Matter

Physical and Chemical Changes

Pure Substances

Mixtures

States of Matter

What is matter?

Everything that has mass and volume is called matter.

What kind of changes does matter undergo?

All matter, regardless of state, undergoes physical and chemical changes. These changes can be microscopic or macroscopic.

Properties of Matter

Property	Description	Example
Electrical conductivity	ability to carry electricity	Copper is a good electrical conductor, so it is used in wiring.
Heat conductivity	ability to transfer energy as heat	Aluminum is a good heat conductor, so it is used to make pots and pans.
Density	mass-to-volume ratio of a substance; measure of how tightly matter is "packed"	Lead is a very dense material, so it is used to make sinkers for fishing line.
Melting point	temperature at which a solid changes state to become a liquid	Ice melts to liquid water at the melting point of water.
Boiling point	temperature at which a liquid boils and changes state to become a gas at a given pressure	Liquid water becomes water vapor at the boiling point of water.
Index of refraction	extent to which a given material bends light passing through it	The index of refraction of water tells you how much light slows and bends as it passes through water.
Malleability	ability to be hammered or beaten into thin sheets	Silver is quite malleable, so it is used to make jewelry.
Ductility	ability to be drawn into a thin wire	Tantalum is a ductile metal, so it is used to make fine dental tools.

What is a physical change?

A physical change occurs when the substance changes state but does not change its chemical composition. For example: water freezing into ice, cutting a piece of wood into smaller pieces, etc. The form or appearance has changed, but the properties of that substance are the same (i.e. it has the same melting point, boiling point, chemical composition, etc.)

Characteristics of Physical Changes

- Melting point
- Boiling point
- Vapor pressure
- Color
- State of matter
- Density
- Electrical conductivity
- Solubility
- Adsorption to a surface
- Hardness

What are chemical changes?

A chemical change occurs when a substance changes into something new. This occurs due to heating, chemical reaction, etc. You can tell a chemical change has occurred if the density, melting point or freezing point of the original substance changes. Many common signs of a chemical change can be seen (bubbles forming, mass changed, etc).

Characteristics of Chemical Changes

- Reaction with acids
- Reaction with bases (alkalis)
- Reaction with oxygen (combustion)
- Ability to act as oxidizing agent
- Ability to act as reducing agent
- Reaction with other elements
- Decomposition into simpler substances
- Corrosion

Intensive and Extensive Properties

- Physical and chemical properties may be intensive or extensive.

What are intensive properties?

- Intensive properties such as density, color, and boiling point do not depend on the size of the sample of matter and can be used to identify substances.

What are extensive properties?

- Extensive properties such as mass and volume do depend on the quantity of the sample.

How can we identify physical properties?

- Physical properties are those that we can determine without changing the identity of the substance we are studying.

Examples of physical properties:

- The physical properties of sodium metal can be observed or measured. It is a soft, lustrous, silver-colored metal with a relatively low melting point and low density.
- Hardness, color, melting point and density are all physical properties.

What are chemical properties?

