CHEM 200/202

Professor Byron W. Purse
bpurse@sdsu.edu
Office: virtual only this semester

All course-related emails are to be sent to:
chem200@sdsu.edu

My office hours will be held on **Zoom** on **Monday from 3:00 to 5:00 PM.** Appointments can be made for special issues, but not one-on-one tutoring.

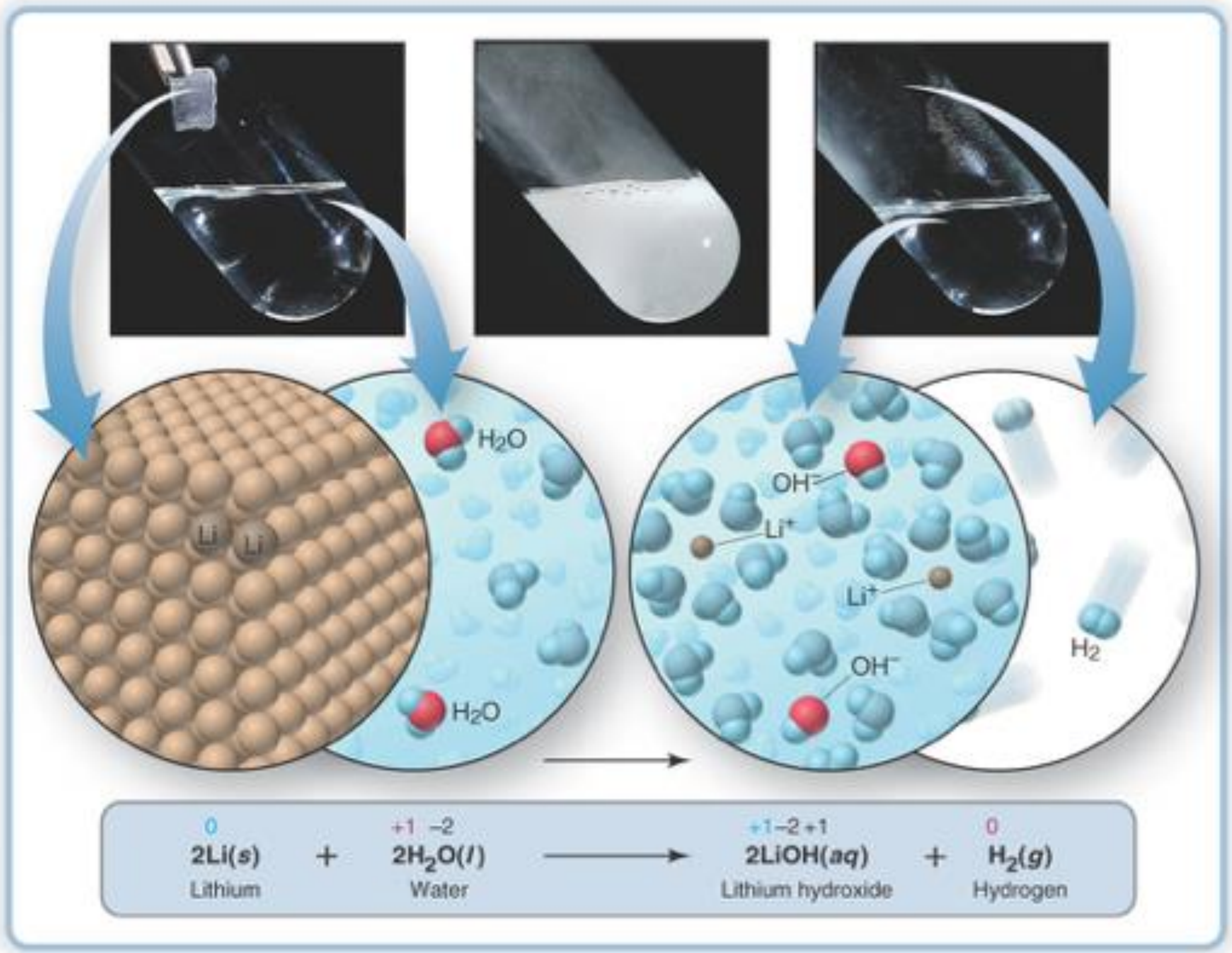
UPCOMING IMPORTANT DATES

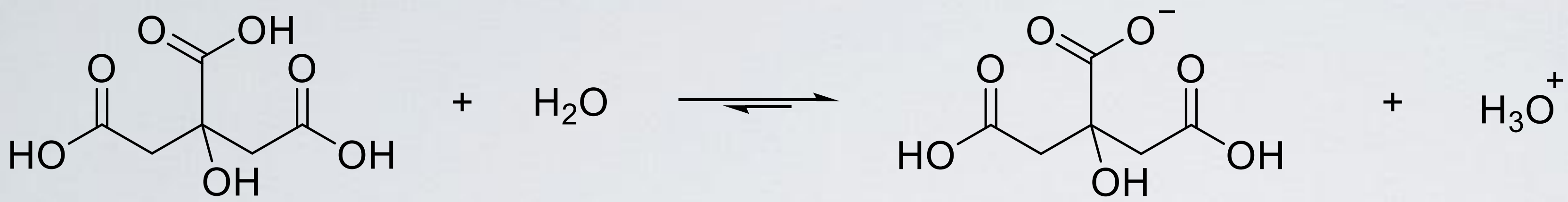
- Chapter 1-4 OWL Assignments (Problem Sets) due **Feb. 18th** (**Start Now**)
- Exam Prep is due **Feb.18th**; 2 chances, no time limit
- Exam 1 is **Feb. 19th** in OWL; Chapters 1-4. Exam starts at 3 PM and you have 24hrs. *Only 2 hrs once you start; be sure to give yourself a full 2 hr time slot.*

