THE PROPERTIES AND STRUCTURE OF MATTER

COURSE CONTENT

1. Define matter and state of matter
2. Properties of solids, liquids and gases
3. Changes in matter
   - Physical and chemical changes
   - Phase changes of matter
4. Classification of matter
   - Elements, compounds and mixtures
5. Separation of mixtures

OBJECTIVES

- Distinguish between physical and chemical properties.
- Define physical change and list several common physical changes.
- Define chemical change and list several indications that a chemical change has taken place
- Explain the gas, liquid and solid states in terms of particles
- Distinguish between mixtures, elements and compounds.
- Classify mixtures as homogeneous or heterogeneous.
- List and describe several techniques used to separate mixtures.

DEFINITION OF MATTER

- **CHEMISTRY** → study of the composition, structure, and properties of matter and the changes it undergoes
- The two properties of **MATTER** are:
- Mass – amount or quantity of matter
- Volume – amount of space occupied
- Therefore…**MATTER** is anything that has mass and takes up space.

DEFINITION OF MATTER

- All matter is composed of atoms
- Atom:
  - Extremely small chemically indivisible particle
  - Atom is Greek for “that which cannot be divided”
- There is so many different kinds of matter, which are organized by their composition and properties
- Composition - the types and amounts of atoms that make up a sample of matter
- Properties - the characteristics that give each substance a unique identity

PROPERTIES OF MATTER

- Properties of matter allow us to distinguish between substances and classify them
- Can reveal the identity of an unknown substance
- Divided into two groups:
  - **PHYSICAL PROPERTIES**
  - **CHEMICAL PROPERTIES**

PHYSICAL PROPERTY

- Defined as - a characteristic that can be observed or measured without changing the identity or composition of the substance
- Example include:
  - Colour
  - Odor
  - Taste
  - Size
  - Physical state (liquid, gas, or solid)
  - Boiling point
  - Melting point
  - Density

PHYSICAL PROPERTIES

- Physical properties used to describe matter can be classified as:

1) Extensive – depends on the *amount* of matter in the sample
   - e.g. Mass, volume, length
2) Intensive – depends on the *type* of matter, not the amount present
   - Hardness, density, boiling point

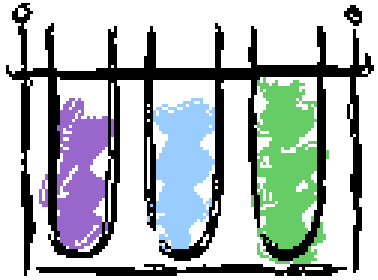
Extensive vs. Intensive

Extensive Properties

- Depend on the amount of matter present
- Mass, volume, length, height, amount of energy, etc.

Intensive Properties

- Do not depend on the amount of matter present
- Density, boiling point, melting point, color, ability to conduct electricity, etc.



CHEMICAL PROPERTIES

- Defined as - ability or inability of a substance to combine with or change into one or more other substances i.e. ability of a substance to undergo a chemical reaction
- Example include:
  - Charcoal burning in air
  - iron rust
  - Decomposition of wood

CHEMICAL PROPERTIES

- Consider terms such as:
  - burn
  - rot
  - rust
  - decompose
  - ferment
  - explode
  - oxidize
  - corrode
  - grow
  - precipitate
  - gas formation
  - digest

Classify each as a physical or chemical property:

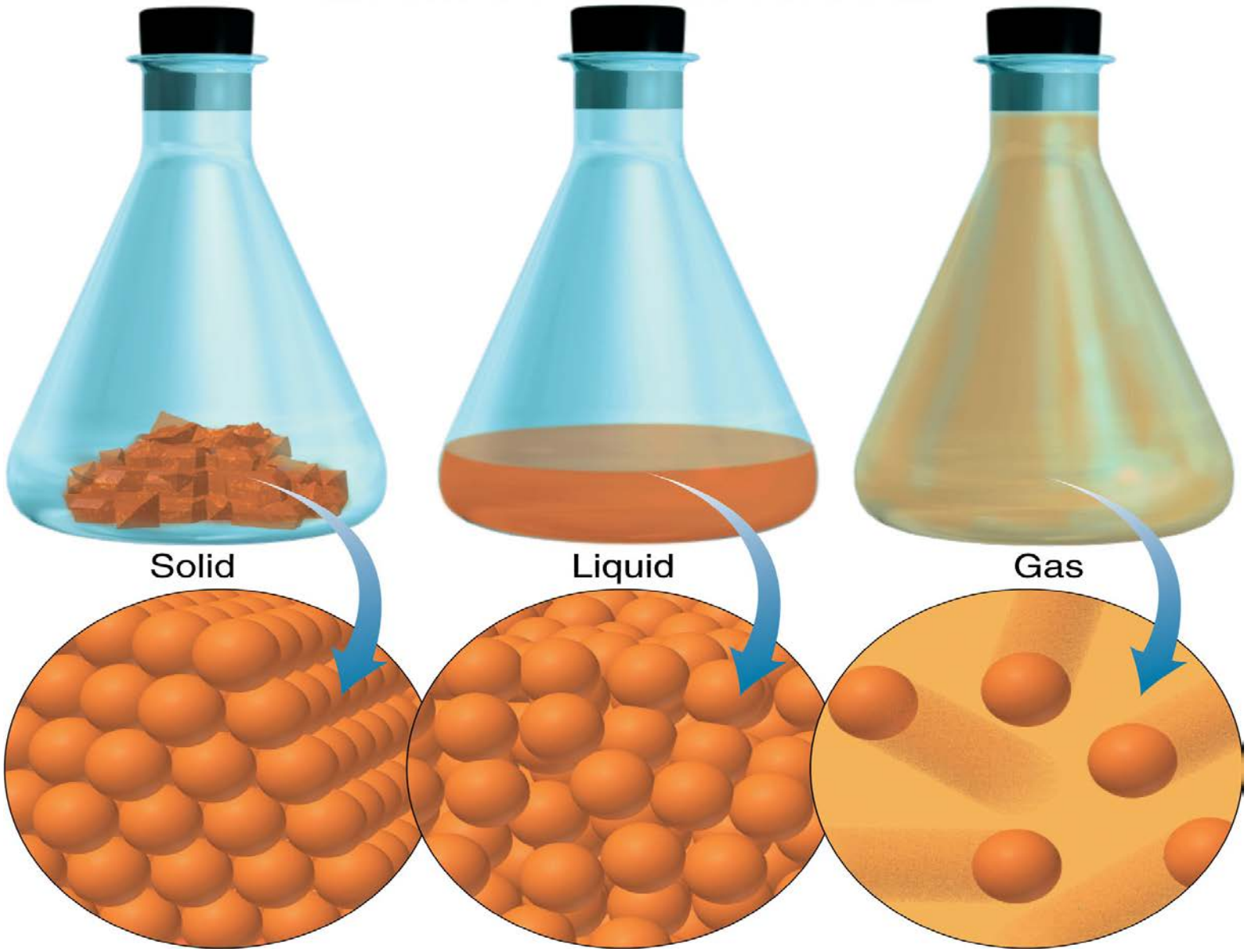
1. Iron and oxygen form rust.
2. Iron is more dense than aluminum
3. Magnesium burns brightly when ignited.
4. Oil and water do not mix.
5. Mercury melts at -39°C.

