SRIRAM'S IAS

Old Rajinder Nagar
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General Studies
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# GENERAL STUDIES

# CHEMISTRY

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# Contents

# 1. MATTER

## Matter

**Matter** is anything made of atoms and molecules. Matter is anything that has a **mass**. Matter is also related to light and electromagnetic radiation. Even though matter can be found all over the universe, you usually find it in just a few forms. As of 1995, scientists have identified five **states of matter**. They are **solids, liquids, gases, plasmas, and a new one called Bose-Einstein condensates.** The first four have been around a long time. The scientists who worked with the **Bose-Einstein condensate received a Nobel Prize for their work in 1995.** But what makes a state of matter? It's about the physical state of molecules and atoms.

## STATES OF MATTER

There are **five** main states of matter. **Solids, liquids, gases, plasmas, and Bose-Einstein condensates** are all different states of matter. Each of these states is also known as a phase. Elements and compounds can move from one phase to another phase when special **physical forces** are present. **One example** of those forces **is temperature**. The phase or state of matter can change when the temperature changes. Generally, as the temperature rises, matter moves to a more active state.

## PLASMA

Plasmas are a lot like gases, but the atoms are different because they are made up of free electrons and ions of the element. If you have ever heard of the Northern Lights or ball lightning, you might know that those are types of plasmas. It takes a very special environment to keep plasmas going. They are different and unique from the other states of matter.

## FINDING A PLASMA

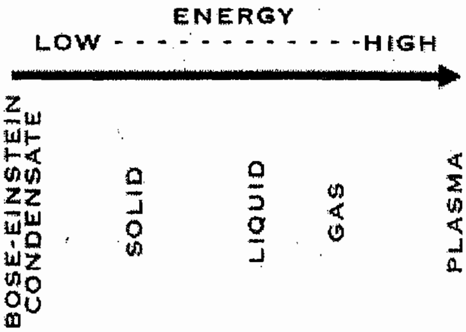
I. Fluorescent light bulb. They are not like regular light bulbs. Inside the long tube is a gas. Electricity flows through the tube when the light is turned on. The electricity acts as that special energy and charges up the gas. This charging and exciting of the atoms creates glowing plasma inside the bulb.

II. Another example of plasma is a neon sign. Just like a fluorescent light, neon signs are glass tubes filled with gas. When the light is turned on, the electricity flows through the tube. The electricity charges the gas, possibly neon, and creates plasma inside of the tube. The plasma glows a special color depending on what kind of gas is inside.

**III.** **Stars** are big balls of gases at really high temperatures. The high temperatures charge up the atoms and create plasma. Stars are another good example of how the temperature of plasmas can be very different.

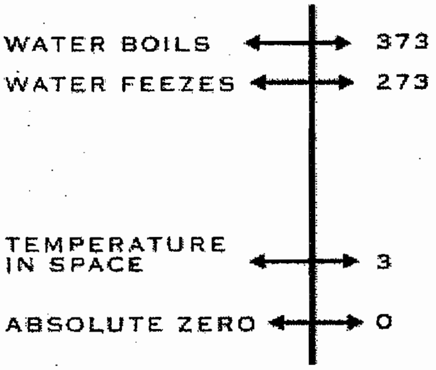
## BOSE-EINSTEIN BASICS

If plasmas are super hot and super excited atoms, the atoms in a Bose-Einstein condensate (BEC) are total opposites. They are super-unexcited and super-cold atoms.



## ABOUT CONDENSATION

Let's explain **condensation** first. Condensation happens when several gas molecules come together and form a liquid. It all happens because of a loss of energy. Gases are really excited atoms. When they lose energy, they slow down and begin to collect. They can collect into one drop. Water condenses on the lid of your pot when you boil water. It cools on the metal and becomes a liquid again. You would then have a condensate.



The BEC happens at super low temperatures. We have talked about temperature scales and Kelvin. At zero Kelvin all molecular motion stops. Scientists have figured out a way to get a temperature only a few billionths of a degree above **absolute zero**. When temperatures get that low, you can create a BEC with a few special elements. Cornell and Weiman did it with Rubidium.

## CLUMPING

A cold ice cube is still a solid. When you get to a temperature near absolute zero something special happens. Atoms begin to clump. The whole process happens at temperatures within a few billionths of a degree so you won't see this at home. The result of this **clumping** is the BEC. A group of atoms takes up the same place, creating a "super atom." There are no longer thousands of separate atoms. They all take on the same qualities and for our purposes become one blob.

## SOLUTIONS AND MIXTURES

Solutions are groups of molecules that are mixed up in a completely even distribution. Scientists say that solutions are **homogenous** systems. Other types of mixtures can have a little higher concentration on one side of the liquid when compared to the other side. Solutions have an even concentration throughout the system. An example: Sugar in water vs. Sand in water. Sugar dissolves and is spread throughout the glass of water. The sand sinks to the bottom. The sugar-water could be considered a solution. The sand-water is a mixture.

A simple solution is basically two substances that are going to be combined. One of them is called the **solute**. A solute is the substance to be dissolved (sugar). The other is a **solvent**. The solvent is the one doing the dissolving (water). As a rule of thumb, there is usually more solvent than solute.

## FACTORS AFFECTING SOLUTIONS

All sorts of things can change the concentrations of substances in solution.. Solubility is the ability of the solvent (water) to dissolve the solute (sugar). Usually when you **heat** up a solvent, it can dissolve more solid materials (sugar) and less gas (carbon dioxide). **Next** on the list of factors is **pressure**. When you increase the surrounding pressure, you can usually dissolve more gases in the liquid. Think about your soda can. They are able to keep the fizz inside because the contents of the can are under higher pressure. Last is the **structure** of the substances. Some things dissolve easier in one kind of substance than another. Sugar dissolves easily in water; oil does not. Water has a low solubility when it comes to oil.

## AMALGAMS

Amalgams are a special type of alloy. We like them because we think mercury (Hg) is a cool element. You might know **mercury** as "quicksilver" or the metal that is liquid at room temperature. Anyway, **amalgams are alloys** that combine mercury and other metals in the periodic table. The most obvious place you may have seen amalgams is in old dental work. The fillings in the mouths of your grandparents may have been amalgams. We already talked about mercury's being a liquid at room temperature. That physical trait was used when they made fillings. Let's say you have an amalgam of mercury (Hg) and silver (Ag). When it is created, it is very soft. As time passes, the mercury leaves the amalgam and the silver remains. The silver that is left is very hard.

**NOTE**: Mercury (Hg) is very poisonous. You shouldn't even touch it because it will seep into your skin. Dentists don't usually use amalgams with mercury anymore because it may have slowly poisoned people and gotten them sick.

## EMULSIONS

Let's finish up with a little information on emulsions. These special **colloids** (another type of mixture) have a mixture of oils and waters. Think about a bottle of salad dressing. Before you mix it, there are two separate layers of liquids. When you shake the bottle, you create an emulsion. As time passes, the oil and water will separate to their original states.

## ISOTOPES

We have already learned that ions are atoms that are either missing or have extra electrons. Let's say an atom is missing a neutron or has an extra **neutron**. That type of atom is called an **isotope**. An atom is still the same element if it is missing

an electron. The same goes for isotopes. They are still the same element. They are just a little different from every other atom of the same element.
There are a lot of carbon atoms in the universe. The normal ones are carbon-12. Those atoms have 6 neutrons. There are a few straggler atoms that don't have 6. Those odd ones may have 7 or even 8 neutrons. Carbon-14 actually has 8 neutrons (2 extra). C-14 is considered an isotope of the element carbon.

## ATOMIC MASS

**Atomic masses** are calculated by figuring out how many atoms of each type are out there in the universe. For carbon, there are a lot of C-12, a couple C-13, and a few C-14 atoms. When you average out all of the masses, you get a number that is a little bit higher than 12 (the weight of a C-12 atom). The mass for element is actually 12.011. Since you never really know which C atom you are using in calculations, you should use the mass of an average C atom.

## RETURNING TO NORMAL

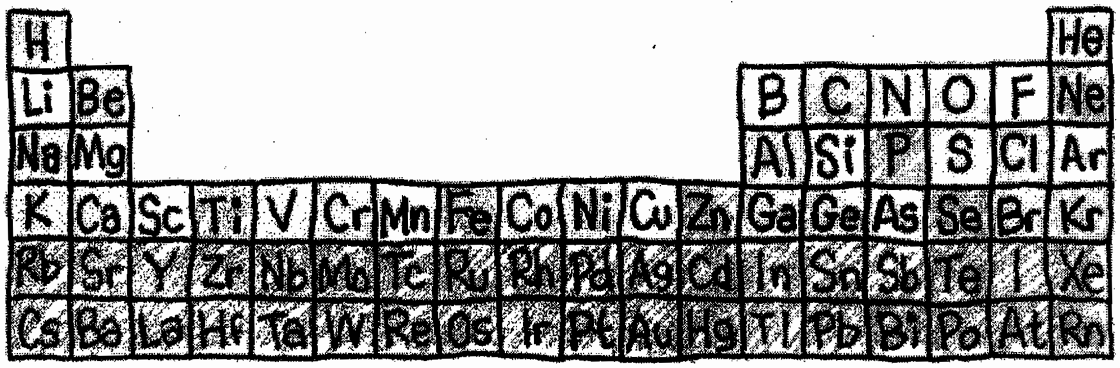
If we look at the C-14 atom one more time we can see that C-14 does not last forever. There is a point where **it loses those extra neutrons** and becomes C-12. That loss of the neutrons is called **radioactive decay**. That decay happens regularly like a clock. For carbon, the decay happens in a couple of thousand years.

## NEUTRONS

Neutrons are the particles on an atom that have a neutral charge. So if an atom has equal numbers of electrons and protons, the charges cancel each other out and the atom has a neutral charge. You could add a thousand neutrons into the mix and the charge will not change. However, if you add a thousand neutrons you will be creating one super-**radioactive** atom. Neutrons play a major role in the mass and radioactive properties of atoms. You may have just read about isotopes. **Isotopes** are created when you change the normal number of neutrons in an atom. You know that neutrons are found in the nucleus of an atom. During **radioactive decay**, they may be knocked out of there. But under normal conditions, protons and neutrons stick together in the nucleus. Their numbers are able to change the mass of atoms because they weigh about as much as a proton and electron together.

**ONE SPECIAL ELEMENT**A normal hydrogen (H) atom does not have any neutrons in its tiny nucleus. You can take away the electron and make an ion, but you can't take away any neutrons

# 2. Periodic Table and the Elements



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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | | | | | | | | | | | | | | | | | He |
| Li | Be | | | | | | | | | | | B | C | N | O | F | Ne |
| Na | Mg | | | | | | | | | | | Al | Si | P | S | Cl | Ar |
| K | Ca | Sc | Ti | V | Cr | Mn | Fe | Co | Ni | Cu | Zn | Ga | Ge | As | Se | Br | Kr |
| Rb | Sr | Y | Zr | Nb | Mo | Tc | Ru | Rh | Pd | Ag | Cd | In | Sn | Sb | Te | I | Xe |
| Cs | Ba | La | Hf | Ta | W | Re | Os | Ir | Pt | Au | Hg | Tl | Pb | Bi | Po | At | Rn |

Up to this point in time we have discovered/created over 100. While there may be more out there to discover, the basic elements remain the same. Iron (Fe) atoms found on Earth are identical to iron atoms found on meteorites. The iron atoms on Mars that make the soil red are the same too.

**Elements as Building Blocks**

The **periodic table** is organized like a big grid. The **elements** are placed in specific places because of the way they look and act. If you have ever looked at a grid, you know that there are rows (left to right) and columns (up and down). The periodic table has rows and columns, too, and they each mean something different.

**Periods**

Even though they skip some squares in between, all of the rows go left to right. When you look at a periodic table, each of the rows is considered to be a different **period**. In the periodic table, elements have something in common if they are in the same row. All of the elements in a period have the same number of atomic orbitals. Every element in the top row (the first period) has one orbital for its electrons. All of the elements in the second row (the second period) have two orbitals for their electrons. It goes down the periodic table like that. At this time, the maximum number of electron orbitals or electron shells for any element is seven.

**Groups**

When a column goes from top to bottom, it's called a **group**. The elements in a group have the same number of electrons in their outer orbital. Every element in the first column (group one) has one electron in its outer shell. Every element on the second column (group two) has two electrons in the outer shell. As you keep counting the columns, you'll know how many electrons are in the outer shell. There are some exceptions to the order when you look at the transition elements.

## Two at the Top

Hydrogen (H) and helium (He) are special elements. Hydrogen can have the talents and electrons of two groups, one and seven. To scientists, hydrogen is sometimes missing an electron, and sometimes it has an extra. Helium is different from all of the other elements. It can only have two electrons in its outer shell. Even though it only has two, it is still grouped with elements that have eight (inert gases).

The elements in the center section are called transition elements. They have special electron rules.

## HALOGENS ON THE RIGHT

In the second column from the right side of the periodic table, you will find Group Seventeen (Group XVII). This column is the home of the **halogen** family of elements. Who is in this family? The elements included are Fluorine (F), Chlorine (Cl), Bromine (Br), Iodine (I), and Astatine (At).

## WHAT MAKES THEM SIMILAR?

When you look at our descriptions of the elements fluorine (F) and chlorine (Cl) you will see that they both have seven electrons in their outer shell. That seven-electron idea applies to all of the halogens. They are all just one electron shy of having full shells. Because they are so close to being happy, they have the trait of combining with many different elements. You will often find them bonding with metals and elements from Group One of the periodic table.

Not all halogens react with the same intensity. Fluorine is actually the most reactive and combines all of the time. As you move down the column, reactivity decreases.

## HALIDE

The elements we are talking about in this section are called halogens. When a halogen combines with another element, the resulting compound is called a **halide**. One of the best examples of a halide is sodium chloride (NaCl). Don't think that the halogens always make ionic compounds. Many halides of the world are made with covalent compounds.

## THE NOBLE INERT GASES

We love the inert gases. Some scientists used to call them the **noble gases**. These gases are another family of elements, and all of them are located in the far right column of the periodic table. The far right is also known as Group Zero (Group 0) or Group Eighteen (Group XVIII). This family has the happiest elements of all.

Using the **Bohr** description of electron shells, happy atoms have full shells. All of the inert gases have full outer shells with eight electrons. That's not totally correct.

At the top of the inert gases is little helium (He) with a shell that is full with two electrons. The fact that their outer shells are full means they are quite happy not reacting with other elements. In fact, they rarely combine with other elements. That nonreactivity is why they are called inert.

All of the elements in Group Zero are inert gases. The list includes Helium (He), Neon (Ne), Argon (Ar), Krypton (Kr), Xenon (Xe), and Radon (Rn). Don't think that because these elements don't like to react, we don't use them. You will find inert gases all over our world. **Neon** is used in **advertising signs**. **Argon** is used in **light bulbs. Helium** is used to **cool things and in balloons. Xenon** is used in **headlights for new cars**. When you move down the periodic table, as the atomic numbers increase, the elements become rarer. They are not just rare in nature but rare as useful elements, too.

As of about 40 years ago, scientists have been able to make some compounds with inert gases. Some have been used in compounds to make **explosives** and other just form compounds in a lab. **The thing to remember is that they were forced.** When going about their natural lives, you will never (never say never because there may be an exception) find the inert gases bonded with other elements.

## METAL BASICS

We will have an overview of **metals**. Almost 75% of all elements are classified as metals. They are not all like silver (Ag), gold (Au), or platinum (Pt). Those are the very cool and shiny ones. There are other metals like potassium (K) and iridium (Ir) that you might not think about right away.

## MANY KINDS OF METALS:

Actinide Metals, Lanthanide Metals, Alkali Metals, Alkaline-Earth Metals, Noble Metals, Rare Metals, Rare-Earth Metals, and Transition Metals. Lucky for you the periodic table is excellent at organizing elements, and you will find each of these groups in specific areas of the periodic table.

## IDENTIFICATION of METAL

**Conduction**: Metals are good at conducting electricity. Silver (Ag) and copper (Cu) are some of the most efficient metals and are often used in electronics.
**Reactivity**: Metals are very reactive, some more than others, but most form compounds with other elements quite easily. Sodium (Na) and potassium (K) are some of the most reactive metals.
**Chemical**: Metals usually make positive ions when the compounds are dissolved in solution. Also, their metallic oxides make hydroxides (bases) (OH-) and not acids when in solution. Think about this example. Sodium chloride (NaCl), when dissolved in water, breaks apart into sodium (Na+) and chlorine (Cl-). See that

sodium is the positive ion? Sodium is the metal. It works that way for other metals. Potassium chlorine (KCl) works the same way.
**Alloys**: Metals are easily combined. Mixtures of many elements are called alloys. Examples of alloys are steel and bronze.

## ALKALI METALS TO THE LEFT

Let's start on the left side of the periodic table. When looking for families, the first one you will find is the **alkali metal** family of elements. They are also known as the alkaline metals. You should remember that there is a separate group called the alkaline earth metals in Group Two. They are a very different family even though they have a similar name. That far left column is Group One (Group I). When we talk about the groups of the periodic table, scientists use Roman numerals when they write them out.

## A FAMILY PORTRAIT

Who's in the family? Starting at the top we find hydrogen (H). But wait. That element is NOT in the family. When we told you about families, we said that they were groups of elements that react in similar ways. Hydrogen is a very special element of the periodic table and doesn't belong to any family. While hydrogen sits in Group I, it is NOT an alkali metal

## FAMILY BONDING

Now that we've covered that exception, the members of the family include: Lithium (Li), Sodium (Na), Potassium (K), Rubidium (Rb), Cesium (Cs) and Francium (Fr). As with all families, these elements share traits. They are very **reactive**. Why? They all have one electron in their outer shell. That's one electron away from being happy (full shells). When you are that close to having a full shell, you want to bond with other elements and lose that electron. An increased desire to bond means you are more reactive. In fact, when you put some of these pure elements in water, they will cause huge explosions. The alkali metals are also metals. That seems obvious from the name. Often, in chemistry, characteristics are assigned by the way elements look. You will find that the alkali group is shiny and light in weight. Their light weight and physical properties separate them from other metals.

## GROUP TWO

The **alkaline earth metals** is in Group II. This is the second most **reactive** family of elements in the periodic table. **Did you know why they are called alkaline? When these compounds are mixed in solutions, they are likely to form solutions with a pH greater than 7. Those pH levels are defined as 'basic' or 'alkaline' solutions.**

Who's in the family?

The members of the alkaline earth metals include: beryllium (Be), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba) and radium (Ra). As with all families, these elements share traits. While not as reactive as the alkali metals, this family knows how to make bonds very easily. Each of them has two electrons in their outer shells. They are ready to give up those two electrons in **electrovalent bonds**. Sometimes you will see them with two halogen atoms ($BeF_2$) and sometimes they might form a double bond (CaO). It's all about giving up those electrons to have a full outer shell.

As you get to the bottom of the list, you will find the radioactive radium (Ra). While radium is not found around your house anymore, **it used to be used in glow-in-the-dark paints**. The other elements are found in many items including **fireworks, batteries, flashbulbs, and special alloys**. The lighter alkaline earth metals such as magnesium and calcium are very important in animal and plant **physiology**. We all know that calcium helps build our bones.

## TRANSITION METALS

Lets start off by telling you that there are a lot of elements that are considered **transition metals**.

### Which metals are the transition metals?

21 (Scandium) through 29 (Copper)
39 (Yttrium) through 47 (Silver)
57 (Lanthanum) through 79 (Gold)
89 (Actinium) and all higher numbers.

## WHAT MAKES THEM SO SPECIAL?

It all has to do with their shells/**orbitals**.. Transition metals are good examples of advanced shell ideas. They have a lot of electrons and distribute them in different ways.

Transition metals are able to put more than eight **electrons** in the shell that is one in from the outermost shell. Think about argon (Ar). It has 18 electrons set up in a 2-8-8 order. Scandium is only 3 spots away with 21 electrons, but it has a configuration of 2-8-9-2. This is where it starts. This is the point in the periodic table where you can place more than 8 electrons in a shell.

The transition metals are able to put up to 32 electrons in their second to last shell. Something like gold (Au) has an organization of 2-8-18-32-18-1. Of course, there are still some rules. No shell can have more than 32 electrons. It's usually 18 or 32 for the maximum number of electrons.

## ONE MORE THING......

Most elements can only use electrons from their outer orbital to bond with other elements. Transition metals can use the two outermost shells/orbitals to bond with other elements. It's a chemical trait that allows them to bond with many elements in a variety of shapes. Why can they do that?

As you learn more, you will discover that most transition elements actually have two shells that are not happy. Whenever you have a shell that is not happy, its electrons can bond with other elements. Example: Molybdenum (Mo) with 42 electrons. The configuration is 2-8-18-13-1. The shells with 13 and 1 are not happy. Those two orbitals can use the electrons to bond with other atoms.

## LANTHANIDE SERIES OF METALS

When you look at the periodic table you will see two rows that kind of sit off to the bottom. One of those rows is called the Lanthanide series. There are a bunch of names that you may hear that describe these 15 elements. Some say Lanthanide, some say **rare-earth** and some say **inner-transition** elements. No matter what you choose everyone will know what you mean if you say Lanthanide.

### THE FAMILY

Fifteen elements that start with lanthanum (La) at atomic number 57 and finishing up with lutetium (Lu) at number 71.

## ACTINIDE SERIES OF METALS

There are two rows under the table. The Lanthanide and Actinide series. The Lanthanide series can be found naturally on Earth. Only one element in the series is **radioactive**. The Actinide series is much different. They are all radioactive and some are not found in nature. Some of the elements with higher atomic numbers have only been made in labs. There are special laboratories across the world that specialize in experimenting on elements. Some of these **particle accelerators** have pounded atomic particles into elements with lower atomic numbers. The buildup of additional parts creates short-lived elements.

### THE FAMILY

Fifteen elements that start with actinium (Ac) at atomic number 89 and finishing up with lawrencium (Lr) at number 103.

# 3. SOME COMMON ELEMENTS

## HYDROGEN

Hydrogen is the first element in the **periodic table** and the most basic and common of all elements in the universe. Over ninety percent of all the atoms in the universe are hydrogen atoms and they are the lightest of all **elements**.

**where we find hydrogen :**

I. **THE SUN**

II. **WELDING AND BLOWTORCHES**

III. **PLANTS AND SUGARS**
Hydrogen is in all plants. There are sugars all throughout plants and there is hydrogen in sugar. That's why animals eat plants... For the sugar and the energy.

IV. **CRYOGENICS**
Hydrogen is used in something called cryogenics. Cryogenics is a process when scientists freeze things. When hydrogen is in a liquid form it is very, very cold. Scientists use this cold hydrogen to freeze things very quickly.

## HELIUM

Named after the **Sun** and the Latin word "helios". Even when first discovered and identified, scientists knew there were large amounts of helium in the Sun.

Similar to hydrogen, helium is usually found as a gas and has no color or smell. Helium is found everywhere in the universe and is the **second** most common element, just like hydrogen.

**we find it in :**

I. **BALLOONS** t.
II. **THE SUN**
Helium is in the Sun. If you were to look at everything in the sun you would discover large amounts of helium. The Sun is a really big ball of gases and all those gases are on fire. One of the results of that fire is helium.
III. **COMPRESSED AIR TANKS**
Whenever you see a SCUBA diver in the water, you should know that he has some helium in his air tank. Divers combine helium and regular air in

those tanks at very high pressures. When they go deep in the water the helium makes it easier for them to breathe.

IV. **LASERS**
Sometimes helium is used in lasers. It's a good element to use **because it is non-reactive**. Even at really high temperatures helium will not bond with other elements.

V. **COOLANTS**
Nuclear Reactors use helium as coolant. When helium is in a liquid form it is a very low temperature. Because a reactor can be very hot, scientists need something very cool to keep everything under control.

VI. **ROCKET FUEL**
A rocket into space is using helium. When we launch rockets into space, they sometimes use helium to cool the engines.

VII. **BLIMPS**
When you go to a football game you might see a blimp. That blimp is using helium to stay up in the air. Helium is lighter than regular air so it helps things float. A blimp is filled with helium and floats for a very long time. They use propellers to move around.

# LITHIUM

This is the first **metal** encountered in the periodic table and it is a silvery colored solid when purified. One thing to remember is that lithium is never found alone in nature. It is always bonded to other elements.

**We find it in :**

I. **BATTERIES**

II. **MEDICINE**
When you take lithium it acts on nerves in your brain and changes the way you act.

III. **ROCKS AND SOIL**

IV. **HOT SPRINGS**

V. **NUCLEAR REACTORS**
Lithium is a very important element in Nuclear Reactors. It is a very light element which makes it important to scientists. It is used in many chemical reactions and processes.

VI. AIR CONDITIONERS

# BERYLLIUM

Purified beryllium is a grey, hard, steel-like **metal** that is very poisonous. Another of its characteristics is its non-magnetic quality. Non-magnetic metals are very useful in electronics.. You can never find beryllium alone. It is always combined with other **elements** when found on Earth.

**We find it in :**

I. **NUCLEAR REACTORS**

II. **EMERALDS AND GEMS**
Beryllium is in emeralds. It is also in another gem called aquamarine. Beryllium is only one of many elements inside an emerald

III. **MACHINE PARTS AND SPRINGS**
Beryllium is a very light metal. It is also used with other metals to make strong pieces for machines. Beryllium is often used in springs. With beryllium the springs become lighter and stronger.

IV. **SATELLITES**
Scientists use beryllium in satellites because it is so light. Satellites need to be light in weight because it is easier to get them into space.

