

CHEM 115

Review for Exam 2

Lecture 17
Prof. Sevian



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Agenda

- Go over Group Problem 6
- Rules about test taking in Chem 115
 - Read the info on the website
 - Sit every other seat, every other row
 - You should bring a calculator and pencil (not pen)
 - Remember to circle your own multiple-choice answers on your test so you'll know what you answered, because you will not get the bubble sheet back
 - Scratch paper will be provided
 - The exam is from 2:30-3:45
 - The exam ends at 3:45
- Review for Exam 2, which will be on Tuesday April 8₂

Group Problem #6

Constants you will need:

$$c = 2.998 \times 10^8 \text{ m}\cdot\text{s}^{-1}$$

$$h = 6.626 \times 10^{-34} \text{ J}\cdot\text{s}$$

$$N_A = 6.022 \times 10^{23} \text{ particles/mol}$$

1. Arrange the following kinds of electromagnetic radiation in order of increasing wavelength:
 - Infrared light
 - Microwaves
 - Green light
 - X-rays
 - Orange light
 - UV radiation
2. Answer the following questions about radiation that has wavelength 236 nm.
 - a) What is the frequency of the radiation?
 - b) What kind of radiation is it?
 - c) What is the energy of a photon of this wavelength?
 - d) How many kJ of energy does 1 mol of photons have?

Question 1: easy

1. Arrange the following kinds of electromagnetic radiation in order of increasing wavelength:
 - Infrared light
 - Microwaves
 - Green light
 - X-rays
 - Orange light
 - UV radiation

Increasing order of λ

X-rays < UV < green < orange < IR < μ waves

How about increasing order of ν ?

μ waves < IR < orange < green < UV < X-rays

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Question 2: more difficult

2. Answer the following questions about radiation that has wavelength 236 nm.
- What is the frequency of the radiation?
 - What kind of radiation is it?
 - What is the energy of a photon of this wavelength?
 - How many kJ of energy does 1 mol of photons have?

Part (a)

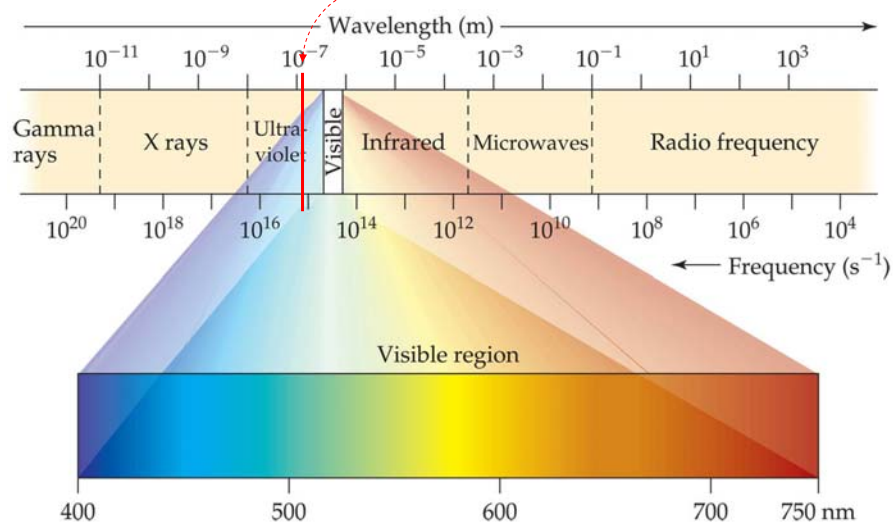
- Convert 236 nm to m $\longrightarrow 236 \text{ nm} \times \frac{10^{-9} \text{ m}}{1 \text{ nm}} = 2.36 \times 10^{-7} \text{ m}$

