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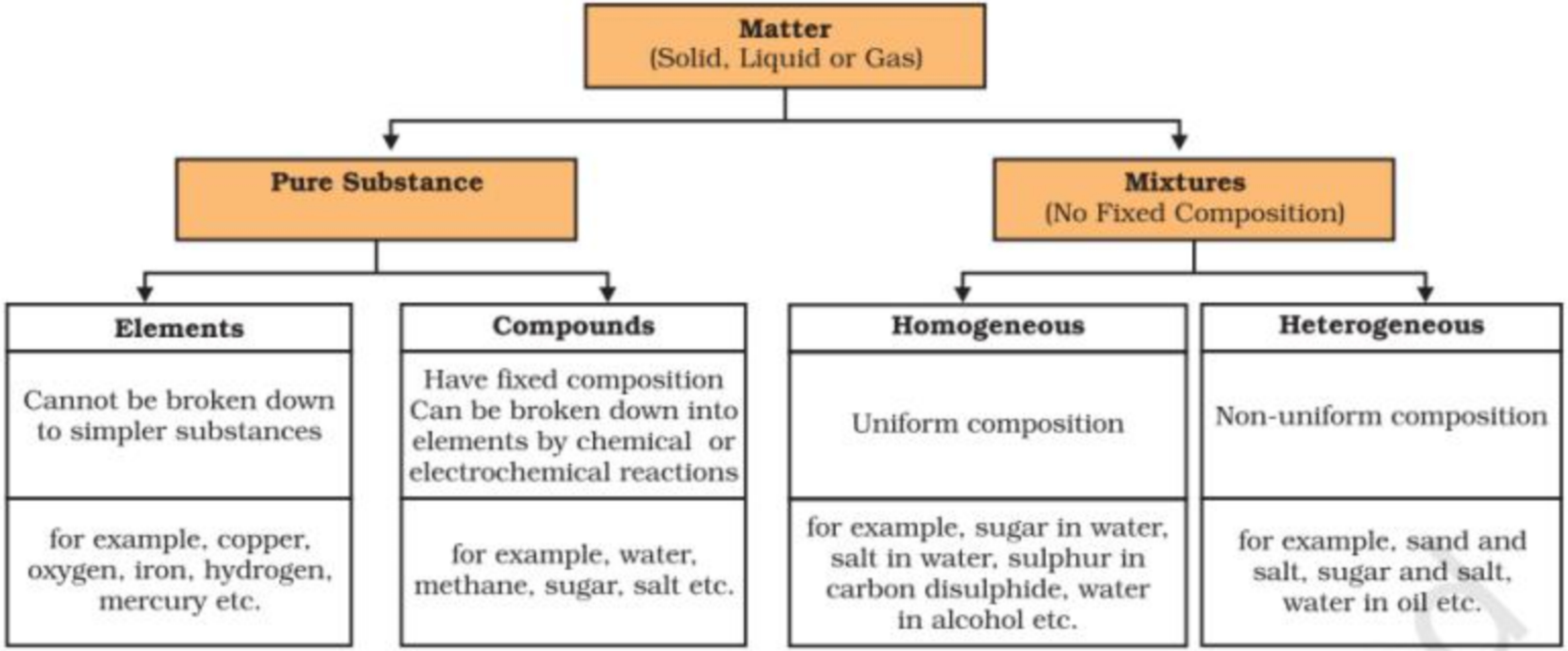
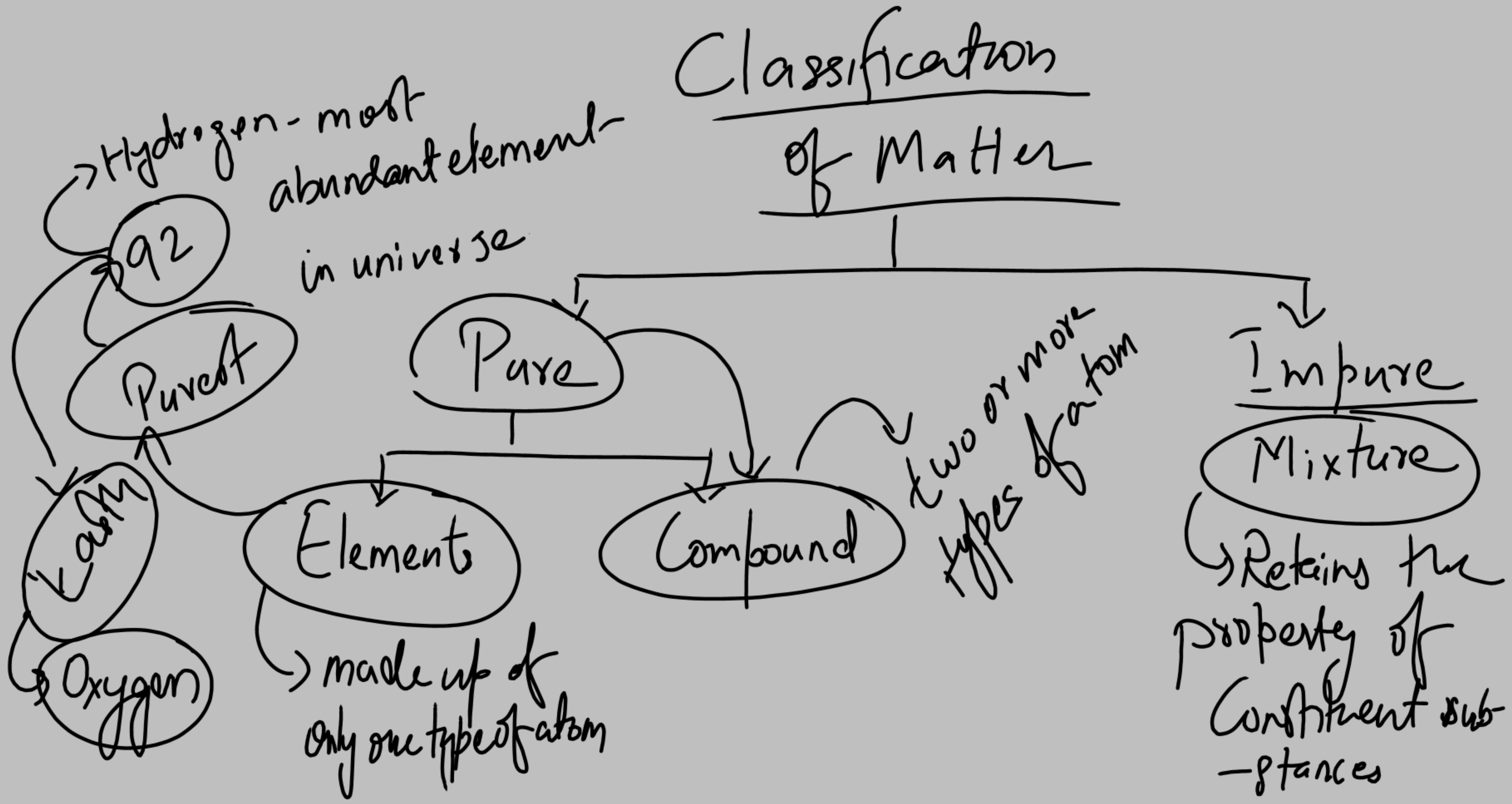
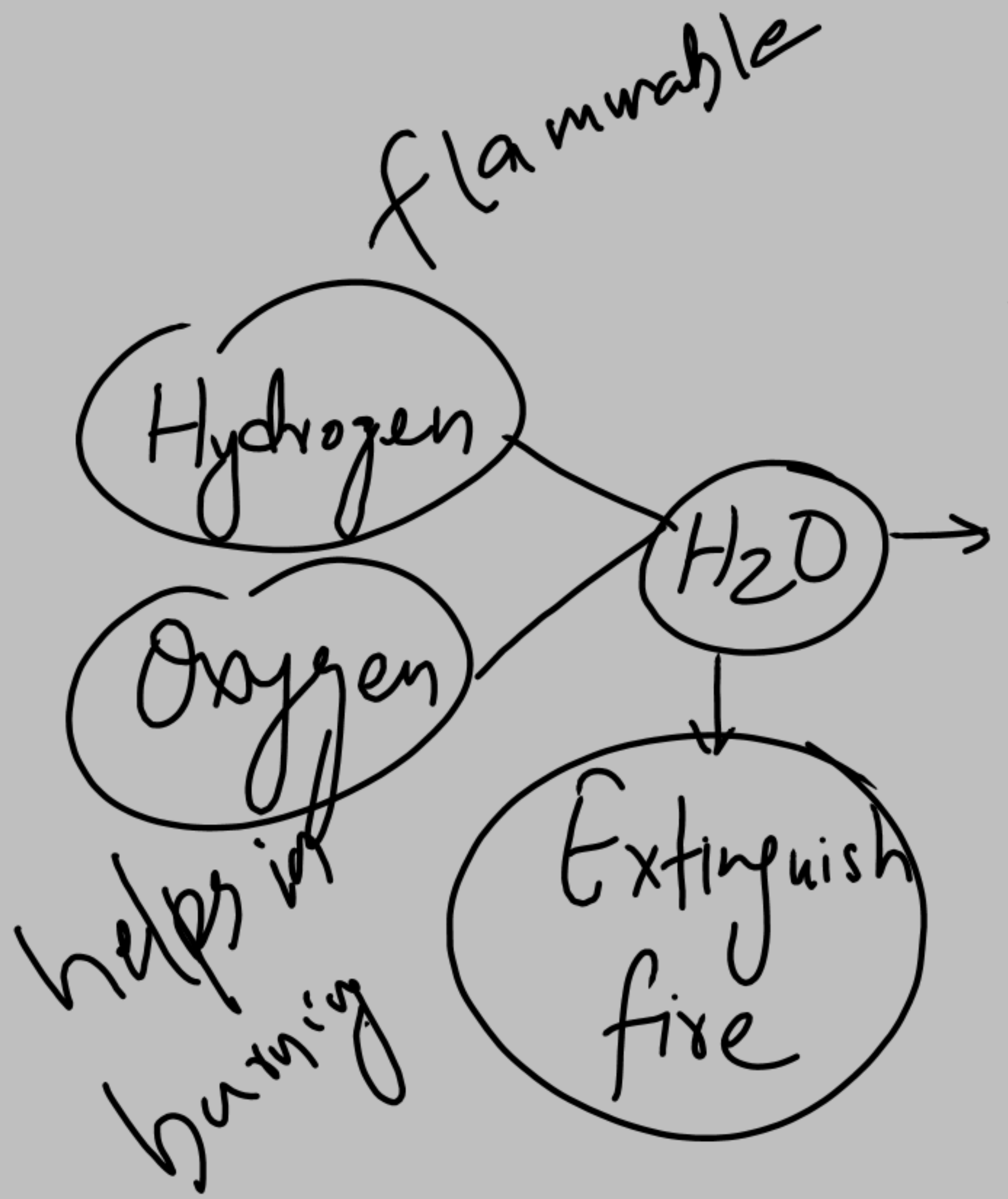
General Science

