Objective 9

Energy and heat 2:
predict heat in a chemical reaction and chemical heat transfer.
Apply using Hess' law.
Predict work in a chemical reaction.

http://en.wikipedia.org/wiki/Rock_%28geology%29

http://www.celebritysentry.com/post/cheltenham-gold-cup-horse-race/

A rock and gold cup lie in the middle of the parking lot on a hot day. Which substance contains more heat?

Atoms and Molecules Contain Energy

<u>Internal Energy</u> (E) is the Energy Inside Atoms and Molecules; property of a substance (state function)

<u>Enthalpy</u> (H) is that part of the internal energy that is converted into heat:

$$q = \Delta H$$

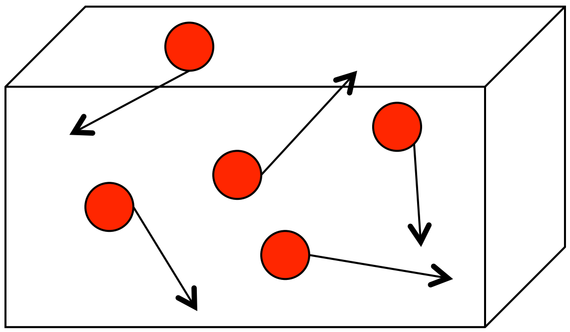
$\Delta H > 0$ — <u>*endothermic*</u> - heat absorbed/supplied

$\Delta H < 0$ — <u>*exothermic*</u> - heat released/given off

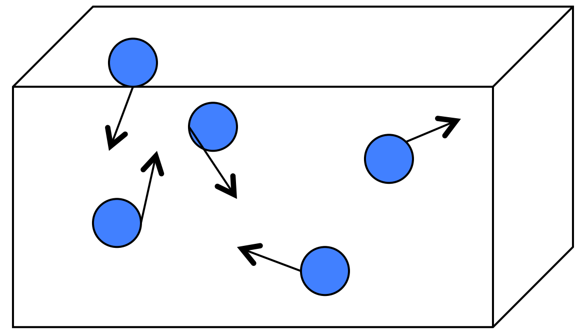
<u>Heat</u> (q) is the energy <u>transferred</u> due to ΔT

<u>Heat</u> is <u>***NOT***</u> a property of a substance (<u>path</u> function)

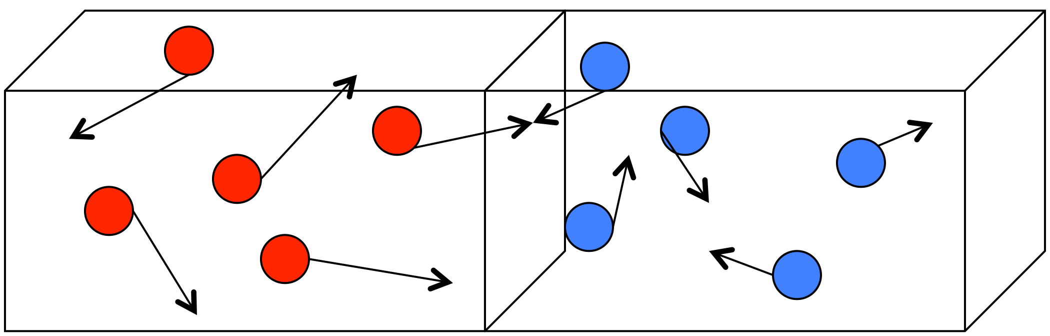
Heat *is the Energy TRANSFERRED between 2 objects due to a difference in TEMPERATURE.*



Hot object: atoms move fast
Higher Internal Energy



Cold object: atoms move slow
Lower Internal Energy



Energy transferred (HEAT) when fast atoms collides with a slow ones.
Fast atoms move slower (T ↓); slow atoms move faster (T ↑).
Internal Energy decreases for Hot object and increases for Cold object.

Two Driving Forces determine whether a chemical reaction occurs: **Enthalpy** and **Entropy**

Entropy (S) refers to the dispersal of energy

Nature: ***Things want to be at low energy.***

It takes energy to keep things ordered.

Entropy: What happens when you can't hold back the door?

http://www.secondgearsports.com/blog

Every Chemical Reaction Involves Energy

Exothermic Reaction
heat is released

http://candlefind.com/candle-reviews/avery-jordan-candle-reviews/friendly-fumes-scented-candles.html

http://www.bpmedicalsupplies.com/category.sc?categoryId=40

Endothermic Reaction
heat is absorbed

How Much Energy Is Involved In A Chemical Reaction? (Heat)

Look up ΔH of formation data:

Chemistry textbook Appendix

http://www.wiredchemist.com/chemistry/chemistry.html

*Calculate ΔH of a chemical reaction from ΔH of formation using **HESS' LAW***

$\Delta H_{reaction} = \Sigma\, n\, \Delta H_{formation}(products) - \Sigma\, n\, \Delta H_{formation}(reactants)$

where n = coefficient in balanced chemical equation

$\Delta H > 0$ *endothermic* - heat absorbed/supplied

$\Delta H < 0$ *exothermic* - heat released/given off

Most chemical reactions are exothermic.

<u>Formation Reaction</u>:

Element(s) in standard state --> compound

When an element is formed, Energy gained or lost = 0
ΔH of formation of an element in std state = 0

Compounds are usually ***<u>more stable</u>*** than the elements it comes from. (Compounds have a lower E than elements.)

Energy is usually lost (released) when a compound is formed from its elements **(ΔH of formation of a compound < 0)**

<u>Stable</u> *means Low Energy.*
<u>Unstable</u> *means High Energy.*

Objective: relate ΔH to stability

Write a chemical equation for the formation of H_2O.

$$2 H_2 (g) + O_2 (g) \rightarrow 2 H_2O (l)$$

Calculate (or look up) ΔH of formation of:

H_2 (g)
O_2 (g)
H_2O (l)
H_2O (g).

http://www.health.gov.ws/AboutUs/Divisions/HPPSD/EnvironmentalHealth/WaterSection/tabid/5437/language/en-US/Default.aspx

Which substance has the *most energy*?