STATES OF MATTER

- Matter can be classified according to its physical state and its composition

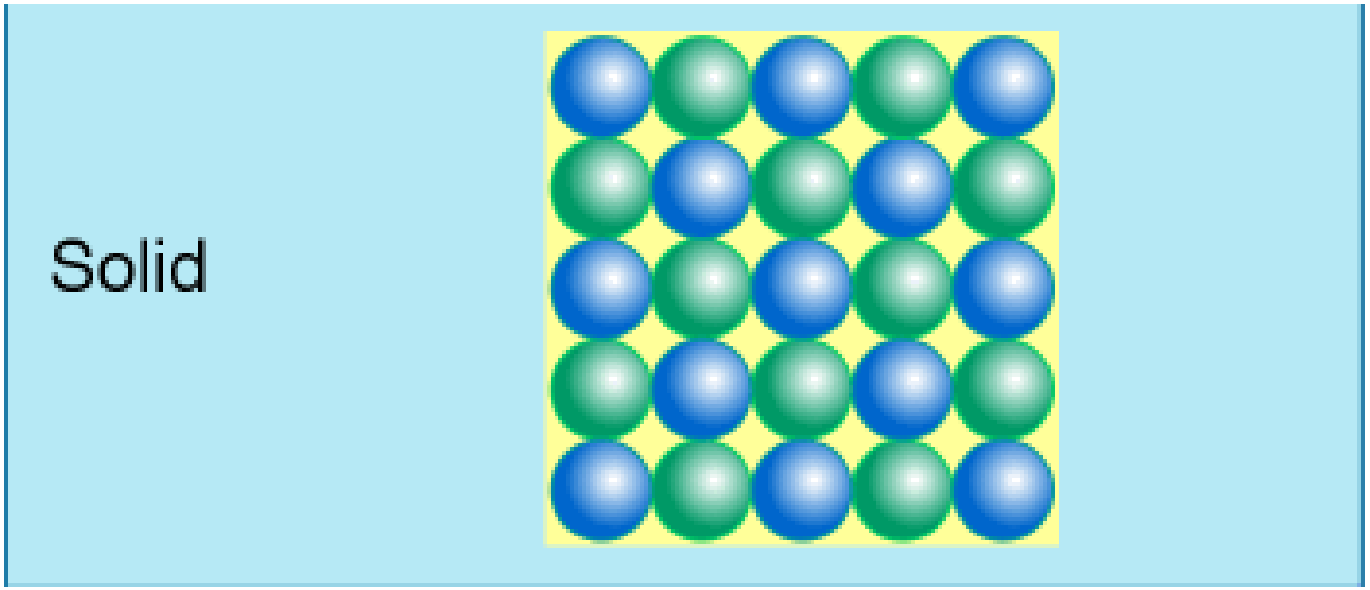
- Physical State:
  - Solid
  - Liquid
  - Gas
- Classification into different states based upon:
  - Particle arrangement
  - Energy of particles
  - Distance between particles
- **State of matter is dependent on temperature and pressure of the surroundings**

STATES OF MATTER



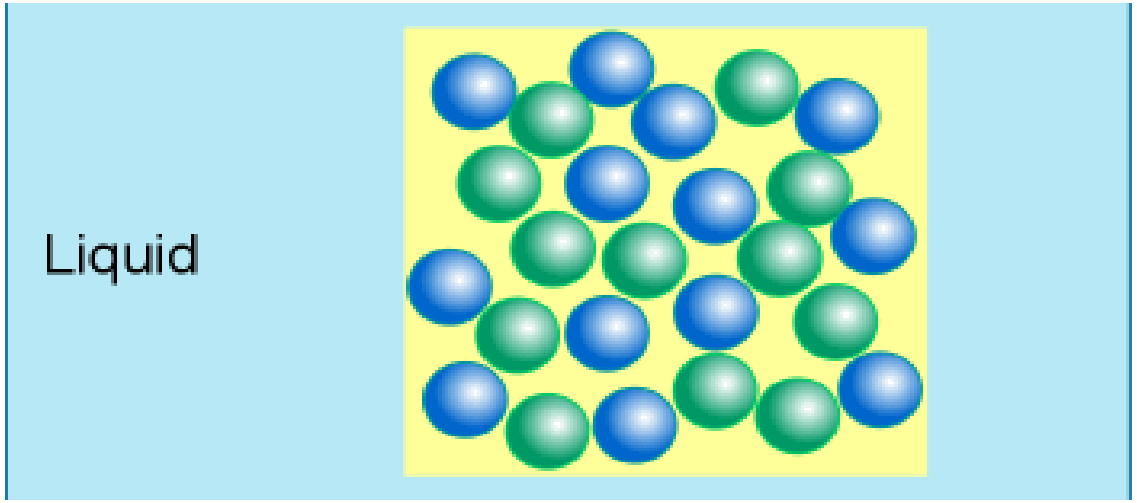
SOLIDS

- Has a definite shape and volume
- True solids have very rigid, ordered structures, in fixed positions i.e. high density
- atoms held tightly together, therefore incompressible
- Atoms move through vibration only, therefore small thermal expansion



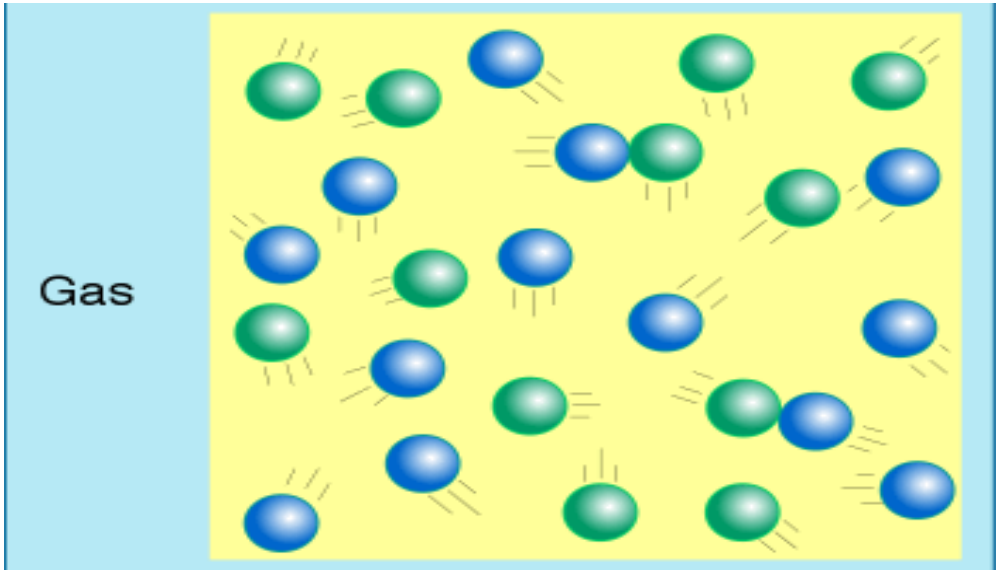
LIQUIDS

- Has a definite volume, atoms are not widely separated, therefore high density and small compressibility
- no definite shape i.e. follows the shape of its container
- Atoms move rapidly enough to slide over one another i.e. ability to flow
- Small thermal expansion



GASES

- Also known as vapour
- No fixed volume or shape, conforms to the volume and shape of its container
- Atoms far apart i.e. low density and can be compressed
- moving at high speeds, colliding with container, moderate thermal expansion



SUMMARY

- **Matter** is anything that has mass and takes up space.
- **Composition** - the types and amounts of atoms that make up a sample of matter
- **Properties** - the characteristics that give each substance a unique identity
- Properties divided into two groups:
  - **Physical properties**
  - **Chemical properties**

