MOLECULES MAY EXPLAIN THE EXPANSION OF THE UNIVERSE

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ABSTRACT

The Hubble diagram continues to remain one of the most important graphical representations in the realm of astronomy and cosmology right from its genesis that depicts the velocity-distance relation for the receding large-scale structures within the observable Universe; it is the diagram that helps us to understand the expansion of the Universe. In this paper I introduce the molecular expansion model in order to explain the expansion of the Universe. The molecular expansion model considers the distribution of large-scale structures as molecules inside a vacuum chamber. Since large-scale structures are ensemble of atoms, therefore, they can be treated as molecules possessing finite amount of energy. Instead of considering that space is expanding, the paper emphasizes upon the actual recession of large-scale structures. The study conducted in this paper finds the recessional behaviour of large-scale structures to be consistent with the recessional behaviour of molecules. Redshift-distance relation has been plotted for 580 Type Ia supernovae from the Supernova Cosmology Project, and, the reason for the deviation of the Hubble diagram from exhibiting a linear redshift-distance relation for the structures belonging to the remote Universe has been explained by introducing the concept of "acceleration phase". This concept further explains the reason for the observed accelerating expansion of the Universe. It is suggested through this concept that accelerating structures belonging to the remote Universe will attain a constant recessional velocity in future.

Key words: cosmology: theory - dark energy - expansion - Hubble diagram - Hubble's law - molecular data.

1 INTRODUCTION

The revolutionizing discovery by Sir Edwin Hubble in 1929 from his observations of distant galaxies from Mount Wilson Observatory in California not only proved that the Universe was expanding, it also paved a new way for modern astronomy and cosmology. The light from all the galaxies that were being observed was found to be redshifted, suggesting that the galaxies were moving away from one another and the Universe was expanding and was not at all "static" as was previously being considered.

Sir Edwin Hubble obtained a linear diagram by plotting the velocity-distance relation for the receding large-scale structures; a diagram that changed our perspective of the Universe forever…….the Hubble diagram. The linear relationship obtained while plotting the Hubble diagram depicts the Hubble's law according to which the recessional velocity of a large-scale structure is directly proportional to its distance, that is, the further away a large-scale structure is, the faster it will be receding away from us. The slope of the straight line yields the Hubble constant which was originally denoted by Sir Edwin Hubble by the letter *K*. The Hubble constant gives the rate of expansion of the Universe while its reciprocal gives the Hubble time or the age of the Universe.

The aim of this paper is to explain the expansion of the Universe on the basis of the molecular expansion model which has been introduced in Section 2. Section 3 looks into the energy that causes the recession of large-scale structures. Section 4 shows that the large-scale structures possess energy by the virtue of which they recede. In Section 5 the recessional behaviour of large-scale structures is found to be in perfect agreement with the recessional behaviour of molecules, thereby suggesting the actual recession of large-scale structures. In Section 6 I discuss that the observed redshifts exhibited by large-scale structures are due to their actual recession rather than expansion of space between them, Section 7 brings actual gas molecules into consideration to further study, compare and confirm the recessional behaviour of large-scale structures with expanding gas molecules, Section 8 looks into the deviation of Hubble diagram from linearity at high redshifts and the accelerating expansion of the Universe, while Section 9 brings in the concept of "acceleration phase" to account for the observed accelerating expansion of the Universe.

2 EXPANSION OF THE UNIVERSE AND THE EXPANSION OF GAS MOLECULES: THE MOLECULAR EXPANSION MODEL

Certain questions that should undoubtedly arise while looking at the Hubble diagram are - why is the Hubble diagram linear? In fact, why should it be linear? The Hubble diagram and therefore the expansion of the Universe can be explained very effectively if we consider the distribution of large-scale structures as molecules inside a vacuum chamber. Since molecules recede by the virtue of the energy possessed by them, therefore, the same logic has been applied to the receding large-scale structures as well, that is, the large-scale structures recede by the virtue of the energy possessed by them instead of energy being possessed by empty space. Also, molecules undergo actual recession rather than expansion of space between them.

Since the large-scale structures are constituted by atoms and molecular matter, therefore, there is more probability that they will be possessing energy instead of energy being possessed by empty space. Now if receding large-scale structures are being considered as gas molecules, then they must exhibit certain properties or behaviour that should perfectly match with the properties or behaviour of actual gas molecules undergoing expansion.

3 ENERGY THAT CAUSES THE RECESSION OF A LARGE-SCALE STRUCTURE: WHY SHOULD A LARGE-SCALE STRUCTURE RECEDE ?

The energy possessed by an object moving with velocity *v* is given as,

$$E = \frac{1}{2}mv^2 \tag{1}$$

Equation (1) can be expressed in terms of velocity as,

$$v = \sqrt{\frac{2E}{m}} \tag{2}$$

Equation (2) suggests that an object possessing sufficient amount of energy will recede with certain velocity. This is exactly what is observed in the case of a molecule, that is, if the molecule gains more energy than before, then according to equation (2) the velocity of the molecule will increase. Now, since a large-scale structure possesses sufficient amount of energy (Section 4), therefore, such structure will recede with a velocity according to equation (2). Equation (2) is in agreement with the actual velocity equations for gas molecules as given by equation (4) and equation (5).

In an environment where gravitational force is stronger, like on Earth's surface, the energy possessed by an object will not cause the object to recede, as gravitational force takes over, however, a molecule is an exception in this case. Since the mass of a molecule is minuscule, therefore, a molecule is not influenced significantly by Earth's gravitational force; the energy possessed by a molecule turns out to be greater than the gravitational force acting upon it, and therefore the molecule recedes purely by the virtue of energy possessed by it. Similarly, in deep space environment since the large-scale structures readily recede away from one another, therefore, the gravitational influence between them has to be weaker than the energy possessed by the large-scale structures that causes them to recede away from one another.

According to equation (2), for a large-scale structure to exhibit higher recessional velocity, the energy possessed by it should be sufficiently large and the mass should be less. So if equal amount of energy is possessed by a galaxy and a galaxy cluster, then the galaxy will exhibit higher recessional velocity as compared to the galaxy cluster. On the other hand, if the recessional velocity of a galaxy and a galaxy cluster are equal, then the galaxy will be found to possess less amount of energy as compared to the galaxy cluster (Section 4).

4 THE ENERGY POSSESSED BY A LARGE-SCALE STRUCTURE

Large-scale structures recede by the virtue of the energy possessed by them instead of energy being possessed by empty space. To validate this claim consider a galaxy cluster. Since the mass of galaxy clusters usually ranges between 10^{14} M$_\odot$ and 10^{15} M$_\odot$, therefore, it would be perfectly fine to consider a galaxy cluster with mass of about 2 x 10^{15} M$_\odot$ (4 x 10^{45} kg). From this mass we obtain the total number of protons making the cluster to be 2.3914 x 10^{72} (not considering dark matter).

The temperature of massive galaxy clusters is dominated by the extremely hot intracluster medium (ICM) at 10^8 K. The energy per molecule, in this case the proton is given as,

$$E = \frac{3}{2}kT \tag{3}$$

where *k* is the Boltzmann constant and *T* is the temperature. Using equation (3), we obtain the energy per proton corresponding to a temperature of 10^8 K to be 2.0709 x 10^{-15} J. Total energy possessed by the galaxy cluster therefore equates to 4.9523 x 10^{57} J.

Now, using equation (2), we will obtain the value of recessional velocity that the cluster will attain, and this is found to be 1,573,578.724 m s^{-1} (1.5 x 10^6 m s^{-1}). This is just an approximation. For comparison, the recessional velocity of Norma Cluster is 4,707 km s^{-1} (4.707 x 10^6 m s^{-1}) (NED 2006 results). Higher recessional velocities are also possible if the energy possessed by the large-scale structure is sufficiently large and the mass is less. For instance, for a 2 x 10^{15} M$_\odot$ (4 x 10^{45} kg) galaxy cluster to exhibit recessional velocity of 7 x 10^6 m s^{-1}, the energy possessed by it must be 9.8 x 10^{58} J. On the other hand, for a 10^{10} M$_\odot$ (2 x 10^{40} kg) galaxy or a quasar to exhibit an equal recessional velocity of 7 x 10^6 m s^{-1}, the energy possessed by them must be 4.9 x 10^{53} J (2 x 10^5 times less energy than the energy possessed by the massive galaxy cluster).

