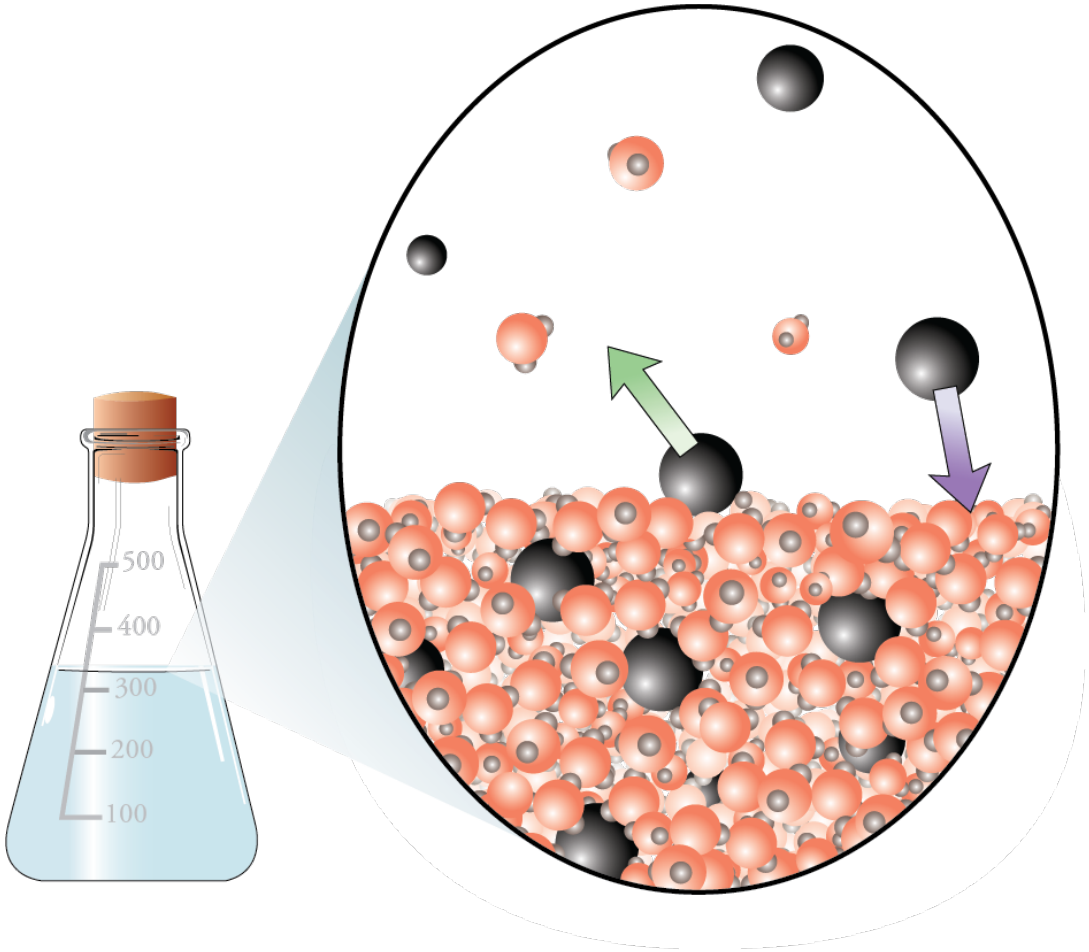
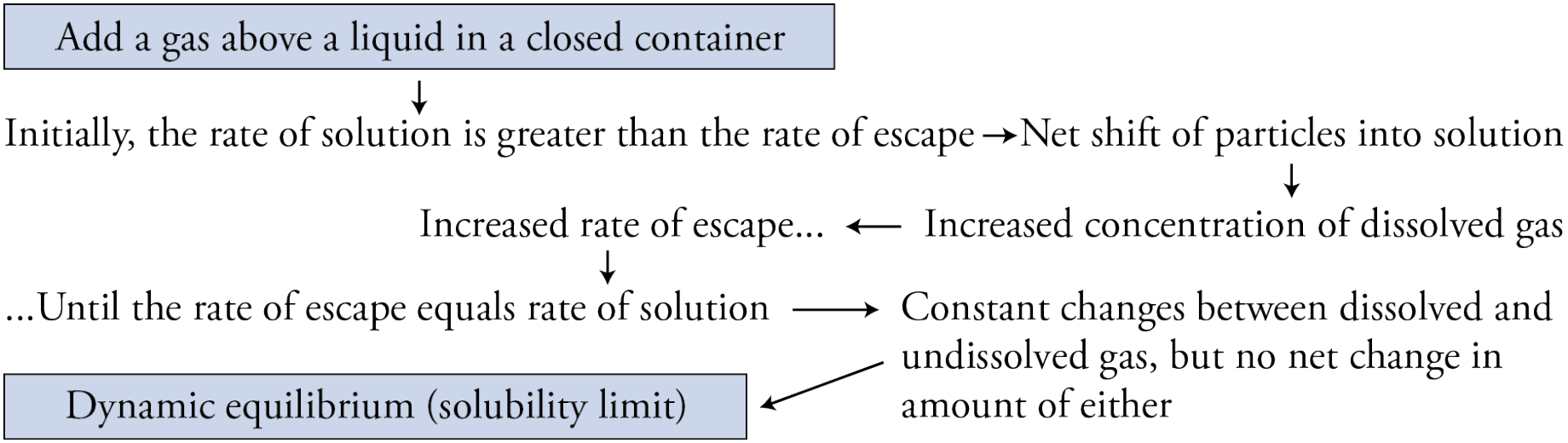
Questions to Answer

