BID: Heat Capacity (Specific Heat)

The Big Ideas

1) Some substances require more heat to raise their temperature than other substances.
2) When in contact, heat flows from hotter stuff to cooler stuff until they reach the same temperature.

More details

Remember: temperature is just a measure of the kinetic energy of a substance (how fast the molecules are moving). If the molecules in one substance really like to hang on to each other (strong intermolecular forces - like hydrogen bonds), then it will be harder to get those molecules to move faster and go up in temperature (ie more heat will be requuired). Ex: Copper has a specific heat of 0.386 J/g ·°C. It takes 0.386 J to raise the temp of 1 g of copper 1 °C. Water has a ***much*** higher heat capacity: 4.186 J/g ·°C.

How to recognize it

Three common variants: 1) Problem gives amount of substance and its specific heat. You are then given either the heat added or the change in temp and asked to find the other. 2) Problem gives amounts of two substances (and one of their specific heats) at two diff temps, their final temp after being put in contact with each other, and asks for the specific heat of the other substance. 3) Problem gives amounts of two substances (and their specific heats) at two different temps put in contact with each other, and asks for the final temp.

How to tackle it

1) Basically just "plug and chug". Use the formula $Q = mc\Delta T$. c = specific heat, Q = heat
2) Set the energy lost by one substance equal to the energy gained by the other substance:
   $m_1 c_1 \Delta T_1 = m_2 c_2 \Delta T_2$ and then solve for the unknown "c" (specific heat).
3) Similar to #2, but use initial temp - final temp for the hotter substance (energy lost) instead of ΔT, and use final temp - initial temp (energy gained) for the cooler substance.

Pitfalls to watch for

1) Specific heats can be given for molar amounts ***or*** gram amounts. Be sure to watch units!
2) Formula is not listed on AP sheet. Use units from specific heat to put together equation.

Example problems

1) *15.0 g of a metal with an initial temperature of 340. °C is immersed in 250.0 g of water at an initial temperature of 25.0 °C. The final temperature of the mixture is 30.2 °C. What is the specific heat of the unknown metal?*

Solution:

$m_1 c_1 \Delta T_1 = m_2 c_2 \Delta T_2$

$250.0\ g \cdot 4.186\ J/g{\cdot}K \cdot 5.2\ K = 15.0\ g \cdot c_2 \cdot 219.8\ K$

$c = \dfrac{250.0\ g \cdot 4.186\ J/(g{\cdot}K) \cdot 5.2\ K}{15.0\ g \cdot 219.8\ K}$ 1.65 J/g·K 1.650530786 J/g·K =

2) *40.0 g of copper at an initial temperature of 350. °C is immersed in 200.0 g of water at an initial temperature of 20.0 °C. What is the final temperature of the water? (specific heats listed above)*

Solution:

$Q_{lost\ by\ hotter} = Q_{gained\ by\ cooler}$

$m_1 c_1 (T_i - T_f) = m_2 c_2 (T_f - T_i)$

$15.0\ g \cdot 0.386\ J/g{\cdot}°C \cdot (250\ °C - T_f) = 200.0\ g \cdot 4.186\ J/g{\cdot}°C \cdot (T_f - 20.0\ °C)$

$1447.5\ J - (5.79\ J/°C) \cdot T_f = (837.2\ J/°C) \cdot T_f - 16{,}744\ J$

$18191.5\ J = (842.99\ J/°C) \cdot T_f$

$T_f = 21.57973404\ °C = \boxed{21.58\ °C}$