- Use $c = \lambda \nu$ to find frequency (ν)

$$\nu = \frac{c}{\lambda} = \frac{2.998 \times 10^8 \text{ m} \cdot \text{s}^{-1}}{2.36 \times 10^{-7} \text{ m}} = \left(\frac{2.998}{2.36} \right) \times \left(\frac{10^8}{10^{-7}} \right) = (1.27) \times (10^{8-(-7)}) = 1.27 \times 10^{15} \text{ s}^{-1}$$

Question 2(b)

What kind of radiation is it? $\nu = 1.27 \times 10^{15} \text{ s}^{-1}$



Question 2

2. Answer the following questions about radiation that has wavelength 236 nm.
- What is the frequency of the radiation?
 - What kind of radiation is it?
 - What is the energy of a photon of this wavelength?
 - How many kJ of energy does 1 mol of photons have?

Part (c)

- Use $E = h\nu$ to find the energy of a photon

$$E = h\nu = (6.626 \times 10^{-34} \text{ J} \cdot \text{s})(1.27 \times 10^{15} \text{ s}^{-1}) = (6.626 \times 1.27) \times (10^{-34} \times 10^{15}) \text{ J} \cdot \text{s} \cdot \text{s}^{-1}$$

$$= (8.42) \times (10^{-34+15}) \text{ J} = 8.42 \times 10^{-19} \text{ J}$$

Question 2

2. Answer the following questions about radiation that has wavelength 236 nm.
- What is the frequency of the radiation?
 - What kind of radiation is it?
 - What is the energy of a photon of this wavelength?
 - How many kJ of energy does 1 mol of photons have?

Part (d)

- 1 photon has $E = 8.42 \times 10^{-19} \text{ J}$
- 1 mol of photons must be N_A times this number:

$$8.42 \times 10^{-19} \frac{\text{J}}{\text{photon}} \times \frac{6.022 \times 10^{23} \text{ photons}}{1 \text{ mol of photons}} = 5.07 \times 10^5 \frac{\text{J}}{\text{mol}} \quad \text{or} \quad 5.07 \times 10^5 \text{ J} \cdot \text{mol}^{-1}$$

- Convert to kJ

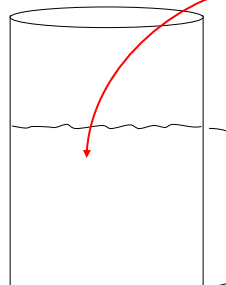
$$5.07 \times 10^5 \text{ J} \times \frac{1 \text{ kJ}}{1000 \text{ J}} = 5.07 \times 10^2 \text{ kJ} = 507 \text{ kJ}$$

Review for Exam 2

- Concentration of solutions
 - Calculating the concentration of a solution
 - Figuring out the concentrations of specific ions in a solution containing dissolved ionic compound(s)
 - Titration problems (involves stoichiometry)
- Redox reactions
 - The oxidation numbers model
 - Who's getting oxidized and who's getting reduced in a rxn
 - Oxidizing and reducing agents
 - Using the metal reactivity series to predict if a rxn occurs
- Writing net ionic equations
 - (Weak acid + strong base) vs. (strong acid + strong base)
 - Redox reactions

Molarity example

What is the concentration of a solution that was made by adding 1.95 g of Na_2SO_4 to 250. mL of water? (f.w. of Na_2SO_4 is $142.05 \text{ g}\cdot\text{mol}^{-1}$)



$$\text{moles Na}_2\text{SO}_4 = 1.95 \text{ g} \times \frac{1 \text{ mol}}{142.05 \text{ g}} = 0.01373 \text{ mol}$$

$$M = \frac{\text{moles solute}}{\text{L of solution}} = \frac{0.01373 \text{ mol}}{\left(250. \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}}\right)} = 0.0549 \frac{\text{mol}}{\text{L}} = 0.0549 \text{ M}$$

} 250. mL

What is the concentration of Na^+ ions in the solution?