By Kinshuk Sir

UPSC


Matter
(Solid, Liquid or Gas)
Pure Substance
Mixtures
(No Fixed Composition)
Elements
Cannot be broken down to simpler substances
for example, copper, oxygen, iron, hydrogen, mercury etc.
Compounds
Have fixed composition Can be broken down into elements by chemical or electrochemical reactions
for example, water, methane, sugar, salt etc.
Homogeneous
Uniform composition
for example, sugar in water, salt in water, sulphur in carbon disulphide, water in alcohol etc.
Heterogeneous
Non-uniform composition
for example, sand and salt, sugar and salt, water in oil etc.


Classification of Matter
Pure
Impure
Mixture
Retains the property of Constituent sub-stances
Compound
two or more types of atom
Elements
made up of only one type of atom
Purest
92
Hydrogen - most abundant element in universe
Earth
Oxygen

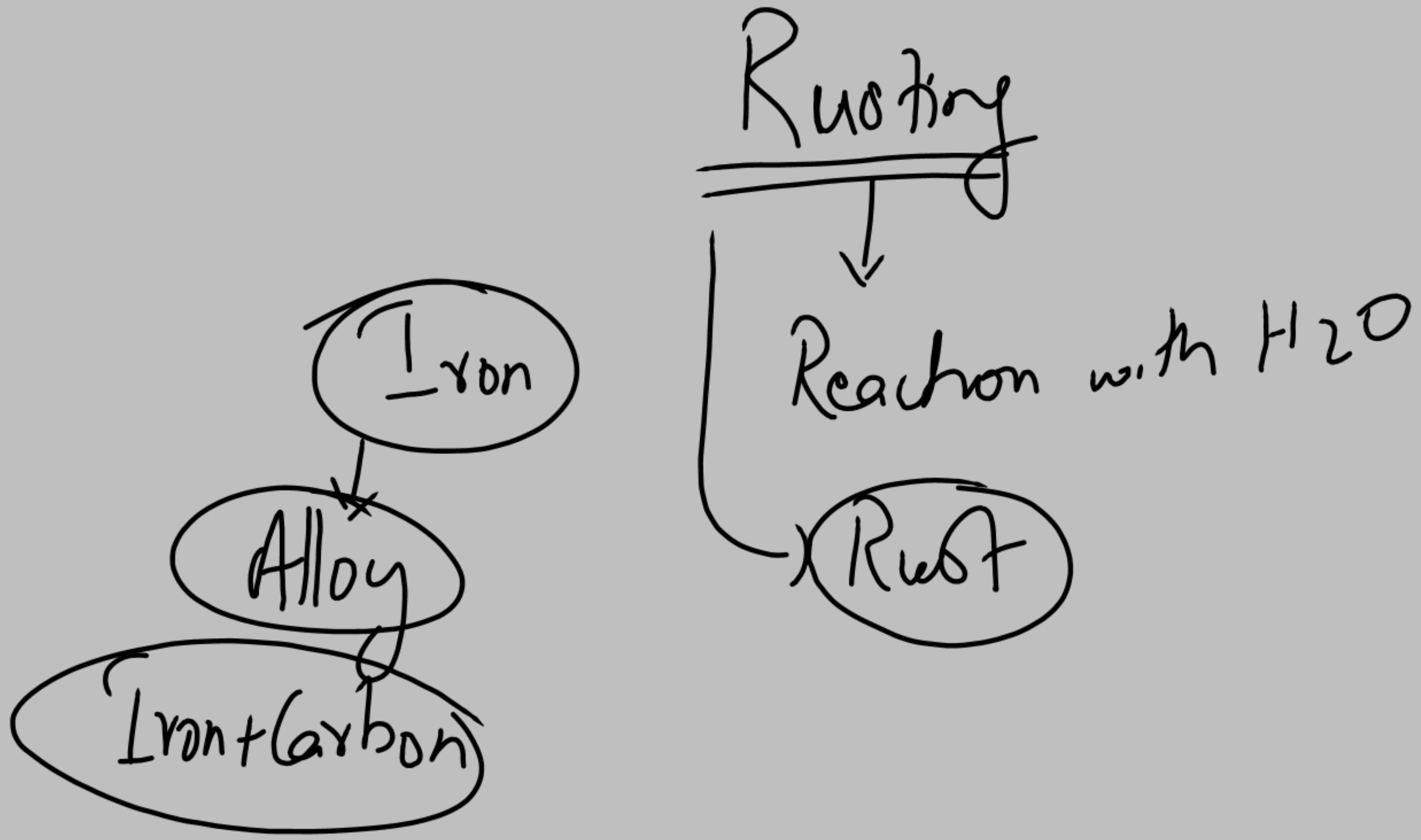


Compound

= 2 or more types of Atom

→ its own properties

→ Its doesnt retain the property of constitent elements


Rusting
Reaction with H2O
Rust
Iron
Alloy
Iron+Carbon

Chemistry

The number of elements known at present are more than 100.

Ninety-two elements are naturally occurring and the rest are manmade.

Majority of the elements are solid.

Eleven elements are in gaseous state at room temperature.

Two elements are liquid at room temperature– mercury and bromine.

Elements, gallium and cesium become liquid at a temperature slightly above room temperature (303 K).