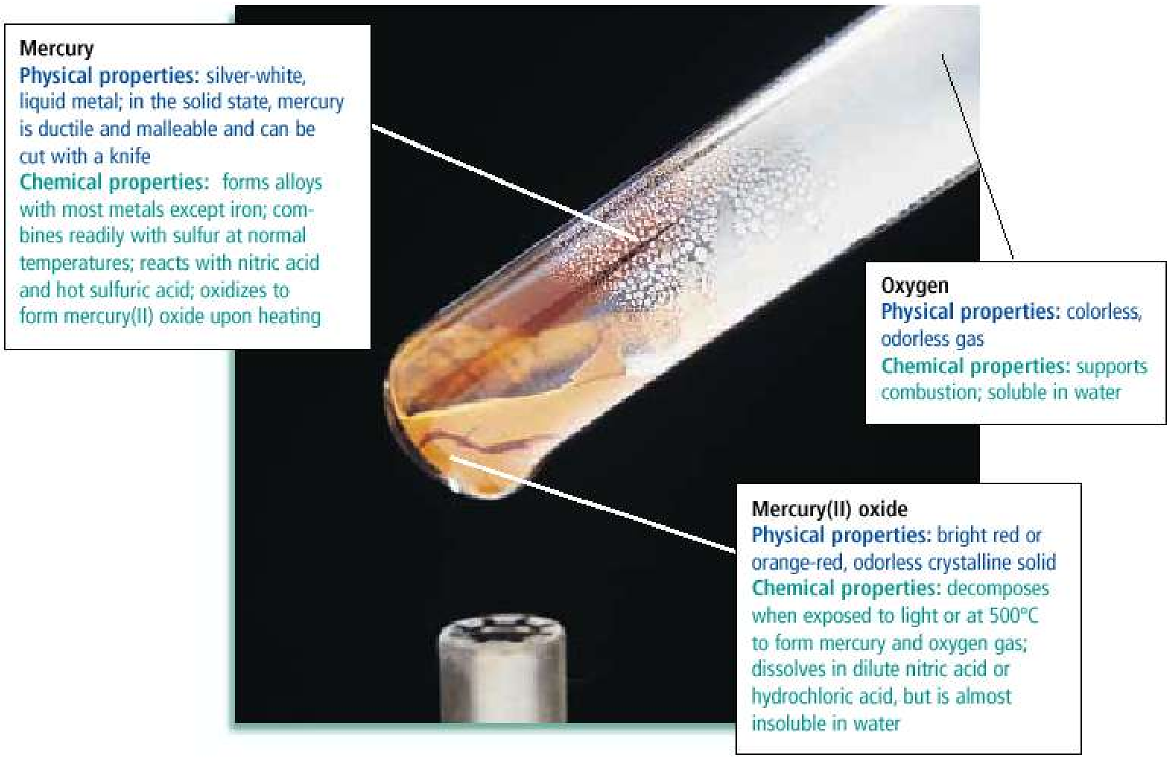
- Chemical properties describe the way a substance can change or react to form other substances. These properties, then, must be determined using a process that changes the identity of the substance of interest.

How can chemical properties be identified?

- One of the chemical properties of alkali metals such as sodium and potassium is that they react with water. To determine this, we would have to combine an alkali metal with water and observe what happens.

- In other words, we have to define chemical properties of a substance by the chemical changes it undergoes.

Comparison of Physical and Chemical Properties



What are "substances"?

Substances can be identified as either an element, compound, or a mixture.

So, what is a substance?

A substance cannot be further broken down or purified by physical means. A substance is matter of a particular kind. Each substance has its own characteristic properties that are different from the set of properties of any other substance.

Characteristics of Pure Substances

- Fixed composition
- Cannot be separated into simpler substances by physical methods (physical changes)
- Can only be changed in identity and properties by chemical methods
- Properties do not vary

What is a pure substance?

Compounds

- Can be decomposed into simpler substances by chemical changes, always in a definite ratio

Elements

- Cannot be decomposed into simpler substances by chemical changes

What is a mixture?

Mixtures are two or more substances that are NOT chemically combined.

Mixtures do not:

- **Have constant boiling points**
- **Have constant melting points**

Characteristics of Mixtures

- Variable composition
- Components retain their characteristic properties
- May be separated into pure substances by physical methods
- Mixtures of different compositions may have widely different properties

Homogenous Mixtures

Homogenous mixtures look the same throughout but can be separated by physical means (dissolution, centrifuge, gravimetric filtering, etc.). Examples: milk, yogurt

Indicators of Homogenous Mixtures

- Have the same composition throughout
- Components are indistinguishable
- May or may not scatter light

Examples: milk, yogurt, etc.

What are solutions?

Solutions are homogenous mixtures that do not scatter light. These mixtures are created when something is completely dissolved in pure water. Therefore, they are easily separated by distillation or evaporation.

Examples: sugar water, salt water

Heterogenous Mixtures

Heterogeneous mixtures are composed of large pieces that are easily separated by physical means (ie. density, polarity, metallic properties).

Indicators of Heterogenous Mixtures

- Do not have same composition throughout
- Components are distinguishable

Examples: fruit salad, vegetable soup, etc.

Law of Conservation of Matter

There is no observable change in the quantity of matter during a chemical reaction or a physical change.

In other words, matter cannot be created nor destroyed. It is just converted from one form to another

What are colloids?

Colloids are solutions. They can be described as a substance trapped inside another substance. They can be identified by their characteristic scattering of light.