- Why does increased carbon dioxide in the atmosphere due to burning fossil fuels and deforestation lead to increased CO_2 dissolved in the ocean?
- Why does this cause the ocean to become more acidic?
- How does the increasing acidity of the ocean affect sea organisms?
- Why should this worry us?

Solution of Gas in Liquid

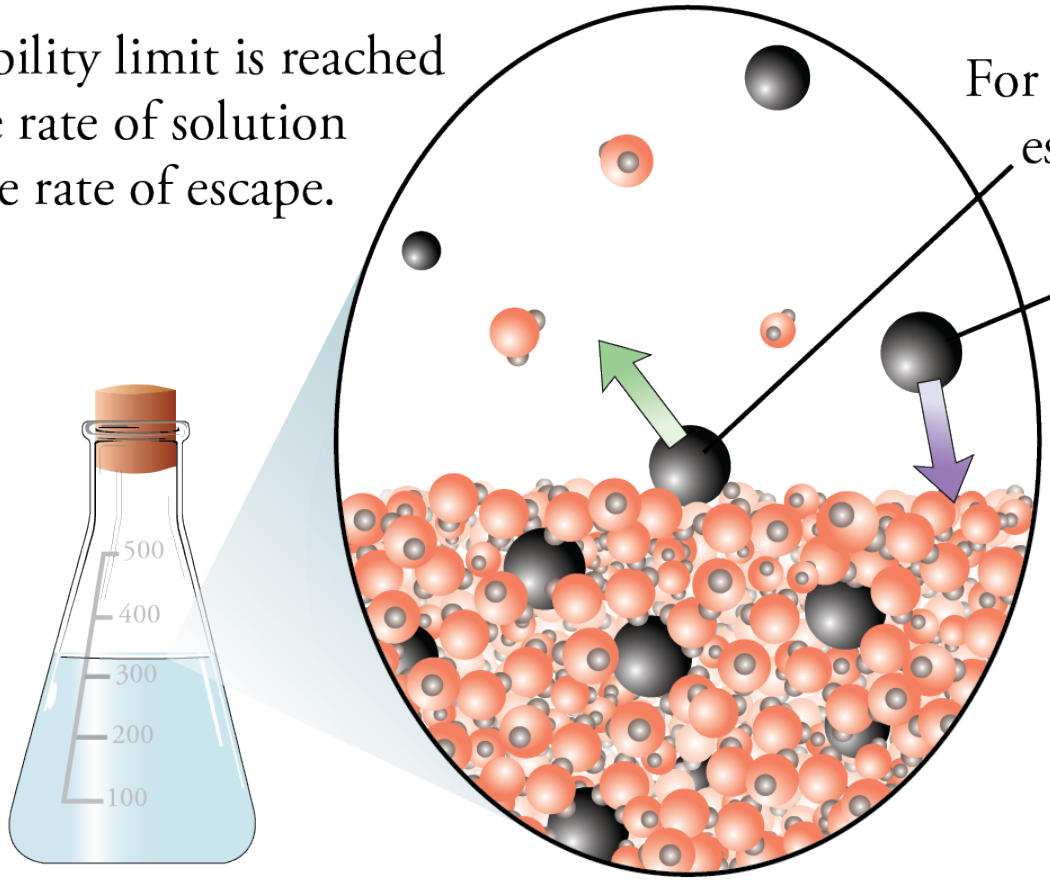


Gas Solubility



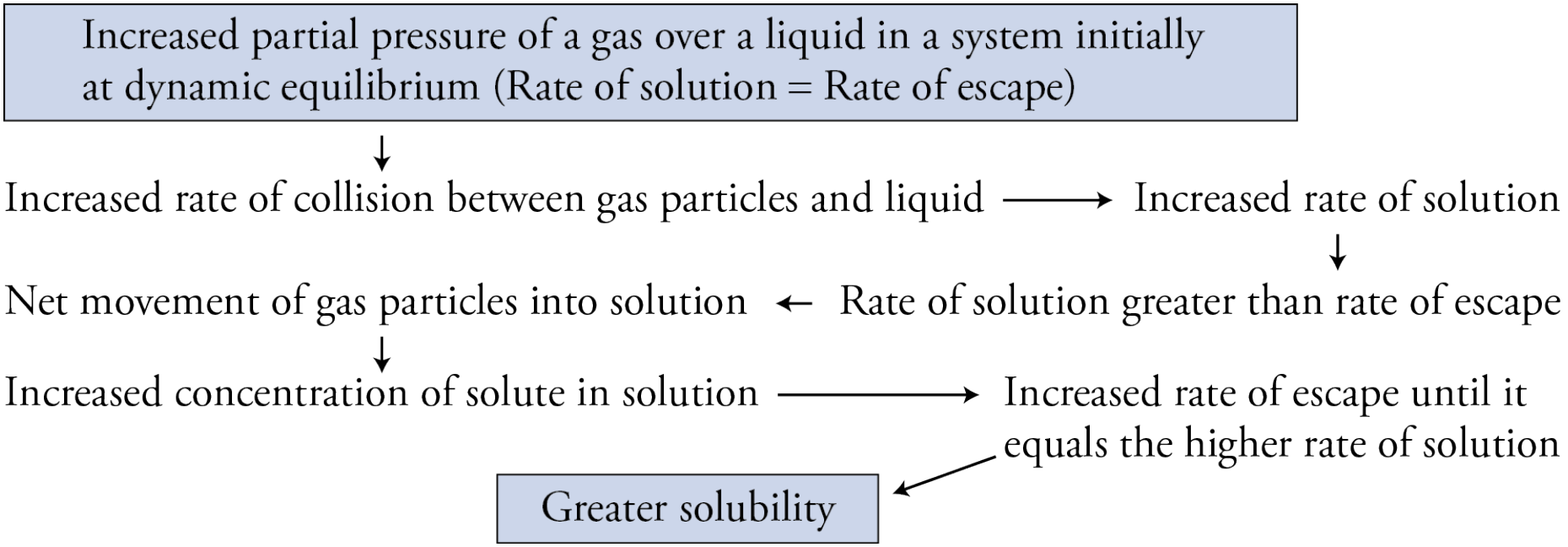
Dynamic Equilibrium for Gas Dissolved in Liquid

The solubility limit is reached when the rate of solution equals the rate of escape.



For every gas particle that escapes from the liquid, another gas particle collides with the surface and goes into solution.

Partial Pressure and Gas Solubility



Oceanic Carbon

- One way that carbon enters the ocean is through solution of atmospheric CO_2.

  $CO_2(g) \rightleftharpoons CO_2(aq)$

- Increased concentration of CO_2 in the atmosphere due to the burning of fossil fuels and deforestation leads to
  - an increase in the rate of collisions with the ocean,
  - increasing the rate of solution,
  - disrupting the dynamic equilibrium, making the $R_{soln} > R_{escape}$,
  - and leading to a net shift of CO_2 into the ocean.

CO_2 and Ocean Acidity

- CO_2 molecules react with water to form carbonic acid.

$$CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$$

- Carbonic acid reacts with water to form hydronium and hydrogen carbonate ions.

$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$$