Chemistry

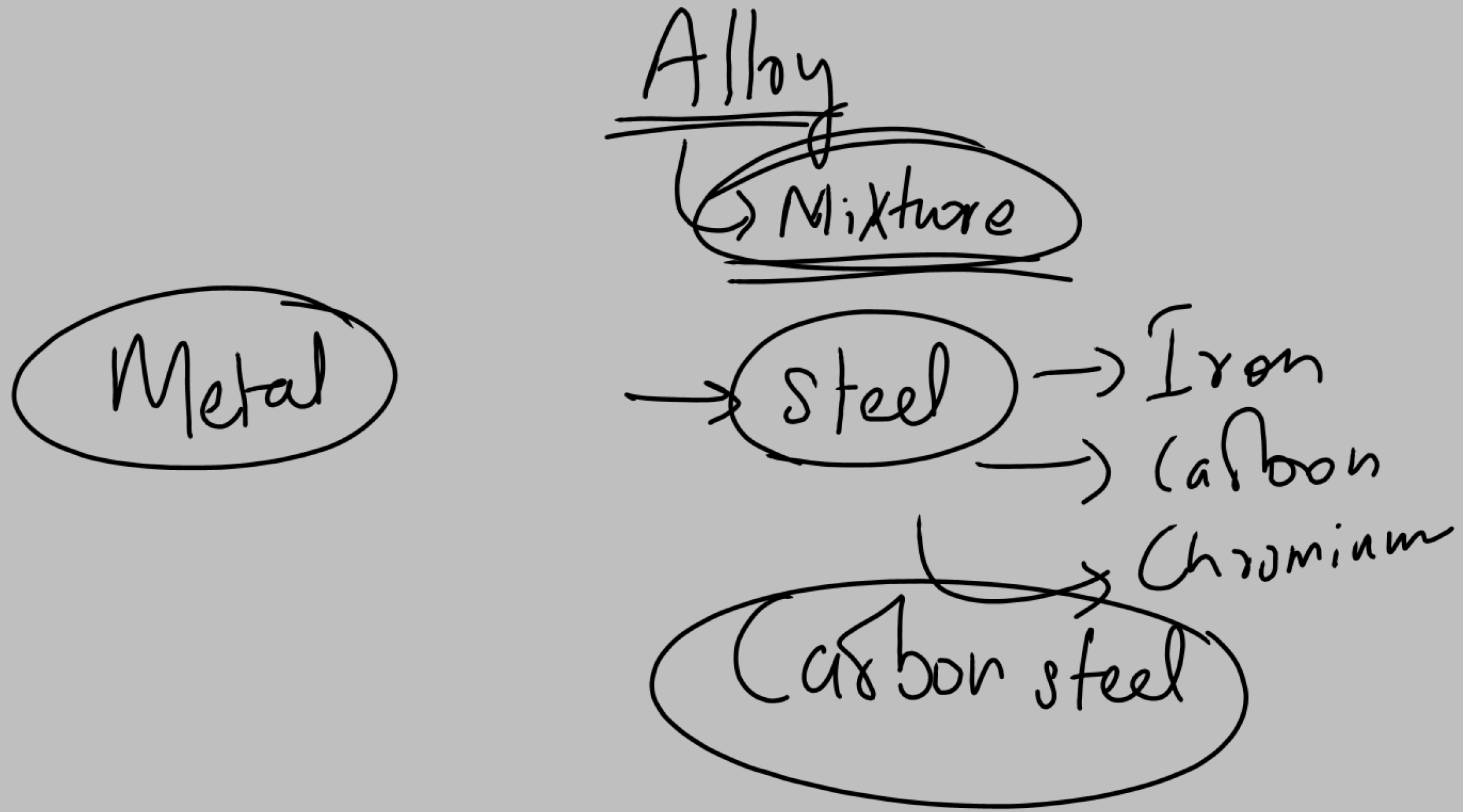
Alloys: Alloys are mixtures of two or more metals or a metal andanon-metal and cannot be separated into their components by physical methods. But still, an alloy is considered as a mixture because it shows the properties of its constituents and can have variable composition. For example, brass is a mixture of approximately 30% zinc and 70% copper.

In alloys the chemical properties of the component elements are retained but certain physical properties are improved.

Metal alloys are stronger than pure metals

Metal alloys are more versatile than pure metals

Metal alloys are more resistant to corrosion than pure metals


Alloy
Mixture
Metal
steel
Iron
Carbon
Chromium
Carbon steel

Chemistry

most common metal alloys?

1. **Brass**
2. **Carbon Steel**
3. **Stainless Steel**
4. **Bronze**
5. **Aluminum Alloy**

Chemistry

Physical & Chemical Change:

The interconversion of states is a physical change because these changes occur without a change in composition and no change in the chemical nature of the substance. Although ice, water and water vapour all look different and display different physical properties, they are chemically the same.

Chemical change brings change in the chemical properties of matter and we get new substances. A chemical change is also called a chemical reaction. Burning is a chemical change. During this process one substance reacts with another to undergo a change in chemical composition.

