MOLECULES CAN EXPLAIN THE EXPANSION OF THE UNIVERSE

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1) Calculations pertaining to Table 1. Mass of different gas molecules.

Eleven gas molecules, Hydrogen, Helium, Nitrogen, Oxygen, Fluorine, Neon, Chlorine, Argon, Krypton, Xenon and Radon have been considered.

Their Atomic Mass (A) in atomic mass units (a.m.u.) or g mol^{-1} has been tabulated; these are standard values that have already been established.

Their Molecular Mass (M) in atomic mass units (a.m.u.) or g mol^{-1} has been tabulated; the Molecular Mass (M) is twice the Atomic Mass (A) since a diatomic molecule is constituted by two atoms.

The Mass of Molecule in kg has been obtained by dividing the value of Molecular Mass (M) by the Avogadro constant $N_A = 6.02214199 \times 10^{23}$ (It is the number of atoms or molecules in one mole of substance). The number obtained is the mass in grams. This number is now divided by 1000 to obtain the mass of molecules in kg.

The noble gases have also been considered as diatomic molecules.

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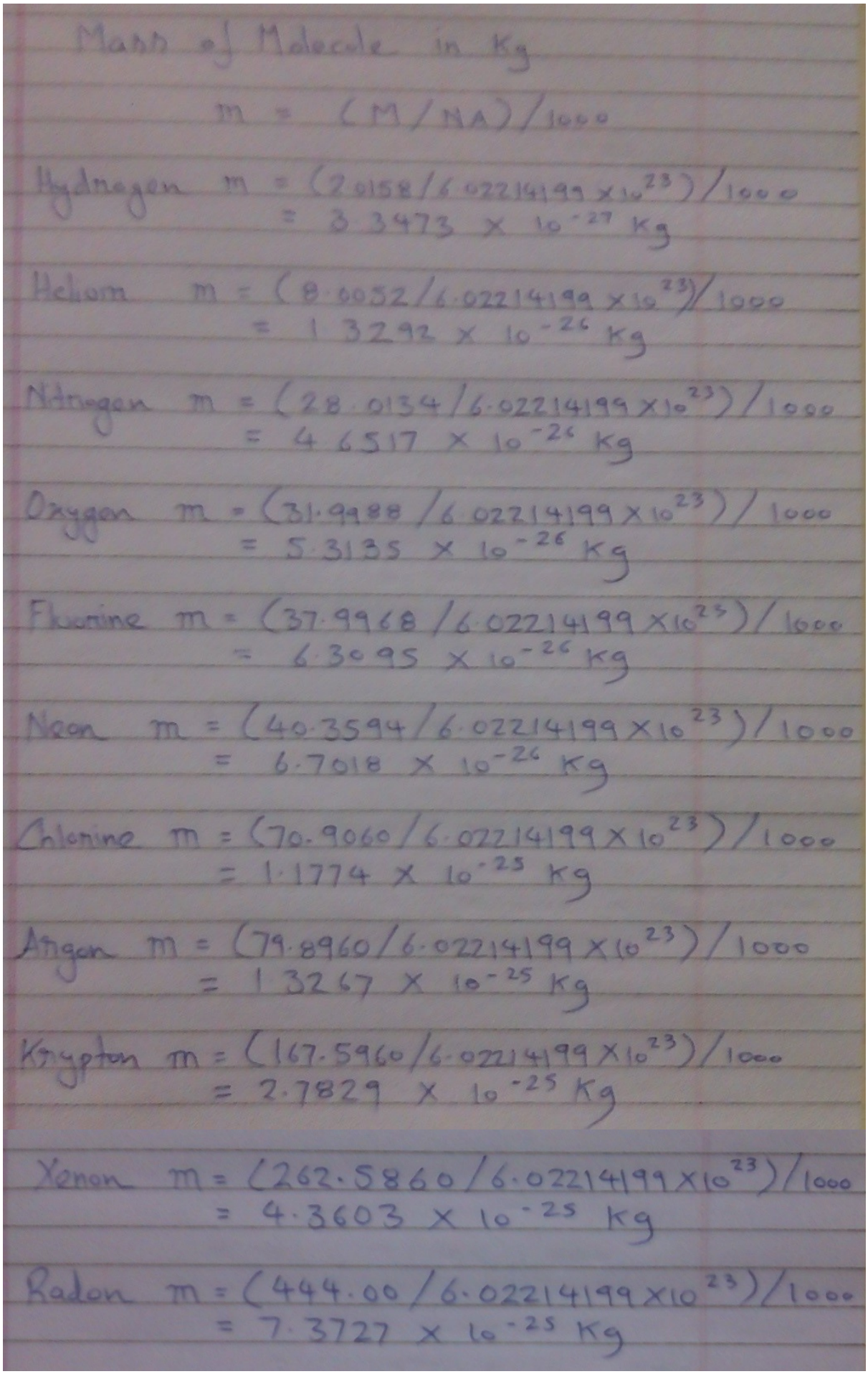

2) Calculations pertaining to the tables, from Table 2 to Table 8. Energy possessed by the gas molecules at a given temperature.

Every gas molecule is subjected to a particular temperature; the energy possessed by the molecule at a particular temperature is obtained by using the equation,

