## Heat \& State Changes

Name: $\qquad$

Student ID: $\qquad$
"When the water starts boiling it is foolish to turn off the heat." - Nelson Mandela

Date: $\qquad$

## Energy and Temperature

Energy is measured in units of calories (cal) or Joules ( J ). The two are related by the equivalence $1 \mathrm{cal}=4.184 \mathrm{~J}$ (exactly). Temperature is measured in Kelvin and Celsius. Kelvin is the Celsius temperature plus the measurement $273.15{ }^{\circ} \mathrm{C}$.

1. Convert each of the following. (USE dimensionalanalysis)
a. What is 42.3 Joules ( J ) in calories (cal, thermal calories)?
b. What is 42.3 Joules $(\mathrm{J})$ in Calories (Cal, nutritional calories)?
2. What is $24.5^{\circ} \mathrm{C}$ in Kelvin (K)? (watch you significant figures)

## Change $\quad \Delta X=X_{\text {FINAL }}-X_{\text {InITIAL }}$

3. Calculate the change in each of the following. (HINT: START wITH THE CHANGE EQUATION)
a. I have 12.6 gallons of gas in my tank today, but had 8.80 gallons yesterday. What is the change in volume $(\Delta \mathrm{V})$ ?
b. A bottle of sauce weighs 275 grams today, but weighed 310.2 grams yesterday. What is the change in mass $(\Delta \mathrm{m})$ ?
c. My coffee measured $67^{\circ} \mathrm{C}$ before, but it measures $32.5^{\circ}$ now. What is the change in temperature $(\Delta T)$ ?

## Heat Capacity $\quad q=C \times \Delta T$

4. An oven mitt with a heat capacity (C) of $155 \mathrm{~J} /{ }^{\circ} \mathrm{C}$ looses 1.24 KJ of energy.
a. What is change in energy (q) of the oven mitt?
b. If the oven mitt starts at $24.5^{\circ} \mathrm{C}$ what is it's change in temperature?
c. What is the final temperature of the oven mitt?
5. An object with a heat capacity (C) of $203 \mathrm{~J} /{ }^{\circ} \mathrm{C}$ experiences a change in energy of $+23.3^{\circ} \mathrm{C}$.
a. What is the change in energy (q) of the object?
b. Was this process endothermic or exothermic?

Specific Heat Capacity $\quad C=C_{s} \times m ; q=C_{s} \times m \times \Delta T$
For a sample of a pure substance, the heat capacity $C$ is equal to the mass of that sample times an intensive property called the specific heat capacity $\left(\mathrm{C}_{s}\right)$. Sometimes we shorten this name and just say specific heat.
6. How much heat is required to heat a 15.2 g block of an unknown metal with a specific heat capacity of $0.942 \mathrm{~J} / \mathrm{g}^{\circ} \mathrm{C}$ from $21^{\circ} \mathrm{C}$ to $45^{\circ} \mathrm{C}$ ?
7. The specific heat capacity of benzene is $1.74 \mathrm{~J} /\left(\mathrm{g}^{\circ} \mathrm{C}\right)$. If 16.7 kJ of energy is absorbed by a 225 g sample of benzene at $22.0^{\circ} \mathrm{C}$, what is its final temperature?

## Changes in State $\quad q=m \times \Delta H$

At critical temperatures, heat doesn't change the temperature of a substance - it causes an amount of it to change state. To melt, boil, freeze or otherwise go from one state of matter to another. The mass ( m ) of the substance that goes from solid to liquid is related to the change in thermal energy (q) by the heat of fusion for that material $\left(\Delta H_{\text {FUs }}\right)$, the mass that goes from a liquid to gas is related by the heat of vaporization( $\Delta H_{\text {vap }}$ ).
8. If a block of ice at exactly $0^{\circ} \mathrm{C}$ (the melting point of water) absorbs 535 J of heat, how much of the that ice will melt? The heat of fusion of water ( $\Delta \mathrm{H}_{\mathrm{FUS}}$ ) is $+334 \mathrm{~J} / \mathrm{g}$.
9. How much heat do you need (in J) to boil 304 grams of water that is at $100^{\circ} \mathrm{C}$ (the boiling point of water). The heat of vaporization of water ( $\Delta \mathrm{H}_{\text {vap }}$ ) is $+2257 \mathrm{~J} / \mathrm{g}$.
10. Iron freezes at $2,862{ }^{\circ} \mathrm{C}$. How much heat do you have to pull out of 752 g of liquid iron at that temperature, to cause it to freeze? The heat of fusion ( $\Delta \mathrm{H}_{\text {FUS }}$ ) of iron is $+6090 \mathrm{~J} / \mathrm{g}$. The heat of freezing for iron would be equal, with an opposite sign $\left(\Delta H_{\text {FRZ }}=-6090 \mathrm{~J} / \mathrm{g}\right)$
11.If you took 50.0 grams of ice at $-25.0^{\circ} \mathrm{C}$ and turned it into liquid water at exactly $0{ }^{\circ} \mathrm{C}$, how much heat (q) would you have added to the water? The heat of fusion of water $\left(\Delta H_{\text {FUS }}\right)$ is $+334 \mathrm{~J} / \mathrm{g}$. The heat capacity of ice is $2.03 \mathrm{~J} / \mathrm{g}^{\circ} \mathrm{C}$. Solve this problem in parts.
a. Figure out how much heat you needed to add to warm the ice to it's critical temperature (exactly $0^{\circ} \mathrm{C}$, the melting point of water).
b. Figure out how much heat you needed to melt the ice at that critical temperature.
c. Decide how much total heat you needed to add to do the entire process.