Physical

→ change in state of matter

Chemical

→ Change in Chemical properties of matter

→ new substance is formed

(A) → Evaporation

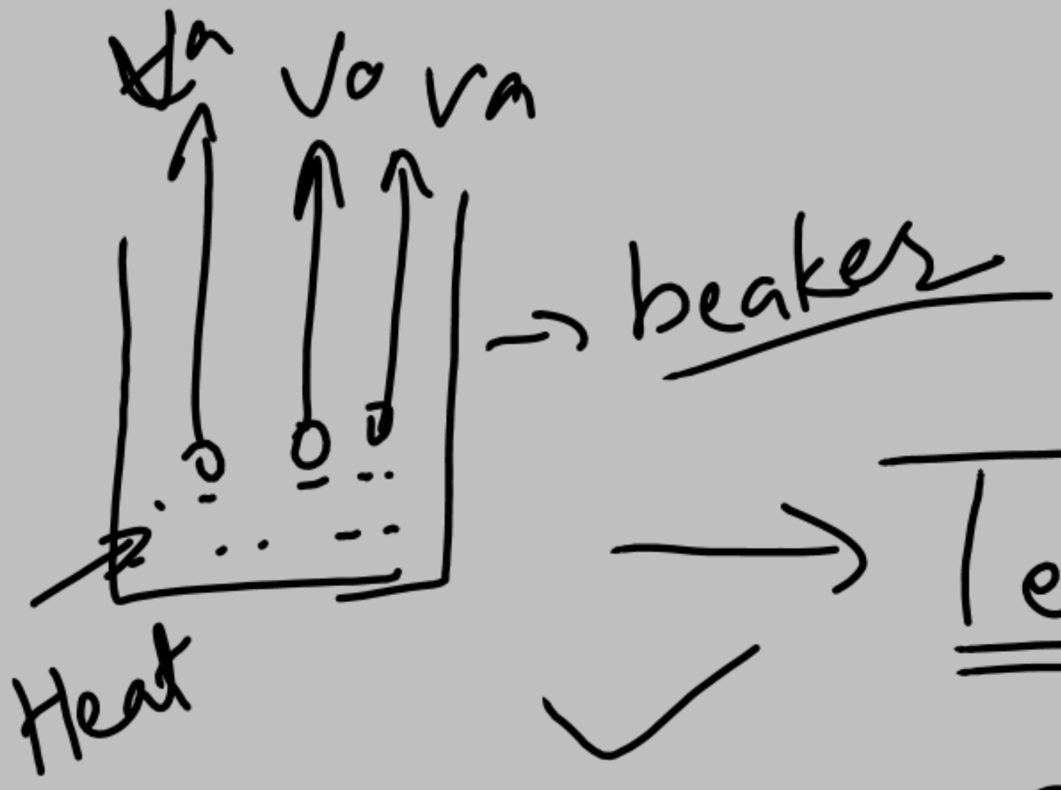
(B) → Burning of Candle

(C) → Water getting converted to Ice

(D) → Milk into Curd

Evaporation

Air 100 H_2O

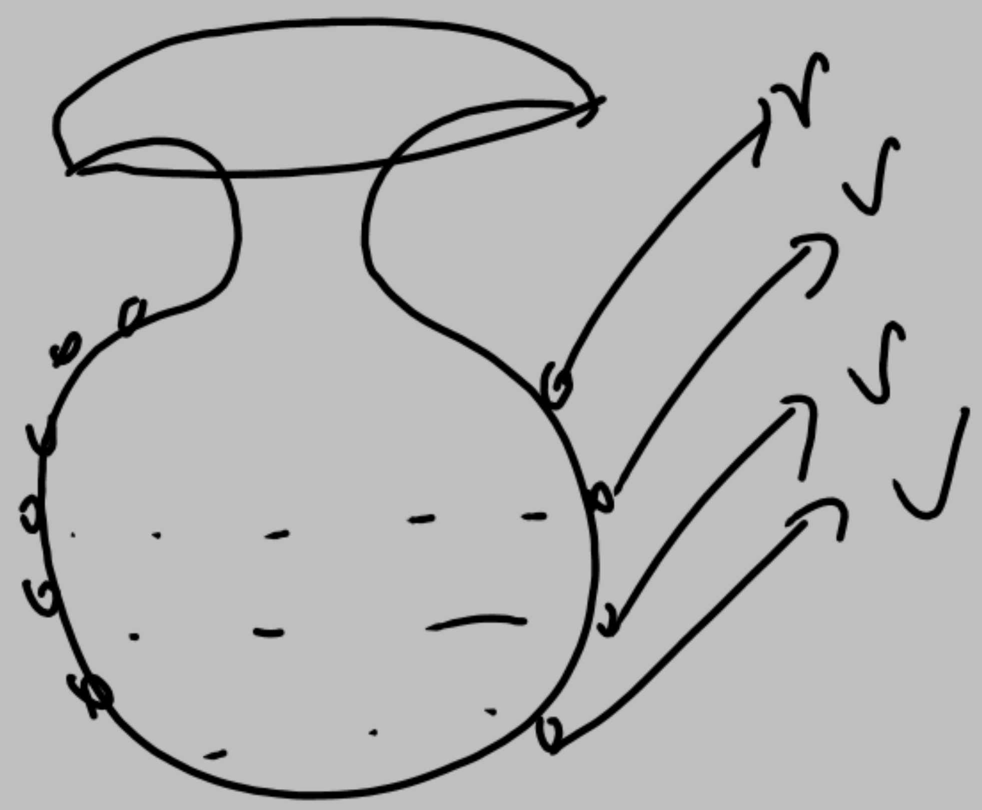


→ Temp → d → humidity → I

humidity ↳ presence of water in air

→ Surface area → d

→ Wind speed → d



Chemistry

Evaporation:

We know that particles of matter are always moving and are never at rest. At a given temperature in any gas, liquid or solid, there are particles with different amounts of kinetic energy. In the case of liquids, a small fraction of particles at the surface, having higher kinetic energy, is able to break away from the forces of attraction of other particles and gets converted into vapour. This phenomenon of change of a liquid into vapours at any temperature below its boiling point is called evaporation.

Chemistry

FACTORS AFFECTING EVAPORATION:

The rate of evaporation increases with–

- **An increase of surface area: We know that evaporation is a surface phenomenon. If the surface area is increased, the rate of evaporation increases. For example, while putting clothes for drying up we spread them out.**
- **An increase of temperature: With the increase of temperature, more number of particles get enough kinetic energy to go into the vapour state.**
- **A decrease in humidity: Humidity is the amount of water vapour present in air. The air around us cannot hold more than a definite amount of water vapour at a given temperature. If the amount of water in air is already high, the rate of evaporation decreases.**
- **An increase in wind speed: It is a common observation that clothes dry faster on a windy day. With the increase in wind speed, the particles of water vapour move away with the wind, decreasing the amount of water vapour in the surrounding.**

Chemistry

HOW DOES EVAPORATION CAUSE COOLING?

In an open vessel, the liquid keeps on evaporating. The particles of liquid absorb energy from the surrounding to regain the energy lost during evaporation. This absorption of energy from the surroundings make the surroundings cold.

After a hot sunny day, people sprinkle water on the roof or open ground because the large latent heat of vaporisation of water helps to cool the hot surface.

Chemistry

Chemical Change Examples:

1. Rusting

Rusting is the process of oxidation, which is the result of a reaction that takes place because of oxygen. It gives a flaky brown layer that gathers over iron surfaces, this layer is formed due to the oxidization of the topmost layer, leading to the formation of metal oxide. It is just not with iron but these layers forms on other metals as well, like copper, silver, and gold.

$$Fe + 3O_2 + xH_2O \rightarrow Fe_3O_4 \, . \, xH_2O$$

2. Digestion

Did you know? Every time we eat something, a chemical reaction is simultaneously taking place to digest it. Digestion is also a complex process, in which thousands of chemical reactions take place. For example, when you eat something, the water and enzyme named amylase breaks down carbohydrates and sugar into simple molecules.

Chemistry

3. Photosynthesis

Just like humans, several chemical reactions take place in plants as well, a chemical reaction called photosynthesis converts carbon dioxide and water into plant food – glucose, and oxygen. It is one of the major chemical reactions as it leads to the generation of oxygen and provides food for both plants and animals.

$6\ CO_2 + 6\ H_2O + light \rightarrow C_6H_{12}O_6 + 6\ O_2$

4. Combustion: Every time you strike a match, burn a candle, build a fire, or light a grill, you see the combustion reaction. Combustion combines energetic molecules with oxygen to produce carbon dioxide and water.

Chemistry

A chemical process in which a substance reacts with oxygen to give off heat is called combustion. The substance that undergoes combustion is said to be combustible. It is also called a fuel. The fuel may be solid, liquid or gas. Sometimes, light is also given off during combustion, either as a flame or as a glow.

Chemistry

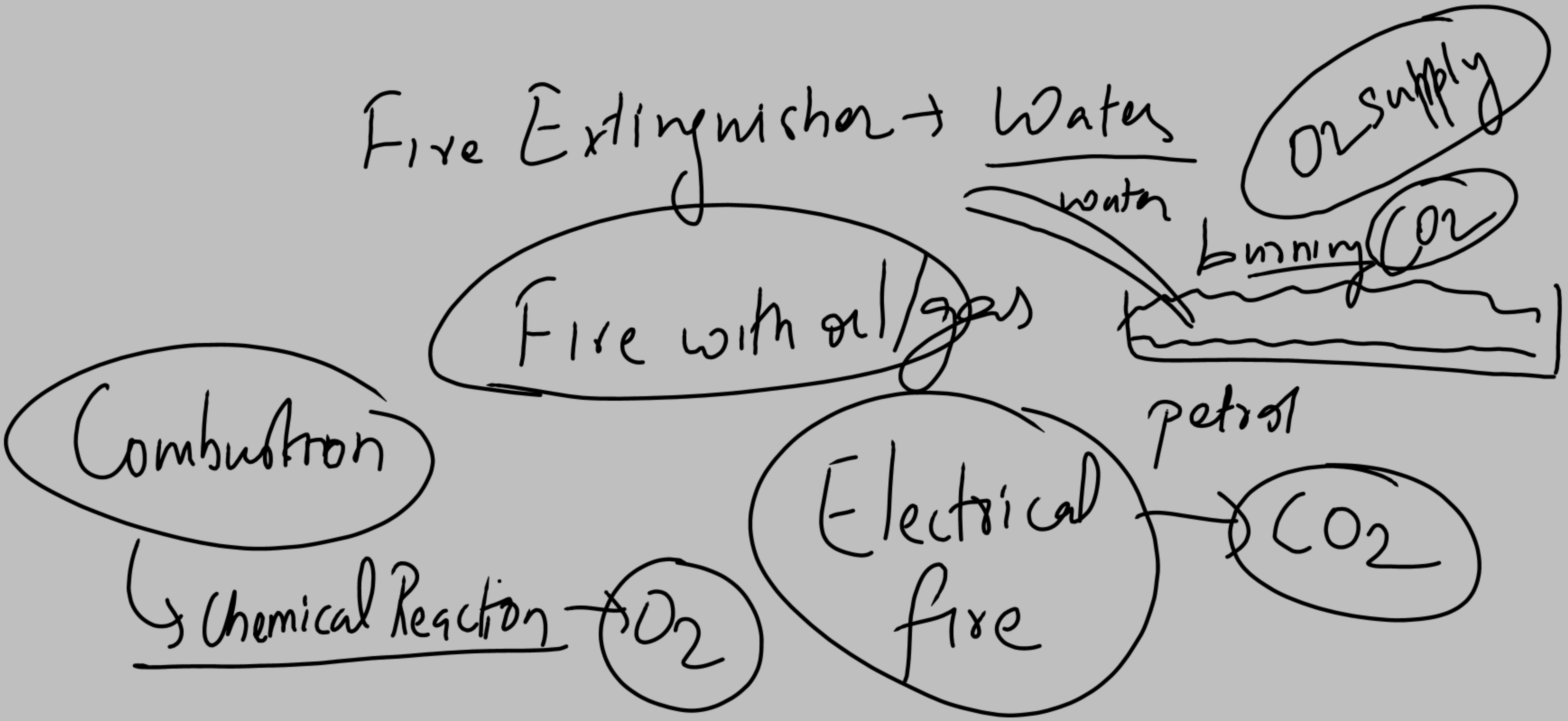
Extinguishing Fire:

The most common fire extinguisher is water. But water works only when things like wood and paper are on fire. If electrical equipment is on fire, water may conduct electricity and harm those trying to douse the fire. Water is also not suitable for fires involving oil and petrol.

Do you recall that water is heavier than oil? So, it sinks below the oil, and oil keeps burning on the top.

For fires involving electrical equipment and inflammable materials like petrol, carbon dioxide (CO2) is the best extinguisher. CO2, being heavier than oxygen, covers the fire like a blanket.

