UGC NET - ENVIRONMENTAL SCIENCE

SAMPLE THEORY

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GEOSPHERE

- The geosphere is considered that portion of the Earth system that includes the Earth's interior, rocks and minerals, landforms and the processes that shape the Earth's surface. The Earth itself (contrary to Christopher Columbus) is not a perfect sphere.
- It is what is called an oblate spheroid, with a radius of 6,357 kilometers (km) from the Earth's center to the North Pole and 6,378 km from the center to the Equator.
- For scientific investigations, the planet Earth is commonly differentiated into three parts: **atmosphere, lithosphere and hydrosphere.** Volumes of information have been collected about each of these parts during last one hundred years or so.
- Artificial satellites are the latest tools for the study of the Earth with the modern scientist. Following brief account gives a more outline of the most important characteristics of these parts.

THE ATMOSPHERE

- The outer gaseous part of the Earth starting from the surface and extending as far as 700 km and even beyond is termed as atmosphere. It makes only about one-millionth part of the total mass of the Earth.
- The gaseous envelope, like the other matter, is held around the planet due to gravitational pull of the body of the Earth. It is now fairly established that the atmosphere possesses a layered structure. Different layers of the atmosphere are distinguished on a number of basis: change in composition, change in temperature, degree of ionization and so on.

- Chemically speaking, the atmosphere is made up of a mechanical mixture of gases commonly called air that has a fairly uniform composition and homogeneous structure as follows:

Table 1 Chemical Composition of Atmosphere (Dry Air).

Component	*Volume Percentage*
Nitrogen	78.084
Oxygen	20.946
Argon	00.934
Carbon dioxide	00.033
Others (Ne, He, Kr, Xe etc.)	00.003

- The above composition of the atmosphere is almost uniform up to a height of 80 km from the surface. This atmospheric zone of uniform composition is sometimes referred as homosphere to differentiate it from the overlying part that forms the heterosphere where the composition varies from place to place.

  Thermally speaking, the atmosphere shows an interesting variation in temperature with increasing height from the surface.
- At some levels, the temperature starts falling with increasing height whereas at other levels, it remains constant with increasing height and then at still other levels the temperature starts rising. Thus a zigzag curve is obtained for variation of temperature records in the atmosphere above the surface. (Fig.1)
- Based on thermal characters, the atmosphere is divided into following layers: troposphere, stratosphere, mesosphere and thermosphere (Fig. 2). Following are the main characteristics of these atmospheric zones:

THE TROPOSPHERE

- It is the lowermost zone of the atmosphere rising from the surface of the earth and extending, on an average to a height of 11 km. Its upper boundary called tropopause lies at about 9 km above the poles and at 18 km above the equator.(5 miles and 11 miles respectively)

- The troposphere contains almost nine-tenths of the total mass of the atmosphere. It is the layer of gases that is responsible for most of the weather forming or meteorological processes on the earth. In the troposphere there is recorded a regular fall in temperature at a lapse rate of 6.3°C/km up to tropopause resulting to as low temperatures as –40°C to –60°C at those heights.
- The most important character of troposphere is occurrence of a strong turbulence and thorough mixing of the gases .

