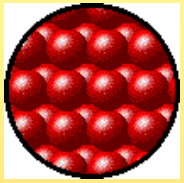
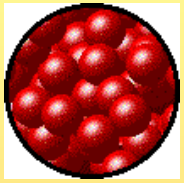
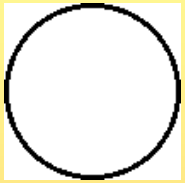
Plasma and BEC State

States of Matter


Each addition of Energy Creates a change in state

+E → **Solids** → +E → **Liquids** → +E → **Gases** → +E → **Plasmas**

SOLID

Tightly packed, in a regular pattern
Vibrate, but do not move from place to place

LIQUID

Close together with no regular arrangement.
Vibrate, move about, and slide past each other

GAS

Well separated with no regular arrangement.
Vibrate and move freely at high speeds

PLASMA

Has no definite volume or shape and is composed of electrical charged particles

But what happens if you raise the temperature to super-high levels… between

1000°C and 1,000,000,000°C ?

Will everything just be a gas?

But it is Naturally impossible

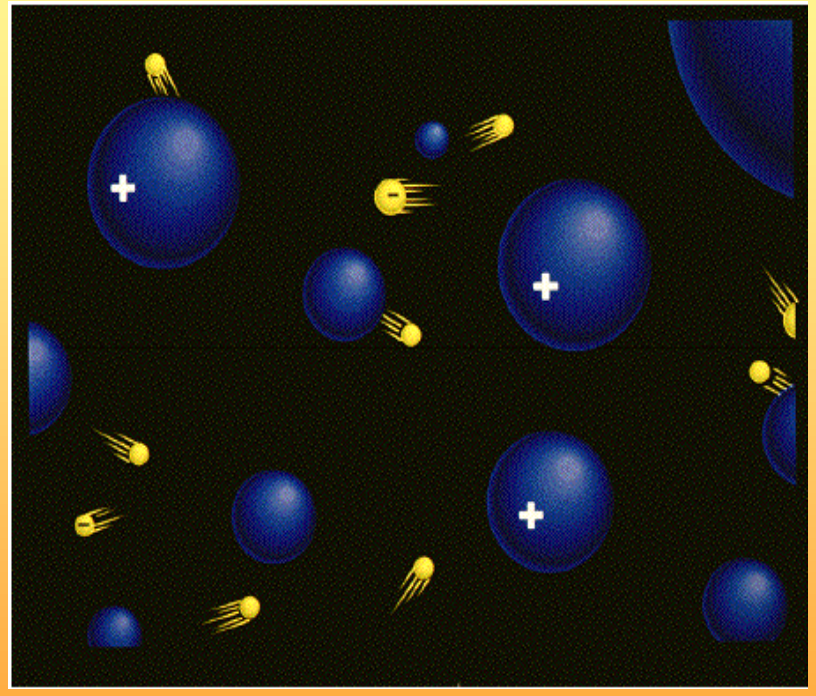
Because

Plasma is known as the fourth state of matter. It is the basis of some of the most spectacular phenomena in nature. The violent spark of lightning, the ghostly luminescent Northern Lights, the cosmic interplay of colors in a nebula, and even the burning brightness in the core of every star—all have their origin in plasma. In fact, plasmas are the most common form of matter in the universe! Plasma's intense, otherworldly glow seems almost supernatural. However, plasmas contain underlying physical concepts.

A plasma is a gas that is heated to the point that the individual gas particles break apart into a collection of positively and negatively charged particles. The distinct glow of a plasma is created by the occasional recombination of positive and negative charges that produces an emission of light with a color determined purely by gas chemistry.

PLASMA

- A plasma is an ionized gas.
- A plasma is a very good conductor of electricity and is affected by magnetic fields.
- Plasmas, like gases have an indefinite shape and an indefinite volume.



