Problem 9: Cool drinking

Pre-Lab answers

1.

a) *Enthalpy of solution of the ionic compound X^+Y^-*

The heat energy change at constant pressure when one mole of X^+Y^- dissolves completely in water;

$$X^+Y^-(s) + \text{water} \rightarrow X^+(aq) + Y^-(aq)$$

b) *Lattice energy of the ionic compound X^+Y^-*

The enthalpy change when one mole of X^+Y^- is formed from its gaseous ions;

$$X^+(g) + Y^-(g) \rightarrow X^+Y^-(s)$$

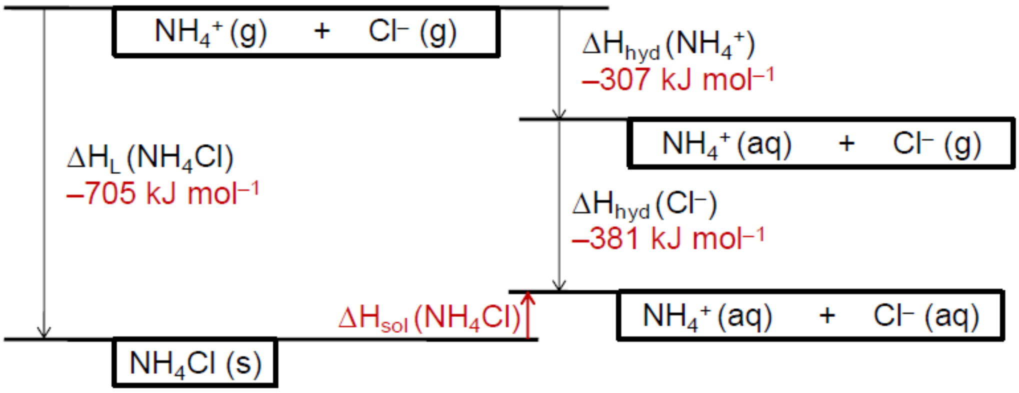
c) *Enthalpy of hydration of the gaseous ion Z^+ (g)*

The enthalpy change when one mole of isolated gaseous ions, Z^+ is dissolved in water to form one mole of aqueous ions under standard conditions;

$$Z^+(g) \rightarrow Z^+(aq)$$

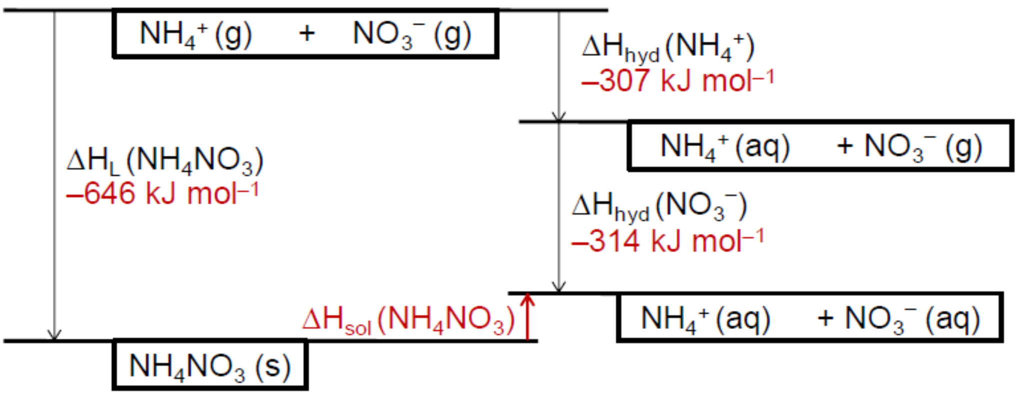
2.

a) The enthalpy of solution of ammonium chloride, NH_4Cl (s);



$\mathbf{\Delta H_{sol}(NH_4Cl)}$ = – –705 + –307 + –381 = **+17 kJ mol^{-1}**

b) The lattice energy of ammonium nitrate, NH_4NO_3(s);



$\mathbf{\Delta H_{sol}(NH_4NO_3)}$ = – –646 + –307 + –314 = **+25 kJ mol^{-1}**

3.

a) $Q = mC\Delta T$ m = 210 g (density of water = 1 g cm^{-3})