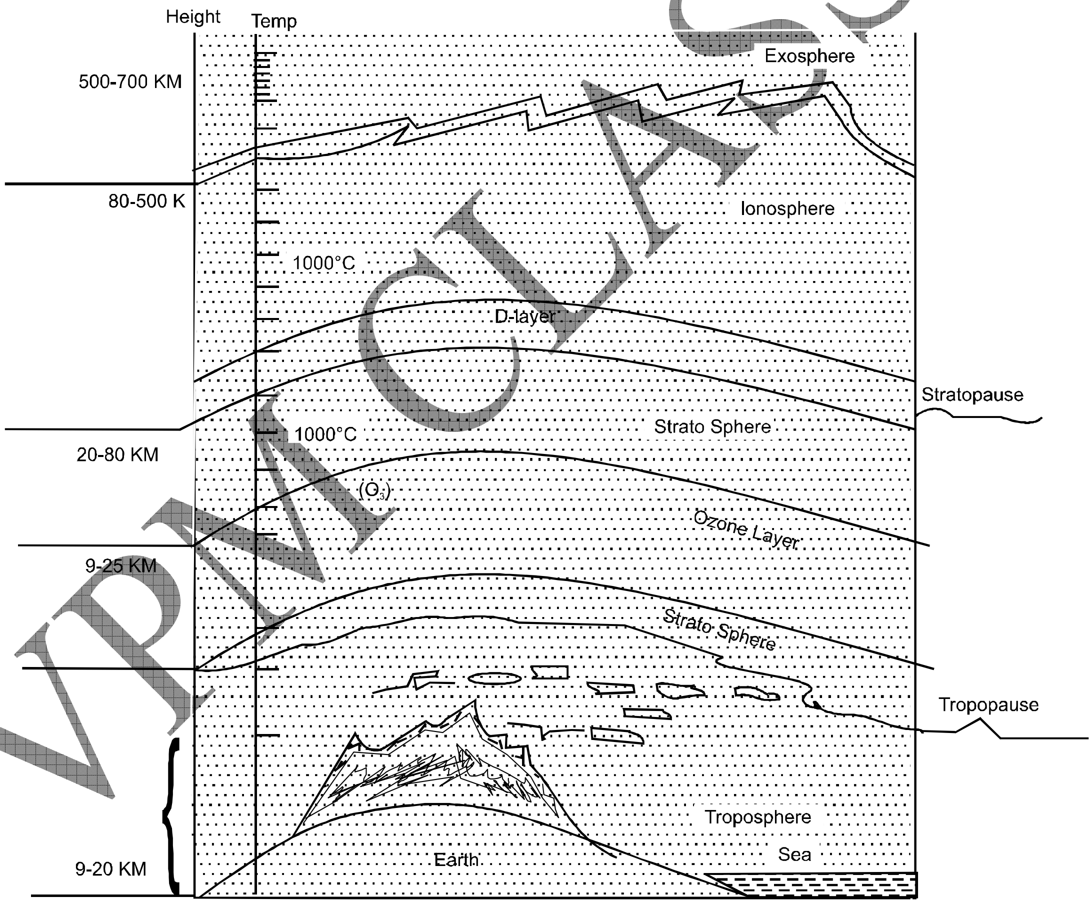
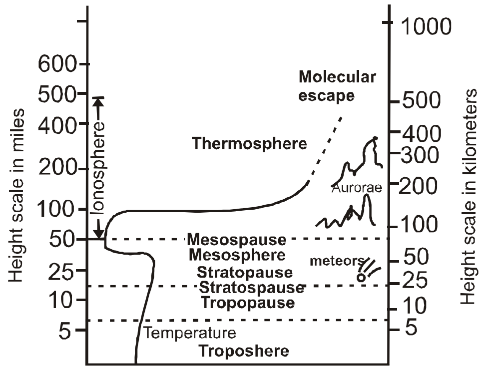


Fig. 1 Structure of the Atmosphere



Vertical divisions of the atmosphere and related phenomena.

Fig. 2

THE STRATOSPHERE

It is the second layer of the atmosphere starting from the tropopause and extending up to an average height of 50 km. The stratosphere differs from the lower layer in following respects:

(i) The temperature becomes constant for a height of 20 km (above tropopause) and then starts increasing.

(ii) It contains almost the entire concentration of OZONE GAS that occurs above the Earth in the form of a well-defined envelope distinguished as the Ozone layer.

(iii) The stratosphere itself has a layered structure and there is no significant mixing or turbulence of gases in this layer.

- The Ozone Layer starts at a height of 9 km above the surface and continues up to 35 km. The maximum concentration of ozone in this layer is estimated at a height of 20-25 km.
- The importance of ozone layer for the life on the planet Earth lies in its capacity to absorb a good proportion of the solar radiation including the entire content of most dangerous ultraviolet rays coming from the Sun. In this process, the gas gets itself

heated up and hence becomes the cause of higher temperature in the upper regions of the atmosphere.

- The upper boundary of the stratosphere is called stratopause.

THE MESOSPHERE

- This is the third thermal zone of atmosphere which begins at stratopause at about 50 km above the surface and continues up to a height of about 80 km.
- It is characterized with a steep fall in temperature that may go to as low levels as –100°C at the upper limit of mesosphere.

THE THERMOSPHERE

- The fourth and the last zone of the atmosphere starts at about 80 km and extends up to 500 km and beyond. In this zone, temperature starts rising once again and reached 1000°C and above.
- This zone is, however, very rarefied in nature, the individual gas particles being separated by considerable distances. Even being heated to such a high degree, these particles pose no threat for a space traveller because there is little chance of their striking him in significant concentration. It is the solar radiation at these heights that is most dangerous.