Which substance is the *most stable*?

Draw an energy diagram with H_2, O_2, and H_2O.

Formation of water: H_2 (g) + O_2 (g) --> H_2O (l)

Energy, kJ

0 — H_2 (g), O_2 (g)

Unstable
High E

-100

-200

— H_2O (g) ΔH_f = -242 kJ/mole

Stable
Low E

— H_2O (l)
ΔH_f = -285 kJ/mole

-300

How Much Energy (Heat) Is Involved When Water Forms?

use Hess' law to calculate $\Delta H_{reaction}$

$\Delta H_{reaction} = \Sigma\, n\, \Delta H_{formation}(\text{products}) - \Sigma\, n\, \Delta H_{formation}\ (\text{reactants})$

Calculate ΔH for

$$H_2\,(g) + O_2\,(g) \dashrightarrow H_2O\,(l)$$

a. -285 kJ/mole
b. -570 kJ/mole
c. 0 kJ/mole

Calculate ΔH for $H_2 (g) + O_2 (g) \dashrightarrow H_2O (l)$

First, **balance** the equation:

$$2\ H_2 (g) + O_2 (g) \rightarrow 2\ H_2O (l)$$

ΔH_f, kJ/mole	0	0	-285

Apply Hess' law:

$$\Delta H_{reaction} = \Sigma\, n\, \Delta H_{formation}(\text{products}) - \Sigma\, n\, \Delta H_{formation}(\text{reactants})$$

$$= [2\ \Delta H_f (H_2O (l))] - [2\ \Delta H_f (H_2 (g)) + 1\ \Delta H_f (O_2 (g))]$$

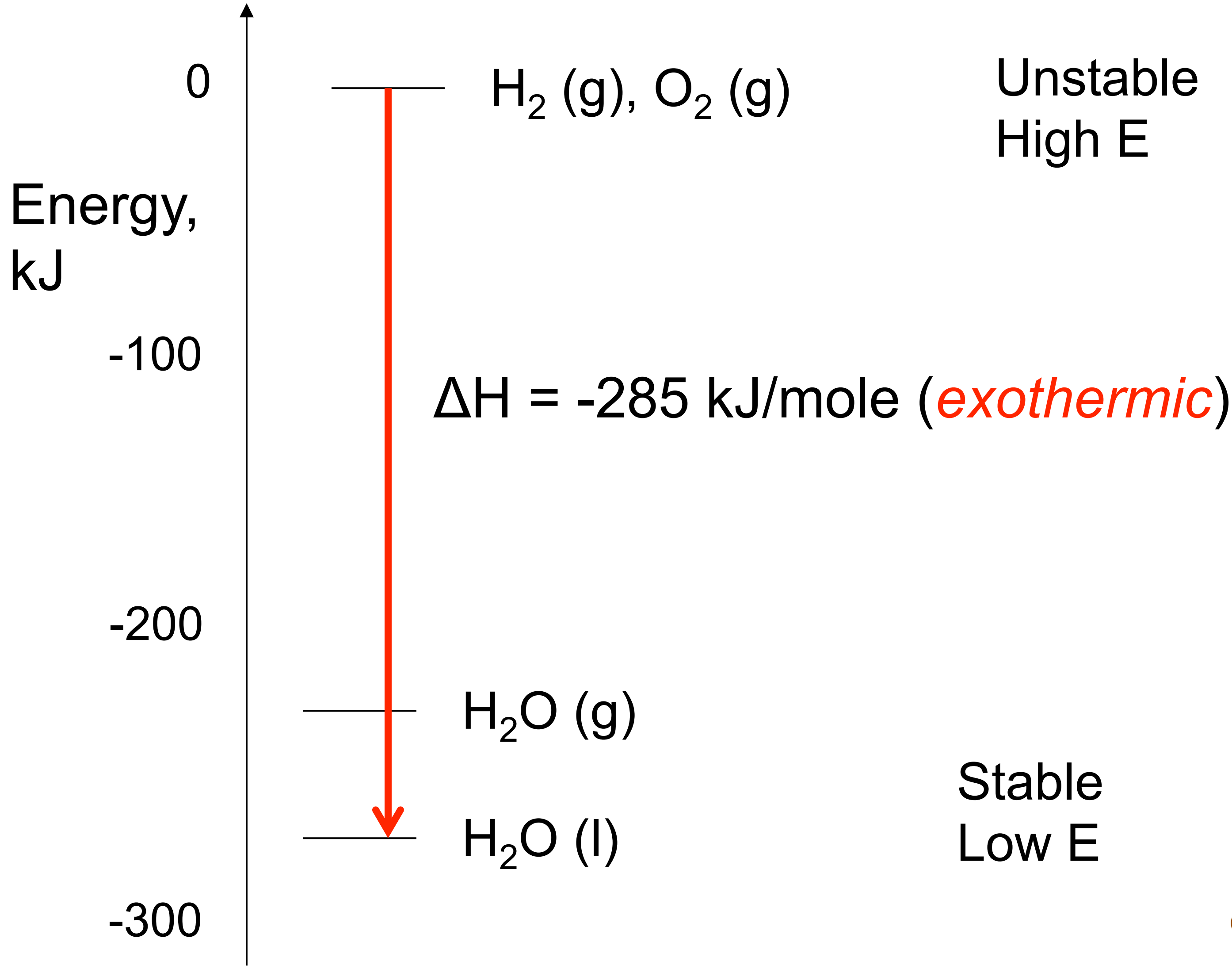
$$= [\ (2)(-285)\ ] - [\ (2)(0) + (1)(0)]$$