$C = 4.18\ J\ K^{-1}\ g^{-1}$

T = 40 °C or 40 K

Hence Q = 210 g × 4.18 J K^{-1} g^{-1} × 40 K = **35112 J or 35.1 kJ**

b) $CaO + H_2O \rightarrow Ca(OH)_2$ ΔH –82 kJ mol^{-1}

Therefore reacting one mole of CaO produces 82 kJ of energy

So the no. of moles of CaO we need to react to heat the can = 35.1 kJ ÷ 82 kJ mol^{-1} = 0.43 moles

Mass of 0.43 moles of CaO (molar mass, 56.1 g mol^{-1}) = 0.43 moles × 56.1 g mol^{-1} = **24.0 g**

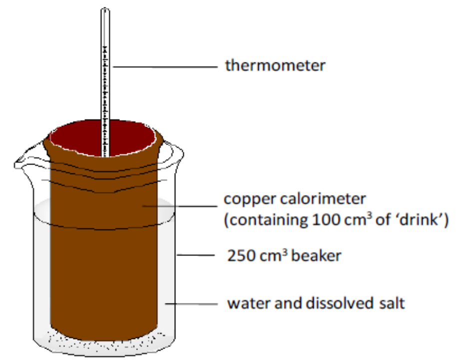
Teacher and Technician Pack

Proposed method

NH_4Cl is **harmful** if swallowed and irritating to eyes

Using the pre-lab questions, the students identify the dissolution of either NH_4Cl or NH_4NO_3 in water as endothermic reactions and therefore suitable methods for cooling the drink.

Following research into the H&S implications of using NH_4NO_3 **[Oxidising]** and its high cost relative to NH_4Cl, students decide on the dissolution of NH_4Cl **[Harmful]** as the **ONLY** suitable option.



Beaker can be insulated further with cotton wool, foil etc.

The students trial possible arrangements for the can design and determine the minimum quantity of water in which the salt can be dissolved for effective heat energy transfer from the surrounding liquid to the copper can.

Using the enthalpy of solution of NH_4Cl calculated in pre-lab Q2 part a, the students complete the theoretical calculations of;

- the heat energy transfer required to cool 100 cm^3 of drink by 5 °C
- the amount of salt which must be dissolved in the surrounding water to bring about the desired energy change

$q = mc\Delta T$ $\quad m = (100\ cm^3 + 85\ cm^3) \times 1\ g/cm^3$

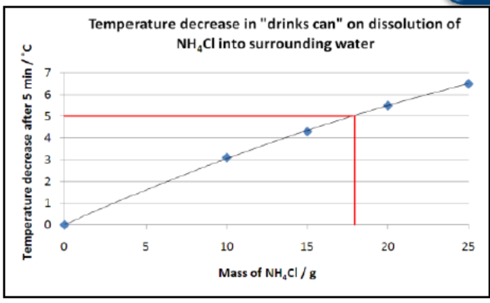
$= 3870\ J$ $\quad c = 4.18\ J\ g^{-1}\ K^{-1}$

$= 3.9\ kJ$ $\quad \Delta T = 5K$

$\therefore$ moles of NH_4Cl needed $= \frac{3.9\ kJ}{\Delta H_{soln}(NH_4Cl)}$

$= \frac{3.9\ kJ}{17\ kJ\ mol^{-1}} = 0.23$ moles

$\therefore$ mass of NH_4Cl needed (m_r 53.5 $g\ mol^{-1}$) $= 0.23$ moles $\times 53.5\ g\ mol^{-1} = 12.3\ g$



Students trial the theoretical quantity and evaluate their method. Systematic experimentation including a calibration graph of mass of salt used *vs* ΔT will allow the students to accurately determine the experimental quantity of salt needed to cool the drink by 5 °C

Final method and design tested

= *ca* 18 g NH_4Cl dissolved in *ca* 85 cm^3 of water surrounding the "drinks can"

Equipment list

Each group will need;

- 120 g ammonium chloride, NH_4Cl [Harmful]
- Accurate thermometer
- 100 cm^3 copper calorimeter (or similar)
- 250 cm^3 beaker
- 100 cm^3 measuring cylinder
- Top pan balance
- Stirring rod
- Spatulas
- Insulation; Paper / aluminium foil / cotton wool etc.
- Boss, clamp and stand
- Graph paper
- Stopclock

Health and safety note

Ammonium nitrate requires very careful handling (R8: Contact with combustible material may cause fire, R9:

Explosive when mixed with combustible material, **Do not allow the salt to become contaminated with organic matter and do not grind it.)**

As a result, ammonium nitrate should NOT be provided to the students under any circumstances.