Are relativistic gases possiple?

Introduction

Einstein's theory of relativity is one of the most successful theories in physics after quantum mechanics. This theory predicts three fundamental phenomena viz time dilation, mass reduction, and length contraction, based on the Lorentz transformation.

We know that, relativistic speeds are achieved by increasing the velocities of subjects much towards the speed of light c. As speeds approach the speed of light, we say we have approached relativistic speeds.

Gasses have a kinetic energy. This energy in principle can be increased by the application of heat. This increases the activity oof atoms which in turn, gives off energy as heat. This heat is what we thought of as increasing to increase the velocity of the gas in question to achive relativistic speeds and thus, a relativistic gas.

But the question is, is this possible?

Gasses are made of atoms. Atoms have electrons which reside on energy levels. As we apply heat, these atoms absorb heat and undergo atomic transitions due to the quantized nature of these energy levels.

When an electron transitions to a higher energy level upon absorption of energy, they come back to lower energies when the absorbed energies are lost often through radiation - light or x-rays for instance. This means that, there is a possibility that, the electrons may never come back to their lower energy levels as they transition to higher energy levels because the energy absorbed can be enormous that, they leave the atom forever - ionisation. This is achieved if the energy gained is greater than or equal to the atom's ionisation energy. In this case, the gas rather that becoming relativistic shifts to a new phase called the plasma state which is not a gas.

With this said, we have to look for a way to prove whether or not relativistic gases are possible to achieve.

Existence of a Relativistic Gas

We asserted, from theory that, relativistic gases must have high temparatures due to their tremendous kinetic energies. An issue could be raised which needs investigation. This is whether the temparature achieved by the gas is enough to cause the gas to plasmarize shifting it into a new phase of matter which is the plasma state. In this case, the idea of a relativistic gas breaksdown and our study becomes impossible as well.

Consider a Helium atom, an atom in general plasmarize if we ionize the constituent molecules. This means that, we have to over come the ionization energies of the atom. Atoms can gain energy as they move and collide with each other which leads to the absorption of energy leading to a quantum mechanical effect- quantum jump. If this energy absorbed is equal to the ionisation energy of the atom, then, we can ionize the atom.

Helium atom has two electrons meaning, it has two ionization energies- the first and the second ioniztion energy. We assume in our study, we were only allowed to remove only one electron. As the Helium atom accelerates towards the speed of light, the atom gains energy which is transferred to the electrons. The electrons absorb this energy which when is equal to the ionization energy, will ionize helium atom. We have the relationship between the Kinetic energy and ionization energy as in equation (1)

$$K = I_n \tag{1}$$

where K is the kinetic energy og Helium atom and In is the nth ionizaton energy of helium atom. So we can rewrite equation (1) in full as in equation (2)

$$\frac{m_{He}v^2}{2} = I_n \tag{2}$$

where m_{He} is the mass of helium atom and v is the velocity of the helium atom. From equation (2), we can deduce whether a relativistic gas can exist with a helium atom. The only varriable in the expression is the velocity of the helium atom. Plugging in all the constants, we obtain a velocity of $34,437ms^{-1}$.

This velocity clearly suggests that, the atom reaches about 0.0115% the speed of light before ionizing hence, the concept of a relativistic gas breaks down as the gas will turn into the plasma state after reaching 0.0115% the speed of light. In addition, the mass of the atom stays relatively constant as the atom cannot reach relativistic speeds in the gaseous state - mass reduction does not occur profoundly here. We have shown graphically the relationship between the ionisation energy and the mass of the gas from which we can infer the velocity needed to produce a given ionisation energy. As the mass of the atom increases as in for a larger atom, we need less and less kinetic energy to ionize the gas. This even complicates the formation of a stable relativistic gas.

This theoretical observation is not out of the blue. In chemistry, ionization energy decreases down the group as shells are being added to the atom as we go down the group, reducing screening effect. All the atoms used here are from the same group hence, the laws of chemistry will be at play here and also we are withn the laws of nature.

Mass and Ionization Energy of mono atomic gases

Element	Mass (Kg)	Ionisation energy
Helium (He)	6.64×10^{-27}	3.94×10^{-18}
Neon (Ne)	3.35×10^{-26}	3.20×10^{-18}
Argon (Ar)	6.63×10^{-26}	2.49×10^{-18}
Krypton (Kr)	1.39×10^{-25}	2.25×10^{-18}
Xenon (Xe)	2.18×10^{-25}	2.08×10^{-18}

Conclusion

So in conclusion, relativistic gases are impossible to exist with at least the monoatomic gases. This is simply because, the energies gained by the atoms is enough to send them to the plasma state.