$$= -570\ \text{kJ}$$

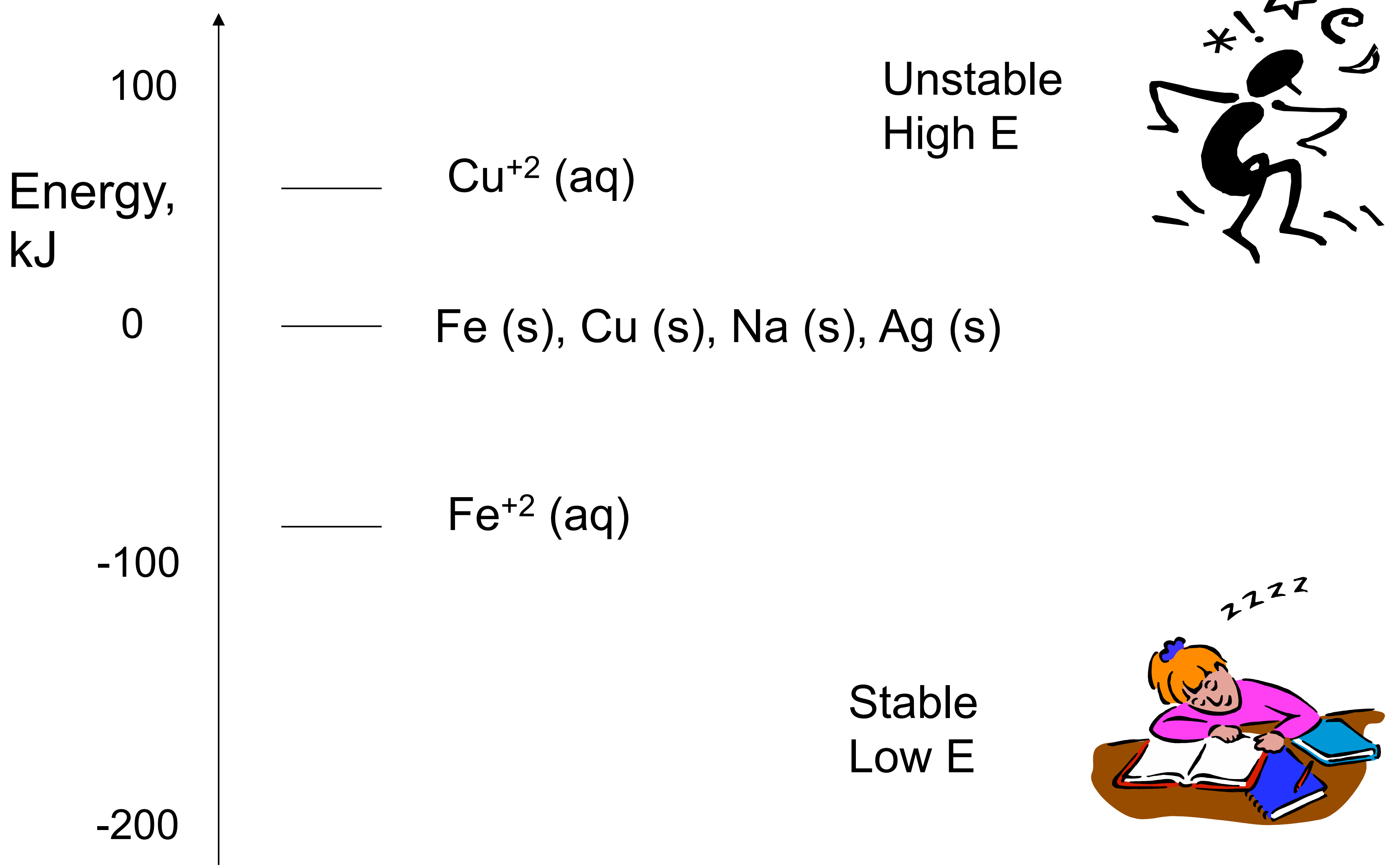
When 2 moles of water (l) are formed, 570 kJ is released.

When 1 mole of water (l) is formed, _______ kJ is released.

Formation of H_2O: H_2 (g) + O_2 (g) --> H_2O (l)

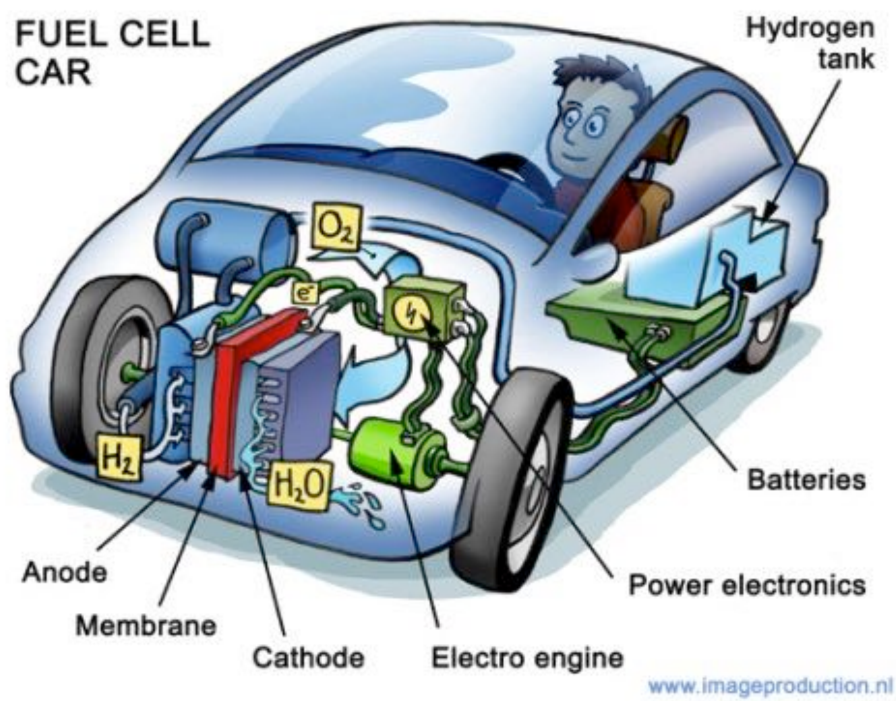


Formation of Metal Ions: M (s) --> M^+ (aq) + e^-



Activity of Metals: Why does Fe rust and Cu does not?

