

Topic 3: Thermal physics

11 hours

Essential idea: Thermal physics deftly demonstrates the links between the macroscopic measurements essential to many scientific models with the microscopic properties that underlie these models.

3.1 – Thermal concepts

Nature of science:

Evidence through experimentation: Scientists from the 17th and 18th centuries were working without the knowledge of atomic structure and sometimes developed theories that were later found to be incorrect, such as phlogiston and perpetual motion capabilities. Our current understanding relies on statistical mechanics providing a basis for our use and understanding of energy transfer in science. (1.8)

Understandings:

- Molecular theory of solids, liquids and gases
- Temperature and absolute temperature
- Internal energy
- Specific heat capacity
- Phase change
- Specific latent heat

Applications and skills:

- Describing temperature change in terms of internal energy
- Using Kelvin and Celsius temperature scales and converting between them
- Applying the calorimetric techniques of specific heat capacity or specific latent heat experimentally
- Describing phase change in terms of molecular behaviour
- Sketching and interpreting phase change graphs
- Calculating energy changes involving specific heat capacity and specific latent heat of fusion and vaporization

International-mindedness:

- The topic of thermal physics is a good example of the use of international systems of measurement that allow scientists to collaborate effectively

Theory of knowledge:

- Observation through sense perception plays a key role in making measurements. Does sense perception play different roles in different areas of knowledge?

Utilization:

- Pressure gauges, barometers and manometers are a good way to present aspects of this sub-topic
- Higher level students, especially those studying option B, can be shown links to thermodynamics (see *Physics* topic 9 and option sub-topic B.4)
- Particulate nature of matter (see *Chemistry* sub-topic 1.3) and measuring energy changes (see *Chemistry* sub-topic 5.1)
- Water (see *Biology* sub-topic 2.2)

3.1 – Thermal concepts

Guidance:

- Internal energy is taken to be the total intermolecular potential energy + the total random kinetic energy of the molecules
- Phase change graphs may have axes of temperature versus time or temperature versus energy
- The effects of cooling should be understood qualitatively but cooling correction calculations are not required

Data booklet reference:

- $Q = mc\Delta T$
- $Q = mL$

Aims:

- **Aim 3:** an understanding of thermal concepts is a fundamental aspect of many areas of science
- **Aim 6:** experiments could include (but are not limited to): transfer of energy due to temperature difference; calorimetric investigations; energy involved in phase changes

Essential idea: The properties of ideal gases allow scientists to make predictions of the behaviour of real gases.

3.2 – Modelling a gas

Nature of science:

Collaboration: Scientists in the 19th century made valuable progress on the modern theories that form the basis of thermodynamics, making important links with other sciences, especially chemistry. The scientific method was in evidence with contrasting but complementary statements of some laws derived by different scientists. Empirical and theoretical thinking both have their place in science and this is evident in the comparison between the unattainable ideal gas and real gases. (4.1)

Understandings:

- Pressure
- Equation of state for an ideal gas
- Kinetic model of an ideal gas
- Mole, molar mass and the Avogadro constant
- Differences between real and ideal gases

Applications and skills:

- Solving problems using the equation of state for an ideal gas and gas laws
- Sketching and interpreting changes of state of an ideal gas on pressure–volume, pressure–temperature and volume–temperature diagrams
- Investigating at least one gas law experimentally

Guidance:

- Students should be aware of the assumptions that underpin the molecular kinetic theory of ideal gases
- Gas laws are limited to constant volume, constant temperature, constant pressure and the ideal gas law
- Students should understand that a real gas approximates to an ideal gas at conditions of low pressure, moderate temperature and low density

Theory of knowledge:

- When does modelling of “ideal” situations become “good enough” to count as knowledge?

Utilization:

- Transport of gases in liquid form or at high pressures/densities is common practice across the globe. Behaviour of real gases under extreme conditions needs to be carefully considered in these situations.
- Consideration of thermodynamic processes is essential to many areas of chemistry (see *Chemistry* sub-topic 1.3)
- Respiration processes (see *Biology* sub-topic D.6)

Aims:

- **Aim 3:** this is a good topic to make comparisons between empirical and theoretical thinking in science
- **Aim 6:** experiments could include (but are not limited to): verification of gas laws; calculation of the Avogadro constant; virtual investigation of gas law parameters not possible within a school laboratory setting

3.2 – Modelling a gas

Data booklet reference:

- $p = \frac{F}{A}$
- $n = \frac{N}{N_A}$
- $pV = nRT$
- $\bar{E}_k = \frac{3}{2} k_B T = \frac{3}{2} \frac{R}{N_A} T$