

## 2. This question is about pollution and the Taj Mahal



You should need to refer to the following solubility data to help answer this question.

Substance	CaCO <sub>3</sub>	CaSO <sub>4</sub>	BaCO <sub>3</sub>	BaSO <sub>4</sub>
Solubility in water / mol dm <sup>-3</sup>	1.3 x 10 <sup>-4</sup>	4.5 x 10 <sup>-2</sup>	9.1 x 10 <sup>-5</sup>	9.4 x 10 <sup>-6</sup>

Although calcium carbonate is effectively insoluble in pure water, it reacts with acidic rainwater, thereby accelerating the erosion of marble and limestone monuments.

- (a) Give the equation for the reaction between calcium carbonate and carbonic acid, H<sub>2</sub>CO<sub>3</sub>(aq).

In addition to this reaction, the pollutant SO<sub>2</sub> forms SO<sub>3</sub> in the atmosphere, which then dissolves in rainwater forming sulfuric acid. This slowly converts calcium carbonate into solid calcium sulfate.

- (b) i) Write the equation for the reaction between calcium carbonate and sulfuric acid.
- ii) Why does the conversion of calcium carbonate into calcium sulfate accelerate the erosion of marble and limestone?

The life of monuments like the Taj Mahal is now being extended by treatment with an aqueous mixture of barium hydroxide, Ba(OH)<sub>2</sub> and urea, CO(NH<sub>2</sub>)<sub>2</sub>. As this solution soaks into the porous marble / limestone, the urea slowly hydrolyses forming ammonia and carbon dioxide. The carbon dioxide released reacts with the barium hydroxide forming barium carbonate.

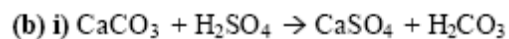
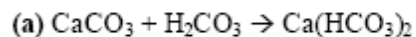
- (c) Write the equation for the hydrolysis of urea.
- (d) i) Write the equation for the reaction between barium hydroxide and carbon dioxide.
- ii) Why does the formation of barium carbonate slow down the rate of erosion of the monument?

Finally, surface barium carbonate on the treated monument can react with sulfur dioxide in the air, forming a layer of barium sulfate, and carbon dioxide.

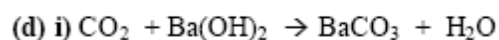
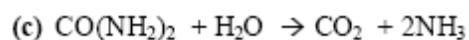
- (e) i) Give the equation for the reaction between barium carbonate and sulfur dioxide, in the presence of oxygen.
- ii) Will this secondary reaction speed up or slow down the erosion process? Explain briefly.

## Answers

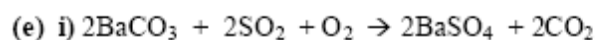
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ii)  $\text{CaSO}_4$  is more soluble than  $\text{CaCO}_3$ .



ii)  $\text{BaCO}_3$  is even less soluble than  $\text{CaCO}_3$ .



ii) Slow down, because  $\text{BaSO}_4$  is least soluble of all/ The reaction consumes  $\text{SO}_2$ , thus less  $\text{H}_2\text{SO}_4$  is formed.

**Total 8**

**Chair's Report**

Many students answered Question 2 very well, although only a handful could write the correct equation for the reaction between carbonic acid and calcium carbonate. It would appear that hard water, if covered at GCSE, was just a distant memory!