STUDY PACK : 4

CAMBRIDGE
International Examinations

STATES OF MATTER

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1. State the properties of the three states of matter.

Solids :

- Has a definite shape & volume.
- Particles are packed closely in a regular pattern. Cannot be compressed.
- Particles are in fixed positions cannot move but can only vibrate.

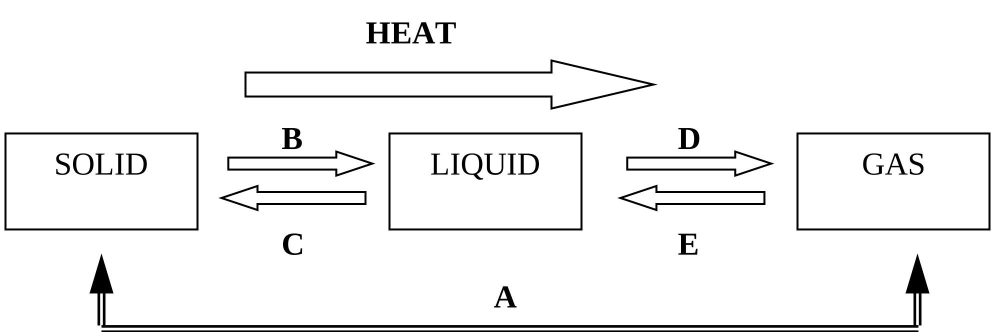
Liquids:

- Has a definite volume but no fixed shape, takes the shape of the container.
- Particles are fairly close to one another, Can be compressed slightly.
- Particles are arranged randomly free to move in an irregular manner.

Gas:

- Has no definite shape or volume, Particles are arranged randomly and are free to move in an irregular manner in all directions.
- Particles are far apart, therefore be compressed.

2. The following diagram refers to phase changes of different states. Name the changes from A to E



A :

B :

C :

D :

E :

The Gaseous State

1. Define the terms Ideal gas & Real gas & state their characteristics.

Ideal gas : is a gas in which there are no intermolecular forces between the molecules. Also, the ideal gas molecules have a mass, but no size. Ideal gases obey all the assumptions of the kinetic theory. (No gas is ideal but some gases come close to ideal behaviour under certain conditions)

Real gas : There are intermolecular forces between the molecules, have a mass & size & does not obey certain assumptions of the kinetic theory. The gases we encounter are real gases.

2. State the assumptions of the kinetic theory of gases.

I. Gases consist of molecules in constant state of random motion. The molecules travel in straight lines unless they collide with one another, or with the walls of the container.

II. The pressure of a gas is due to the collisions of the molecules with the walls of the container. The pressure exerted is equal in all parts of the container.

III. In these collisions (with the walls & between molecules) the total energy of the molecules does not change. (No loss in energy due to the collisions with the walls) Thus all collisions are said to be elastic.

IV. The volume of a gaseous molecule held to be negligible compared to the volume of the container. This is due to the distance between gas molecules being greater than the diameter of the molecules.

V. There are no intermolecular forces of attraction or repulsion between the molecules.

3. State how real gases deviate from the ideal gas behaviour.

   I. Real gases have intermolecular forces of attraction.
   II. The molecules have a size; therefore, take up space in the container therefore volume cannot be ignored.
   III. Real gases liquefy at low temperatures & high pressure.
   IV. Energy of the molecules will be less due to the collisions.

4. Noble gases show behaviour closer to ideal gas, but no real gas is ideal. State & explain under what conditions real gases can approach ideal behaviour.

Under high temperature & low pressure.

The kinetic energy of the molecules increases due to increase temperature, as a result molecules move faster & overcome their intermolecular attractions, which results in closer behaviour to ideal gas.

When the pressure is low the molecules in a unit volume decreases, as a result there will be more space for the molecules to move, which results in closer ideal gas behaviour.

Gas Laws.

5. State the Charles' Law & plot a graph of volume against temperature for different gases.

6. State the Boyle’s law & plot graphs of volume against pressure (V vs. 1/P, V vs.P & PV vs.P)

7. Derive the universal gas equation (General gas equation) from Boyle’s & Charle’s law. Define each symbol & write the units.

8. Derive the value & unit of gas constant (R) at standard temperature & pressure

9. Modify the universal gas equation to determine the molar mass of a gas.

10. If an ideal gas is at two different conditions of pressure, volume & temperature, derive an equation to show the relationship between the two.