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

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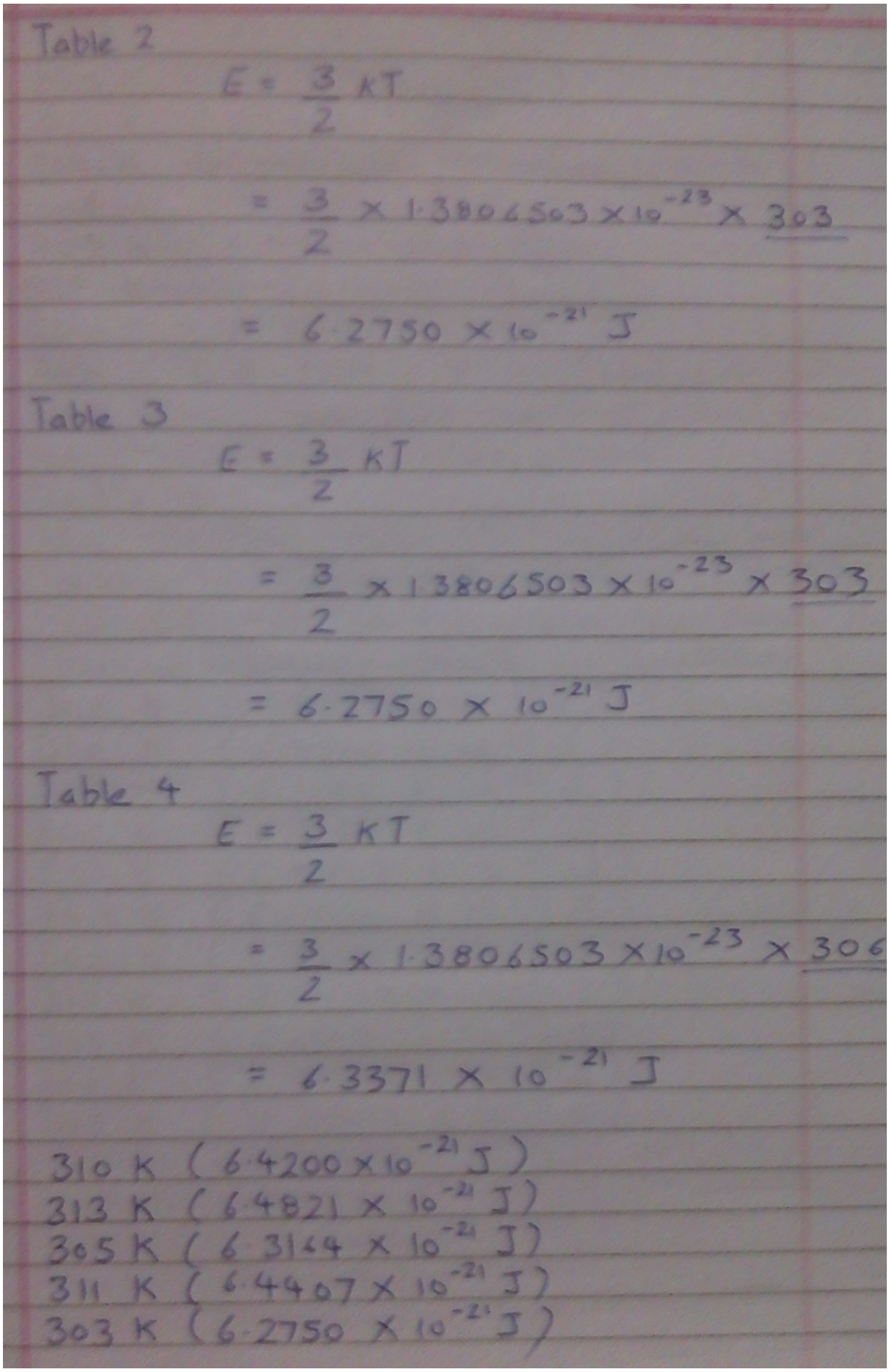
where E is the energy in Joules (J), k is the Boltzmann constant with a value of $1.3806503 \times 10^{-23}$ J K^{-1} and T is the temperature. The Boltzmann constant is the ratio of the gas constant (R = 8.314472 J K^{-1}) to the Avogadro constant (N_A= $6.02214199 \times 10^{23}$).



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308 K (6.3786×10^{-21} J)
312 K (6.4614×10^{-21} J)
304 K (6.2957×10^{-21} J)
307 K (6.3578×10^{-21} J)
309 K (6.3993×10^{-21} J)

Table S

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

306 K (6.3371×10^{-21} J)
310 K (6.4200×10^{-21} J)
313 K (6.4821×10^{-21} J)
305 K (6.3164×10^{-21} J)
311 K (6.4407×10^{-21} J)
303 K (6.2750×10^{-21} J)
308 K (6.3786×10^{-21} J)
312 K (6.4614×10^{-21} J)
304 K (6.2957×10^{-21} J)
307 K (6.3578×10^{-21} J)
309 K (6.3993×10^{-21} J)

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Table 6

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

1000 K	(2.0709×10^{-20} J)
2000 K	(4.1419×10^{-20} J)
10000 K	(2.0709×10^{-19} J)
9000 K	(1.8638×10^{-19} J)
900 K	(1.8638×10^{-20} J)
8000 K	(1.6567×10^{-19} J)
800 K	(1.6567×10^{-20} J)
9000 K	(1.8638×10^{-19} J)
10000 K	(2.0709×10^{-19} J)
700 K	(1.4496×10^{-20} J)
15000 K	(3.1064×10^{-19} J)

Table 7

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

1000 K	(2.0709×10^{-20} J)
10000 K	(2.0709×10^{-19} J)
9000 K	(1.8638×10^{-19} J)
2000 K	(4.1419×10^{-20} J)
8000 K	(1.6567×10^{-19} J)
9000 K	(1.8638×10^{-19} J)
10000 K	(2.0709×10^{-19} J)
15000 K	(3.1064×10^{-19} J)
900 K	(1.8638×10^{-20} J)
800 K	(1.6567×10^{-20} J)
700 K	(1.4496×10^{-20} J)

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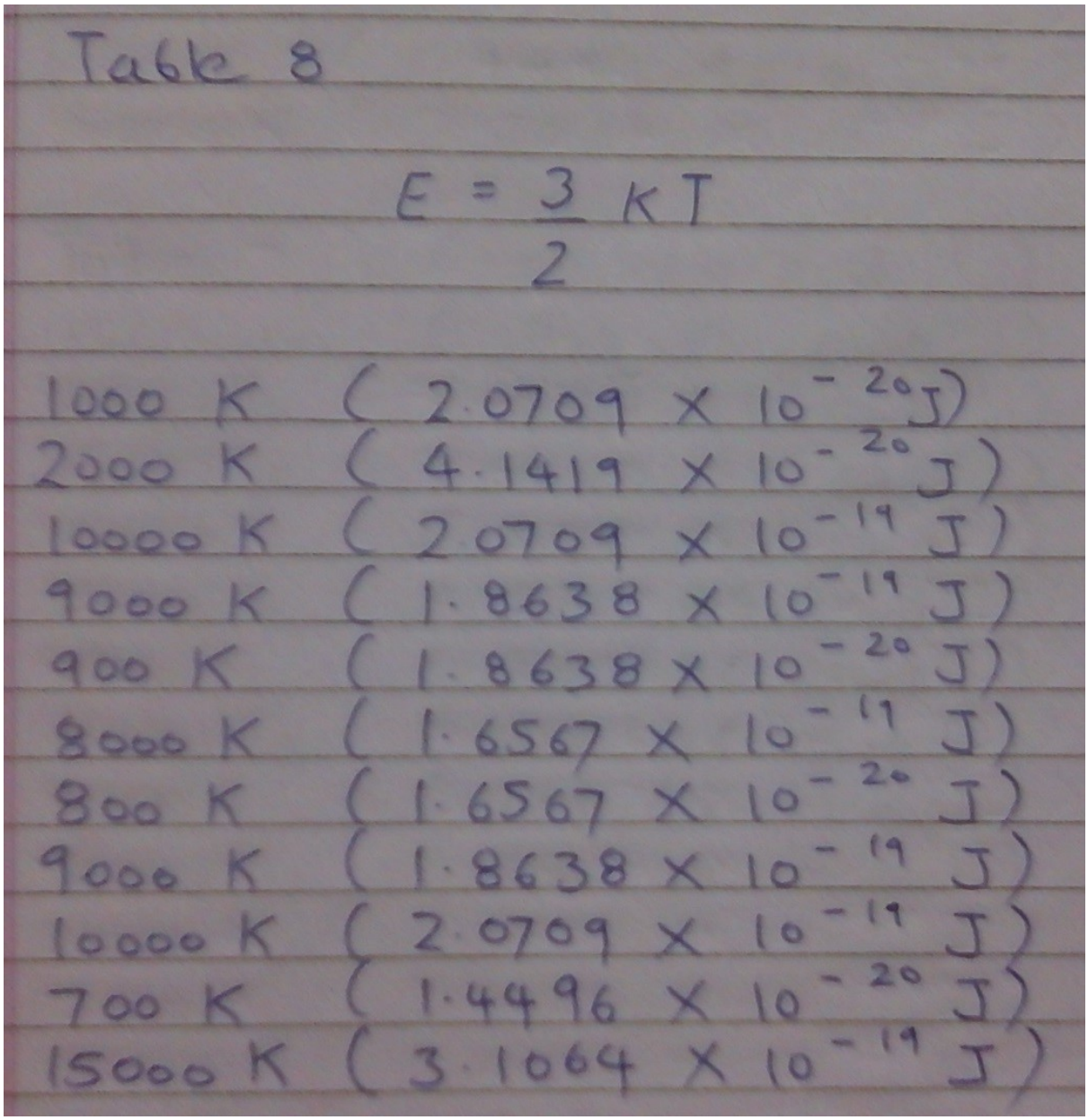

