HEAT

ENERGY

- **Definition:** Energy is the ability to do work.
- Examples:
  - Light
  - Sound
  - Mechanical energy
  - Heat
  - Electricity
  - Nuclear energy
  - Chemical energy

Types:

Kinetic

Potential

TYPES OF ENERGY

WRITE DOWN

- Kinetic energy is the energy of motion.
- Potential energy is stored energy.
  - atomic energy - energy stored in the nucleus of an atom [$E = mc^2$]
  - chemical energy - energy stored in chemical bonds
- Heat is kinetic energy. What is moving?

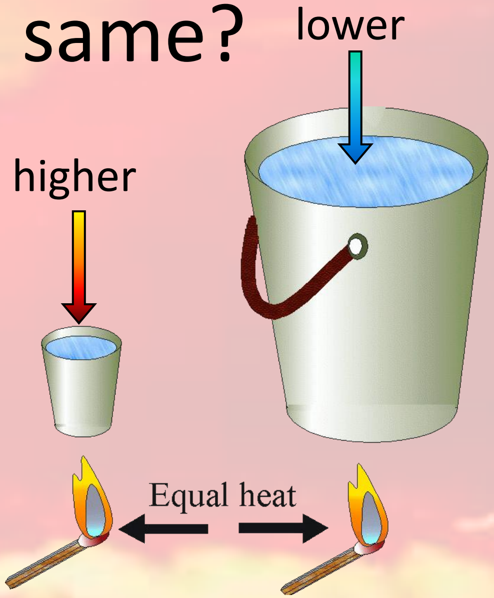
WRITE DOWN

Heat is the energy of moving molecules.

- When something heats up, the molecules move faster.

TEMPERATURE vs. HEAT

- Are heat and temperature the same?
- Imagine a glass of water and a pail of water each absorb the same amount of heat.
- Which has the higher temperature? (or are they the same?)



WHY?

AN ANALOGY

You win the lottery and convert it to $1 bills.

Scenario 1

- You win $1,000,000.
- You stand in the center of a room of 1,000 people and toss the bills in the air.
- There is a mad scramble for the money.

How much do people get? $1,000

Scenario 2

- You win $100,000.
- You stand in the center of a room of 20 people and toss the bills in the air.
- There is a mad scramble for the money.

How much do people get?$5,000

- Heat and temperature work like money.
- No matter how much heat you have, the more molecules that share it, the lower the average.

DEFINITIONS

- ***Heat*** is the total kinetic energy of moving molecules.
- ***Temperature*** is the average kinetic energy of moving molecules.
- Which has more heat, a cup of water at 99°C or the Atlantic Ocean at 10°C?

The total is higher here.

The average is higher here.

THE RELATIONSHIP

- As heat is added to a substance, the temperature increases.
  - Heat and temperature are directly proportional.
- As the mass of the substance being heated increases, the temperature change becomes smaller.
  - Mass and temperature are indirectly proportional.
- This relationship can be expressed mathematically.

THE EQUATION

- Heat is proportional to the product of the mass and the temperature change.
- The equation is not an equality.
  - joules ≠ g × °C (It can't be equal! Look at the units!!)
- How can we get an equality? (We need one to do calculations!)

$q \propto m \times \Delta T$

q = heat (joules or calories)

m = mass (g)

ΔT = temperature change (K *or* °C)

∝ = proportional to

THE EQUALITY PROBLEM

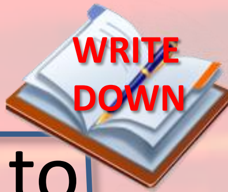
- On December 1, 2007, a 3.3 lb white truffle was sold at auction for $330,000.

- This means a 1lb chunk of the fungus would fetch $100,000. Still, since the units are different, . . .
  - 1 lb ≠ $100,000,
  - and 3.3 lb ≠ $330,000,
  - but they are proportional.
- The price per pound, $\frac{\$100{,}000}{1\text{ lb}}$, is a constant that turns this proportionality into an equality.

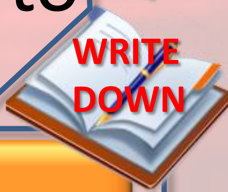
$$\$330{,}000 = 3.3\text{ lb} \times \frac{\$100{,}000}{1\text{ lb}}$$

$$\$100{,}000 = 1\text{ lb} \times \frac{\$100{,}000}{1\text{ lb}}$$

SPECIFIC HEAT CAPACITY



- ***Specific heat*** is the amount of heat needed to raise the temperature of 1 gram of a substance by 1°C.