V. **SPACECRAFT**

# BORON

It's a tough **element** to isolate because it is never found alone in nature. Boron is always part of larger compounds in the real world. When you do find it... It will either be in a brown powder or a crystal. As more tests were completed, it was discovered that boron was also a very **poor conductor** of electricity.

**USED IN**

I. CERAMICS

II. SOAPS

III. GLASS MANUFACTURING

IV. FLARE GUNS

V. FIBERGLASS
and cars instead of metal. Next time you see speedboats racing or someone surfing you will know that those things are made out of fiberglass.

# CARBON

This is the magic **element** for everything on Earth. All life on Earth depends on carbon. It is in nearly every biological compound that makes up our bodies, systems, organs, cells, and organelles. When you breathe out, it's carbon combined with oxygen. Carbon has been known and used for thousands of years.
Carbon is the sixth element in the **periodic table**. Located between boron and nitrogen, it is a very stable element. Because it is stable, it can be found in many naturally occurring compounds and by itself. Scientists describe the three states of carbon as **diamond**, **amorphous**, and **graphite**.
It was never really discovered. Ancient people knew of the black soot left over after a fire. That was carbon.

**OCCURANCE:**

I. **PLANTS**

II. **DIAMONDS**

III. **CHARCOAL**

IV. **GRAPHITE**
V. **PETROLEUM PRODUCTS**
VI. **PLASTICS**

# NITROGEN

The second of the big three elements in row two is nitrogen. Nitrogen is the seventh element of the **periodic table** located between carbon and oxygen. Along with carbon and oxygen, it is essential in most of the compounds that allow life to exist. Eighty percent of Earth's **atmosphere** is made of nitrogen gas.
Nitrogen is a clear gas that has no smell when it is in its pure form. It is not very reactive when it is in a pure molecule, but it can create very **reactive** compounds when combined with other elements including hydrogen (ammonia).

**USED IN :**

I. **AMMONIA**
Nitrogen is in something called ammonia. Ammonia is used as a disinfectant because it kills bacteria and fungus. It is very poisonous.

II. **STEEL MANUFACTURING**
Nitrogen is used in the processes to make steel. Many other elements are

also used to make steel. It is not an easy thing to do. Scientists use nitrogen in many difficult processes.

III. **COOLANT**
Nitrogen is used as a refrigerant. When it is in a liquid form nitrogen is very cold. Scientists use that cold nitrogen to keep things frozen.

IV. **OIL AND PETROLEUM REFINERIES**
Nitrogen is used to refine oil. Scientists get oil out of the ground but it can't be made into gasoline without nitrogen

V. **SOIL NUTRIENTS.**

# OXYGEN

oxygen makes over twenty percent of the Earth's **atmosphere**. We are the only planet in the solar system with enough oxygen available to let us survive.
Oxygen is the eighth element of the **periodic table** and found in the second row (period). Alone, oxygen is a colorless and odorless compound that is a gas at room temperature. Oxygen molecules are not the only form of oxygen in the atmosphere; you will also find oxygen as **ozone** and **carbon dioxide.**

**Find it in**:

I. OZONE LAYER
II. PLASTICS
Oxygen is inside things made out of plastic
III. BREATHABLE AIR.
IV. ROCKS AND SOILS
V. WATER

# FLUORINE

Located in the second period of the table (row 2), fluorine is the first **element** in the family of **halogen** gases. Fluorine is a yellowish gas at room temperature and is very dangerous. Fluorine is both poisonous and very **reactive** with other elements. It can combine with nearly any element on Earth.

**Find it in**:

I. **ROCKET FUEL.**
II. **URANIUM PURIFICATION**
III. **REFRIGERATION FLUIDS**
There is something that helps your refrigerator work. It's called **Freon** One of the main elements in Freon is fluorine.
IV. **TOOTHPASTE**
V. **ETCHING SOLUTIONS**
Artists use fluorine when they etch glass

# NEON

Neon is one of the fun elements. The first thing most people think of is a big neon sign. The gas is placed in glass tubes and an electric **current** is sent through the gas. When excited, neon enters a plasma state and glows red. Neon is the tenth element of the **periodic table** and the second of the **inert** or **noble** gases. The element is incredibly **non-reactive** because of its electron configuration.
When you find it, neon is a clear, odorless gas that isn't very exciting without **electricity**.

**Find it in**:

TV TUBES

I. CRYOGENICS
Scientists use neon in something called cryogenics. **Cryogenics is when scientists freeze things very quickly.**.

II. SIGNS
Neon is a gas. Scientists take neon and pump it into glass tubes.

III. LASERS
Neon is also used in lasers. Right now lasers aren't in guns to blow things up. Scientists use those lasers in experiments. Doctors also use them to do surgery. When you see a doctor using a red light on someone... It might be a laser!

# SODIUM

Being in the first column, sodium is a member of the **alkali metal** family with potassium and lithium.
When you purify sodium, you actually wind up with a silvery bright metal that is quite soft and malleable. Sodium is one of the few metals that will float when it is placed in water. Its a**tomic mass** is less that water's atomic mass.
**Find it in**:

**I. GLASS MANUFACTURING**

**II. PAPER MANUFACTURING**

**III. TABLE SALT**

IV. DEVELOPING SOLUTION
When your send their pictures to be developed the company uses different liquids to make the pictures appear. Sodium is in some of those solutions.

V. FERTILIZER

# MAGNESIUM

As we move across the third row of the **periodic table**, we find magnesium in the number two position. Humans have used magnesium, like many other simple **elements**, for hundreds of years.

Located in the second column of the periodic table, magnesium is in the family of **alkali earth metals** with calcium and beryllium. When purified, magnesium is a very light and silvery metal. Its lightness makes it perfect for use in many other metal alloys to increase strength without increasing the weight of the structure.

Magnesium is also an important element in our diet. Both we and plants need magnesium to live and be healthy. It is called a **trace metal**.

**Find it in**:

I. **MEDICINE**
   Scientist use magnesium in medicine.
II. **CHLOROPHYLL MOLECULES**

III. **CAMERA FLASH BULBS**

# ALUMINUM

The metal is a silvery white color and very **reflective**. Another great trait of aluminum is that it is not toxic.

The thirteenth element in the **periodic table** has many other uses. When aluminum is combined with other metals it becomes very strong. It is so strong that engineers use it to build planes and ships

**Find it in:**

I. **SERVING UTENSILS**
II. **RUBIES AND GEMS**
   There is a very special stone called a ruby. It is found in all sorts of jewelry. It has a very deep red color. There are aluminum atoms inside of all rubies.
III. **ALUMINUM FOIL**
IV. **POWER TRANSMISSION LINES**
V. **AIRPLANES AND HELICOPTERS**
VI. **SAPPHIRES**
   Aluminum is in a lot of gem stones.
VII. **CANS AND PACKAGING**

# SILICON

The periodic table's close relative of carbon is silicon. Silicon is found everywhere in the universe, but is not found by itself in nature. You will always find silicon bound to other elements (usually oxygen). The **rocks** with silicon and oxygen are called **silicates**.
You will find silicon just below carbon in the third row (period) of the **periodic table**. Silicon has a similar makeup to carbon in the way its electrons are arranged. **When purified, it is a metallic looking and grayish crystal. While it might be shiny like a metal, it is not a metal.**

**Find it in**:

I. **CONSTRUCTION MATERIALS**
there is silicon inside all of those sidewalks and brick houses!
II. **CERAMICS**
III. **COMPUTER CHIPS**
IV. **GLASS**
V. **SKELETAL SYSTEM**
You might not know that there is an element called calcium which is the main ingredient of your skeleton. Silicon is also inside your skeleton. Silicon keeps your skeleton strong and healthy.

# PHOSPHORUS

It is very **reactive**. When isolated and pure, phosphorus is clear and almost transparent. There are four common forms used today: white, black, red, and violet. It's easy to spot phosphorus on the **periodic table** just under nitrogen at position number fifteen.
**Find it in**:

I. **BAKING POWDER**
Scientists use phosphorus to make baking powder. You will find it as the compound calcium phosphate. It's even in some of your cheeses.
II. **CHINA AND PLATES**
Phosphorus is also used to make dishes. Fine china is very expensive because a lot of special procedures go into making it. Phosphorus is one of the special elements that are used to make that fine china.
III. **FIREWORKS**
You can find lots of phosphorus in fireworks. When phosphorus gets hot it

burns really brightly. The bright sparks and flashes are usually because of that phosphorus.

IV. **FERTILIZER**
Phosphorus is a very important element in fertilizers. Plants need small amounts of phosphorus to grow up healthy. People also need phosphorus and they get it by eating plants.

V. **GLASS**
Scientists use phosphorus when they make glass.

# SULPHUR

It is bright yellow in color and it has a really bad smell (like rotten eggs). Beyond the obvious physical traits of sulphur, man has been using this element for thousands of years.. Sulphur is often found near **volcanoes** and hot springs. Sulfur is even mentioned in the bible where it is called **brimstone**.
It's just under oxygen at position sixteen. Naturally occuring sulfur is a yellowish color and often found as a crystal. At normal temperatures, sulfur is **non-reactive**.

**Find it in:**

I. **FERTILIZER**

II. **MEDICINE**
Sulfur is an important element in medicines. If you have bronchitis and are coughing all the time, sometimes doctors give you sulfa-drugs. This medicine is made with sulfur and helps kill the bacteria making you sick.

III. **VOLCANOES**
If you ever get close enough to a volcano you'll be able to smell the sulfur. It smells like rotten eggs.

IV. **FIREWORKS**
Fireworks are also a good place to find sulfur. Fireworks and firecrackers are filled with gunpowder. One of the main ingredients of gunpowder is sulfur.

V. **MATCHES**
Just like fireworks, there is sulfur in matches that sparks and starts the flames.

# CHLORINE

Chlorine is the second member of the **halogen** family. It's is right there in the **periodic table** with other elements like bromine and iodine. Being a halogen, chlorine is found in many salts that are formed with both alkali metals and alkali earth metals (groups I and II).

**Find it in**:

I. **SWIMMING POOLS**
People put chlorine in the pool to kill bacteria and disease. That addition makes the pool clean for you so you won't get sick

II. **MAKING PAPER**
Scientists use chlorine to make paper white. It bleaches the paper of all color.

III. **BLEACH**
Chlorine in bleach makes your white clothes really white. It also takes the color out of your darker clothes.

IV. **WATER PURIFICATION**
The next time you get a glass of water you should thank chlorine. Chlorine is use to clean the water that comes to your house.

V. **SALT**
The salt on your table is made with chlorine.

**VI.** **PLASTICS**

VII. It is a special plastic called PVC. That's poly-vinyl-chloride. Chloride is the element chlorine.

# ARGON

Argon makes up a little over one percent of our **atmosphere**. Once isolated, argon was not that special. It has no smell and not color. It wound up as the last **element** in period three at position number eighteen. As usual, the last element in the row is an **inert gas**. Argon is in the same family as helium and neon. For a long time, scientists thought that Argon did not combine with any other **elements**. They were wrong.

**Find it in**:

I. **WELDING**
If you see someone welding you should know that sometimes they use argon. Argon is non-reactive so it is a good element when you use really high temperatures. It makes things safer.

II. **GROWING CRYSTALS**
Argon is used to grow silicon crystals. When scientists grow silicon crystals it must be done in a pure environment. There can be no other elements that might combine with the silicon. Argon is used because it will not react with the silicon.

III. **LIGHT BULBS**
When you look in a light bulb it looks like there's nothing there. But there is! Argon is a gas that scientists put in light bulbs to help them work better.

IV. **VACUUM TUBES**
Many years ago, radios used to be much larger and had big glass tubes inside. Those radio tubes were filled with argon gas.

## 4. ACIDS AND BASES

Scientists use something called the **pH scale** to measure how acidic or basic a liquid is. Although there may be many types of ions in a solution, pH focuses on concentrations of hydrogen ions (H+) and hydroxide ions (OH-). The scale goes from values very close to 0 through 14. Distilled water is 7 (right in the middle). Acids are found between a number very close to 0 and 7. Bases are from 7 to 14. Most of the liquids you find every day have a pH near 7. They are either a little below or a little above that mark. When you start looking at the pH of chemicals, the numbers go to the extremes. If you ever go into a chemistry lab, you could find solutions with a pH of 1 and others with a pH of 14. There are also very stong acids with pH values below one such as battery acid. Bases with pH values near 14 include drain cleaner and sodium hydroxide (NaOH). Those chemicals are very dangerous.

### NAMES TO KNOW

Here are a couple of definitions
**Acid:** A solution that has an excess of H+ ions. It comes from the Latin word acidus that means "sharp" or "sour".
**Base:** A solution that has an excess of OH- ions. Another word for base is alkali.
**Aqueous:** A solution that is mainly water. Think about the word aquarium. AQUA means water.
**Strong Acid:** An acid that has a very low pH (0-4).
**Strong Base:** A base that has a very high pH (10-14).

**Weak Acid:** An acid that only partially ionizes in an aqueous solution. That means not every molecule breaks apart. They usually have a pH close to 7 (3-6).
**Weak Base:** A base that only partially ionizes in an aqueous solution. That means not every molecule breaks apart. They usually have a pH close to 7 (8-10).
**Neutral:** A solution that has a pH of 7. It is neither acidic nor basic.

Acids are compounds that break into hydrogen (H+) ions and another compound when placed in an aqueous solution. Bases are compounds that break up into hydroxide (OH-) ions and another compound when placed in an aqueous solution.

If you have an ionic compound and you put it in water, it will break apart into two ions. If one of those ions is H+, the solution is acidic. If one of the ions is OH-, the solution is basic.

That pH scale we talked about is actually a measure of the number of H+ ions in a solution. If there are a lot of H+ ions, the pH is very low. If there are a lot of OH- ions, that means the number of H+ ions is very low, so the pH is high.

## Catalysts

A catalyst is a substance that will change the rate of a reaction. A catalyst is often used to make a reaction go faster. The catalyst itself does not take part in the reaction as a reactant. It is not changed by the reaction, it is not used up during the reaction. It is still there in the same form when the reaction is complete. A catalyst is usually a transition metal, a transition metal oxide or an enzyme in living cells. An exception is aluminium oxide, used in the cracking of hydrocarbons. A substance which works well as a catalyst for one reaction might not work well as a catalyst for a different reaction.

How does a catalyst work?

A catalyst works by providing a convenient surface for the reaction to occur.
The reacting particles gather on the catalyst surface and
1) collide more frequently with each other
2) more of the collisions result in a reaction between particles because the catalyst can lower the activation energy for the reaction.

A catalyst is often used as a powder, so that it has a bigger surface area per gram.

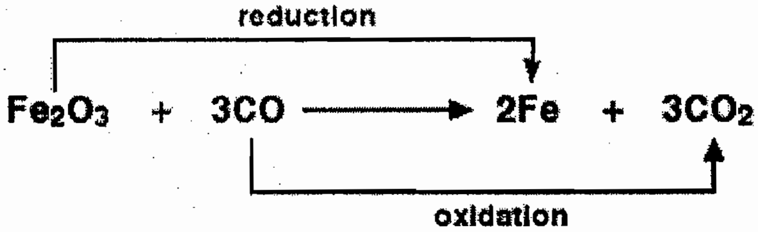
# 5. DEFINITIONS OF OXIDATION AND REDUCTION (REDOX)

### Oxidation and reduction in terms of oxygen transfer

### Definitions

- Oxidation is gain of oxygen.
- Reduction is loss of oxygen.

For example, in the extraction of iron from its ore:



$$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$$

Because both ***red***uction and ***ox***idation are going on side-by-side, this is known as a ***redox*** reaction.

### Oxidising and reducing agents

An oxidising agent is substance which oxidises something else. In the above example, the iron(III) oxide is the oxidising agent.

A reducing agent reduces something else. In the equation, the carbon monoxide is the reducing agent.

- Oxidising agents give oxygen to another substance.
- Reducing agents remove oxygen from another substance.

### Oxidation and reduction in terms of hydrogen transfer

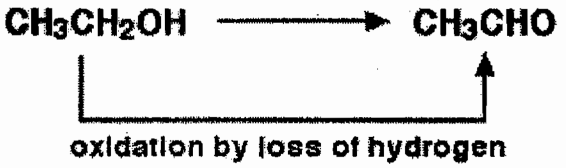
These are old definitions which aren't used very much nowadays. The most likely place you will come across them is in organic chemistry.

### Definitions

- Oxidation is loss of hydrogen.
- Reduction is gain of hydrogen.

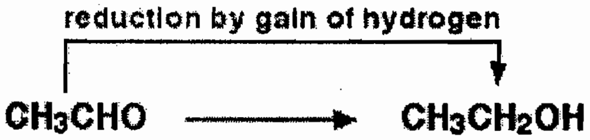
Notice that these are exactly the opposite of the oxygen definitions.

For example, ethanol can be oxidised to ethanal:



You would need to use an oxidising agent to remove the hydrogen from the ethanol. A commonly used oxidising agent is potassium dichromate(VI) solution acidified with dilute sulphuric acid.

Ethanal can also be reduced back to ethanol again by adding hydrogen to it. A possible reducing agent is sodium tetrahydridoborate, $NaBH_4$. Again the equation is too complicated to be worth bothering about at this point.



**An update on oxidising and reducing agents**

- Oxidising agents give oxygen to another substance or remove hydrogen from it.
- Reducing agents remove oxygen from another substance or give hydrogen to it.

**Oxidation and reduction in terms of electron transfer:** This is easily the most important use of the terms oxidation and reduction at A' level.

**Definitions**

- ***Oxidation is loss of electrons.***
- ***Reduction is gain of electrons.***

It is essential that you remember these definitions. There is a very easy way to do this. As long as you remember that you are talking about electron transfer:

**OIL RIG**

oxidation is loss    reduction is gain

# 6. Electrolytes and Electrolysis

In any chemical reaction, the existing chemical bonds are broken and new chemical bonds are formed. Hence, all chemical reactions are fundamentally electrical in nature since electrons are involved in some way or the other in all types of chemical bonding. Many chemical reactions utilize electrical energy, whereas others can be used to produce electrical energy. As electrical energy involves the flow of electrons, these reactions are concerned with the transfer of electrons from one substance to the other.

**Examples of Electrolytes**

| Strong electrolyte | Weak electrolyte | Non-electrolyte |
|---|---|---|
| Sea water | Tap water | Chemically pure water |
| Hydrochloric acid | Carbonic acid | Alcohol |
| Sulphuric acid | Acetic acid | Kerosene |
| Aqueous copper sulphate | Ammonium hydroxide | Aqueous sugar solution |
| Molten lead bromide | Citric acid | Carbon disulphide |
| Aqueous sodium chloride | Oxalic acid | |
| Nitric acid | | |
| Aqueous potassium hydroxide | | |

"Electrolysis is the electrolytic dissociation and decomposition of an electrolyte (electrovalent substance), by the passage of a direct current or electricity through its aqueous or molten form

**Electrolyte**

A compound (mostly an ionic compound) that conducts electricity in molten (fused) or aqueous (solution) state, and which simultaneously undergoes decomposition with the passage of electric current through it is known as an electrolyte.

## Electrodes

The two metallic conductors in the form of rods dipped in the electrolyte and connected to the two terminals of the battery are called electrodes.

The anode is the electrode connected to the positive terminal of the battery.

The cathode is the electrode connected to the negative terminal of the battery.

## Anions

The negatively charged atoms or group of atoms, which under the influence of an electric field migrate towards the anode (or positive electrode) are called anions.

## Cations

The positively charged atoms or group of atoms, which under the influence of an electric field migrate towards the cathode (or negative electrode) are called cations.

## Electrolytic cell

The container or a vessel consisting of the cathode, anode and the electrolyte is called an electrolytic cell. It is also known as a voltameter.

## Battery or cell

For a current to flow through a conductor, a difference in charge should be maintained between the two ends of the conductor. To ensure this, a cell or a battery is used. The cell or a battery converts its chemical energy into electrical energy thus maintaining a constant difference of charge between any two points.

## Simple Voltaic Cell

In a simple voltaic cell a zinc plate and a copper plate are immersed in a very dilute solution of sulphuric acid, taken in a glass vessel. These two metal plates are called electrodes and the solution is called the electrolyte. The copper plate and the zinc plate are externally connected to a bulb as shown in the figure

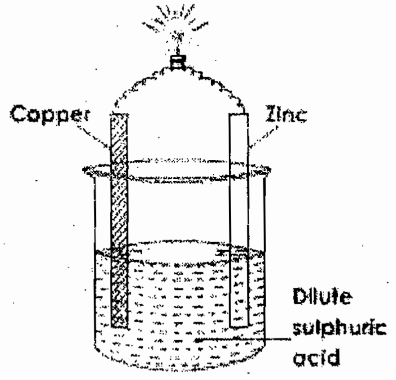


*Fig. 4.7. Simple voltaic cell*

Zinc loses electrons more readily than copper, as it is more electropositive than copper. Each zinc atom loses two free electrons and hence gains two units of positive charge.

$$Zn \longrightarrow Zn^{2+} + 2e^-$$

As copper is lower in the metal activity series, it does not undergo a similar reaction and hence remains a region of deficiency of electrons. So, when the zinc plate and the copper plate are connected by means of a metal wire, free electrons from the zinc plate flow to the copper plate and the bulb connected externally starts glowing.

Some of these electrons get added to hydrogen ions of the sulphuric acid of the electrolyte, to form free hydrogen.

$$H_2SO_4 \rightleftharpoons 2H^+ + SO_4^{2-}$$

$$[H^+ + 1e^- \longrightarrow H] \times 2 \rightarrow H_2$$

It may be noted that in a voltaic cell, that the direction the flow of electrons is not affected if the position of the two metals is reversed.

As zinc metal is oxidised to zinc ions, oxidation occurs here. The electrons given up by zinc leave the cell from this electrode and travel the external circuit to copper electrode. Here, the electrons enter the cell and bring about the reduction of the hydrogen ions of the sulphuric acid. Thus an electric current is delivered as a result of a spontaneous oxidation reduction reaction.

**Applications of Electrolysis**

Electrolysis has various applications. Some of them are mentioned below:

a) Electroplating or coating of metals.
b) Electrorefining or purification of metals.
c) Electrometallurgy or extraction of metals from metallic ores.

**Electroplating**

Electroplating is a process of depositing a thin layer of a fine and superior metal (like chromium, zinc, nickel, gold etc.) over the article of a baser and cheaper metal (like iron, copper, brass), with the help of electric current.

**Uses**

Electroplating is very useful because of the following reasons:

- Surface protection e.g. nickel plating of iron to prevent corrosion.
- Makes the article attractive e.g., electroplating of silver or gold on brass etc.
- Repair of finer machine parts.

**Process**

The process of electroplating involves the following steps:

- Before electroplating the metal surface is cleaned thoroughly. Firstly, an alkaline solution is used to remove grease and then it is treated with acid to remove any oxide layer. It is then washed with water.
- The article to be electroplated is made cathode since metallic ions are positive and thus get deposited on the cathode.
- The anode is made of pure metal, which is to be coated on the article.
- The electrolyte is the salt of the metal to be coated on the article.
- A direct (D.C.) current is passed through the electrolyte. The anode dissolves, depositing the metal ions from the solution on the article in the form of a metallic coating. The passage of low current is continued for a long time to ensure an even coating.
- To obtain a thin, coherent and bright deposit, the conditions of low current density, optimum temperature and low metal ion concentration are found to be helpful.
- The choice of electrolyte for use in the electroplating bath is very important. A good electrolyte should have the following characteristics.
- It should be highly soluble in water.
- Its solution should be a reasonably good conductor of electricity.
- Its solution should be stable towards oxidation, reduction and hydrolysis.
- It should be reasonably priced.

### a) Electroplating with Nickel

Electrolyte - Aqueous solution of nickel sulphate

| Reaction at Cathode (Reduction) | Reaction at Anode (Oxidation) |
|---|---|
| **Ions at cathode:** $Ni^{2+}$, $H^+$ | **Ions at anode:** $SO_4^{2-}$, $OH^-$ |
| Preferential discharge of $Ni^{2+}$ ions takes place. | None of the above ions discharge at anode; instead Ni atoms of the anode lose electrons to form $Ni^{2+}$ ions. |
| $Ni^{2+}(aq) + 2e^- \longrightarrow Ni^0(s)$ | $Ni^0(s) - 2e^- \longrightarrow Ni^{2+}(aq)$ |
| Nickel metal deposits on the article, i.e., nail. | $Ni^{2+}$ ions are formed at anode. |

### b) Electroplating with Silver

Electrolyte - Aqueous solution of sodium argento cyanide $Na[Ag(CN)_2]$.

| Reaction at Cathode (Article to be plated) | Reaction at Anode (Silver Block) |
|---|---|
| **Ions at cathode:** $Ag^+$, $Na^+$, $H^+$ | **Ions at anode:** $OH^-$, $CN^-$ |
| Preferential discharge of $Ag^+$ ions takes place (Reduction). | Neither of the anions discharge, instead silver atoms lose electrons and become $Ag^+$ ions (Oxidation). |
| $Ag^+(aq) + e^- \longrightarrow Ag^0(s)$.<br>Silver deposits on the article i.e., spoon | $Ag^0(s) - e^- \longrightarrow Ag^+$<br>Silver ions enter the solution at anode |

# 7. The Reactivity Series of Metals

| | | |
|---|---|---|
| K | Potassium | ↑ |
| Na | Sodium | Most reactive |
| Ca | Calcium | |
| Mg | Magnesium | |
| Al | Aluminium | |
| C | Carbon | |
| Zn | Zinc | |
| Fe | Iron | |
| Sn | Tin | |
| Pb | Lead | |
| H | Hydrogen | |
| Cu | Copper | Least reactive |
| Ag | Silver | |
| Au | Gold | |
| Pt | Platinum | ↓ |

*C H added for comparison*

- The higher the metal in the series, the more reactive it is i.e., its reaction is fast and more exothermic.
- This also implies that the reverse reaction becomes more difficult i.e., the more reactive a metal, the more difficult it is to extract from its ore. The metal is also more susceptible to corrosion with oxygen and water.
- The reactivity series can be established by observation of the reaction of metals with water, oxygen or acids.
- A metal in the series, can displace any metal below it in the series, from the oxide, chloride or sulphate of the less reactive metal.

$$\text{Iron} + \text{Copper (II) sulphate} \longrightarrow \text{Iron (II) sulphate} + \text{copper}$$

$$Fe + CuSO_4 \longrightarrow FeSO_4 + Cu$$

Copper (II) sulphate solution is blue, iron sulphate solution is almost colourless when dilute. During the displacement, the blue solution loses its colour, and the iron metal is seen to turn pink-brown as the displaced copper becomes deposited on it.