3) Calculations pertaining to the tables, from Table 2 to Table 8. Velocity of molecules.

Once we know the energy possessed by a molecule at a given temperature, we can calculate its velocities by using any one of the following velocity equations,

$$v = \sqrt{\frac{2E}{m}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3kT}{m}}$$

where v is the velocity of the molecule in m s^{-1}, E is the energy possessed by the molecule in Joules (J), m is the mass of the molecule in kg, R is the gas constant (8.314472 J K^{-1}), T is the temperature in Kelvin, M is the Molecular Mass (M) in atomic mass units (a.m.u.) or g mol^{-1}, k is the Boltzmann constant (1.3806503 x 10^{-23} J K^{-1}), T is the temperature in Kelvin and m is the mass of the molecule in kg.

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Table 2

$$V = \sqrt{\frac{2E}{m}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3kT}{m}}$$

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

$$= \sqrt{\frac{2 \times 6.2750 \times 10^{-21}}{3.3473 \times 10^{-27}}}$$

$$= \sqrt{\frac{1.255 \times 10^{-20}}{3.3473 \times 10^{-27}}}$$

$$V_{(Hydrogen)} = 1936.30 \ m\,s^{-1}$$

Helium ($971.68 \ m\,s^{-1}$)
Nitrogen ($519.41 \ m\,s^{-1}$)
Oxygen ($485.99 \ m\,s^{-1}$)
Fluorine ($445.98 \ m\,s^{-1}$)
Neon ($432.73 \ m\,s^{-1}$)
Chlorine ($326.48 \ m\,s^{-1}$)
Argon ($307.56 \ m\,s^{-1}$)
Krypton ($212.36 \ m\,s^{-1}$)
Xenon ($169.65 \ m\,s^{-1}$)
Radon ($130.46 \ m\,s^{-1}$)

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Table 3

$$v = \sqrt{\frac{2E}{m}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3kT}{M}}$$

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

$$= \sqrt{\frac{2 \times 6.2750 \times 10^{-21}}{3.3473 \times 10^{-27}}}$$

v (Hydrogen) $= 1936.30 \ m\,s^{-1}$

Helium ($971.68 \ m\,s^{-1}$)
Nitrogen ($519.41 \ m\,s^{-1}$)
Oxygen ($485.99 \ m\,s^{-1}$)
Fluorine ($445.98 \ m\,s^{-1}$)
Neon ($432.73 \ m\,s^{-1}$)
Chlorine ($326.48 \ m\,s^{-1}$)
Argon ($307.56 \ m\,s^{-1}$)
Krypton ($212.36 \ m\,s^{-1}$)
Xenon ($169.65 \ m\,s^{-1}$)
Radon ($130.46 \ m\,s^{-1}$)

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Table 4

$$V = \sqrt{\frac{2E}{m}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3kT}{m}}$$

$$V = \sqrt{\frac{2E}{m}}$$

$$= \sqrt{\frac{2 \times 6.3371 \times 10^{-21}}{3.3473 \times 10^{-27}}}$$

$$= \sqrt{\frac{1.26742 \times 10^{-20}}{3.3473 \times 10^{-27}}}$$

$$V_{(\text{Hydrogen})} = 1945.86 \text{ m s}^{-1}$$

Helium (982.85 m s^{-1})
Nitrogen (527.91 m s^{-1})
Oxygen (487.59 m s^{-1})
Fluorine (451.83 m s^{-1})
Neon (432.73 m s^{-1})
Chlorine (329.16 m s^{-1})
Argon (312.09 m s^{-1})
Krypton (212.71 m s^{-1})
Xenon (170.76 m s^{-1})
Radon (131.75 m s^{-1})

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Table 5

$$V = \sqrt{\frac{2E}{m}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3kT}{m}}$$

$$V = \sqrt{\frac{2E}{m}}$$

$$= \sqrt{\frac{2 \times 6.3371 \times 10^{-21}}{3.3473 \times 10^{-27}}}$$

$$= \sqrt{\frac{1.26742 \times 10^{-20}}{3.3473 \times 10^{-27}}}$$

$$V_{(Hydrogen)} = 1945.86 \ m\ s^{-1}$$

Helium (982.85 $m\ s^{-1}$)
Nitrogen (527.91 $m\ s^{-1}$)
Oxygen (487.59 $m\ s^{-1}$)
Fluorine (451.83 $m\ s^{-1}$)
Neon (432.73 $m\ s^{-1}$)
Chlorine (329.16 $m\ s^{-1}$)
Argon (312.09 $m\ s^{-1}$)
Krypton (212.71 $m\ s^{-1}$)
Xenon (170.76 $m\ s^{-1}$)
Radon (131.75 $m\ s^{-1}$)