It has been observed that the most distant celestial objects (billions of light-years away) exhibit very high recessional velocities as evident from their redshifts. Such distant structures reveal themselves to us as they were billions of years ago when the Universe was comparatively younger than it is today. Since the early Universe was much more energetic than it is today, therefore, it is very likely that the structures during that energetic era possessed surplus amount of energy that made them recede with such high recessional velocity. We do not know the present day recessional velocity of such distant celestial objects since we are observing them how those structures were billions of years ago. Therefore, it would be more accurate if we obtain the instantaneous amount of energy possessed by a large-scale structure from its instantaneous recessional velocity, after all, it is the energy possessed by the large-scale structure that is causing it to recede.

5 RECEDING LARGE-SCALE STRUCTURES AND RECEDING GAS MOLECULES EXHIBIT A SIMILAR BEHAVIOUR

It is always observed that the highest recessional velocities are exhibited by the most distant galaxies and quasars and not by galaxy clusters as evident from their redshifts. Galaxy clusters being extremely massive are unable to efficiently utilize the energy possessed by them to exhibit such high recessional velocities as those exhibited by such distant galaxies and quasars which comparatively are very much less massive than galaxy clusters. This is in perfect agreement with the recessional behaviour of molecules, that is, a lighter molecule recedes faster as compared to a massive molecule even when they both possess an equal amount of energy (see Table 2; Graph 1 and Table 3; Graph 2). A lighter molecule will therefore cover a larger distance with time as compared to the massive molecule; a lighter molecule will therefore become the most distant molecule as compared to the massive molecule (see Graphs 1 to 5). Galaxies and quasars being less massive than galaxy clusters exhibit higher recessional velocities and therefore they manage to become the most distant structures within the observable Universe. The recessional behaviour of large-scale structures being consistent with the recessional behaviour of molecules suggests the actual recession of large-scale structures and validates the credibility of the molecular expansion model to some extent.

6 REDSHIFTS: COSMOLOGICAL OR DOPPLER ?

It is firmly believed that large-scale structures are stationary and the distance between them is increasing due to metric expansion of space between them. Such expansion causes the light emitted by the large-scale structures to get stretched (cosmological redshift). Such firm belief involving the concept of metric expansion of space arises undoubtedly due to the fact that nothing can travel faster than light. All receding structures exhibiting redshifts also suggests metric expansion of space between them. An expansion that is homogeneous and isotropic also suggests the same. However, if the large-scale structures are actually receding away from each other, just like expanding gas molecules, then the light emitted by them would still undergo redshifting due to the involvement of actual recession rather than expansion of space between them (Doppler redshift).

In the previous section the recessional behaviour of large-scale structures was found to be consistent with the recessional behaviour of molecules; the light from a very distant galaxy and a quasar is redshifted to higher extent as compared to the light from a galaxy cluster (galaxies and quasars being less massive than a galaxy cluster exhibit higher recessional velocities and therefore they manage to become the most distant structures); such consistent behaviour of large-scale structures with molecules suggests their actual recession rather than expansion of space between them. If space between the large-scale structures was expanding, then even massive galaxy clusters should be exhibiting redshifts as high as, or even higher than the highest redshifts exhibited by the most distant galaxies and quasars.

7 PLOTTING THE GAS MOLECULES

Consider a spherical metallic vessel filled with gas molecules. This vessel is placed somewhere in the Universe. The mass of every gas molecule inside this vessel is different and therefore unique. The motion of molecules within the vessel will be random; the molecules will collide with one another as well as with the walls of this metallic vessel. We want to witness the gas molecules expand freely in every direction, if we open the lid, then the molecules would escape out into the vacuum of the Universe just from that particular opening available and there would not be any expansion of molecules in every direction, therefore, to ensure free expansion of molecules in every direction, imagine that the walls of this metallic vessel disappear. As soon as the walls disappear, the molecules will expand freely in every direction. The molecules will move along that direction along which they were moving when the walls of the vessel disappeared. Since the molecules were moving in all possible directions when they were contained, therefore, as soon as the walls of the vessel vanish, the molecules will expand freely in every direction. When the molecules expand freely, the probability that they will collide with one another is extremely low.

With such arrangement available, eleven gaseous elements from the Periodic Table, right from Hydrogen to Radon have been considered to prove the molecular expansion model. The mass of the gas molecules has been obtained in Table 1. The mass of gas molecules increases from Hydrogen onwards; Hydrogen is the least massive molecule, whereas Radon is the most massive molecule. Hydrogen molecule can therefore be considered analogous to a galaxy or a quasar, whereas Radon molecule can be considered analogous to a massive galaxy cluster. All these gas molecules are initially contained before they are allowed to expand freely into the vacuum. The gas molecules will expand freely and recede into the vacuum by the virtue of the energy possessed by them at particular temperature as given by equation (3), while their recessional velocity due the energy possessed by them is given by equation (2). Equation (2) is in agreement with the actual velocity equations for gas molecules given as,

$$v = \sqrt{\frac{3RT}{M}} \tag{4}$$

and,

$$v = \sqrt{\frac{3kT}{m}} \tag{5}$$

where R is the gas constant, T is the temperature, M is the molecular mass (kg mol^{-1}) of the gas, that is, M/1000 (see M from Table 1), k is the Boltzmann constant and m is the mass of the molecule in kg.

In Table 2, all gas molecules are at same temperature of 303 K, the energy possessed by every molecule will therefore be equal. The recessional velocity of the molecules is obtained from equation (2) and the distance covered by them in 1 second (observation time) has been calculated. In Table 3, all molecules are still at the same temperature of 303 K, however, the observation time has been increased to 60 seconds. In Table 4, the observation time is 1 second, and every molecule is at a different temperature, therefore, the energy possessed by every molecule will also be different. In Table 5, every molecule is still at different temperature, however, the observation time has been increased to 60 seconds. In Table 6, the observation time is 60 seconds, and every gas molecule is subjected to a very high temperature, and, the temperature difference is very large, therefore, the energy possessed by every molecule will be different by a significant amount as compared to the previous settings.

From the tables (Table 2 to Table 6), the velocity-distance relation for the gas molecules has been plotted (Graph 1 to Graph 5). Surprisingly, the straight line obtained is remarkably similar to the straight line obtained in the Hubble diagram (depiction of Hubble's law) (Figure 1) which is also the velocity-distance relation plot for the receding large-scale structures. According to the Hubble's law, the recessional velocity of a large-scale structure is directly proportional to its distance, that is, the further away a large-scale structure is, the faster it will be receding away from us. Therefore, according to the Hubble's law,

$$v = H \times D \tag{6}$$

and,

$$D = \frac{v}{H} \tag{7}$$

where v is the recessional velocity of the large-scale structure, D is its distance from us and H is the Hubble constant. The reciprocal of the Hubble constant (H) gives us the Hubble time which is the age of the Universe.

Now this is found to be true for the gas molecules under consideration as well. From the tables (Table 2 to Table 5) and graphs (Graph 1 to Graph 4), it can be seen that the highest recessional velocity is exhibited by the Hydrogen molecule, followed by Helium, whereas the lowest recessional velocity is found to be exhibited by the Radon molecule. Hydrogen molecule being less massive exhibits higher recessional velocity as compared to the massive Radon molecule. In Table 6; Graph 5, the highest recessional velocity is still being exhibited by the Hydrogen molecule. Helium which previously remained the second fastest receding molecule behind Hydrogen has been replaced by Nitrogen. Similarly, Radon which previously remained the slowest receding molecule has been replaced by Xenon. Such change has occurred due to the involvement of large temperature differences. Such large differences in temperature influence the energy possessed by the molecules, thereby affecting their recessional velocities too. But no matter how the data changes for the gas molecules, the graphs continue to remain linear. Therefore, just like the Hubble's law, we can say that the recessional velocity of gas molecules is directly proportional to their distance, that is, the further away a molecule is, the faster it is receding away from us. The Slope of this straight line is also remarkably similar to the Hubble constant (H) (the slope of Hubble diagram) since its reciprocal gives us the observation time in seconds, just like the Hubble time obtained from the reciprocal of H. Furthermore, the following equations,

$$v = Slope \text{ x } D \tag{8}$$

and,

$$D = \frac{v}{Slope} \tag{9}$$

are also found to be obeyed by the gas molecules just like the receding large-scale structures. In the above equations, v is the recessional velocity of the molecules and D is the distance covered by the molecules within the given time frame. Since the velocity-distance relation plot for receding large-scale structures is similar to the velocity-distance relation plot for receding gas molecules, therefore, the molecular expansion model holds true for the receding large-scale structures. The gas molecules and the large-scale structures get arranged in terms of velocity and distance. Their mass and the energy possessed by them play a vital role in determining their velocity-distance relation.