CO_2 and Ocean Acidity

- The absorption of human generated CO_2 has acidified the surface layers of the ocean, with a steady decrease of about 0.02 pH units per decade over the past 30 years and an overall decrease since the pre-industrial period of 0.1 pH units.
- Because the pH scale is a logarithmic scale, this is a 30% increase in hydronium ion concentration.
- This leads to substantial changes in ocean chemistry.

Effects of Increasing Ocean Acidity

- Carbonate ions combine with calcium ions in the ocean to form calcium carbonate, which forms shells, skeletons for coral reefs and other sea animals, and other $CaCO_3$ structures of ocean organisms.

$$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightleftharpoons CaCO_3(s)$$

- Hydronium ions react with carbonate ions to form hydrogen carbonate ions, decreasing the carbonate ions available to build and maintain calcium carbonate structures.

$$H_3O^{+}(aq) + CO_3^{2-}(aq) \rightarrow HCO_3^{-}(aq) + H_2O(l)$$

Effects of Increasing Ocean Acidity

- Ocean acidification affects organisms in other ways than decreasing carbonate ions. For example,
  - seagrasses may grow faster if more dissolved carbon dioxide is available,
  - the number of oysters may decrease as fewer larvae complete their life cycle,
  - the ability of some fish, such as clownfish, to detect predators and find suitable habitats decreases in more acidic waters, threatening the whole ocean food web.