Thermodynamics Lesson 3: Equilibrium Calculations and Efficiency

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Outline

Recap: Quantifying Heat

Quick Quiz: Match the scenario to the formula!

- Heating 1kg water from 20°C to 80°C $\implies$ Use ____________ [N3]
- Melting 0.5kg ice at 0°C $\implies$ Use ____________ [N5]
- Cooling 2kg steam at 120°C to 110°C $\implies$ Use ____________ [N3]
- Boiling 0.2kg water at 100°C $\implies$ Use ____________ [N5]

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Answers: $Q{=}mc\Delta T$, $Q{=}mL_f$, $Q{=}mc\Delta T$, $Q{=}mL_v$ Today: Combining

these when things mix and reach equilibrium.

Principle of Thermal Equilibrium Problems

Scenario: Mix hot and cold substances in an *isolated* system (no heat loss to surroundings). **Principle (Conservation of Energy):**

- Heat energy flows from hotter object(s) to colder object(s).
- Flow stops when thermal equilibrium (same final temperature T_f) is reached.
- Total heat energy **lost** by hot objects = Total heat energy **gained** by cold objects.

$$\sum Q_{lost} = \sum Q_{gained}$$

Each 'Q' term could involve $mc\Delta T$ or mL depending on temperature changes and phase changes.

Guided Example: Hot Metal in Cold Water

(Refer to Worksheet 3, Part 1 for step-by-step guidance) **Problem:** 50g

Copper ($c_{Cu} = 385$) at 90°C dropped into 100g Water ($c_w = 4186$) at 15°C. Find final temp (T_f). **Setup:**

- Identify Hot (Cu) / Cold (Water).
- $Q_{lost,Cu} = Q_{gained,w}$
- $(mc\Delta T)_{Cu} = (mc\Delta T)_w$
- $m_{Cu}c_{Cu}(T_{i,Cu} - T_f) = m_w c_w(T_f - T_{i,w})$

Key Steps (Teacher demonstrates on board):

1. Substitute values (ensure mass in kg if needed, though g cancels if consistent).
2. Expand brackets carefully.
3. Group T_f terms on one side.
4. Solve for T_f.

[Numeracy focus: Algebraic manipulation]

Introduction to Thermal Efficiency

Energy Transformations (Inquiry Q2): Energy is conserved, but changes form. **Think about a Car Engine:**

- **Energy Input:** Chemical Energy in Fuel
- **Useful Energy Output:** Kinetic Energy (Motion)
- **Wasted Energy Output:** Heat (Exhaust, Friction, Engine Block heating -> lost via Conduction/Convection/Radiation [N4 link])

Thermal Efficiency (Qualitative Definition):

$$\text{Efficiency} = \frac{\text{Useful Energy Output}}{\text{Total Energy Input}}$$

- Always less than 1 (or 100%). Why? Some energy is always "lost" as less useful thermal energy during transformations (related to the 2nd Law of Thermodynamics).
- **Relevance (Inquiry Q3):** Understanding losses helps improve efficiency (e.g., insulation, better engine design) $\implies$ Sustainability.

Applying Equilibrium Principles

Now, try the problems in Worksheet 3, Part 2.

- Work individually or in pairs.
- Problem 1: Similar to guided example (metal in water).
- Problem 2: Challenge involving phase change (melting ice). Remember to include $Q = mL_f$ for the ice melting!

Connecting back to Inquiry Questions:

- Q1 (Temp/Energy/Motion): Underpins all calculations.
- Q2 (Transformation/Laws): Efficiency shows energy changes form, conservation applies.
- Q3 (Direction/Efficiency): Equilibrium determines direction, efficiency measures usefulness.

Lesson 3 Summary

- Thermal equilibrium problems are solved using Conservation of Energy: $\sum Q_{lost} = \sum Q_{gained}$ [N2 Apply].
- These problems combine specific heat ($mc\Delta T$) [N3] and potentially latent heat (mL) [N5] calculations.
- Thermal efficiency describes how effectively input energy is converted to useful output energy [Inquiry Q3].
- Understanding heat transfer mechanisms [N4] is key to understanding energy losses and efficiency.

Final Steps:

- Complete Worksheet 3 Practice Problems.
- Complete #MarkSense Quiz 3.
- Review all concepts from the 3 lessons.

Thank you!

End of Thermodynamics Introduction. Questions?