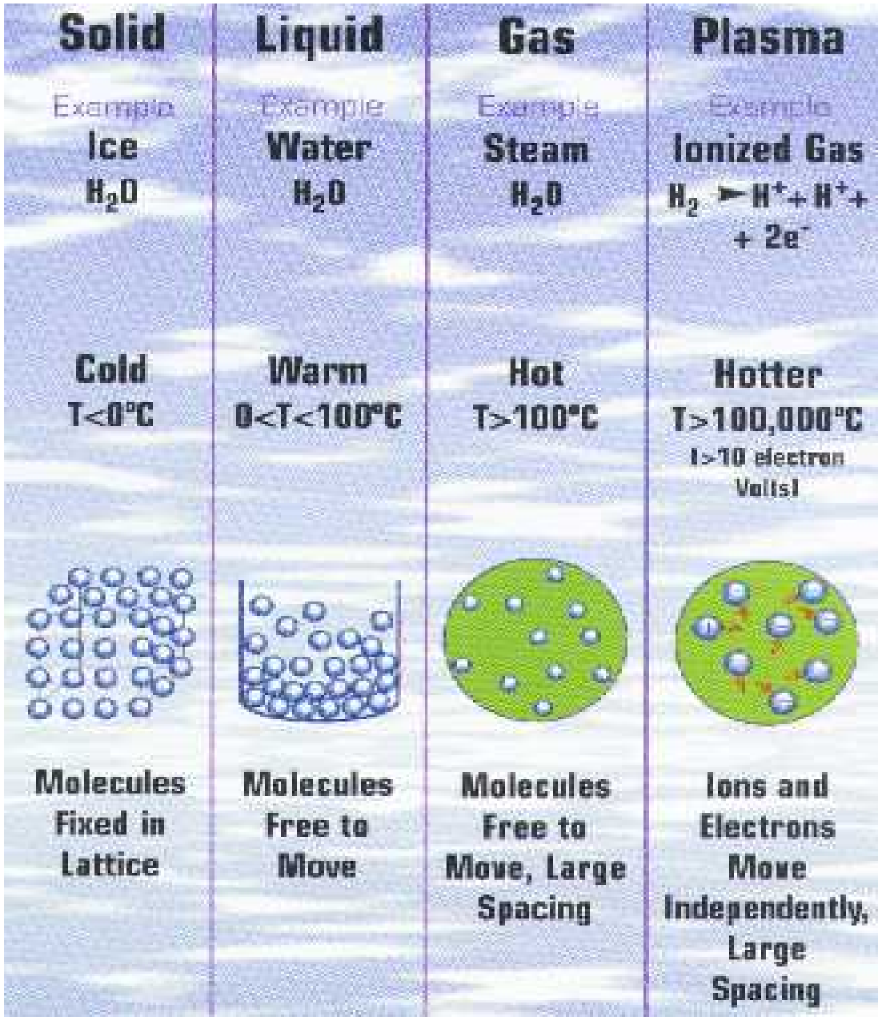
For example: air trapped inside the fat molecules in whipped cream.

States of Matter

(And how the Kinetic Molecular Theory affects each)

- Solids
- Liquids
- Gases
- Plasma
- Others

States of Matter



Solids

- Have a definite shape
- Have a definite volume

Kinetic Molecular Theory

Molecules are held close together and there is very little movement between them.

Liquids

- Have an indefinite shape
- Have a definite volume

Kinetic Molecular Theory:
Atoms and molecules have more space between them than a solid does, but less than a gas (ie. It is more “fluid”.)

Gases

- Have an indefinite shape
- Have an indefinite volume

Kinetic Molecular Theory:

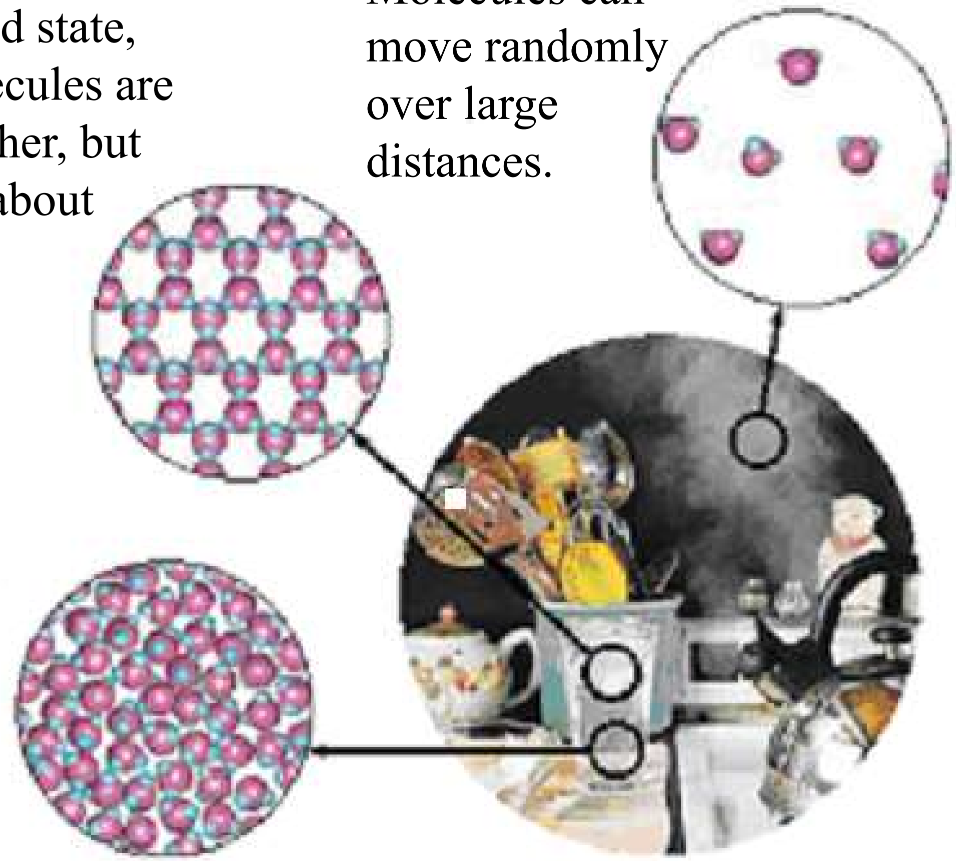
Molecules are moving in random patterns with varying amounts of distance between the particles.

Kinetic Molecular Model of Water

At 100°C, water becomes water vapor, a gas. Molecules can move randomly over large distances.

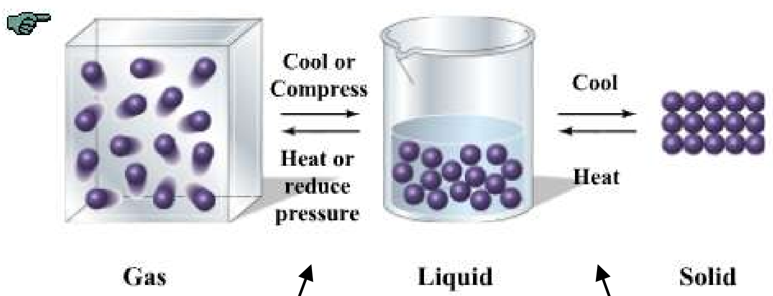
Between 0°C and 100 °C, water is a liquid. In the liquid state, water molecules are close together, but can move about freely.

Below 0°C, water solidifies to become ice. In the solid state, water molecules are held together in a rigid structure.



Changing States

Changing states requires energy in either the form of heat. Changing states may also be due to the change in pressure in a system.



Heat of formation, H_f.

Heat of vaporization, H_v

Plasma

Plasma is by far the most common form of matter. Plasma in the stars and in the tenuous space between them makes up over 99% of the visible universe and perhaps most of that which is not visible.

On earth we live upon an island of "ordinary" matter. The different states of matter generally found on earth are solid, liquid, and gas. We have learned to work, play, and rest using these familiar states of matter. Sir William Crookes, an English physicist, identified a fourth state of matter, now called plasma, in 1879.

Plasma temperatures and densities range from relatively cool and tenuous (like aurora) to very hot and dense (like the central core of a star). Ordinary solids, liquids, and gases are both electrically neutral and too cool or dense to be in a plasma state.