SUMMARY

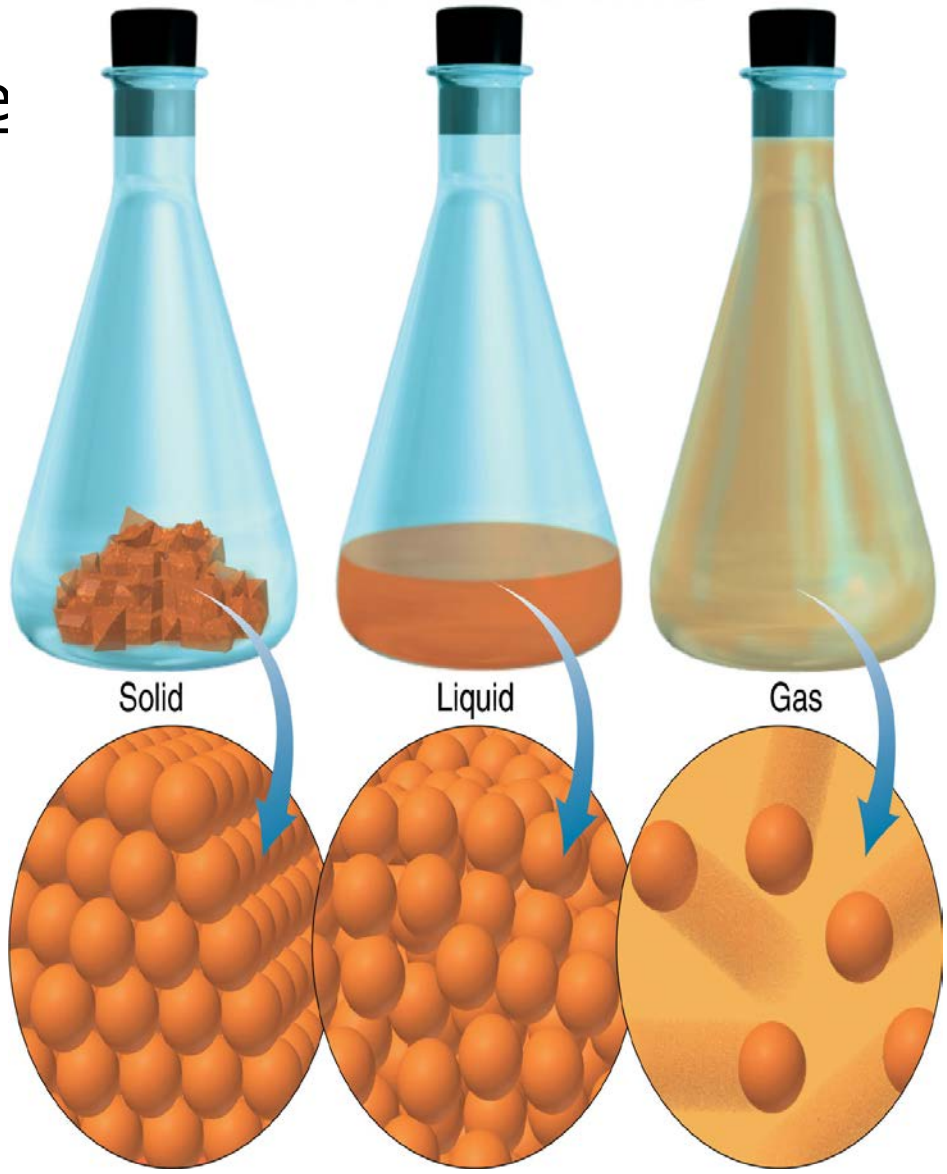
- Physical properties - a characteristic that can be observed or measured without changing the identity or composition of the substance
- Physical properties used to describe matter can be classified as:
  1) Extensive – depends on the *amount* of matter in the sample
     - e.g. Mass, volume, length
  2) Intensive – depends on the *type* of matter, not the amount present
     - Hardness, density, boiling point

SUMMARY

- Chemical properties - ability or inability of a substance to combine with or change into one or more other substances i.e. ability of a substance to undergo a chemical reaction
  - burn
  - rot
  - rust
  - decompose
  - ferment
  - explode
  - oxidize

SUMMARY

- Matter can be classified according to its physical state and its composition
- Physical states – solid, liquid gas
- Classification into different states based upon:
  - Particle arrangement
  - Energy of particles
  - Distance between particles
- **State of matter is dependent on temp and pressure of the surroundings**



States of Matter

	Definite Volume?	Definite Shape?	Result of a Temperature increase?	Will it Compress?
Solid	YES	YES	Small Expans.	NO
Liquid	YES	NO	Small Expans.	NO
Gas	NO	NO	Large Expans.	YES

CHANGES IN MATTER

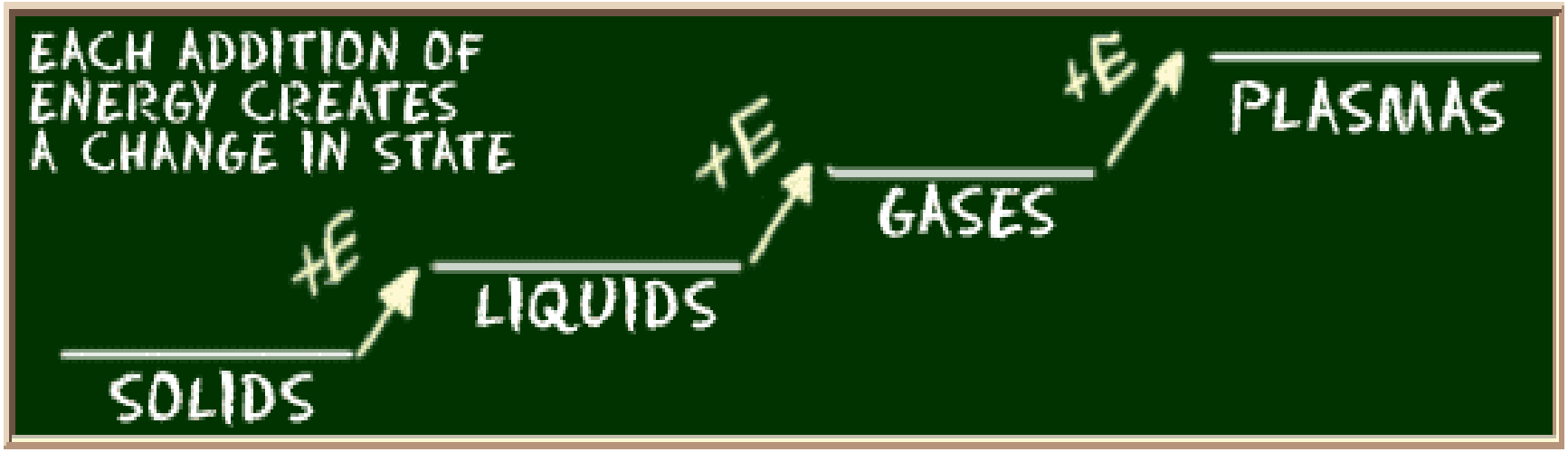
- All matter can undergo physical and chemical changes
- Physical change – occurs when a substance alters its state (phase change), but does not change its chemical composition
  - E.g. Grinding, cutting
- Phase change – transition of a substance from one state to another
  - Depend on temperature and pressure
  - E.g. Boiling, freezing, melting, and condensing
- Physical changes can be classified as reversible or irreversible.