If the energy possessed by every receding large-scale structure was equal, then the large-scale structures would have been segregated according to their mass. Their velocity-distance relation in such scenario would have been in such a way, that the most distant structure would be the lightest and the fastest, whereas the structure nearest to us would be the most massive and the slowest. This can be seen in the molecular plots (Graph 1; Table 2 and Graph 2; Table 3), the mass of every molecule is different, but the energy possessed by them is equal, therefore, the molecules get segregated according to their mass. It can be seen that the mass of the molecules is decreasing with distance, while their recessional velocities are increasing with distance. Therefore, the most distant molecule is not only the lightest, but it is also the fastest receding molecule.

In Graph 5; Table 6, the energy possessed by every molecule is different and so is their mass, therefore, there is no segregation of molecules according to their mass and the molecules are distributed homogeneously irrespective of their mass. However, it can be seen that the most distant molecule is still the lightest and therefore the fastest receding molecule. This is consistent with actual observations of receding large-scale structures within the observable Universe. Since the energy possessed by every receding large-scale structure is different and so is their mass, therefore, we observe a homogeneous distribution of large-scale structures within the Universe irrespective of their mass. However, when it comes to the most distant structures such as galaxies and quasars, then they are indeed the lightest and therefore the fastest receding objects as compared to massive galaxy clusters.

Plotting the velocity-distance relation for receding gas molecules is same as plotting the velocity-distance relation for receding large-scale structures (the Hubble diagram). If we were able to observe the receding gas molecules and plot them in terms of velocity-distance relation then we will get the Hubble diagram. Also, it can be seen from the molecular plots that no matter on which molecule we would be situated upon, all other molecules will exhibit redshift; there is expansion in every direction, there is no preferred centre. This is in agreement with the Copernican principle, as well as with homogeneous and isotropic expansion.

The similar linear relationship obtained while plotting the velocity-distance relation plot for the receding large-scale structures and the receding gas molecules is neither any coincidence nor any adjustment, it is only because the receding large-scale structures behave like receding gas molecules that the velocity-distance relation plots turn out to be remarkably same.

Since gas molecules exhibit Hubble diagram and obey all Hubble equations solely due to their recession by the virtue of the energy possessed by them, therefore, the large-scale structures that are known to exhibit Hubble diagram and obey all Hubble equations have to be receding solely by the virtue of the energy possessed by them.

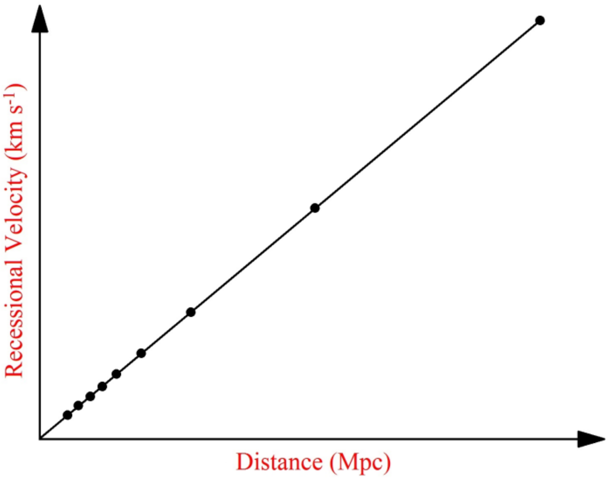


Figure 1. The Hubble diagram. Velocity-distance relation plot for receding large-scale structures. The slope of the straight line is the Hubble constant (H). The reciprocal of the Hubble constant (H) gives us the age of the Universe (Hubble time). The Hubble diagram depicts the Hubble's law according to which the recessional velocity of large-scale structures is directly proportional to their distance. Note that the velocity-distance relation plots for receding gas molecules (Graph 1 to Graph 5) are exactly like the velocity-distance relation plot for receding large-scale structures according to the Hubble diagram; the molecules receding slowly are closer to us whereas the molecules receding faster are further away from us.

Table 1. Mass of different gas molecules

Gaseous Elements	Atomic Mass (A) a.m.u. or g mol^{-1}	Molecular Mass (M) a.m.u. or g mol^{-1}	Mass of Molecule (M/N$_A$)/1000 kg
H	1.0079	2.0158	3.3473 x 10^{-27}
He*	4.0026	8.0052	1.3292 x 10^{-26}
N	14.0067	28.0134	4.6517 x 10^{-26}
O	15.9994	31.9988	5.3135 x 10^{-26}
F	18.9984	37.9968	6.3095 x 10^{-26}
Ne*	20.1797	40.3594	6.7018 x 10^{-26}
Cl	35.4530	70.9060	1.1774 x 10^{-25}
Ar*	39.9480	79.8960	1.3267 x 10^{-25}
Kr*	83.7980	167.5960	2.7829 x 10^{-25}
Xe*	131.2930	262.5860	4.3603 x 10^{-25}
Rn*	222.0000	444.0000	7.3727 x 10^{-25}

N$_A$ = 6.02214199 x 10^{23} (Avogadro constant)

Note: * are the non-reactive noble gases, they do not form molecules and remain in monoatomic state, however, since molecular expansion model is the emphasis of this paper, therefore, they have been considered as molecules too.

Table 2. Energy possessed by the gas molecules at same temperature of 303 K, their recessional velocities and the distance covered by them in 1 second **(Graph 1)**

Gaseous Elements	Temperature (*T*) K	Energy possessed by molecule (*E*) J	Recessional Velocity (*v*) m s^{-1}	Distance covered in 1 second (*D*) m
H	303	6.2750 x 10^{-21}	1936.30	1936.30
He*	303	6.2750 x 10^{-21}	971.68	971.68
N	303	6.2750 x 10^{-21}	519.41	519.41
O	303	6.2750 x 10^{-21}	485.99	485.99
F	303	6.2750 x 10^{-21}	445.98	445.98
Ne*	303	6.2750 x 10^{-21}	432.73	432.73
Cl	303	6.2750 x 10^{-21}	326.48	326.48
Ar*	303	6.2750 x 10^{-21}	307.56	307.56
Kr*	303	6.2750 x 10^{-21}	212.36	212.36
Xe*	303	6.2750 x 10^{-21}	169.65	169.65
Rn*	303	6.2750 x 10^{-21}	130.46	130.46

Table 3. Energy possessed by the gas molecules at same temperature of 303 K, their recessional velocity and the distance covered by them in 60 seconds **(Graph 2)**

Gaseous Elements	Temperature (*T*) K	Energy possessed by molecule (*E*) J	Recessional Velocity (*v*) m s^{-1}	Distance covered in 60 seconds (*D*) m
H	303	6.2750 x 10^{-21}	1936.30	116178.0
He*	303	6.2750 x 10^{-21}	971.68	58300.8
N	303	6.2750 x 10^{-21}	519.41	31164.6
O	303	6.2750 x 10^{-21}	485.99	29159.4
F	303	6.2750 x 10^{-21}	445.98	26758.8
Ne*	303	6.2750 x 10^{-21}	432.73	25963.8
Cl	303	6.2750 x 10^{-21}	326.48	19588.8
Ar*	303	6.2750 x 10^{-21}	307.56	18453.6
Kr*	303	6.2750 x 10^{-21}	212.36	12741.6
Xe*	303	6.2750 x 10^{-21}	169.65	10179.0
Rn*	303	6.2750 x 10^{-21}	130.46	7827.6

Table 4. Energy possessed by the gas molecules at different temperature, their recessional velocity and the distance covered by them in 1 second **(Graph 3)**