- Plasma is the common state of matter

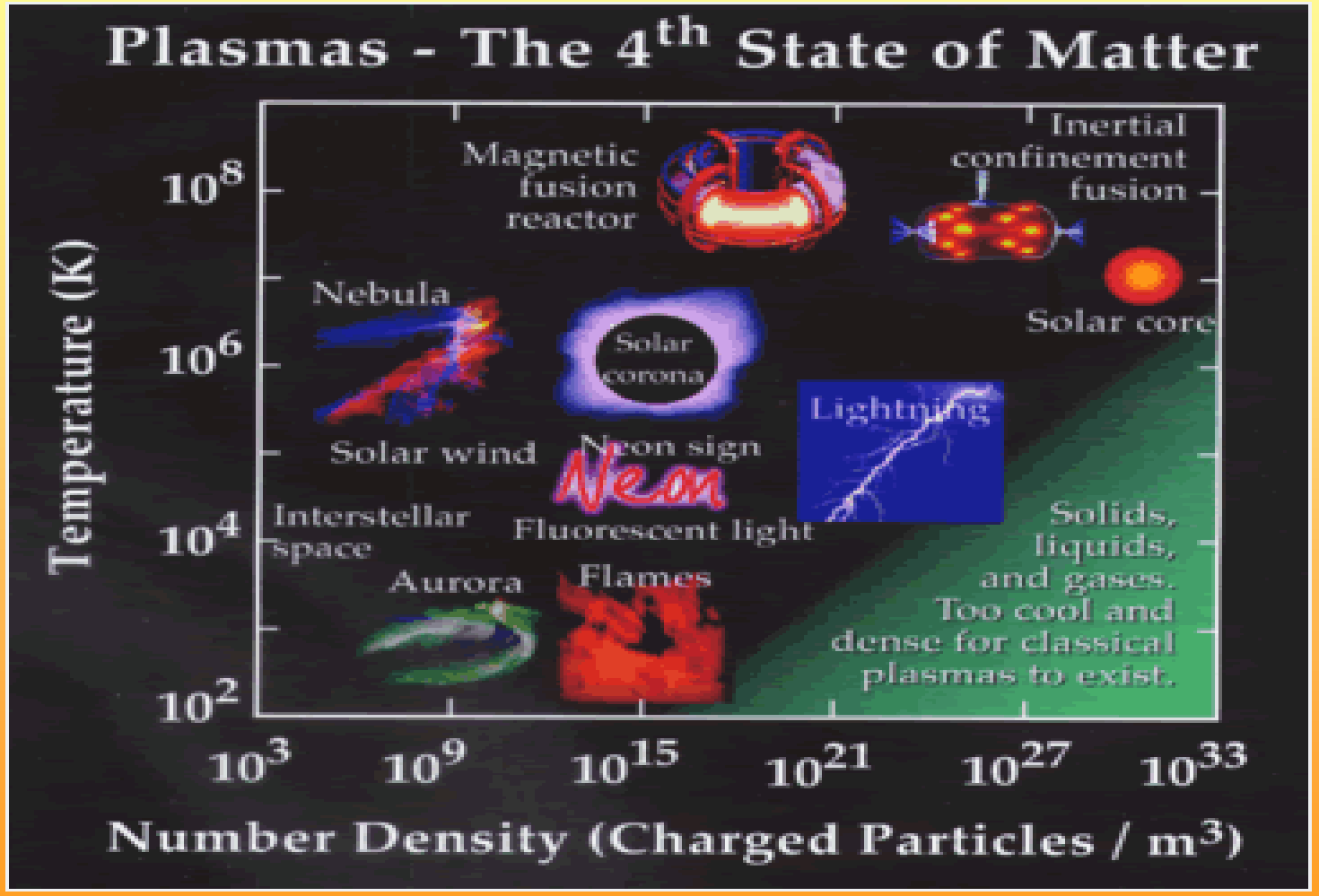
Some places where plasmas are found…

1. Flames

2. Lightning

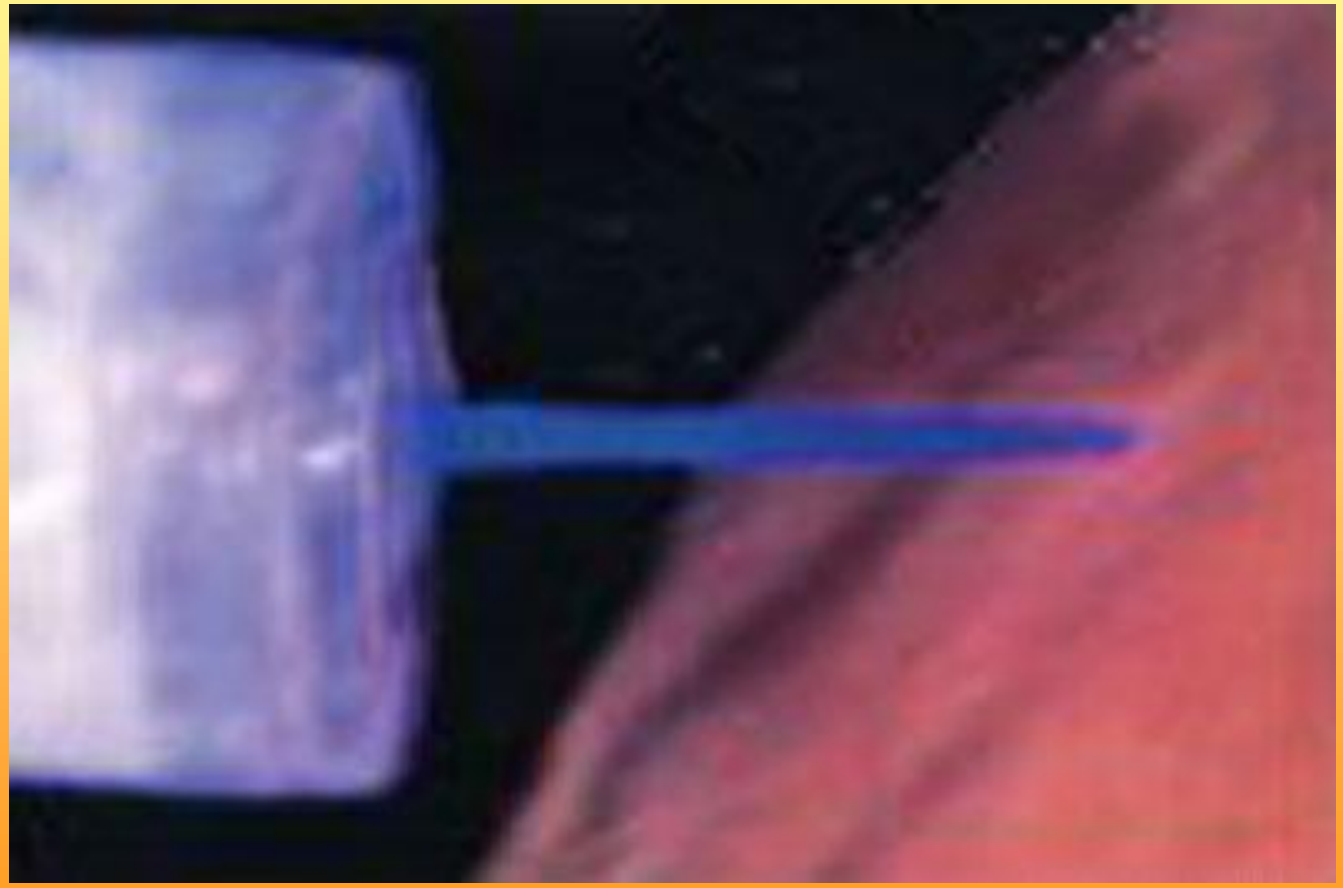
3. Aurora (Northern Lights)

The Sun is an example of a star in its plasma state


Plasmas - The 4th State of Matter
Temperature (K)
10^8
10^6
10^4
10^2
Magnetic fusion reactor
Inertial confinement fusion
Nebula
Solar corona
Solar core
Solar wind
Neon sign
Neon
Lightning
Interstellar space
Fluorescent light
Aurora
Flames
Solids, liquids, and gases. Too cool and dense for classical plasmas to exist.
10^3
10^9
10^15
10^21
10^27
10^33
Number Density (Charged Particles / m^3)

COLD PLASMA IN SEA

COLD PLASMA PEN



Star formation in the Eagle Nebula
Space Telescope Science Institute NASA

(below)

(Above)

X-ray view of Sun from Yohkoh, ISAS and NASA

Plasma radiation within the Princeton Tokamak during operation.