11.

i. If volume of 200ml of a gas was collected at 27 C & 1 atm pressure. Calculate the volume collected at standard temperature & pressure in dm^3

ii. Calculate the number of gas molecules in 5 liters of gas at 5 atm & at 20 C.

iii. A 0.65g sample of a gas takes up a volume of 50 cm^3 at 100 C & $1.52 x 10^5$ Pa. Calculate the molar mass of the gas.

iv. Calculate the density of oxygen gas at 27C & at 1.6 atm pressure

v. Using the ideal gas equation, calculate the pressure in 'Pa', that NO_2 gas would exert at 25 C. The internal volume of the gas cylinder is 3 liters & it contains 2kg of NO_2

vi. Use the ideal gas equation to calculate the mass of air in 'kg' in a container of $1000 m^3$ at a temperature of 25 C & a pressure of $1.01 x 10^5$ Pa. The molar mass of air is 29 g mol^{-1}

12. Describe the limitations of ideality at very high pressures & very low temperatures

Real gases depart from ideal behaviour at high pressure & low temperature.

- **Deviations at high pressure:**

As the pressure is increase the molecules come closer to each other as a result their intermolecular forces become significant. Also increase in pressure results in less volume of the gas therefore the volume of the gas molecules cannot be ignored.

- **Deviations at low temperatures:**

As the temperature is lowered the kinetic energy of the molecules decrease resulting significant intermolecular attractions between the gas molecules.

13. Plot a graph for PV against P for real gases & comment on their non ideal behaviour

Liquid State.

1. Describe the liquid state by kinetic-molecular model

Liquid possess stronger intermolecular attractions than gases, as a result the molecules in a liquid state are closer than in a gas. When a gas is cooled the molecules lose their kinetic energy & the gas liquefies as their kinetic energy will no longer can overcome the intermolecular attraction. When a solid is heated the molecules gain kinetic energy as a result they vibrate faster. At one point they overcome the forces between the molecule & the solid melts at this point.

2. Describe the terms evaporation, saturated vapour pressure , condensation & boiling

- Evaporation :-

Occurs at a temperature between freezing & boiling point of the liquid. When the temperature of a liquid is raised, the particles acquire more energy as a result they move faster. Some particles near the surface of the liquid, escape & forms a vapour above the liquid. The energy required to change one mole of liquid to one mole of gas is referred to as enthalpy change of vapourisation.

- Saturated vapour pressure :-

The maximum pressure exerted by the gases on the walls of the container at a given temperature is called the saturated vapour pressure.

- Condensation:-

When freely movable gaseous molecules collide with each other they will be attracted to the other particles & move on to a liquid state. Hence a liquid in a closed system will be in a dynamic equilibrium. The liquid evaporates to form the vapour thus vapour condenses to form the liquid.

- Boiling :-

When a liquid is heated there comes a point when bubbles of gas form in the actual liquid. The temperature at which bubbles of gas from throughout the liquid is called the boiling point of the liquid. Addition of heat at boiling point produces no further rise in temperature.

The boiling point of a liquid is the temperature at which its saturated vapour pressure becomes equal to the atmospheric pressure. Therefore, when the pressure is more water boils at a higher temperature as the atmospheric pressure is less than the sea level.

Solid State.

1. State the six types of structures found in elements & compounds.

- Simple Atomic, eg: Noble gases
- Simple Molecular, eg: Oxygen gas, Carbon dioxide
- Simple Molecular lattice: Iodine molecules
- Giant Ionic lattice, eg: Lithium Flouride, Sodium Chloride
- Giant Metallic lattice, eg: Metals
- Giant Molecular lattice, eg: Silica (sand/SiO_2), Diamond, Graphite

2. Describe in simple terms the lattice structure of crystalline solid sodium chloride & magnesium oxide.

In a crystal lattice, each cation surrounds many anions around it. Likewise, each anion will be surrounded by many cations in order to preserve the electrical neutrality. This type of arrangement of ions produces a giant assembly of ions held in a rigid crystal lattice.

In both NaCl & MgO lattice each cation accommodates anions around it similarly, each anion is surrounded by cations to preserve electrical neutrality. The ions are packed closely, held by many electrostatic attractive forces.

Due to the strong attractive forces, they are hard and brittle, also possess high boiling & melting points due to many forces of attraction between the ions. Many are soluble and conducts in aqueous or in molten state.

Lattice Structure of NaCl & MgO :

3. Describe the solid structure of simple molecular lattice of Iodine

In a molecular solid, molecules are attracted by weak intermolecular forces. As these forces are weak simple molecular solids have low melting temperatures.