there are 2 moles of Na^+ ions in every 1 mol of Na_2SO_4

$$0.0549 \frac{\text{mol Na}_2\text{SO}_4}{\text{L}} \times \frac{2 \text{ mol Na}^+}{1 \text{ mol Na}_2\text{SO}_4} = 0.110 \frac{\text{mol Na}^+}{\text{L}} \quad \text{or} \quad [\text{Na}^+] = 0.110 \text{ M}$$

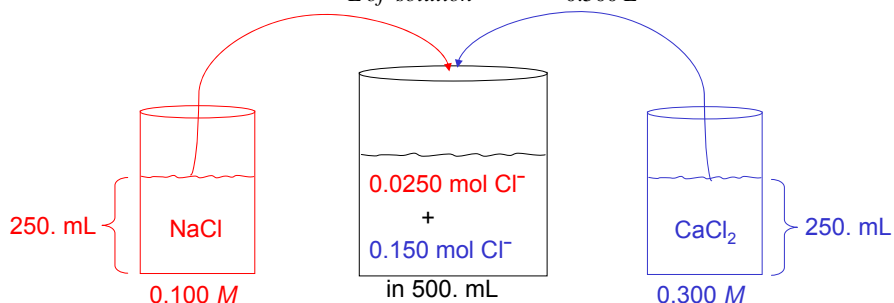
Two solutions combined

What is the Cl^- concentration when 250. mL of 0.100 M NaCl solution and 250. mL of 0.300 M CaCl_2 solution are mixed?

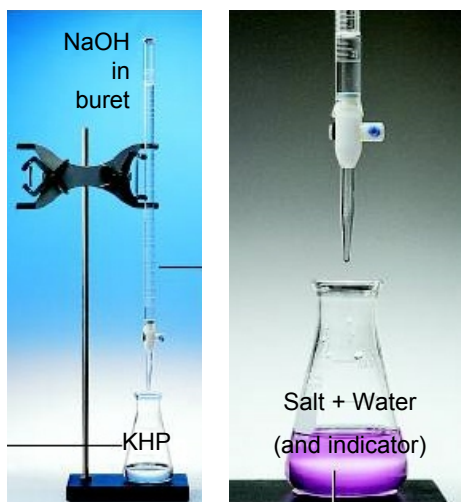
$$\text{moles of } \text{Cl}^- \text{ from the NaCl} = 0.250 \text{ L} \times 0.100 \frac{\text{mol}}{\text{L}} = 0.0250 \text{ mol}$$

$$\text{moles of } \text{Cl}^- \text{ from the CaCl}_2 = 2 \times \left(0.250 \text{ L} \times 0.300 \frac{\text{mol}}{\text{L}} \right) = 2 \times (0.0750 \text{ mol}) = 0.150 \text{ mol}$$

$$\text{Molarity of } \text{Cl}^- = [\text{Cl}^-] = \frac{\text{total moles } \text{Cl}^-}{\text{L of solution}} = \frac{0.0250 + 0.150 \text{ mol}}{0.500 \text{ L}} = 0.350 \text{ M}$$



Titration example problem from Lecture 12



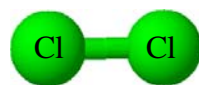
Solid sodium hydroxide absorbs moisture from the air, so it is difficult to weigh accurately to make a solution of known concentration. Potassium hydrogen phthalate, or KHP (m.w. 204.23), is monoprotic, can be weighed accurately, and is often used to standardize solutions of bases. 0.05182 grams of KHP are placed in a flask beneath a buret filled with NaOH solution of unknown concentration. If 23.4 mL of NaOH solution are required to exactly neutralize the KHP solution, what is the concentration of the NaOH solution?