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Table 6

$$V = \sqrt{\frac{2E}{m}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3kT}{m}}$$

$$V = \sqrt{\frac{2E}{m}}$$

$$= \sqrt{\frac{2 \times 2.0709 \times 10^{-20}}{3.3473 \times 10^{-27}}}$$

$$= \sqrt{\frac{4.1418 \times 10^{-20}}{3.3473 \times 10^{-27}}}$$

V (Hydrogen) $= 3517.60 \text{ m s}^{-1}$

Helium (2496.43 m s^{-1})
Nitrogen (2983.93 m s^{-1})
Oxygen (2698.64 m s^{-1})
Flooring (768.62 m s^{-1})
Neon (2223.52 m s^{-1})
Chlorine (530.48 m s^{-1})
Argon (1676.20 m s^{-1})
Krypton (1219.96 m s^{-1})
Xenon (257.85 m s^{-1})
Radon (917.97 m s^{-1})

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Table 7

$$v = \sqrt{\frac{2E}{m}} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3kT}{m}}$$

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

$$= \sqrt{\frac{2 \times 2.0709 \times 10^{-20}}{3.3473 \times 10^{-27}}}$$

$$= \sqrt{\frac{4.1418 \times 10^{-20}}{3.3473 \times 10^{-27}}}$$

$$= \sqrt{12373554.81}$$

$v = 3517.60 \text{ m s}^{-1}$ (Hydrogen)

Nitrogen (2983.93 m s^{-1})
Oxygen (2648.64 m s^{-1})
Helium (2496.43 m s^{-1})
Neon (2223.52 m s^{-1})
Argon (1676.20 m s^{-1})
Krypton (1219.96 m s^{-1})
Radon (917.97 m s^{-1})
Fluorine (768.62 m s^{-1})
Chlorine (530.48 m s^{-1})
Xenon (257.85 m s^{-1})

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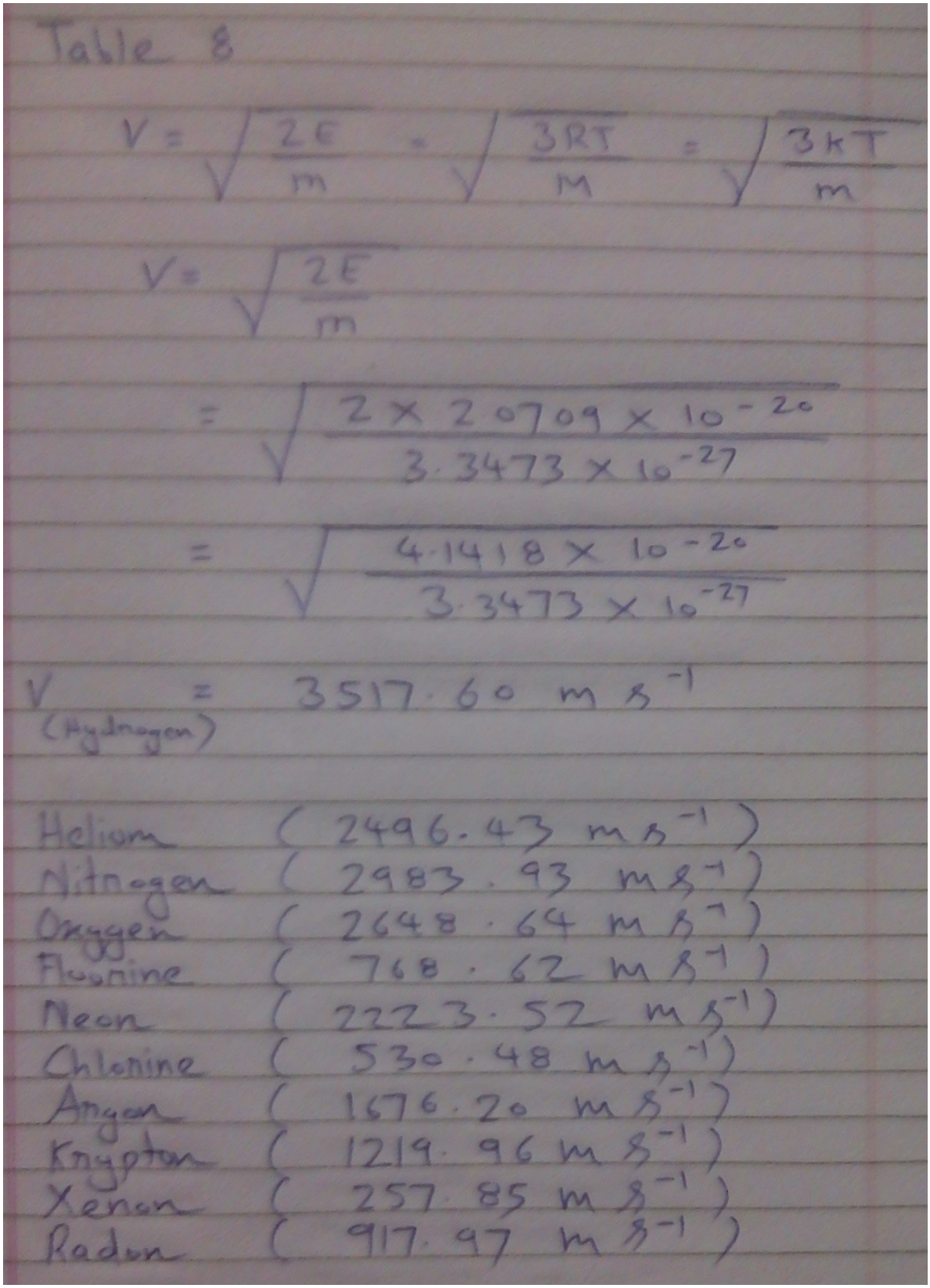

4) Calculations pertaining to the tables, from Table 2 to Table 8. Distance covered by the molecules.

Once we know the velocity of a molecule, we can calculate the distance covered by it in a given time frame by using the equation,

$$D = v\,t$$

where D is the distance covered by the molecule in meters, v is the velocity of the molecule in m s^{-1}, and t is the given time frame in seconds. Since every gas molecule is different, therefore, every gas molecule will exhibit a unique and non-overlapping velocity profile, due to this, the velocities of molecules will be proportional to their distances (velocities will be increasing with distance) – the further away a gas molecule is, the faster it will be moving away.

