149
296.86	300	2 360 742 859
496.82	500	3 991 647 651
996.88	1000	7 859 519 504
1996.84	2000	1.594 573 12 × 10^{10}
2996.79	3000	2.424 671 811×10^{10}
3996.90	4000	3.124 430 618 × 10^{10}
4996.86	5000	3.958 820 247 × 10^{10}
5996.82	6000	4.815 233 973 × 10^{10}
6996.77	7000	5.693 113 276 × 10^{10}
7996.88	8000	6.288 723 844 × 10^{10}
8996.84	9000	7.170 373 014 × 10^{10}
9996.80	10 000	8.074 555 981 × 10^{10}

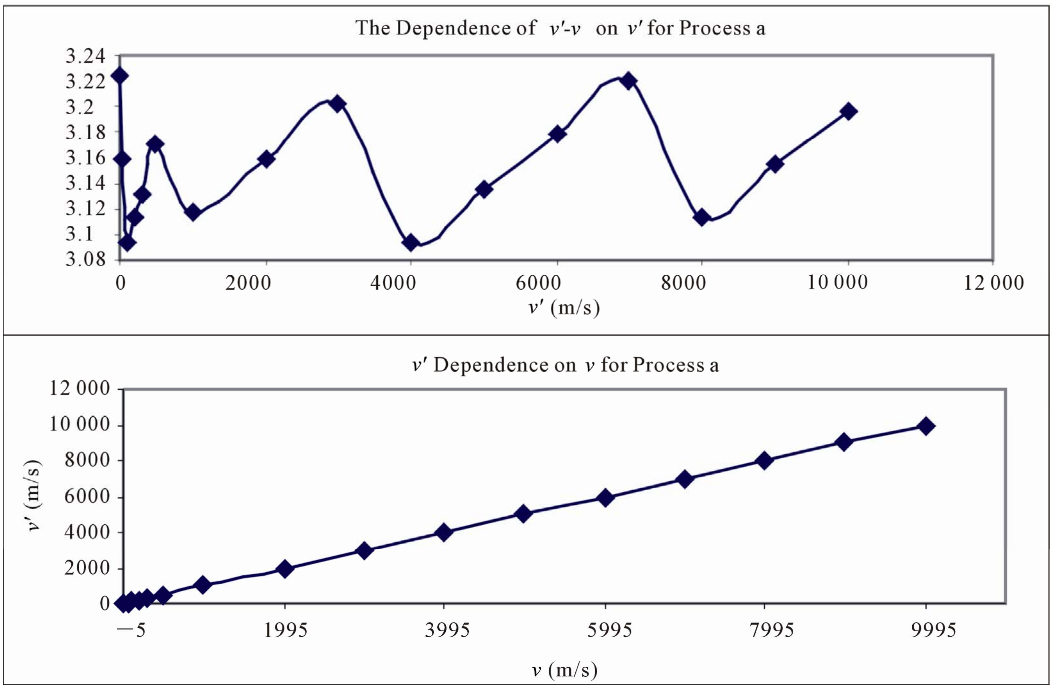

Figure 4. The relation between *v*, *v*' and *v*'–*v* for process a.

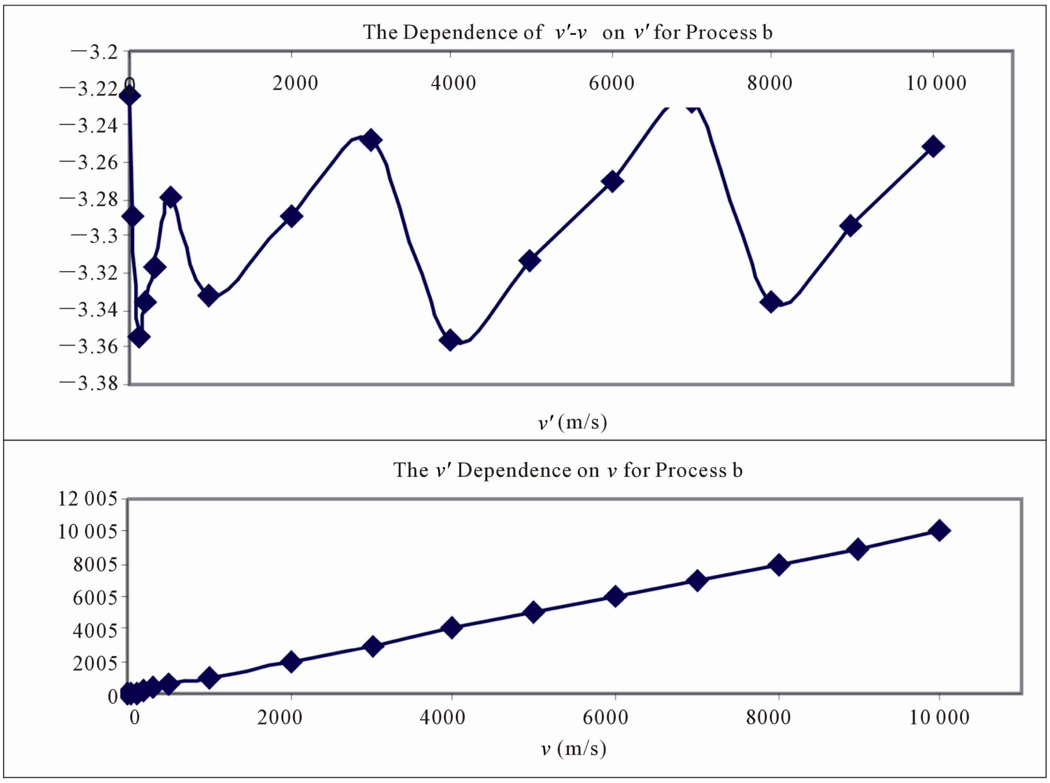

Figure 5. The relation between *v*, *v*' and *v*'–*v* for process b.

changed, then the frequency shift may change sign as we discussed in process a. Therefore, we can't uniquely conclude the hydrogen atom moving away or toward us just based on the frequency shift observation.

Table 2. The frequency shift for process b (n_1---->n_2; fundamental frequency: 2.441 506 795 × 10^{15} s^{-1}).

v(m/s)	v' (m/s)	Frequency Shift (s^{-1})
3.22	0	–13,130,646
53.28	50	–429,149,114
103.35	100	–861,574,263
203.33	200	–1,699,219,374
303.31	300	–2,527,310,064
503.27	500	–4,153,467,966
1003.33	1000	–8,430,721,454
2003.28	2000	–1.663229962 × 10^{10}
3003.24	3000	–2.461910336 × 10^{10}
4003.35	4000	–3.391175542 × 10^{10}
5003.31	5000	–4.185565845 × 10^{10}
6003.27	6000	–4.957931183 × 10^{10}
7003.22	7000	–5.708830943 × 10^{10}
8003.33	8000	–6.742244456 × 10^{10}
9003.29	9000	–7.489375187 × 10^{10}
10 003.25	10 000	–8.213981327 × 10^{10}

In summary, we determined the speed threshold of hydrogen atom and find this speed threshold depends on both the main quantum number and the speed of final state of proton and electron. We also calculate the frequency shift due to the movement of the hydrogen atom during its excitation. Our work here reveals that the frequency shift depends on both the speed of initial and final state of hydrogen atom. Most importantly, in some cases, the frequency shift may change sign, which may find application in spectroscopy analysis and new technology may be developed.

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