How to assign oxidation numbers

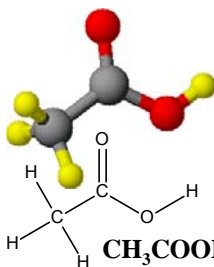
- Oxidation numbers sum to zero if compound is neutral, and total charge on ion if not neutral
- Atoms in free, neutral elements have oxidation number zero (0)
 Zn (s) , Ar (g) , $\text{O}_2 \text{ (g)}$, $\text{S}_8 \text{ (s)}$, Ag (s) , $\text{N}_2 \text{ (g)}$
- Charged ions have oxidation number equal to their charges
 $\text{FeCl}_3 \text{ (s)}$, $\text{FeCl}_2 \text{ (s)}$, $\text{Na}^+ \text{ (aq)}$, $\text{Al}^{3+} \text{ (aq)}$, $\text{AlBr}_3 \text{ (s)}$
- Oxygen, when in a compound or ion, nearly always has oxidation number -2 (exception: peroxides)
 $\text{Al}_2\text{O}_3 \text{ (s)}$, MgO (s) , $\text{SO}_4^{2-} \text{ (aq)}$, $\text{NO}_3^- \text{ (aq)}$; Exceptions: $\text{H}_2\text{O}_2 \text{ (l)}$, $\text{Na}_2\text{O}_2 \text{ (s)}$
- Hydrogen, when in a compound or ion, nearly always has oxidation number +1 (exception: hydrides)
 HCl (l) , $\text{H}_2\text{SO}_3 \text{ (aq)}$, $\text{CH}_3\text{COO}^- \text{ (aq)}$; Exceptions: $\text{CaH}_2 \text{ (s)}$, NaH (s)

Practice with oxidation numbers

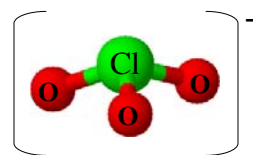
Identify oxidation numbers for each atom



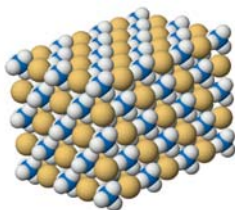
$\text{Cl}_2 \text{ (g)}$



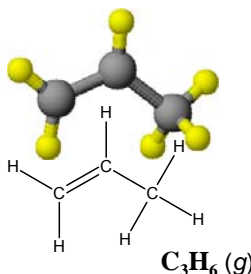
$\text{CH}_3\text{COOH} \text{ (aq)}$



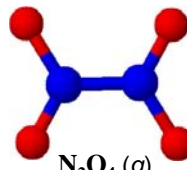
$\text{ClO}_3^- \text{ (aq)}$



$\text{NH}_4\text{Cl} \text{ (s)}$



$\text{C}_3\text{H}_6 \text{ (g)}$

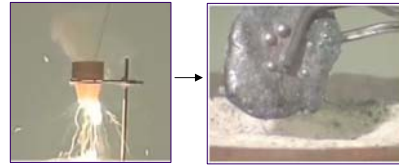


$\text{N}_2\text{O}_4 \text{ (g)}$

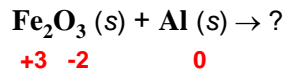
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Redox Reactions

Symbolic Representation

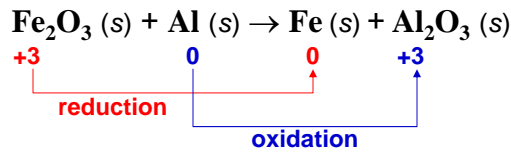


Thermite reaction: Iron (III) oxide + aluminum



<http://www.ice.divched.org/JCESoft/CCA/samples/cca7thermite.html>

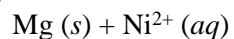
What are the products?



- Fe_2O_3 gets reduced to Fe metal. It gets reduced by Al. Therefore, Al is the reducing agent.
- Al metal gets oxidized to Al_2O_3 . It gets oxidized by Fe_2O_3 . Therefore, Fe_2O_3 is the oxidizing agent.