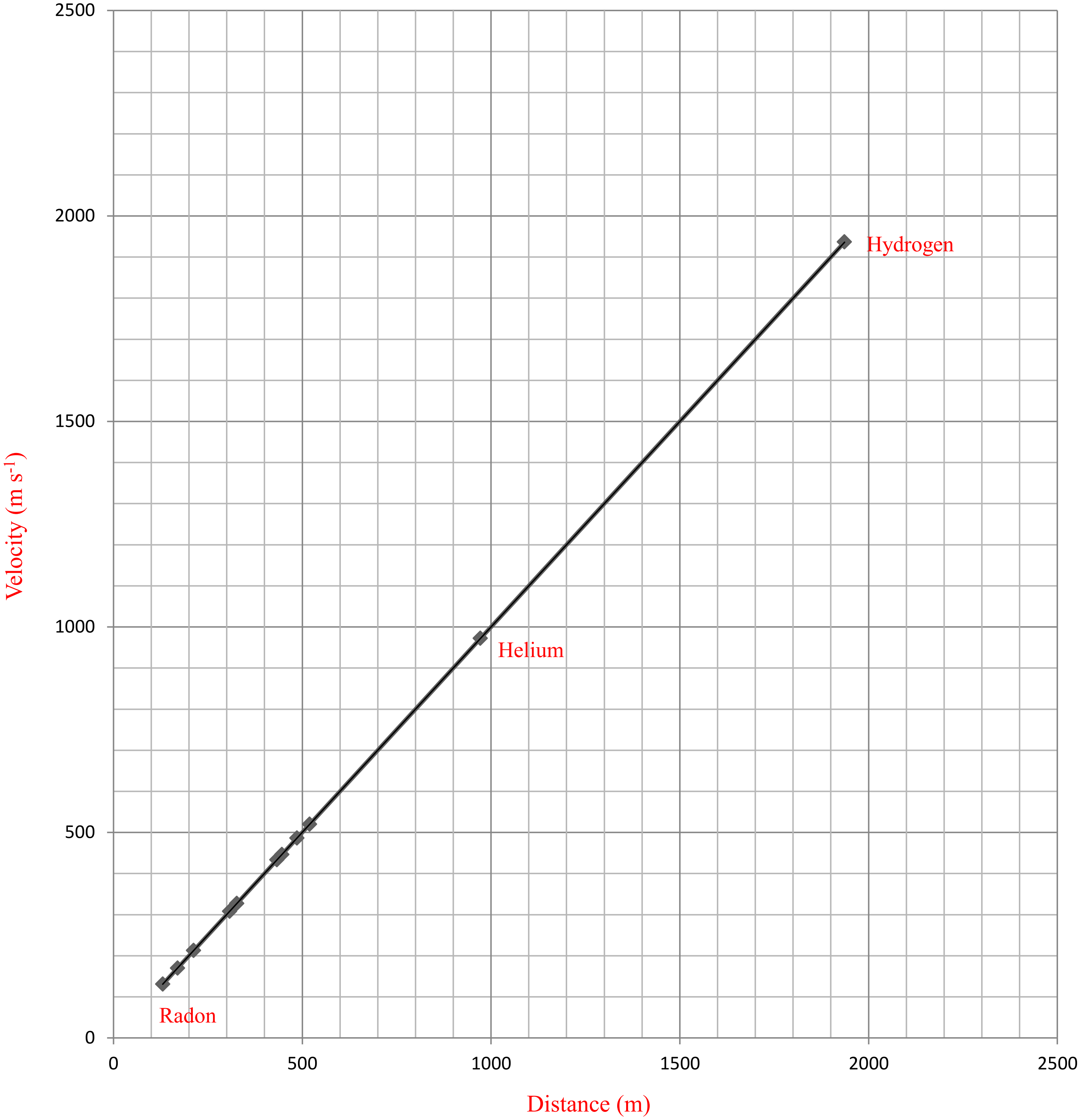
Gaseous Elements	Random Temperature (*T*) K	Energy possessed by molecule (*E*) J	Recessional Velocity (*v*) $m\ s^{-1}$	Distance covered in 1 second (*D*) m
H	306	6.3371×10^{-21}	1945.86	1945.86
He*	310	6.4200×10^{-21}	982.85	982.85
N	313	6.4821×10^{-21}	527.91	527.91
O	305	6.3164×10^{-21}	487.59	487.59
F	311	6.4407×10^{-21}	451.83	451.83
Ne*	303	6.2750×10^{-21}	432.73	432.73
Cl	308	6.3786×10^{-21}	329.16	329.16
Ar*	312	6.4614×10^{-21}	312.09	312.09
Kr*	304	6.2957×10^{-21}	212.71	212.71
Xe*	307	6.3578×10^{-21}	170.76	170.76
Rn*	309	6.3993×10^{-21}	131.75	131.75

Table 5. Energy possessed by the gas molecules at different temperature, their recessional velocity and the distance covered by them in 60 seconds **(Graph 4)**

Gaseous Elements	Random Temperature (*T*) K	Energy possessed by molecule (*E*) J	Recessional Velocity (*v*) $m\ s^{-1}$	Distance covered in 60 seconds (*D*) m
H	306	6.3371×10^{-21}	1945.86	116751.6
He*	310	6.4200×10^{-21}	982.85	58971.0
N	313	6.4821×10^{-21}	527.91	31674.6
O	305	6.3164×10^{-21}	487.59	29255.4
F	311	6.4407×10^{-21}	451.83	27109.8
Ne*	303	6.2750×10^{-21}	432.73	25963.8
Cl	308	6.3786×10^{-21}	329.16	19749.6
Ar*	312	6.4614×10^{-21}	312.09	18725.4
Kr*	304	6.2957×10^{-21}	212.71	12762.6
Xe*	307	6.3578×10^{-21}	170.76	10245.6
Rn*	309	6.3993×10^{-21}	131.75	7905.0

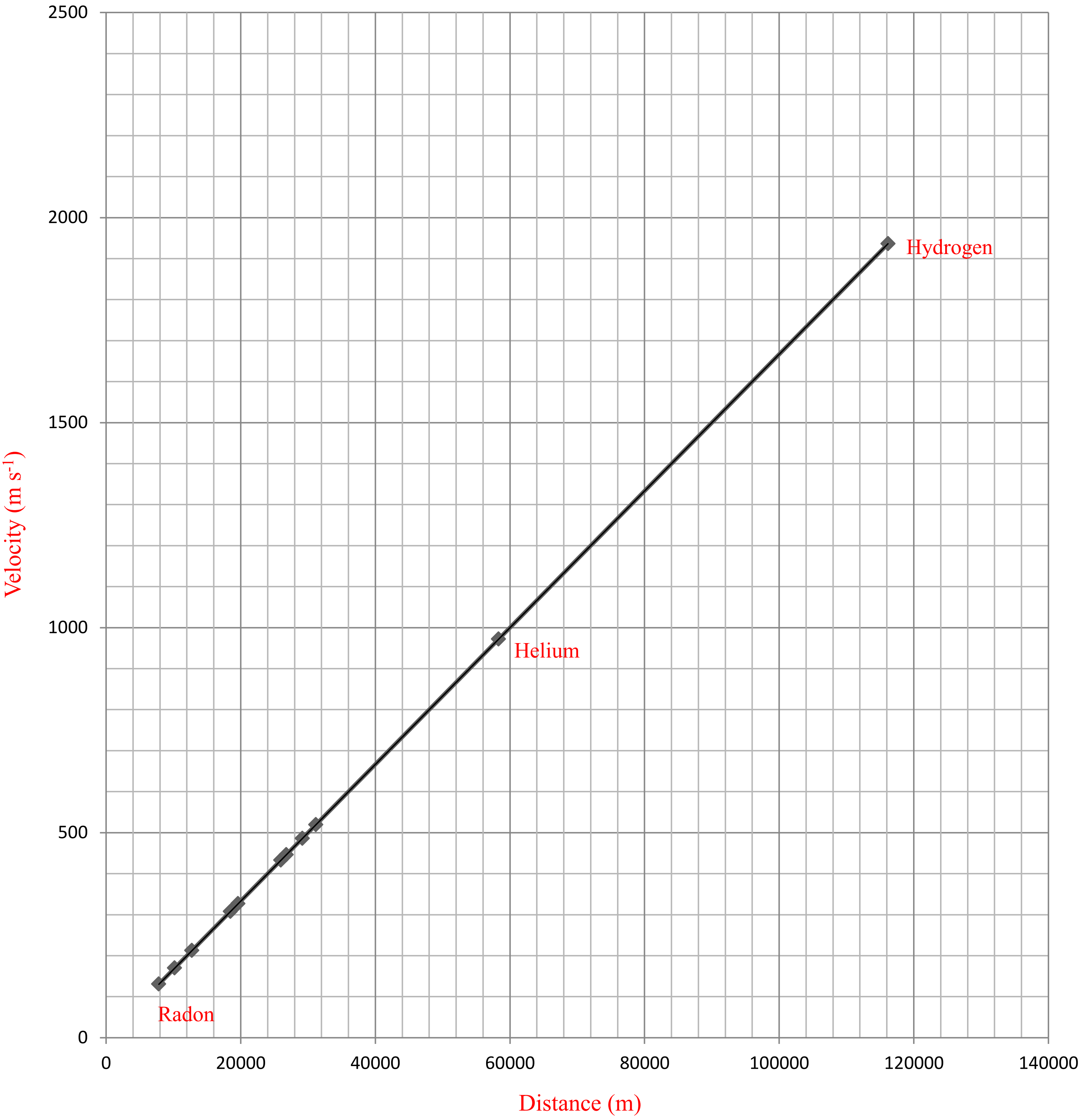
Table 6. Energy possessed by the gas molecules at high temperature with large differences in temperature, their recessional velocity and the distance covered by them in 60 seconds **(Graph 5)**

