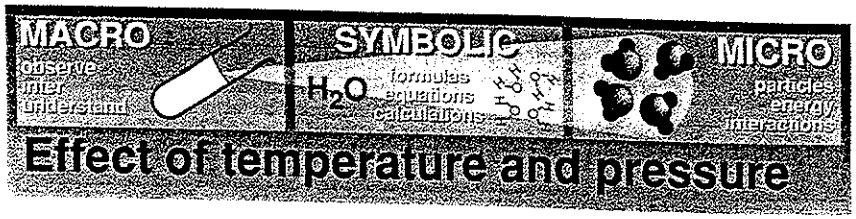


Effect on the solubility of gases

What happens to the solubility of carbon dioxide gas in a soft drink when you remove the lid?

1 List your observations.

2 Explain your observations using the particle theory.

Check your answers.

Removing the lid lowers the pressure and dissolved gas particles are released. The greater the pressure of gas above a liquid the more particles there are colliding with the surface and the greater the solubility.

What happens to the dissolved air in water when a small container of water is placed in a warm location?

1 List your observations.

2 Explain your observations using the particle theory.

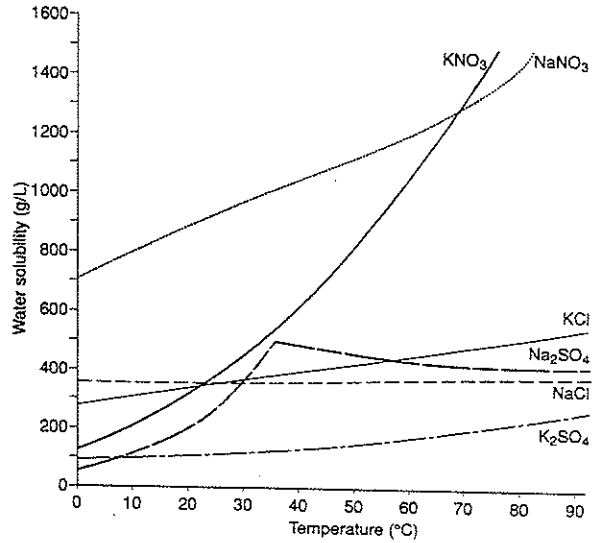
Check your answers.

Raising the temperature lowers the solubility of gases in water. This is why fish may not obtain sufficient oxygen to stay alive when water is thermally polluted or overheated.

Effect on the solubility of salts

The application of pressure does not normally affect the solubility of salts but temperature change can have a significant effect.

The graph below shows the solubilities of a number of salts at different temperatures. Make a general statement about the solubility of salts and temperature. Comment specifically about the solubility of sodium chloride, the main salt in sea water, and temperature.



Check your answer.

Salt ion	Formula	Ion conc. in sea water ($g\ L^{-1}$)	Salt solubilities in water ($g\ L^{-1}$)
chloride	Cl^-	1.90	
sodium	Na^+	1.06	NaCl 360
sulfate	SO_4^{2-}	0.26	
magnesium	Mg^{2+}	0.13	$MgSO_4$ 36 $MgCi_2$ 55
calcium	Ca^{2+}	0.04	$CaSO_4$ 0.2 $CaCO_3$ 0.001
potassium	K^+	0.04	KCl 36
hydrogen carbonate	HCO_3^-	0.01	
bromide	Br^-	0.01	NaBr 95

When sea water evaporates salts will precipitate in a particular order. The order depends on salt solubility and the relative amounts of ions. The order is normally $CaCO_3$, $CaSO_4$, NaCl, $MgSO_4$, $MgCl_2$, NaBr, KCl.

The solubility of calcium carbonate, $CaCO_3$, a major constituent of marine organism shells, is of interest. $CaCO_3$ is actually more soluble in cold water than warm water! There is a depth below which $CaCO_3$ remains of dead organisms do not accumulate because the deep water is cold enough to dissolve all carbonate. This depth is called the carbonate compensation depth (CCD). Below the CCD (about 5 km near the equator and 3 km near the poles) only silicate remains of dead organisms accumulate on the ocean floor.

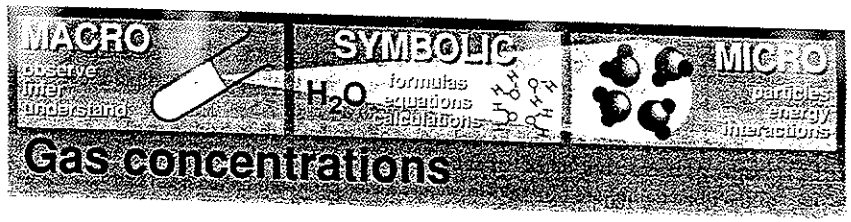
Account for the difference in CCD between the Equator and the poles.

