NATURE OF HEAT
OBJECTIVES

• Differentiate between the caloric and kinetic theories of heat as they existed in the eighteenth century.

• Discuss the role of Joule’s experiments in establishing the principle of conservation of energy.
CALORIC THEORY

• The caloric theory of heat is an obsolete theory from the 18th century.
  • Heat was believed to be an invisible fluid called ‘caloric’, which could combine with matter and raise its temperature.
ARGUMENTS FOR THE CALORIC THEORY

1. Objects expand when heated because the increased ‘caloric’ they contain causes them to occupy more space.

2. Heat flows from hotter to cooler bodies because ‘caloric’ particles repel each other.
ARGUMENTS AGAINST THE CALORIC THEORY

1. When bodies are heated so that they change state (solid to liquid or liquid to gas), an increase in ‘caloric’ cannot be detected.

2. When different materials are given the same amount of heat (‘caloric’), their temperatures increase by different amounts, indicating that they receive different quantities of ‘caloric’.

3. The weight of a body should increase as it is heated, because it should then contain more ‘caloric’. However, the weight remains the same.
RUMFORD’S CANNON-BORING EXPERIMENT AS EVIDENCE AGAINST CALORIC THEORY

• Count Rumford was an army officer responsible for the boring of cannons during the late 18th century.

• He realised that the heat energy transferred when a cannon was being bored was inexhaustible and depended only on the work done in boring the hole.

• The ‘caloric’ theory was therefore not possible; if ‘caloric’ was a material substance, there would be a time when all of it had left the cannon.
KINETIC THEORY

• The kinetic theory of matter states the following.
  • The particles of matter (atoms, molecules) are in constant motion. The kinetic energy they possess is responsible for their temperature, or hotness.
  • There is space between particles. Forces (bonds) pull them together when they are near to each other, and so the particles have potential energy.
  • When a substance is heated, the heat energy supplied could result in an increase in the kinetic energy of the particles of the substance, and hence in its thermal energy, causing the temperature to rise.
  • When a substance is heated so that it changes state, the heat energy supplied results in an increase in the spacing of the particles and hence an increase in their potential energy, allow them to break bonds with their neighbours and to expand against any surrounding pressure.
JOULE'S EXPERIMENT

• In the 1840s James Joule carried out experiments to determine the amount of work required to raise the temperature of a fixed mass of water by 1°C.
JOULE’S EXPERIMENT (cont’d)

• He determined that:
  • the gravitational potential energy of falling weights was converted into thermal energy ($E_H$)
  • $E_H$ was related to the change in the temperature of the water ($\Delta \theta$) by the relationship: $E_H = mc\Delta \theta$

  where $m$ is the mass of the water used and $c$ is a constant known as the specific heat capacity of the water.

• Joule found that 4.2 kJ of work raised the temperature of 1 kg of water by 1°C.

• He also measured, experimentally, the quantity of heat produced when electric currents flowed through conductors (resistors).
JOULE’S EXPERIMENT (cont’d)

• The total energy was constant in all systems that Joule investigated.
  • The quantity of energy ‘lost’ as work or electricity ‘reappeared’ as heat.

• Joule’s experiment established:
  • heat as a form of energy
  • the importance of the principle of the conservation of energy