Hydrogen is the fuel of the 21st century



http://barryonenergy.wordpress.com/2013/04/05/hydrogen-fuel-cell-breakthrough/

What type of reaction occurs when H_2 is used as a fuel?

Write a chemical equation that represents this reaction.

Is energy absorbed or released in this reaction?

Chem 1A Reactions: **predict products**

1. Double replacement
    - Precipitation
    - Acid-base
    - Gas forming

2. Single replacement
    - Oxidation-reduction

3. Combustion
    - Fuel reacts with oxygen. Energy is produced.
    - $H_2 + O_2 \rightarrow H_2O$ + energy
    - carbon based (fossil) fuel + $O_2 \rightarrow H_2O + CO_2$ + energy

Lab 7. Natural Gas is Used in Bunsen Burners

What is natural gas? Write a chemical equation that represents the combustion of natural gas.

The color of the flame tells you which reactant is the limiting reactant.

http://fineartamerica.com/featured/2-bunsen-burner-flame-.html

http://www.instructables.com/id/Bernoullis-Principle/step12/Practical-Applications-Bunsen-Burner/

How do you adjust the amount of reactant that reacts in a Bunsen burner?

Use these ***Heat Equations*** in calculations:

Heat gained by cold object = - Heat lost by hot object

For physical heat transfer: $q = m\ s\ \Delta T$

For chemical heat transfer: $q = \Delta H$

ΔH for a chemical reaction: Hess' law

Look up $\Delta H_{formation}$ in Appendix.

<u>Lab 7</u>. *Alcohol Is Used As A Fuel*

Bring an empty 0.5 liter plastic water or soda bottle to lab.

+

----> ??

http://becuo.com/empty-plastic-water-bottle

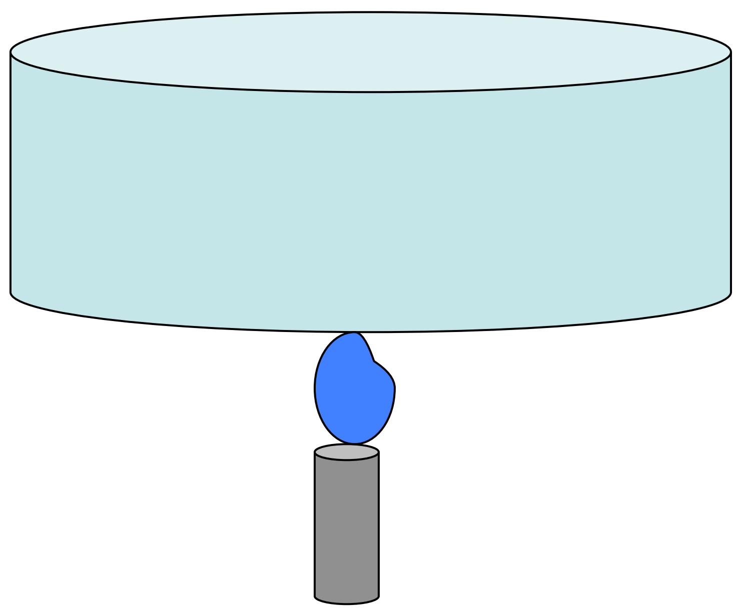
https://hif.wikipedia.org/wiki/Ethanol

How much energy is produced when 1 g of C_2H_5OH burns?

***Lab 7*. Alcohol Is Used As A Fuel**

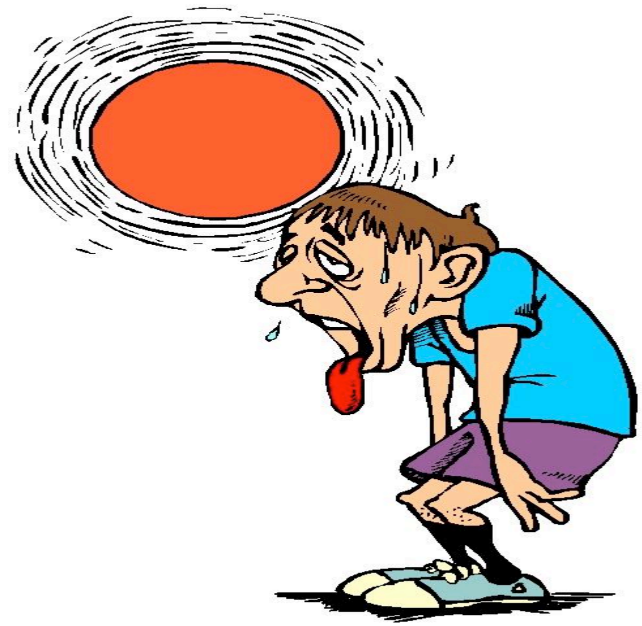
a. 1 g of alcohol is burned to heat up water. Calculate the volume of water that can be heated from 25^{o}C to 90^{o}C when 1 g of alcohol burns.

b. You want to heat up 1 liter of water from 25^{o}C to 90^{o}C. Calculate the mass of alcohol that will heat up the water.



1. a. Is heat absorbed or released when water vaporizes to steam?
b. Is heat absorbed or released when steam condenses to water?
c. Is the same amount of heat involved in each phase change?
d. Calculate ΔH of reaction of H_2O (l) → H_2O (g).
e. When steam condenses, what is ΔH?