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Table 2

$$D = v t$$

$$= 1936.30 \times 1$$

$$D_{(Hydrogen)} = 1936.30 \text{ m}$$

Helium	(971.68 m)
Nitrogen	(519.41 m)
Oxygen	(485.99 m)
Fluorine	(445.98 m)
Neon	(432.23 m)
Chlorine	(326.48 m)
Argon	(307.56 m)
Krypton	(212.36 m)
Xenon	(169.65 m)
Radon	(130.46 m)

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Table 3

$$D = vt$$

$$= 1936.30 \times 60$$

$$D = 116178.0 \text{ m}$$
(Hydrogen)

Helium	(58300.8 m)
Nitrogen	(31164.6 m)
Oxygen	(29159.4 m)
Fluorine	(26758.8 m)
Neon	(25963.8 m)
Chlorine	(19588.8 m)
Argon	(18453.6 m)
Krypton	(12741.6 m)
Xenon	(10179.0 m)
Radon	(7827.6 m)

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Table 4

$D = vt$

$= 1945.86 \times 1$

$D_{(Hydrogen)} = 1945.86\ m$

Helium (982.85 m)
Nitrogen (527.91 m)
Oxygen (487.59 m)
Fluorine (451.83 m)
Neon (432.73 m)
Chlorine (329.16 m)
Argon (312.09 m)
Krypton (212.71 m)
Xenon (170.76 m)
Radon (131.75 m)

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Table 5

$D = vt$

$= 1945.86 \times 60$

$D_{(Hydrogen)} = 116751.6\ m$

Helium	(982.85 m)
Nitrogen	(527.91 m)
Oxygen	(487.59 m)
Fluorine	(451.83 m)
Neon	(432.73 m)
Chlorine	(329.16 m)
Argon	(312.09 m)
Krypton	(212.71 m)
Xenon	(170.76 m)
Radon	(131.75 m)

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Table 6

$D = vt$

$= 3517.60 \times 60$

$D_{(Argon)} = 211056.0\ m$

Helium	(149785.8 m)
Nitrogen	(179035.8 m)
Oxygen	(158918.4 m)
Fluorine	(46117.2 m)
Neon	(133411.2 m)
Chlorine	(31828.8 m)
Argon	(100572.0 m)
Krypton	(73197.6 m)
Xenon	(15471.0 m)
Radon	(55078.2 m)

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Table 7

$D = vt$

$= 3517.60 \times 1.9$

$D_{(Hydrogen)} = 6683.44\ m$

Nitrogen 1.8 Sec (5371.074 m)

Oxygen 1.7 Sec (4502.688 m)

Helium 1.6 Sec (3994.288 m)

Neon 1.5 Sec (3335.28 m)

Argon 1.4 Sec (2346.68 m)

Krypton 1.3 Sec (1585.948 m)

Radon 1.2 Sec (1101.564 m)

Fluorine 1.1 Sec (845.482 m)

Chlorine 1.0 Sec (530.48 m)

Xenon 1.0 Sec (257.85 m)

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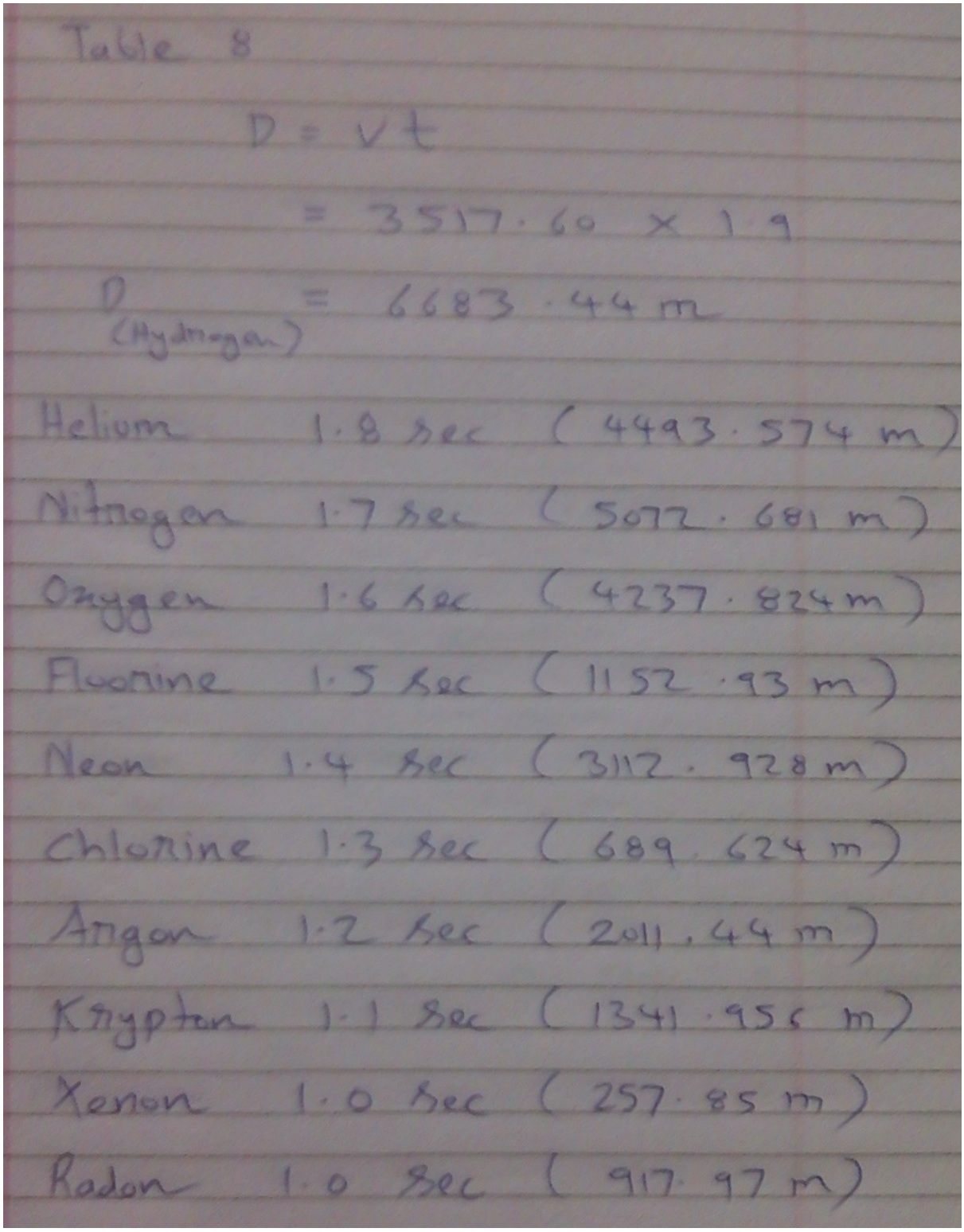

5) Calculations for obtaining the value of Slope for different gas molecules undergoing free expansion into the vacuum of the Universe at the same time.

Distance covered by a gas molecule depends upon its velocity. The faster the molecule is, the further it will travel in a given time frame. Velocities would therefore be proportional to distance, we can use the equation,

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

where v is the velocity of the gas molecule in m s^{-1} and D is the distance in meters covered by the molecule in a given time frame (time being measured in seconds).

The inverse of the Slope (1/Slope or $Slope^{-1}$) gives back the original observation time in seconds.