DISPLACEMENT REACTION

An active metal displacing hydrogen from water

$2Li_{(s)} + 2H_2O_{(l)} \rightarrow 2LiOH_{(aq)} + H_{2(g)}$

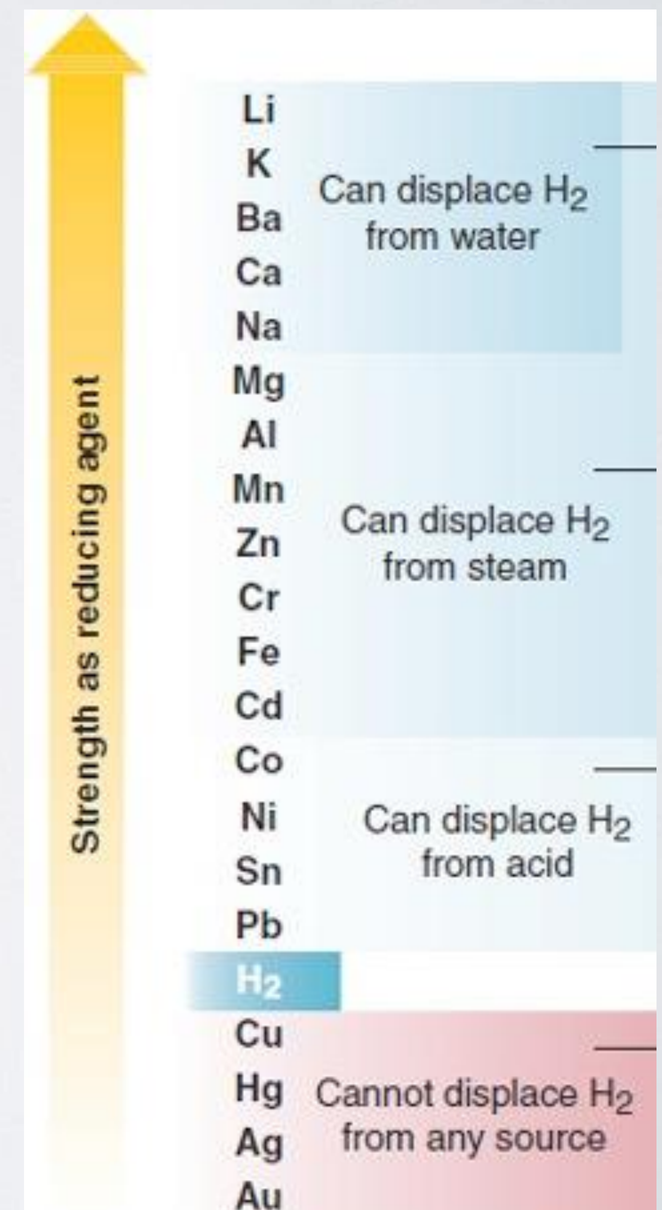


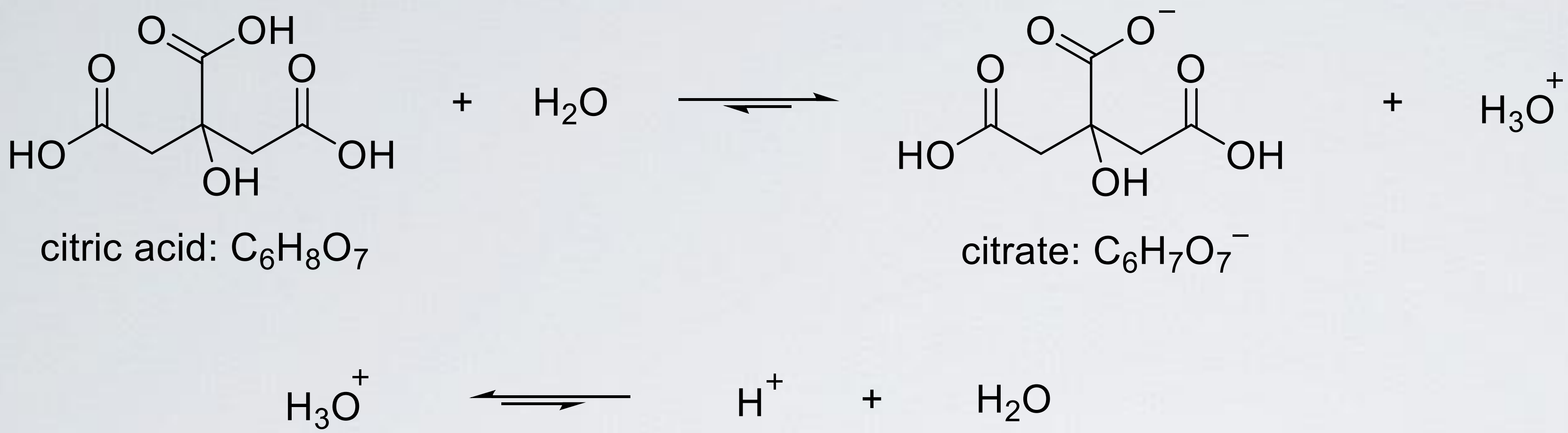


citric acid: $C_6H_8O_7$ citrate: $C_6H_7O_7^-$

$$H_3O^+ \rightleftharpoons H^+ + H_2O$$

Write the redox equations to explain how this lemon battery generates a current and 0.906 V. Which way does the current flow (along the wire from Zn to Cu, or from Cu to Zn)?





A typical lemon weighs ~ 3.5 oz and is around 0.7% w/w citric acid. **Note that citric acid is triprotic!** To derive the maximum possible total amount of current from the lemon battery (i.e. 100% yield of the redox reactions), what's the minimum mass that you would need of each of the Zn and Cu electrodes?

2. Aluminum oxidizes according to the following equation:

________Al + ______O_2 → _________Al_2O_3

(a) Powdered Al (0.048 mol) is placed into a container containing 0.030 mol O_2. What is the limiting reactant? (Balance the equation first)

(b) How many moles of the excess reactant remain?

5. A process by which zirconium metal can be produced from the mineral zirconium (IV) orthosilicate, $ZrSiO_4$, starts by reacting it with chlorine gas to form zirconium (IV) chloride.

_______ $ZrSiO_4$ + _______ Cl_2 → _______ $ZrCl_4$ + _______ SiO_2 + _______ O2

What mass of $ZrCl_4$ can be produced if 954 g of $ZrSiO_4$ and 830. g of Cl_2 are available? (Balance the equation first)

7. Huge quantities of sulfur dioxide are produced from zinc sulfide by means of the following reaction:

________ $ZnS(s)$ + ________ $O_2(g) \rightarrow$ ________ $ZnO(s)$ + ________ $SO_2(g)$

If the typical yield is 78.86%, how much SO_2 should be expected if 4765 g of ZnS are used? (Balance the equation first)

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LECTURE OBJECTIVES

- Chapter 5.1
  - Define, distinguish, and describe types of energy, and energy changes.
  - Identify the related properties of heat, thermal energy, and temperature.
  - Differentiate between specific heat and heat capacity.
  - Perform calculations employing heat, specific heat, and temperature change.

