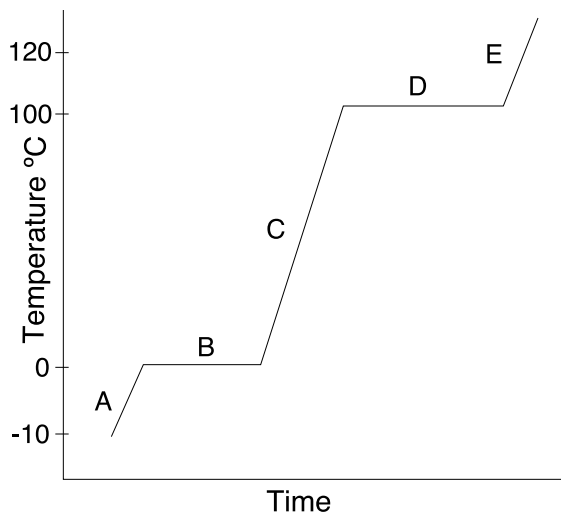


- The first part of thermochemistry is just about energy bookkeeping, keeping track of energy that goes into a system, out of a system, created by a system, etc.
- The first basic picture is just heating a substance up and having it go through phase changes. Heating up or cooling down a substance while it's all one phase (solid, liquid, or vapor) is called a **sensible heat process**. Phase changes are called **latent heat processes**. Latent heat processes require a lot more energy than sensible heat processes, and they occur at constant temperature.
- We'll start with a look at ice (water in the solid phase) and keep track of each part of the process as it is heated up, melted, heated up some more, and finally vaporized. q = heat, m = mass, S = specific heat.



- A:** Sensible Heat Process.
The ice is heated up to its melting point.
 $q_A = mS_{\text{ice}} \Delta T$
- B:** Latent heat process.
Melt all the ice at constant temperature.
 $q_B = n\Delta H_{\text{fusion}}$
- C:** Sensible Heat Process.
The water is heated up to its boiling point.
 $q_C = mS_{\text{water}} \Delta T$
- D:** Latent heat process.
Evaporate all the water at constant T.
 $q_D = n\Delta H_{\text{vaporization}}$
- E:** Sensible Heat Process.
The steam is heated up.
 $q_E = mS_{\text{steam}} \Delta T$

For the entire process: $q_{\text{total}} = q_A + q_B + q_C + q_D + q_E$

- Calorimetry** is an experimental way of measuring heat generation/consumption by essentially catching all the heat energy in a water bath or in a water bath + metal apparatus.

Coffee cup calorimeter—Styrofoam cup insulates the contents so any heat generated/consumed in the water within can be measured by the water's temperature change

$$q = -(\Delta H_{\text{rxn}}) = mS_{\text{H}_2\text{O}}\Delta T \quad \leftarrow \text{Mainly you just dissolve things in the water within the cup and look at temperature changes.}$$

Bomb-Calorimeter—Used to measure heats of reaction. It's a bomb because you set off little combustion reactions in it. The big difference is that its metal innards absorb heat, and you have to keep track of the heat absorbed by them as well as the heat absorbed by the water.

$$q = \underbrace{mS_{\text{H}_2\text{O}}\Delta T}_{\text{water}} + \underbrace{C_p\Delta T}_{\text{apparatus}} = C_{p\text{total}} \Delta T = -(\Delta H_{\text{rxn}})$$

(Sometimes the water+ innards are all grouped together and then $q = C_p\Delta T$. C_p is the heat capacity, when you use it you don't have to use the mass of the substance or object)

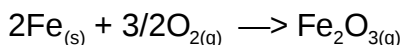
Be very careful with the sign of q ; it depends upon the point of view of the problem. See how if you raise the temperature of the water you will get a positive q , the water absorbs heat. But from the point of view of the reaction, heat was given off, which gives a negative q for the exothermic process.

Student Packet: 7.2: Calorimetry: AssessMe questions

- 1) "Heating an exothermic reaction which is near equilibrium will speed up the rate of reaction thereby forming more products."
- A) True, as the reaction is heated the rate constant increases producing a higher concentration of products.
B) Unclear, there will be a trade-off between reaction kinetics and the equilibrium point and it is impossible to predict the exact result.
C) False, heating will have no effect on an exothermic reaction.
D) False, although the reaction rate will increase, the equilibrium point will shift toward reactants decreasing the concentration of products.
E) I'm clueless
- 2) Consider the equilibrium reaction: $2\text{NO}_{2(g)} \rightarrow \text{N}_2\text{O}_{4(g)}$
increasing the net pressure of the reaction will
- A) favor product formation.
B) favor reactant formation.
C) not affect the equilibrium distribution of reactants and products.
D) cause the reaction to oscillate.
E) I'm clueless
- 3) In order to have a buffer system one must have a high concentration of
- A) an acid present.
B) a base present.
C) both an acid and its conjugate base.
D) none of the above.
E) I'm clueless
- 4) $\text{pK}_a = 2.12$ for the reaction: $\text{H}_3\text{PO}_4 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{PO}_4^- + \text{H}_2\text{O}^+$
Over what range of pH would this system offer reasonable buffering?
- A) 1 to 14 B) 1-7 C) 7-8 D) 1-3 E) I'm clueless
- 5) Which of the following choices is an example of a high melting, network solid consisting of covalently bonded atoms?
- A) sodium B) germanium C) neon D) quartz E) I'm clueless
- 6) Which of the following would have the lowest melting point?
- A) gold B) BaO C) Br₂ D) ice E) I'm clueless