- Specific heat is the constant that turns the relationship $q \propto m \times \Delta T$ into an equality.

$$q = m \times C \times \Delta T$$

q = heat (joules or calories)

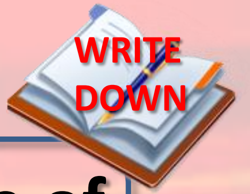
m = mass (g)

ΔT = temperature change (K *or* °C)

C = specific heat capacity ($^{J}/_{g°C}$ or $^{cal}/_{g°C}$)

- Many heat problems are based on water. The specific heat of water is 4.18 $^{J}/_{g°C}$ or 1 $^{cal}/_{g°C}$

SAMPLE PROBLEM 1



How much heat is needed to raise the temperature of 500. g of water by 15°C?

- **Step1:** List the known variables
  - $m = 500.\ g$
  - $C = 4.18\ ^{J}/_{g°C}$
  - $\Delta T = 15°C$
- **Step 2:** Determine the product
  - $q = mC\Delta T$
  - $q = (500.\ \cancel{g})(4.18\ ^{J}/_{\cancel{g°C}})(15\cancel{°C})$
  - $q = 31{,}350\ J \approx 31{,}000\ J$

SAMPLE PROBLEM 2

WRITE DOWN

How much heat is needed to raise the temperature of 25 g of water from 27°C to 47°C?

(In this problem, the initial temperature [T_i] and the final temperature [T_f] are given instead of the temperature change [ΔT].)

- **Step 1:** Determine ΔT ($\Delta T = T_f - T_i$)
  - ΔT = 47°C − 27°C = 20.°C
- **Step 2:** List the known variables
  - m = 25 g
  - C = 4.18 $^{J}/_{g°C}$
  - ΔT = 20.°C
- **Step 3:** Determine the product
  - q = mCΔT
  - q = (25 g)(4.18 $^{J}/_{g°C}$)(20.°C)
  - q = 2090 J ≈ 2100 J

SAMPLE PROBLEM 3

What is the final temperature when 84 joules of heat are added to 2.0 gram of water at 15°C?

(In this problem, the amount of heat [q] and the initial temperature [T_i] are given. The final temperature [T_f] and the temperature change [ΔT] are the unknowns.)

- **Step 1:** List the known variables
  - $q = 84$ J
  - $m = 2.0$ g
  - $C = 4.18\ ^{J}/_{g°C}$
  - $T_i = 15°C$
- **Step 2:** Determine ΔT ($q = mC\Delta T$)
  - $84\ J = (2.0\ g)(4.18\ ^{J}/_{g°C})(\Delta T)$
  - $\Delta T = 10.05°C \approx 10°C$
- **Step 3:** Determine T_f ($\Delta T = T_f - T_i$)
  - $10°C = T_f - 15°C$
  - $T_f = 25°C$

Other Specific Heats

- Consider two frying pans, one with a metal handle, and the other with a wood handle:
- Which one is more comfortable to handle with the bare hands after it has been on a hot flame? The wood handle

- Why are they different?
- Wood has a higher specific heat than metal. Wood is more resistant to temperature change. The wood is cooler even though it absorbed as much heat as the metal.
- It is possible to do calculations with specific heats other than that of water ($4.18\ ^{J}/_{g^\circ C}$). It is also possible for specific heat to be the unknown.

Sample Problem 4

The specific heat of gold is 0.134 $^{J}/_{g°C}$. How many joules will it take to make the temperature of a 20.0 g nugget go up 10.0°C?

(In this problem, the specific heat of gold is used instead of the specific heat of water.)

- **Step 1:** List the known variables
  - m = 20.0 g
  - C = 0.134 $^{J}/_{g°C}$
  - ΔT = 10.0°C
- **Step 2:** Determine the product
  - q = mCΔT
  - q = (20.0 g)(0.134 $^{J}/_{g°C}$)(10.0°C)
  - q = 26.8 J

Sample Problem 5

WRITE DOWN

What is the specific heat of silicon if a 5.00 g sample is heated from 22.0°C to 42.0°C by adding 75.24 J?

(In this problem, the specific heat is the unknown.)

- **Step 1:** Determine ΔT ($\Delta T = T_f - T_i$)
  - ΔT = 42.0°C − 22.0°C = 20.0°C
- **Step 2:** List the known variables
  - q = 75.24 J
  - m = 5.00 g
  - ΔT = 20.0°C
- **Step 3:** Solve for the specific heat, C (q = mCΔT)
  - 75.24 J = (5.00 g)(C)(20.0°C)
  - $C = 0.752\ ^{J}/_{g°C}$