Since the contact between the fuel and oxygen is cut off, the fire is controlled. The added advantage of CO2 is that in most cases it does not harm the electrical equipment.


Fire Extinguisher → Water
water
O_2 supply
CO_2
burning
Fire with oil/gas
petrol
Combustion
→ Chemical Reaction → O_2
Electrical fire
→ CO_2

Chemistry

5. When a candle burns, both physical and chemical changes occur.

Physical Changes: On heating, candle wax gets melted. Since it again turns into solid wax on cooling. So, the melting of wax and vapourisation of melted wax are physical changes.

Chemical Changes : The wax near flame burns and gives new substances like carbon dioxide, carbon soot, water vapour, heat and light.

6. LPG is another example of a familiar process in which both the chemical and physical changes take place. LPG is present in liquid form in the cylinder. When it comes out of the cylinder, it converts into gaseous form which is a physical change. It undergoes chemical change when gas burns in air.

Chemistry

Rare earth elements

The Rare earth elements are a group of 17 metallic elements having similar chemical properties found in the periodic table.

These comprise 15 lanthanides elements plus two other elements namely scandium and yttrium.

Scandium and yttrium are considered rare-earth elements because they tend to occur in the same ore deposits as the lanthanides and exhibit similar chemical properties, but have different electronic and magnetic properties

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Rare earth name	Discovery tear	Atomic name &number	Light/heavy REE	Critical/ Uncritical
Yttrium	1788	Y-39	Heavy	Critical
Cerium	1803	Ce-58	Light	Excessive
Lanthanum	1839	La-57	Light	Uncritical
Erbium	1842	Er-68	Heavy	Critical
Terbium	1843	Tb-65	Heavy	Critical
Ytterbium	1878	Yb-70	Heavy	Excessive
Holmium	1878	Ho67	Heavy	Excessive
Scandium	1879	Sc-21	Heavy	Critical

Samarium	1879	Sm-62	Light	Uncritical
Thulium	1879	Tm-69	Heavy	Excessive
Praseodymium	1885	Pr-59	Light	Uncritical
Neodymium	1885	Nd-60	Light	Critical
Dysprosium	1886	Dy-66	Heavy	Critical
Europium	1886	Eu-63	Heavy	Critical
Gadolinium	1886	Gd-64	Heavy	Uncritical
Lutetium	1907	Lu-71	Heavy	Excessive
Promethium	1947	Pm-61		

Chemistry

The term 'rare-earth' is a misleading term because they are not actually scarce.

Though rare-earth elements are technically relatively plentiful in the entire Earth's crust (cerium being the 25th-most-abundant element and more abundant than copper),

In practice, this is spread thin across trace impurities, so to obtain rare earths at usable purity requires processing enormous amounts of raw ore at great expense, thus the name "rare" earths.

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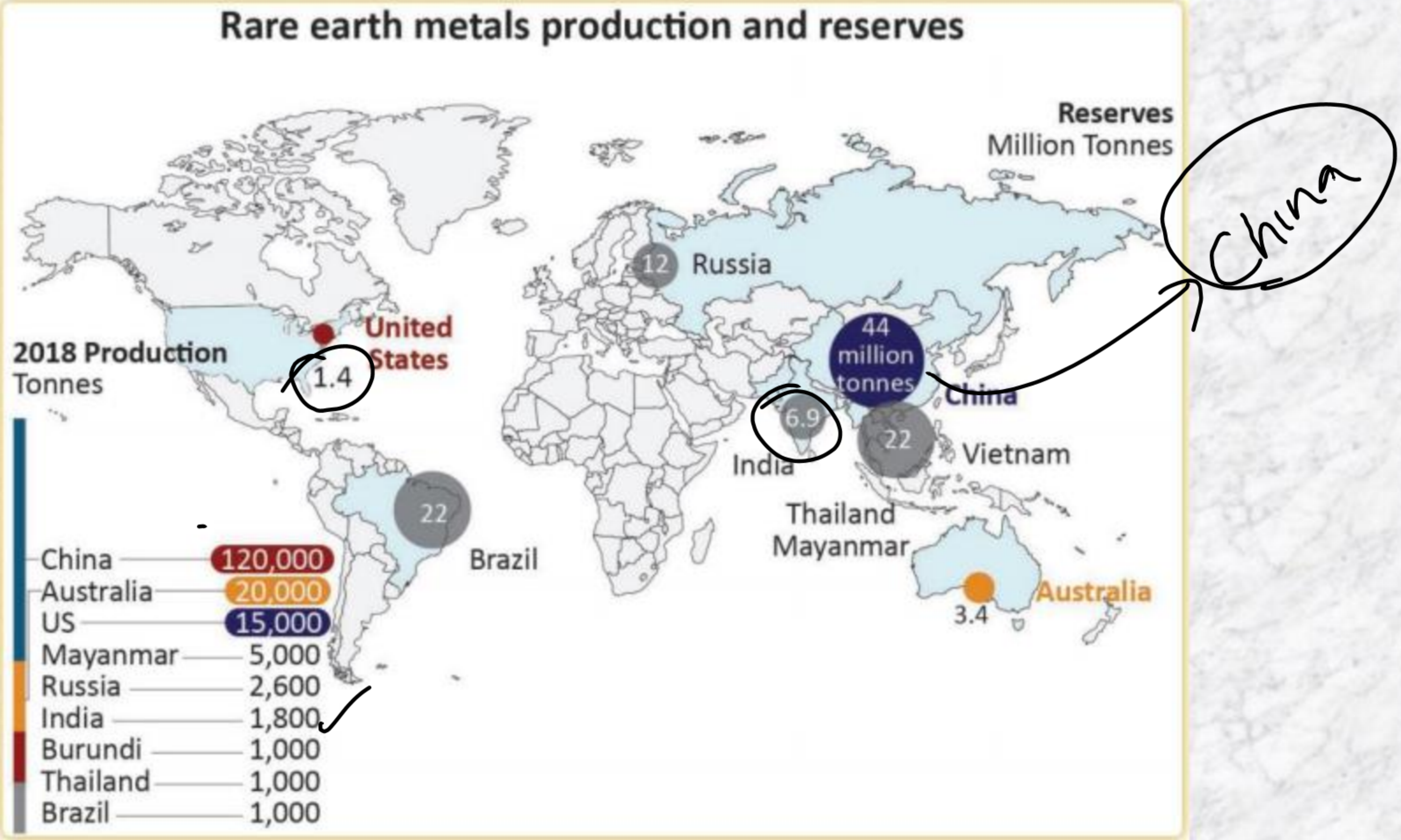
Rare earth metals production and reserves
Reserves
Million Tonnes
12
Russia
United States
1.4
44 million tonnes
China
6.9
India
22
Vietnam
Thailand
Mayanmar
22
Brazil
3.4
Australia
2018 Production
Tonnes
China 120,000
Australia 20,000
US 15,000
Mayanmar 5,000
Russia 2,600
India 1,800
Burundi 1,000
Thailand 1,000
Brazil 1,000
China

Chemistry

Rare Earth Metal

Supply Chain problems: Rare earths have a highly concentrated global supply scenario—much more so than oil and hydrocarbons—which presents a strategic challenge.

– Until a couple of years prior, China controlled 90% of the stockpile of intriguing earths.

– China's share is now 60%, despite the aggressive production of the US, Australia, and Canada. Following a dispute with Japan over the East China Sea's Senkaku Islands in 2010;

– China shut down products of Interesting Earth Components to Japan. China might use similar strategies in the future given the border dispute with India.

Chemistry

To exploit domestic resources: India has more noteworthy stores than the US and Australia, just behind China, Vietnam, Russia, and Brazil.

– India must become a supplier for both domestic and international consumption given Russia's involvement in the conflict

Diverse uses especially in new technologies: Rare earth elements are utilized in numerous high-tech processes and applications, including EVs, medical devices, LEDs, and others. Hence, such elements must eventually be manufactured domestically

Increasing demand: The numerous applications of rare earth elements in modern technologies indicate that their demand will rise in the future.

Technology

Use

→ Electronics

→ Electric vehicles

→ Clean Energy.

Supply

- → Over dependence on china
- → lack of Technology for feasible commercial exploitation
- → Unviable deposits of REE

Chemistry

– For example, the ongoing interest in neodymium in India is little, at around 900 tons for each annum, since homegrown assembling of EVs and wind turbines is as yet restricted.

– However, it is anticipated that the demand for neodymium will sharply increase by 6-7 times by 2025 (6,000 tonnes) and by 18-20 times by 2030 (20,000 tonnes) as the production of electric vehicles and wind turbines picks up.