Simple diatomic molecule of I_2 can also arrange in a regular pattern resulting in a lattice. Iodine forms a crystalline solid lattice with regular intermolecular forces between iodine molecules. This is due to the regular arrangement of molecules. When solid iodine heated van der waal forces are brocken & iodine molecules are separated as gases. Thus, iodine sublimes but the covalent bond between I-I atoms does not break.

4. What are Carbon nanoparticles?

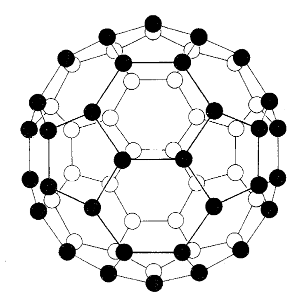
Allotropes of carbon which has dimensions between 0.1 and 100 nanometers ($1nm=10^{-9}m$) are called nanoparticles. Eg : Fullerenes, Graphene

5. Describe the structure of Fullerene allotropes of carbon.

- **Fullerene**

In 1985, a new form of carbon was discovered. A species with a molecular formula C_{60} was made as a result of the action of Laser beams on a sample of graphite. It is made up of 20 hexagons & 12 pentagons which are arranged like the panels on a football.

The perfect sphere is called "buckminsterfullerene". It is named after the American architect Buckminster Fuller, because of its similarity to the domes designed by him. The C_{60} molecule is often referred to as a "Buckyball"



A buckyball

Each Carbon atom has 3 sigma bonds & the fourth electron has delocalized in the structure similar to that of graphite. Each carbon atom is sp^2 hybridized. C_{60} is a relatively reactive substance. It undergoes addition reactions converting sp^2 hybrid carbons to sp^3 hybrid ones. Thus, the chemistry of C_{60} molecule is similar to that of alkenes. They undergo addition reactions with hydrogen & halogens.
This third synthetic allotrope of carbon is less than a nanometer in size. It is sparingly soluble in many organic solvents & their solutions are coloured.

Properties of Bucky Balls:-

- It is a molecular structure with weak dispersion forces therefore possesses relatively low sublimation point of 600 ^{0}C

- Relatively soft due to weak intermolecular forces.
- Poor conductor of electricity. Delocalized electrons are found within the molecule thus cannot freely move between the molecule.

- More reactive compared to diamond / graphite. This is due to relatively high electron density in certain parts of the molecule.

Medical Importance of C_{60}

Radioactive Radon-224 atoms can be trapped inside a C60 molecule, which are coated with tumor targeting antibodies. When the C_{60} molecules containing radon are injected to the patient, treated C_{60} is absorbed by the cancer cells, thus the radon atoms emit gama rays, which destroy the cancer cells in the tumor but do not affect the other organs in the body due to the short range of the gama rays.

- **Carbon Nanotubes (CNT)**

A nanotube consists of a cylinder of interlocking hexagons of carbon atoms. It is similar to a stretched fullerene. The cylindrical tube consists of only six-member carbon rings. The closed end is one half of a bucky ball. The internal radius of the carbon Nanotube is few nanometers. They contain delocalized electrons thus conducts electricity.

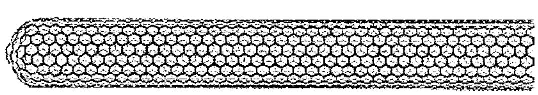
Some molecules are open at the both ends & resemble a rolled-up sheet of graphite. (Repeating hexagons)

Properties of CNT:

- Many times stronger than steel,
- High melting points due to strong covalent bonds.
- Thermal & electrical conductors, therefore used in batteries, fuel cells & cables.
- Very high tensile strength.

Medical Importance:

Nanotubes are used as vehicles to deliver drugs to specific parts of body.



A nanotube

6. Describe the **giant molecular lattice structures** of graphite, diamond, graphene allotropes of carbon & silicon (IV) oxide

- Structure of Silicon (IV) oxide:

Structure of silicon (IV) oxide is similar to that of diamond. It has a tetrahedral arrangement of atoms. Each silicon atom is tetrahedrally linked to 4 other oxygen atoms & an oxygen atom is attached to two silicon atoms by covalent bonds. $SiO2$ (Silica /Sand) has properties similar to diamond. It is a hard colorless crystal with high melting & boiling points. Does not conduct electricity.