_____

_____

_____

Check your answer.



Many different units are used to measure gas concentrations in the ocean and atmosphere. It is important that you compare measurements given in the same units for the different gases, and understand why variations occur for some gases but not others.

Surface air and surface sea water

Gas	Air % (v/v)	Surface sea water % (v/v)
N_2	78	0.8 – 1.5
O_2	21	0 – 0.9
CO_2	0.03	4.5 – 5.4

1 Account for the great variation in oxygen in surface sea water.

_____

_____

_____

_____

2 Explain why the CO_2 level is so high in surface sea water.

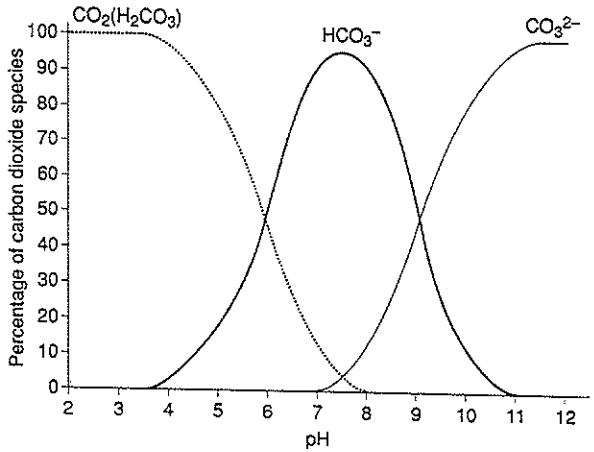
_____

_____

_____

_____

3 Dissolved carbon dioxide is principally in the form of dissolved gas molecules $CO_2(g)$, hydrogen carbonate ions HCO_3^- or carbonate ions. Use the diagram below to estimate the percentages of these different forms in sea water with a pH of 7.5.



Carbon dioxide species in sea water as a function of pH.

Check your answers.

The average balance for inorganic carbon in a sea water sample is 88% as hydrogen carbonate ion, 11% as carbonate ion and 1% as carbon dioxide (carbonic acid). The amount of carbon stored as HCO_3^-, CO_3^{2-} and CO_2 (H_2CO_3) in the oceans is enormous – it is 3.5 times the carbon in fossil fuel deposits and 50 times the carbon in atmospheric CO_2!

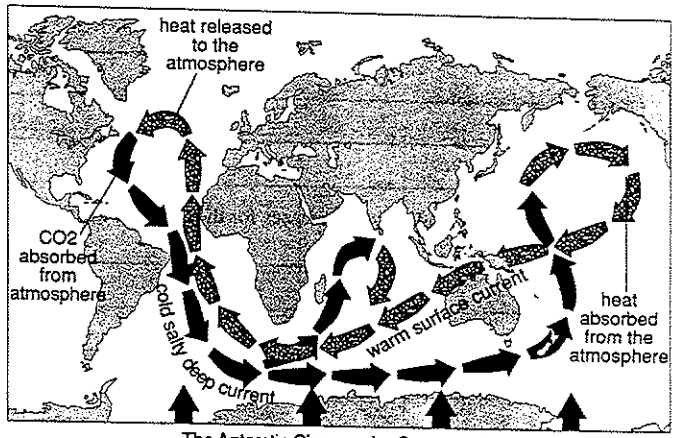
Gas concentrations and ocean depth

The data in the previous table shows significant variation in gas concentrations in surface sea water.

At greater depths there is less variation unless there is a water current present containing very different concentrations of dissolved gas.

In the last ten years major movements of ocean water have been discovered that are believed to have a significant impact on atmospheric climate and gas concentrations.

Up to a third of the carbon dioxide released into the atmosphere each year may be absorbed in the North Atlantic Ocean and carried by what has been called the great ocean conveyor belt into the Indian and Pacific Oceans. The water in this 'conveyor belt' is very salty because it starts near Greenland where ice containing hardly any salt freezes out of sea water. Because it transfers heat and salt it is also called the thermohaline circulation.



The Antarctic Circumpolar Current mixes waters of the Atlantic, Indian and Pacific Oceans.

The Antarctic continent has an eastward circular movement, known as the Antarctic circumpolar current, surrounding it. This circumpolar current ensures mixing of the waters of the three most important oceans.

Cold dense sea water containing large amounts of dissolved gas moves from the edge of Antarctica to the Equator at great depths. This is represented in the diagram by the four thick arrows pointing upwards.

The concentrations of chemically inert gases such as nitrogen and argon increase steadily with depth as the temperature of the water decreases. Sea water is generally saturated with nitrogen and argon.