Increases import dependency and bill: The majority of rare earths in India are almost entirely imported, placing enormous pressure on foreign exchange.

– Additionally, as demand for rare elements rises, so do their prices. For instance, the global cost of neodymium has skyrocketed from less than US$ 100 per kilogram in 2018 to more than US$ 200 per kilogram today.

Chemistry

Rare Earth Elements in India

The Rare Earth (RE) resources in India are reported to be the fifth largest in the world.

Indian resource is significantly lean w.r.t. grade and it is tied with radioactivity making the extraction long, complex and expensive.

Further, Indian resources contain Light Rare Earth Elements (LREE) while Heavy Rare Earth Elements (HREE) are not available in extractable quantities.

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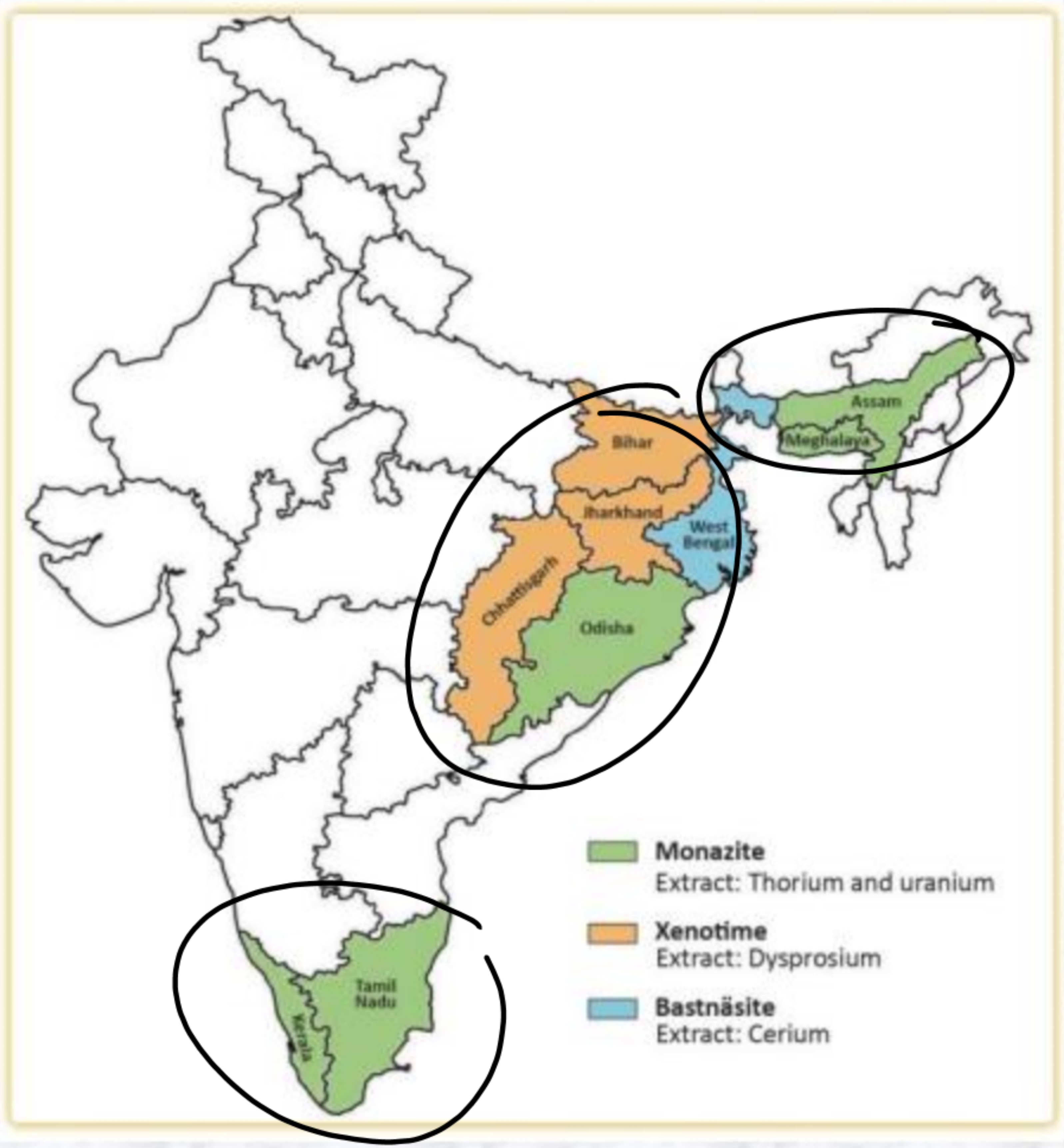

Assam
Meghalaya
Bihar
Jharkhand
West Bengal
Chhattisgarh
Odisha
Tamil Nadu
Kerala
Monazite
Extract: Thorium and uranium
Xenotime
Extract: Dysprosium
Bastnäsite
Extract: Cerium

Chemistry

Graphene: Why is Graphene the wonder Material?

It is the world's thinnest, strongest, and most conductive material of both electricity and heat.

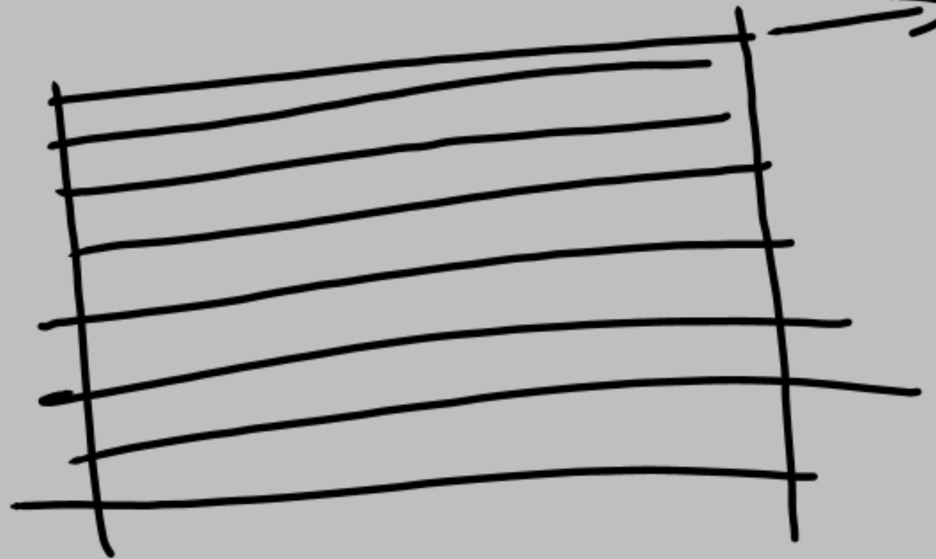
It conducts electricity better than copper.

It is 200 times stronger than steel but six times lighter.

It is almost perfectly transparent as it absorbs only 2% of light.

It is impermeable to gases, even those as light as hydrogen and helium.

Graphene



→ one layer of Carbon atom

Carbon
→ Diamond
→ Graphite
→ Conduct electricity.