CHAPTER 5 -THERMOCHEMISTRY

Sliding a match head along a rough surface initiates a combustion reaction that produces energy in the form of heat and light. (credit: modification of work by Laszlo Ilyes)

EXAMPLES OF THERMOCHEMISTRY

(a) (b) (c)

The energy involved in chemical changes is important to our daily lives: (a) A cheeseburger for lunch provides the energy you need to get through the rest of the day; (b) the combustion of gasoline provides the energy that moves your car (and you) between home, work, and school; and (c) coke, a processed form of coal, provides the energy needed to convert iron ore into iron, which is essential for making many of the products we use daily. (credit a: modification of work by “Pink Sherbet Photography”/Flickr; credit b: modification of work by Jeffery Turner)

POTENTIAL VS. KINETIC ENERGY

(a) (b)

(a) Water that is higher in elevation, for example, at the top of Victoria Falls, has a higher potential energy than water at a lower elevation. As the water falls, some of its potential energy is converted into kinetic energy.

(b) If the water flows through generators at the bottom of a dam, such as the Hoover Dam shown here, its kinetic energy is converted into electrical energy. (credit a: modification of work by Steve Jurvetson; credit b: modification of work by "curimedia"/Wikimedia commons)

EXOTHERMIC/ENDOTHERMIC

(a) (b)

(a) An oxyacetylene torch produces heat by the combustion of acetylene in oxygen. The energy released by this exothermic reaction heats and then melts the metal being cut. The sparks are tiny bits of the molten metal flying away.

(b) A cold pack uses an endothermic process to create the sensation of cold. (credit a: modification of work by "Skatebiker"/Wikimedia commons)

HEAT CAPACITY

Due to its larger mass, a large frying pan has a larger heat capacity than a small frying pan. Because they are made of the same material, both frying pans have the same specific heat. (credit: Mark Blaser)

specific heat = specific heat *capacity* (it's an abbreviation)

CHEMICAL ENERGY

- Energy is directly linked to chemistry and a key to understanding how chemical reactions proceed.
- **All chemical changes are accompanied with a change in energy**.
  - Burning fuel releases energy.
  - Forming aluminum metal from bauxite ($Al(OH)_3$) requires massive amounts of energy.

ENERGY

- **Energy** is divided into two main categories: **work** and **heat**.
- Energy is also divided into **potential** and **kinetic** energy.
  - Potential energy: due to composition, position, or condition of the object.
  - Kinetic energy: due to the motion of the object.
- **Crucially, energy is always conserved.**
- Energy is measured in **Joules (J)**: $1 J = 1 kg \cdot m^2/s^2$
  or in **calories (cal)**: 1 cal = 4.184 J

WORK ENERGY

- **Work (*w*) energy** is that which is required to move matter against an opposing force.
  - Lifting a book opposes the force of gravity.
- Obtaining work from chemical systems typically involves the production of gas.
  (or, increasingly, the generation of an electrical current)
  - Expanding a volume against an external pressure.

THERMAL ENERGY

- **Thermal energy** is kinetic energy, associated with the **random motion of molecules**.
- The temperature of an object is a **quantitative measure** of the kinetic energy of the molecules of that object.
- The higher the kinetic energy (faster movement) the hotter the object.
- If there is no phase change, or chemical reaction, when the thermal energy of a substance changes, the temperature will change in the same manner.

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Friday’s Lecture is Moved to Thursday at 2:00 PM.

This week only! The recording will be posted if you have to miss it.

Same Zoom link.

It will all be review for Midterm 1.

1. Only email chem200@sdsu.edu.

This is an important announcement especially if they have an issue during the exam!

2. Remind them to check that they know which version letter they have for exam 1. They need to go to Blackboard > (left hand side) Exam Groups > they should see the exam group and inside is the password and a picture of the page before the exam with some useful troubleshooting tips.

