Theory v practice: do they compare?

Time

2–3 h for the theoretical approach depending on ability and on amount of assistance that needs to be given.

2– 4 h for the practical approach.

Curriculum links

Born-Haber cycle calculations, hydration enthalpies, practical calorimetry.

Access to data books will be needed. The book by Stark and Wallace[1] contains the most useful compilation of data for this exercise.

Group size

Minimum of 3 for theoretical work (*ie* for group discussion).

Materials and equipment

Materials per group

- 0.5–1.0 g fresh calcium metal
- 60 mm × 60 mm copper gauze to make a cage in which to sink the calcium.

Equipment per group

- 2 dm^3 beaker (plastic if possible)
- 0°–100° × 0.1°C thermometer
- safety screen or fume cupboard
- safety glasses.

Safety

Eye protection must be worn.

When attempting the practical route students must have their proposals approved before starting on any experimental work.

In contact with water calcium releases flammable gases

The use of a safety screen or fume cupboard should be mandatory.

Risk assessment

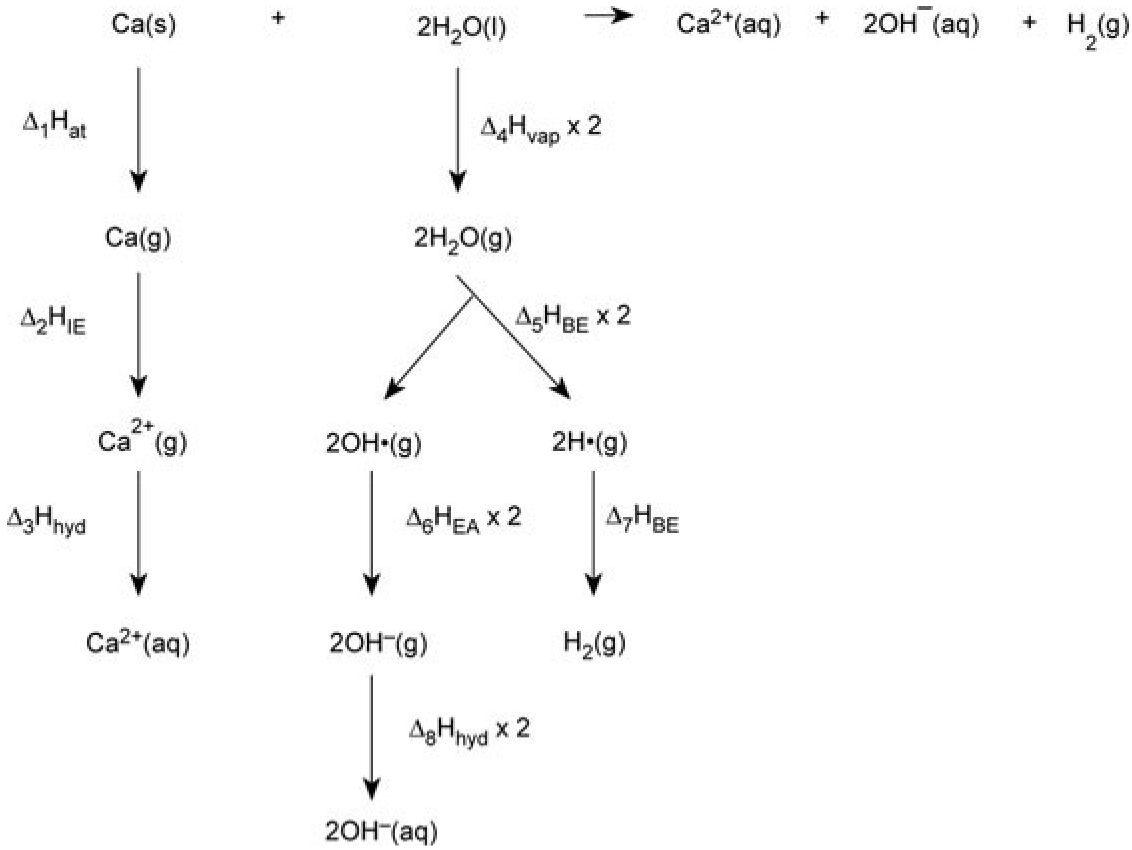
It is the responsibility of the teacher to carry out a suitable risk assessment.

This is an open-ended problem solving activity, so the guidance given here is necessarily incomplete. Teachers need to be particularly vigilant, and a higher degree of supervision is needed than in activities which have more closed outcomes. Students must be encouraged to take a responsible attitude towards safety, both their own and that of others. In planning an activity students should always include safety as a factor to be considered. Plans should be checked by the teacher before implementing them.

You must always comply with your employer's procedures and in some cases may decide that a particular activity is inappropriate in your situation. Further information on Health and Safety should be obtained from reputable sources such as CLEAPSS [http://science.cleapss.org.uk/] in England, Wales and Northern Ireland and, in Scotland, SSERC [https://www.sserc.org.uk/].

Commentary

Various versions of the cycle are possible, but if the students invoke the electron affinity of the hydroxide radical, which is given in the brief, they should eventually arrive at the following:



Energy values ΔH/kJ mol^{-1} (from data books and textbooks)[1]

Δ_1H_{at} = atomisation of Ca(s) =	+ 193
Δ_2H_{IE} = 1st and 2nd ionisation energies of Ca = +590 +1150 =	+ 1740
Δ_3H_{hyd} = hydration energy of Ca^{2+} =	–1650
Δ_4H_{vap} = vaporisation of water × 2 = +44 × 2=	+ 88
Δ_5H_{BE} = bond energy O–H × 2 = +463 × 2 =	+ 926
Δ_6H_{EA} = electron affinity of $OH^{\bullet}$(g) = –176.5 × 2=	– 353
Δ_7H_{BE} = bond energy H–H = –436	– 436
Δ_8H_{hyd} = hydration energy of OH^-(aq) = –460 × 2	– 920
	– 412 kJ mol^{-1}

Procedure

The experimental work is straight forward and gives results within 95% of the theoretical value using the following method.

Weigh about 100.00 g of deionised water in a 2 dm^3 beaker. Carefully wipe the inside of the beaker to remove droplets above the water. Stand the beaker in a fume cupboard, insert a thermometer capable of reading to 0.1°C in the water and leave to obtain a constant value. Weigh out about 0.5 g of calcium metal, choosing large pieces rather than smaller ones. Quickly empty the metal into the water and stir with the thermometer. If the calcium is fresh the reaction will be complete in *ca* 90 *s* and the temperature increase is roughly 1.2°C.

Some of the calcium floats, despite its density, because of the rapid evolution of hydrogen, hence some of the heat is lost to the air rather than to the water. To circumvent this problem during trialling some students designed a copper cage to ensure that the calcium remained submerged. If this is done a correction factor for the copper will be needed.

The accuracy of the experiment can be improved by using lagging and plotting cooling curves to find the theoretical maximum temperature rise.

Calculation

The experimental calculation is based on the energy change being related to the product of the mass of water x specific heat capacity of water x temperature rise.

Reference

1. J. G. Stark and H. G. Wallace, *Chemistry data book*. London: John Murray, 1982.

Acknowledgement

This activity is based on a problem written by Joe Burns.

Credits

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