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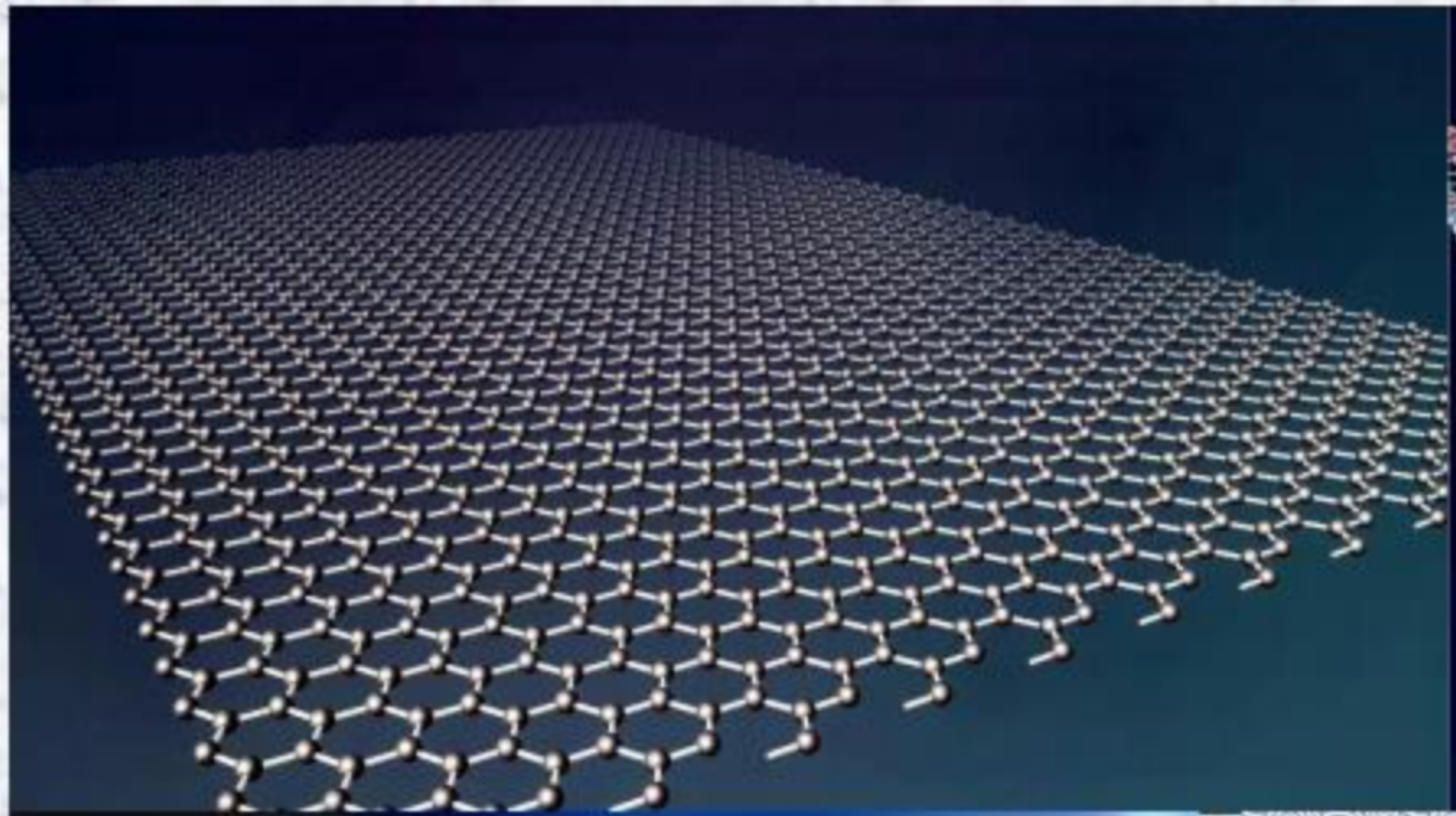