2. You are really hot. You pour 1 liter of water on your head to cool off.
Calculate the heat loss from your body.
s of $H_2O(l)$ = 4.18 J/g °C
s of $H_2O(g)$ = 2 J/g °C



http://guysandgoodhealth.com/2012/06/28/what-to-do-if-you-get-overheated/

McDonald’s was sued by a customer who claimed she was very badly burned when she spilled a hot cup of coffee on herself.

See Practice Problem 2

http://www.clipartguide.com/_pages/1552-0906-3020-1509.html

a. 1 cup of water is heated from 25^{o}C to 100^{o}C. Calculate heat.

b. 1 cup of water at 25^{o}C is boiled. Calculate heat.

c. Explain why being burned by steam is much worse than being burned by hot water.

A Chemical Reaction ***Releases/Absorbs*** Heat in a ***Hot/Cold Pack***

http://www.bcfirstaidcourses.com/sfa/home.php?cat=372

http://www.bpmedicalsupplies.com/category.sc?categoryId=40

Can NaCl be used in a hot pack or cold pack?

If a hot pack, how much NaCl is used to heat 50 ml of water from 25^{o}C to 40^{o}C.
If a cold pack, how much NaCl is used to cool 50 ml of water from 25^{o}C to 0^{o}C?

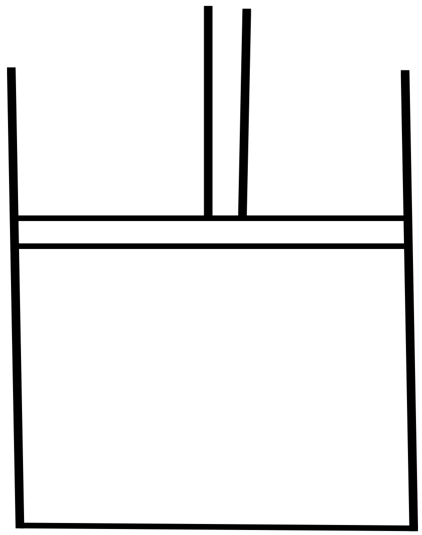
Can NaCl be used in a hot pack or cold pack? **Cold pack**

If a cold pack, how much NaCl is used to cool 50 ml of water from 25^{o}C to 0^{o}C? **73.9 g NaCl**

1. *Chemical Equation*: NaCl (s) --> Na^{+} (aq) + Cl^{-} (aq)
2. *Calculate ΔH* of reaction using Hess' law: **ΔH = 4.14 kJ/ mole**
3. Use *sign of ΔH* to determine use in hot or cold pack.
   ΔH > 0 ==> cold pack, ΔH < 0 ==> hot pack
4. Use *heat gained by* _____ = *-heat lost by* _______
   ΔH of NaCl dissolution > 0 (***endo***) ==> **cold** pack
   heat gained by NaCl chem rxn = - heat lost by water
   ΔH x moles of NaCl = - m_w s_w (T_f -T_i)
   Solve for moles of NaCl ==> convert to g of NaCl.
5. *Check solubility* of NaCl in water.

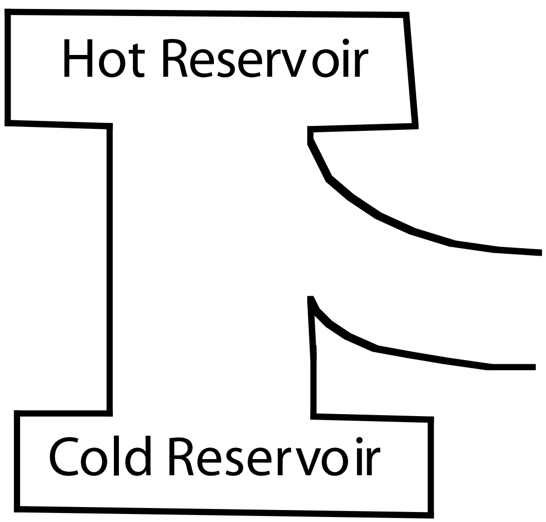
<u>Lab 7</u> Make a HOT/COLD Pack from ionic compounds:
LiCl, KCl, $CaCl_2$, NH_4NO_3, KNO_3, $NaNO_3$, $MgSO_4$, $CaSO_4$

- For each salt, calculate ΔH of dissolution.
- Is the salt used in a hot pack or cold pack?
- Calculate mass of salt to use for hot/cold pack.
- Calculate cost of hot/cold pack.
- Determine safety. See NFPA Rating or Saf-T Rating.
- Choose 2 salts each for hot/cold pack based on cost and safety.
- Test performance: Does hot pack T rise to 40^{o}C and stay there for 10 min? Does cold pack T drop to 0^{o}C and stay there for 10 min?
- Choose one salt for hot/cold pack based on cost, safety, and performance.



Objective: know how a heat engine works

What is the source of gas in a car engine?
What causes the gas to expand?



What happens in the hot reservoir?
How is heat converted to work?
Is all of the heat converted into work?

Efficiency = output/input.
What is the efficiency of a heat engine? Relate q to w.

Heat Engines Produce Heat in a ***Combustion Reaction***

Cars run on gasoline. The major component of gasoline is ***octane***, C_8H_{18}.
What is the heat of combustion of octane in kJ/mole?
What is the heat of combustion of octane in kJ/g?

Some cars run on ***Ethanol***, C_2H_5OH.
What is the heat of combustion of ethanol in kJ/mole?
What is the heat of combustion of ethanol in kJ/g?

Some cars run on natural gas, CH_4 (***methane***).
What is the heat of combustion of methane in kJ/mole?
What is the heat of combustion of methane in kJ/g?

Which fuel stores the most energy?