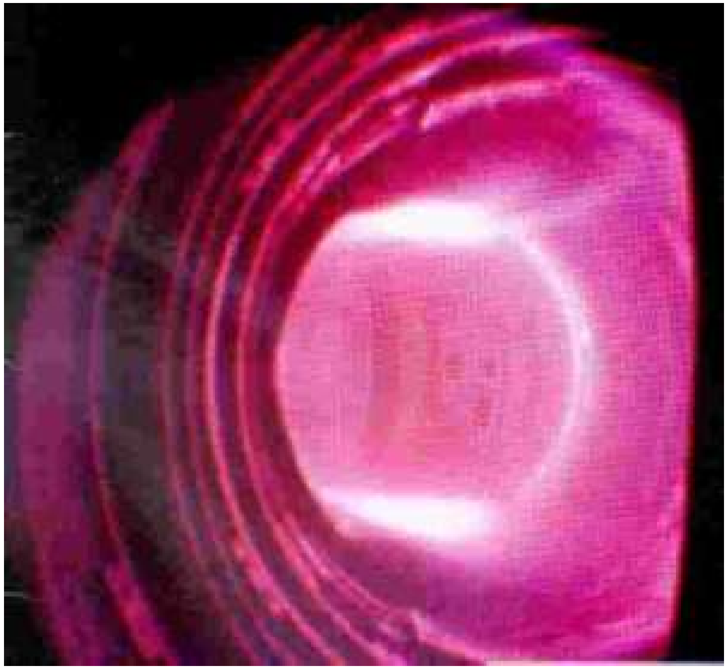
The word "PLASMA" was first applied to ionized gas by Dr. Irving Langmuir, an American chemist and physicist, in 1929.

Star formation in the Eagle Nebula
Space Telescope Science Institute, NASA

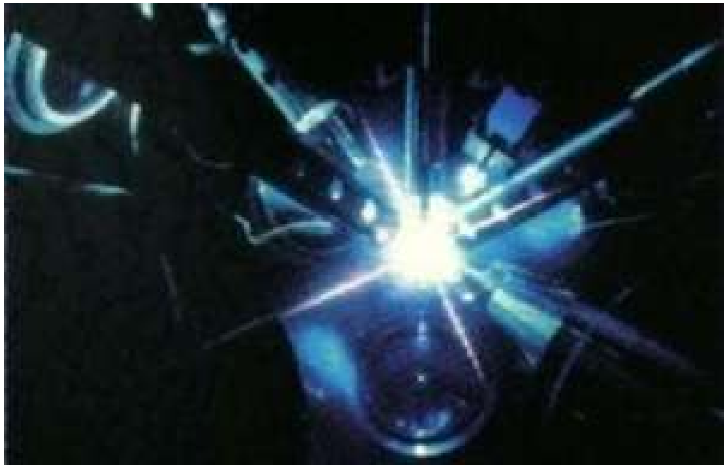
(below)

(Above)

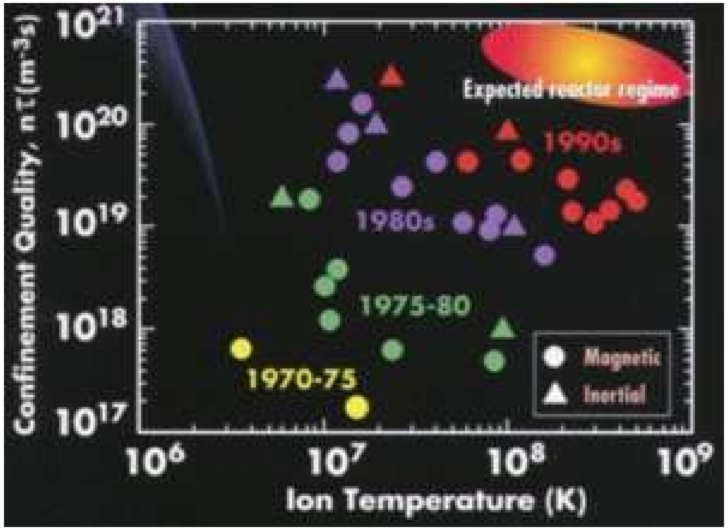
X-ray view of Sun from Yohkoh, ISAS and NASA



Plasma radiation within the Princeton Tokamak during operation.