Ranking reactivity of metals with other metal cations in aqueous solution

- Called the activity series
- Metals that are higher are more reactive, *i.e.*, will react more readily than those below them
- Example: which reaction will occur?



or



TABLE 4.5 Activity Series of Metals in Aqueous Solution

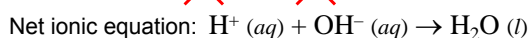
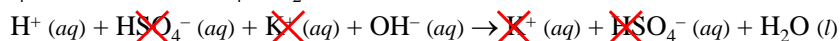
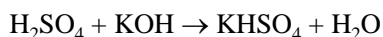
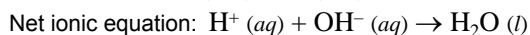
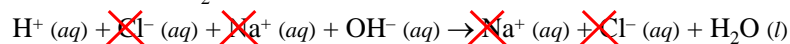
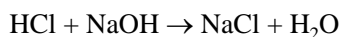
Metal	Oxidation Reaction
Lithium	$\text{Li}(s) \rightarrow \text{Li}^+(aq) + e^-$
Potassium	$\text{K}(s) \rightarrow \text{K}^+(aq) + e^-$
Barium	$\text{Ba}(s) \rightarrow \text{Ba}^{2+}(aq) + 2e^-$
Calcium	$\text{Ca}(s) \rightarrow \text{Ca}^{2+}(aq) + 2e^-$
Sodium	$\text{Na}(s) \rightarrow \text{Na}^+(aq) + e^-$
Magnesium	$\text{Mg}(s) \rightarrow \text{Mg}^{2+}(aq) + 2e^-$
Aluminum	$\text{Al}(s) \rightarrow \text{Al}^{3+}(aq) + 3e^-$
Manganese	$\text{Mn}(s) \rightarrow \text{Mn}^{2+}(aq) + 2e^-$
Zinc	$\text{Zn}(s) \rightarrow \text{Zn}^{2+}(aq) + 2e^-$
Chromium	$\text{Cr}(s) \rightarrow \text{Cr}^{3+}(aq) + 3e^-$
Iron	$\text{Fe}(s) \rightarrow \text{Fe}^{2+}(aq) + 2e^-$
Cobalt	$\text{Co}(s) \rightarrow \text{Co}^{2+}(aq) + 2e^-$
Nickel	$\text{Ni}(s) \rightarrow \text{Ni}^{2+}(aq) + 2e^-$
Tin	$\text{Sn}(s) \rightarrow \text{Sn}^{2+}(aq) + 2e^-$
Lead	$\text{Pb}(s) \rightarrow \text{Pb}^{2+}(aq) + 2e^-$
Hydrogen	$\text{H}_2(g) \rightarrow 2\text{H}^+(aq) + 2e^-$
Copper	$\text{Cu}(s) \rightarrow \text{Cu}^{2+}(aq) + 2e^-$
Silver	$\text{Ag}(s) \rightarrow \text{Ag}^+(aq) + e^-$
Mercury	$\text{Hg}(l) \rightarrow \text{Hg}^{2+}(aq) + 2e^-$
Platinum	$\text{Pt}(s) \rightarrow \text{Pt}^{2+}(aq) + 2e^-$
Gold	$\text{Au}(s) \rightarrow \text{Au}^{3+}(aq) + 3e^-$



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Net Ionic Equations of Weak vs. Strong Acid + Strong Base Reactions Differ

Strong acid examples (acid ionizes nearly completely):

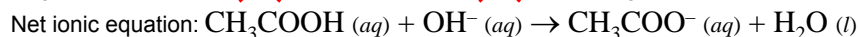
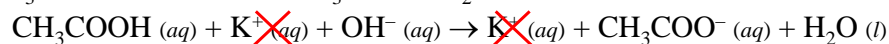
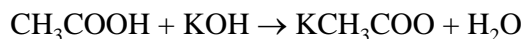
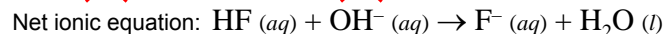
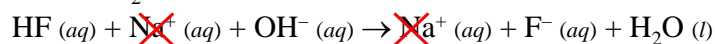
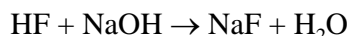


Notice that only the first H^+ in the H_2SO_4 reacted

- Only the first H^+ (in H_2SO_4) is highly acidic, resulting in a complete ionization to form H^+ and HSO_4^- .
- The second H^+ is only weakly acidic. That is, HSO_4^- remains mostly intact and does not ionize to any considerable extent.
- This means that if HSO_4^- were a reactant, then it would remain that way on the product side.