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Figure 2 (Table 2)

$$\text{Slope} = \frac{v}{D}$$

$$= \frac{1936.30}{1936.30}$$

$$\text{Slope}_{(\text{Hydrogen})} = 1\ m\ s^{-1}\ m^{-1}$$

$$t = \frac{1}{\text{Slope}} \quad \text{or} \quad \text{Slope}^{-1}$$

$$= 1\ \text{Sec}$$

Helium
Nitrogen
Oxygen
Fluorine
Neon
Chlorine
Argon
Krypton
Xenon
Radon

$\text{Slope} = 1\ m\ s^{-1}\ m^{-1}$

$\frac{1}{\text{Slope}}$ or $\text{Slope}^{-1} = 1\ \text{Sec}$

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Figure 3 (Table 3)

$$\text{Slope} = \frac{V}{D}$$

$$= \frac{1936\ 30}{116178\ 0}$$

$$\text{Slope}_{(\text{Hydrogen})} = 0.016666666\ m\ s^{-1}\ m^{-1}$$

$$t = \frac{1}{\text{Slope}} \text{ or } \text{Slope}^{-1}$$

$$= 60\ sec$$

Helium
Nitrogen
Oxygen
Fluorine
Neon
Chlorine
Argon
Krypton
Xenon
Radon

$$\text{Slope} = 0.016666666\ m\ s^{-1}\ m^{-1}$$

$$\frac{1}{\text{Slope}} \text{ or } \text{Slope}^{-1} = 60\ sec$$

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Figure 4 (Table 4)

$$\text{Slope} = \frac{V}{D}$$

$$= \frac{1945.86}{1945.86}$$

$$\text{Slope} = 1\ m s^{-1} m^{-1}$$

(Hydrogen)

$$t = \frac{1}{\text{Slope}} \quad \text{or} \quad \text{Slope}^{-1}$$

$$= 1\ \text{Sec}$$

Helium
Nitrogen
Oxygen
Fluorine
Neon
Chlorine
Argon
Krypton
Xenon
Radon

$$\text{Slope} = 1\ m s^{-1} m^{-1}$$

$$\frac{1}{\text{Slope}} \quad \text{or} \quad \text{Slope}^{-1} = 1\ \text{Sec}$$

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Figure 5 (Table 5)

$$\text{Slope} = \frac{V}{D}$$

$$= \frac{1945.86}{116751.6}$$

$$\text{Slope}_{(\text{Hydrogen})} = 0.016666666 \; m\,s^{-1}\,m^{-1}$$

$$t = \frac{1}{\text{Slope}} \quad \text{or} \quad \text{Slope}^{-1} = 60 \text{ sec}$$

Helium
Nitrogen
Oxygen
Fluorine
Neon
Chlorine
Argon
Krypton
Xenon
Radon

$$\text{Slope} = 0.016666666 \; m\,s^{-1}\,m^{-1}$$

$$\frac{1}{\text{Slope}} \quad \text{or} \quad \text{Slope}^{-1} = 60 \text{ sec}$$

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Figure 6 (Table 6)

$$\text{Slope} = \frac{V}{D}$$

$$= \frac{3517.60}{211056.0}$$

$$\text{Slope}_{(\text{Hydrogen})} = 0.016666666\ m\,s^{-1}\,m^{-1}$$

$$t = \frac{1}{\text{Slope}} \quad \text{or} \quad \text{Slope}^{-1} = 60\ sec$$

Helium
Nitrogen
Oxygen
Fluorine
Neon
Chlorine
Argon
Krypton
Xenon
Radon

$$\text{Slope} = 0.016666666\ m\,s^{-1}\,m^{-1}$$

$$\frac{1}{\text{Slope}} \quad \text{or} \quad \text{Slope}^{-1} = 60\ sec$$

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Figure 7 (Table 7)

$$\text{Slope} = \frac{V}{D} \; ; \; t = \frac{1}{\text{Slope}}$$

Slope (Hydrogen) $= \frac{3517.60}{6683.44} = 0.5263 \; ms^{-1}m^{-1} = 1.9\,sec$

Slope (Nitrogen) $= \frac{2983.93}{5371.074} = 0.5555 \; ms^{-1}m^{-1} = 1.8\,sec$

Slope (oxygen) $= \frac{2648.64}{4502.688} = 0.5882 \; ms^{-1}m^{-1} = 1.7\,sec$

Slope (Helium) $= \frac{2496.43}{3994.288} = 0.625 \; ms^{-1}m^{-1} = 1.6\,sec$

Slope (Neon) $= \frac{2223.52}{3335.28} = 0.6666 \; ms^{-1}m^{-1} = 1.5\,sec$

Slope (Argon) $= \frac{1676.20}{2346.68} = 0.7142 \; ms^{-1}m^{-1} = 1.4\,sec$

Slope (Krypton) $= \frac{1219.96}{1585.948} = 0.7692 \; ms^{-1}m^{-1} = 1.3\,sec$

Slope (Radon) $= \frac{917.97}{1101.564} = 0.8333 \; ms^{-1}m^{-1} = 1.2\,sec$

Slope (Fluorine) $= \frac{768.62}{845.482} = 0.9090 \; ms^{-1}m^{-1} = 1.1\,sec$

Slope (Chlorine) $= \frac{530.48}{530.48} = 1 \; ms^{-1}m^{-1} = 1\,sec$

Slope (Xenon) $= \frac{257.85}{257.85} = 1 \; ms^{-1}m^{-1} = 1\,sec$

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Figure 8 (Table 8)

$$\text{Slope} = \frac{V}{D} \; ; \; t = \frac{1}{\text{Slope}}$$

Slope (Hydrogen) $= \frac{3517.60}{6683.44} = 0.5263 \; ms^{-1}m^{-1} = 1.9 \; sec$

Slope (Helium) $= \frac{2496.43}{4493.574} = 0.5555 \; ms^{-1}m^{-1} = 1.8 \; sec$

Slope (Nitrogen) $= \frac{2983.93}{5072.681} = 0.5882 \; ms^{-1}m^{-1} = 1.7 \; sec$

Slope (oxygen) $= \frac{2648.64}{4237.824} = 0.625 \; ms^{-1}m^{-1} = 1.6 \; sec$

Slope (Fluorine) $= \frac{768.62}{1152.93} = 0.6666 \; ms^{-1}m^{-1} = 1.5 \; sec$

Slope (Neon) $= \frac{2223.52}{3112.928} = 0.7142 \; ms^{-1}m^{-1} = 1.4 \; sec$

Slope (Chlorine) $= \frac{530.48}{689.624} = 0.7692 \; ms^{-1}m^{-1} = 1.3 \; sec$

Slope (Argon) $= \frac{1676.20}{2011.44} = 0.8333 \; ms^{-1}m^{-1} = 1.2 \; sec$

Slope (Krypton) $= \frac{1219.96}{1341.956} = 0.9090 \; ms^{-1}m^{-1} = 1.1 \; sec$