PHASE CHANGES

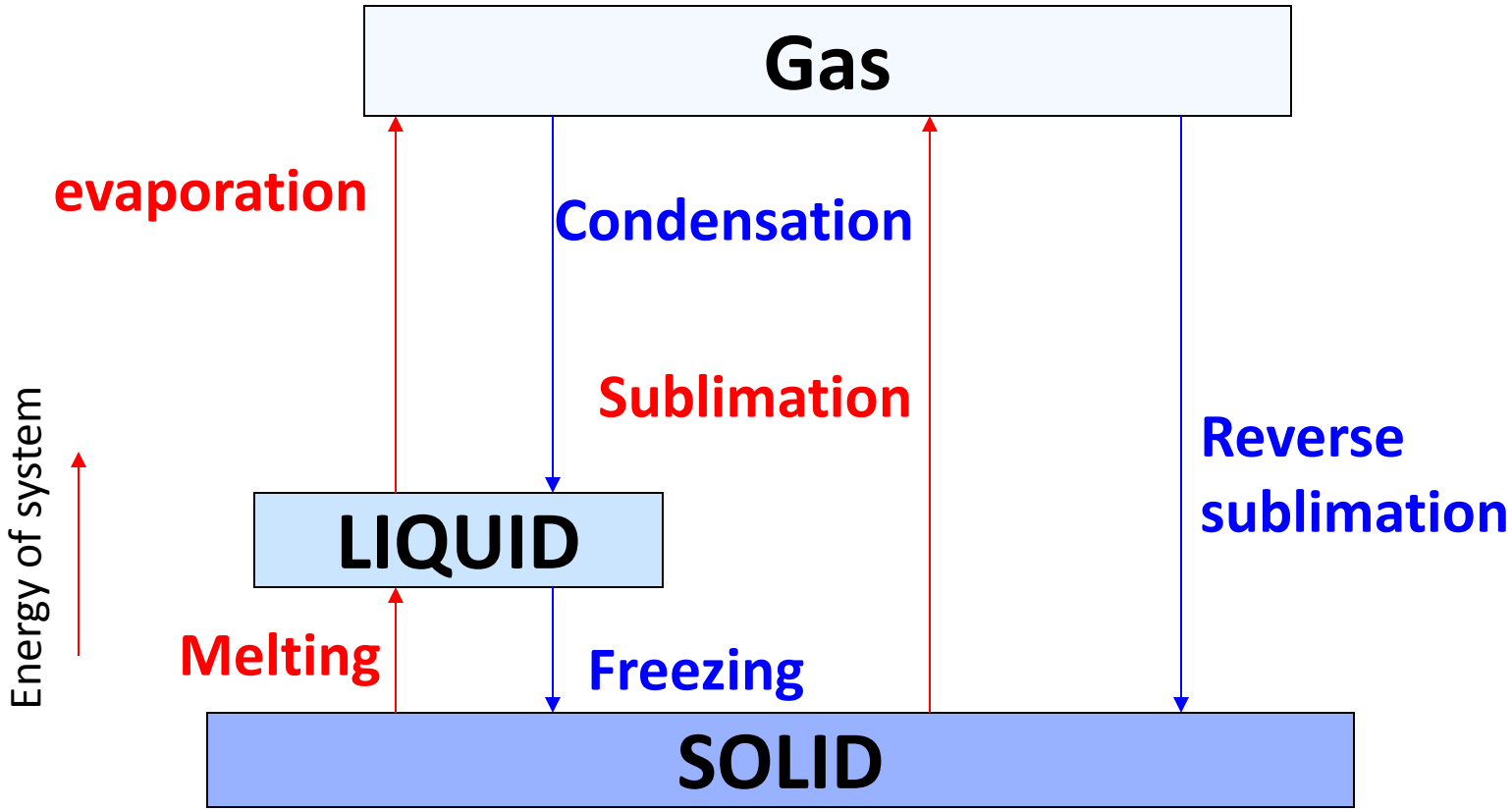
- Depend on Temperature and Pressure
- Affects:
  - Particle arrangement
  - Energy of particles
  - Distance between particles
- Phase change is either an exothermic or endothermic process
  - Exothermic – heat is given off i.e. Removal of E
  - Endothermic – absorption of heat i.e. Input of E
- Phase changes include:
  - melting, evaporation/ boiling, condensation, freezing, sublimation and reverse sublimation

CHANGES OF STATE

- Melting - solid to liquid
- Freezing - liquid to solid
- Evaporation/ boiling - liquid to gas
- Condensation - gas to liquid
- Sublimation – solid to gas
- Reverse Sublimation – gas to solid



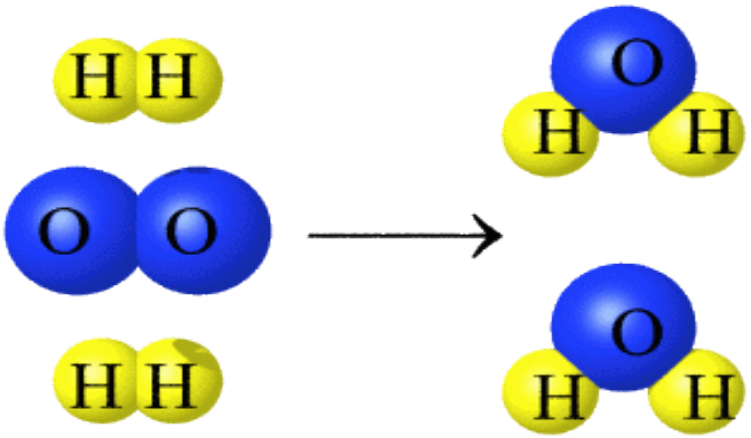
PHASE CHANGES



Brown, LeMay, Bursten, Chemistry 2000, page 405

CHANGES IN MATTER

- Chemical change – occurs when a substance is converted into a new or different substance i.e. Change in the composition of a substance
- Also referred to as a chemical reaction
- Chemical reaction consists of reactants and products
  - reactants – starting substances
  - products – substances which are form/produced



Law of Conservation of Mass

- The law of the conservation of mass applies to chemical reactions
- Mass is neither created nor destroyed during a chemical reaction
- Mass is conserved!
- $\text{Mass}_{\text{reactants}} = \text{Mass}_{\text{products}}$

Classify each as a physical or chemical change:

1. A dead fish rotting
2. Dissolving salt in water
3. Boiling salt water until only salt remains
4. Melting steel
5. Bending steel
6. Cracking ice

Identify the following as physical or a chemical change:

- Sugar ferments to form alcohol.
- Gallium metal melts in your hand.
- Platinum reacts with hydrogen peroxide at room temperature.
- Leaves turn colour in the Fall.
- Milk turns sour.

Identify the following as physical or a chemical change:

- Wax is melted over a flame and then catches fire and burns.
- You make scrambled eggs.
- You step on a piece of chalk and it becomes powdered.
- You light a candle when the electricity goes out.
- Steam from your hot shower condenses on a cold

SUMMARY

- Physical change – occurs when a substance alters its state (phase change), but does not change its chemical composition
  - E.g. Grinding, cutting
- Phase change – transition of a substance from one state to another
  - Depend on temperature and pressure
  - Affects:
    - » Affects particle arrangement
    - » Energy of particles
    - » Distance between particles
  - Either exothermic or endothermic process

SUMMARY

- Chemical change – occurs when a substance is converted into a new or different substance i.e. Change in the composition of a substance
- Also referred to as a chemical reaction
- Chemical reaction consists of reactants and products

CLASSIFICATION OF MATTER

- All matter is composed of atoms
- All matter can be classified or identified as either pure substances or mixtures
- Substance – kind of matter that cannot be separated by any physical process
- Pure substances are considered as either elements or compounds

ELEMENTS

- Element – a substance that cannot be broken down into simpler substance by physical and chemical reaction
- Consists only of one kind of atom
- Building blocks for other substances
- Elements are organised on the periodic table, based on their properties
  - Consists of name and symbol (one, two or three letters)
  - 92 naturally occurring elements, 25 synthesised
  - E.g. Fe, Cu, Ag, Si etc.