Gaseous Elements	Random Temperature (*T*) K	Energy possessed by molecule (*E*) J	Recessional Velocity (*v*) $m\ s^{-1}$	Distance covered in 60 seconds (*D*) m
H	1000	2.0709×10^{-20}	3517.60	211056.0
He*	2000	4.1419×10^{-20}	2496.43	149785.8
N	10000	2.0709×10^{-19}	2983.93	179035.8
O	9000	1.8638×10^{-19}	2648.64	158918.4
F	900	1.8638×10^{-20}	768.62	46117.2
Ne*	8000	1.6567×10^{-19}	2223.52	133411.2
Cl	800	1.6567×10^{-20}	530.48	31828.8
Ar*	9000	1.8638×10^{-19}	1676.20	100572.0
Kr*	10000	2.0709×10^{-19}	1219.96	73197.6
Xe*	700	1.4496×10^{-20}	257.85	15471.0
Rn*	15000	3.1064×10^{-19}	917.97	55078.2



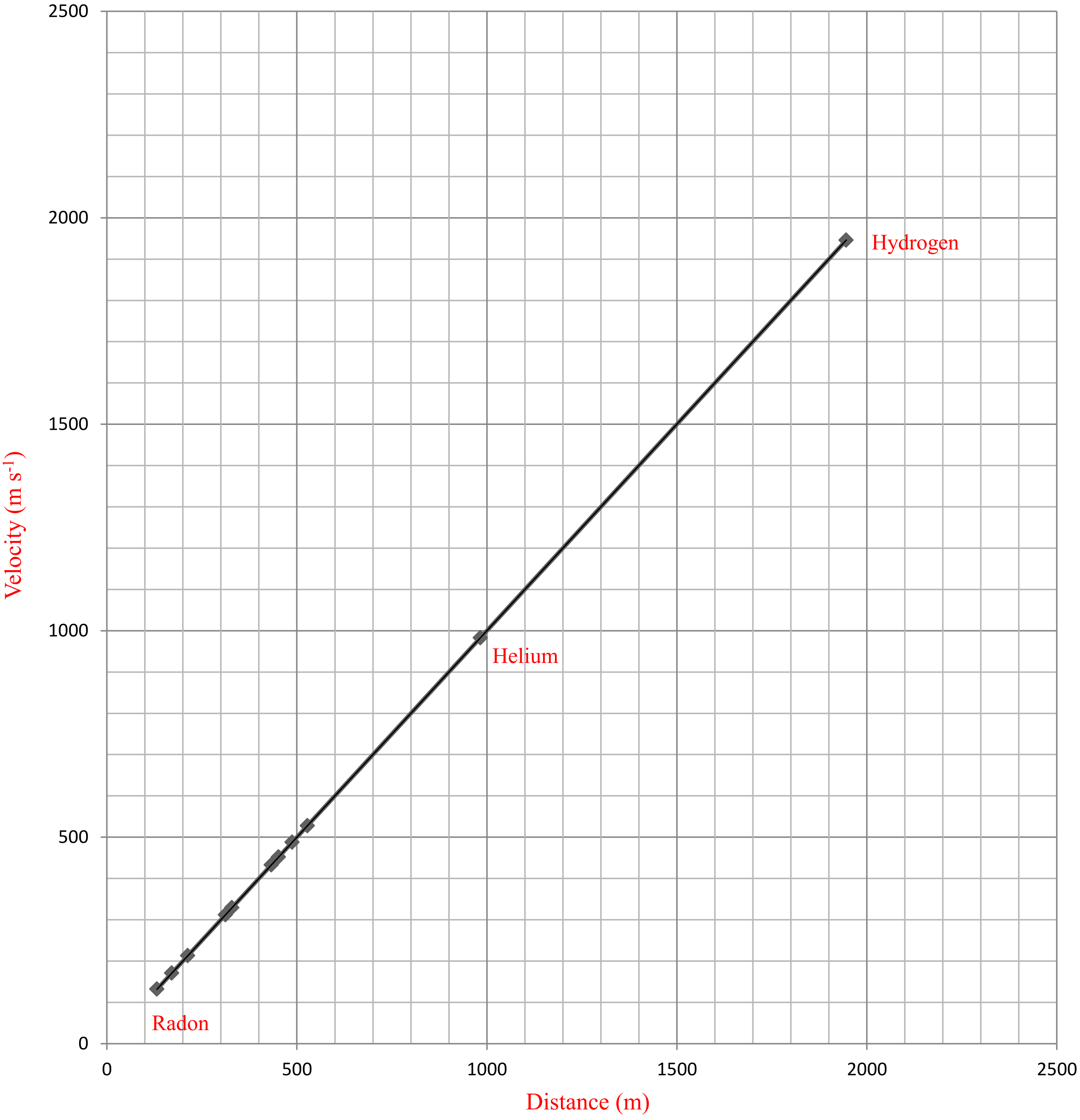
Graph 1. Velocity-distance relation plot for molecules expanding at same temperature (303 K). Observation time = 1 second **(Table 2)**

(Slope = 1 m s^{-1} m^{-1})



Graph 2. Velocity-distance relation plot for gas molecules expanding at same temperature (303 K). Observation time = 60 seconds **(Table 3)**

(Slope = 0.016666666 m s^{-1} m^{-1})



Graph 3. Velocity-distance relation plot for gas molecules expanding at different temperature. Observation time = 1 second **(Table 4)**