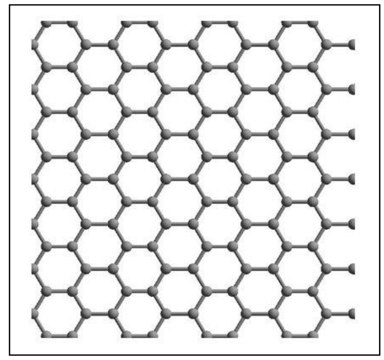
- Structure of Graphite:

Each carbon atom is covalently bonded to 3 other carbon atoms. The arrangement of bonds around each carbon is trigonal planer. Therefore, give rise to hexagonal 'C' plates or sheets of 'C' atoms. The unhybridized 'p' orbital has an electron which form a delocalized cloud of electrons between the hexagonal sheets. Therefore, due to this graphite conducts electricity. The layers can slide over one another thus makes graphite slippery & soft. Delocalized electrons move along the layers when a voltage difference is applied thus good conductor of electricity. Possess high boiling and melting points due to many strong covalent bonds around each 'C' atom.

- Structure of Diamond :

Each 'C' atom tetrahedrally linked to 4 other carbon atoms by single covalent bonds, which results in continuous 3D structure. Therefore, very hard/ rigid & it is the hardest naturally occurring substance. When heated to a higher temperature does not melt but sublimes at a very high temperature. As there are no free electrons it does not conduct electricity.

Structure of Graphene:



Graphene is a single atomic layer of carbon bound together in a hexagonal honeycomb arrangement. It is the most reactive form of carbon. It can be described as a single atom thick layer of graphite. It is the basic structural element of other allotropes, including graphite, carbon nanotubes and fullerenes. Not only does it have high stability within the layer, the thinness of the individual layers also means it exhibits an extremely high surface area to volume ratio.

Graphene the thinnest material known to mankind; it is also 200 times stronger than steel. It is pure carbon in the form of a very thin, nearly transparent sheet, one atom thick. It is remarkably strong for its very low weight and it conducts heat and electricity with great efficiency. While scientists had theorized about graphene for decades, it was first produced in the lab in 2004.

Technically, graphene is a crystalline allotrope of carbon with 2-dimensional properties. Racecars, airplanes, space shuttles, windmill blades, phone cases, and other strong lightweight technology will all be enhanced by graphene's high strength to weight ratio. Scientists are also anticipating graphene to replace silicon in the next generation of high-speed electronics. Because of its amazing conductivity and flexibility, graphene may be folded, squeezed, or otherwise made more compact for even thinner, lighter, yet faster electronics. In the future, these perks also may generate a foldable type of touchscreen, and perhaps an entire generation of 'foldable' electronics, including phones, watches, tablets, and more.

Graphene, unlike carbon–nanotubes, has edges that can react chemically. These exposed carbon molecules have special reactivity, as do any imperfections in the graphene sheets. Not surprisingly, because of its 2-dimensional structure and the lateral availability of the carbon, graphene is now known to be the most reactive form of carbon.

7. Discuss the structure & biological importance of ice

The combination of bent structure of water & the linear nature of 'H' bonds leads to an open structure of ice with hexagonal holes. When water freezes the linear 'H' bonds are formed & the molecules space out. The 4 bonds are tetrahedrally arranged around 'O' atom similar to that of diamond.

The increase in volume due to the 'H' bonding causes ice to be less dense than water. The lower density of ice plays an important role in the survival of life in ponds, lakes ect. The fact is that ice forms on top due to being less dense than water.

- Tetrahedral arrangement of inter & intra hydrogen bonds in ice:

8. Outline the importance of 'H' bonding in the physical properties of ice & water

'H' bonding between water molecules causes the unexpectedly high melting point & boiling point. This is due to Hydrogen bonding between water molecules. 'H' bonding causes water to exist as a liquid. This also causes high surface tension of water resulting small relatively dense particles such as razor blades & beetles to float on water.

The presence of 2 'H' atoms & two lone pairs in each water molecule results in 3D tetrahedral structure of ice. Due to the linear nature of 'H' bonds the molecules space out & form hexagonal holes resulting ice less dense than water.

The anomalous physical property of ice & water which is due to 'H' bonding has a great influence biologically & environmentally.

If there were no 'H' bonds in water, water would probably be a gas under normal atmospheric conditions. Oceans, lakes & rivers would never exist.

The high surface tension of water helps plants take in water through the capillary tube in stems. & roots. The high polarity helps to dissolve ionic substances. Therefore, the plants can obtain the salts which they require for the growth.

9. Describe the metallic lattice structure of Copper.

A metal is a giant structure where electrons are free to move throughout the whole structure. The metal atoms lose their valence electrons and form cations. The electrons which have been lost, will act as the sea of delocalized electrons between the cations. The cations are often packed in hexagonal layers or in a cubic arrangement. A metallic bond is the electrostatic attraction between the metal cations and the delocalized sea of electrons.