Much more variation occurs in the concentrations of the biologically and chemically active gases oxygen and carbon dioxide.

Photosynthesis by plants, $CO_2 + H_2O \rightarrow CH_2O + O_2$, is important in the top 100 m where light can penetrate.

Significant respiration ($CH_2O + O_2 \rightarrow CO_2 + H_2O$) occurs in the top 1000 m where most animals are found. As the remains of dead organisms sink towards the ocean floor bacterial decay consumes oxygen. This is replaced by oxygen passing upwards from the deep, well-oxygenated waters of the great conveyor belt.

Solubility of O_2 and CO_2 at different depths

Examine the graphs on the next page for a deep part of the Pacific Ocean: Then explain the following phenomena.

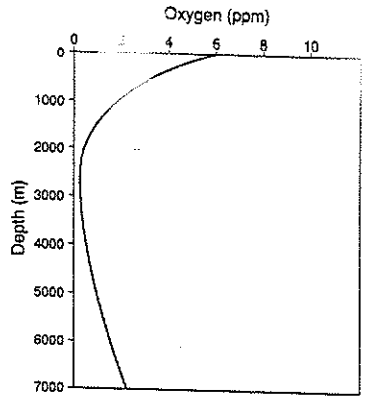
1 Oxygen level is at a maximum at the water surface.

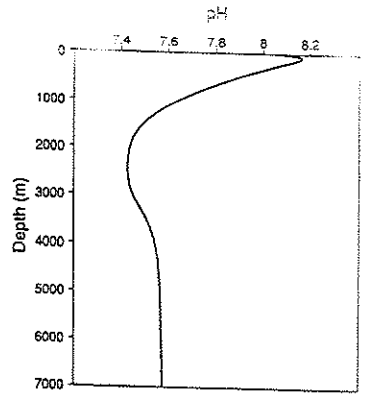
2 Carbon dioxide level decreases for the first 100 m then increases.

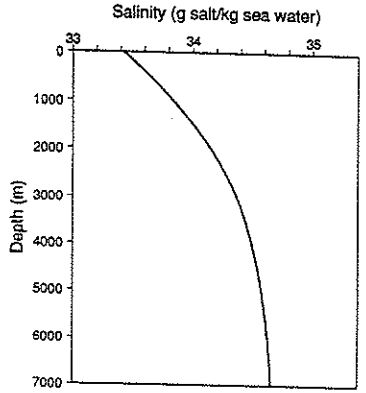
3 Oxygen levels increase after a minimum between 2 000 m and 4 000 m

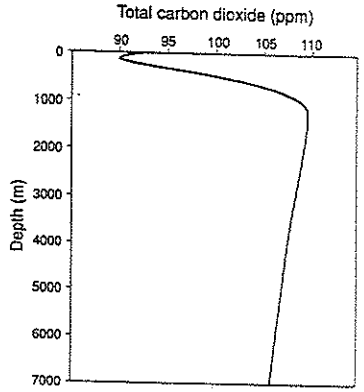
4 Oxygen graph is for dissolved O_2 but carbon dioxide graph refers to total carbon dioxide instead of just carbon dioxide.

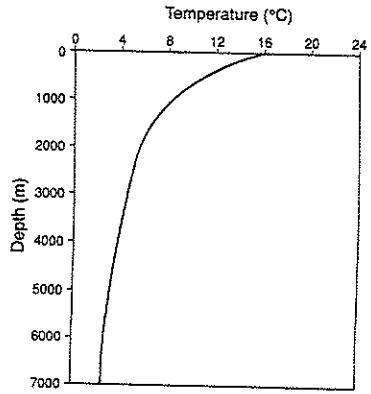
Check your answers.











Rate of metal corrosion

The rate of corrosion of iron varies enormously with conditions. A rough figure is 0.1 mm of thickness per year in moist air and about ten times this rate in sea water. In some locations such as dry desert regions corrosion rates are close to zero. The environmental factors that are most important are listed below.

- Oxygen concentration. The higher the oxygen concentration, the greater the rate of oxidation.
- Salinity, that is, salt concentration. The higher the salinity, the greater the conductivity and the greater the rate of galvanic corrosion.
- Temperature. The lower the temperature, the slower the rate of reaction.
- pH. The more acidic the pH, the greater the rate of corrosion for most metals.

Use the evidence in the graphs given for the previous exercise to predict the depth for:

a maximum rate of corrosion of a metal wreck. _____

b minimum rate of corrosion of a metal wreck. _____

Give reasons for the predictions made.

_____

_____

_____

_____

_____

_____

_____

_____

Check your answers.