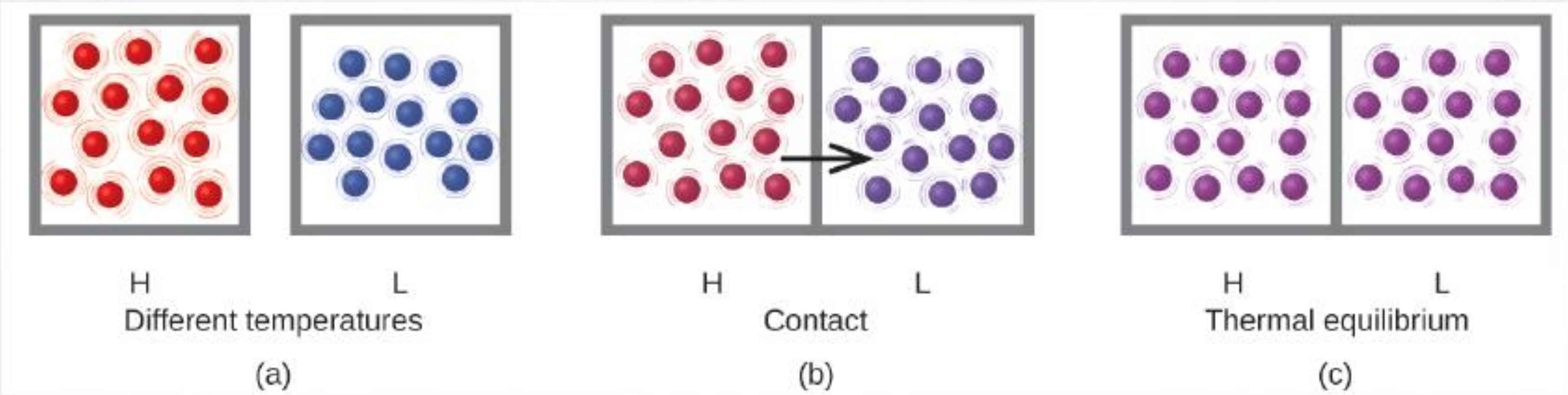
3. For the exam (again this is an announcement) they need to use chrome, have cleared their cache and cookies before they started, turned off their ad blockers, AND they don't open up any tabs. FYI opening up tabs will speed up their timer for the exam. It's a bug that has yet to be resolved by Cengage. They will need to print from the Course Documents on the Chem 200 website: the periodic table, solubility chart, and the exam sheet. This way they have the information in front of them. Also, using other outside resources will lead to errors in their calculations or even wrong answers.

4. I am uploading OWL Labs and Hayden McNeil grades tonight and tomorrow into Blackboard. If they see a zero they didn't follow my directions that I sent several announcements about. They will have until Friday, February 19th at 5:00 PM to email me there was an issue otherwise the grades will stay as zeros.

5. Remind them that the OWL Chapter Problem Sets will close on Thursday, February 18th at 11:59 PM as well as the Chapter Exam Preps.

HEAT

- **Heat (*q*)** is the transfer of thermal energy for a substance.
- Heat is always transferred from the higher kinetic energy substance to the lower kinetic energy one.
- Similar to the kinetic energy transfer from the cue ball to the others



QUANTIFYING HEAT TRANSFER

- In many situations there is a need to **determine how much heat will be transferred** between substances.
- This is typically **measured as a change in temperature**.
- However, **not all substances change temperature to the same extent** given the same amount of energy input (e.g. pavement versus water).

HEAT CHANGE

- **The change of heat** for a substance can either be **positive or negative**, when undergoing a chemical or physical change.

- If a substance **releases heat** (negative change) the process is called **exothermic** (e.g. combustion).

- If the substance **gains heat** (positive change) the process is termed **endothermic** (e.g instant cold packs).

HEAT CAPACITY

- The **heat capacity (*C*)** of a substance is the measure of how its **temperature will change (ΔT)** based on the amount of **heat change (*q*)**.

$$C = \frac{q}{\Delta T}$$

- However heat capacity does not account for mass of the substances - different masses require different amounts of heat.

SPECIFIC HEAT CAPACITY

$$c = \frac{q}{m\Delta T}$$

$$q = mc\Delta T$$

- The **specific heat capacity (c)** accounts for the amount of substance that is involved in the heat change.
- The specific heat capacity for every substance is different.
- Units of specific heat capacity are **J/g•°C** (or J/g•K)

Substance	Specific heat capacity
Water	4.184
Iron	0.449
Helium	5.193
Gold	0.129

PROBLEMS

- It a block of metal has been found to require 27.345 kJ in order to raise its temperature by 35 °C. What is the heat capacity of the metal?
- If the block of metal weighs 2.613 kg, what is its specific heat capacity?
- How much energy would be required to raise the temperature of the block of metal by another 20.7 °C?
- How much energy would be released as the block of metal cooled from 92.3 °C to 23.8 °C?

Midterm Review Problem

Uranium can be isolated from its ores by dissolving it as $UO_2(NO_3)_2$, then separating it as solid $UO_2(C_2O_4)\cdot 3H_2O$. Addition of 0.4031 g of sodium oxalate, $Na_2C_2O_4$, to a solution containing 1.481 g of uranyl nitrate, $UO_2(NO_3)_2$, yields 1.073 g of solid $UO_2(C_2O_4)\cdot 3H_2O$.

$$Na_2C_2O_4 + UO_2(NO_3)_2 + 3H_2O \longrightarrow UO_2(C_2O_4)\cdot 3H_2O + 2NaNO_3$$

Determine the limiting reactant and the percent yield of this reaction. Also determine the amount of excess reagent that is left.

