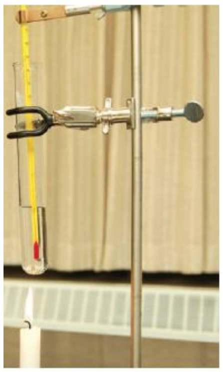
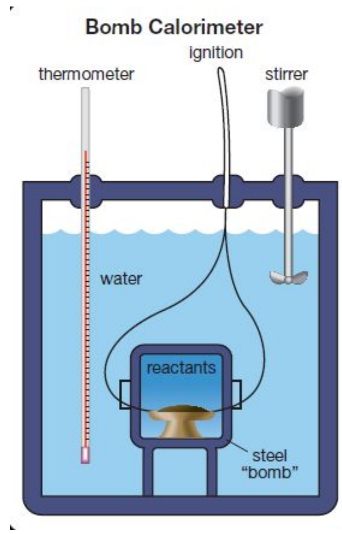
Science 30	Unit D: Energy and the Environment
Lesson 7 - Theoretical Heat of Combustion	84 mins

Calorimetry

calorimeter: a device that measures energy changes



- Need to contain the whole reaction to be able to measure all the energy.
- Where the term calorie comes from
- Our results (not contained)
    - Wax (4343kJ/mol)
- Real (contained)
    - Wax (21,464kj/mol)



Calculating Theoretical Heat of Combustion - Hess's Law

$$\Delta_r H^\circ = \sum n\Delta_f H^\circ \text{ products} - \sum n\Delta_f H^\circ \text{ reactants}$$

where $\Delta_r H^\circ$ = energy change of reaction (kJ)

$\sum$ = the sum of

n = amount (number of moles) represented by coefficient from balanced chemical equation

$\Delta_f H^\circ$ = standard heat of formation

standard heat of formation ($\Delta_f H^o$): the energy change for a chemical reaction that involves the formation of a compound from its elements determined at standard conditions

Ex.
Energy of Combustion of Butane

Step 1) Chemical Formula

$$2\ C_4H_{10(g)} + 13\ O_{2(g)} \rightarrow 8\ CO_{2(g)} + 10\ H_2O_{(g)}$$

Step 2) Organize Data (from pg. 5)

$$2\ C_4H_{10(g)} \quad + \quad 13\ O_{2(g)} \quad \rightarrow \quad 8\ CO_{2(g)} + \quad 10\ H_2O_{(g)}$$

Reactants			Products	
2 mols -125.7 kJ/mol	13 mols 0 kJ/mol (element)		8 mols -393.5 kJ/mol	10 mols -241.8 kJ/mol

Step 3) Use your formula

$$\Delta_r H^o = \Sigma n\Delta_f H^o products - \Sigma n\Delta_f H^o reactants$$

$$= \{(8\ mols \bullet\ -393.5\ kJ/mol) + (10\ mols \bullet\ -241.8\ kJ/mol)\} - \{(2\ mols \bullet\ -125.7\ kJ/mol) + (13\ mols \bullet\ 0\ kJ/mol)\}$$

$= \{\ -3148kJ + \ -2418kJ\} - \{\ -251.4kJ + 0kJ\}$ = -5314.6 kJ

Laws of Thermodynamics

<table>
<tr>
<td>First law of thermodynamics: a law stating that energy cannot be created or destroyed. Energy is always conserved.

Second law of thermodynamics: a law stating that when energy is transferred or changed from one form into another, some of the energy is always transferred to the surroundings (usually as waste heat)</td>
<td>Energy efficiency = $\frac{useful\ output\ energy}{input\ energy} \times 100\% \neq\ > 100\%$</td>
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Generating Electricity from Burning

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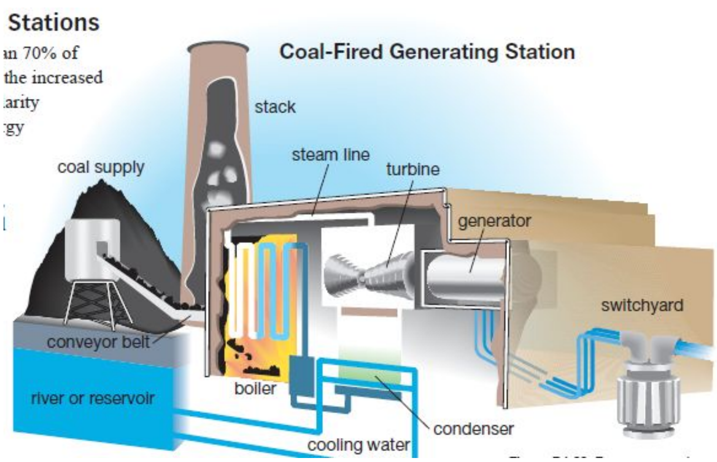
<tr>
<td>
</td>
<td>Steps
$E_p \rightarrow E_k \rightarrow E_k \rightarrow E_k \rightarrow E_k$
Coal □ Steam □ Turbine □ Generator □ Electricity</td>
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Science 30 - Lesson 43 - Unit D - Theoretical Heat of Combustion

Name: ___________________________________

1) The following balanced chemical equations are for the combustion reactions for each of the fuels tested in the "Determining Heat of Combustion" investigation. Calculate the heats of combustion for each reaction.
   a) $CH_{4(g)} + 2\ O_{2(g)}$ □ $CO_{2(g)} + 2\ H_2O_{(g)}$

   b) $C_2H_5OH_{(l)} + 3\ O_{2(g)}$ □ $2\ CO_{2(g)} + 3\ H_2O_{(g)}$

   c) $2\ C_{36}H_{74(s)} + 109\ O_{2(g)}$ □ $72\ CO_{2(g)} + 74\ H_2O_{(g)}$
      Note: Assume the heat of formation for paraffin wax, $C_{36}H_{74(s)}$, is - 1862.6 kJ/mol.

2) Fill out the chart below and calculate the Percent Efficiency of your Calorimeter for last class' lab

Fuel	Ethanol	Butane	Paraffin Wax
Useful Output Energy (from lab)			
Input Energy (from question 1)			
Efficiency			

   a) Calculate an average efficiency of the calorimeter.

   b) List possible reasons why the energy efficiency of the calorimeter was less than 100%.

c) State the precision (number of decimal places (**significant figures**)) of the balance used in the "Determining Heat of Combustion" investigation. Describe the effect the precision of the masses measured has on the values calculated for the efficiency of your calorimeter.

3) Electricity can be produced using natural gas—a fossil fuel—in place of coal. Use the Internet to research natural gas-fired electricity generation. Identify similarities and differences between coal-fired electricity generation and natural gas-fired generation in terms of processes used to produce electricity and the energy transformations involved.

4) Modifications to the processes in a coal-fired power plant are listed in the following table. Explain how each modification could improve the energy efficiency of the plant.

Modification	Description
I	evaporating water normally found within coal prior to combustion
II	allowing the steam to pass more than once across turbine blades