On heating the mixture of magnesium powder and black copper(II) oxide, white magnesium oxide is formed with brown bits of copper:

$$Mg + CuO \overset{\Delta}{\Rightarrow} MgO + Cu$$

Adding magnesium to blue copper(II) sulphate solution, the blue colour fades as colourless magnesium sulphate is formed and brown bits of copper metal form a precipitate:

$Mg + CuSO_4 \Rightarrow MgSO_4 + Cu$

- Hydrochloric acid makes a metal chloride
- Sulphuric acid makes a metal sulphate
- Reactions with nitric acid are complex, the nitrate is formed but the gas is rarely hydrogen, and more often, an oxide of nitrogen.
- Within the general reactivity or activity series there are some periodic table trends:

Two non-metals, carbon and hydrogen are important chemical reference points with regard to the method of metal extraction and reactivity towards acids. Metals above carbon cannot be extracted by carbon reduction and are usually extracted by electrolysis. Metals below hydrogen will not displace hydrogen from acids:

| Metals | Reactivity and Reactions |
|---|---|
| **Potassium** K | Very reactive, very rapid with cold water forming the alkali potassium hydroxide and hydrogen gas (which is ignited).<br>$2K + 2H_2O_{(l)} \Rightarrow 2KOH_{(aq)} + H_{2(g)}$ |
| Sodium<br>Na | □ Fast reaction with cold water forming the alkali sodium hydroxide and hydrogen gas.<br>$2Na_{(s)} + 2H_2O_{(l)} \Rightarrow 2NaOH_{(aq)} + H_{2(g)}$<br>□ The reaction of sodium with water - the sodium melts to a silvery ball and fizzes as it spins over the water. The rapid exothermic reaction produces a colourless gas - gives a squeaky pop! with a lit splint - hydrogen. Universal indicator will turn from green to purple/violet - the strong alkali sodium hydroxide is formed. The sodium floats because it is less dense than water. |
| Calcium<br>Ca | □ Quite reactive with cold water forming the moderately soluble alkali calcium hydroxide and hydrogen gas.<br>$Ca_{(s)} + 2H_2O_{(l)} \Rightarrow Ca(OH)_{2(aq/s)} + H_{2(g)}$<br>□ Very reactive with dilute hydrochloric acid forming the colourless soluble salt calcium chloride and hydrogen gas.<br>$Ca_{(2)} + 2HCl_{(aq)} \Rightarrow CaCl_{2(aq)} + H_{2(g)}$<br>□ Not very reactive with dilute sulphuric acid because the colourless calcium sulphate formed is not very soluble and coats the metal inhibiting the reaction.<br>$Ca_{(s)} + H_2SO_{4(aq)} \Rightarrow CaSO_{4(s)} + H_{2(g)}$ |

| | |
|---|---|
| **Magnesium Mg** | □ Slow reaction with water forming the slightly soluble alkali magnesium hydroxide and hydrogen gas.<br>$Mg_{(s)} + 2H_2O_l \Rightarrow Mg(OH)_{2\,(aq/s)} + H_{2\,(g)}$<br>□ With steam, the reaction is faster with heated magnesium and the white powder magnesium oxide is formed with the hydrogen. Magnesium will burn with a bright white flame in steam, if previously ignited in air!<br>$Mg_{(s)} + H_2O_{(g)} \Rightarrow MgO_{(s)} + H_{2(g)}$<br>□ In fact it will even burn in carbon dioxide forming black specks of carbon!<br>$2Mg_{(s)} + CO_{2(g)} \Rightarrow 2MgO_{(s)} + C_{(s)}$<br>□ Very reactive with dilute hydrochloric acid forming the colourless soluble salt magnesium chloride and hydrogen gas.<br>$Mg_{(s)} + 2HCl_{(aq)} \Rightarrow MgCl_{2(aq)} + H_{2(g)}$<br>□ Very reactive with dilute sulphuric acid forming colourless soluble magnesium sulphate and hydrogen.<br>$Mg_{(s)} + H_2SO_{4(aq)} \Rightarrow CaSO_{4(s)} + H_{2(g)}$ |
| **Aluminium Al** | □ Aluminium has no reaction with water or steam due to a protective aluminium oxide layer of $Al_2O_3$.<br>□ Slow reaction with dilute hydrochloric acid to form the colourless soluble salt aluminium chloride and hydrogen gas.<br>$2Al_{(s)} + 6HCl_{(aq)} \Rightarrow 2AlCl_{3(aq)} + 3H_{2\,(g)}$<br>□ The reaction with dilute sulphuric acid is extremely slow to form colourless aluminium sulphate and hydrogen.<br>$2Al_{(s)} + 3H_2SO_{4\,(aq)} \Rightarrow Al_2(SO_4)_{3\,(aq)} + 3H_{2(g)}$ |
| **(Carbon C, a non-metal)** | □ Elements higher than carbon ie aluminium or more reactive, must be extracted by electrolysis (or displacing it with an even more reactive metal). Metals below it, ie zinc or a less reactive, can be extracted by reducing the hot metal oxide with carbon |

| | |
|---|---|
| **Zinc Zn** | ☐ No reaction with cold water.<br>☐ When the metal is heated in steam zinc oxide and hydrogen are formed.<br>$Zn_{(s)}+H_2O_{(g)} \Rightarrow ZnO_{(s)} + H_{2(g)}$<br>☐ Quite reactive with dilute hydrochloric acid forming the colourless soluble salt zinc chloride and hydrogen gas.<br>$Zn_{(s)} + 2HCl_{(gg)} \Rightarrow ZnCl_{2(gg)} + H_{2(g)}$<br>☐ Quite reactive with dilute sulphuric acid forming the colourless soluble salt zinc sulphate and hydrogen gas.<br>$Zn_{(s)} + H_2SO_{4(g)} \Rightarrow ZnSO_{4(s)} + H_{2(g)}$<br>(this reaction is catalysed by adding a trace of copper sulphate solution)<br>☐ Zinc can be extracted by reducing the hot metal oxide on heating with carbon<br>$2ZnO_{(s)}+ C_{(s)} \Rightarrow 2Zn_{(s)}+ CO_{2(g)}$<br>☐ A zinc coating (galvanising) is used to protect iron from rusting. |
| **Iron Fe** | ☐ No reaction with cold water (rusting is a joint reaction with oxygen).<br>☐ When the metal is heated in steam an iron oxide (unusual formula) and hydrogen are formed. This oxide is 'technically' Iron (III,II) oxide!!!!<br>$3Fe_{(s)} + 4H_2O_{(g)} \Rightarrow Fe_3O_{4(s)} + 4H_{2(g)}$<br>☐ Slow reaction with dilute hydrochloric acid forming the soluble pale green salt iron(II) chloride and hydrogen gas.<br>$Fe_{(s)} + 2HCl_{(gg)} \Rightarrow FeCl_{2(gg)} + H_{2(g)}$<br>☐ Slow reaction with dilute sulphuric acid forming the soluble pale green salt iron(II) sulphate and hydrogen gas.<br>$Fe_{(s)} + H_2SO_{4(g)} \Rightarrow FeSO_{4(s)} + H_{2(g)}$<br>☐ Iron can be extracted by reducing the hot metal oxide on heating with carbon monoxide formed from carbon in the blast furnace eg<br>$Fe_2O_{3(s)} + 3CO_{(g)} \Rightarrow 2Fe_{(s)} + 3CO_{2(g)}$<br>$Fe_3O_{4(s)} + 4CO_{(g)} \Rightarrow 3Fe_{(s)} + 4CO_{2(g)}$ |
| **(Hydrogen H non-metal** | ☐ None of the metals below hydrogen can react with acids to form hydrogen gas. They are least easily corroded metals and partly accounts for their value and uses in jewellery, electrical contacts etc. |
| **Copper Cu** | ☐ No reaction with cold water or when heated in steam.<br>☐ No reaction with dilute hydrochloric acid or dilute sulphuric acid.<br>☐ Copper can be extracted by reducing the hot black metal oxide on heating with carbon<br>$2CuO_{(s)}+ C_{(s)} \Rightarrow 2Cu_{(s)}+ CO_{2(g)}$ |

| | |
|---|---|
| **Silver Ag** | ❑ No reaction with cold water or when heated in steam.<br>❑ No reaction with dilute hydrochloric acid or dilute sulphuric acid.<br>❑ Silver can be extracted by reduction but can be found 'native' as the element |
| **Gold Au** | ❑ No reaction with cold water or when heated in steam.<br>❑ No reaction with dilute hydrochloric acid or dilute sulphuric acid.<br>❑ Gold can be readily extracted from its ores easily by reduction but it is usually found 'native' . Pure gold is 24 carat |
| **Platinum Pt** | ❑ No reaction with cold water or when heated in steam.<br>❑ No reaction with dilute hydrochloric acid or dilute sulphuric acid.<br>❑ Like gold, it is a very rare metal . It is used in expensive jewellery, laboratory ware (inert crucible container) and catalytic converters in car exhausts. |

# 8.Minerals and Ores

Metals and their compounds are found in earth as natural elements known as minerals. Ores are minerals from which metals are extracted at low cost with minimum effort. Ores contains metal compounds with a percentage of impurities. All the ores are minerals, but all the minerals are not ores.

## Metals and their Ores

| Oxides | Carbonates | Halides | Sulphides | Sulphates |
|---|---|---|---|---|
| Zincite( ZnO) | Marble or Lime stone ($CaCO_3$) | Flurospar ($CaF_2$) | Zinc blende (ZnS)<br>Galena (PbS) | Anglesite ($PbSO_4$) |
| Haematite ($Fe_2O_3.xH_2O$)<br>Magnitite ($Fe_3O_4$) | Calamine ($ZnCO_3$) | Cryolite ($Na_3AlF_6$) | Iron pyrites ($FeS_2$) | Baryle ($BaSO_4$) |
| Bauxite ($Al_2O_32H_2O$) | Siderite ($FeCO_3$) | Horn Silver (AgCl) | Cinnabar (HgS) | Gypsum ($CaSO_4$ $2H_2O$) |
| Cuprite ($Cu_2O$) | Magnesite (Mg $CO_3$) | Rock salt (NaCl) | | Epsom Salt ($MgSO_4.7H_2O$) |

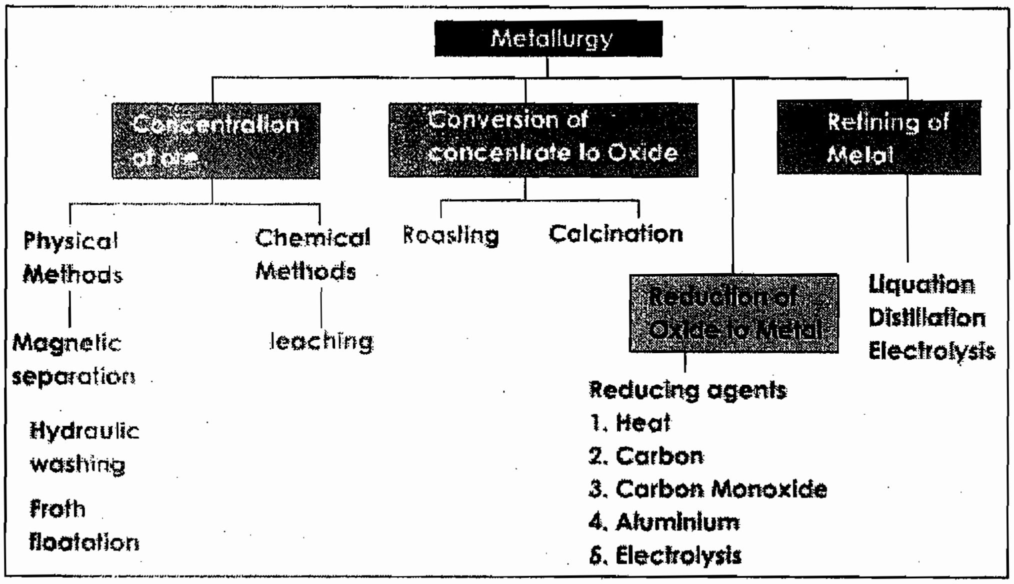
## Occurrence of Metals

- Metals like gold and platinum occur in the free metallic form not acted upon by air or water
- The rest of the metals occur in the combined form as compounds. Copper is one of the metals which occur in free as well as combined state
- Aluminium is the most abundant metal in the earth's crust
- The second most abundant metal in the earth is iron and the third one is calcium

## Metallurgy

It is a study of the physical and chemical behavior of metallic elements and their mixtures, called alloys. Metallurgists study the microscopic mechanisms that cause a metal or alloy to behave in the way that it does, the changes that occur at the atomic level, that affect the metal's (or alloy's) macroscopic properties. The various processes involved in the extraction of metals from their ores and refining are known as metallurgy. The compounds of various metals mixed with impurities and found in nature are called minerals. The naturally occurring metals from which metal can be extracted profitably and conveniently are called ores.

### Processes Involved during Metallurgy



## Zone Refining

This method is used for obtaining ultra pure metals like germanium, silicon and gallium.

## Van Arkel's Method

This method is used for obtaining ultra pure titanium

## Metal Corrosion and the Rusting of Iron

Iron (or steel) corrodes more quickly than most other transition metals and readily does so in the presence of both oxygen (in air) and water to form an iron oxide. Rusting is speeded up in the presence of salt solution.

Rusting is $Fe_{(s)} + O_{2(g)} + H_2O_{(l)}$ □ $Fe_2O_3 . x\ H_2O_{(5)}$ i.e., rust is hydrated iron (III) oxide (the equation is not meant to be balanced and the amount of water x is variable, from dry to soggy). Rusting is oxidation because it involved iron gaining or iron atoms losing electrons .

The rusting of iron is a major problem in its use as a structural material.

Iron and steel (alloy of iron) are most easily protected by paint which provides a barrier between the metal and air/water. Moving parts on machines can be protected by a water repellent oil or grease layer.

This 'rusting' can be prevented by connecting iron to a more reactive metal (e.g., zinc or magnesium). This is referred to as sacrificial protection or sacrificial corrosion, because the more reactive protecting metal is preferentially oxidised away, leaving the protected metal intact. Iron or steel can also be protected by mixing in other metals (e.g., chromium) to make non-rusting alloys called stainless steel. The chromium, like aluminium, forms a protective oxide layer.

Coating iron or steel with a thin **zinc layer** is called **'galvanizing'**. The layer is produced by electrolytic deposition by making the iron/steel the negative cathode or dipping the iron/steel object in molten zinc. The zinc preferentially corrodes or oxidises to form a zinc oxide layer that doesnot flake off like iron oxide rust. Also, if the surface is scratched, the exposed zinc again corrodes before the iron and continues to protect it.

Steel cans are protected by relatively unreacted tin and works well as long as the thin tin layer is complete.

Aluminium does not oxidise (corrode) as quickly as its reactivity would suggest. Once a thin oxide layer of ($Al_2O_3$) has formed on the surface, it forms a barrier to oxygen and water and so prevents further corrosion of the aluminium.

Aluminium is a useful structural metal. It can be made harder, stronger and stiffer by mixing it with small amounts of other metals (e.g magnesium) to make alloys.

Copper and lead are both used in roofing situations because neither are very reactive. The compounds formed do not flake away as easily as rust does from iron. Lead corrodes to a white lead oxide or carbonate and copper corrodes to form a basic green carbonate (combination of the hydroxide $Cu(OH)_2$ and carbonate $CuCO_3$).

Both metals have been used for piping but these days lead is considered too toxic. Copper is usually used as the stronger, but equally unreactive alloy brass.

The Group 1 Alkali Metals rapidly corrode in air and need to be stored under oil.

| | | |
|---|---|---|
| **Nickel Steel (Fe,C,Ni)** | Hard, corrosion resistant, elastic<br>Light, hard, tough, corrosion resistant | Cables, aircraft parts and propeller shafts |
| **Tungsten steel** | Very hard Corrosion resistant<br>Alloy: Acquires hardness on alloying with tungsten (W) | High speed machine parts |

**Alloying of Gold**

From the first discoveries of gold in ancient times, its beauty and the ease with which it could be worked inspired craftsmen to create it into ornaments, not just for adornment, but as symbols of wealth and power

Pure gold is used in those parts of the world where jewellery is purchased as much for in- vestment as it is for adornment, but it tends to be vulnerable to scratching. Elsewhere, it is usually mixed, or alloyed, with other metals. Not only do they harden it, but influence the colour; white shades are achieved by alloying gold with silver, nickel or palladium; red alloys contain mainly copper. A harder alloy is made by adding nickel or a tiny percentage of titanium.

The proportion of gold in jewellery is measured on the carat (or karat) scale. The word carat comes from the **carob seed, which was originally used to balance scales in Oriental bazaars**. Pure gold is designated 24 carat, which compares with the "fineness" by which bar gold is defined.

**Pure Gold alloys**

| Caratage | Fineness | % Gold |
|---|---|---|
| 24 | 1000 | 100 |
| 22 | 916.7 | 91.67 |
| 18 | 750 | 75 |
| 14 | 583.3 | 58.3 |
| 10 | 416.7 | 41.67 |
| 9 | 375 | 37.5 |

The most widely used alloys for jewellery in Europe are 18 and 14 carat, although 9 carat is popular in Britain. Portugal has a unique designation of 19.2 carats. In the United States 14 carat predominates, with some 10 carat. In the Middle East, India and South East Asia, jewellery is traditionally 22 carat (sometimes even 23 carat). In China, Hong Kong and some other parts of Asia, "chuk kam" or pure gold jewellery of 990 fineness (almost 24 carat) is popular. In many countries the law requires that every item of gold jewellery is clearly stamped with its caratage. This is often controlled through hallmarking, a system which originated in London at Goldsmiths' Hall in the 14th century. Today it is compulsory in such countries as Britain, France, the Netherlands, Morocco, Egypt, and Bahrain. Where there is no compulsory marking manufacturers themselves usually stamp the jewellery both with their own individual identifying mark and the caratage or fineness.

## Some common alloys and what we use them for

There are zillions of different alloys used for zillions of different purposes. We've listed 20 of the more common (or otherwise interesting) ones in the table below. There are lots of different variations on most alloys and the precise mixture can vary widely, so the percentage figures you see quoted in different books will often not agree exactly.

| Alloy | Components | Typical uses |
|---|---|---|
| Alnico | Iron (50%+), aluminum (8-12%), nickel (15-25%), cobalt (5-40%), plus other metals such as copper and titanium. | Magnets in loudspeakers and pickups in electric guitars. |

| | | |
|---|---|---|
| Amalgam | Mercury (45-55%), plus silver, tin, copper, and zinc. | Dental fillings. |
| Babbitt metal ("white metal") | Tin (90%), antimony (7-15%), copper (4-10%). | Friction-reducing coating in machine bearings. |
| Brass | Copper (65-90%), zinc (10-35%). | Door locks and bolts, brass musical instruments, central heating pipes. |
| Bronze | Copper (78-95%), tin (5-22%), plus manganese, phosphorus, aluminum, or silicon. | Decorative statues, musical instruments. |
| Cast iron | Iron (96-98%), carbon (2-4%), plus silicon. | Metal structures such as bridges and heavy-duty cookware. |
| Cupro-nickel (copper nickel) | Copper (75%), nickel (25%), plus small amounts of manganese. | Coins. |
| Duralumin | Aluminum (94%), copper (4.5-5%), magnesium (0.5-1.5%), manganese (0.5-1.5%). | Automobile and aircraft body parts, military equipment. |
| Gunmetal | Copper (80-90%), tin (3-10%), zinc (2-3%), and phosphorus. | Guns, decorative items. |
| Magnox | Magnesium, aluminum. | Nuclear reactors. |
| Nichrome | Nickel (80%), chromium (20%). | Firework ignition devices, heating elements in electrical appliances. |
| Nitinol | Nickel (50-55%), titanium (45-50%). | Shape memory alloy used in medical items, spectacle frames that spring back to shape, and temperature switches. |
| Pewter | Tin (80-99%) with copper, lead, and antimony. | Ornaments, used to make tableware before glass became more common. |
| Solder | Tin (50-70%), lead (30-50%), copper, antimony, and other metals. | Connecting electrical components into circuits. |
| Steel (general) | Iron (80-98%), carbon (0.2-2%), plus other metals such as chromium, manganese, and vanadium. | Metal structures, car and airplane parts, and many other uses. |

| | | |
|---|---|---|
| Steel (stainless) | Iron (50%+), chromium (10-30%), plus smaller amounts of carbon, nickel, manganese, molybdenum, and other metals. | Jewelry, medical tools, tableware. |
| Stellite | Cobalt (67%), chromium (28%), tungsten (4%), nickel (1%). | Coating for cutting tools such as saw teeth, lathes, and chainsaws. |
| Sterling silver | Silver (92.5%), copper (7.5%). | Cutlery, jewelry, medical tools, musical instruments. |
| White gold (18 carat) | Gold (75%), palladium (17%), silver (4%), copper (4%) | Jewelry. |
| Wood's metal | Bismuth (50%), lead (26.7%), tin (13.3%), cadmium (10%). | Solder, melting element in fire sprinkler systems. |

# Other Metal Alloys

**Nickel silver**

is a metal alloy of copper with nickel and often but not always zinc. It is named for its silvery appearance, but contains no elemental silver unless plated. Other common names for this alloy are **German silver**, **paktong**, **new silver** and **alpacca** (or **alpaca**).

**Monel**

Monel (or monel metal) is a trademarked name for a range of corrosion-resistant bright metal alloys containing typically 67 percent nickel, 30 percent copper, and trace proportions of iron, manganese, and other elements. It is not a synonym for Nickel Silver and should not be confused with it. Monel is more expensive than Nickel Silver because of the high proportion of nickel and its more specialist applications.

**Gun Metal**

An alloy in the bronze family, used especially where resistance to wear and corrosion is desired. Clasically, an alloy of Cu 88 %, Sn 10%, Zn 2%, traditionally used for making cannon and other industrial products. Also used loosely to describe other dark-grey cast metals such as found in toys, badges, buckles etc.

### Pinchbeck

Pinchbeck is a yellow metal alloy in the brass family. Invented by Christopher Pinchbeck in the 18th century, it was claimed to be a secret recipe, but is generally believed to be 83% copper and 17% zinc. This ratio optimises the gold matching colour of the alloy. Commonly known as "poor man's gold". It and similar alloys were widely used in costume jewellery, and as the metal substrate for fire gilding and (from 1840) gilt electroplating. Now included under the generic name "Gilding Metal".

### Spelter

Spelter is an alternative name for the metal zinc, especially when used in decorative arts manufacture and casting. Spelter castings were often patinated to imitate more valuable bronze.

### Tutania

Tutania is an alloy of copper, antimony, zinc and tin patented in 1770 by William Tutin whose Birmingham firm (Tutin and Haycroft) used it in commercial production of housewares.

### Cupro-Nickel

A silvery-coloured binary alloy of copper and nickel. Widely used for minting coinage. It is also called copper-nickel, especially in US usage. In the UK it has been used since 1947 for "silver" coins, usually in an alloy of Cu 75%, Ni 25%. The alloy in the current 20p coin of the UK is Cu 84%, Ni 16%.

### Bronze

Any of various alloys of copper with tin and often zinc. Widely used for minting coinage. In the UK bronze coinage (the copper-coloured coins of 1860-1992) the alloy was Cu 95.5%, Sn 3%, Zn 1.5%

### Nickel Brass

Any of various brass coloured alloys of copper with zinc and a small component of nickel. Widely used for minting coinage. In the UK's nickel brass coinage (the twelve-sided threepenny piece) the alloy was Cu 79%, Zn 20%, Ni 1%.

**Britannia Metal**

Britannia metal is another name for pewter in its modern lead-free formulation, usually 91% tin, 7.5% antimony, 1.5% copper.

# 10. SOME IMPORTANT COMPOUNDS

## 1.Ammonia

**Uses**

- Ammonia solutions are used to clean, bleach, and deodorize; to etch aluminum; to saponify (hydrolyze) oils and fats; and in chemical manufacture.
- Ammonia is also used in large amounts in the Ostwald process for the synthesis of nitric acid; in the Solvay process for the synthesis of sodium carbonate; in the synthesis of numerous organic compounds used as dyes, drugs, and in plastics; and in various metallurgical processes.
- The ammonia sold for household use is a dilute water solution of ammonia in which ammonium hydroxide is the active cleansing agent.
- As a constituent of smelling salt, it revives a fainted person. But it should be used with caution since it can attack the skin and eyes. The vapors are especially irritating prolonged exposure and inhalation cause serious injury and may be fatal.
- Ammonia and its compounds are mainly used as fertilizers.
- Liquid ammonia is used as refrigirant.

