Year 13 Science: The ocean carbon cycle and ocean acidification

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. If ocean pH fell from 8.10 to 7.80, by what factor would $[H^+]$ increase?

2. Calculate $[H^+]$ in seawater at pH 8.1.

3. Using the solubility table, how many times more CO_2 dissolves at 10 °C than at 30 °C?

4. Phytoplankton turn CO_2 into sugar, and their remains sink as marine snow. Which pump is this?

5. Why does adding CO_2 to seawater reduce the concentration of carbonate ions?

Exam-style question: carbon and pāua

The cold waters south and east of New Zealand take up large amounts of CO_2 each year. Pāua farmers worry that falling pH could affect their young pāua.

6. Describe how the physical pump moves CO_2 from the air into the deep ocean.

7. Explain how the biological pump removes carbon from surface water.

8. Using equations, explain how dissolving CO_2 lowers the pH of seawater.

9. Explain why young pāua may grow weaker shells as the ocean takes up more CO_2.

Fix the mistake

10. Correct this statement: "Ocean acidification means the sea is now an acid with a pH below 7."

11. Correct this statement: "A fall of 0.1 in pH is too small to matter."

12. Correct this statement: "Extra CO_2 gives shellfish more carbonate to build shells with."

13. Correct this statement: "Warm tropical water absorbs the most CO_2 because it has the most plankton."

Answer key (for parents and tutors)

1. If ocean pH fell from 8.10 to 7.80, by what factor would $[H^+]$ increase?
   10^(8.10 − 7.80) = 10^0.30 = 2.0 times.

2. Calculate $[H^+]$ in seawater at pH 8.1.
   $[H^+] = 10^{(-8.1)} = 7.9 \times 10^{-9}$ mol L^{-1}.

3. Using the solubility table, how many times more CO_2 dissolves at 10 °C than at 30 °C?
   2.32 ÷ 1.26 = 1.84 times.

4. Phytoplankton turn CO_2 into sugar, and their remains sink as marine snow. Which pump is this?
   The biological pump.

5. Why does adding CO_2 to seawater reduce the concentration of carbonate ions?
   The extra H^+ from carbonic acid reacts with carbonate, $H^+ + CO_3^{2-} \rightarrow HCO_3^-$, turning it into hydrogencarbonate.

6. Describe how the physical pump moves CO_2 from the air into the deep ocean.
   CO_2 dissolves at the surface, faster in cold water and where wind and waves mix the surface; sinking (downwelling) cold water carries it down away from the air (Achieved for dissolving and cold water; Merit adds wind, waves and downwelling).

7. Explain how the biological pump removes carbon from surface water.
   Phytoplankton photosynthesise, $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$, making organic carbon that passes through the food web; dead matter and faecal pellets sink as marine snow and are decomposed at depth or buried, so carbon leaves the surface (Merit).

8. Using equations, explain how dissolving CO_2 lowers the pH of seawater.
   $CO_2 + H_2O \rightleftharpoons H_2CO_3$, then $H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$ and $HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$. More CO_2 shifts the equilibria right, raising $[H^+]$, so pH = −log$[H^+]$ falls (Merit for two equations with charges and an explanation).

9. Explain why young pāua may grow weaker shells as the ocean takes up more CO_2.
   The extra H^+ combines with carbonate, $H^+ + CO_3^{2-} \rightarrow HCO_3^-$, so fewer carbonate ions are available for $Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3$. Pāua larvae and juveniles must spend more energy building shell, and in cold water, already low in carbonate, the shell may grow thinner or even dissolve, reducing survival (Excellence links uptake, equilibrium shift, carbonate loss and the effect on the organism).

10. Correct this statement: "Ocean acidification means the sea is now an acid with a pH below 7."
    The sea is still basic (about pH 8.1); acidification means its pH is falling towards acidic.

11. Correct this statement: "A fall of 0.1 in pH is too small to matter."
    pH is logarithmic: a 0.1 fall means about 26% more hydrogen ions.

12. Correct this statement: "Extra CO_2 gives shellfish more carbonate to build shells with."
    The extra H^+ reacts with carbonate to form hydrogencarbonate, so carbonate ions decrease.

13. Correct this statement: "Warm tropical water absorbs the most CO_2 because it has the most plankton."
    Cold water dissolves more CO_2, and cold, windy, sinking regions like the Southern Ocean take up the most.