Topic 15: Energetics/thermochemistry

7 hours

Essential idea: The concept of the energy change in a single step reaction being equivalent to the summation of smaller steps can be applied to changes involving ionic compounds.

15.1 Energy cycles

Nature of science:

Making quantitative measurements with replicates to ensure reliability—energy cycles allow for the calculation of values that cannot be determined directly. (3.2)

Understandings:

- Representative equations (eg $M^+(g) \rightarrow M^+(aq)$) can be used for enthalpy/energy of hydration, ionization, atomization, electron affinity, lattice, covalent bond and solution.
- Enthalpy of solution, hydration enthalpy and lattice enthalpy are related in an energy cycle.

Applications and skills:

- Construction of Born-Haber cycles for group 1 and 2 oxides and chlorides.
- Construction of energy cycles from hydration, lattice and solution enthalpy. For example dissolution of solid NaOH or NH_4Cl in water.
- Calculation of enthalpy changes from Born-Haber or dissolution energy cycles.
- Relate size and charge of ions to lattice and hydration enthalpies.
- Perform lab experiments which could include single replacement reactions in aqueous solutions.

Guidance:

- Polarizing effect of some ions producing covalent character in some largely ionic substances will not be assessed.
- The following enthalpy/energy terms should be covered: ionization, atomization, electron affinity, lattice, covalent bond, hydration and solution.
- Value for lattice enthalpies (section 18), enthalpies of aqueous solutions (section 19) and enthalpies of hydration (section 20) are given in the data booklet.

International-mindedness:

- The importance of being able to obtain measurements of something which cannot be measured directly is significant everywhere. Borehole temperatures, snow cover depth, glacier recession, rates of evaporation and precipitation cycles are among some indirect indicators of global warming. Why is it important for countries to collaborate to combat global problems like global warming?

Utilization:

- Other energy cycles—carbon cycle, the Krebs cycle and electron transfer in biology.

Syllabus and cross-curricular links:
Topics 1.2 and 1.3—stoichiometric relationships
Topic 3.2—ionization energy, atomic and ionic radii
Topic 5.3—bond enthalpy

Aims:

- **Aim 4**: Discuss the source of accepted values and use this idea to critique experiments.
- **Aim 6**: A possible experiment is to calculate either the enthalpy of crystallization of water or the heat capacity of water when a cube of ice is added to hot water.
- **Aim 7**: Use of data loggers to record temperature changes. Use of databases to source accepted values.

Essential idea: A reaction is spontaneous if the overall transformation leads to an increase in total entropy (system plus surroundings). The direction of spontaneous change always increases the total entropy of the universe at the expense of energy available to do useful work. This is known as the second law of thermodynamics.

15.2 Entropy and spontaneity

Nature of science:

Theories can be superseded—the idea of entropy has evolved through the years as a result of developments in statistics and probability. (2.2)

Understandings:

- Entropy (*S*) refers to the distribution of available energy among the particles. The more ways the energy can be distributed the higher the entropy.
- Gibbs free energy (*G*) relates the energy that can be obtained from a chemical reaction to the change in enthalpy (*ΔH*), change in entropy (*ΔS*), and absolute temperature (*T*).
- Entropy of gas>liquid>solid under same conditions.

Applications and skills:

- Prediction of whether a change will result in an increase or decrease in entropy by considering the states of the reactants and products.
- Calculation of entropy changes (*ΔS*) from given standard entropy values (*S°*).
- Application of $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ in predicting spontaneity and calculation of various conditions of enthalpy and temperature that will affect this.
- Relation of *ΔG* to position of equilibrium.

Guidance:

- Examine various reaction conditions that affect *ΔG*.
- *ΔG* is a convenient way to take into account both the direct entropy change resulting from the transformation of the chemicals, and the indirect entropy change of the surroundings as a result of the gain/loss of heat energy.
- Thermodynamic data is given in section 12 of the data booklet.

International-mindedness:

- Sustainable energy is a UN initiative with a goal of doubling of global sustainable energy resources by 2030.

Theory of knowledge:

- Entropy is a technical term which has a precise meaning. How important are such technical terms in different areas of knowledge?

Utilization:

Syllabus and cross-curricular links:
Topic 5.2—Hess's Law
Topic 5.3—bond enthalpy
Topic 7.1—equilibrium
Option C.1—quality of energy
Physics option B.2—thermodynamics

Aims:

- **Aims 1**, **4** and **7**: Use of databases to research hypothetical reactions capable of generating free energy.
- **Aim 6**: Experiments investigating endothermic and exothermic processes could be run numerous times to compare reliability of repetitive data and compare to theoretical values.