Table. Fuel Comparison

Fuel	Formula	Molar Mass	ΔH, kJ/mole	ΔH, kJ/g
Methane	CH_4	16	-802	-50.1
Ethanol	C_2H_5OH	46	-1234	-26.8
Octane	C_8H_{18}	114	-5074	-44.5

Heat Engines Produce Work from Heat

Work is the Ability to Move Matter

Physics: $w = f \cdot d$

<u>Chemistry</u>: $w = - p \Delta V$

<u>Work</u> involves ***<u>Gases</u>***

https://play.google.com/store/apps/details?id=sp.app.myWorkClock

Gas ***<u>Expands</u>*** ==> $\Delta V > 0$ ==> $w < 0$ ***<u>Work Produced</u>***
Work Done by Gas

<u>Example</u>: gas expands in explosion

<u>Gas</u> **<u>Expands</u>** in car **<u>Engine</u>** ==> ***<u>Work Produced</u>***

Gas ***<u>Contracts</u>*** ==> $\Delta V < 0$ ==> $w > 0$ ***<u>Work Supplied</u>***
Work Done on Gas

<u>Example</u>: gas contracts in compressor

Objective: Calculate Work in a Chemical Reaction
e.g., butane (C_4H_{10}) combustion

a. Write chemical equation.

$$1\ C_4H_{10}\ (g) + 6.5\ O_2\ (g) \rightarrow 4\ CO_2\ (g) + 5\ H_2O\ (g)$$

b. Compare moles of gas reactants to gas products.

7.5 moles of gas reactants 9 moles gas products

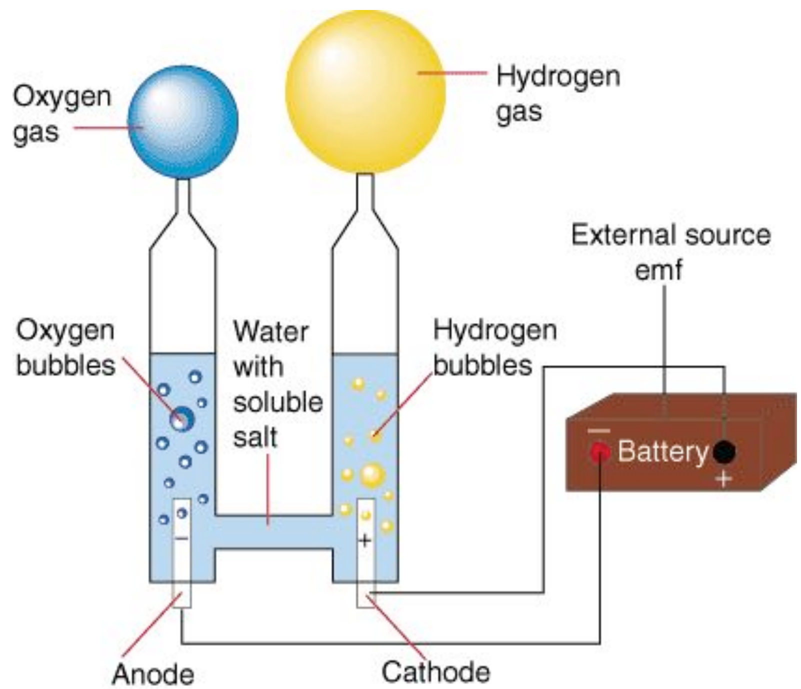
c. Is $\Delta n > 0$, < 0, or $=0$?

$$\Delta n = n_f - n_i = 9 - 7.5 = 1.5 \text{ moles}$$

If $\Delta n > 0$, then $\Delta V > 0$ ∴ w is < 0 (work is produced)
If $\Delta n < 0$, then ΔV is _____ ∴ w is ____ (work is _________)

Butane combustion reaction Produces Work!

Octane is the major component of gasoline.
Hydrogen is the fuel of the 21st century.
(i) Is work produced in the octane combustion reaction?
(ii) Is work produced in the hydrogen combustion reaction?
(iii) Which fuel is better for a car engine?



http://atom.smasher.org/gas-station/

http://www.instructables.com/id/Separate-Hydrogen-and-Oxygen-from-Water-Through-El/

Fossil Fuels are Burned For Energy
WE Use A Lot Of Fossil Fuels

Gasoline for our cars: octane number

- 2007: World oil demand = 85 million barrels/day

- US oil demand = 20 million barrels/day,
  approximately 10 million barrels/day for gasoline
  141 billion gallons gas/year

- SJ Mercury News, 11/9/07: 32 million registered cars in CA.

- California = 16 billion gallons gas/year

Fossil Fuels are Burned For Energy
WE Use A Lot Of Fossil Fuels

Engine Friction consumes 10% of a car's or truck's fuel:

≈ 1.4 million barrels of oil wasted per day in U.S.

≈ $31 billion worth of petroleum lost in automobile engines every year (at $60 per bbl).

Reduce friction losses ==> significant savings in fuel consumption

Tribology: study of friction (in mechanical engineering field)
http://cen.acs.org/articles/88/i41/Fighting-Friction.html

What is in the Cost of a Gallon of Gasoline?

2/3 to crude oil suppliers

12% to refining costs (crude oil processing, oxygenate additives, product shipment, storage, brand advertising) and profits

9% to distribution, marketing, and retail costs (franchise fees, rents, wages, environmental fees, credit cards fees, insurance costs, billboard, TV, and newspaper ads)

12% to taxes (federal and state)

http://atom.smasher.org/gas-station/

http://www.marketplace.org/topics/world/numbers/will-instability-iraq-flow-pump

Objective: do a chemical calculation

Calculate how much CO_2 goes in the atmosphere from cars.

Fossil Fuels Produce CO_2 ==> ***Global Warming***

Calculate the mass of CO_2 produced when 1 gallon of octane burns.

352 g 1031 g 8250 g 10 kg

Estimate the mass of CO_2 that goes into the Earth's atmosphere per day from cars.