Slope (Xenon) $= \frac{257.85}{257.85} = 1 \; ms^{-1}m^{-1} = 1 \; sec$

Slope (Radon) $= \frac{917.97}{917.97} = 1 \; ms^{-1}m^{-1} = 1 \; sec$

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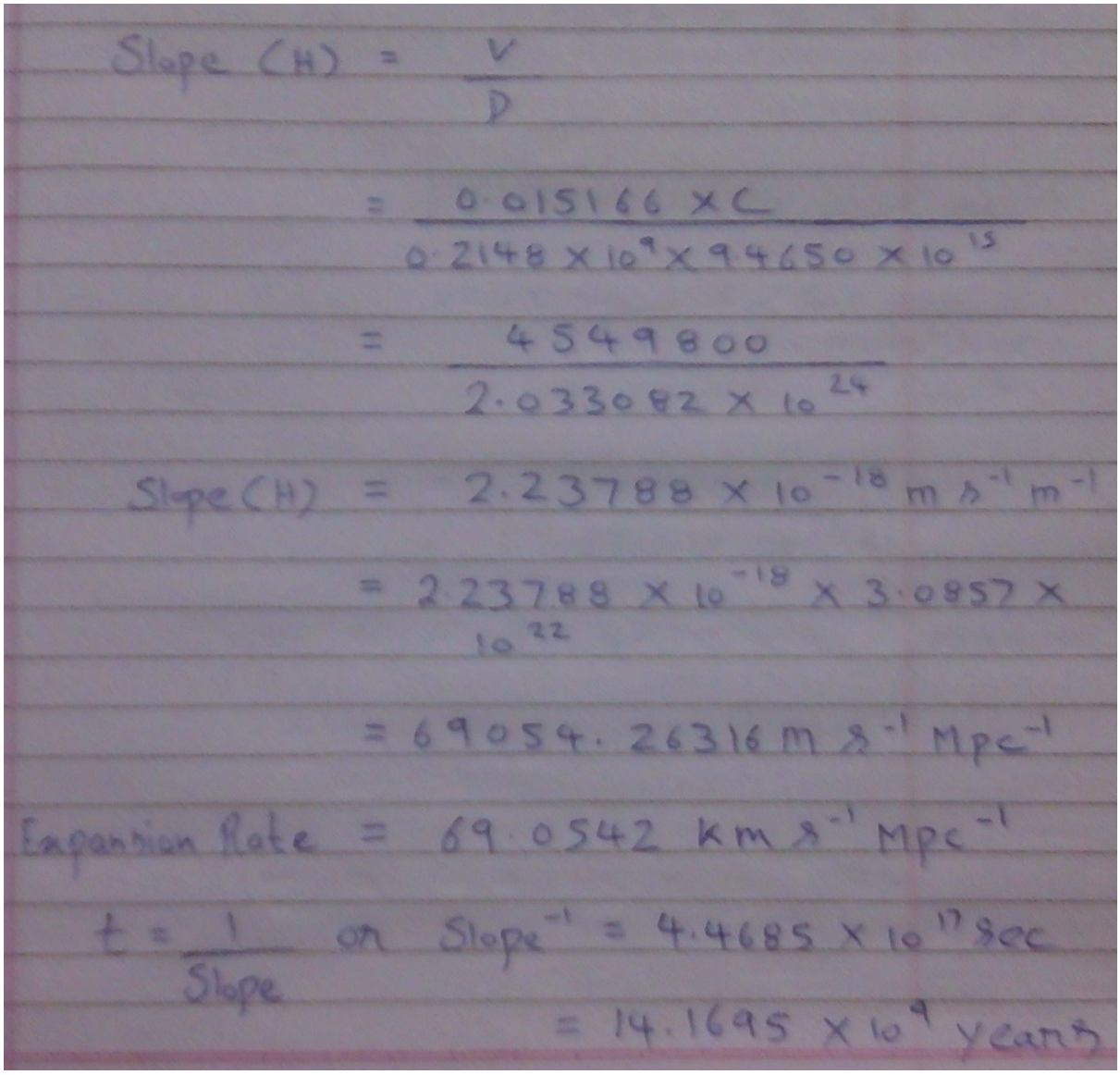
6) Calculations pertaining to Figure 9. Obtaining the value of slope and hence the expansion rate from the supernovae.

The redshift-distance relationship for 580 type Ia supernovae have been plotted by using the Supernova Cosmology Project data for 580 type Ia supernovae from Union 2 (Amanullah et al. 2010) and Union 2.1 (Suzuki et al. 2012), 7 additional high redshift type Ia supernovae discovered through the ACS (Advanced Camera for Surveys) on the Hubble Space Telescope from the GOODS (Great Observatories Origins Deep Survey) Treasury program (joint work conducted by Giavalisco et al. 2004 and Riess et al. 2004), and 1 additional very high redshift type Ia supernova discovered with WFPC2 (Wide Field and Planetary Camera 2) on the Hubble Space Telescope (Gilliland et al. 1999). The data is publically available.

[c is the velocity of light (3×10^8 m s^{-1}), 1 light year = 9.4650×10^{15} m, billion = 10^9, 1 year = 31536000 seconds, 1 pc = 3.0857×10^{16} m, 1 Mpc = 10^6 pc = 3.0857×10^{22} m]

It is the velocity-interpretation of the observed redshifts that helps us to determine and compare the expansion rate of local and remote supernovae. Expansion rate would literally have no significance if redshifts are not interpreted as velocities.

The value of slope (H) for a very nearby local supernova at a distance of 0.2148 Gly (billion light years) exhibiting a redshift (z) of 0.015166,