THE IONOSPHERE

- It is a special zone recognized within the atmosphere. It starts from 80 km and extends upwards to variable heights. Atmospheric gases at these heights absorb a great part of solar radiation coming to the Earth. In this process, these gases break up into ions or electrically charged particles. As a result, this part of the atmosphere is made up entirely of ions and hence is designated as ionosphere. The degree of ionization is not uniform throughout the ionosphere.

- In fact scientists have distinguished five layers making this zone, which can be distinguished on the basis of degree of ionization. The most strongly ionized layer is located at the base of ionosphere and is designated as D-layer. It is also sometimes referred as **Kennelly-Heavisiside layer** after the names of its discoverers.
- Scientists have taken due advantage of the existence of ionosphere. It has proved a boon for long distance radio-communication by virtue of this property of reflecting long radio waves.
- The region of atmosphere beyond 700 km is termed **exosphere**. It is believed to be an extremely rarefied, low-density and high-temperature region with minimum atomic collusions. The subject of structure of the atmosphere is being constantly enriched with findings from artificial satellites.
- Much new information is being gathered about the physical, chemical, electrical, thermal and other properties of the atmosphere through new tools of investigations. The exact boundaries and nature of various atmospheric zones as described above are under constant revision.

Composition of Earth

The Structure

- Scientists divide the Earth into three layers—the crust, the mantle, and the core—based on the composition of each layer. These layers are made up of progressively denser materials toward the center of the Earth. Earth's thin outer layer, the is made almost entirely of light elements. It makes up less than 1 percent of the planet's mass.
- The crust is Earth's thinnest layer. It is 5 km to 8 km thick beneath the oceans and is 20 km to 70 km thick beneath the continents. The which is the layer beneath the crust, makes up 64 percent of the mass of the Earth.

- The mantle is approximately 2,900 km thick and is made of rocks of medium density. Earth's innermost layer is the core is composed of the densest elements. It has a radius of approximately 3,400 km.

The Lithosphere

- It is the stony part of the Earth (litho = stone) and in a broader sense includes all the solid materials composing the Earth from surface downwards.
- In the detailed study of the interior of the Earth, however, the body of the planet is subdivided into three specific layers or zones: the crust, the mantle and the core. The term lithosphere is now understood to include only the uppermost shell of the earth, the crust and a part of the second layer, the mantle, up to which the material exists in a definite solid state. Following is just an outline of important features of the three layers.