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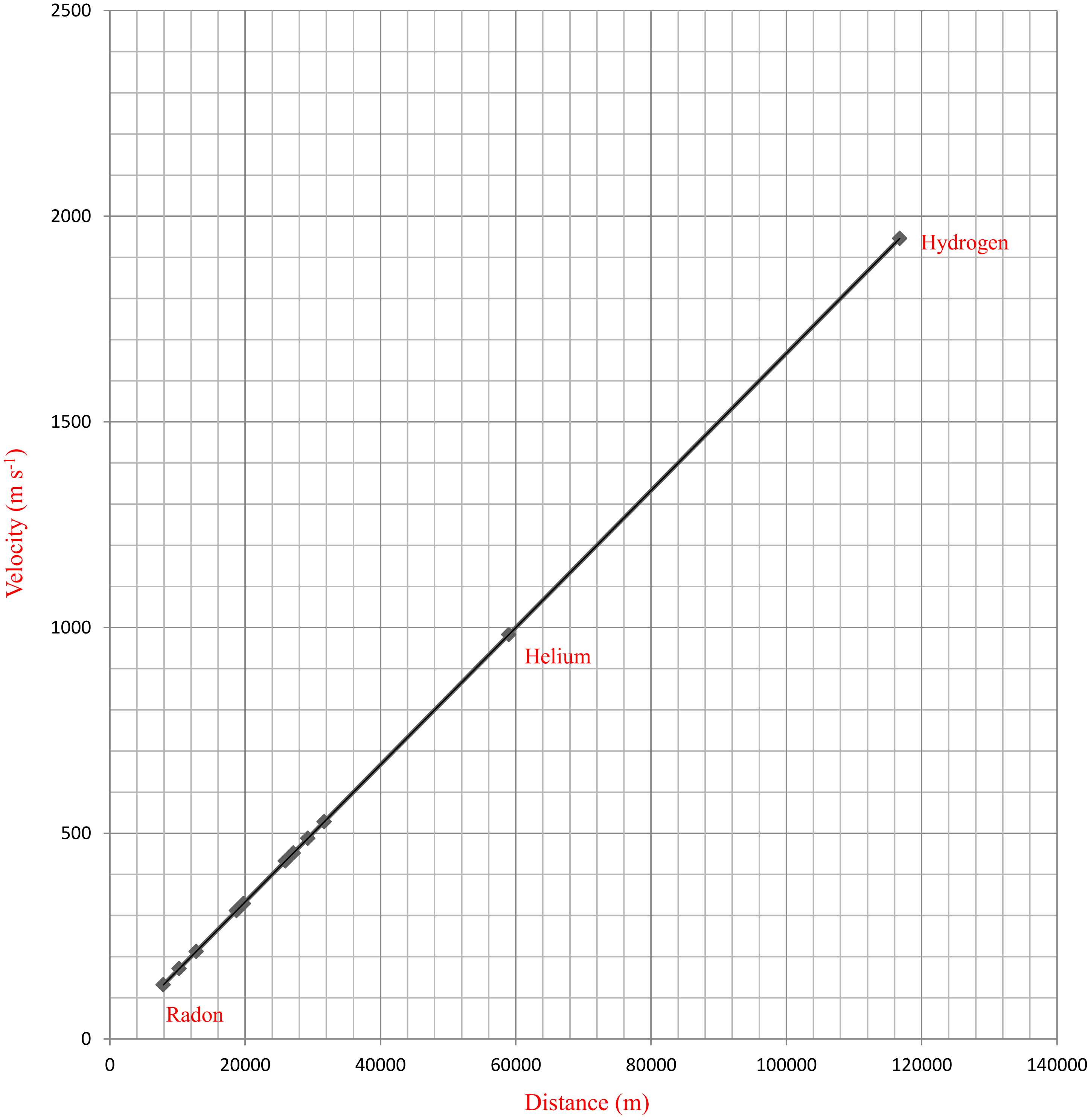
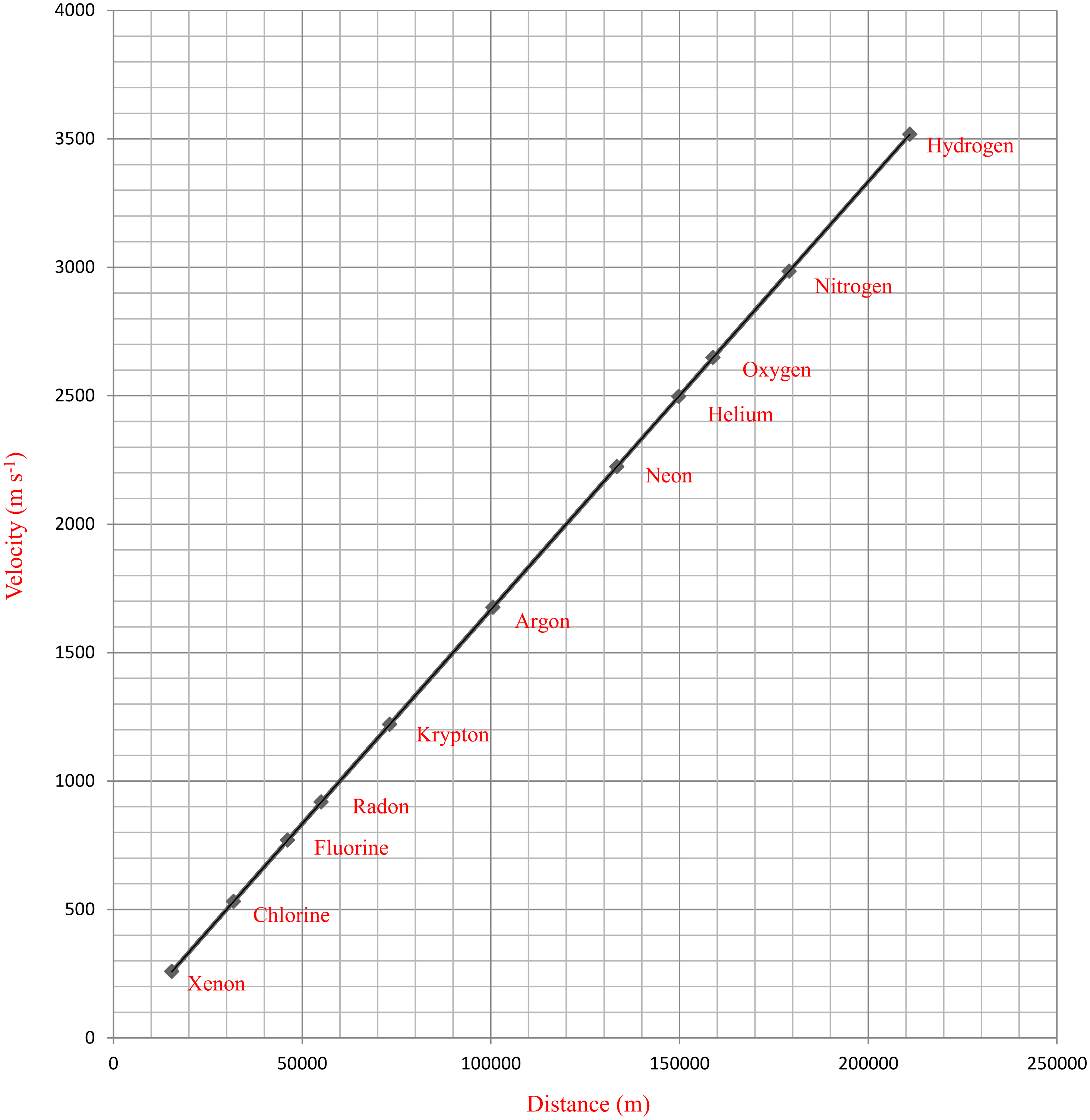


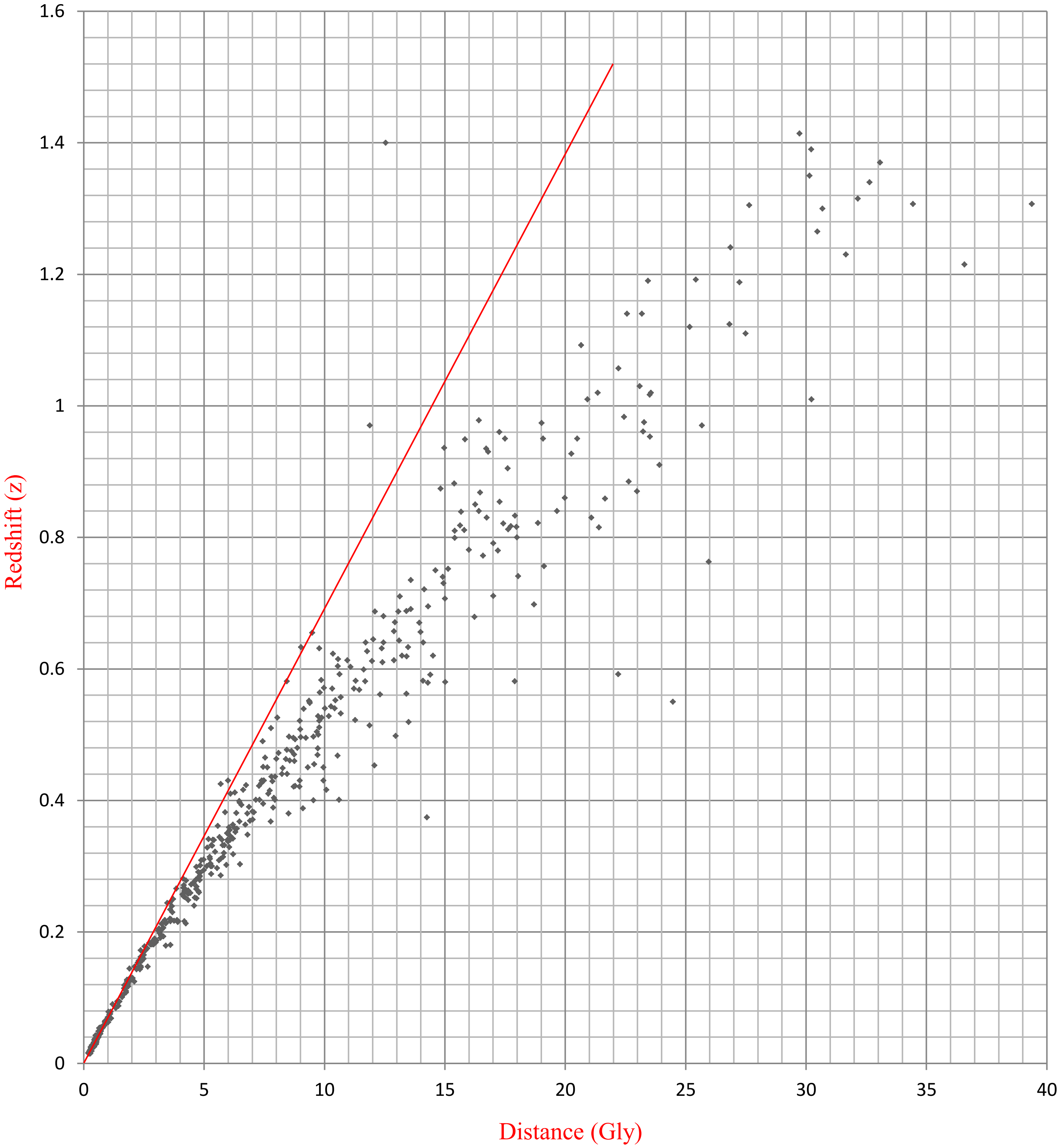
Graph 4. Velocity-distance relation plot for gas molecules expanding at different temperature. Observation time = 60 seconds **(Table 5)**