## 2.Sulphur Dioxide

**Uses**

- It is a powerful germicide and insecticide and hence it is used a household fumigant.
- It can bleach delicate fibres.
- It undergoes easy liquefaction and vaporization and hence it is used as refrigerent in cold storage plants.
- It is used in the manufacture of sulphuric acid by contact process
- It is raw material for manufacture of calcium bi sulphite used in treatment of wood pulp for paper industry.
- It is used in sugar industry for refining sugar.

### 3.Sulphuric acid

**Uses**

- In the manufacture of fertilizers, ammonium phosphate and calcium super phosphate.
- In the manufacture of rayon and nylon and also in the preparation of dyes and drugs from coal tar derivatives.
- In the manufacture of the explosives such as Tri-nitro toluene , Tri-nitro glycerine and picric acid.
- In the manufacture of nitric acid, hydrochloric acid and phosphoric acid.
- In the manufacture of sodium sulphate for glass industry and ferrous sulphate for ink industry.
- In the purification of petrol, kerosene, and lubricants.
- It is used in metallurgy for extraction of metals. Leaching of metallic compounds gives sulphates which on electrolysis gives the metal in pure form .It is used for pickling of metals.
- It is used in storage of batteries.
- It is used as a laboratory reagent for the preparation of iodine, carbon monoxide and hydrogen.

### 4. Sodium Carbonate ($Na_2CO_3$)

Popularly known as washing soda or soda ash, sodium carbonate is a commercially important compound. In earlier days, it was obtained from the ash of plants and from natural deposits in India and Egypt.

**Uses of Sodium Carbonate**

Sodium carbonate is used :

- as washing soda in laundry as a cleansing agent
- for softening hard water
- in manufacturing glass, paper, soap and caustic soda
- as a valuable laboratory reagent
- in quantitative analysis to standardise acid solutions
- in qualitative analysis in the detection of acid radicals of insoluble salts

### 5. Sodium Bicarbonate ($NaHCO_3$)

Sodium bicarbonate is commonly called baking soda.

**Uses of Sodium Bicarbonate**

- Used in the preparation of carbon dioxide
- Used as a constituent of baking powder, and in effervescent drinks. Baking powder has sodium bicarbonate and tartaric or citric acid. When it is

dissolved in water or heated carbon dioxide is produced. This carbon dioxide gas causes the puffiness and lightness of cakes, biscuits etc.

- Sodium bicarbonate is used to extinguish fire as it produces carbon dioxide gas.
- It is used to remove acidity. Due to its alkaline nature, it reacts with excess acid generated in the stomach and neutralises it to relieve acidity.

### 6. Bleaching Powder ($CaOCl_2$)

Calcium oxychloride is the chemical name of bleaching powder.

**Uses**

- Bleaching powder is commonly used for bleaching clothes.
- It is also used in bleaching wood pulp in the paper industry.
- It is used to disinfect drinking water.
- It is used in the manufacture of chloroform ($CHCl_3$), an anaesthetic.
- It is used as an oxidising agent.
- It is used to shrink wool.

### 7. Plaster of Paris ($CaSO_4$) $2.H_2O$

Chemically, plaster of paris is known as calcium sulphate hemihydrate (hemi means half).

**Uses**

- Plaster of Paris is used to set fractured bones due to its setting property on hydration.
- It is used as a sealant in laboratories.
- Can be used to make casts for toys, statues, ornaments and decorative items.
- It is used as a fire proofing material.
- Used in the manufacture of black-board chalk.

### 8. Cement

Portland cement is a very important building material. It was first discovered in England. It got its name because on setting, it hardened to a stone-like mass and was compared to the famous Portland Rock of England. It is a mixture of calcium and aluminium silicates with gypsum.

The approximate composition of cement is

Calcium oxide (CaO) = 50 - 60%

Silica ($SiO_2$) = 20 - 25%

Alumina ($Al_2O_3$) = 5 - 10%

Magnesium oxide (MgO) = 2 - 3%

Ferric oxide ($Fe_2O_3$) = 1 - 2%

Sulphur trioxide ($SO_3$) = 1 - 2%

## 9. Glass

Any amorphous and transparent solid that is a product of the solidification of a liquid is called glass. However, glass is generally referred to as the transparent substance obtained when white sand is fused with oxides and carbonates of alkaline earth metals and the molten mixture is cooled. Glass is a super cooled liquid i.e., it is a liquid cooled much below its freezing point. The ordinary room temperature is much below the freezing point of glass.

From Egypt to Alexandria to other European countries and the US, the history of glass dates back to the 17th century and before.

### Manufacture of Glass

### Raw Materials

- Silica (in the form of sand)
- Compounds of alkali metals, like $Na_2CO_3$, $Na_2SO_4$, $NaNO_3$, $K_2CO_3$ and $KNO_3$.
- Compounds of alkaline earth metals, like $CaCO_3$, CaO, $BaCO_3$. (for glass with high refractive index)
- Oxides of heavy metals, like PbO, $Pb_3O_4$
- Calcium phosphate, $Ca_3(PO_4)_2$ (for opalescent glass that also contains arsenic and antimony oxides)
- Colouring materials - Metallic oxides like ferric oxide (yellow), chromic oxide (green), manganese oxide (purple) and cobalt oxide (blue) are added to fused silicates to get coloured glass.

### Properties of Glass

As we have seen, glass is a mixture of number of silicates. Therefore, when heated, it does not melt at a fixed temperature. But, it softens gradually and hence can be moulded into any desired shape. It is this property that makes glass one of the widely used materials.

## Annealing

Glass if cooled rapidly becomes brittle and fragile and if cooled very slowly becomes opaque because of devitrification. For this purpose, before making articles, glass is passed through a long tunnel like furnace that is very hot at one end and very cold at the other. When glass is passed through this furnace, it is progressively cooled. This process is known as annealing and takes several days to be completed.

## Varieties of Glass

### I. Soda Glass

Otherwise known as soft glass

- **Composition**

Sand /Quartz : $SiO_2$ : 75% (will be nice if this can be a mouse over)
Sodium Oxide : $Na_2O$ : 15%
Calcium Oxide : CaO : 8%
Aluminium Oxide : $Al_2O_3$ : 2% (impurity)

**Uses**

Since it softens at a comparatively lower temperature and can be shaped into different forms, it finds use in making windowpanes, bottles, etc.

### II. Potash Glass (Hard Glass)

- **Composition**

Sand /Quartz : $SiO_2$
Potassium oxide : $K_2O$
Calcium Oxide : CaO
Aluminium Oxide : $Al_2O_3$

**Uses**

Has a higher melting point and can withstand higher temperature. Hence it finds use in laboratory ware.

### III. Flint Glass

- **Composition**

Silica : 45%
Sodium oxide : 4%
Potassium oxide : 4%
Calcium oxide : 3%
Lead oxide : 44%

Lead carbonate or oxide replaces calcium carbonate. Potassium carbonate partly replaces sodium carbonate.

**Uses**

It has higher density, transparency and refracting power than ordinary glass. Hence used for making optical instruments. It is also used for ornament purposes.

IV. **Pyrex Glass**

- **Composition**

Silica : 80%
Sodium oxide : 4%
Calcium oxide : 0.5%
Potassium oxide : 0.5%
Boron trioxide :12%
Aluminium trioxide : 3%

**Uses**

It has very low co-efficient of expansion and can withstand sudden changes in temperature. Therefore highly suitable for laboratory ware like flasks, beakers and oven proof cook wares.

V. **Jena Glass**

- It has lesser alkaline and higher alumina content than soda glass. It also contains barium oxide, zinc oxide and boron trioxide instead of silica.

**Uses**

More resistant to the action of acid or alkali. Hence can be used to make acid and alkali containers.

VI. **Crooke's Glass**

- Contains cerium oxide as one of the constituents as one of the constituents.

**Uses**

It is used for optical purposes as it has the capacity to cut off the ultra violetrays.

VII. **Safety Glass or Unbreakable Glass**

- It is prepared by placing a layer of transparent plastic (sheet of vinyl acetate resin) between two layers of glass and sealing the layers with adhesive.

**Uses**

This variety of glass does not break easily under ordinary impact. Even though it breaks under heavy impact, glass pieces are not shattered because they are held by plastic. Therefore it is used in making windscreens of automobiles, aeroplanes and trains. It can also serve as bullet proof glass to some extent.

## 10. Steel

Carbon content of steel is between 0.1 and 1.5%. This is intermediate between cast iron and wrought iron. The hardness of steel increases with increase in carbon content. Steel contains other elements like manganese, chromium, silicon, nickel, tungsten, vanadium, and molybdenum. These elements are added for making steels of different kinds.

### Properties of Steel

The properties of steel depend on the carbon content and the heat treatment imparted to it.

If the carbon content is low, the steel is soft and ductile and is called mild steel.

As the carbon content increases, the ductility decreases, but the tensile strength increase upto 1.5% of carbon content. After that it decreases.

Steel melts at a lower temperature than wrought iron. Adding a little manganese imparts elasticity to steel and if 10% manganese is added, steel becomes very hard. It can be used in making mechanical crushers.

Adding chromium makes steel chemically resistant and is used as stainless steel in utensils, cutlery, surgical tools etc.

### Heat Treatment of Steel

The hardness and elasticity of steel can be controlled by heat treatment. When it is heated to redness and then allowed to cool slowly, it becomes soft. This process is known as **annealing**.

If it is cooled suddenly by plunging into ice-cold water **(quenching)**, steel becomes very hard and brittle. On reheating to 250° - 300°C, the brittleness disappears but the hardness is retained.

The degree of hardness can be controlled by heating the product once again to a temperature ranging from 200° to 350°C and then allowing it cool slowly. This is called **tempering**. Based on the temperature, the colour of the oxide film formed on the surface varies.

| Temperature | Colour |
|---|---|
| 230°C | Pale yellow |
| 260°C | Brown |
| 280°C | Purple |
| 300°C | Blue |

Colour of oxide film formed due to tempering of steel

### Case Hardening

When wrought iron absorbs carbon at the surface, its surface becomes hard. This is called **case-hardening**. This can also be done by heating wrought iron and potassium ferrocyanide. A surface layer of steel is formed on wrought iron. This is used to make armour plates and parts of machinery that face constant wear and tear.

### Nitriding

When steel (containing 1% of aluminium) is heated in an atmosphere of ammonia at 550°C - 600°C, the surface of steel becomes very hard. This is called **nitriding**. Nitrogen formed by the dissociation of ammonia reacts with iron and aluminium to form the respective nitrides on the surface. These nitrides settle in the interstices (an intervening space, crevice) of the iron crystals resulting in a compact and hard surface.

## 11. Calcium Oxide (CaO)

Calcium oxide is commonly called Quick Lime. Quick lime has always been a cheap commodity because limestone deposits are readily available. Lime manufacturing and application dates back to the Roman, Greek and Egyptian civilizations.

### Uses of Lime

- Lime is indispensable for use with mortar and plaster.
- Lime is used for medicinal purposes, insecticides and plant and animal food.
- It is used as a laboratory reagent for gas absorption, precipitation, dehydration etc.
- It is used as a reagent in the manufacture of paper, high grade steel and cement.
- If finds use in dehairing hides.
- It can be used for water softening and in the recovery of ammonia (by-product of Solvay process).
- It finds enormous use in the manufacture of soap, rubber, varnish, refractories and lime bricks.
- It also finds use in the preparation of calcium carbide, basic calcium nitrate and calcium bisulphite.
- Improves the quality of soil.

### 12. Slaked Lime $Ca(OH)_2$

When calcium oxide reacts with water, it liberates heat and cracks into a white powder. This white powder is calcium hydroxide or slaked lime. The process is called slaking of lime.

**Uses**

Calcium hydroxide is used for:

- Testing carbon dioxide ($CO_2$) in laboratories. It turns milky when carbon dioxide is passed into it due to the precipitation of calcium carbonate ($CaCO_3$).
- White washing buildings. This reacts slowly with carbon dioxide ($CO_2$) in the air to form calcium carbonate ($CaCO_3$) on the walls and give a bright appearance.
- Making mortar when mixed with sand and water.
- Preparing bleaching powder, caustic soda (NaOH) and ammonia ($NH_3$).
- Reducing acidity of soil.
- Softening temporary hard water.
- Tanning leather.

**Summary**

| Common name | Chemical name | Formula |
|---|---|---|
| Washing soda | Sodium carbonate decahydrate | $Na_2CO_3.10H_2O$ |
| Baking soda | Sodium bi carbonate | $NaHCO_3$ |
| Quick lime | Calcium oxide | $CaO$ |
| Bleaching powder | Calcium oxychloride | $CaOCl_2$ |
| Slaked lime | Calcium hydroxide | $Ca(OH)_2$ |
| Plaster of Paris | Calcium sulphate hemi hydrate | $(CaSO_4)_2.H_2O$ |
| Gypsum | Calcium sulphate dihydrate | $CaSO_4.2H_2O$ |
| Dead burnt plaster | Calcium sulphate anhydrous | $CaSO_4$ |
| Lime stone | Calcium carbonate | $CaCO_3$ |

Some of the important compounds of sodium and calcium were discussed in this chapter. It may be understood that the properties of similar compounds of other elements in Group I and Group II will resemble the properties of the compounds discussed in this chapter. The fact that the elements are classified in groups help us in understanding their properties and therefore their application in a better perspective.

# 11.Chemistry in Everyday Life

**Chemotherapy**

Chemotherapy is the use of chemicals or drugs to selectively destroy infectious micro-organisms without destroying the live tissues or the host. Paul Ehrlich called drugs as magic bullets and the first milestone of his research was the discovery of Salvarsan for curing syphilis, in 1909. In 1935, Gerhard Domagk, administered a dose of a dye called prontosil (inhibits the growth of streptococci bacteria) to cure his daughter's fever. This laid the foundation for modern chemotherapy and got a Nobel Prize for medicine for Domagk in 1939. Ernest Fourneau, a French scientist in 1936 proved that in the human body, prontosil breaks down to give sulphanilamide. Sulphanilamide is the actual active agent that inhibits streptococci. This study led to the discovery of sulpha drugs and from there on growth of chemotherapy has reached amazing heights.

**Analgesics**

Drugs that are used as pain relievers are called analgesics. They are of two types:

a) Narcotics
b) Non-narcotics

**Narcotics**

These analgesics are mainly opium and its products. Some examples are

- morphine
- codeine and
- heroin.

They are effective analgesics but cause addiction. Over dosage can cause sleep and unconsciousness.

**Non-narcotics**

Drugs belonging to this group also have antipyretic properties (decrease body temperature). **Aspirin** and **analgin** are common drugs in this category.

**Tranquillisers**

Tranquillisers reduce anxiety and tension. They are of two types:

1) Sedatives
2) Antidepressants (mood elevators or Pep pills)

**Sedatives**

Sedatives are used for mentally agitated or violent patients. Equanil (chemical name - meprobanate) and calmpose (diazepam) are a couple of common drugs in this category.

**Antidepressants or Mood Elevators or Pep Pills**

Antidepressants are useful for patients who are highly depressed or have lost self-confidence. These drugs produce a feeling of well-being and improve efficiency. Tofranil, vitalin, amphetamines and cocaine are some examples.

**Antiseptics and Disinfectants**

Sterilization is the process of complete elimination of micro-organisms. The chemicals used for sterilization are classified as:

a) Antiseptics
b) Disinfectants

**Antiseptics**

Antiseptic can be used to kill bacteria or prevent their multiplication. Antiseptics do not harm the living tissues. Therefore, they can be applied on cuts and wounds. Dettol, cetavelon, savlon, acriflavin, gentian-violet, mercuro chrome, boric acid and potassium permanganate are some examples.

**Disinfectants**

Disinfectants are used to kill bacteria. They are used to sterilize instruments, utensils, clothes, floors, sanitary fittings, sputum and excreta. They harm the living tissues and cannot be used on skin. Some examples are phenol, methyl phenol, hydrogen peroxide and sulphur dioxide.

Sometimes the same substance may be used as an antiseptic or disinfectant. When the concentration is less, it is an antiseptic and when the concentration is more, the substance acts as disinfectant. For instance, 0.2% solution of phenol is an antiseptic and 1.0% solution of phenol is a disinfectant.

**Anti-fertility Drugs**

With global population growing by the day, birth control has become essential. There are drugs that control ovulation and if regularly consumed, function as effective contraceptives. Some examples of birth control pills are orthonovum and Enovid. Orthonovum is a mixture of norethindrone and mestranol, estratriene. Envoid is a mixture of norethynodrel and mestranol.

**Antacids**

Tension and mental stress escalate the level of acid in bile juice. This hyperacidity can be combated using bases like calcium carbonate, magnesium hydroxide or aluminium hydroxide in the form of tablets or aqueous suspensions. These react with hydrochloric acid in the stomach and neutralize it partially. Gelusil and Digene are two examples of antacids

**Antihistamines**

Histamine is naturally present in almost all body tissues. When the human body meets substances causing allergies, histamine is released. For e.g., when a person is suffering from hay fever, histamine is released. Amines that are used as drugs to control the allergy caused by histamines are called **Antihistamines**. Histamine release induces allergic responses in the human body like:

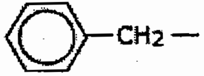
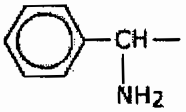
i) Tissue inflammation
ii) Itching
iii) Asthma
iv) Skin irritation

**Antibiotics**

They are produced by micro-organisms that are toxic to other micro organisms. Alexander Fleming in 1920 found that bacteria donot flourish in nutrient agar surrounded by the fungus Penicillium notatum westling. He found that this fungus produces an antibiotic called penicillin. There are many varieties of pencillin with the empirical formula $C_9H_{11}O_4SN_2R$. Penicillin is very effective for:

i) Pneumonia
ii) Bronchitis
iii) Sore throat

Six natural penicillins are isolated till now. They are got by substituting various groups for R.

| Name | Substituent (R) |
|---|---|
| Penicillin G or Benzyl pencillin | R is  |
| Penicillin P | R is $CH_3CH_2CH{=}CH{-}CH_2{-}$ |
| Penicillin K | R is $CH_3{-}(CH_2)_6{-}$ |
| Ampicillin | R is  |

Ampicillin though quite effective, can cause allergy in certain patients.

**Other antibiotics**

Chloramphenicol is a suitable drug for diseases like pneumonia, relapsing fever, typhoid, dysentry, whooping cough and urinary infections.

**Streptomycin**

Streptomycin is very effective against tuberculosis, throat and lung infections, ear and kidney infections as well.

**Tetracyclines**

Tetracyclines (Chloro and oxy) are broad spectrum antibiotics (antibiotics capable of curing many infections) and cure diseases caused by many bacteria, large viruses, protozoa, parasites and rickettsiae. These can be orally administered since they are absorbed from the gastro intestinal tract.

**Dyes - Chromophores**

Unsaturated groups or groups with multiple bonds that impart color to the organic compound are called chromophores. Examples are the nitro, the nitroso and the azo groups.

**Chromogens**

The compounds containing the chromophoric group are called the chromogens. Depth of their color increases with the number of chromophores.

**Auxochromes as Dyes**

Auxochromes (salt forming groups like hydroxyl, amino) do not impart color to the chromogens in the absence of chromophores. However, when the chromogen has a chormophore, the auxochrome deepens the color of the chromogen. It is also used to make the chromogen a dye.

Dyes were obtained from animal and vegetable sources in the earlier days. Today most of the available dyes are prepared synthetically from aromatic compounds.

## Classification of Dyes Based on Application

### Direct or Substantive Dyes

These can be directly applied by immersing the cloth in a hot solution of the dye in water. They can be again classified into acid and basic dyes.

Acid dyes are sodium salts of sulphonic acid and nitrophenols. They are used for dyeing animal fibers (wool and silk) but not vegetable fibers (cotton). The dye solution is acidified with sulphuric or acetic acid.

Basic dyes are salts of color bases with hydrochloric acid or zinc chloride. They can directly dye animal fibers. They need a fixing agent called mordant (tannin) to dye vegetable fibers. These are used for dyeing silk and cotton.

### Mordant or Adjective Dyes

Mordant is any substance that can be fixed to fiber and later dyed on. Hydroxides or basic salts of chromium aluminium or iron are examples. Tannic acid is a suitable mordant for basic dyes. The fabric is first dipped into the solution of mordant and then in the dye solution. An insoluble colored complex called lake is obtained. It is insoluble and fast to washing.

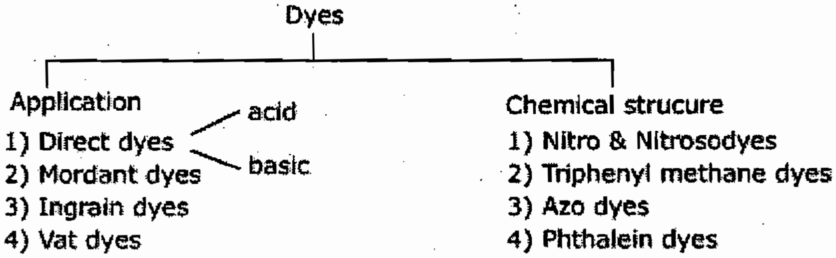
### Ingrain Dyes

They are produced in the fiber itself during dyeing. For example, a cloth is soaked in an alkaline solution of □ - naphthol and dipped in a diazonium salt solution. Azodye is produced on the fiber due to coupling.

### Vat Dyes

These are water insoluble colored compounds. They can be reduced to colorless (leuco) compounds, that are soluble in alkali and are easily reoxidized to give the dye. These dyes dye both animal and vegetable fibers directly. Mostly they are used for cotton fibers. The cloth treated with alkali is oxidised by air which makes the dye return to the insoluble form.

Example: Indigo



## Classification of Dyes Based on Chemical Structure

### Nitro and Nitroso dyes

Oldest synthetic dyes do not have much commercial importance.

### Triphenyl methane dyes

These have brilliant colors but fade with washing and on exposure to light. They are used for coloring paper and typewriter ribbons. By introducing - $NH_2$, $NR_2$, or - OH groups (anxochromes) into the triphenyl methane ring (chromogen) a colorless leuco compound is obtained. The leuco compound gives the tertiary alcohol called the color base (colorless benzenoid compound) on oxidation. This in presence of acid readily changes to the quinonoid dye due to salt formation. We observe reversible changes.

Leuco base --oxidation ⇌ Colour base----acid ⇌ Dye
(colourless) ⇌ reduction----(colourless) ⇌ alkali ---(coloured)

Examples are malachite green, para rosaniline, rosaniline, crystal violet and aurin.

**Azodyes**

They have the same chromophore - N = N -, the azo group. They differ in auxochromes. Common auxochromes are - $NH_2$, $NR_2$ and -OH groups. Examples are aniline yellow, butter yellow, methyl orange, methyl red, resorcin yellow, congo red, chrysoidone, bismark brown.

Phthaleins are got by the condensation of phenol with phthalic anhydride in the presence of dehydrating agent like concentrated sulphuric acid or anhydrous zinc chloride. Examples are phenolphthalein, fluorescein and eosin.

**Natural Dyes (Alizarin and Indigo)**

Dyes can also be classified as natural and synthetic dyes. Compounds extracted from plants are called natural dyes. These were used in olden days to color fabrics. Alizarin (red) and indigo (blue) are two examples. Synthetic dyes came into being to provide more varieties of colors.

Alizarin belongs to the anthraquinone class of dyes. Indigo belongs to the indigoid type of dyes.

**Perfumes**

Perfumes have pleasant smell due to the esters used in their synthesis.

Characteristics of a good perfume are:

Harmonious and lasting smell

- Stability
- Volatility
- Ability to affix in the cosmetic

**Sources of Perfumes**

**Plant Sources**

- Essential oils of
- Flowers
- Leaves

- Fruits
- Roots or wood

**Animal Sources**

- Musk
- Ambergris

**Composition**

**Odoriferous components**

These are essential oils or synthetic substances or both. Constitute 2 -10% of the perfume and impart a pleasant smell to the perfume. Blending many odoriferous components will give a harmonious fragrance.

**Fixatives**

These impart stability by fixing volatile odoriferous substances. Examples are civet, musk, vanillin and castor.

**Solvent**

Solvents dilute the odor causing substances. These solvents should be odorless, volatile, inert and harmless. Ethyl alcohol and water are examples. Components of essential oils such as terpenoids like citronellol, nerol, geraniol are widely used in perfumes.

Perfumes are widely used in soaps, lotions, shampoos, deodorants etc.

**Deodorants**

Decrease or eliminate body odors due to perspiration. Bacterial growth and action on perspiration causes objectionable odors. This odor varies from one person to another and also according to the diet and activity in the same person.

Salts of aluminium, iron and zinc prevent perspiration by their astringent action. Many such salts also have antibacterial properties and therefore are widely used as deodorants.

**Talcum Powder**

All kinds of facial and body powders contain hydrated magnesium silicate (talc - 3 Mg 0.4 $SiO_2.H_2O$). These powders absorb perspiration and superficial skin oil. A good powder should

- spread evenly
- stay on
- have the right degree of opacity (covering power)

**Composition of Talcum Powder**

- Calcium carbonate, magnesium carbonate - Help absorbency
- Titanium dioxide, zinc oxide, magnesium dioxide - Impart opacity

- Talc, metallic soaps - slipping
- Magnesium and zinc stearates - imparts adhesive property

**Talc - Particle Size**

Right grade or particle size of talc is important. A coarse talc has poor adhesiveness and is abrasive.