PERIODIC TABLE OF THE ELEMENTS

http://www.periodni.com

PERIOD	GROUP 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 1.0079 H HYDROGEN																	2 4.0026 He HELIUM
2	3 6.941 Li LITHIUM	4 9.0122 Be BERYLLIUM											5 10.811 B BORON	6 12.011 C CARBON	7 14.007 N NITROGEN	8 15.999 O OXYGEN	9 18.998 F FLUORINE	10 20.180 Ne NEON
3	11 22.990 Na SODIUM	12 24.305 Mg MAGNESIUM											13 26.982 Al ALUMINIUM	14 28.086 Si SILICON	15 30.974 P PHOSPHORUS	16 32.065 S SULPHUR	17 35.453 Cl CHLORINE	18 39.948 Ar ARGON
4	19 39.098 K POTASSIUM	20 40.078 Ca CALCIUM	21 44.956 Sc SCANDIUM	22 47.867 Ti TITANIUM	23 50.942 V VANADIUM	24 51.996 Cr CHROMIUM	25 54.938 Mn MANGANESE	26 55.845 Fe IRON	27 58.933 Co COBALT	28 58.693 Ni NICKEL	29 63.546 Cu COPPER	30 65.38 Zn ZINC	31 69.723 Ga GALLIUM	32 72.64 Ge GERMANIUM	33 74.922 As ARSENIC	34 78.96 Se SELENIUM	35 79.904 Br BROMINE	36 83.798 Kr KRYPTON
5	37 85.468 Rb RUBIDIUM	38 87.62 Sr STRONTIUM	39 88.906 Y YTTRIUM	40 91.224 Zr ZIRCONIUM	41 92.906 Nb NIOBIUM	42 95.94 Mo MOLYBDENUM	43 (98) Tc TECHNETIUM	44 101.07 Ru RUTHENIUM	45 102.91 Rh RHODIUM	46 106.42 Pd PALLADIUM	47 107.87 Ag SILVER	48 112.41 Cd CADMIUM	49 114.82 In INDIUM	50 118.71 Sn TIN	51 121.76 Sb ANTIMONY	52 127.60 Te TELLURIUM	53 126.90 I IODINE	54 131.29 Xe XENON
6	55 132.91 Cs CAESIUM	56 137.33 Ba BARIUM	57-71 La-Lu Lanthanide	72 178.49 Hf HAFNIUM	73 180.95 Ta TANTALUM	74 183.84 W TUNGSTEN	75 186.21 Re RHENIUM	76 190.23 Os OSMIUM	77 192.22 Ir IRIDIUM	78 195.08 Pt PLATINUM	79 196.97 Au GOLD	80 200.59 Hg MERCURY	81 204.38 Tl THALLIUM	82 207.2 Pb LEAD	83 208.98 Bi BISMUTH	84 (209) Po POLONIUM	85 (210) At ASTATINE	86 (222) Rn RADON
7	87 (223) Fr FRANCIUM	88 (226) Ra RADIUM	89-103 Ac-Lr Actinide	104 (267) Rf RUTHERFORDIUM	105 (268) Db DUBNIUM	106 (271) Sg SEABORGIUM	107 (272) Bh BOHRIUM	108 (277) Hs HASSIUM	109 (276) Mt MEITNERIUM	110 (281) Ds DARMSTADTIUM	111 (280) Rg ROENTGENIUM	112 (285) Cn COPERNICIUM						

LANTHANIDE	57 138.91 La LANTHANUM	58 140.12 Ce CERIUM	59 140.91 Pr PRASEODYMIUM	60 144.24 Nd NEODYMIUM	61 (145) Pm PROMETHIUM	62 150.36 Sm SAMARIUM	63 151.96 Eu EUROPIUM	64 157.25 Gd GADOLINIUM	65 158.93 Tb TERBIUM	66 162.50 Dy DYSPROSIUM	67 164.93 Ho HOLMIUM	68 167.26 Er ERBIUM	69 168.93 Tm THULIUM	70 173.05 Yb YTTERBIUM	71 174.97 Lu LUTETIUM
ACTINIDE	89 (227) Ac ACTINIUM	90 232.04 Th THORIUM	91 231.04 Pa PROTACTINIUM	92 238.03 U URANIUM	93 (237) Np NEPTUNIUM	94 (244) Pu PLUTONIUM	95 (243) Am AMERICIUM	96 (247) Cm CURIUM	97 (247) Bk BERKELIUM	98 (251) Cf CALIFORNIUM	99 (252) Es EINSTEINIUM	100 (257) Fm FERMIUM	101 (258) Md MENDELEVIUM	102 (259) No NOBELIUM	103 (262) Lr LAWRENCIUM

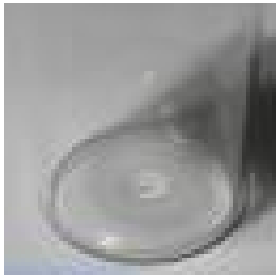
COMPOUNDS

- Compound – a substance that consists of two or more elements chemically bonded
- Compound is always composed of the same elements, in the same proportion by mass
  - Represented by a formula e.g. NaCl, H_2O
  - ➢ NOTE: Understand method of writing formula
- Most of matter in the universe exists as compounds
- Compounds can be synthesised or decomposed
- Synthesis – combination of elements to form compounds
- Decomposition – splitting of compounds into their individual elements

COMPOUNDS

- Properties of a compound are different from its component elements
- Ex: water—liquid at room temp.

Hydrogen—a colorless, tasteless gas



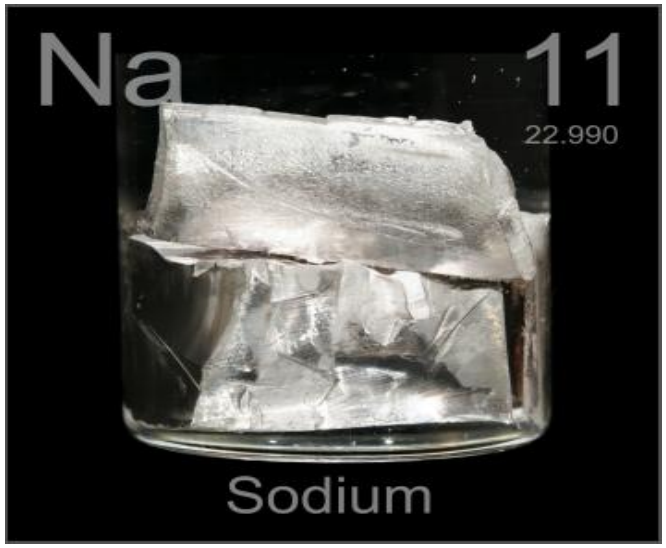
Oxygen—a colorless, tasteless gas

Sodium Chloride

- As a compound, it is a white, unreactive solid that adds flavour to food
- Its component elements:

Chlorine—poisonous, pale, green gas

Sodium—a highly reactive metal



MIXTURES

- Mixture – combination of two or more substances in which each substance retains its individual properties
- Therefore, substances **ARE NOT** chemically combined, just mixed physically
- Mixtures can be separated by physical methods
- Mixtures can either be classified as:
  - Homogeneous
  - Heterogeneous

    Based on the distribution of the components

MIXTURES

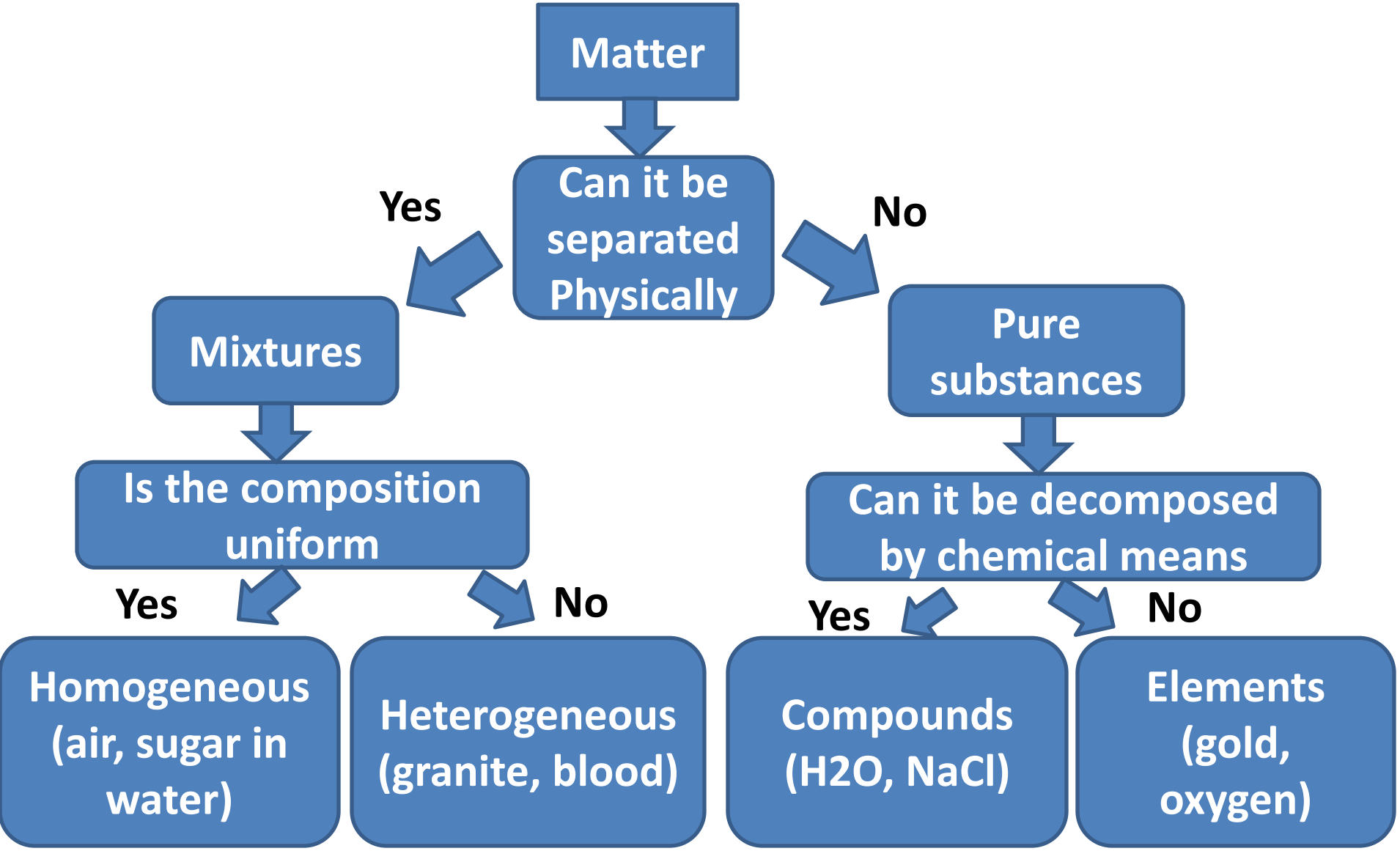
- Homogeneous – mixture where the composition of the substances is constant throughout i.e. Uniform
- Therefore, individual substances are indistinguishable
- Also referred to as solutions – mixture of solute and solvent
  - Solute = substance in a smaller amount, which is dissolved in the solvent
  - Solvent = the liquid in which the solution is made of and is in a greater amount.