Laser plasma interaction during inertial confinement fusion test at the University of Rochester.

Plasma consists of a collection of free-moving electrons and ions - atoms that have lost electrons. Energy is needed to strip electrons from atoms to make plasma. The energy can be of various origins: thermal, electrical, or light (ultraviolet light or intense visible light from a laser).

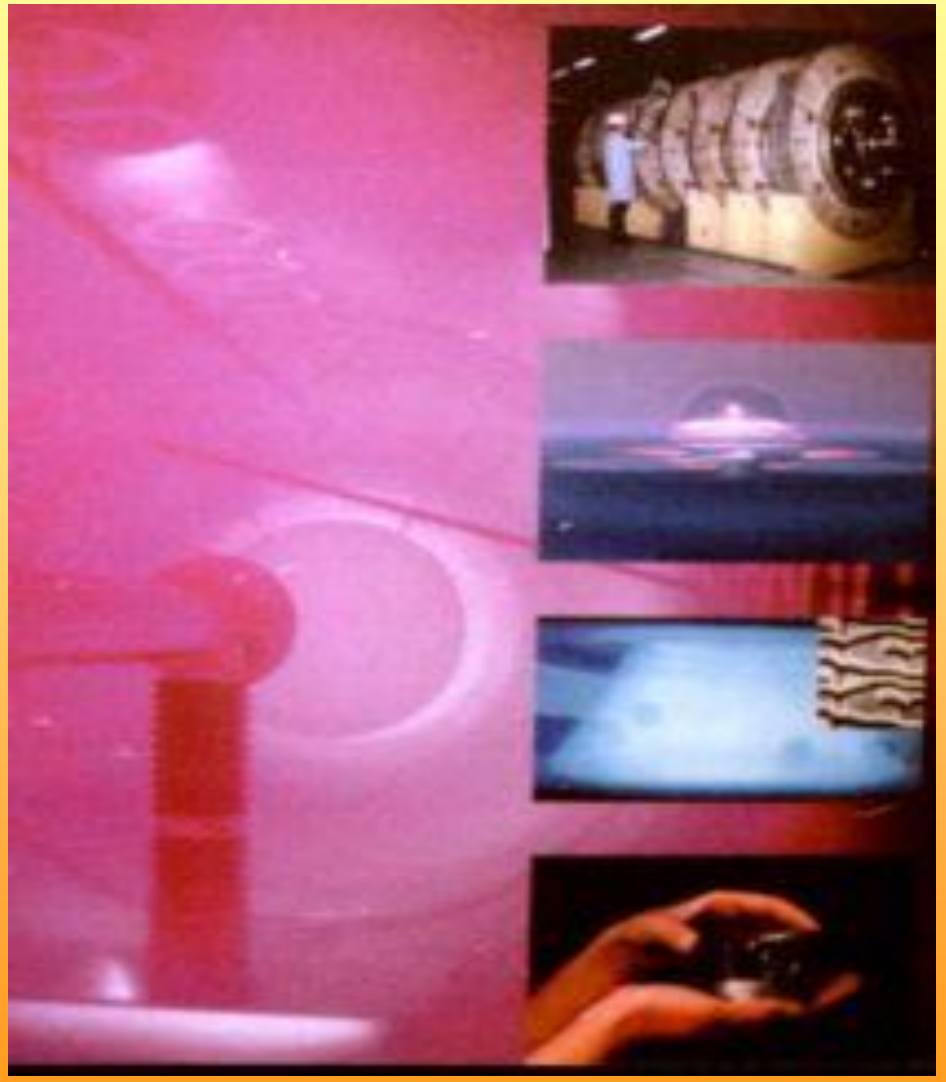
With insufficient sustaining power, plasmas recombine into neutral gas.

Plasma can be accelerated and steered by electric and magnetic fields which allows it to be controlled and applied. Plasma research is yielding a greater understanding of the universe. It also provides many practical uses: new manufacturing techniques, consumer products, and the prospect of abundant energy.