The particle size of talc should be less than 74 microns for face powder. The powder becomes soft, fluffy, light and transparent when the talc is of the right nature.

Talc can:

- repel water
- slide over with minimum friction because of the flat structure of its particles.

**Role of Magnesium carbonate**

It is about five times more powerful than talc in absorbing water. Hence it is often used to enhance absorbency and lightness of powders.

**Boric acid in Powders**

Boric acid being a germicide and a buffering agent is often added to powders. However, it is not advisable to use powders containing boric acid for babies.

**Micro Alloys**

Micro alloyed steels are intermediate carbon steel alloys with 0.3 to 0.6% carbon content. They also include vanadium, columbium (niobium), titanium and so on. These micro alloys are tougher than higher alloys. Their enhanced strength is due to the precipitation hardening reaction where nitrides or carbonitrides are formed in steel. Therefore, nitrogen level control is a key factor.

Today we have second-generation and third generation micro alloys. These have 0.1 to 0.3 % carbon and 0.15% carbon respectively. These second-generation and third generation micro alloys are tougher than the earlier micro alloy grades.

**Applications**

High performance micro alloys are used in automotive, agricultural, truck and heavy equipment components.

**Chemical Preservatives**

Chemicals added to food materials to prevent the growth of micro organisms or prevent spoilage and to increase their shelf life are called preservatives. Some examples are given below:

1. Sodium benzoate is used as a preservative for fruits, fruit juices, jams and squashes. 0.06% to 0.1% (concentration) of sodium benzoate is added. It is easily soluble in water and therefore readily mixes with the food product.
2. Potassium metabisulphite or sodium metasulphite can also be used as preservative for fruits like apples, lichies and raw mango preparations besides fruit juices. However, these chemicals cannot be used for preserving colored food materials as sulphur dioxide, one of their products, behaves as a bleaching agent with acids. Sulphur dioxide is a very good chemical to kill the harmful micro organisms in food.
3. Vinegar (acetic acid) is usually used as a preservative in pickles.

### Antioxidants

Antioxidants prevent rancidity in oils and fats. For example, butylated hydroxy anisole is a very common antioxidant. Vitamin-E is a natural antioxidant.

### Artificial Sweetening Agents

For diabetic patients, sugar cannot be used as a sweetening agent. Artificial sweetening agents that are non-nutritive in nature are used as substituents for sugar (specially in soft drinks). Examples are saccharin (500 times sweeter than sucrose) and cyclamates.

However cyclamates are suspected to cause cancer and are banned generally.

Aspartame (160 times sweeter than sucrose), another artificial sweetener is the methyl ester of the dipeptide aspartyl phenylalanine.

### Edible Colors and Flavors

Food colors are used in ice creams, dairy products, sweet meat, soft drinks, confectionery, etc. These colors are also used in oral medicines like capsules, tablets, syrups and liquids to improve their appearance. Some of the primary colors are water soluble. They are: quinoline yellow, tartrazine, sunset yellow FCF, erythrosine, poncean 4R, carmoisine, amaranth and brilliant blue.

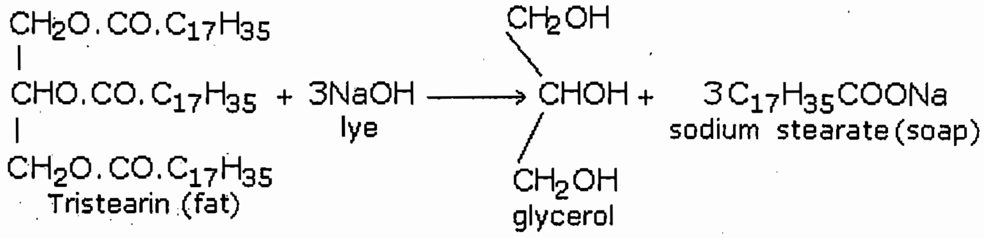
Flavors are used to give pleasant smell for juices, jams etc. Vanillin is used as a flavor. Generally esters are used as flavors

## Soaps and Detergents

Soaps are sodium or potassium salts of higher fatty acids like stearic, palmitic and oleic acids. Fatty acids are organic acids that have more than sixteen carbon atoms in their molecular structure. The sodium soaps are called hard soaps and the potassium soaps are known as soft soaps. Soaps are obtained from oils and fats. For e.g., tristearin is got from beef and mutton tallow, tripalmitin from palm oil and triolein from lard (pig fat), olive oil and cotton seed oil. In India, soap is commonly got from coconut, groundnut, til and mahua oils.

### Manufacture of Soap - Saponification

Saponification is the process where oil or fat (tristearin) is treated with sodium hydroxide solution called lye, to form soap and glycerine.



$$\begin{array}{l} CH_2O.CO.C_{17}H_{35} \\ | \\ CHO.CO.C_{17}H_{35} \\ | \\ CH_2O.CO.C_{17}H_{35} \\ \text{Tristearin (fat)} \end{array} + \underset{\text{lye}}{3NaOH} \longrightarrow \begin{array}{l} CH_2OH \\ \quad \backslash \\ \quad CHOH \\ \quad / \\ CH_2OH \\ \text{glycerol} \end{array} + \underset{\text{sodium stearate (soap)}}{3C_{17}H_{35}COONa}$$

Soap can be manufactured by:

- The hot process
- The cold process
- The modern process

### The Hot Process

Manufacture of soap by the hot process involves the following steps:

**I. Saponification**

Oil or fat is taken in a huge iron-pan called soap kettle and heated with open steam. 10% sodium hydroxide solution (lye) is added in a thin stream. The steam keeps the mass boiling and ensures thorough mixing as well. Saponification is complete after several hours to give a frothy mixture of sodium salts and glycerine.

Fat or Oil + Lye → Soap + Glycerol

**II. Salting out of Soap**

Saponfication is complete when we see a slight excess of the alkali in the transparent reaction mixture. Common salt or brine is then added to precipitate soap and heating is continued. Soap forms in the upper layer as a thick mass. This is known as **salting out of soap**.

The unused alkali solution in the lower layer is called spent lye or sweet lye. This along with glycerol and salts is drawn from below the reaction vessel. Glycerol can be recovered from this.

### III. Finishing

The soap obtained after salting out is boiled again with sodium hydroxide for complete saponificaiton. This converts all the unsaponified fat. The spent lye is then drawn off. The solid soap is then boiled with water to dissolve excess of alkali. It is then allowed to settle when the impure soap called **nigre** forms the lower layer. The pure soap in the upper layer is transferred through a swing pipe to a steam-jacketed tank called crutcher.

It is then shredded into small chips, dried to the requisite amount of moisture content and mixed with colouring substances and perfumes. Some fillers like rosin, sodium silicate, borax and sodium carbonate are added to laundry soaps. They have detergent value and are less expensive than soap.

In the next step, the soap is allowed to run into moulds and permitted to solidify. The bigger blocks are then cut with steel wires into smaller slabs, which are then cut into smaller cakes and stamped.

### The Cold Process

Oil or molten fat is taken in an iron pan fitted with a stirrer. It is then treated with lye (any strong alkaline solution, like potassium hydroxide used for washing or cleansing). Stirring is continued till the soap begins to set. After solidification in frames, it is cut into slabs and further into cakes. All the glycerine remains in the soap. Starch or other fillers are thoroughly mixed with the oil before lye is added. This process is not so economical as the hot process and the soap obtained is also not pure.

### Proportions of Ingredients

| | |
|---|---|
| Alkali | 1 part |
| Water | 7 parts |
| Starch | 1 part |

## Difference between Toilet Soap and Laundry Soap

| Toilet Soap | Laundry Soap |
|---|---|
| High quality fats and oils as raw materials | Cheaper quality fats and oils |
| Expensive perfumes added | Cheap perfumes added |
| Care is taken to ensure that there is no free alkali content to prevent injuries to skin | No such care is taken |
| No fillers | Fillers present |

## Special Varieties of Soap

- Floating Soaps

Made by beating large quantities of air into soap in a crutcher when the soap is in a creamy state

- Transparent Soaps

Contains glycerol or alcohol. Obtained by dissolving soap in alcohol and evaporating the solvent alcohol.

- Medicated Soaps

Medicinal substances added. Examples are neem soap and carbolic soap.

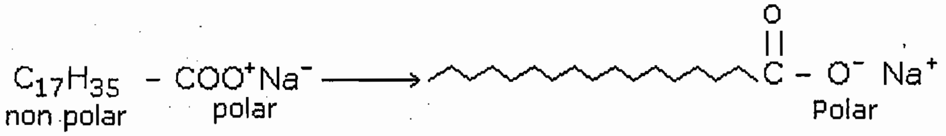
- Shaving Soaps

Potassium sodium stearates (produces lasting lather) containing gum and glycerine to prevent lather drying.

## Cleansing Action of Soap

### Unimolecular film of soap molecules on water surface

A soap has two dissimilar ends. At one end is the hydrocarbon chain that is non-polar and hydrophobic (oil soluble). At the other end there is the carboxylate ion that is polar and hydrophilic (water soluble).



$$C_{17}H_{35} - COO^{+}Na^{-} \longrightarrow \overset{O}{\overset{||}{C}} - O^{-}\ Na^{+}$$

When soap is added to water, its molecules make a unimolecular film on the surface of water with their carboxyl groups dissolved in water and the hydrocarbon chains standing on end to form a hydrocarbon layer

Cleansing action of a soap

When a soiled cloth is soaked in soap solution, soap dissolves dirt (fat or oil with dust absorbed in it) by micelle formation. Micelles are an aggregate of molecules in a colloidal solution. The oil or fat is at the centre of the sphere with fat-soluble hydrocarbon chains of soap dissolved in it. The water soluble carboxylate ions make a hydrophilic surface around this sphere and render the miscelles of oil or fat water-soluble. Thus the micelles are dissolved in water and are washed away. Soap tends to concentrate on the solution surface and therefore lowers its surface tension, causing foaming. This helps it to penetrate the fabric. It emulsifies fat in dirt to form micelles and renders all the micelles water-soluble. Thus the water washes the dirt away.

**Synthetic Detergents**

They possess the desirable properties of ordinary soaps and can be used with hard water and in acidic solutions as well. Synthetic detergents are sodium salts of long chain benzene sulphonic acids or sodium salt of long chain alkyl hydrogen sulphates. Their calcium or magnesium salts are soluble in water.

The hydrophobic part is the hydrocarbon chain and the water soluble part can be:

- An anionic group like sulphate or sulphonate
- A cationic group like amine salt or quaternary ammonium compound
- A non-ionic group like alcohol or ether

Some examples of detergents are as follows:

**Alkyl Sulphates (Anionic)**

- $CH_3(CH_2)_{10}CH_2OSO_3^-Na^+$ - sodium lauryl sulphate
- $CH_3(CH_2)_{16}CH_2OSO_3^-Na^+$ - sodium stearyl sulphate
- Alkyl benzene sulphonates (Anionic)

**Properties**

Some of the synthetic detergents with a branched hydrocarbon chain have very low biodegradability. They are resistant to bacterial attack and are not fully degraded in sewage treatment units. Therefore, they cause water pollution when they are discharged into a river or any other water body. Phosphate salts present in synthetic detergents cause rapid growth of algae that deplete the oxygen content in the water. (A condition known as eutrophication). Due to this aquatic animals die resulting in the imbalance of the ecosystem as well.

These detergents lower the surface tension of water and act as cleansing agents (wetting agents). They can be used for delicate fabrics because they do not hydrolyze to give hydroxyl ions. They have equal action in both hard and soft water.

Composition of a Common Detergent

| | |
|---|---|
| Sodium alkylbenzene sulphonate | 18% |
| Dedusting agent | 3% |
| Foam booster | 3% |
| Sodium tripolyphosphate, builder | 50% |
| Anti-corrosion agent | 6% |
| Optical brightener | 0.3% |
| Water and inorganic filler | 19.7% |

Tripolyphosphate can produce hydroxyl ions by reacting with water. It keeps the wash water slightly alkaline, to emulsify grease particles. They can also tie up calcium and magnesium ions that cause hardness of water.

**Advantages of Detergents Over Soaps**

Soaps are not suitable when hard water is used. Detergents can be used with both hard and soft water. Detergents are more soluble in water than soaps. They also have a stronger cleansing action than soaps. Detergents do not need expensive vegetable oil for their preparation as they can be prepared from hydrocarbons of petroleum. They can be used in acidic solutions whereas soaps cannot be used (free fatty acids are precipitated).

| Soaps | Detergents |
|---|---|
| Soaps are sodium salts of higher fatty acids | Detergents are sodium salts of long chain benzene sulphonic acid or the sodium salts of a long chain alkyl hydrogen sulphate |
| Calcium and magnesium salts of soaps are in soluble in water. Therefore cleansing action of soap reduces in hard water | Calcium and magnesium salts of detergents are soluble in water. Therefore cleansing action of detergents remain unaffected in hard water |
| Soaps are prepared from natural oils and fats | Synthetic detergents are prepared from hydrocarbons of petroleum |

| | |
|---|---|
| Soaps cannot be used in acidic medium | Detergents can be used in acidic medium |
| Soaps are biodegradable | Most of the detergents are non-biodegradable |

# Dry cleaning

**Dry cleaning** is any cleaning process for clothing and textiles using an organic solvent rather than water. The solvent used is typically tetrachloroethylene (perchloroethylene), abbreviated "perc" in the industry and "dry-cleaning fluid" by the public. Dry cleaning is necessary for cleaning items which would otherwise be damaged by water and soap or detergent. It may be used if hand washing— needed for some delicate fabrics — is excessively laborious.

## Solvents used:

### Modern

- **Glycol ethers** (dipropylene glycol tertiary-butyl ether) (Rynex) — In many cases more effective than perchloroethylene (perc) and in all cases more environmentally friendly.
- **Hydrocarbon** — This is most like standard dry cleaning, but the processes use hydrocarbon solvents such as Exxon-Mobil's DF-2000 or Chevron Phillips' EcoSolv. These petroleum-based solvents are less aggressive than perc and require a longer cleaning cycle.
- **Liquid silicone** (decamethylcyclopentasiloxane or D5) — gentler on garments than Perc and does not cause color loss.
- **Modified hydrocarbon blends** (Pure Dry)
- **Perchloroethylene** — In use since the 1940s, perc is the most common solvent, the "standard" for cleaning performance, and most aggressive cleaner. It can cause color bleeding/loss, especially at higher temperatures, and may destroy special trims, buttons, and beads on some garments. Better for oil-based stains (which account for about 10% of stains) than more common water-soluble stains (coffee, wine, blood, etc). Known for leaving a characteristic chemical smell on garments. Nonflammable.
- **Liquid $CO_2$** — superior to conventional methods, but the Drycleaning and Laundry Institute commented on its "fairly low cleaning ability" in a 2007 report.
- **Wet cleaning** — Not a solvent, but a system that uses water and biodegradable soap. Computer-controlled dryers and stretching machines ensure that the fabric retains its natural size and shape. Wet cleaning is

claimed to clean a majority of "dry clean only" garments safely, including leather, suede, most tailored woolens, silk and rayon. (Neckties seem to be the one exception.)

### Historical

- Carbon tetrachloride — Toxic and corrosive.
- Trichloroethane — Overly aggressive and harsh.
- Stoddard solvent — Very flammable and explosive.
- CFC-113 - Freon — Ozone destroying CFC.

## Rocket Propellants

Propellants are the fuels used in rockets for propulsion. For example, alcohol, liquid hydrogen, liquid ammonia, kerosene, hydrazine and paraffin can be used as propellants.

To burn them, rocket fuels require an oxidising agent. Examples are: liquid oxygen, liquid fluorine, dinitrogen tetroxide ($N_2O_4$), nitric acid ($HNO_3$), a nitrate, chlorate or perchlorate.

There are two types of propellants:

### Solid Propellants

Solid propellants are a mixture of solid hydrocarbon and an oxidising agent. This oxidising agent is stable at room temperature. For example, a mixture of paraffin and potassium nitrate ($KNO_3$). Paraffin is the solid hydrocarbon and $KNO_3$ acts as the oxidising agent. These are divided into:

- Composite and
- Double base propellants

### Composite Propellants

They consist of a polymeric binder (polyurethane or polybutadiene) and ammonium perchlorate (oxidiser). Additives like finely divided aluminium or magnesium enhance their performance.

### Double Base Propellants

Double base propellants mainly use nitroglycerine and nitrocellulose. These two together constitute a gel to give a semisolid mass.

**Disadvantage**

Fire caused due to the burning of solid propellants is very difficult to control.

**Liquid Propellants**

Liquid propellants are widely used as rocket fuels. They can be monopropellants or biliquid propellants based on the number of liquids in the propellant mixture.

**Advantages**

- They give better thrust than solid propellants
- By propellant flow regulation, thrust can be controlled

A mixture of liquid oxygen and liquid hydrogen is one of the most important liquid propellants. Oxygen burns liquid hydrogen to produce heat energy.

Liquid propellant examples are alcohols, liquid ammonia, kerosene, hydrazine (unsymmetrical dimethyl hydrazine - UDMH and monomethyl hydrazine - MMH)

Oxiding agents can be liquid oxygen, liquid fluorine, hydrogen peroxide and nitric acid.

**Hybrid Propellant**

When the propellant has a solid fuel and a liquid oxidiser composition, it is called a hybrid propellant.

Example: A mixture of acrylic rubber and liquid dinitrogen tetraoxide

**Characteristics of Propellants**

A good rocket propellant must

- produce large volumes of gases for every gram of fuel which undergoes combustion
- burn at a fast rate
- burn completely without leaving behind residue or ash (dead weight)
- have high calorific value for high efficiency of fuel

**Principle**

When the fuel is ignited, combustion occurs. The liberated gases pass through the nozzle of the rocket motor, providing the necessary thrust for the rocket to lift and take off.

**Insect Repellents**

The chemicals like dimethyl phthalate, N, N-diethyl - meta - toulamide (Deet), N - N - diethyl benzamide are used as effective repellents against mosquitoes, flies and other insects. These are widely used in insect repellant body creams.

**Pheromones or Sex Attractants**

Another way to get rid of insects is to use pheromones or insect sex attractants. These chemicals help induce the mating urge and attract insects of opposite sex. When coated on poisonous baits, they prove fatal for insects. Methyl engenol attracts the oriental fruit fly. Bombykol attracts the silk worm moth.

Insects like pink bollworms, cabbage loopers and natural silk worm moth are attracted by these pheromones.

## Commercially Important Condensation Polymers

**Polyesters**

Polymers with ester linkage are called polyesters.

**Terylene or Dacron**

Terylene or Dacron is manufactured from ethylene glycol and terephthalic acid. The reaction is carried out at 420 - 460 K in the presence of catalyst zinc acetate and antimony trioxide.

**Properties**

Terylene forms strong fibers. It is crease resistant, has high moisture absorption and has a high tensile strength.

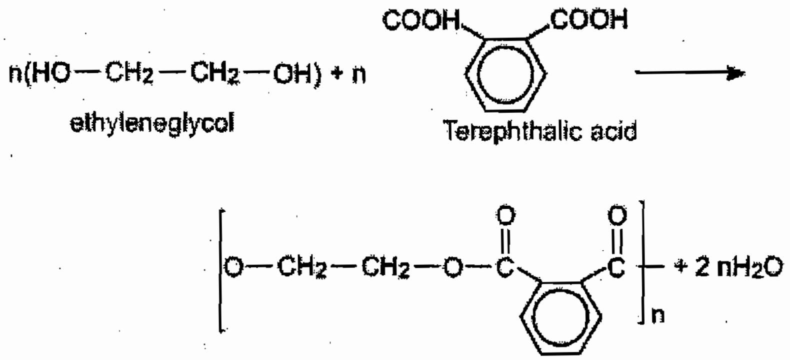
**Uses**

i) Making wash and wear garments.

ii) In seat belts and sails.

**Glyptal or Alkyl Resin**

**Preparation :**



**Property**

It is a thermoplastic. It dissolves in suitable solvent and the solution on evaporation leaves a tough but non flexible film.

**Uses**

It is used in the manufacture of paints and lacquers.

**Polyamides**

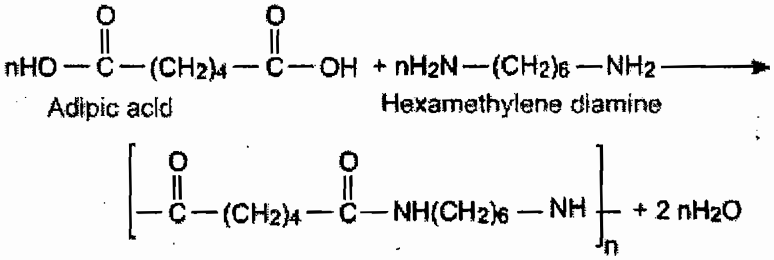
Polyamides are polymers with amide linkage (-NH-CO-).

**Nylon-66**

In Nylon-66 both monomers have 6 carbon atoms each and hence the name.

**Preparation of Nylon-66**

Here the polyamide Nylon-66 is formed by heating the reactant mixture under pressure and the process has been developed so that the molecular mass of the polymer is controlled in the range of 12,000 to 20,000 amu.



$$nHO-\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-OH + nH_2N-(CH_2)_6-NH_2 \longrightarrow \left[-\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-NH(CH_2)_6-NH-\right]_n + 2\,nH_2O$$

**Properties of Nylon-66**

High tensile strength, tough, abrasion resistant and elastic.

**Uses of Nylon-66**

It is fabricated into sheets, bristles for brushes and in textiles as crinkled nylon fibers that are used for making elastic hosiery.

**Nylon-6 or (perlon)**

**Preparation**

Nylon-6 is prepared from the monomer caprolactum which is obtained from cyclohexane (petrochemical). Since caprolactum is more easily available, it is used for polymerization which is carried out in the presence of water that first hydrolyses the caprolactum to amino acid. Subsequently the amino group of the amino acid can react with caprolactum to form the polyamide polymer. Filaments of Nylon-6 are obtained by melt-spinning of the polymer. The fibers are cooled by a stream of air.

**Uses of Nylon-6**

i) Nylons are insoluble in common solvents, have good strength and absorb little moisture.
ii) It is used for tyre cords, fabrics, ropes, carpets and manufacture of garments.

## Formaldehyde Resins

### Bakelite (Phenol Formaldehyde Resin)

Bakelite is made from phenol and formaldehyde in the presence of a base catalyst. It involves formation of methylene bridges at the ortho and para positions. The reaction starts with the initial formation of ortho and/or para-hydroxymethyl phenol derivatives which further react with phenol to form compounds where the rings are formed to each other with -$CH_2$ groups.

Thus linear and cross linked material can be prepared. Cross linked bakelite is a thermosetting polymer.

On further heating with HCHO, novalac undergoes cross-linking to an infusible solid called bakelite. It is hard scratch and water resistant.

**Soft bakelite (Low degree of polymerization)**

Used as bonding for laminated wooden planks and in varnish and paint.

**Hard bakelite (High degree of polymerization)**

It possesses excellent electrical insulating character and hence its major use in making electrical goods.

Used to make combs, fountain pen barrels, gramophone records, electric goods, formica table tops. Sulphonated bakelites are used as ion exchange resins.

### Melamine Formaldehyde Resins

**Uses**

Hard and unbreakable - so used to make non-breakable plastic crockery i.e., cups and plates that do not break on being dropped.

### Natural Rubber

Natural rubber is an excellent example of a natural polymer and an **elastomer** in particular. Elastomers are substances that can be readily stretched. They retract rapidly to their original form when released. It undergoes long range reversible extension under relatively small applied force. This elasticity makes it valuable for variety of uses. Natural rubber is also called plantation rubber.

**Preparation**

Latex, the white milky liquid obtained by making a cut in the rubber tree contains 30%-40% of rubber and is a colloidal solution of rubber in water. This is coagulated (changed from fluid to solid state or clotting) with acetic or formic acid and can then be squeezed, rolled, milled and vulcanized.

**Vulcanization of Rubber**

Charles Goodyear discovered the process of vulcanization in 1893 to modify the properties of natural rubber. Vulcanization is the addition of right amount of sulphur to natural rubber to impart high elasticity, tensile strength and resistance to abrasion.

### Synthetic Rubbers

Synthetic rubbers are made by the polymerization of dienes, in the presence of Zeigler-Natta catalyst. These rubbers are tougher, more flexible and more durable than natural rubbers.

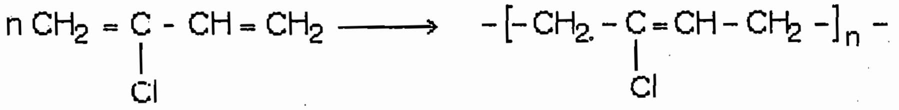
### Polymerization of 1,3 - butadiene

Synthetic rubbers are either homopolymers of 1,2-butadiene derivatives or are copolymers in the formation of which one of the monomers is 1,3-butadiene or its derivative so that the polymer has the availability of double bonds for its vulcanization.

Synthetic or artificial rubbers are also polymers. They are not natural rubbers and are superior to natural rubber.

### Neoprene or Polychloroprene

The first commercially successful rubber substitute, manufactured in the US is neoprene (1931). It is prepared by the polymerization of chloroprene (2-chlorobutadiene).



$$n\,CH_2=\underset{Cl}{\underset{|}{C}}-CH=CH_2 \longrightarrow -[-CH_2-\underset{Cl}{\underset{|}{C}}=CH-CH_2-]_n-$$

chloroprene (2-chlorobutadiene) neoprene

Commonly used synthetic rubbers are Buna-S, Buna-N and neoprene.

