LESSON MAKER PRO

Mixing Temperature Evidence

Use mass and temperature data to predict thermal equilibrium.

HIGH SCHOOL · HS-PS3-4

HS-PS3-4 "Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components..."

NAME _____ **DATE** _____

ENERGY BALANCES OUT

When samples of the same substance combine in an insulated container, thermal energy moves from warmer material to cooler material until they reach one final temperature. Find that temperature with Tf = (m1 x T1 + m2 x T2)/(m1 + m2), assuming no energy leaves the system. This ideal calculation also neglects energy absorbed by the container, assumes approximately equal constant specific heat for both water samples and no phase change. A closed system exchanges no matter; insulation reduces, but does not guarantee zero, energy exchange.

WORKED EXAMPLE

Combine 16 g of water at 11 C with 24 g of water at 31 C. Find Tf.

1. Tf = (16 x 11 + 24 x 31)/(16 + 24)
2. Tf = 920/40
3. Tf = 23 C

Answer: 23 C

PRACTICE 5 problems

1 Equal masses of water at 20 C and 36 C are combined. Find Tf.

ANSWER _____

2 Combine 10 g of water at 18 C with 30 g of water at 38 C. Find Tf.

ANSWER _____

3 Combine 25 g of water at 52 C with 25 g of water at 20 C. Find Tf.

ANSWER _____

4 Combine 30 g of water at 15 C with 10 g of water at 45 C. Find Tf.

ANSWER _____

5 Combine 28 g of water at 48 C with 28 g of water at 32 C. How many degrees does each sample change?

ANSWER _____

APPLY IT Show your work

1 For a sports drink test, a student mixes 200 g of cold water at 10 C with 100 g of warm water at 40 C in an insulated cup. Predict the final temperature.

WORK SPACE

ANSWER _____

2 A robotics team tests a cooling loop by combining 150 g of water at 60 C with 50 g of water at 20 C in an insulated container. A sensor reads 50 C. Is the reading consistent with the calculation?

WORK SPACE

ANSWER _____

CHALLENGE One step up

Three water samples are combined in an insulated container: 10 g at 12 C, 20 g at 27 C, and 30 g at 42 C. Find Tf, then state which samples transfer thermal energy. Then plan and conduct a real two-sample investigation with teacher-provided warm water below 45 °C, room-temperature water, a balance, two thermometers, timer, stirrer and an insulated cup with a fitted lid and probe openings. Write your safe procedure and prediction first. Measure each sample's mass and initial temperature. Combine them promptly, fit the lid and stir gently. Record temperature at two positions every 15 seconds for one minute; keep probes away from the cup wall. Repeat with fresh samples. On separate paper, tabulate both trials, compute ideal final temperatures from your measured inputs, and compare predictions with readings and the initial/final temperature differences. Explain the direction of energy transfer and whether the readings support a more uniform distribution, noting measurement resolution and heat exchange with the cup or room. If the two positions agree within thermometer resolution, use their mean as Tf and estimate each original sample's energy change: $Q = m \times 4.18 \times (Tf - Ti)$ J, with m in grams and temperatures in °C. Compare the two Q values; if temperatures have not stabilized, report that limitation.

WORK SPACE AND ANSWER

ANSWER KEY

Mixing Temperature Evidence

PART 1 · PRACTICE

#	PROBLEM	ANSWER
1	Equal masses of water at 20 C and 36 C are combined. Find Tf.	**28 C**
2	Combine 10 g of water at 18 C with 30 g of water at 38 C. Find Tf.	**33 C**
3	Combine 25 g of water at 52 C with 25 g of water at 20 C. Find Tf.	**36 C**
4	Combine 30 g of water at 15 C with 10 g of water at 45 C. Find Tf.	**22.5 C**
5	Combine 28 g of water at 48 C with 28 g of water at 32 C. How many degrees does each sample change?	**The warmer water cools 8 C, and the cooler water warms 8 C.**

PART 2 · APPLY IT

1. **20 C** Tf = (200 x 10 + 100 x 40)/(200 + 100) = 6000/300 = 20 C.
2. **Yes. The predicted final temperature is 50 C.** Tf = (150 x 60 + 50 x 20)/(150 + 50) = 10000/200 = 50 C. The measured value matches the prediction.

CHALLENGE

Tf = 32 C. The 42 C water transfers thermal energy to the 12 C and 27 C water. Actual investigation results must come from the learner's two trials. Predict each final value with the measured masses and initial temperatures. The two final positions should approach a common intermediate temperature in a well-mixed setup; record differences honestly rather than force equality. Warmer water loses internal energy as cooler water gains it, tending toward a uniform temperature. Cup heating and heat exchange with the room can shift the value from the ideal prediction. For the real experiment, Q is positive for the initially cooler sample and negative for the warmer one if Tf lies between their initial temperatures. Their sum is approximately zero only when cup/room energy exchange is negligible; use recorded data and stated measurement limits.

Accept equivalent calculations and 22.5 C as 22 1/2 C. For explanations, accept wording that correctly identifies energy moving from warmer water to cooler water until the temperatures become uniform. Require a plan, completed supported experiment, two actual data tables and quantitative/conceptual conclusions. Keep water below 45 °C and let the teacher prepare it. The fitted lid limits matter exchange after combination; the real apparatus only approximates an isolated energy system. Equal temperature does not mean unequal masses contain equal total internal energy. Compare position readings within thermometer resolution; an unexplained discrepancy is evidence to investigate, not permission to replace a measurement with the calculated result.