Midterm Review Problem

What volume of a 0.2089 M KI solution contains enough KI to react exactly with the $Cu(NO_3)_2$ in 43.88 mL of a 0.3842 M solution of $Cu(NO_3)_2$?

$2Cu(NO_3)_2 + 4KI \longrightarrow 2CuI + I_2 + 4KNO_3$

Midterm Review Problem

Identify the oxidation, reduction, oxidizing agent, or reducing agent from the following:

$$2CuCl_2 + 4KI \longrightarrow 2CuI + 4KCl + I_2.$$

Midterm Review Problem

At the beginning of the Copper Age, around 7000 years ago, the smelting of copper ore was discovered. Malachite is one suitable copper ore likely to have been used at that time. This chemistry brought about the end of the Stone Age, leading to the first metal tools.

malachite
$Cu_2CO_3(OH)_2$

Heating powdered malachite generates CuO.

$$Cu_2CO_3(OH)_2 \longrightarrow CuO + CO_2 + H_2O$$

(1) Balance the equation and determine if this is a redox reaction.

(2) Heating CuO in the presence of charcoal (C) at around 1000 °C generates copper metal. Balance the equation and identify the oxidation, reduction, oxidizing agent, and reducing agent.

$$CuO + C \longrightarrow Cu + CO_2$$

(3) How much malachite is need to produce 100. g of copper metal, assuming 100% yield?

PROBLEM

- A flask containing 8.0×10^2 g of water is heated, and the temperature of the water increases from 20 °C to 85 °C. How much heat did the water absorb?

Specific Heats of Common Substances at 25 °C and 1 bar

Substance	Symbol (*state*)	Specific Heat (J/g °C)
helium	He(*g*)	5.193
water	H_2O(*l*)	4.184
ethanol	C_2H_6O(*l*)	2.376
ice	H_2O(*s*)	2.093 (at −10 °C)
water vapor	H_2O(*g*)	1.864
nitrogen	N_2(*g*)	1.040

Table 5.1

PROBLEM

- Calculate the heat transfer when 12.0 g of water (c= 4.184 J/g•K) is heated from 20.0°C to 100.°C?

PROBLEM

- A 545 g aluminum block (c=0.900 J/g•K) at an initial temperature of -15.0°C absorbs 125 kJ of heat. What is the final temperature of the block?

PROBLEMS

An aluminum kettle weighs 1.05 kg. Specific heat capacity of Al is c = 0.897 J/g°C.

(a) What is the heat capacity of the kettle?

(b) How much heat is required to increase the temperature of this kettle from 23.0 °C to 99.0 °C?