Student Packet: 7.2: Calorimetry: ShowMe questions

- 1) A beaker contains a 100 g of solution with a specific heat of $3.0 \text{ J/}^\circ\text{C}\cdot\text{g}$. Assume that no heat is lost to the surroundings, what quantity of heat in joules is required to raise the solution from room temperature (25°C) to 30°C ?
- 2) Ten grams of $\text{Fe}_{(\text{s})}$ is added to 48 g of oxygen gas in a calorimeter whose heat capacity is $480 \text{ J}\cdot\text{K}^{-1}$. The temperature increase is 153 K. Calculate $\Delta H^\circ_{\text{rxn}}$ in kJ for the reaction:



- 3) Sucrose, $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ is combusted in a bomb calorimeter. A three gram sample is placed in a calorimeter with a heat capacity of $4.92 \text{ kJ}\cdot\text{K}^{-1}$. The temperature increase is 10.06 K. What is the heat of reaction?
- 4) Glucose is combusted in a bomb calorimeter. If 2 g of glucose is placed in a calorimeter with a heat capacity of $5.12 \text{ kJ}\cdot\text{K}^{-1}$, what temperature change would be measured given that $\Delta H^\circ_{\text{rxn}} = -2815.8 \text{ kJ}\cdot\text{mol}^{-1}$ and the formula for glucose is $\text{C}_6\text{H}_{12}\text{O}_6$?

Student Packet: 7.2: Calorimetry: TestMe questions

- 1) Determine the heat of reaction for the combustion of stearin, $C_{57}H_{110}O_6$ if a bomb calorimeter with a heat capacity of 4.18 kJ/K increases in temperature 54.2 K when 3 g of stearin is burned.

A) 7,552 kJ/mole
 B) -75,519 J/mole
 C) 75,519 kJ/mole
 D) -75,519 kJ/mole
 E) None of the above

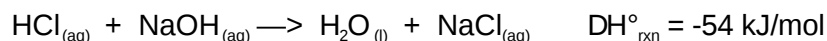
- 2) One gram of octane is burned in a bomb calorimeter. The enthalpy change for this reaction is

$$\Delta H^\circ_{\text{rxn}} = -10,920 \text{ kJ/mol}$$

The temperature increased 70 K. What is the total heat capacity of the calorimeter? The molecular formula of octane is C_8H_{18} .

A) 13.7 kJ•K⁻¹ B) 137 kJ•K⁻¹ C) 56.1 kJ•K⁻¹ D) 1.37 kJ•K⁻¹ E) None of the above

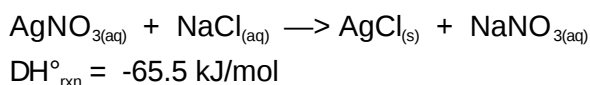
- 3) The following reaction is carried out in a bomb calorimeter with a heat capacity of 3.1 kJ/K:



If 0.2 g of HCl and 0.22 g NaOH are put in the calorimeter how much will the temperature rise?

A) 0.096 K B) 96 K C) 17 K D) 1.74 K E) None of the above

- 4) Two students make a calorimeter out of a styrofoam cup to measure the heat of a reaction but they don't know the heat capacity of the cup. To figure it out they run the following reaction and notice the temperature rise 82 K when they put 1 g of $AgNO_3$ in the cup. What is the heat capacity?



A) 47.2 kJ•K⁻¹ B) .0047J•K⁻¹ C) 4 72 kJ•K⁻¹ D) 4.72 J•K⁻¹ E) None of the above

- 5) It is estimated that steak has an energy value of 1400 kJ/100 g. If all the energy released from eating a steak is used to heat your body, how many grams of steak do you have to eat to raise your temperature 1 K if you weigh 100 kg? Assume that the heat capacity per gram of your body is 4.18 J/g•K.

A) 100 g of steak
 B) 29.9 g of steak
 C) .15 g of steak
 D) 54 g of steak
 E) None of the above