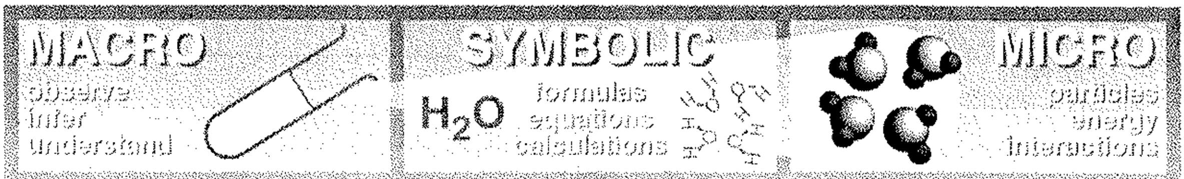

Suggested answers

Effect on the solubility of gases

1 A hissing sound is heard when lid is removed. This sound is immediately followed by bubbles of gas being released from the solution.

2 The high pressure achieved by many CO_2 molecules hitting the surface of the liquid is lost when the lid is removed. By Le Chatelier's principle, lowering the CO_2 gas pressure causes CO_2 molecules to shift from solution to the gas phase in the equilibrium. $CO_2(aq) \rightleftharpoons CO_2(g)$. CO_2 is lost from solution.

1 Small bubbles appear in the liquid as the solution temperature increases.

2 As the temperature rises the dissolved gas molecules move faster. More have sufficient kinetic energy to overcome attraction of the water molecules and escape from solution forming gas bubbles.

Effect on the solubility of salts

Most salts increase in solubility as the temperature rises. The change in solubility with temperature is different for different salts. Unusually, the solubility of sodium chloride hardly changes with temperature.

It is only possible for water to be cold enough to dissolve $CaCO_3$ at a depth below 5 km near the Equator. A depth of 3 km is cold enough near the poles.

Gas concentrations in the ocean and atmosphere

1 Low oxygen concentrations could be in water containing decaying organic matter. High oxygen concentration could be in water with extensive photosynthesis by algae.

2 CO_2 from the air reacts chemically with water to form hydrogen carbonate and carbonate ions. These ions are more soluble in polar water molecules than non-polar CO_2 molecules could be.

3 3% dissolved CO_2 gas or H_2CO_3 , 94% HCO_3^- , 3% CO_3^{2-}

Solubility of O_2 and CO_2 at different depths

1 Wind and wave turbulence increases contact between air and water and oxygen solubility. Photosynthesis by algae at surface raises oxygen concentration.

2 Photosynthetic algae have sufficient light available in the top 100 m to absorb carbon dioxide by carrying out photosynthesis.

3 Dense cold water currents from cold regions carry much oxygen to low depths and this oxygen diffuses upwards.

4 All dissolved oxygen is in the form of dissolved O_2 molecules. Total carbon dioxide consists of dissolved gas (H_2CO_3), HCO_3^- and CO_3^{2-}.

Rate of metal corrosion

a Maximum rate of corrosion would probably be at shallow depths of a few hundred metres where oxygen levels and temperature are highest. Salinity levels and pH levels do not change very much with depth.

b Minimum rate of corrosion would be between 2 to 4 km depth where oxygen levels are at a minimum and temperature is 5 to 3°C.

Predictions

The *Titanic* was in the region of lowest oxygen level and a temperature of 4°C. Low oxygen levels and little heat energy slow the rate of corrosion.

$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ to proceed at a slow rate.

Explanations

Knowing that the oxidation state of oxygen is always –2 and hydrogen is +1 the oxidation states of sulfur are:

+6 in SO_4^{2-}, 0 in S, –2 in H_2S, –2 in S^{2-}

The changes from sulfate, oxidation state +6, to S, H_2S or S^{2-} all involve reducing the oxidation state of sulfur. Thus the term, sulfate reducing describes what the bacteria do to sulfate ions.

1 Sulfur is directly under oxygen in Group 15. These two elements have similar chemical properties. In an environment free of oxygen sulfur can be an alternative oxidant. The high oxidation state of sulfur, +6, in SO_4^{2-} will be a better oxidant, able to attract more electrons, than lower oxidation states such as in elemental sulfur, 0.

2 In the equilibrium $SO_4^{2-} + 5H_2O + 8e^- \rightleftharpoons HS^- + 9OH^-$ the hydrogen ions neutralise the hydroxide ions. A lower concentration of hydroxide ions causes the equilibrium position to move to the right.

Metal ions such as Fe^{2+} combine with sulfide ions S^{2-} forming insoluble sulfides such as FeS. This reduces the concentration of S^{2-} and, by Le Chatelier's Principle, leads to more ionisation of hydrogen sulfide molecules. $H_2S \rightleftharpoons 2H^+ + S^{2-}$. In turn $S(s) + 2H^+ + 2e^- \rightleftharpoons H_2S$ shifts position to the right causing $SO_4^{2-} + 8H^+ + 6e^- \rightleftharpoons S(s) + 4H_2O$ to shift position to the right. The two equilibria shifting position to the right result in more reduction of sulfate ions.

Corrosion of iron in the *Titanic* forms iron(II) compounds because there was no O_2 available to oxidise iron(II) to iron(III). Remember that the rusting of iron normally involves two steps, formation of iron(II) hydroxide followed by oxidation with oxygen to rust.