Problem 9: Cool drinking

Curriculum links;
enthalpy changes, Born-Haber cycles

Practical skills;
experimental design, Health and Safety

The students are set the problem of designing a new drinks container which will cool 100 cm^3 of a drink by 5 °C in 5 min. The students need to decide which of ammonium nitrate and ammonium chloride should be used based on the enthalpy of solution, the solubility is in water, the cost and the relevant health and safety information for each salt. They then need to trial their method and modify the quantity of salt required accordingly.

Pre-Lab questions
(Remember to give full references for any information beyond A-level that you find out)

1. Give definitions for each of the following enthalpy changes. In each case include an equation to represent the process to which the enthalpy change applies;

a) Enthalpy of solution of the ionic compound X^+Y^-
b) Lattice energy of the ionic compound X^+Y^-
c) Enthalpy of hydration of the gaseous ion Z^+ (g)

2. The enthalpy of solution of an ionic compound can be calculated from its lattice enthalpy and the enthalpies of hydration of the individual ions. Use the enthalpy changes shown and a Born-Haber type cycle to calculate;

a) The enthalpy of solution of ammonium chloride, NH_4Cl (s)
b) The enthalpy of solution of ammonium nitrate, NH_4NO_3 (s)

	Enthalpy change / kJ mol^{-1}
Lattice energy of NH_4Cl (s)	–705
Lattice energy of NH_4NO_3 (s)	–646
Enthalpy of hydration NH_4^+ (g)	–307
Enthalpy of hydration Cl^- (g)	–381
Enthalpy of hydration NO_3^- (g)	–314

3. In 2001, Nescafe launched a self-heating can of coffee. To heat up the coffee a button is pressed which mixes the heating ingredients; a single step mixes calcium oxide and water to produce calcium hydroxide and generate heat;

$$CaO + H2O \rightarrow Ca(OH)2\ \Delta H\ –82\ kJmol^{-1}$$

The can warms up 210 cm^3 of coffee by 40◦C.

a) Assuming that the heat capacity for coffee is the same as that of water (4.18 $JK^{-1}g^{-1}$) calculate the energy needed to warm 210 cm^3 of coffee by 40 ◦C.

b) Use this value to hence calculate the minimum mass of CaO needed in the can for it to function as specified.

(Question taken from 2003 International Chemistry Olympiad Booklet 2003 – Round 1)

Bettie's Beverages
Milton Keynes, England

Dear Scientist,

Congratulations! You and your group have been selected for the contract job of designing my company's latest product. We are working to a tight schedule so your product must be finished A.S.A.P.

The product is a drinks can that, when desired, can be activated to cool the drink it contains wherever the user may be at the time. In the first instance we are looking for a product that can cool 100 cm^3 of drinkable water by 5 ◦C in no more than 5 minutes. Try not to exceed this temperature change as we do not want our customers' teeth to freeze!
You and your team will need to use your knowledge of chemistry to come up with a product design which includes full details of the cooling process with exact quantities of any chemicals used and time periods required to give us our desired –5 ◦C temperature change. We would like you to provide us with both theoretical and experimental quantities for any chemicals used in order for us to evaluate the effectiveness of your design. In order to pass the strict requirements of the Food Standards Agency it is also imperative that the cooling process is safe. We at the department have done a little research ourselves and have found two chemicals that we think would be useful;

ammonium chloride (NH_4Cl); solubility 37.2 g / 100 g water, £2.55 per 500g
ammonium nitrate (NH_4NO_3); solubility 192 g / 100 g water, £10.95 per 500g

Please include with your final product design an explanation of which chemical you decided most suitable and why, including careful consideration of the Health and Safety implications of your chosen design.
Finally we need to know that you have successfully tested your design. Please provide data to indicate this.

Thank you for accepting this contract and we look forward to seeing your results.

Regards,
George Marshall

George Marshall

Product Development Manager