➢ NOTE: differentiate between dilute, concentrated and saturated solutions

MIXTURES

- Heterogeneous – mixture where the individual substances remain distinct i.e. not uniform
- Therefore, individual components can be distinguished
- May form suspensions, lumps due to insolubility
- Mixture can easily be separated by physical methods e.g. Filtration
- E.g. Sand and water

SUMMARY


Matter
Can it be separated Physically
Yes
No
Mixtures
Pure substances
Is the composition uniform
Can it be decomposed by chemical means
Yes
No
Yes
No
Homogeneous (air, sugar in water)
Heterogeneous (granite, blood)
Compounds (H2O, NaCl)
Elements (gold, oxygen)

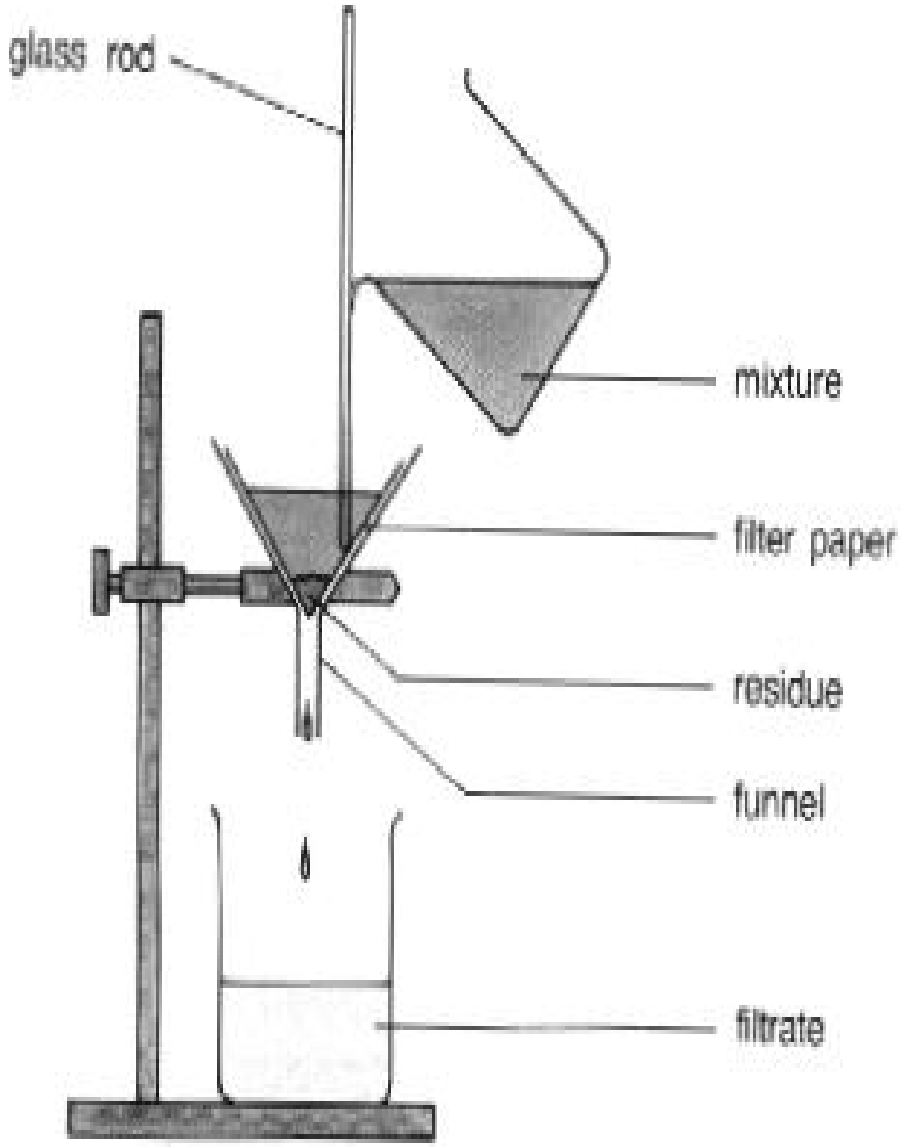
SEPARATION OF MIXTURES

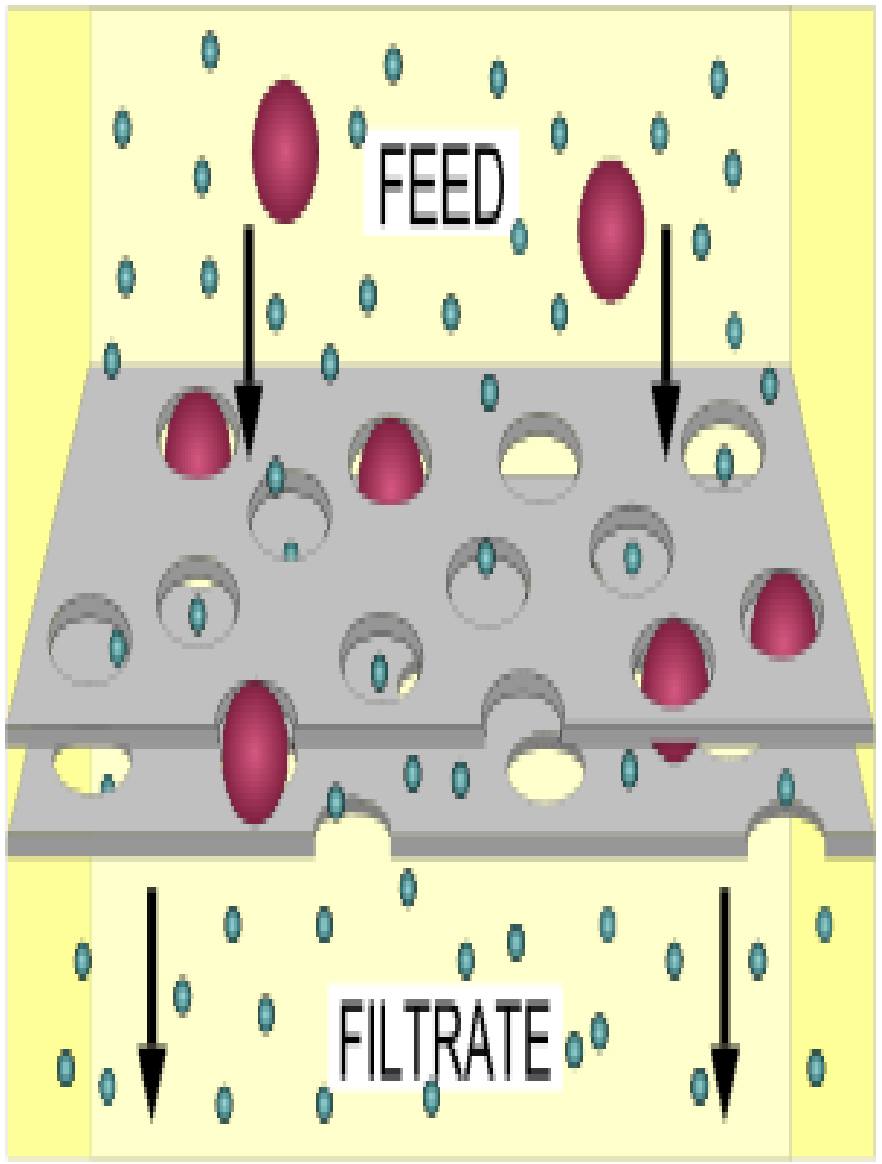
- The different substances within a mixture can be separated as they are not chemically bonded
- Different techniques can be used, depending on the phase the two components exist.
- Techniques include:
  - magnetisation, filtration, centrifugation, evaporation, simple distillation, fractional distillation, separating funnel, chromatography