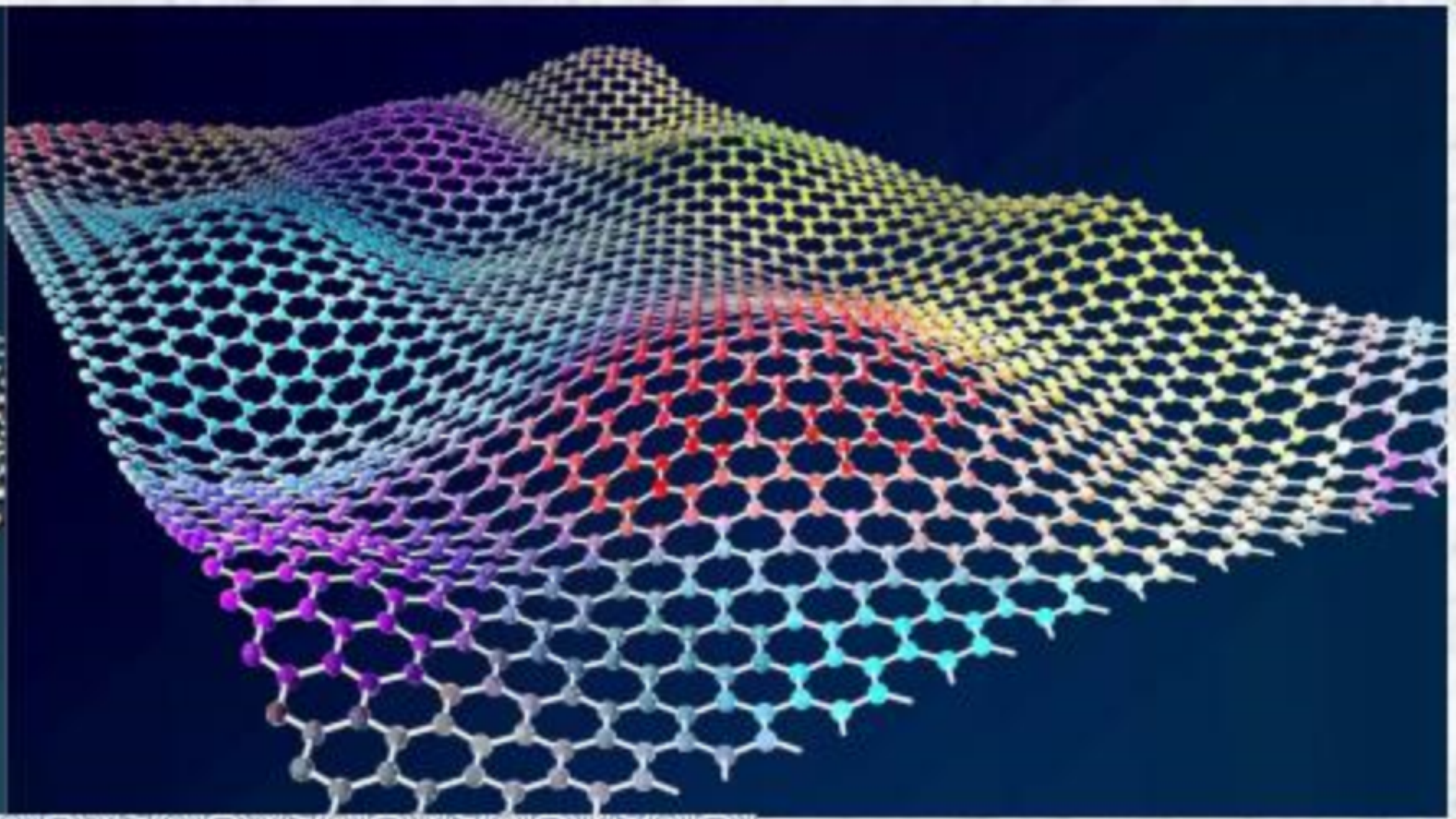

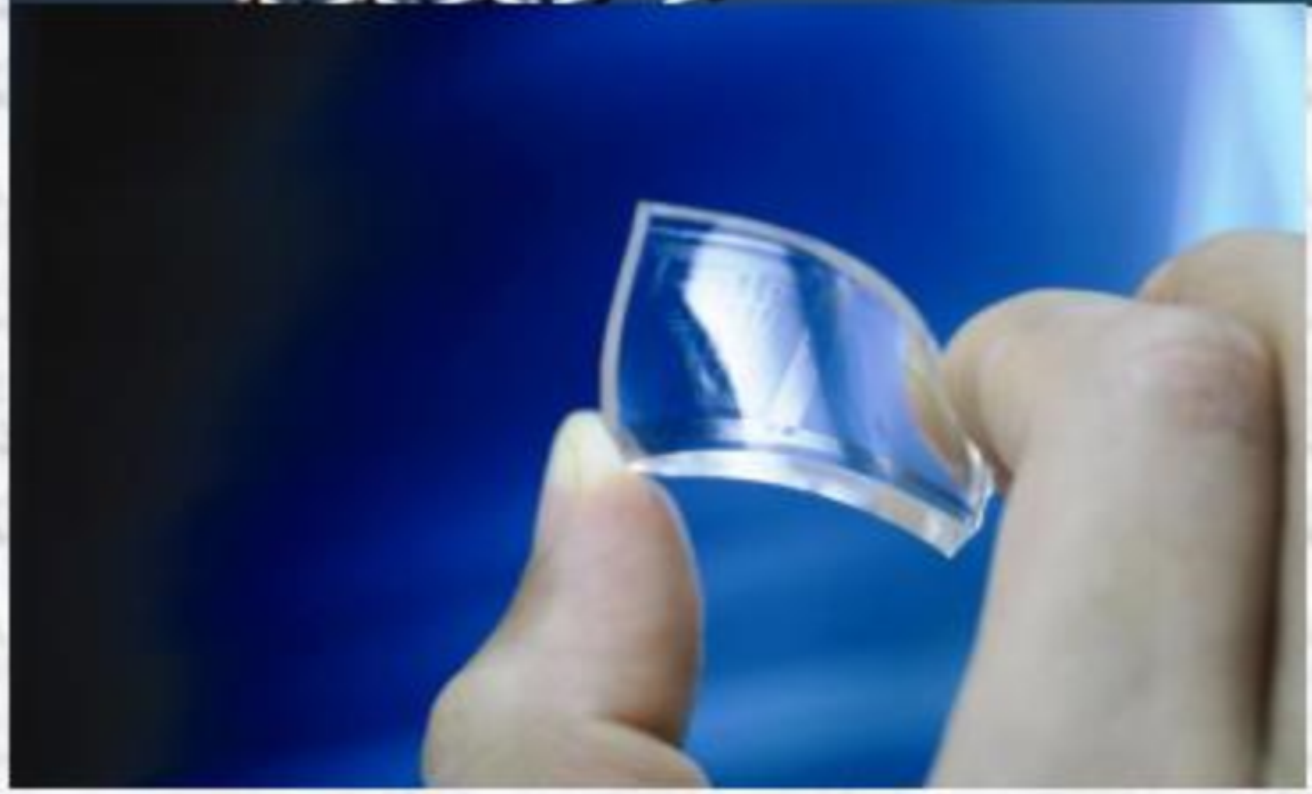

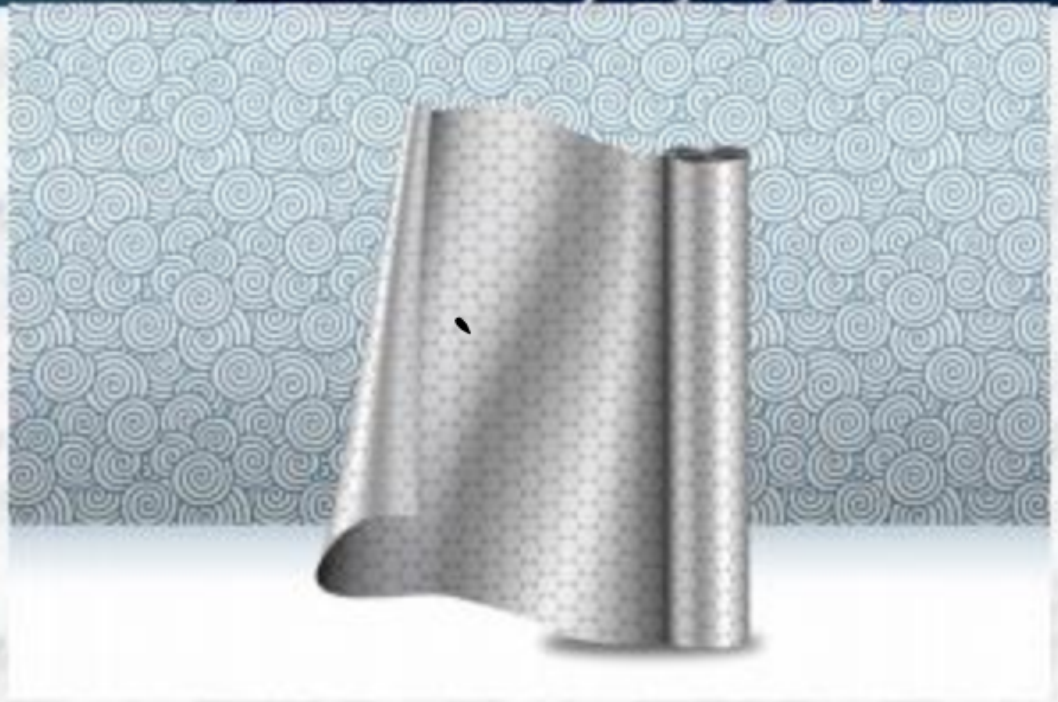

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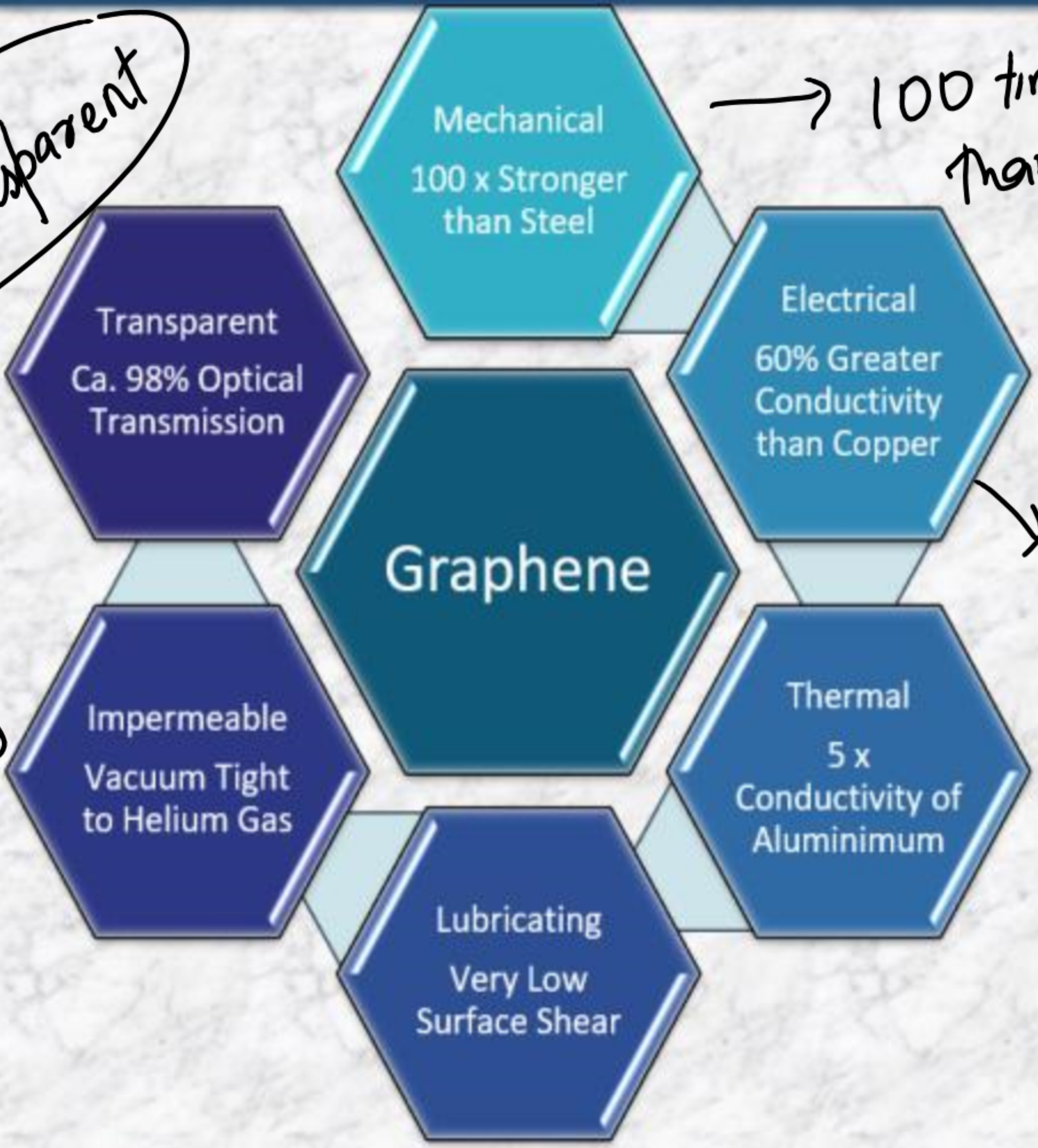
Transparent

100 times stronger than steel



60% more conductive than copper

However, the commercial value of graphene lies in the ability to robustly transfer these outstanding intrinsic properties into other materials to add value and create products which possess specifically enhanced characteristics.

Chemistry

Use of Graphene

Graphene composites are used in aerospace, automotive, sports equipment and construction.

It is used for high-performance batteries and super-capacitors, touchscreens, and conductive inks.

Graphene-based sensors are used for environmental monitoring, healthcare and wearable devices.

Graphene oxide membranes are used for water purification and desalination.

Graphene-based masks were made during COVID.

Chemistry

Other applications of Graphene:

Its exceptional strength makes it promising material for armour and ballistic protection.

Graphene has the potential to absorb and dissipate electromagnetic waves, making it valuable for developing stealth coatings and materials that reduce radar signatures and electromagnetic interference.

Graphene is highly sensitive to environmental changes, which makes it an excellent candidate for sensing chemical and biological agents, explosives, radiation, and other hazardous substances.

Besides, graphene-based materials can also protect us against chemical and biological attacks.

Better energy storage and electronics properties make graphene attractive in defence and aerospace as well as in civil and commercial applications.

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THANKS FOR WATCHING