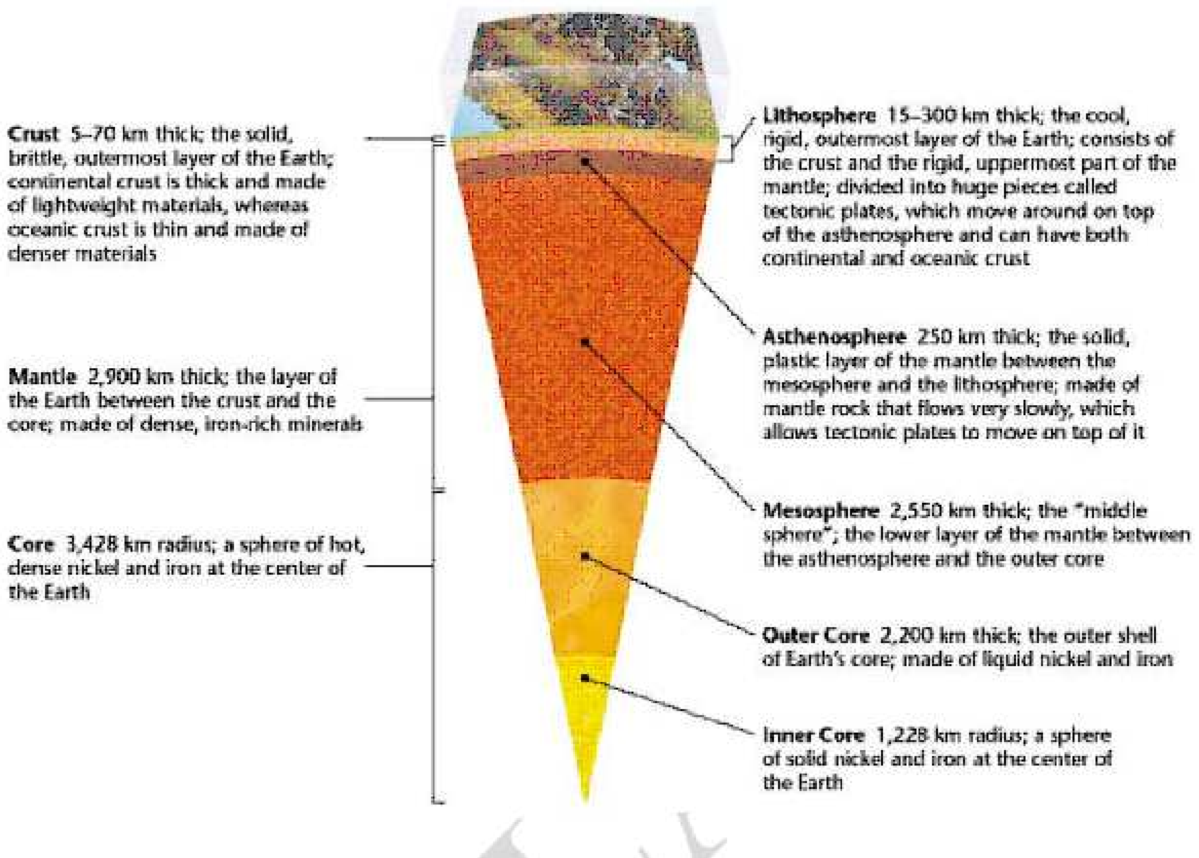


Figure 3 : Earth's Layers Scientists divide the Earth into different layers based on composition and physical properties.

The Crust

It is the uppermost solid shell of the earth which has varying thickness in different areas as follows :

(a) Under the oceans : 5 - 6 km

(b) Under the continents : 30 - 35 km

(c) Under the mountains : 60 - 70 km

- It is obvious that when compared with the radius of the Earth (6730 km, on an average), the crust makes just an insignificant part in the structure of the earth. It is at best analogous to the skin of a big sized apple. As regards the chemical composition of the crust, analyses made by Clarke, Washington, Goldscmidt and Plodervaat on rock samples from different geographic zones have all shown that:

(i) Silica (SiO_2) is the most dominant component; its value lies above 50% by volume in the oceanic crust and above 62% in the continental crust;

(ii) Alumina (Al_2O_3) is the next dominant component, its value varying between 13-16 per cent;

(iii) Iron Oxide (Fe_2O_3)-8%, Lime (CaO)-6%; Sodium Oxide-4%, Magnesium Oxide-4%, Potassium Oxide-2.5% and Titanium oxide-2% are the other components making the crust of the Earth.

The solid aggregate that makes the crust of the earth is named as a rock. This is undoubtedly the most common term used in geological literature, and is broadly synonymous with the word stone. The entire crust is made up of different types of rocks.

CONTINENTAL CRUST & OCEANIC CRUST

- The **continental crust** ranges from about 15 km to more than 60 km. (under high mountain ranges). It is composed mainly of light colored rocks rich in silicon, aluminum and potassium. Some of these are similar in composition and density to granite so it is generalized as “granitic.
- The **oceanic crust** is composed mainly of dark-colored iron and magnesium rich rocks such as basaltic lava flows and dark-colored plutonic rocks with a thin layer (average 0.5 km.) of sediments. It is termed “basaltic”. It makes up about 65% of the surface of the earth.

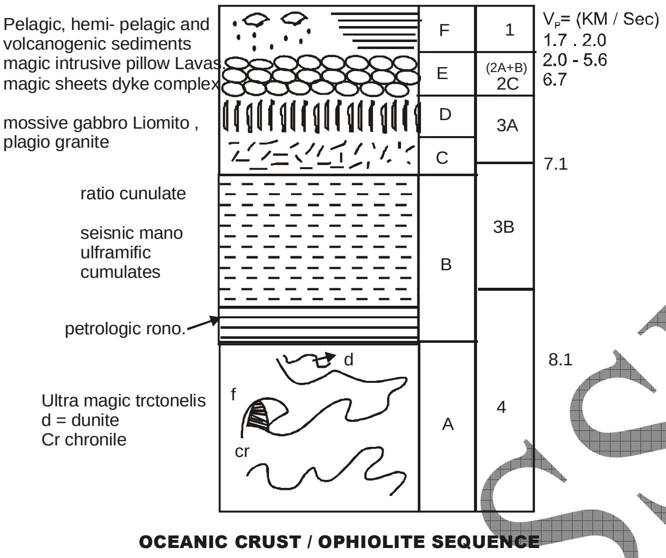


Fig. 4

Crust has two subdivisions:-

(I) SIAL - It is also known as the upper continental crust. It consists of all types of rocks like igneous, sedimentary and metamorphic which are exposed at the land surface. Its composition is usually granitic to grano - dioritc. In the ocean basins, they are floored by a basaltic - horizon which are poorer in potassium and richer in aluminium than the basalts of the land surface and are called " ocean tholeiites"

