SPECIFIC HEAT CAPACITY - takes different amts of heat to heat-up diff materials

$$Q = c\,m\,(T_f - T_i)$$

Heat

Q = heat transferred
T_f = final temp
T_i = initial temp

c = specific heat capacity
or
specific heat $\quad J\,kg^{-1}\,K^{-1}$
$cal\,g^{-1}\,{}^\circ C^{-1}$
$BTU\,lb^{-1}\,{}^\circ F^{-1}$

n.b. $T_f > T_i \Rightarrow$ heat is added to system
HEAT IN IS POSITIVE

$T_f < T_i \Rightarrow$ heat leaves system
HEAT OUT IS NEGATIVE

e.g. How much does the drop of Niagra Falls raise the temperature of the water ($h = 162ft$)

$$PE = mgh \rightarrow KE \left(\tfrac{1}{2}mv^2\right) \rightarrow Q \text{ (splash)}$$

$$Q = c\,m\,\Delta T$$

$$mgh = cm\,\Delta T$$

$$\Delta T = \frac{gh}{c} = \frac{9.8\,m\,s^{-2} \cdot 50\,m}{4186\,J\,kg^{-1}\,K^{-1}}$$

$$= 0.12\,K \;(0.22^\circ F)$$

Some Specific Heats

H_2O	4.186 $kJ\,kg^{-1}K^{-1}$	1.000 $c\,g^{-1}\,°c^{-1}$ ($C\,kg^{-1}\,°c^{-1}$)
Human	3.5	0.8
Ice	2.1	0.5
Air (O_2+N_2)	1.0	0.24
H_2	14.2	3.4
Iron	0.47	0.11
Lead	0.13	0.03
Wood	1.8	0.42

Isn't it interesting that these gasses have such different specific heats. Can you use kinetic theory to demonstrate that H_2 ($m = 2$ g/mole) would have a specific heat 14x greater than air ($m \approx 28.4$ g/mole)

If we perform the mixing expt with different materials, the resulting temperature depends upon the materials

H_2O (m = 18) $c = 4186\ J/kg \cdot K$ or $1\ cal/g \cdot {}^\circ C$

C_2H_5OH (46) $c = 2400$ ~~0.47~~ 0.47

Take 1g alcohol at 5°C, 1g water at 95°C

$$Q_{in}(C_2H_5OH) = Q_{out}(H_2O)$$

$$c_{C_2H_5OH}\, m_1 \Delta T_1 = c_{H_2O}\, m_2 \Delta T_2$$

since $m_1 = m_2$

$$c_{C_2H_5OH}(T_f - 5^\circ) = c_{H_2O}(95 - T_f)$$

Solving for T_f

$$(c_{C_2H_5OH} + c_{H_2O})T_f = 95^\circ \cdot c_{H_2O} + 5^\circ c_{C_2H_5OH}$$

$$T_f = \frac{95^\circ c_{H_2O} + 5^\circ c_{C_2H_5OH}}{c_{H_2O} + c_{C_2H_5OH}}$$

$$= \frac{95^\circ \cdot 1 + 5^\circ \cdot 0.47}{1.47}$$

$$= 66.2\ {}^\circ C$$

$\frac{Q}{m} = 28.8\ cal/gm$ $\quad 120\ J/gm$

$1.2 \times 10^5\ J/kg$

Consider 1 kg of air and 1 kg of H_2
It takes 1000 J to raise the temperature of air 1 K, while it takes 14,200 J to raise the temperature of H 1K - how do we understand that - in the case of ideal gases it is relatively simple:

1 kg = 1000 g contains 500 moles of H_2

$$N_{H_2} = 500 \times 6.02 \times 10^{23} \approx 3 \times 10^{26} \text{ molecules}$$

whereas 1 kg contains 28 moles of N_2
and 6.25 moles of O_2

$$N_{O_2+N_2} = 2.1 \times 10^{25} \text{ molecules}$$

Because Temperature is the mean energy per molecule, the fact that there are 14x more H_2 molecules in a kg accounts for the difference in specific heat.
Sometimes the SPECIFIC HEAT per MOLE or MOLAR SPECIFIC HEAT IS USED TO avoid this

HOW SPECIFIC HEAT WORKS

Recall our result from kinetic theory

$$\langle KE \rangle = \frac{3}{2} k_B T$$