Plasma technologies are important in industries with annual world markets approaching $200 billion

- Waste processing
- Coatings and films
- Electronics
- Computer chips and integrated circuits
- Advanced materials (e.g., ceramics)
- High-efficiency lighting

Product manufactured using plasmas impact our daily lives:



EXAMPLES:

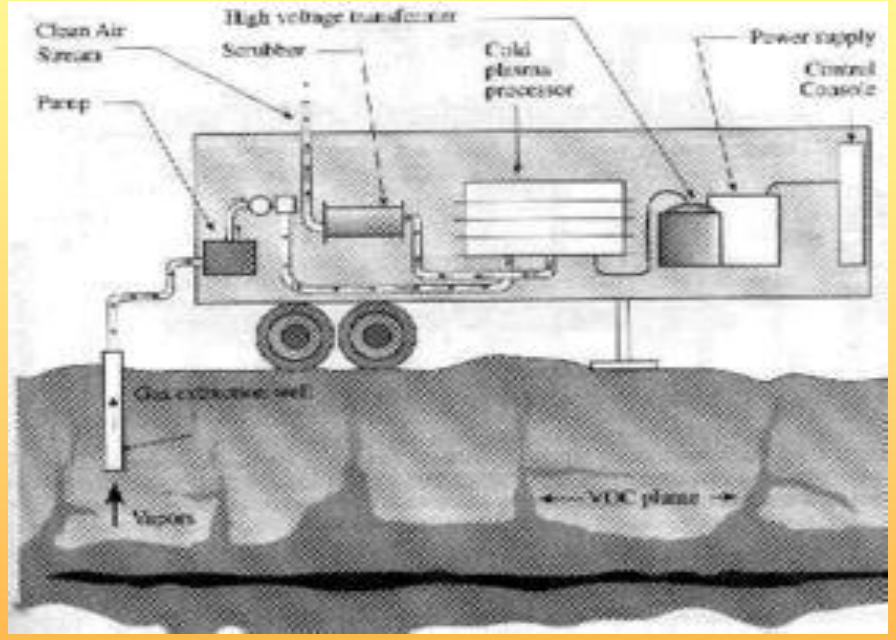
- Computer chips and integrated circuits
- Computer hard drives
- Electronics
- Machine tools
- Medical implants and prosthetics
- Audio and video tapes
- Aircraft and automobile engine parts
- Printing on plastic food containers
- Energy-efficient window coatings
- High-efficiency window coatings
- Safe drinking water
- Voice and data communications components
- Anti-scratch and anti-glare coatings on eyeglasses and other optics

Water Purification Systems

Plasma-based sources can emit intense beams of UV & X ray radiation or electron beams for a variety of environmental applications.

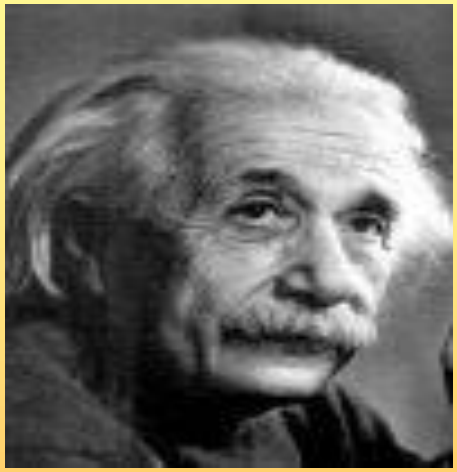
High-temperature plasmas in arc furnaces can convert, in principle, any combination of materials to a vitrified or glassy substance with separation of molten metal. Substantial recycling is made possible with such furnaces and the highly stable, nonleachable, vitrified material can be used in landfills with essentially no environmental impact.