Smog Check Vehicle Inspection Report (VIR)

Test Date: 12/21/05

1988 Honda Prelude

Idle Emission Test Results

Test	RPM	CO_2 MEAS, %	O_2 MEAS, %	HC MAX, ppm	HC AVE, ppm	HC MEAS, ppm	CO MAX, %	CO AVE, %	CO MEAS, %	Results
Idle	738	14.50	0.40	120	29	96	1.00	0.10	0.18	?
2500 RPM	2264	14.50	0.30	140	20	24	1.00	0.10	0.30	?

MAX = Maximum Allowable Emissions AVE = Average Emissions For Passing Vehicles MEAS = Amount Measured

Did this vehicle pass the Smog Check?

YES NO

2006: 24 billion metric tons of annual anthropogenic CO_2 emissions (CEN, 4/30/07, p. 11)

What Can We Do With Carbon Dioxide?

Convert CO_2 into fuels and other value-added products:

CO_2 + urea ----> nitrogen fertilizers

CO_2 + salicylic acid as a pharmaceutical ingredient

polycarbonate-based plastics

Solvent: supercritical CO_2 (the state existing at 31.0 °C and 72.8 atm) offers advantages in terms of stereochemical control, product purification, and environmental issues for synthesizing fine chemicals and pharmaceuticals

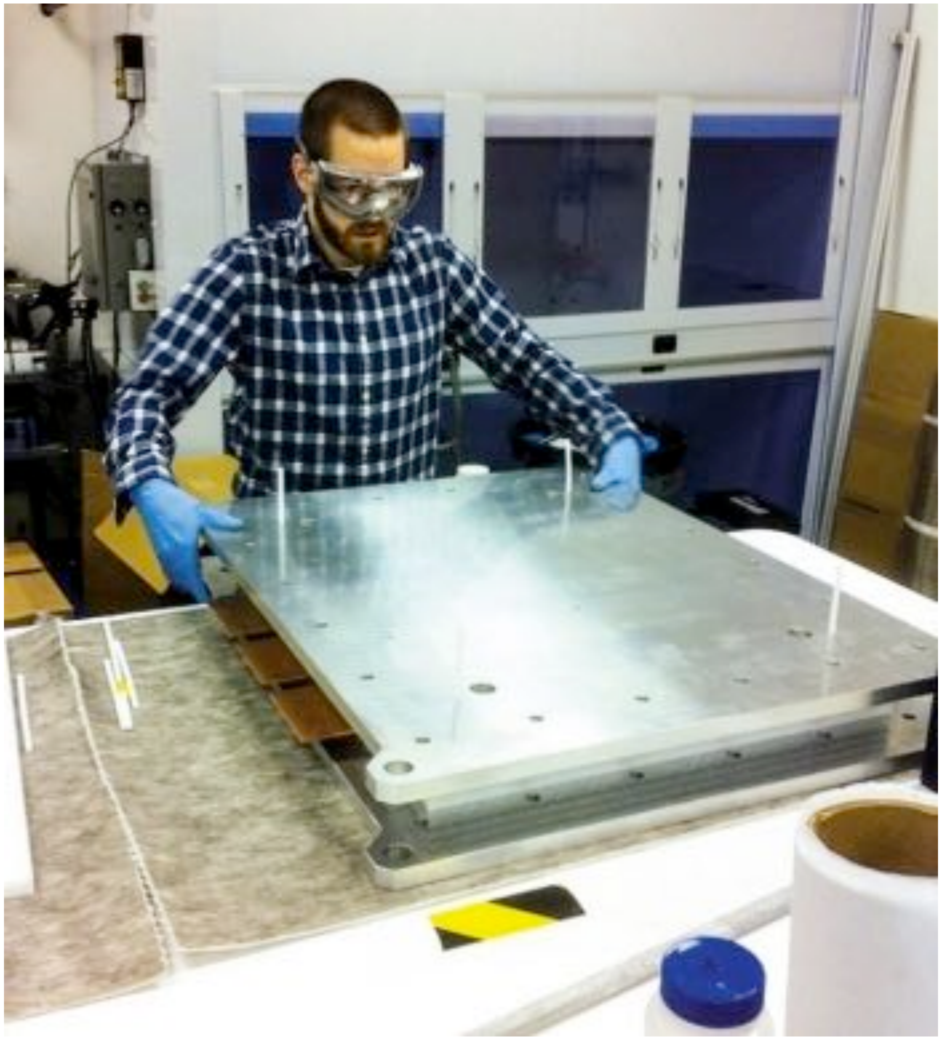
CO_2 can be sequestered by:

Trees = 1 tree absorbs 26 lb of CO_2 per year (CEN, 8/27/07, p. 3 Letter)

Underground Storage (CEN, 9/24/07, p. 74)

C&EN, 6/2/14, p. 5 (http://cen.acs.org/articles/92/i22/Waste-Gases-Power-Chemical-Start.html)

Start-ups Use Waste CO_2 to Make Chemicals



Skyonic (Austin, TX):
$CO_2 \rightarrow$ HCl and $CaCO_3$

Liquid Light (NJ):
$CO_2 \rightarrow$ ethylene glycol

Newlight Technologies (CA):
CO_2 and $CH_4 \rightarrow$ polymers

A Liquid Light employee assembles an electrocatalytic cell that makes ethylene glycol from CO_2.

A Combustion Reaction Occurs Inside Us

We use Fuel to provide energy for our body.

$$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O$$

We exhale greenhouse gases.

How much energy is produced when 1 g of $C_6H_{12}O_6$ burns?

http://knowyourmeme.com/memes/events/burning-man

http://www.mealsonwheelswest.org/the-nutritional-value-of-corn/

Corn use in U.S.:

1/3 to feed livestock
13% exported (most to feed livestock)
40% to produce ethanol
Rest for food and beverages
http://www.nytimes.com/2012/07/31/opinion/corn-for-food-not-fuel.html?_r=0

Ethanol, C_2H_5OH, is a fuel used in sternos and is used as a fuel additive (see Flex fuels).

a. When ethanol burns, is work produced? Give reasons.

b. 2 g of ethanol is burned to heat up 2 cups of water at 25^{o}C. Calculate the final temperature of the water.