(II) SIMA - It is also known as lower - Continental crust . Its thickness is about 22 kms. It includes two parts:-

(a) Outer Sima (up to 19 km)

(b) Inner Sima (up to 19 – 33 Kms)

The composition of outer sima is intermediate and the composition of the inner sima is basic to ultrabasic composition.

* The seismic discontinuity at depths ranging from 10 to 30 km (in between SIMA and SIAL) is called **CONRAD DISCONTINUITY** (V_P = 6.4 kms^{-1})

* The chemical compositions of the crust have been determined by TAYLOR AND MCCLENNAN (1985), which is based upon 75% Arehaean average crust plus 25% model, andesite, the latter to reflect post - early Precambrian additions to the continents. The model has a rationable based also on the trace element data ,whereas the overall composition of the ocean crust is Mafic (basaltic) and the overall composition the continental crust is intermediate (55 – 64% SiO_2)

* **Continental crust has three parts :-**

(a) Continental shields that consists of Precambrian (>570 Ma) crystalline igneous and high grade metamorphic rocks.

(b) Continental platforms contain flat lying, gently folded younger metasedimentary rocks usually overlying more Precambrian basement.

(c) Young, mainly tertiary (< 70 Ma) fold mountains that may contain older, deformed metasedimentary rocks and that almost contain young igneous, both volcanic and intrusive rocks.

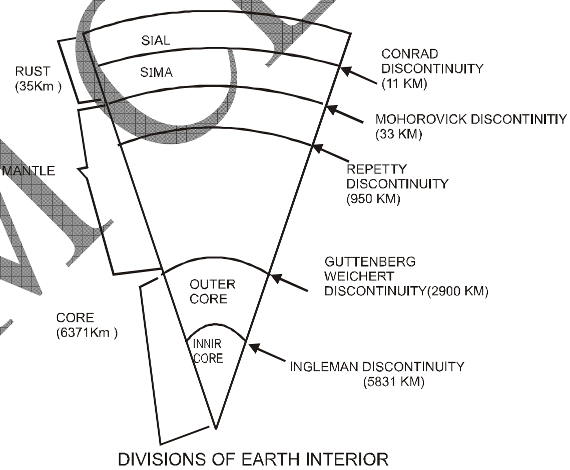


Fig. 5

The Mantle

- The next layer is a **low-velocity zone** in the upper mantle from a depth of about 100 km to a depth of about 250 km. This zone is also called the **asthenosphere** ("weak layer") and is considered to be plastic compared to the rigid zone above which is called the **lithosphere**.
- The lithosphere contains the crust and the upper mantle down to the low velocity zone. This partially melted zone is thought to be the base of the plates which move on the surface of the Earth.This layer makes up about 80% of the earth by volume. **Solid Samples** ripped out of the mantle by volcanic action as well as some exposed mantle rocks show us that the mantle is much more homogeneous than the crust.
- It is made primarily of olivine (Mg_2 SiO4) with some pyroxene (MgSiO3) and garnet. It's named for the gem quality olivine (peridot) as **peridotite.**
- The temperature in the earth increases with depth (30 degree C/ km near the surface) to about 3000 degrees at the mantle-core boundary, but the rate of increase in the mantle is so small that mantle must be a good transporter of heat from deep to shallower areas. It does this by flowing plastically in a process called convection. Due to the decay of radioactive elements like uranium, thorium and potassium about half the heat flow comes out of the earth.
- Because the mantle is plastic, it is not rigid enough to support the continental and oceanic crusts, so they have to "float" on the mantle. So mountains have crust thicknesses of up to 60 km. while average thickness may be 35 km.
- Oceanic crust is thin and dense so it floats much lower than continental material would. Glaciers on Greenland have depressed the central part of the "continent" to below sea level.