### Properties of Neoprene

Neoprene is superior to natural rubber because of the following properties:

- Neoprene is non-inflammable but natural rubber is inflammable.
- Neoprene is resistant to oils, organic solvents, petrol and grease. Natural rubber swells and rots in contact with these materials.
- Neoprene is stable even at high temperatures. Natural rubber retains its usefulness only over a low range of temperatures.
- Neoprene does not require vulcanization like natural rubber.
- Neoprene is resistant to the action of oxygen and ozone. Natural rubber deteriorates when exposed to oxygen.

- Neoprene is a thermoplastic. It need not be vulcanized but can be compounded with other suitable ingredients like magnesia, wood resin and zinc oxide before using.

### Uses of Neoprene

Neoprene is used for making transmission belts, printing rolls and flexible tubing for carrying oil and petrol. It is also used as insulator making conveyor belts and printing rollers.

### Biopolymers

Nature has many polymeric species which are essential for life and are called biopolymers. Polysaccharides, proteins and nucleic acids are examples.

### Biodegradable Polymers

The large scale use of synthetic polymers has been based on their relative inertness to environmental process so that degradation reactions leading to any change in the properties of the polymer during the service life of its product does not occur. It is due to this property that management of polymeric waste has become so difficult that use of polymers has created acute environmental problems.

In biological systems, biopolymers degrade mainly by enzymatic hydrolysis and to some extent by oxidation. Biodegradable synthetic polymers have been developed which are safe for use by humans and disposal of polymer waste does not arise.

These synthetic polymers mostly have functional groups prevalent in biopolymers and lipids.

Aliphatic polyesters are one important class of biodegradable polymers as several of them are commercially potential biomaterials.

### Poly-hydroxybutyrate-co-□-hydroxyvalerate

(PHBV) is a copolymer of 3-hydroxybutanoic acid and 3-hydroxypentanoic acid, in which the monomer units are connected by ester linkages.

The properties of PHBV vary according to the ratio of both the acids.

3-hydroxybutanoic acid provides stiffness and 3-hydroxypentanoic acid imparts flexibility to the copolymer.

It is used in specialty packaging, orthopaedic devices and even in controlled drug release. When a drug is put into a capsule of PHBV it is released only after the polymer is degraded. PHBV also undergoes bacterial degradation in the environment.

### Poly (Glycolic acid) and poly lactic acid

Poly (Glycolic Acid) and Poly Lactic Acid are commercially successful biodegradable polymers such as sutures. Dextrin was the first bio absorbable suture made from biodegradable polyesters for post-operative stitches.

**Nylon-2-Nylon-6**

Nylon-2-Nylon-6 an alternating polyamide copolymer of glycine and amino caproic acid and is biodegradable

## Fuel Types.

Unleaded Petrol (ULP) ULP has a Research Octane Number (RON) of between 91 and 93.

### Premium Unleaded Petrol (PULP)

PULP is a special blend of petrol designed to bring high octane, and hence high engine power, as well as knock- free performance to unleaded cars with a high-octane requirement. Most petrol companies have a specially named version of PULP PULP has a Research Octane Number (RON) of 95.

### Diesel

Diesel engines are usually very efficient engines, offering better fuel economy in comparison to equivalent petrol models. Diesel engines emit very low levels of exhaust hydrocarbons and carbon monoxide when correctly tuned and maintained. The main concern diesel engines raise is the smoke they emit, which can be a health hazard.

### Liquefied Petroleum Gas (LPG)

LPG, most commonly a blend of propane and butane, is an environmentally cleaner fuel compared to petrol and diesel. It is the most widely accepted alternative fuel for the automotive sector.

Despite LPG cars having lower fuel economy compared to petrol-powered vehicles, fuel costs will usually be

### 98 RON

98 RON has a Research Octane Number (RON) of 98. It is a high-octane unleaded fuel that maximizes engine power and performance, as well as producing

less pollution. It is more commonly used by imported and high performance vehicles

98 RON is promoted as providing excellent fuel economy. It has low levels of benzene, sulphur and lower aromatics and a sulphur content which is 10 times lower than the national standard for unleaded fuels.

### Biodiesel and Biodiesel Blends (B20 diesel)

Biodiesel is 100% biodiesel fuel and is referred to as B100 or “neat biodiesel”. Biodiesel is made from natural renewable sources and can be blended in almost any ratio with petroleum based diesel. Biodiesel blends are often known by the ratio of biodiesel to regular diesel i.e. B20 means 20% biodiesel and 80% petroleum based diesel. The most common blends available internationally are B5 (a mix of 5% biodiesel and 95% petroleum based diesel) and B20 (a mix of 20% biodiesel and 80% petroleum based diesel).

### Ethanol

Ethanol is made from natural renewable sources and can be blended with petroleum based unleaded fuels. Ethanol is pure 100% ethanol, referred to as E100 or "neat ethanol". Ethanol blends are often known by the ratio of ethanol to regular petrol i.e. E10 means a mix of 10% ethanol and 90% unleaded petrol.

### Lead Replacement Petrol (LRP)

Now phased out, LRP (96 RON) was introduced as an environmental alternative for cars that used leaded petrol. LRP was refined to contain no lead, along with lower concentrations of benzene and sulphur, respectively identified as health hazards and pollutants. Lead was historically added to petrol as a cost-effective way of increasing octane and hence engine power rating and providing a measure of engine protection by way of its lubricating qualities.

### Rocket propellant

**Rocket propellant** is mass that is stored, usually in some form of propellant tank, prior to being used as the propulsive mass that is ejected from a rocket engine in the form of a fluid jet to produce thrust.

Chemical rocket propellants are most commonly used, which undergo exothermic chemical reactions which produce hot gas which is used by a rocket for propulsive purposes.

The first stage will usually use high-density (low volume) propellants to reduce the area exposed to atmospheric drag and because of the lighter tankage and higher thrust/weight ratios. Thus, the Apollo-Saturn V first stage used kerosene-liquid oxygen rather than the liquid hydrogen-liquid oxygen used on the upper stages (hydrogen is highly energetic per kilogram, but not per cubic metre).

### Chemical propellants

There are three main types of propellants: solid, liquid, and hybrid.

### Solid propellants

The earliest rockets were created hundreds of years ago by the Chinese, and were used primarily for fireworks displays and as weapons. They were fueled with black powder, a type of gunpowder consisting of a mixture of charcoal, sulfur and potassium nitrate (saltpeter). Rocket propellant technology did not advance until the end of the 19th century, by which time smokeless powder had been developed, originally for use in firearms and artillery pieces. Smokeless powders and related compounds have seen use as double-base propellants.

Solid propellants (and almost all rocket propellants) consist of an oxidizer and a fuel. In the case of gunpowder, the fuel is charcoal, the oxidizer is potassium nitrate, and sulfur serves as a catalyst. (Note: sulfur is not a true catalyst in gunpowder as it is consumed to a great extent into a variety of reaction products such as $K_2S$. The sulfur acts mainly as a sensitizer lowering threshold of ignition.) During the 1950s and 60s researchers in the United States developed what is now the standard high-energy solid rocket fuel. The mixture is primarily ammonium perchlorate powder (an oxidizer), combined with fine aluminium powder (a fuel), held together in a base of PBAN or HTPB (rubber-like fuels). The mixture is formed as a liquid, and then cast into the correct shape and cured into a rubbery solid. Solid fueled rockets are much easier to store and handle than liquid fueled rockets, which makes them ideal for military applications. In the 1970s and 1980s the U.S. switched entirely to solid-fuelled ICBMs: the LGM-30 Minuteman and LG-118A Peacekeeper (MX). In the 1980s and 1990s, the USSR/Russia also deployed solid-fuelled ICBMs (RT-23, RT-2PM, and RT-2UTTH), but retains two liquid-fuelled ICBMs (R-36 and UR-100N). All solid-fuelled ICBMs on both sides have three initial solid stages and a precision maneuverable liquid-fuelled bus used to fine tune the trajectory of the reentry vehicle.

Their simplicity also makes solid rockets a good choice whenever large amounts of thrust are needed and cost is an issue. The Space Shuttle and many other orbital launch vehicles use solid fuelled rockets in their first stages (solid rocket boosters) for this reason.

However, solid rockets have a number of disadvantages relative to liquid fuel rockets. Solid rockets have a lower specific impulse than liquid fueled rockets. It is also difficult to build a large mass ratio solid rocket because almost the entire rocket is the combustion chamber, and must be built to withstand the high combustion pressures. If a solid rocket is used to go all the way to orbit, the payload fraction is very small. (For example, the Orbital Sciences Pegasus rocket is an air-launched three-stage solid rocket orbital booster. Launch mass is 23,130 kg, low earth orbit payload is 443 kg, for a payload fraction of 1.9%. Compare to a Delta IV Medium, 249,500 kg, payload 8600 kg, payload fraction 3.4% without air-launch assistance.)

A drawback to solid rockets is that they cannot be throttled in real time, although a predesigned thrust schedule can be created by altering the interior propellant geometry.

Solid rockets can often be shut down before they run out of fuel. Essentially, the rocket is vented or an extinguishant injected so as to terminate the combustion process. In some cases termination destroys the rocket..

### Liquid propellants

Liquid fueled rockets have better specific impulse than solid rockets and are capable of being throttled, shut down, and restarted. Only the combustion chamber of a liquid fueled rocket needs to withstand combustion pressures and temperatures. On vehicles employing turbopumps, the fuel tanks carry very much less pressure and thus can be built far more lightly, permitting a larger mass ratio. For these reasons, most orbital launch vehicles and all first- and second-generation ICBMs use liquid fuels for most of their velocity gain.

The primary performance advantage of liquid propellants is the oxidizer. Several practical liquid oxidizers (liquid oxygen, nitrogen tetroxide, and hydrogen peroxide) are available which have much better specific impulse than ammonium perchlorate when paired with comparable fuels.

Most liquid propellants are also cheaper than solid propellants. For orbital launchers, the cost savings do not, and historically have not mattered; the cost of fuel is a very small portion of the overall cost of the rocket, even in the case of solid fuel.

The main difficulties with liquid propellants are also with the oxidizers. These are generally at least moderately difficult to store and handle due to their high reactivity with common materials, may have extreme toxicity (nitric acids), moderately cryogenic (liquid oxygen), or both (liquid fluorine, FLOX- a fluorine/LOX mix). Several exotic oxidizers have been proposed: liquid ozone ($O_3$), $ClF_3$, and $ClF_5$, all of which are unstable, energetic, and toxic.

Liquid fuelled rockets also require potentially troublesome valves and seals and thermally stressed combustion chambers, which increase the cost of the rocket. Many employ specially designed turbopumps which raise the cost enormously due to difficult fluid flow patterns that exist within the casings.

Though all the early rocket theorists proposed liquid hydrogen and liquid oxygen as propellants, the first liquid-fuelled rocket, launched by Robert Goddard on March 16, 1926, used gasoline and liquid oxygen. Liquid hydrogen was first used by the engines designed by Pratt and Whitney for the Lockheed CL-400 Suntan reconnaissance aircraft in the mid-1950s. In the mid-1960s, the Centaur and Saturn upper stages were both using liquid hydrogen and liquid oxygen.

The highest specific impulse chemistry ever test-fired in a rocket engine was lithium and fluorine, with hydrogen added to improve the exhaust thermodynamics (making this a tripropellant). The combination delivered 542 seconds (5.32 kN·s/kg, 5320 m/s) specific impulse in a vacuum. The impracticality of this chemistry highlights why exotic propellants are not actually used: to make all three components liquids, the hydrogen must be kept below -252 °C (just 21 K) and the lithium must be kept above 180 °C (453 K). Lithium and fluorine are both extremely corrosive, lithium ignites on contact with air, fluorine ignites on contact with most fuels, and hydrogen, while not hypergolic, is an explosive hazard. Fluorine and the hydrogen fluoride (HF) in the exhaust are very toxic, which damages the environment, makes work around the launch pad difficult, and makes getting a launch license that much more difficult. The rocket exhaust is also ionized, which would interfere with radio communication with the rocket.

The common liquid propellant combinations in use today:

- LOX and kerosene (RP-1). Used for the lower stages of most Russian and Chinese boosters, the first stages of the Saturn V and Atlas V, and all stages of the developmental Falcon 1 and Falcon 9. Very similar to Robert Goddard's first rocket. This combination is widely regarded as the most practical for civilian orbital launchers.

- LOX and liquid hydrogen, used in the Space Shuttle, the Centaur upper stage, Saturn V upper stages, the newer Delta IV rocket, the H-IIA rocket, and most stages of the European Ariane rockets.
- Nitrogen tetroxide ($N_2O_4$) and hydrazine ($N_2H_4$), MMH, or UDMH. Used in military, orbital and deep space rockets, because both liquids are storable for long periods at reasonable temperatures and pressures. This combination is hypergolic, making for attractively simple ignition sequences. The major inconvenience is that these propellants are highly toxic, hence they require careful handling. Hydrazine also decomposes energetically to nitrogen, hydrogen, and ammonia, making it a fairly good monopropellant.

### Gas propellants

A gas propellant usually involves some sort of compressed gas. However, due to the low density and high weight of the pressure vessel, gases see little current use.

### Hybrid propellants

A hybrid rocket usually has a solid fuel and a liquid or gas oxidizer. The fluid oxidizer can make it possible to throttle and restart the motor just like a liquid fuelled rocket. Hybrid rockets are also cleaner than solid rockets because practical high-performance solid-phase oxidizers all contain chlorine, versus the more benign liquid oxygen or nitrous oxide used in hybrids. Because just one propellant is a fluid, hybrids are simpler than liquid rockets.

Hybrid motors suffer two major drawbacks. The first, shared with solid rocket motors, is that the casing around the fuel grain must be built to withstand full combustion pressure and often extreme temperatures as well. However, modern composite structures handle this problem well, and when used with nitrous oxide or hydrogen peroxide relatively small percentage of fuel is needed anyway, so the combustion chamber is not especially large.

The primary remaining difficulty with hybrids is with mixing the propellants during the combustion process. In solid propellants, the oxidizer and fuel are mixed in a factory in carefully controlled conditions. Liquid propellants are generally mixed by the injector at the top of the combustion chamber, which directs many small swift-moving streams of fuel and oxidizer into one another. Liquid fuelled rocket injector design has been studied at great length and still resists reliable performance prediction. In a hybrid motor, the mixing happens at the melting or evaporating surface of the fuel. The mixing is not a well-controlled process and generally quite a lot of propellant is left unburned[citation needed], which limits the efficiency and thus the exhaust velocity of the motor. Additionally, as the burn continues, the hole down the center of the grain (the 'port') widens and the mixture ratio tends to become more oxidiser rich.

There has been much less development of hybrid motors than solid and liquid motors. For military use, ease of handling and maintenance have driven the use of solid rockets. For orbital work, liquid fuels are more efficient than hybrids and most development has concentrated there. There has recently been an increase in hybrid motor development for nonmilitary suborbital work.

## Chemical Names of Common Substances

### Alternate Words for Familiar Materials

Chemical or scientific names are used to give an accurate description of a substance's composition. Even so, you rarely ask someone to pass the sodium chloride at the dinner table. It's important to remember that common names are inaccurate and vary from one place and time to another. Therefore, don't assume that you know the chemical composition of a substance based on its common name. This is a list of archaic names and common names for chemicals, with their modern or IUPAC equivalent name.

| **Common Name** | **Chemical Name** |
|---|---|
| acetone | dimethyl ketone; 2-propanone (usually known as acetone) |
| acid potassium sulfate | potassium bisulfate |
| acid of sugar | oxalic acid |
| ackey | nitric acid |
| alcali volatil | ammonium hydroxide |
| alcohol, grain | ethyl alcohol |
| alcohol sulfuris | carbon disulfide |
| alcohol, wood | methyl alcohol |
| alum | aluminum potassium sulfate |
| alumina | aluminum oxide |
| antichlor | sodium thiosulfate |

| | |
|---|---|
| antimony black | antimony trisulfide |
| antimony bloom | antimony trioxide |
| antimony glance | antimony trisulfide |
| antimony red (vermillion) | antimony oxysulfide |
| aqua ammonia | aqueous solution of ammonium hydroxide |
| aqua fortis | nitric acid |
| aqua regia | nitrohydrochloric acid |
| aromatic spirit of ammonia | ammonia in alcohol |
| arsenic glass | arsenic trioxide |
| azurite | mineral form of basic copper carbonate |
| asbestos | magnesium silicate |
| aspirin | acetylsalicylic acid |
| baking soda | sodium bicarbonate |
| banana oil (artificial) | isoamyl acetate |
| barium white | barium sulfate |
| benzol | benzene |
| bicarbonate of soda | sodium hydrogen carbonate or sodium bicarbonate |
| bichloride of mercury | mercuric chloride |
| bichrome | potassium dichromate |
| bitter salt | magnesium sulfate |
| black ash | crude form of sodium carbonate |
| black copper oxide | cupric oxide |
| black lead | graphite (carbon) |
| blanc-fixe | barium sulfate |
| bleaching powder | chlorinated lime; calcium hypochlorite |
| blue copperas | copper sulfate (crystals) |
| blue lead | lead sulfate |
| blue salts | nickel sulfate |

| | |
|---|---|
| blue stone | copper sulfate (crystals) |
| blue vitriol | copper sulfate |
| bluestone | copper sulfate |
| bone ash | crude calcium phosphate |
| bone black | crude animal charcoal |
| boracic acid | boric acid |
| borax | sodium borate; sodium tetraborate |
| bremen blue | basic copper carbonate |
| brimstone | sulfur |
| burnt alum | anhydrous potassium aluminum sulfate |
| burnt lime | calcium oxide |
| burnt ochre | ferric oxide |
| burnt ore | ferric oxide |
| brine | aqueous sodium chloride solution |
| butter of antimony | antimony trichloride |
| butter of tin | anhydrous stannic chloride |
| butter of zinc | zinc chloride |
| calomel | mercury chloride; mercurous chloride |
| carbolic acid | phenol |
| carbonic acid gas | carbon dioxide |
| caustic lime | calcium hydroxide |
| caustic potash | potassium hydroxide |
| caustic soda | sodium hydroxide |
| chalk | calcium carbonate |
| Chile saltpeter | sodium nitrate |
| Chile nitre | sodium nitrate |
| Chinese red | basic lead chromate |
| Chinese white | zinc oxide |

| | |
|---|---|
| chloride of soda | sodium hypochlorite |
| chloride of lime | calcium hypochlorite |
| chrome alum | chromic potassium sulfate |
| chrome green | chromium oxide |
| chrome yellow | lead (VI) chromate |
| chromic acid | chromium trioxide |
| copperas | ferrous sulfate |
| corrosive sublimate | mercury (II) chloride |
| corundum (ruby, sapphire) | chiefly aluminum oxide |
| cream of tartar | potassium bitartrate |
| crocus powder | ferric oxide |
| crystal carbonate | sodium carbonate |
| dechlor | sodium thiophosphate |
| diamond | carbon crystal |
| emery powder | impure aluminum oxide |
| epsom salts | magnesium sulfate |
| ethanol | ethyl alcohol |
| farina | starch |
| ferro prussiate | potassium ferricyanide |
| ferrum | iron |
| flores martis | anhydride iron (III) chloride |
| fluorspar | natural calcium fluoride |
| fixed white | barium sulfate |
| flowers of sulfur | sulfur |
| 'flowers of' any metal | oxide of the metal |
| formalin | aqueous formaldehyde solution |
| French chalk | natural magnesium silicate |
| French vergidris | basic copper acetate |

| | |
|---|---|
| galena | natural lead sulfide |
| Glauber's salt | sodium sulfate |
| green verditer | basic copper carbonate |
| green vitriol | ferrous sulfate crystals |
| gypsum | natural calcium sulfate |
| hard oil | boiled linseed oil |
| heavy spar | barium sulfate |
| hydrocyanic acid | hydrogen cynanide |
| hypo (photography) | sodium thiosulfate solution |
| Indian red | ferric oxide |
| Isinglass | agar-agar gelatin |
| jeweler's rouge | ferric oxide |
| killed spirits | zinc chloride |
| lampblack | crude form of carbon; charcoal |
| laughing gas | nitrous oxide |
| lead peroxide | lead dioxide |
| lead protoxide | lead oxide |
| lime | calcium oxide |
| lime, slaked | calcium hydroxide |
| limewater | aqueous solution of calcium hydroxide |
| liquor ammonia | ammonium hydroxide solution |
| litharge | lead monoxide |
| lunar caustic | silver nitrate |
| liver of sulfur | sufurated potash |
| lye or soda lye | sodium hydroxide |
| magnesia | magnesium oxide |
| manganese black | manganese dioxide |
| marble | mainly calcium carbonate |

| | |
|---|---|
| mercury oxide, black | mercurous oxide |
| methanol | methyl alcohol |
| methylated spirits | methyl alcohol |
| milk of lime | calcium hydroxide |
| milk of magnesium | magnesium hydroxide |
| milk of sulfur | precipitated sulfur |
| "muriate" of a metal | chloride of the metal |
| muriatic acid | hydrochloric acid |
| natron | sodium carbonate |
| nitre | potassium nitrate |
| nordhausen acid | fuming sulfuric acid |
| oil of mars | deliquescent anhydrous iron (III) chloride |
| oil of vitriol | sulfuric acid |
| oil of wintergreen (artificial) | methyl salicylate |
| orthophosphoric acid | phosphoric acid |
| Paris blue | ferric ferrocyanide |
| Paris green | copper acetoarsenite |
| Paris white | powdered calcium carbonate |
| pear oil (artificial) | isoamyl acetate |
| pearl ash | potassium carbonate |
| permanent white | barium sulfate |
| plaster of Paris | calcium sulfate |
| plumbago | graphite |
| potash | potassium carbonate |
| potassa | potassium hydroxide |
| precipitated chalk | calcium carbonate |
| Prussic acid | hydrogen cyanide |
| pyro | tetrasodium pyrophosphate |

| | |
|---|---|
| quicklime | calcium oxide |
| quicksilver | mercury |
| red lead | lead tetraoxide |
| red liquor | aluminum acetate solution |
| red prussiate of potash | potassium ferrocyanide |
| red prussiate of soda | sodium ferrocyanide |
| Rochelle salt | potassium sodium tartrate |
| rock salt | sodium chloride |
| rouge, jeweler's | ferric oxide |
| rubbing alcohol | isopropyl alcohol |
| sal ammoniac | ammonium chloride |
| sal soda | sodium carbonate |
| salt, table | sodium chloride |
| salt of lemon | potassium binoxalate |
| salt of tartar | potassium carbonate |
| saltpeter | potassium nitrate |
| silica | silicon dioxide |
| slaked lime | calcium hydroxide |
| soda ash | sodium carbonate |
| soda nitre | sodium nitrate |
| soda lye | sodium hydroxide |
| soluble glass | sodium silicate |
| sour water | dilute sulfuric acid |
| spirit of hartshorn | ammonium hydroxide solution |
| spirit of salt | hydrochloric acid |
| spirit of wine | ethyl alcohol |
| spirits of nitrous ether | ethyl nitrate |
| sugar, table | sucrose |

| | |
|---|---|
| sugar of lead | lead acetate |
| sulfuric ether | ethyl ether |
| talc or talcum | magnesium silicate |
| tin crystals | stannous chloride |
| trona | natural sodium carbonate |
| unslaked lime | calcium oxide |
| Venetian red | ferric oxide |
| verdigris | basic copper acetate |
| Vienna lime | calcium carbonate |
| vinegar | impure dilute acetic acid |
| vitamin C | ascorbic acid |
| vitriol | sulfuric acid |
| washing soda | sodium carbonate |
| water glass | sodium silicate |
| white caustic | sodium hydroxide |
| white lead | basic lead carbonate |
| white vitriol | zinc sulfate crystals |
| yellow prussiate of potash | potassium ferrocyanide |
| yellow prussiate of soda | sodium ferrocyanide |
| zinc vitriol | zinc sulfate |
| zinc white (philosopher's wool) | zinc oxide |

## Chemistry of Firework Colors

Creating firework colors is a complex endeavor, requiring considerable art and application of physical science. Excluding propellants or special effects, the points of light ejected from fireworks, termed 'stars', generally require an oxygen-producer, fuel, binder (to keep everything where it needs to be), and color producer. There are two main mechanisms of color production in fireworks, incandescence and luminescence.

**Incandescence**

Incandescence is light produced from heat. Heat causes a substance to become hot and glow, initially emitting infrared, then red, orange, yellow, and white light as it becomes increasingly hotter. When the temperature of a firework is controlled, the glow of components, such as charcoal, can be manipulated to be the desired color (temperature) at the proper time. Metals, such as aluminum, magnesium, and titanium, burn very brightly and are useful for increasing the temperature of the firework.

**Luminescence**

Luminescence is light produced using energy sources other than heat. Sometimes luminescence is called 'cold light', because it can occur at room temperature and cooler temperatures. To produce luminescence, energy is absorbed by an electron of an atom or molecule, causing it to become excited, but unstable. When the electron returns to a lower energy state the energy is released in the form of a photon (light). The energy of the photon determines its wavelength or color.

Sometimes the salts needed to produce the desired color are unstable. Barium chloride (green) is unstable at room temperatures, so barium must be combined with a more stable compound (e.g., chlorinated rubber). In this case, the chlorine is released in the heat of the burning of the pyrotechnic composition, to then form barium chloride and produce the green color. Copper chloride (blue), on the other hand, is unstable at high temperatures, so the firework cannot get too hot, yet must be bright enough to be seen.