SEPARATION OF MIXTURES

- MAGNETISATION – use of a magnet to separate a magnetic substance from a non-magnetic substance
  - E.g. Sand and iron
- FILTRATION – used to separate an insoluble solid or suspension from a liquid
  - Based on size
  - Substances separated into a filtrate and a residue
  - Filtrate = liquid that passes through the filter paper
  - Residue = solid that remains on the filter paper
  - E.g. Sand and water

FILTRATION


glass rod
mixture
filter paper
residue
funnel
filtrate

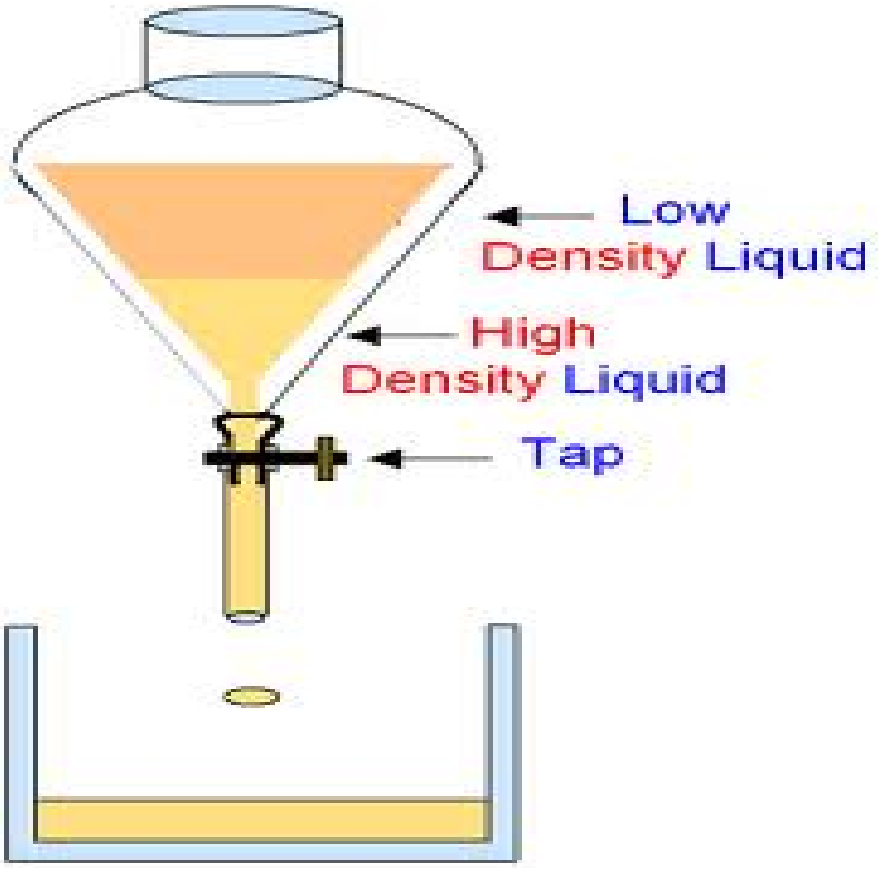

FEED
FILTRATE

SEPARATION OF MIXTURES

- CENTRIFUGATION – used to separate insoluble solid or suspension from a liquid
  - Use of rotational force to separate substance based on their density
  - Sometimes used instead of filtration
- Evaporation – used to separate a solute from a solution
  - The solution is heated until all of the solvent evaporates
  - E.g. Salt from water

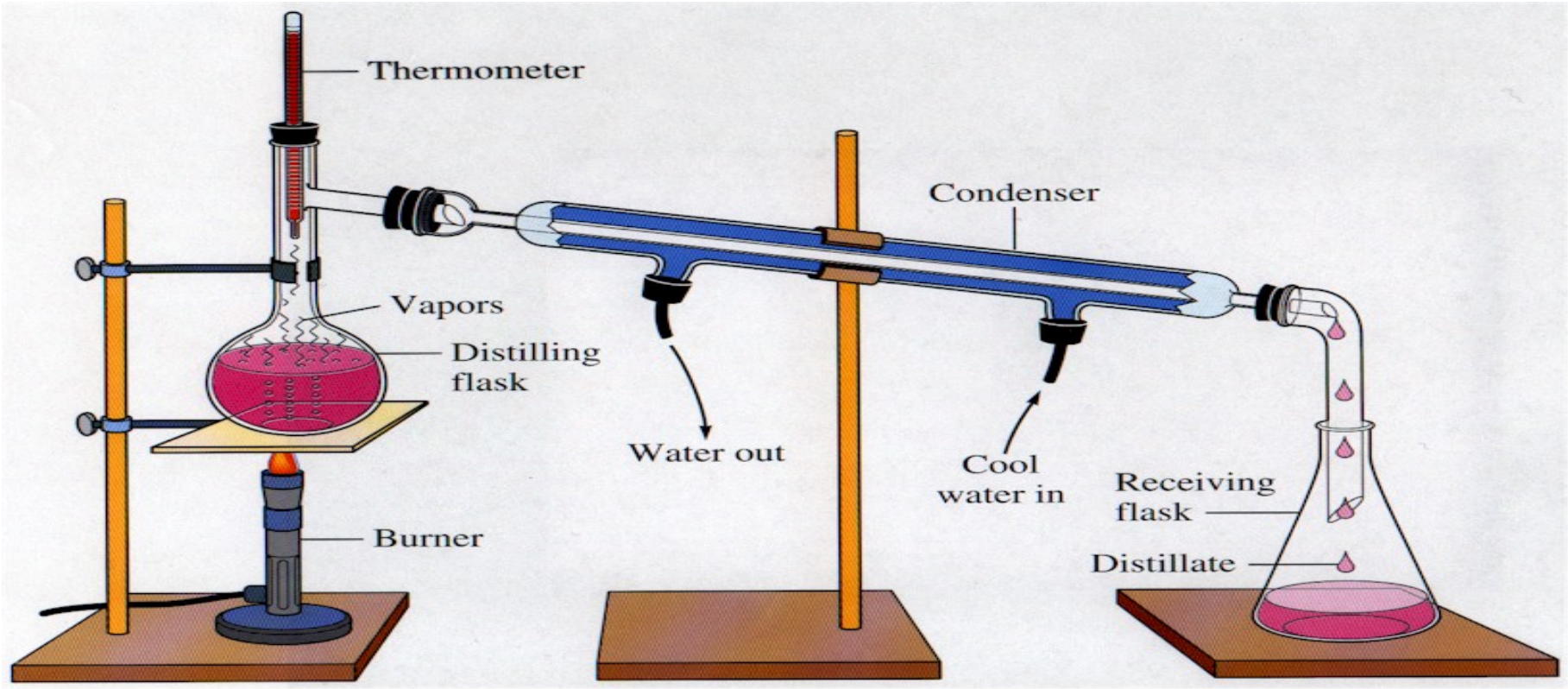
SEPARATION OF MIXTURES

- SEPARATING FUNNEL – use to separate two immiscible liquids
  - Depends on the density
  - E.g. Oil and water