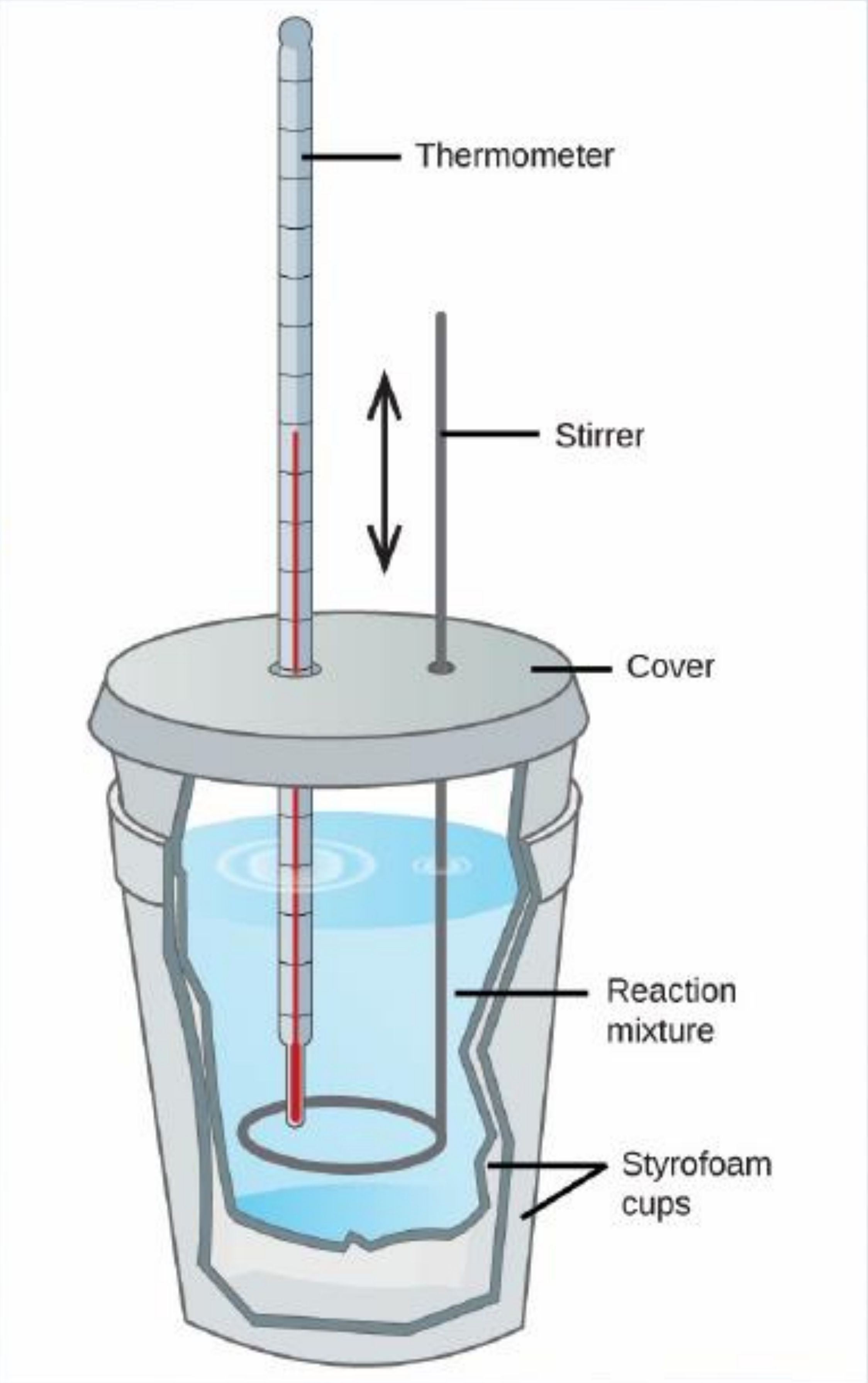
(c) How much heat is required to heat this kettle from 23.0 °C to 99.0 °C if it contains 1.25 L of water (density of 0.997 g/ml and a specific heat of 4.184 J/g°C)?

CALORIMETRY

- **Calorimetry** is the process of measuring the **heat involved in chemical or physical changes**.
- The objective in calorimetry is to **contain all the heat within one environment** that can come to equilibrium **without influence from external sources**.
- For example, an ice cube can cool a drink, but the drink will also be warmed by the room it is in. How can the heat change due to the ice be quantified?

CALORIMETER

- The **calorimeter is a very well insulated container** that greatly limits the heat exchange to the room around it.
- As such we can make accurate measurements of the heat involved inside the calorimeter.