(Slope = 0.016666666 m s^{-1} m^{-1})



Graph 5. Velocity-distance relation plot for molecules expanding at very high temperature with large differences in temperature. Observation time = 60 seconds **(Table 6)**

(Slope = 0.016666666 m s^{-1} m^{-1})



Graph 6. The redshift-distance relation for 580 Type Ia Supernovae plotted by using the data (Union 2 and Union 2.1) from the Supernova Cosmology Project. The straight red line indicates the linear redshift-distance relation exhibited by the structures within the local Universe.

8 THE DEVIATION OF THE HUBBLE DIAGRAM FROM LINEARITY AT HIGH REDSHIFTS AND THE ACCELERATING EXPANSION OF THE UNIVERSE

The independent research conducted by the High-Z Supernova Search Team in the 1998 (Riess et al.) and by Supernova Cosmology Project team in the 1999 (Perlmutter et al.) by using Type Ia supernovae as standard candles (magnitude-redshift relation) resulted into a very surprising discovery. A surprising feat was found to be displayed by the Universe, a feat that was so extraordinary that the remarkable results obtained were not even expected. It was the remarkable discovery of Universe expanding at an accelerating rate. A research that was actually aimed at observing the expected deceleration of the Universe was welcomed by something completely unexpected. This is what perfectly defines a discovery; instead of getting the expected result something unexpected comes knocking at the door.

A mysterious energy that rightfully got coined as dark energy is considered responsible for causing the Universe to expand at an accelerating rate. Acceleration began with the introduction of dark energy 5 billion years ago (Frieman, Turner and Huterer 2008) and since then the Universe has continued to expand at an accelerating rate. Unfortunately, what type of energy dark energy exactly is remains an unsolved mystery.

The expansion of the Universe is best depicted by the Hubble diagram that exhibits a linear velocity-distance relation or redshift-distance relation for the local Universe, that is, for the large-scale structures that exhibit lower redshifts and are comparatively closer to us than the structures that exhibit higher redshifts or the most distant ones that belong to the remote Universe. It is for these structures belonging to the remote Universe that the Hubble diagram deviates from exhibiting a linear redshift-distance relation as shown in Graph 6 which has been plotted by using the Supernova Cosmology Project data from Union 2 (Amanullah et al. 2010) and Union 2.1 (Suzuki et al. 2012).

9 THE ACCELERATION PHASE

If we gaze into the very local Universe, few million light years away, we find the Andromeda Galaxy racing towards our home galaxy. Gazing further away, some millions of light years away, within the extent of the local Universe, we observe the receding large-scale structures exhibiting the linear redshift-distance relation and obeying the Hubble's law very well. Further away begins the remote Universe within which the receding large-scale structures exhibit high redshifts (high recessional velocities). These structures deviate from exhibiting the linear redshift-distance relation and they are found to be accelerating.

Now, the most distant large-scale structures, those belonging to the very remote Universe reveal themselves to us as they were billions of years ago when the Universe was comparatively younger than it is today. Such structures exhibit high redshifts, and basically, the higher the redshift, the greater is the distance and the larger is the look-back time; with higher and higher redshifts we are literally looking back into an earlier epoch. We do not know the present day recessional velocity of such distant celestial objects since we are observing them how those structures were billions of years ago when the Universe was much younger, and younger were those structures too. Therefore, at present the most distant large-scale structures that are not falling within the linear regime of the Hubble diagram are not revealing their present day picture to us, but how they were billions of years ago. Such structures most probably by now would already be exhibiting a linear redshift-distance relation, this would however remain unknown to us probably for a considerable amount of time, since at present we just know the linear redshift-distance relation being exhibited by the large-scale structures that are millions of light years distant (structures within the local Universe; structures that appear much older and quite evolved). We do not know when such local structures began exhibiting the linear redshift-distance relation, but before attaining such constant recessional velocities they would have surely been accelerating since constant recessional velocities are not achieved directly in an instant. Gradually and gradually a body accelerates before attaining a constant recessional velocity (this also suggests the actual recession of large-scale structures rather than expansion of space between them).

As far as the laws of Physics go, and knowing that the Hubble's law is a valid law since it applies quite precisely to the local Universe, then most likely it should be equally applicable to the very remote Universe as well, that is, there should not be any deviation from a linear redshift-distance relation and all receding large-scale structures should lie on the straight Hubble line, unless we are looking into an earlier epoch within which the receding structures are rightfully expected to be accelerating since they appear younger, and recession has begun for them; such structures are therefore still within their "acceleration phase".

When we look at the most distant structures, we are actually gazing back in time, we are looking into the past of those structures, therefore, there is an utmost probability that we will observe such remote structures to be accelerating in order to achieve a constant recessional velocity. Now since the most distant or the remote structures are already exhibiting recessional velocities that are higher than the recessional velocities of the local structures (the further away an object is, the faster it is receding), therefore, any further increase in their already-high recessional velocities would simply suggest an accelerating Universe. So as long as the accelerating structures remain in their "acceleration phase" their recessional velocities would keep on increasing before becoming constant in future.

From the point of accelerating expansion of the Universe it is believed that the structures that are exhibiting the linear redshift-distance relation within the local Universe, structures that are receding with constant recessional velocity will begin to accelerate in distant future, however, this may probably not be the case at all, in fact there is more probability that the distant structures belonging to the remote Universe that are accelerating as observed today will attain a constant recessional velocity in the distant future probably by the time they get as old and evolved as the structures that are within the local Universe. The rule is, if the older and therefore the more evolved structures are following the linear trend on the Hubble diagram since they have already gone through the billion-year evolutionary phase, then we should most probably expect the younger structures to exhibit the same trend by the time they get equivalently old and evolved. (It is not necessary that the accelerating structures belonging to the remote Universe have to appear equivalently old and evolved as the local structures to exhibit constant recessional velocities. Remote structures that appear to be accelerating may attain constant recessional velocities at any time in future. This would help us to know when local structures attained constant recessional velocities, or, during which evolutionary phase their acceleration phase terminated).

The rate at which the remote structures are accelerating will decide how long their acceleration phase will last. Extremely low rate of acceleration will require a cosmological time span for the accelerating structures to attain a constant recessional velocity. For instance, a remote structure exhibiting a redshift of 0.7 and accelerating at a rate of 10^{-9} m s^{-2} in order to attain a constant recessional velocity corresponding to a redshift of 0.8 will take 3 x 10^{16} seconds (approx. 0.95 billion years), whereas an acceleration rate of 10^{-10} m s^{-2} will take 3 x 10^{17} seconds (approx. 9.5 billion years). Since the local structures are billions of years old, therefore, they have already gone through this acceleration phase in the past and as a result they are now observed to be receding with constant recessional velocity.

From the redshift-distance relation plot as shown in Graph 6 there are two most distant supernovae that appear to fall within the linear regime of the Hubble diagram, one is situated at a distance of 8.4406 Gly exhibiting a redshift of 0.581 and another one further away at a distance of 9.4941 Gly with redshift of 0.655. Using these supernovae the slope (H) of the red line is found to be 2.226372435 x 10^{-18} m s^{-1} m^{-1}, thereby giving a Hubble constant of 68.6991 km s^{-1} Mpc^{-1}.