**Quality**

Pure colors require pure ingredients. Even trace amounts of sodium impurities (yellow-orange) are sufficient to overpower or alter other colors. Careful formulation is required so that too much smoke or residue doesn't mask the color. With fireworks, as with other things, cost often relates to quality. Skill of the manufacturer and date the firework was produced greatly affect the final display (or lack thereof).

**Firework Colorants**

| Color | Compound |
|---|---|
| Red | strontium salts, lithium salts<br>lithium carbonate, $Li_2CO_3$ = red<br>strontium carbonate, $SrCO_3$ = bright red |
| Orange | calcium salts<br>calcium chloride, $CaCl_2$<br>calcium sulfate, $CaSO_4 \cdot xH_2O$, where x = 0,2,3,5 |
| Gold | incandescence of iron (with carbon), charcoal, or lampblack |
| Yellow | sodium compounds<br>sodium nitrate, $NaNO_3$<br>cryolite, $Na_3AlF_6$ |
| Electric White | white-hot metal, such as magnesium or aluminum<br>barium oxide, BaO |
| Green | barium compounds + chlorine producer<br>barium chloride, $BaCl^+$ = bright green |
| Blue | copper compounds + chlorine producer<br>copper acetoarsenite (Paris Green), $Cu_3As_2O_3Cu(C_2H_3O_2)_2$ = blue<br>copper (I) chloride, CuCl = turquoise blue |
| Purple | mixture of strontium (red) and copper (blue) compounds |
| Silver | burning aluminum, titanium, or magnesium powder or flakes |

## Explosives

Explosives are materials that produce violent chemical or nuclear reactions. These reactions generate large amounts of heat and gas in a fraction of a second. Shock waves produced by rapidly expanded gases are responsible for much of the destruction seen following an explosion.

Probably the oldest known explosive is black gunpowder, a mixture of charcoal (carbon), sulfur, and saltpeter (potassium nitrate). When these three chemicals are ignited, a chemical reaction takes place very quickly. The products of that reaction are carbon dioxide, carbon monoxide, sulfur dioxide, and nitric oxide (all gases) as well as potassium carbonate and potassium sulfide (two solids). The four gases formed in the reaction are heated to very high temperatures and expand very rapidly. They form shock waves that have the ability to knock down trees, buildings, people, and other objects in their way. The shock wave also carries with it very hot gases that can burn objects and initiate fires. The combination of shock wave and high temperature is characteristic of most kinds of explosives.

**History**

Gunpowder was first invented in China no later than about A.D. 850. For hundreds of years, it was used mainly to create fireworks. The Chinese did not use gunpowder as a weapon of war; it was the Europeans who first adapted explosives for use in weapons. By the fourteenth century, Europeans were widely using the explosive as a military device to project stones, spearlike projectiles, and metal balls from cannons and guns.

**Words to Know**

**Chemical explosive:** A compound or mixture that releases chemical energy violently and rapidly, creating heat and a shock wave generated by a release of gases.

**Dynamite:** An explosive made by soaking an inert (inactive or stable), absorbent substance with a mixture of (1) nitroglycerin or ammonium nitrate, (2) a combustible substance (a substance with the ability to burn), such as wood pulp, and (3) an antacid.

**Gunpowder:** An explosive mixture of charcoal, potassium nitrate, and sulfur often used to propel bullets from guns and shells from cannons.

**Nitroglycerine:** An explosive liquid used to make dynamite. Also used as a medicine to dilate blood vessels.

**Nuclear explosive:** A device that obtains its explosive force from the release of nuclear energy.

**TNT:** Trinitrotoluene, a high explosive.

For the next 500 years, gunpowder was used almost exclusively for pyrotechnic (fireworks) displays and in warfare. Then, in 1856, Italian chemist Ascanio Sobrero (1812–1888) invented the first modern explosive, nitroglycerin. Sobrero's discovery was, unfortunately for many early users, too unstable to be used safely. Nitroglycerin readily explodes if bumped or shocked.

In 1859, Swedish inventor Alfred Nobel (1833–1896) began to look for a way to package nitroglycerin safely. His solution was to mix nitroglycerin with an inert (inactive) absorbent material called *kieselguhr.* He called his invention dynamite.

Virtually overnight, Nobel's invention revolutionized the mining industry. Dynamite was five times as powerful as gunpowder, relatively easy to produce, and reasonably safe to use. For the first time in history, explosives began to be used for a productive purpose: the tearing apart of land in order to gain access to valuable minerals.

Nobel became extremely wealthy as a result of his discovery. But he is said to have been worried about the terrible potential for destruction that his invention had made possible. When he died, he directed that his fortune be used to create the Nobel Foundation, the purpose of which was to bring about lasting peace and advance technology. The Nobel Prizes in various fields of science are now the highest honors that scientists can earn.

**Types of explosives**

Explosives can be classified into one of four large categories: primary, low, high, and nuclear explosives.

**Primary explosives.** Primary explosives are generally used to set off other explosives. They are very sensitive to shock, heat, and electricity and, therefore, must be handled with great care. Two common examples are mercury fulminate and lead azide. Primary explosives also are known as initiating explosives, blasting caps, detonators, or primers.

**Low explosives.** Low explosives are characterized by the fact that they burn only at their surface. For example, when a cylinder of black gunpowder is ignited, it begins burning at one end of the cylinder and then continues to the other end. This process takes place very rapidly, however, and is complete in just a few thousandths of a second.

This property of slowed combustion is preferred in guns and artillery because too rapid an explosion could cause the weapon itself to blow up. A slower explosive has the effects of building up pressure to force a bullet or shell smoothly out of the weapon. Fireworks also are low explosives.

**High explosives.** High explosives are much more powerful than primary explosives. When they are detonated, all parts of the explosive blow up within a few millionths of a second. Some also are less likely than primary explosives to explode by accident. Examples of high explosives include ANFO (ammonium nitrate-fuel oil mixture), dynamite, nitroglycerin, PETN (pentaerythritol tetranitrate), picric acid, and TNT (trinitrotoluene). They provide the explosive force delivered by hand grenades, bombs, and artillery shells.

High explosives that are set off by heat are called primary explosives. High explosives that can be set off only by a detonator are called secondary explosives. When mixed with oil or wax, high explosives become like clay. These plastic explosives can be molded into various shapes to hide them or to direct explosions. In the 1970s and 1980s, plastic explosives became a favorite weapon of terrorists (people who use violence in order to force a government into granting their demands). Plastic explosives can even be pressed flat to fit into an ordinary mailing envelope for use as a "letter bomb."

**Nuclear explosives.** Research during World War II (1939–45) produced an entirely new kind of explosive: nuclear explosives. Nuclear explosives produce their explosive power not by chemical reactions, as with traditional explosives, but through nuclear reactions. In some types of nuclear reactions, large atomic nuclei are split (or fissioned) into two pieces with the release of huge amounts of energy. In a second type of nuclear reaction, small atomic nuclei are combined (or fused) to make a single large nucleus, again with the release of large amounts of energy.

These two kinds of nuclear explosives were first used as weapons at the end of World War II. The world's first atomic bomb, dropped on Hiroshima, Japan, in 1945, for example, was a fission weapon. The world's first hydrogen bomb, tested at Bikini Atoll in the Pacific Ocean in 1952, was a fusion weapon.

Since the end of World War II, a half-dozen nations in the world have continued to develop and build both fission and fusion weapons. Efforts also have been made to find peaceful uses for nuclear explosives, as in mining operations, although these efforts have not been fully successful.

### Composition of the material

An explosive may consist of either a chemically pure compound, such as nitroglycerin, or a mixture of an oxidizer and a fuel, such as black powder.

### Mixtures of an oxidizer and a fuel

An oxidizer is a pure substance (molecule) that in a chemical reaction can contribute some atoms of one or more oxidizing elements, in which the fuel component of the explosive burns. On the simplest level, the oxidizer may itself be an oxidizing element, such as gaseous or liquid oxygen.

- **Black powder**: Potassium nitrate, charcoal and sulfur
- **Flash powder**: Fine metal powder (usually aluminium or magnesium) and a strong oxidizer (e.g. potassium chlorate or perchlorate).
- **Ammonal**: Ammonium nitrate and aluminium powder.

- **Armstrong's mixture**: Potassium chlorate and red phosphorus. This is a very sensitive mixture. It is a primary high explosive in which sulfur is substituted for some or all phosphorus to slightly decrease sensitivity.
- **Sprengel explosives**: A very general class incorporating any strong oxidizer and highly reactive fuel, although in practice the name most commonly was applied to mixtures of chlorates and nitroaromatics.
    - **ANFO**: Ammonium nitrate and fuel oil.
    - **Cheddites**: Chlorates or perchlorates and oil.
    - **Oxyliquits**: Mixtures of organic materials and liquid oxygen.

**Chemically pure compounds**

Some chemical compounds are unstable in that, when shocked, they react, possibly to the point of detonation. Each molecule of the compound dissociates into two or more new molecules (generally gases) with the release of energy.

- **Nitroglycerin**: A highly unstable and sensitive liquid.
- **Acetone peroxide**: A very unstable white organic peroxide
- **TNT**: Yellow insensitive crystals that can be melted and cast without detonation.
- **Nitrocellulose**: A nitrated polymer which can be a high or low explosive depending on nitration level and conditions.
- **RDX**, **PETN**, **HMX**: Very powerful explosives which can be used pure or in plastic explosives.

- C-4 (or Composition C-4): An RDX plastic explosive plasticized to be adhesive and malleable.

The above compositions may describe the majority of the explosive material, but a practical explosive will often include small percentages of other materials. For example, dynamite is a mixture of highly sensitive nitroglycerin with sawdust, powdered silica, or most commonly diatomaceous earth, which act as stabilizers. Plastics and polymers may be added to bind powders of explosive compounds; waxes may be incorporated to make them safer to handle; aluminium powder may be introduced to increase total energy and blast effects. Explosive compounds are also often "alloyed": HMX or RDX powders may be mixed (typically by melt-casting) with TNT to form Octol or Cyclotol

# SRIRAM'S IAS

# GENERAL STUDIES

## FUNDAMENTAL OF COMPUTERS

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# Computer basics

## Bits and Bytes

If you have used a computer for more than five minutes, then you have heard the words **bits** and **bytes**. Both RAM and hard disk capacities are measured in bytes, as are file sizes when you examine them in a file viewer.

You might hear an advertisement that says, "This computer has a **32-bit** Pentium processor with 64 **megabytes** of RAM and 2.1 **gigabytes** of hard disk space." And many HowStuffWorks articles talk about bytes (for example, How CDs Work). In this article, we will discuss bits and bytes so that you have a complete understanding.

Computers happen to operate using the base-2 number system, also known as the **binary number system** (just like the base-10 number system is known as the decimal number system). Find out why and how that works in the next section.

### The Base-2 System and the 8-bit Byte

The reason computers use the base-2 system is because it makes it a lot easier to implement them with current electronic technology. You could wire up and build computers that operate in base-10, but they would be fiendishly expensive right now. On the other hand, base-2 computers are relatively cheap.

So computers use binary numbers, and therefore use **binary digits** in place of decimal digits. The word **bit** is a shortening of the words "Binary digIT." Whereas decimal digits have 10 possible values ranging from 0 to 9, bits have only two possible values: 0 and 1. Therefore, a binary number is composed of only 0s and 1s, like this: 1011. How do you figure out what the value of the binary number 1011 is? You do it in the same way we did it above for 6357, but you use a base of 2 instead of a base of 10. So:

(1 * 2^3) + (0 * 2^2) + (1 * 2^1) + (1 * 2^0) = 8 + 0 + 2 + 1 = 11

You can see that in binary numbers, each bit holds the value of increasing powers of 2. That makes counting in binary pretty easy. Starting at zero and going through 20, counting in decimal and binary looks like this:

0 = 0
1 = 1
2 = 10
3 = 11
4 = 100
5 = 101
6 = 110

7 = 111
8 = 1000
9 = 1001
10 = 1010
11 = 1011
12 = 1100
13 = 1101
14 = 1110
15 = 1111
16 = 10000
17 = 10001
18 = 10010
19 = 10011
20 = 10100

When you look at this sequence, 0 and 1 are the same for decimal and binary number systems. At the number 2, you see carrying first take place in the binary system. If a bit is 1, and you add 1 to it, the bit becomes 0 and the next bit becomes 1. In the transition from 15 to 16 this effect rolls over through 4 bits, turning 1111 into 10000.

Bits are rarely seen alone in computers. They are almost always bundled together into 8-bit collections, and these collections are called **bytes**. Why are there 8 bits in a byte? A similar question is, "Why are there 12 eggs in a dozen?" The 8-bit byte is something that people settled on through trial and error over the past 50 years.

With 8 bits in a byte, you can represent 256 values ranging from 0 to 255, as shown here:

0 = 00000000
1 = 00000001
2 = 00000010
...
254 = 11111110
255 = 11111111

### The Standard ASCII (American Standard Code for Information Interchange ) Character Set

Bytes are frequently used to hold individual characters in a text document. In the **ASCII character set**, each binary value between 0 and 127 is given a specific character. Most computers extend the ASCII character set to use the full range of 256 characters available in a byte. The upper 128 characters handle special things like accented characters from common foreign languages.

You can see the 127 standard ASCII codes below. Computers store text documents, both on disk and in memory, using these codes.

## Byte Prefixes and Binary Math

When you start talking about lots of bytes, you get into **prefixes** like kilo, mega and giga, as in kilobyte, megabyte and gigabyte (also shortened to K, M and G, as in Kbytes, Mbytes and Gbytes or KB, MB and GB). The following table shows the **binary** multipliers:

| **Name** | **Abbr.** | **Size** |
|---|---|---|
| Kilo | K | 2^10 = 1,024 |
| Mega | M | 2^20 = 1,048,576 |
| Giga | G | 2^30 = 1,073,741,824 |
| Tera | T | 2^40 = 1,099,511,627,776 |
| Peta | P | 2^50 = 1,125,899,906,842,624 |
| Exa | E | 2^60 = 1,152,921,504,606,846,976 |
| Zetta | Z | 2^70 = 1,180,591,620,717,411,303,424 |
| Yotta | Y | 2^80 = 1,208,925,819,614,629,174,706,176 |

## **History** of computers

Nearly 5,000 years ago the abacus emerged in Asia Minor. The abacus may be considered the first computer. This device allowed its users to make computations using a system of sliding beads arranged on a rack. Early shopkeepers used the abacus to keep up with transactions. The use of pencil and paper spread, the abacus lost its importance. Nearly twelve centuries past before the next important advance in computing devices emerged.

In 1642, Blaise Pascal, the 18-year-old son of a French tax collector, invented what he called a numerical wheel calculator to help his father with his duties. The Pascaline, a brass rectangular box, used eight movable dials to add sums up to eight figures long. Pascal's device used a base of ten to achieve this. The disadvantage to the Pascaline, of course, was its limitation to addition. In 1694, Gottfried Wilhem von Leibniza a German mathematician and philosopher improved the Pascaline by creating a machine that could also multiply. Like its predecessor, Leibniz's mechanical multiplier worked by a system of gears and dials.

It wasn't until 1820, however, that mechanical calculators gained widespread use. A Frenchman, Charles Xavier Thomas de Colmar, invented a machine that could perform the four basic mathematic functions. The arithometer, presented a more systematic approach to computing because it could add, subtract, multiply and divide. With its enhanced versatility, the arithometer was widely used up until World War I.

The real beginnings of computers began with an English mathematics professor, Charles Babbage. Babbage's steam-powered Engine, outlined the basic elements of a modern general purpose computer and was a breakthrough concept. The Analytical Engine consisted of over 50,000 components. The basic design of included input devices in the form of perforated cards containing operating instructions and a "store" for memory of 1,000 numbers of up to 50 decimal digits long.

In 1889, an American inventor, Herman Hollerith, created a machine that used cards to store data information which was fed into a machine and compiled the results mechanically. Each punch on a card represented one number, and combinations of two punches represented one letter. As many as 80 variables could be stored on a single card. Hollerith brought his punch card reader into the business world, founding Tabulating Machine Company in 1896, later to become International Business Machines (IBM) in 1924 after a series of mergers. Other companies also manufactured punch readers for business use. Both business and government used punch cards for data processing until the 1960's.

When World War II began, the governments sought to develop computers to accomplishment their potential strategic importance. This increased funding for computer development projects and hastened technical progress. In 1941, a German engineer Konrad Zuse had developed a computer to design airplanes and missiles. The Allied forces, however, made greater strides in developing powerful computers. American efforts produced a broader achievement. In 1933, Howard H. Aiken, a Harvard engineer working with IBM, succeeded in producing an all-electronic calculator. The purpose of the computer was to create ballistic charts for the U.S. Navy. It was about half as long as a football field and contained about 500 miles of wiring. It used electromagnetic signals to move mechanical parts. The machine was slow taking 3-5 seconds per calculation and inflexible in that sequences of calculations could not change; but it could perform basic arithmetic as well as more complex equations.

Another computer development spurred by the war was the Electronic Numerical Integrator and Computer (ENIAC). It consisted of 18,000 vacuum tubes, 70,000 resistors and 5 million soldered joints, the computer was such a massive piece of machinery that it consumed 160 kilowatts of electrical power. ENIAC was developed by John Presper Eckert and John W. Mauchl. ENIAC was a general-purpose computer.

In 1945, Von Neumann designed the Electronic Discrete Variable Automatic Computer (EDVAC) with a memory to hold both a stored program as well as data. This "stored memory" technique as well as the "conditional control transfer," that allowed the computer to be stopped at any point and then resumed, allowed for greater versatility in computer programming. The key element to the von Neumann architecture was the central processing unit, which allowed all computer functions to be coordinated through a single source. In 1951, the UNIVAC I (Universal Automatic Computer), built by Remington Rand, became one of the first commercially available computers to take advantage of these advances. The first computers were characterized by the fact that operating instructions were made-to-order for the specific task for which the computer was to be used. Each computer had a different binary-coded program called a machine language that told it how to operate. This made the computer difficult to program and limited its versatility and speed. Other unique features of first computers were the use of vacuum tubes and magnetic drums for data storage.

The invention of the transistor greatly changed the computer's development in 1948. The transistor replaced the large, cumbersome vacuum tubes. The transistor was at work in the computer by 1956. Throughout the early 1960's, there were a number of commercially successful computers used in business, universities, and government from companies such as Burroughs, Honeywell, IBM, and others. These computers also contained transistors in place of vacuum tubes. They also contained all the components we associate with the modern day computer: printers, disk storage, memory, tape storage, operating systems, and stored programs.

By 1965, most large business routinely processed financial information using computers. It was the stored program and programming language that gave computers the flexibility to finally be cost effective and productive for business use. Though transistors were clearly an improvement over the vacuum tube, they still generated a great deal of heat, which damaged the computer's sensitive internal parts. Jack Kilby, an engineer with Texas Instruments, developed the integrated circuit in 1958. The IC combined three electronic components onto a small silicon disc, which was made from quartz. Scientists later managed to fit even more components on a single chip, called a semiconductor.

By the 1980's, very large scale integration squeezed hundreds of thousands of components onto a chip. Ultra-large scale integration increased that number into the millions. The ability to fit so much onto an area about half the size of a dime helped diminish the size and price of computers. It also increased their power, efficiency and reliability. By the mid-1970's, computer manufacturers sought to bring computers to general consumers. These minicomputers came complete with user-friendly software packages that offered even non-technical users an arrangement of applications, most popularly word processing and spreadsheet programs..

In 1981, IBM introduced its personal computer (PC) for use in the home, office and schools. The 1980's saw an expansion in computer use in all three arenas as clones of the IBM PC made the personal computer even more affordable. The number of personal computers in use more than doubled from 2 million in 1981 to 5.5 million in 1982. Ten years later, 65 million PCs were being used. As computers became more widespread in the workplace, new ways to harness their potential developed. As smaller computers became more powerful, they could be linked together, or networked, to share memory space, software, information and communicate with each other. Computers continue to grow smaller and more powerful.

## Categories of Computers

- Personal computers

Personal computers are desktop computers designed for an individual's use. They run programs designed to help individuals accomplish their work more productively.

- Servers

Servers are not designed to be used directly. They make programs and data available for people hooked up to a computer network, a collection of computers connected together so that they can exchange data.

- Minicomputers

Minicomputers are multi-user systems that can handle the computing needs of a smaller corporation or organization. Many people use them simultaneously by means of remote terminals or personal computers.

- Personal computers

Mainframes are huge, multi-user systems designed to handle gigantic processing jobs in large corporations or government agencies.

### Supercomputers

Supercomputers are ultra fast computers designed to process hugh amounts of scientific data then display the underlying patterns that have been discovered.

## Input Devices

An input device lets you communicate with a computer. You can use input devices to enter information and issue commands. A keyboard, mouse, scanner, digital camera, touch pads and joystick are examples of input devices.

**Some Common Computer Input Devices:**

### Keyboard

- Used to type data into the computer
- Most common input device today
- Has special keys for giving the computer commands
    - Commands tell the computer to do something, like save the file
    - These special keys are called command or function keys

### Pointing Devices

- Pointing devices move some object on the screen and can do some action
- Common pointing devices
    - **Mouse - most common pointing device**
    - Track ball - basically an upside down mouse
    - Joystick
    - Game controller

### Scanner

A scanner allows you to scan documents, pictures, or graphics and view them on the computer. You can also use software to edit the items you scan.

- Used to put printed pictures and text into a computer
- Converts an image into dots that the computer can understand
- To scan text, optical character recognition (OCR) software is needed

### ●Digital Camera

- Used to take electronic pictures of an object
- The pictures taken by a digital camera can be used directly by a computer

### ●Microphone

- Used to put sound into a computer
- Need sound recording software

### ●CD-ROM/DVD-ROM

- Can be used to put both sound and images into a computer
- Use a laser to read a Compact Disk (CD) or a DVD disk

### ●Video Capture Card

- Usually place inside the computer's case
- Use to put video into a computer
- Need a video source, either a video camera or video recorder

## Output Devices

An output device displays information on a screen, creates printed copies or generates sound. A monitor, printer, and speakers are examples of output devices.

**Some Common Output Devices:**

### ●Monitors and Displays

- Shows the processed information on a screen
  - A monitor uses a Picture Tube like a television with the image displayed on the front of the tube, which is called the screen.
  - Displays are flat and use plasma, LCD, active-matrix, or some other technology.
- Monitors used to be called Cathode Ray Tubes (CRTs) because of the picture tube, which is a large vacuum tube.
- A monitor or display produce a soft copy. When the device is turned off the information goes away.
- Monitors are slowly being replaced by flat panel displays.

## Printers

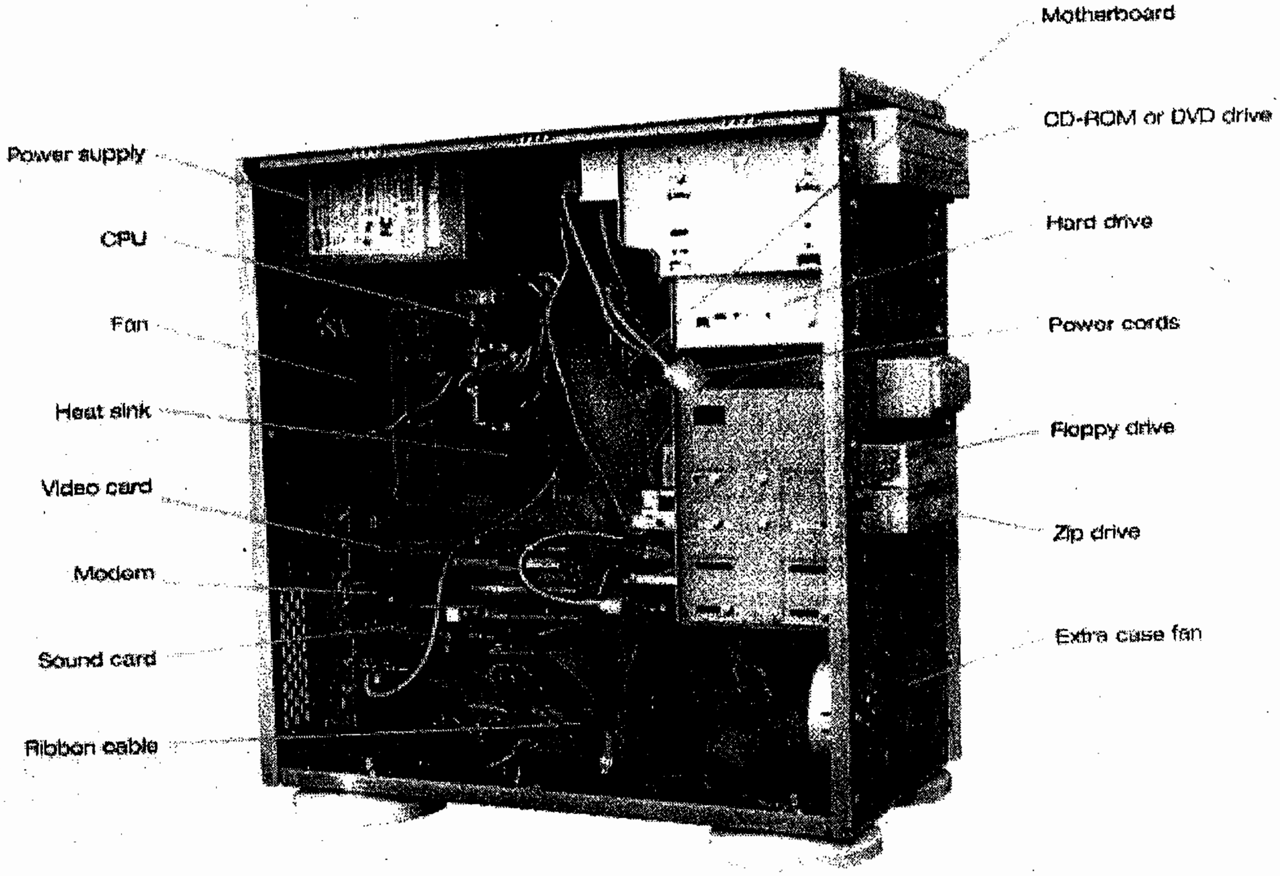
- Printers produce a hard copy
- The information is printed on paper and can be used when the device is off.
- It is also called a printout
- Dot-matrix printers (impact printer)
    - Uses metal pins to strike an inked ribbon to make dots on a piece of paper.
    - Can see the dots that make up the letters or images.
    - Lowest print quality of all of the printers.
    - Very low in cost per page to use.
    - Rarely used today because of the poor print quality, but still used in business to print multi-part forms.
- Ink jet printers (non-impact printer)
    - Use drops of magnetic ink to produce dots on a page to produce text or images.
    - The print quality is almost the same as a laser printer's.
    - Problems with the ink
        - The ink is very expensive
        - The ink is water soluble and will run if the paper gets wet
    - Highest cost per page of all the printers
    - For producing color documents, it has the highest quality at a reasonable price.
- Laser printers (non-impact printer)
    - How the laser printer produces an image
        - A laser or LEDs make dots on a light sensitive drum
        - Toner (very tiny particles of plastic) stick to the drum where the dots where made
        - Paper is pressed against the drum and the toner is placed on the paper
        - The paper is heated and the toner melts into the paper
    - Produces the highest quality printout
    - For black and white printouts, very low cost per page
    - Printout is permanent
    - Color laser printers are still fairly expensive ($3,000 to $10,000)

●**Speakers**

- used to output sound

## System Unit

●A computer system unit contains many parts.