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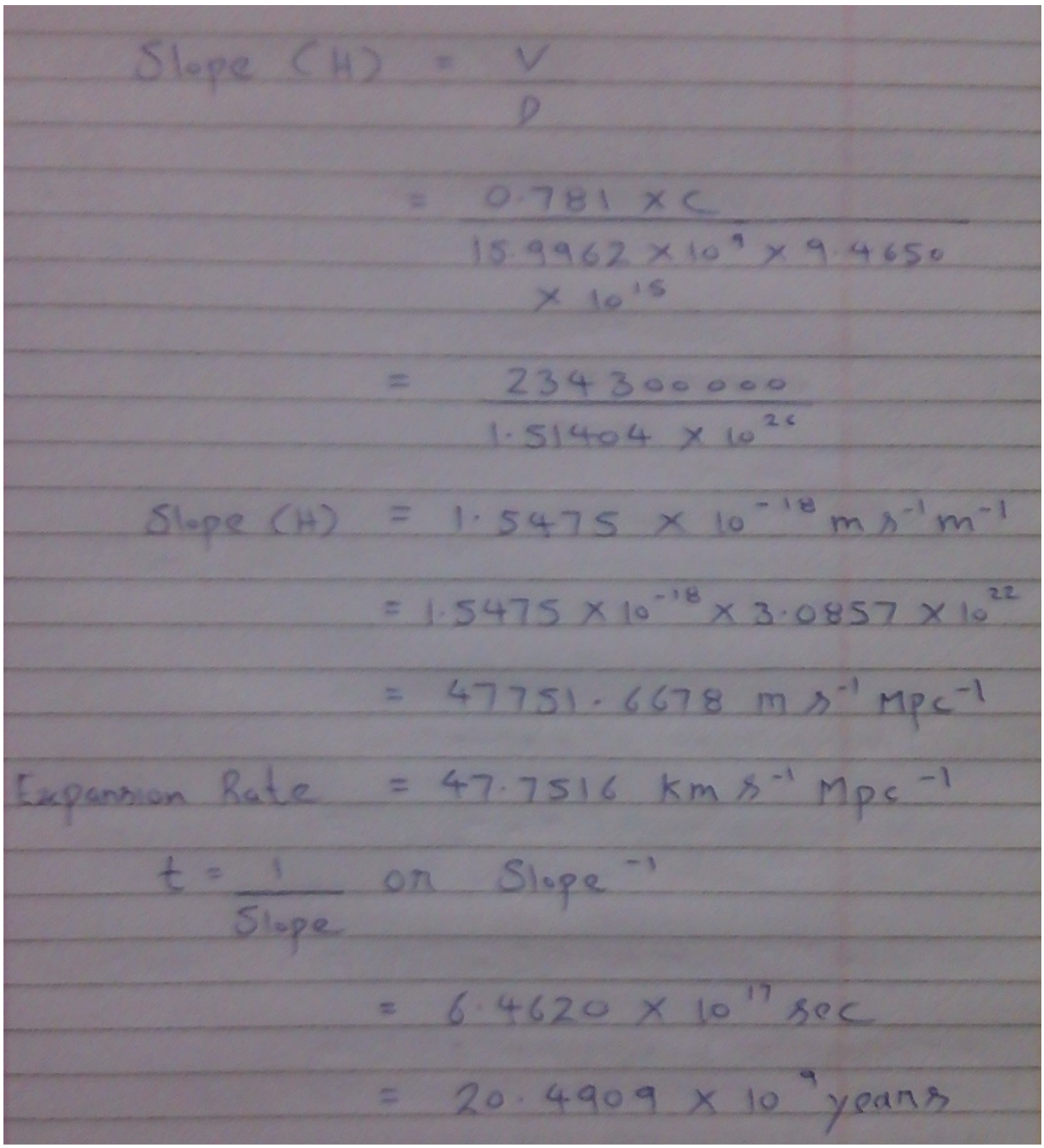
The value of slope (H) for an intermediately-distant supernova at a distance of 15.9962 Gly (billion light years) exhibiting a redshift (z) of 0.781,



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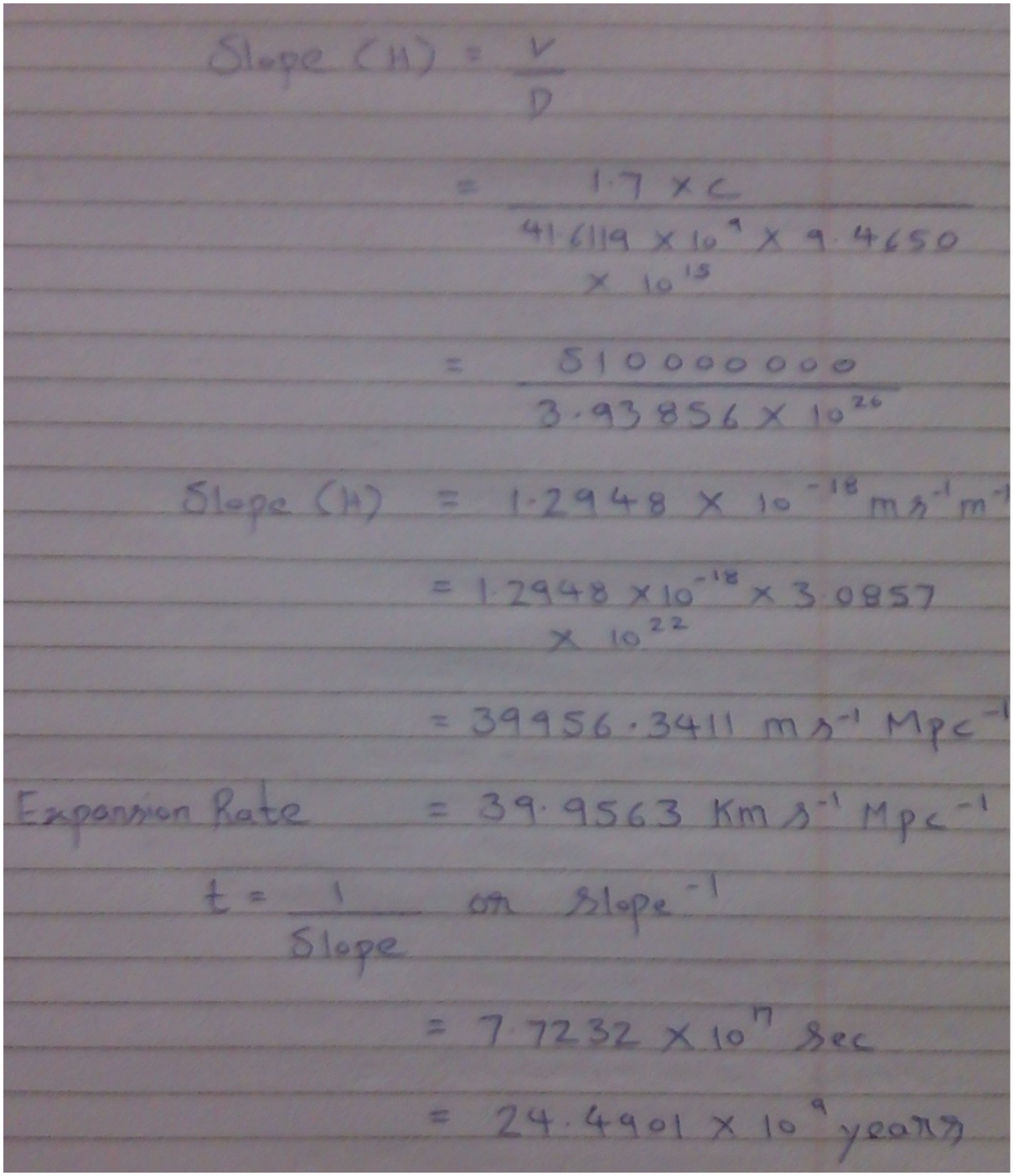
The value of slope (H) for the most distant supernova at a distance of 41.6119 Gly (billion light years) exhibiting a redshift (z) of 1.7,



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