Net Ionic Equations of Weak vs. Strong Acid + Strong Base Reactions Differ

Weak acid examples (acid is mostly present as whole molecule):



The difference between strong and weak acid-base reactions:

Strong acid present as ions, so it cancels out of net ionic equation.

Weak acid present as molecules, so doesn't cancel out of net ionic equation.

Note: Also see Group Problem #4

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Net ionic equation for a redox rxn

Write the net ionic equation for the reaction that occurs when a piece of magnesium metal is dropped into a beaker containing a solution of hydrochloric acid.

Solution:

- Mg (s) + HCl (aq) are the reactants
- Mg is a very reactive metal
- This looks like a redox reaction because Mg can change to dissolved Mg²⁺ ions
- If Mg → Mg²⁺, that is an oxidation, so a reduction must also occur
- Which can reduce? Cl⁻ or H⁺
- Cl⁻ can't become more negative, so must be H⁺ → H₂
- Products must be MgCl₂ (aq) and H₂ (g)
- Overall reaction is Mg (s) + HCl (aq) → MgCl₂ (aq) + H₂ (g)
- Dissolved Cl⁻ is a spectator ion (same on both sides)
- Net ionic equation (unbalanced) is: Mg (s) + H⁺ (aq) → Mg²⁺ (aq) + H₂ (g)

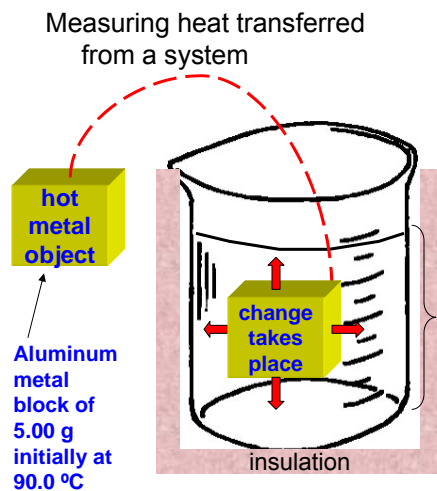
Review for Exam 2

- Systems
 - Internal energy at the particle level (each individual particle)
 - kinetic energy (KE) related to speed, temperature
 - potential energy (PE) is stored energy, in classical case attractions between particles over a distance
 - Internal energy at the laboratory/macrosopic level (can be measured in the lab)
 - heat energy (q)
 - work (w)
 - Relationship between various terms
 - internal energy change (ΔE) and enthalpy change (ΔH)
 - internal energy change (ΔE) and heat energy (q) and work (w)
 - enthalpy change (ΔH) and heat energy (q) when pressure is held constant

Review for Exam 2

- Getting ΔH for a reaction by a calorimetry measurement in the lab
 - Equipment
 - Need a way to measure heat lost or gained by the system, usually as the heat energy goes into or comes from the surroundings (usually water)
 - Measurements
 - $q_{\text{surr}} = m_{\text{surr}} C_{\text{surr}} \Delta T_{\text{surr}}$
 - Need to get q_{surr} so must measure m_{surr} and ΔT_{surr} (C is known for water)
 - q_{sys} is the opposite of q_{surr}
 - $\Delta H_{\text{sys}} = q_{\text{sys}} /$ (moles of whichever chemical you're interested in that reacted)
- Getting ΔH for a reaction by using Hess's law
 - Hess's law
 - "Products – Reactants" equation is just a special case of Hess's law, when all the reactions you're using are formation reactions

Example from Lecture 14: A hot metal block placed in cold water



Given information

Initial temperature of Al block = 90.00°C
 Mass of Al block = 5.00 g
 Mass of water = 100.0 g
 Temperature of water before = 23.00°C
 Temperature of both after = 23.71°C
 $C_{\text{water}} = 4.184 \text{ J/g}\cdot\text{K}$

Question:

What is the heat capacity of Al?