By looking at Graph 6, the remote structures are not there where they should be; they are not on the red line as precisely as their local counterparts; they are below the line. The supernovae that fall below the red line deviate from exhibiting the redshift-distance linearity. From Hubble's law point of view (equation (6) and equation (7)), the distances to these supernovae are large with respect to their low recessional velocities, or, their recessional velocities are low with respect to their large distances. For instance, if we consider a supernova from Graph 6 at a distance of 17.605 Gly exhibiting a redshift of 0.905, then according to equation 6, its redshift (recessional velocity) at this distance with respect to the slope of the straight line (H) should be 1.2366; this should be the redshift of this supernova at a distance of 17.605 Gly for it to fall on the red line and obey the Hubble's law. Similarly, by using equation 7, the distance of this supernova if it is exhibiting a redshift of 0.905 should be 12.8840 Gly for if to fall on the red line.

Since recessional velocities of remote structures are increasing with time and so is the distance being covered by them, therefore, it is very likely that they will fall on the red line in distant future, most probably by the time they get equivalently old and evolved as the structures within the local Universe that fall on the red line and obey the Hubble's law.

The structures within the local Universe appear much older and evolved since they are closer to us. We observe such local structures having gone through the billion-year evolutionary phase quite efficiently, therefore, they are the ones that should appear to be accelerating due to the fact that acceleration began or dark energy got introduced during the formation, evolution and development of structures billions of years ago, and since we are observing the local structures in much evolved state as they were millions of years ago, therefore, the billion-year accelerating effect of dark energy upon the local structures should already be visible to us the way we are observing them now.

The most distant structures or the accelerating ones are billions of light years away and therefore they appear comparatively younger and therefore newer than the structures within the local Universe. Since these younger and newer structures belong to an early era of the Universe, therefore, as seen today they are still found to be within their "acceleration phase", that is, they are still undergoing the process of attaining a constant recessional velocity, and as a result they are found to be accelerating, just like an object that keeps accelerating before attaining a constant recessional velocity; the velocity keeps increasing every second as long as the permissible constant recessional velocity is not attained. It will probably take significant amount of time for the remote structures to achieve a constant recessional velocity as achieved by the large-scale structures within the local Universe; structures that exhibit the linear redshift-distance relation. In fact, the very distant large-scale structures belonging to the remote Universe that do not exhibit the linear redshift-distance relation or the linear Hubble diagram, still obey the Hubble's law in the sense that, the further away they are, the faster they are receding.

The observed acceleration of remote structures suggests that in future they will cope with the linearity of the red line since their recessional velocities are increasing and so is the distance being covered by them. It is all about time that their actual recessional behaviour would get revealed in the distant future, behaviour that would either be consistent with the Hubble diagram and hence the Hubble's law suggesting constant recessional velocity and hence redshift-distance linearity, or behaviour that would suggest acceleration that is eternal and inevitable.

CONCLUSIONS

(1) In this paper the expansion of the Universe has been explained by conducting a detailed study based upon the molecular expansion model.

(2) The molecular expansion model considers the distribution of large-scale structures as molecules. The molecular expansion model shows that the expansion of gas molecules is homogeneous and isotropic.

(3) According to the molecular expansion model the distance between the large-scale structures is increasing due to their actual recession by the virtue of the energy possessed by them.

(4) Large-scale structures recede with velocity corresponding to the total amount of energy that they possess.

(5) For a large-scale structure to exhibit higher recessional velocity the energy possessed by it should be sufficiently large and the mass should be less.

(6) The highest recessional velocities are always found to be exhibited by the most distant galaxies and quasars and not by galaxy clusters. This observation is consistent with the recessional behaviour of molecules, that is, a lighter molecule exhibits higher recessional velocity as compared to a massive molecule even when they both possess an equivalent amount of energy. Such consistent recessional behaviour suggests the actual recession of large-scale structures rather than expansion of space between them.

(7) Since galaxies and quasars are less massive than galaxy clusters, therefore, galaxies and quasars exhibit higher recessional velocities than galaxy clusters. For this reason, galaxies and quasars manage to become the most distant structures within the observable Universe and not galaxy clusters.

(8) From the tables and the graphs it becomes very evident that the behaviour of receding large-scale structures is similar to the behaviour of freely expanding gas molecules into the vacuum of the Universe. The velocity-distance relation plot for expanding gas molecules is consistent with the velocity-distance relation plot for the receding large-scale structures obtained according to the Hubble diagram which depicts the Hubble's law. Such consistency also suggests the actual recession of large-scale structures rather than expansion of space between them; if the space between the large-scale structures was expanding, then the velocity-distance relation plot for the receding large-scale structures and the receding gas molecules would have been completely different from one another.

(9) The molecular plots are exactly like the Hubble diagram; the molecules receding slowly are closer to us, whereas the molecules receding faster are further away from us. The distribution of molecules in Graph 5 is relatable to the homogeneous distribution of large-scale structures within the observable Universe since the molecules are distributed homogeneously irrespective of their mass.

(10) The gas molecules have deliberately been subjected to random temperatures to see if the molecules deviate from exhibiting a linear velocity-distance relation. No matter how randomly the data changes for the gas molecules, the velocity-distance relation plots continue to exhibit the linear behaviour just like the Hubble diagram.

(11) The value of the Slope obtained from the velocity-distance relation plot for the expanding gas molecules is similar to the Hubble constant (H) (the slope of Hubble diagram), since its reciprocal gives us the observation time in seconds, just like the Hubble time obtained from the reciprocal of (H).

(12) From the velocity-distance relation plot for the gas molecules it is found that the further away a gas molecule is, the faster it will be receding away from us, that is, the recessional velocity of gas molecules is directly proportional to their distance. This is also consistent with the Hubble's law.

(13) The Hubble's law and all Hubble equations are found to be obeyed by the receding gas molecules as well, equations like $v = H \text{ x } D$, $D = v/H$, $t_{\mathrm{H}} = 1/H$; where v is the recessional velocity, H is the Hubble constant, D is the distance and t_H is the Hubble time. For gas molecules the corresponding equations are v = Slope x D, $D = v/$Slope, t = 1/Slope.

(14) No matter on which molecule we are situated upon, all other molecules will exhibit redshift, therefore, there is expansion in every direction, there is no preferred centre. This is consistent with the observation of receding large-scale structures since all receding large-scale structures exhibit redshift except for some exceptionally rare ones.

(15) By knowing the values of the Slope and the distance covered by the receding gas molecules, their recessional velocity can be recalculated. Similarly, by knowing the values of the Slope and the recessional velocity of gas molecules, the distance covered by them can be recalculated. This is again consistent with the Hubble diagram.

(16) Since gas molecules exhibit Hubble diagram and obey all Hubble equations solely due to their recession by the virtue of the energy possessed by them, therefore, the large-scale structures that are known to exhibit Hubble diagram and obey all Hubble equations have to be receding solely by the virtue of the energy possessed by them.

(17) The gas molecules and the large-scale structures get arranged in terms of velocity and distance. The mass and the energy possessed by the molecules and the large-scale structures play an important role in determining their velocity-distance relation.

(18) Since the mass and the energy possessed by every large-scale structure are different, therefore, the large-scale structures get distributed homogeneously throughout the Universe irrespective of their mass. However, the most distant structure is a galaxy or a quasar, these being less massive than galaxy clusters exhibit higher recessional velocities.

(19) Plotting the velocity-distance relation for the receding large-scale structures is same as plotting the velocity-distance relation for receding gas molecules.

(20) Receding gas molecules will always exhibit Hubble-diagram. Since receding large-scale structures behave like receding gas molecules; justified by identical velocity-distance relation plots, the Hubble diagram therefore simply is the velocity-distance relation plot for receding gas molecules.

(21) The similarities encountered while plotting the velocity-distance relation plots for the receding large-scale structures and the receding gas molecules validate the credibility of the molecular expansion model.

(22) Based upon the concept of "acceleration phase" the reason for the deviation of Hubble diagram from linearity at high redshifts, and the reason for the observed accelerating expansion of the Universe have been explained. The accelerating recession of large-scale structures that we are observing at present is their recessional velocities billions of years ago when they were still within their "acceleration phase". The present day recessional velocity of such accelerating structures would remain unknown to us for a significant amount of time.

(23) Whether the remote structures are still accelerating or not cannot be correctly inferred since we are observing them how they were billions of years ago. There is more probability that the accelerating remote structures will attain a constant recessional velocity in future by the time they get as old and evolved as the structures within the local Universe for which the redshift-distance relation according to the Hubble diagram is linear, suggesting constant recessional velocity.

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