The Mohorovicic discontinuity

- The depth below the surface of the Earth at which a striking change in the properties of the materials is observed has been named as Mohorovicic discontinuity. In geological literatsse it is often referred as **M-discontinuity or simply as Moho**.
- The material below Moho forms a nearly homogeneous zone till a depth of 2900 km is reached. Mantle is that zone within the Earth that starts from M-discontinuity and continues up to a depth of 2900 km
- Mantle is made up of extremely basic material called aptly ultra basic, that is very rich in iron and magnesium but quite poor in silica. This zone is characterized with a high density that increases with depth.
- The material of the mantle is believed to be variably viscous in nature so much that the overlying crystal blocks can virtually float over it, of course at a very slow rate and in a broader sense of the term.
- Thus, it defines the boundary between the crust and the mantle of the earth. It is at an average depth of 35 km on the continents and 8 km in the oceans (not counting the water),

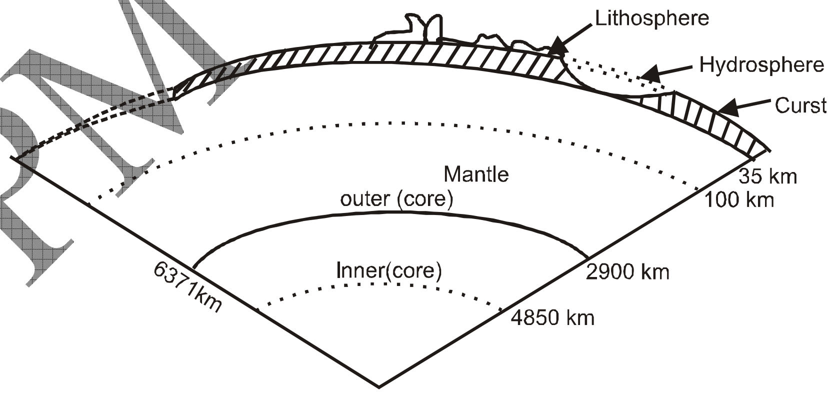


Fig. 6 Generalized structure of the Earth (Not to the scale).

- Many of the most important geological processes such as volcanism, seismic activity and formation of mountains-orogeny- are believed to originate in the mantle. In fact, very little is known as yet about the mantle because we have not yet been able to pierce the earth up to actual depth of this zone. All observations about this zone are of indirect nature, mostly based on the behavior of seismic waves (shock waves released during an earthquake) from their passage within the earth.
- These studies show that the mantle also has a complex layered structure like the crust. It is also sometimes distinguished into upper mantle, middle mantle and lower mantle.

The Core

- It is the third and the innermost structural shell of the earth as conclusively proved by the seismic evidence. It starts at a depth of 2900 km below the surface and extends right up to the center of the earth, at a depth of 6370 km.
- The core remains a mystery in many ways. Within the core, the physical nature and composition of the material is not uniform throughout its depth. Further, it has a very high density at mantle-core boundary, above 10g/cc. But despite such a high density, the outer core behaves like a liquid towards the seismic waves. The liquid like core extending from a depth of 2900 km to about 4800 km is often termed as outer core.

  The inner core - starting from 4800 km and extending up to 6370 km is of unknown nature but definitely of solid character and with properties resembling to a metallic body. According to a widely favored view, the core may be made up of iron and nickel, allowed in some yet unknown manner. This view gets some support from the composition of meteorites that are often recovered from different regions of the globe. The meteorites, as already mentioned, are wandering fragments from the interiors of some other destroyed planets that enter our atmosphere as meteors from time to time.

- The total core has a radius of about 3486 km.
- The inner core has a radius of 1216 km.
- The core's average density is over 10 gm/cm3
- Densities of silicate minerals in the crust and the mantle range from about 2.6 to about 4. Because the average density of the earth is a little over 5.4 gm/cm3, it makes sense that the core has to have a high density to compensate for the average.
- Oxygen (most common anion in the mantle) is such a large, low density element that no amount of

  compression could account for the high density of these core materials.
- From meteorite analyses and cosmic abundances of elements the outer core is thought to be primarily made of iron with small amounts of oxygen, nickel, chromium, silicon and carbon, to lower its melting point. Also the density would be higher if it were pure iron.
- The inner core is thought to be almost pure iron with a higher melting point. Its diameter can be measured using seismic reflection. In the early stages of the earth formation, when it was molten, elements were segregated by density and by combining with other elements to form compounds of different densities. Evidently blocks of iron rich material sank towards the center.