Problem Solving Strategy

$$q_w = m_w C_w \Delta T_w$$

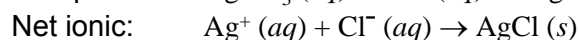
where $\Delta T_w = \text{temp change of H}_2\text{O}$

q_{sys} is opposite of q_w

Another Calorimetry Example from Lecture 14

Exercise on p. 186

When 50.0 mL of 0.100 M AgNO₃ and 50.0 mL of 0.100 M HCl are mixed in a constant-pressure calorimeter, the temperature of the mixture increases from 22.20 °C to 23.11 °C. The temperature increase is caused by the following reaction:



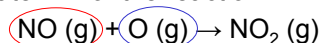
Calculate ΔH for this reaction in kJ/mol AgNO₃, assuming that the combined solution has density and heat capacity approximately equal to that of pure water since the solution is dilute. (D = 1.00 g/mL and C = 4.184 J/g·°C)

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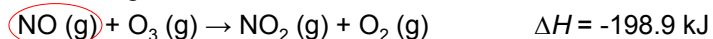
An example of Hess's law: Summing intermediate rxns to total an overall rxn

Practice exercise from p. 191

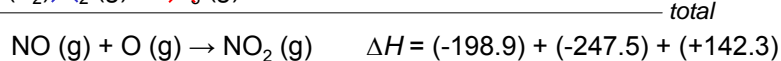
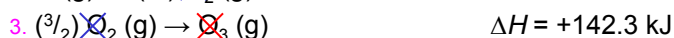
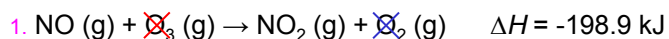
Calculate ΔH for the reaction



given the following information:



Solution:



$$\Delta H = -304.1 \text{ kJ}$$

Using Heats of Formation to Calculate Enthalpies of Reaction

Standard enthalpies of formation

$$\Delta H_f^\circ[\text{H}_2\text{O}(l)] = -285.83 \text{ kJ/mol}$$

$$\Delta H_f^\circ[\text{CO}_2(g)] = -393.5 \text{ kJ/mol}$$

$$\Delta H_f^\circ[\text{C}_2\text{H}_5\text{OH}(l)] = -277.7 \text{ kJ/mol}$$

Example problem: Use standard enthalpies of formation to calculate the enthalpy of reaction for the combustion of ethanol, $\text{C}_2\text{H}_5\text{OH}(l)$.

Solution: Start by writing the reaction



Method 1: Write all the formation reactions for any non-elements at standard state. Then figure out how to arrange those reactions to sum to the overall reaction and do the same to the ΔH_f° 's.

Method 2: Use the equation

$$\Delta H_{\text{rxn}}^\circ = \sum_{\text{products}} \Delta H_f^\circ - \sum_{\text{reactants}} \Delta H_f^\circ$$

Review for Exam 2

- Waves and radiation
 - Light is electromagnetic radiation
 - Electromagnetic radiation can be characterized as waves
 - $c = \lambda \nu$
 - c is the speed of light (in a vacuum) and is constant
 - λ is the wavelength of the light, often given in nm, but to use it in this equation you have to change it to m
 - ν is the frequency of the light, in s^{-1} or Hz
 - Electromagnetic radiation can be characterized as particles (photons) of light
 - The energy of a single photon with frequency ν is $E = h \nu$
 - h is a constant
 - If you wish to know the energy of a mole of photons, then you would need to multiply the single photon energy by Avogadro's number, N_A