**Motherboard** - The motherboard is the main circuit board of a microcomputer. It is also known as the mainboard or system board.

**CPU** - The CPU is the central electronic chip that determines the processing power of the computer.

**Memory** - Memory is the part of the computer that temporarily stores applications, documents, and stem operating information.

**Bus** - A bus is an electronic line that allows 1s and 0s to move from one place to another.

**Expansion Slots** - Expansions slots appear on the motherboard. They are sockets into which adapters are connected.

**Ports and Connectors** - A port is a connector located on the motherboard or on a separate adapter.

**Bays** - A bay is a space inside the computer case where a hard drive, floppy drive or CD-ROM drive sits

**Power Supply** - A power supply changes normal household electricity into electricity that a computer can use.

**Sound Components** - A sound card lets a computer play and record high quality sound.

## ● Central Processing Unit (CPU)

**Does all of the work for the computer**

1. Does all of the mathematics, mainly addition
2. Does all the logical comparisons of values
3. Directs the flow of data in a computer
4. Controls the operation of the parts of the computer

**Today, all CPUs are microprocessors**

5. A microprocessor is a complete computer on a silicon chip
6. A microprocessor does all of the functions of a computer
    - stores data and instructions waiting to be used
    - follows changeable instructions
    - does input, processing, and output

**CPUs have three basic parts**

7. The Arithmetic Logic Unit (ALU)
    - does all of the mathematics in a computer
    - does all of the logic comparisons of values
    - some common logic comparison symbols
        - = equal to

  - < less than
  - > greater than
  - <= less than or equal to
  - >= greater than or equal to
  - <> not equal

8. The Control Unit
   - directs the flow of information into the CPU and/or memory or storage
   - controls which instructions the CPU will do next

9. Registers
   - Used to store data and instructions inside the processor
   - Size of the registers can affect the speed and performance of the processor

**Speed of CPUs**

10. The speed of CPUs is measured in hertzs.
    - A hertz is on cycle per second.
    - Need to measure time to determine cycles per second
      - All computers have a clock built into them for timing the cycles
      - The clock is usually located in a small metal box on the motherboard.
    - Today, many CPUs can complete over six (6) instructions per second.

11. Speeds of modern CPUs
    - Most computers have a CPU that can do more than 400 MHz.
      - MHz stands for megahertzs
      - A MHz is 1,000,000 cycles per second.
    - Computers will soon be at speeds of over a gigahertz, 1,000,000,000 Hertzs.

## ●Memory

**Primary memory can be used directly by the CPU**

1. Consists of silicon chips, usually either VLS or VLSI technology is used to create the chips
2. Two forms of Primary Memory
   - o Read Only Memory (ROM)

  - Random Access Memory (RAM)

3. Primary memory is also called primary storage

### Read Only Memory (ROM) Stores instructions that are used by the CPU

  - Tells the CPU how to be the kind of computer it is, for example a Windows, Macintosh, or Play Station computers.
  - Tells the CPU how to work with the different parts of the computer
  - ROM can also hold programs that are directly accessed by the CPU. One such program is the self-test when the computer is first turned on. The self-test tests to seem if all the parts on the main circuit board (mother board) are working correctly.

2. The instructions in ROM can not usually be changed
    - The instructions are built into the electronic circuits of the chips
    - These instructions in ROM are called **firmware**
    - To change the instructions in ROM you need to usually change the chips or do some other special process that is normally not available to an average user.
3. The instructions in ROM are nonvolatile. They stay in ROM even when the computer is turned off.
4. Access to information is random access.
    - Random access means that any piece of information in ROM can be accessed at any given time without access other information first. It is a lot like the tracks on a music CD. You can access any track at any time and in any order.
    - The other kind of access is sequential access. You must access the information in the order that they are located. This is a lot like a music tape. You must play the songs in order, or you have to fast forward past songs to get to the one you want.

### Random Access Memory (RAM)

1. Store data and instructions that are used by the CPU to perform some task.
    - These instructions are usually loaded into RAM from a secondary storage device.
    - RAM is also used to store instructions that tell the CPU how to work with its parts. These instructions are usually called drivers.
2. The instructions in RAM are constantly changing, depending on the needs of the CPU.
3. The instructions in RAM are volatile.
    - When the computer is turned off the information in RAM disappears.

- The information in RAM needs to be saved to secondary storage before the computer is turned off.

4. Access to information is random access.

# Storage Devices

**How a computer stores information**

1. The computer stores information as a string of zeros (0) and ones (1)
    - The standard string length is eight 0's or 1's in a row
    - This standard length is called a byte
    - A byte equals one character
        - A character is a letter, number, or symbol - it is about any thing that can be typed on a keyboard
        - There are 256 standard characters used by almost all computers

2. Information size measurements
    - Kilobyte (KB)
        - One kilobyte equals about 1024 bytes
        - 1KB is about 140 words, about a half page of typed double-spaced text (words only)
    - Megabyte (MB)
        - One megabyte equals about 1000 KB
        - One megabyte equals about 1,000,000 bytes
        - One megabyte equals about 500 pages of text, or one large book
    - Gigabyte (GB)
        - One gigabyte equals about 1000 MB
        - One gigabyte equals about 1,000,000 KB
        - One gigabyte equals about 1,000,000,000 bytes
        - One gigabyte equals over 1,000 books of text

### ●Some Common Storage Devices

**Hard Drive**

The hard drive is the primary device that a computer uses to store information. The hard drive stores programs, data files, saves files, and organizes files. The hard drive is located inside the computer case. The hard drive, magnetically stores data on stacks of rotating disks called platters.

**Floppy Drive**

The floppy drive stores and retrieves information on a floppy disk.

**CD -ROM Drive**

CD-ROM is a device that reads information stored on a compact disc. CD-ROM stands for Compact Disc Read Only Memory. One CD is equal to the space in over 40 floppy disc.

**Removable Hard Disk**

A zip disk is a removable disk that holds a large amount of information. A zip disk can be used to achieve, protect and transfer large amounts of data.

## Communications Devices

Specific equipment and programs are needed to connect to the Internet or to communicate with other computers. You can use any type of computer such as IBM compatible or Macintosh to connect to the Internet or communicate with other computers. You need special programs to use the Internet. Most companies that connect you to the Internet provide the programs you need free of charge. You also need a modem to connect to the Internet. A modem translates computer information into a form that can be transmitted over telephone lines. Modems can be used to connect you to the Internet, exchange information, and to send and receive faxes.

## Peripheral Devices

A peripheral devices is any piece of hardware attached to a computer. A few examples of peripheral devices are printers, scanners, and digital cameras.

# Software

### Software -- General Information

Computer software provides instruction that tell the computer how to operate.

1. Software are also called programs.
2. Programs are usually created using other software called programming languages.

**There are two (2) main types of software**

1. System Software
   - Used by the computer to accomplish a task.
   - What system software does:
     - controls the internal function of the computer
     - controls other devices connected to the CPU

2. Application Software
   - Used by people to accomplish a specific task.
   - Some common kinds of application software
     - Word Processor software
     - Database software
     - Spreadsheet software
     - Games
     - Web Page Browsers

### Kinds of Software

1. Public Domain Software
   - Has no copyright - no one owns the right to control who can make copies of the software.
   - Free to use or make copies of.
   - Can be copied, used in other programs, or changed by anyone.

2. Freeware
    - Has a copyright - someone owns the right to determine who can make copies of the software.
    - Free to use and make copies of.
    - Can only give away exact copies of the software.
    - Can not be changed or used in another program without the copyright holder's permission.

3. Shareware
    - Has a copyright.
    - Allowed to use the software before paying for it.
        - Can be a demo - which limits some major features like the Save command.
        - Can set an amount of time you can use the software.
        - Can trust that you will pay for it if you like the software.
    - Can only give away exact copies of the software.
    - Can not be changed or used in another program without the copyright holder's permission.

4. Commercial Software
    - Has the most resistive copyright.
    - Have to buy the software before you can use it.
    - Can usually make one copy of the software as a backup copy.
        - A backup copy is used in case something goes wrong with the original software.
        - Can not give away or sell the backup copy.
    - Can not copy, look at the program's code, change, or use the software in another program without the copyright holder's permission.
    - Commercial Software is the best software in the world.

### How Software is Inputted Into Computer

1. Built into the computer's circuits, the ROM chips.
2. Loaded into the computer from a secondary storage device, like a floppy disk or hard disk drive.
3. Typed in from the keyboard.
    - Usually need to use a programming language to create the software.
    - Rarely done by most computer users today.

## System Software

**System software** is a type of program that acts like a conductor in an orchestra. It directs all the activities and sets all the rules for how the hardware and software work together. MS DOS and Microsoft Windows are examples of system software or operating system software.

**Some System Software is built into the computer.**

1. ROM chips and BIOS.
2. Helps to setup the computer and start it.

**Operating Systems**

1. The operating system is usually located on a disk.
    - Can be on either the hard disk drive, a floppy disk, or CD-ROM disk.
    - Must be loaded into RAM before it can be used.

2. Used by the computer's hardware to work with its parts.
    - Tells the computer how to:
        - display information on the screen.
        - use a printer.
        - store information on a secondary storage device.
    - The system software that controls peripherals are called drivers.

3. An operating system works with application software.
    - Does basic tasks, like printing a document or saving a file
    - The operating system starts (launches) the application software so that it can be used.

**User Interfaces**

1. The user interface is how the computer's operating system presents information to the user and the user gives instructions (commands) to the computer.

2. There are two kinds of User Interfaces
    - Text Interface

  - Presents information to the user in the form of text.
  - Have to type in commands or select commands from a menu displayed as text on the screen.
  - Hard to use or learn, because the user must memorize and type in commands.
  - Examples:
    - MS-Dos (MicroSoft Disk Operating System)
    - ProDos (Professional Disk Operating System)
  - Many of the Text Interfaces had shells placed over them.
    - A shell was more of a Graphic User Interface.
    - Made using the Text Interface easier to use.
- Graphic User Interface (GUI)
  - Presents information to the use in the form of pull-down menus and icons.
    - Pull-down menus the user clicks on to display the menu
    - Icons are small pictures that stand for something, like a file, volume, trash, or program
  - The user gives commands to the computer by selecting items from a menu or by clicking on an icon when using a pointing device.
  - GUIs are easy to learn and use
  - Examples:
    - Windows 98
    - Windows 2000
    - MacOS

## ● Application Software

**Application software** programs work with the operating system software to help you use your computer to do specific types of work such as word processing to type a letter.

1. Used by people to solve general problems
   - Can be used to do more than one thing - adapted to a wide variety of tasks
   - Some common tasks done by general purpose application software
     - Planning
     - Writing
     - Record keeping
     - Calculating

        - Communicating
        - Drawing
        - Painting
    - What can be done with general purpose application software is only limited by the imagination of the user.

2. Examples of general purpose application software
    - Word Processing Software
    - Database Software
    - Spreadsheet Software
    - Desktop Publishing Software
    - Paint and Draw Software

## Utilities

**Utilities** allow you to complete certain tasks on your computer. Examples of some of these tasks are file organizations.

- Specific purpose application software used to help a computer work better or to avoid problems.
- Some utility programs are built into the operating system
    - Scandisk in the Windows operating system
    - Disk formatting software
- Examples of utility programs
    - Anti-virus software
    - Disk maintenance software
- File management programs
- Security software

### Viruses and Worms

In general terms a virus is a program that runs on a system against the owner's or user's wishes and knowledge. Viruses have one or more methods they use to spread. Most commonly they will attach a file to an e-mail message and attempt to trick victims into running the attachment.

### Virus Damage

In most cases, viruses can do any amount of damage the creator intends them to do. They can send your data to a third party and then delete your data from your computer. They can also ruin your system and render it unusable without a re-installation of the operating system. Most have not done this much damage in the past, but could easily do this in the future. Usually the virus will install files on your system then will change your system so the virus is run every time you start your system. It will then attempt to replicate itself by sending itself to other potential victims.

The normal effect a virus will have on your system is that over time your system will run slower. Also when you are using the internet your connection may seem to run slower. Eventually you may have trouble running programs on your system, your system may freeze, and in the worst case you may not be able to get it to boot up when you turn your computer on.

### Worms and Prevention

Since worms spread by taking advantage of vulnerabilities in operating systems or application programs (remember from earlier discussion, vulnerabilities are software errors that allow some kind of unauthorized access when they are used or exploited). You do not need to do anything special to get a worm except to connect to the internet or an infected network with a system that has vulnerabilities. There are several good defenses against worms.

### What is a Firewall?

A firewall is a device that limits access to your system from the outside. A firewall may be a software program running on your computer or it may be a piece of hardware outside your computer. The firewall screens any attempts to access your system and only allows access that you decide to allow. In this way many vulnerabilities that could be used to gain unauthorized access to your system are eliminated.

### Spam

Spam is unsolited junk e-mail sent to large numbers of e-mail addresses. It is used to promote some product or service and many spam e-mails are pornographic in nature.

### Spam for Webmasters

If you are a webmaster, spammers will send spam to your domain by sending it to general possible accounts such as administration@yourdomain.com. One way to prevent this is to configure your account with your hosting provider not to respond to undeliverable emails and just automatically delete them. This is called a "::blackhole" setting. The only problem with this is that spammers will still use your bandwidth that you pay for to send you their junk, even though your server deletes them. As spam gets more excessive, it may increase bandwidth costs for webmasters thus discouraging some sites from operating.

## Computer Terms Glossary

**boot**

Starting up an <u>OS</u> is booting it. If the computer is already running, it is more often called rebooting.

**browser**

A browser is a <u>program</u> used to browse the <u>web</u>. Some common browsers include <u>Netscape</u>, <u>MSIE</u> (Microsoft Internet Explorer), <u>Safari</u>, <u>Lynx</u>, Mosaic, <u>Amaya</u>, <u>Arena</u>, Chimera, Opera, Cyberdog, <u>HotJava</u>, etc.

**bug**

A bug is a mistake in the design of something, especially <u>software</u>. A really severe bug can cause something to <u>crash</u>.

**database**

A database is a collection of data, typically organized to make common retrievals easy and efficient. Some common database programs include Oracle, Sybase, <u>Postgres</u>, Informix, Filemaker, Adabas, etc.

**desktop**

A desktop system is a computer designed to sit in one position on a desk somewhere and not move around. Most general purpose computers are desktop systems. Calling a system a desktop implies nothing about its platform. The fastest desktop system at any given time is typically either an <u>Alpha</u> or <u>PowerPC</u> based system, but the <u>SPARC</u> and <u>PA-RISC</u> based systems are also often in the running. Industrial strength desktops are typically called <u>workstations</u>.

**format**

The manner in which data is stored; its organization.

**graphics**

Anything visually displayed on a computer that is not text.

**hardware**

The physical portion of the computer.

**hypertext**

A hypertext document is like a text document with the ability to contain pointers to other regions of (possibly other) hypertext documents.

**Internet**

The Internet is the world-wide network of computers. There is only one Internet, and thus it is typically capitalized (although it is sometimes referred to as "the 'net"). It is different from an intranet.

**laptop**

A laptop is any computer designed to do pretty much anything a desktop system can do but run for a short time (usually two to five hours) on batteries. They are designed to be carried around but are not particularly convenient to carry around. They are significantly more expensive than desktop systems and have far worse battery life than PDAs. Calling a system a laptop implies nothing about its platform. By far the fastest laptops are the PowerPC based Macintoshes.

**modem**

A modem allows two computers to communicate over ordinary phone lines. It derives its name from **modu**late / **dem**odulate, the process by which it converts digital computer data back and forth for use with an analog phone line.

**multimedia**

This originally indicated a capability to work with and integrate various types of things including audio, still graphics, and especially video. Now it is more of a marketing term and has little real meaning. Historically the Amiga was the first multimedia machine. Today in addition to AmigaOS, IRIX and Solaris are popular choices for high-end multimedia work.

**OS**

The operating system is the program that manages a computer's resources. Common OSes include Windows '95, MacOS, Linux, Solaris, AmigaOS, AIX, Windows NT, etc.

**www**

The **W**orld-**W**ide-**W**eb refers more or less to all the publically accessable documents on the Internet. It is used quite loosely, and sometimes indicates only HTML files and sometimes FTP and Gopher files, too. It is also sometimes just referred to as "the web".

**AI**

**A**rtificial **i**ntelligence is the concept of making computers do tasks once considered to require thinking. AI makes computers play chess, recognize handwriting and speech, helps suggest prescriptions to doctors for patients based on imput symptoms, and many other tasks, both mundane and not.

**baud**

A measure of communications speed, used typically for modems indicating how many bits per second can be transmitted.

**bcode**

Identical in intent to uucode, bcode is slightly more efficient and more portable across different computer types. It is the preferred method used by MIME.

**blog**

Short for web log, a blog (or weblog, or less commonly, 'blog) is a web site containing periodic (usually frequent) posts. Blogs are usually syndicated via either some type of RSS or Atom and often supports TrackBacks. It is not uncommon for blogs to function much like newspaper columns. A blogger is someone who writes for and maintains a blog.

**C**

C is one of the most popular computer languages in the world, and quite possibly *the* most popular. It is a compiled langauge widely supported on many platforms. It tends to be more portable than FORTRAN but less portable than Java

**COBOL**

The **Co**mmon **B**usiness **O**riented **L**anguage is a language developed back in 1959 and still used by some businesses. While it is relatively portable, it is still disliked by many professional programmers simply because COBOL programs tend to be physically longer than equivalent programs written in almost any other language in common use.

**compression**

It is often possible to remove redundant information or capitalize on patterns in data to make a file smaller. Usually when a file has been compressed, it cannot be used until it is uncompressed. Image files are common exceptions, though, as many popular image file formats have compression built-in.

**cookie**

A cookie is a small file that a web page on another machine writes to your personal machine's disk to store various bits of information.

**crash**

If a bug in a program is severe enough, it can cause that program to crash, or to become inoperable without being restarted. On machines that are not multitasking, the entire machine will crash and have to be rebooted. On machines that are only partially multitasking the entire machine will sometimes crash and have to be rebooted. On machines that are fully multitasking, the machine should never crash and require a reboot.

**Cray**

A Cray is a high-end computer used for research and frequently heavy-duty graphics applications. Modern Crays typically have Solaris for their OS and sport sixty-four RISC processors; older ones had various other configurations. Current top-of-the-line Crays can have over 2000 processors.

**crippleware**

Crippleware is a variant of shareware that will either self-destruct after its trial period or has built-in limitations to its functionality that get removed after its purchase.

**DNS**

Domain name service is the means by which a name (like www.saugus.net or ftp.saugus.net) gets converted into a real Internet address that points to a particular machine.

**download**

To download a file is to copy it from a remote computer to your own. The opposite is upload.

**driver**

A driver is a piece of software that works with the OS to control a particular piece of hardware, like a printer or a scanner or a mouse or whatever.

**EDBIC**

The EDBIC character set is similar to (but less popular than) the ASCII character set in concept, but is significantly different in layout. It tends to be found only on old machines..

**emacs**

Emacs is both one of the most powerful and one of the most popular text editing programs in existence.

**terminator**

A terminator is a dedicated device used to mark the end of a device chain (as is most typically found with SCSI devices). If such a chain is not properly terminated, weird results can occur.

**TrackBack**

TrackBacks essentially provide a means whereby different web sites can post messages to one another not just to inform each other about citations, but also to alert one another of related resources. Typically, a blog may display quotations from another blog through the use of TrackBacks.

**Unicode**

The Unicode character set is a superset of the ASCII character set with provisions made for handling international symbols and characters from other languages. Unicode is sixteen bit, so takes up roughly twice the space as simple ASCII, but is correspondingly more flexible.

**upload**

To upload a file is to copy it from your computer to a remote computer. The opposite is download.

**UPS**

An **u**ninterrupted **p**ower **s**upply uses heavy duty batteries to help smooth out its input power source.

**URI**

A **U**niform **R**esource **I**dentifier is basically just a unique address for almost any type of resource. It is similar to but more general than a URL; in fact, it may also be a URN.

**URL**

A **U**niform **R**esource **L**ocator is basically just an address for a file that can be given to a browser. It starts with a protocol type (such as http, ftp, or gopher) and is followed by a colon, machine name, and file name in UNIX style. Optionally an octothorpe character "#" and and arguments will follow the file name; this can be used to further define position within a page and perform a few other tricks. Similar to but less general than a URI.

**URN**

A **U**niform **R**esource **N**ame is basically just a unique address for almost any type of resource unlike a URL it will probably not resolve with a browser.

**USB**

A really fast type of serial port that offers many of the best features of SCSI without the price. Faster than many types of parallel port, a single USB port is capable of chaining many devices without the need of a terminator. USB is much slower (but somewhat less expensive) than FireWire.

**uucode**

The point of uucode is to allow 8-bit binary data to be transferred through the more common 7-bit ASCII channels (most especially e-mail). The facilities for dealing with uucoded files exist for many different machine types, and the most common programs are called "uuencode" for encoding the original binary file into a 7-bit file and "uudecode" for restoring the original binary file from the encoded one. Sometimes different uuencode and uudecode programs will work in subtly different manners causing annoying compatibility problems. Bcode was invented to provide the same service as uucode but to maintain a tighter standard.

**virtual memory**

This is a scheme by which disk space is made to substitute for the more expensive RAM space. Using it will often enable a comptuer to do things it could not do without it, but it will also often result in an overall slowing down of the system. The concept of swap space is very similar.

**virtual reality**

Virtual reality (often called VR for short) is generally speaking an attempt to provide more natural, human interfaces to software. It can be as simple as a pseudo 3D interface or as elaborate as an isolated room in which the computer can control the user's senses of vision, hearing, and even smell and touch.

**VoIP**

VoIP means "Voice over IP" and it is quite simply a way of utilizing the Internet (or even in some cases intranets) for telephone conversations. The primary motivations for doing so are cost and convenience as VoIP is significantly less expensive than typical telephone long distance packages, plus one high speed Internet connection can serve for multiple phone lines.

**W3C**

The World Wide Web Consortium (usually abbreviated W3C) is a non-profit, advisory body that makes suggestions on the future direction of the World Wide Web, HTML, CSS, and browsers.

**WebTV**

A WebTV box hooks up to an ordinary television set and displays web pages. It will not display them as well as a dedicated computer.

**Windows Vista**

Windows Vista is the newest flavor of MS-Windows (specifically the planned replacement for Windows XP). Windows Vista (originally known as Longhorn) currently only runs on x86 processors.

**WYSIWYG**

What you see is what you get; an adjective applied to a program that attempts to exactly represent printed output on the screen. Related to WYSIWYM but quite different.

**WYSIWYM**

What you see is what you mean; an adjective applied to a program that does not attempt to exactly represent printed output on the screen, but rather defines how things are used and so will adapt to different paper sizes, etc. Related to WYSIWYG but quite different.

**X-Face**

X-Faces are small monochrome images embedded in headers for both provides a e-mail and news messages. Better mail and news applications will display them (sometimes automatically, sometimes only per request).

**Y2K**

The general class of problems resulting from the wrapping of computers' internal date timers is given this label in honor of the most obvious occurrence -- when the year changes from 1999 to 2000 (abbreviated in some programs as 99 to 00 indicating a backwards time movement). Contrary to popular belief, these problems will not all manifest themselves on the first day of 2000, but will in fact happen over a range of dates extending out beyond 2075. A computer that does not have problems prior to the beginning of 2001 is considered "Y2K compliant", and a computer that does not have problems within the next ten years or so is considered for all practical purposes to be "Y2K clean

**zip**

There are three common zips in the computer world that are completely different from one another. One is a type of removable removable disk slightly larger (physically) and vastly larger (capacity) than a floppy. The second is a group of programs used for running interactive fiction. The third is a group of programs used for compression.