Environmental impact:



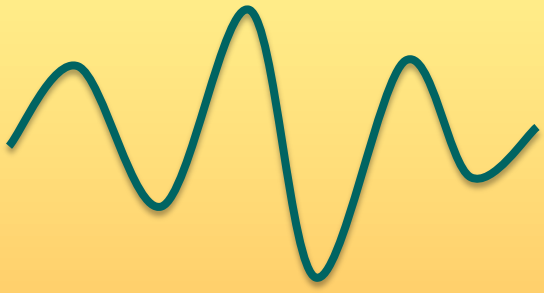
Electron-beam generated plasma reactors can clean up hazardous chemical waste or enable soil remediation. Such systems are highly efficient and reasonably portable, can treat very low concentrations of toxic substances, and can treat a wide range of substances.

Bose and Einstein



- In 1924 an Indian physicist named Bose studied the quantum behaviour of a collection of photons.
- Bose sent his work to Einstein, who realized that it was important.
- Einstein generalized the idea to atoms, considering them as quantum particles with mass.
- Einstein found that when the temperature is high, they behave like ordinary gases.
- However, when the temperature is very low, they will gather together at the lowest quantum state. This is called Bose-Einstein condensation.

Q1: What Is Bose-Einstein Condensation?



De Broglie (1929 Nobel Prize winner) proposed that all matter is composed of waves. Their wavelengths are given by

λ = de Broglie wavelength

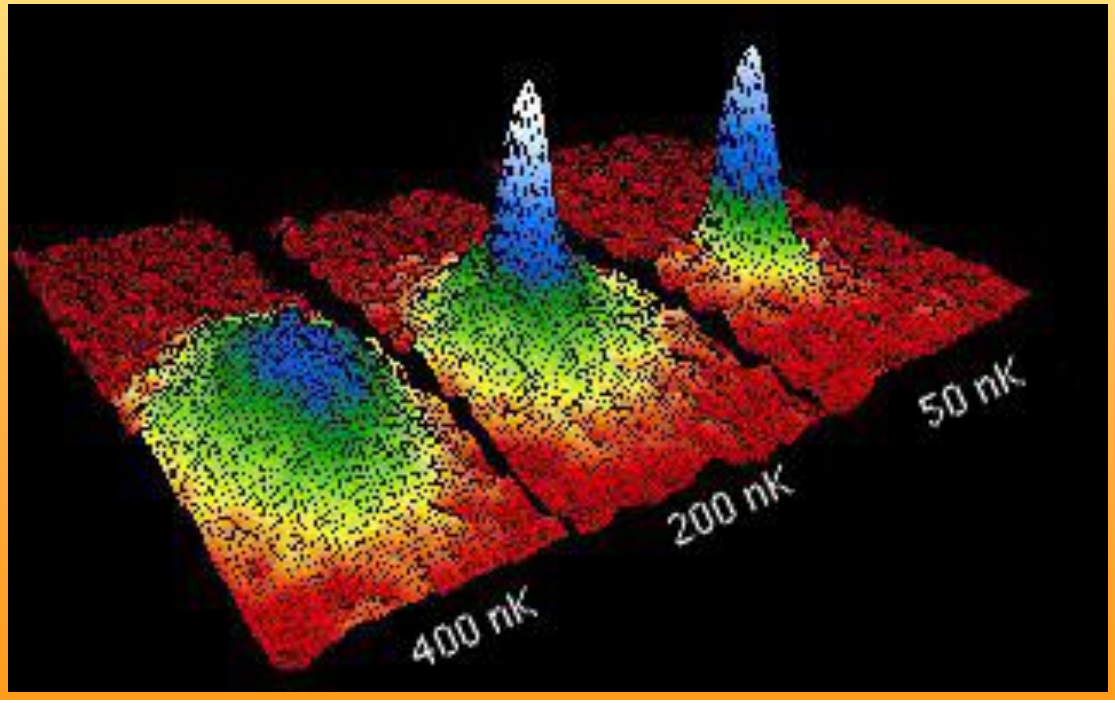
h = Planck's constant

m = mass

v = velocity

Q: What Does a Bose-Einstein Condensate Look Like?

- There is a drop of condensate at the centre.
- The condensate is surrounded by uncondensed gas atoms.
- The combination looks like a cherry with a pit.
- See the movie when it cools from 400 nK to 50 nK (1 nK= 10^{-9}K). :



Thanks…