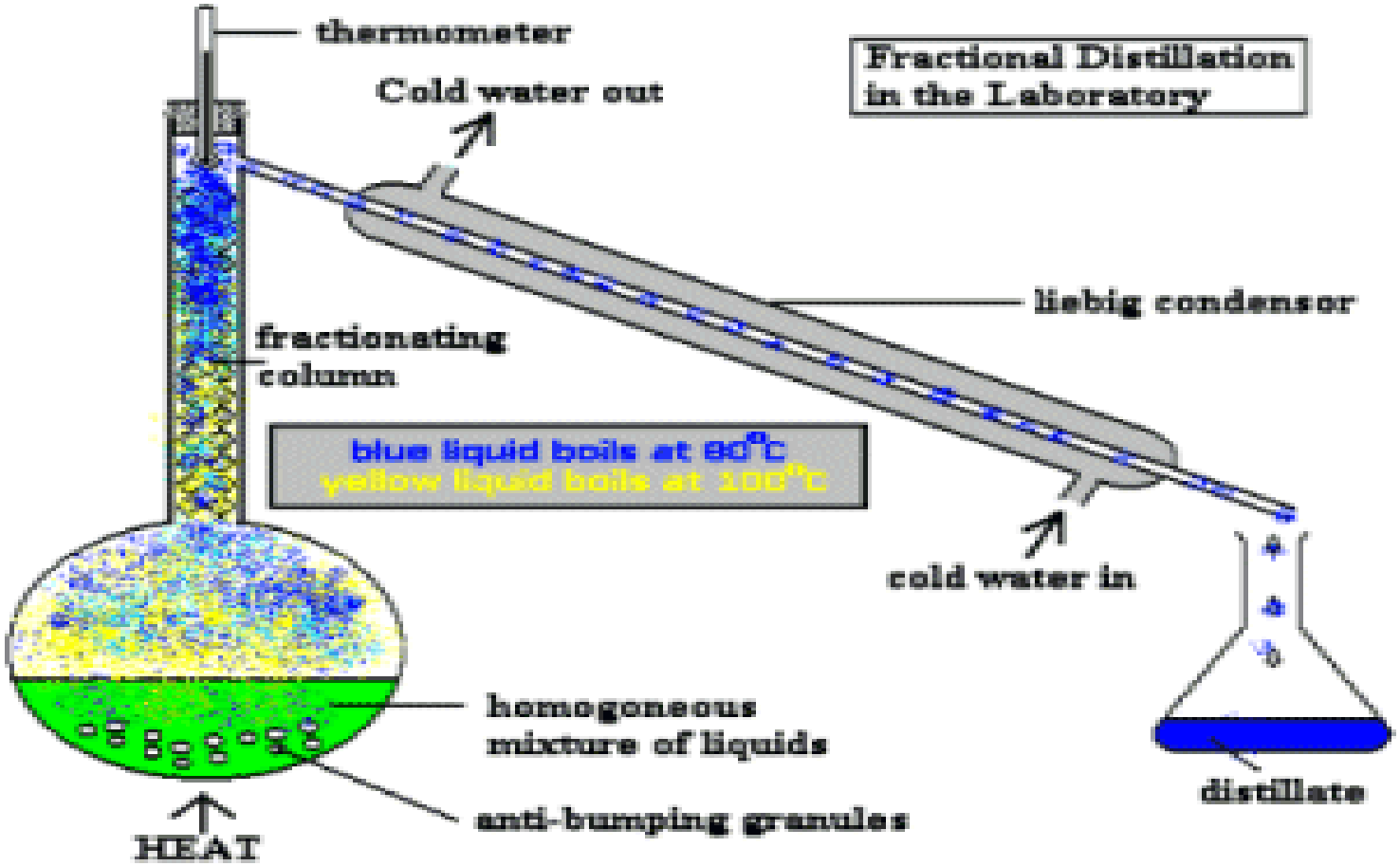
SEPARATION OF MIXTURES

- SIMPLE DISTILLATION – used to separate a pure solvent from a solution
  - Involves vaporization, condensation and collection
  - E.g. Water from salt



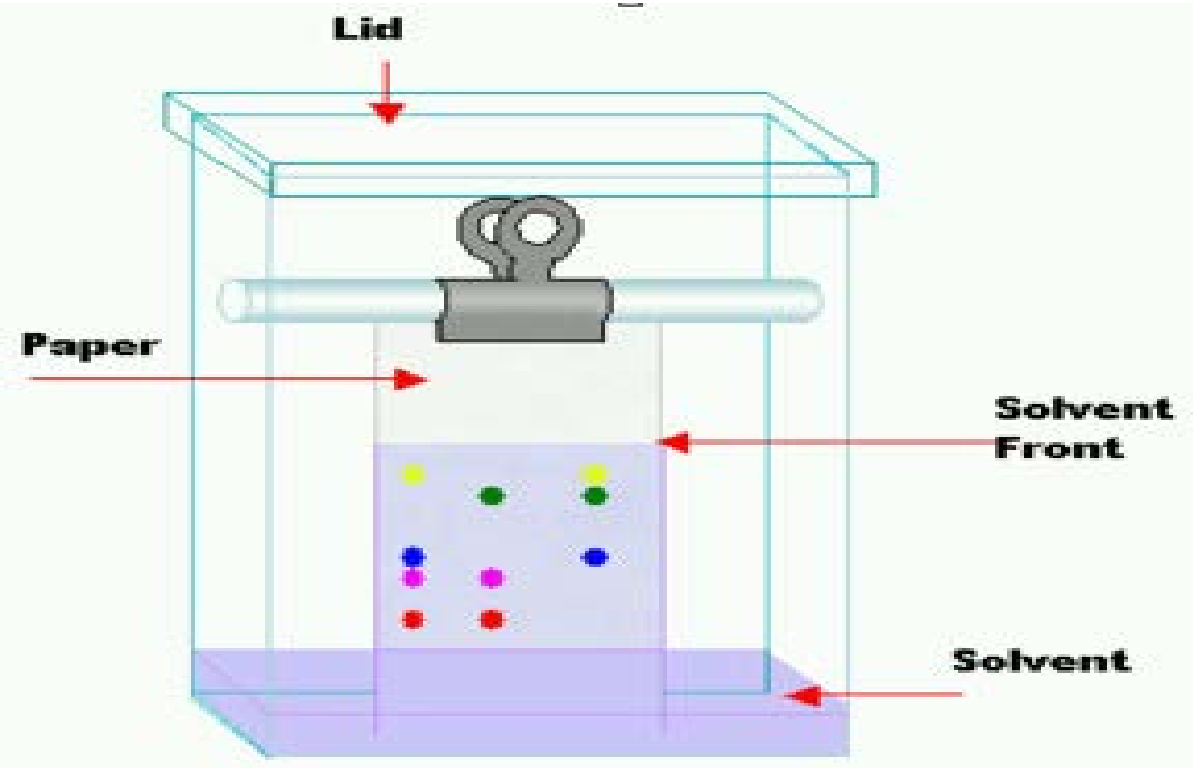
SEPARATION OF MIXTURES

- FRACTIONAL DISTILLATION – used to separate one liquid from a mixture of liquids, that have different boiling points
  - E.g. Ethanol and water



SEPARATION OF MIXTURES

- CHROMATOGRAPHY – used to separate a mixture of substances based on their solubility within a given solvent
  - Components which prefer the solvent move faster and further up the chromatography paper, causing separation
  - E.g. Separation of ink



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