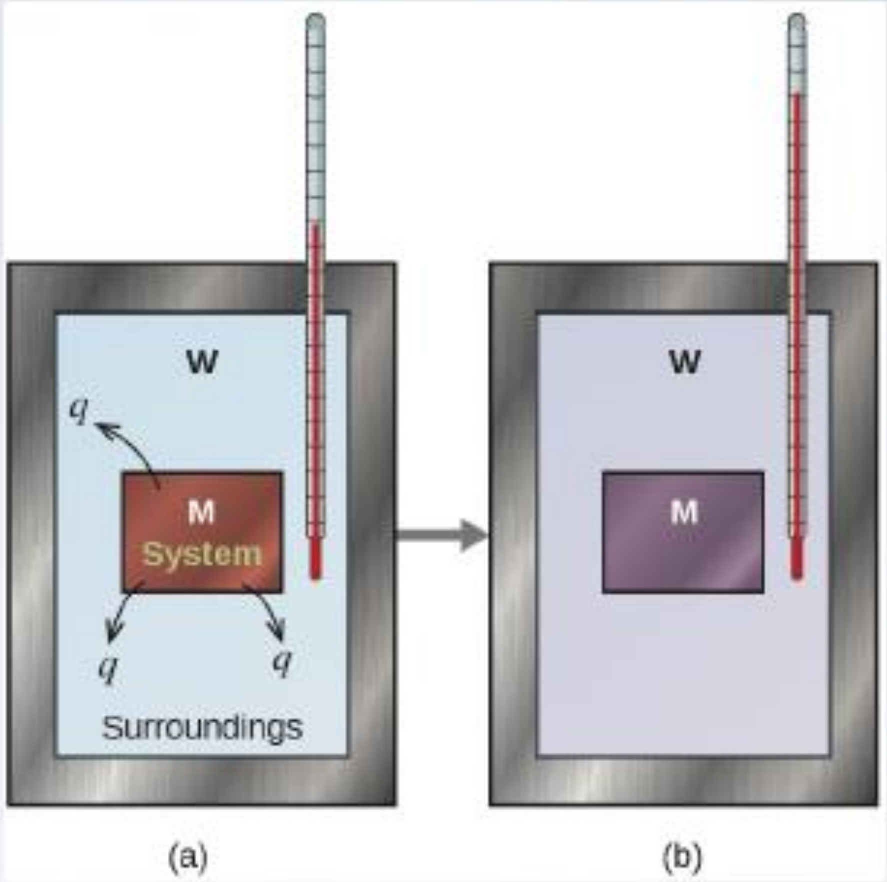
CALORIMETRY

- The temperature inside the calorimeter will change depending on the process that is taking place.

- **The medium inside the calorimeter** that changes temperature (usually water) and is well know, is call the **surroundings**.

- **The substance/reaction** that is undergoing a chemical of physical process in the calorimeter is call the **system**.

- <u>The net change in heat in the calorimeter is always zero</u> (ideally).



$$q_{system} + q_{surroundings} = 0$$

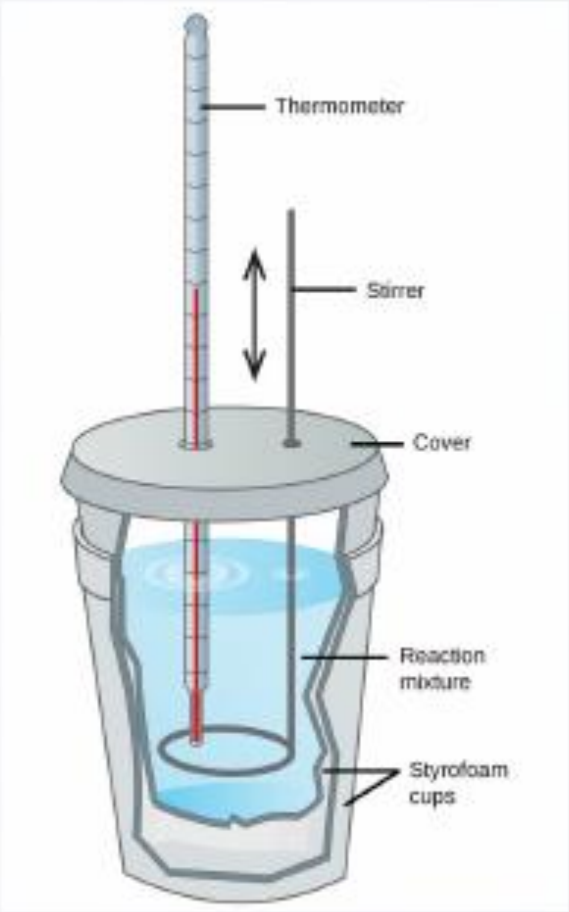
$$q_{system} = -q_{surroundings}$$

IMPERFECT CALORIMETERS

- Though we often neglect the **calorimeter** itself from calculations, it **may need to be considered.**
- The calorimeter will inherently gain (or lose) some heat from/to the material inside of it.
- This will be associated with a **temperature change**, dependent on the heat capacity of the calorimeter (***C_{cal}***)

$$q_{system} + q_{surroundings} + q_{cal} = 0$$

$$q_{cal} = C_{cal} \Delta T$$



PROBLEM

A 70.0–g piece of metal at 80.0 °C is placed in 100 g of water at 22.0 °C contained in a calorimeter. The metal and water come to the same temperature at 24.6 °C.

- How much heat did the metal give up to the water?
- What is the specific heat of the metal?

PROBLEM

Dissolving 3.0 g of $CaCl_2(s)$ in 150.0 g of water in a calorimeter at 22.4 °C causes the temperature to rise to 25.8 °C. What is the approximate amount of heat involved in the dissolution, assuming the heat capacity of the resulting solution is 4.18 J/g °C? Is the reaction exothermic or endothermic?

PROBLEM

When solid ammonium nitrate dissolves in water, the solution becomes cold. When 3.21 g of solid NH_4NO_3 dissolves in 50.0 g of water at 24.9 °C in a calorimeter, the temperature decreases to 20.3 °C. Calculate q of the reaction and determine if the reaction is exothermic or endothermic.