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

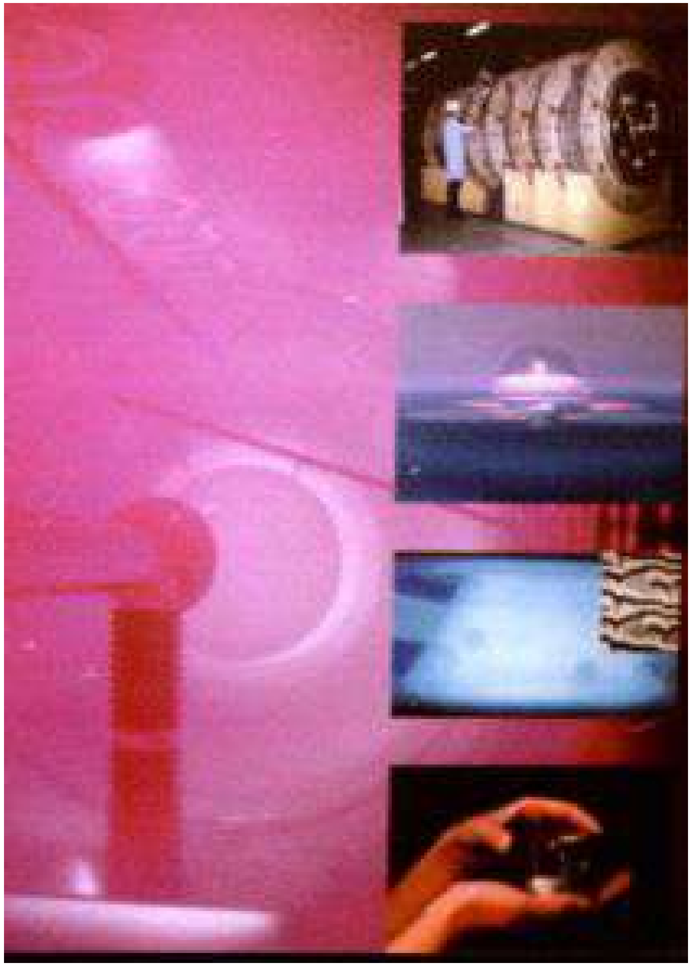


Both inertial and magnetic confinement fusion research have focused on confinement and heating processes with dramatic results. The next stage of operating power reactors will produce about 1 GW of power and operate at 120 million degrees Kelvin.

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.

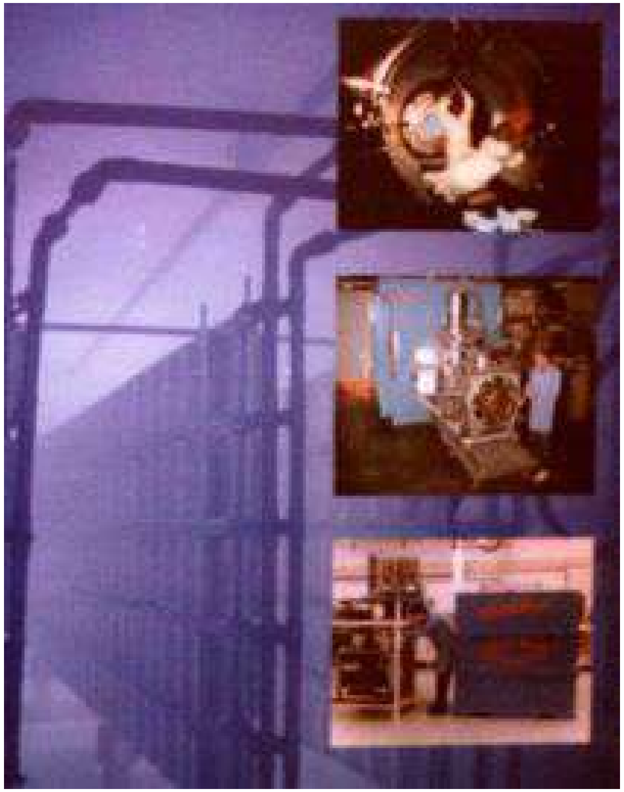
Products manufactured using plasmas impact our daily lives:



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

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



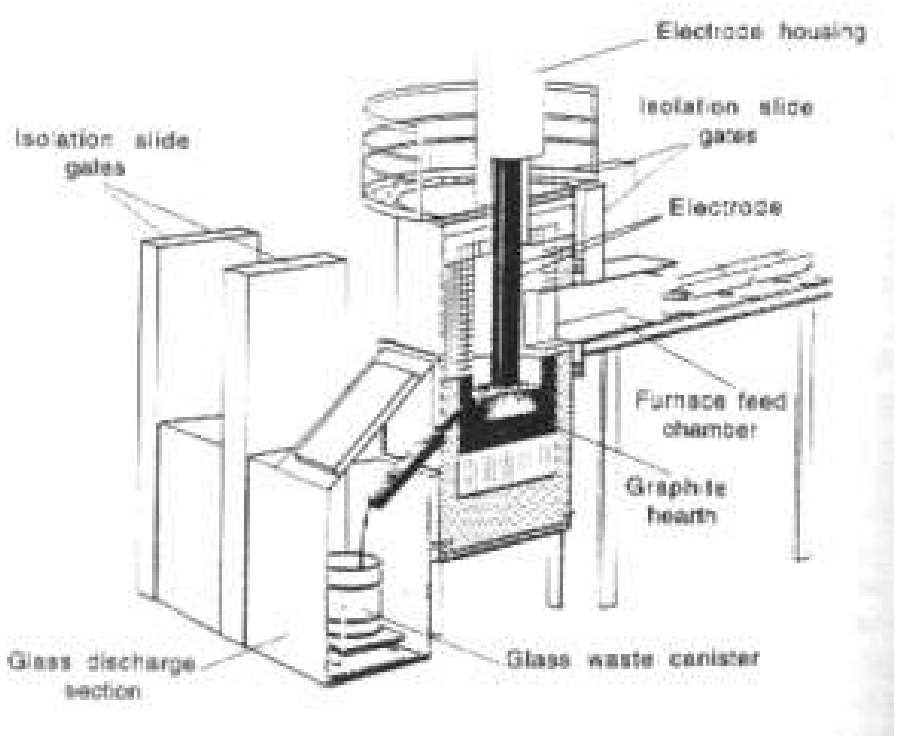
- Waste processing
- Coatings and films
- Electronics
- Computer chips and integrated circuits
- Advanced materials (e.g., ceramics)
- High-efficiency lighting

Water Purification Systems

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

For water sterilization, intense UV emission disables the DNA of microorganisms in the water which then cannot replicate. There is no effect on taste or smell of the water and the technique only takes about 12 seconds.

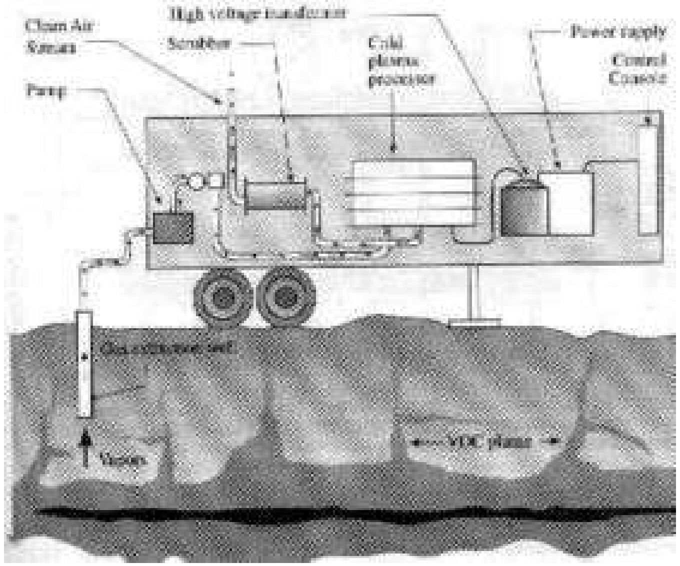
This plasma-based UV method is effective against all water-born bacteria and viruses. Intense UV water purification systems are especially relevant to the needs of developing countries because they can be made simple to use and have low maintenance, high throughput and low cost. Plasma-based UV water treatment systems use about 20,000 times less energy than boiling water!



Environmental impact:

Drastically Reduce Landfill Size

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.