When force is applied the metal cations slide over one another without breaking the metallic bond due to the attraction between metal ions and the delocalized electrons as a result metals are malleable and ductile.

10.

a. What is an alloy?

An alloy is a mixture of a metal with another metal or non-metal.
Eg: Brass, Stainless steel

Making alloys with other elements is one of the most common methods of changing the properties of metals.
Eg: Strength, Melting point

b. Some important alloys & their properties

Alloy	Typical composition	Particular properties
Brass	Cu 70%, Zn 30%	Harder than pure copper. Gold coloured
Bronze	Cu 90%, Sn 10%	Harder than pure copper.
Mild steel	Fe 99.7%, C 0.3%	Stronger & harder than pure iron.
Stainless steel	Fe 70% Cr 20% Ni 10%	Harder than pure iron, Does not rust.
Solder	Sn 50%, Pb 50%	Lower melting point than Sn & Pb

2. Explain how alloys are formed

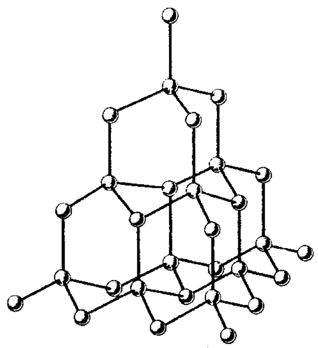
Alloys are formed by mixing molten metal with another element (metal / nonmetal) together & allowing them to cool. When liquid, the metals mix thoroughly. The resulting alloy will show different physical properties due to the different metals not the properties of constituent elements.

3. Draw a diagram to represent the structure of an alloy

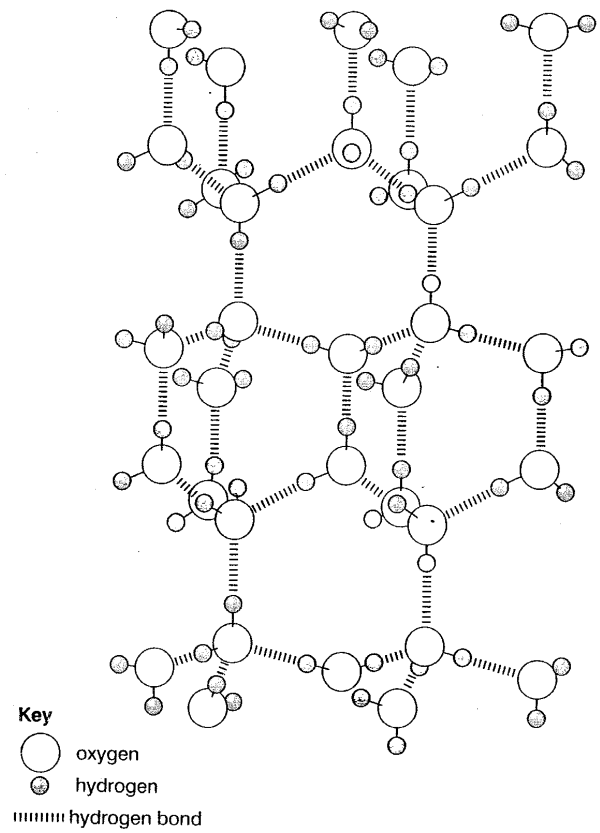
4. Explain in terms of the structure why most alloys are stronger than the original metals

The presence of an atom of different size (impurity atom) interrupts the orderly arrangement of atoms in the lattice & prevents them sliding over each other. The below figure shows how the presence of the impurity atom reduces the slip between the layers by 'Keying' them together.

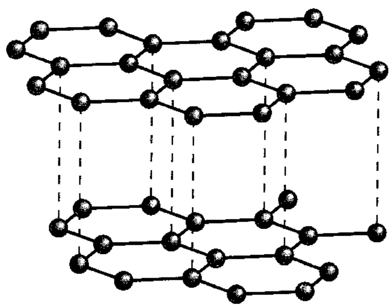
Diamond



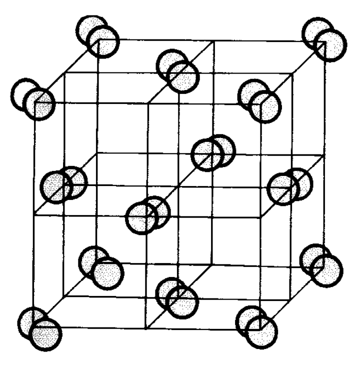
Structure of Ice



Graphite



Iodine



Silicon dioxide