MAKING CELLULOSIC BIOFUELS

Renewable Fuel Standard goal for 2012 production[a]:
500 million gal

Estimated 2012 actual production:
25 thousand gal

U.S. capacity on-line in 2013:
75 million gal

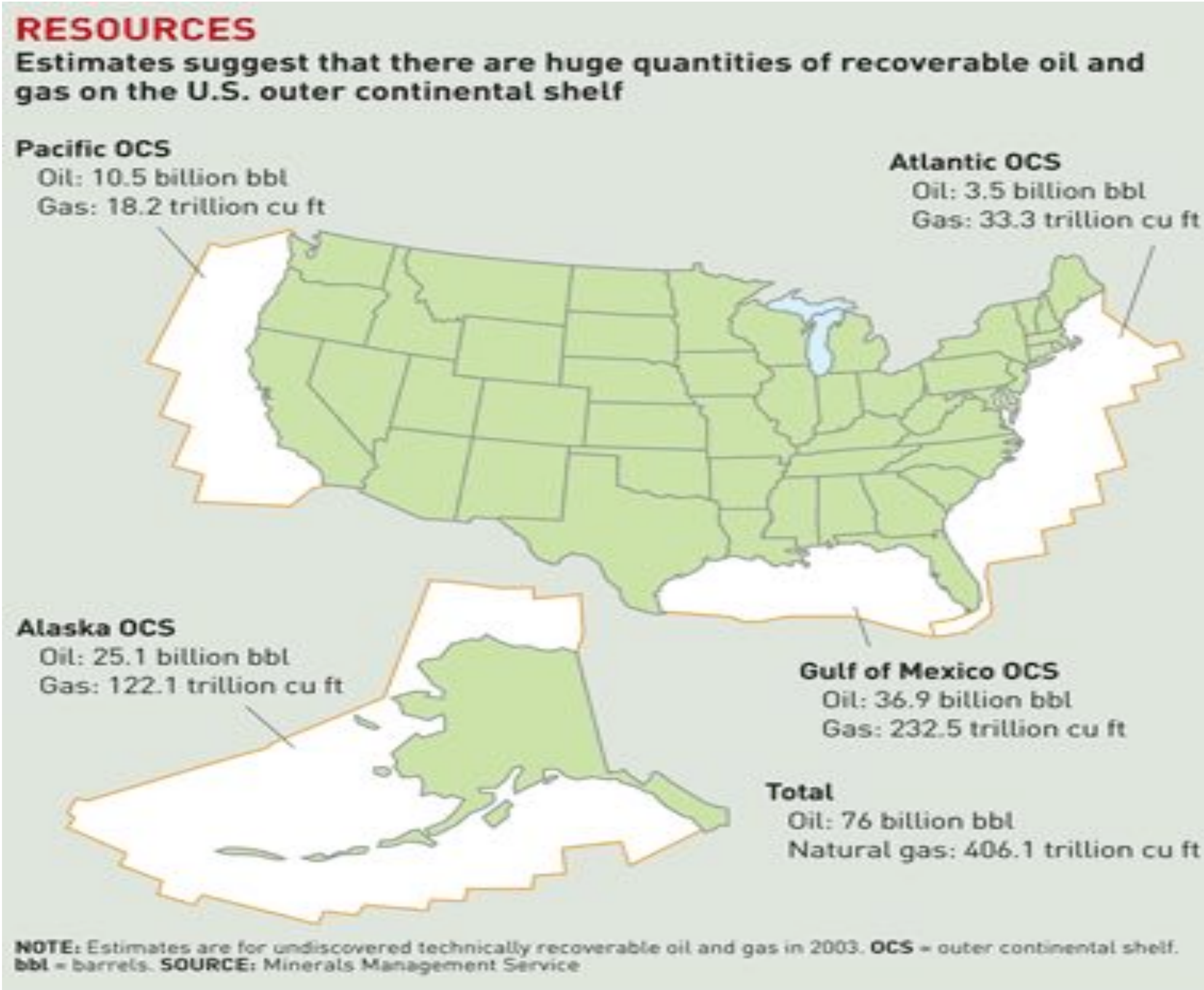
To make 25 million gal ethanol requires[b]
285,000 tons of corn stover collected from
445 square miles of cropland or
250,000 tons of corn harvested from
96 square miles of cropland

One acre of cropland can produce
80 gal of cellulosic ethanol and
400 gal of corn ethanol

a As required by the Energy Independence & Security Act of 2007.
b Assumes 1 dry ton of stover collected per acre.

SOURCES: Energy Information Administration, company information

http://cen.acs.org/articles/91/i4/Building-New-Biofuels-Industry.html



CEN, October 3, 2005, pp. 31–34 Rethinking Energy Policy

<u>Hydraulic Fracturing</u> (Fracking) pumps ***millions*** of gallons of treated water and sand into the ground at extremely high pressure to generate fractures or cracks in shale rocks to release natural gas.

Year	% of U.S. natural gas from shale rock
2000	1
2010	20
2035	50

"***Most significant energy innovation of this century***"

U.S. now has about 2,074 trillion cu ft of technically recoverable natural gas resources—enough to meet domestic demand for more than a century at the current rate of consumption.

http://cen.acs.org/articles/88/i22/Drilling-Process-Draws-Scrutiny.html

Water is 98-99% of fracking fluid.

CHEMICAL COCKTAIL

Hydraulic fracturing for natural gas employs numerous compounds

COMPOUND	PURPOSE
Acids	Help dissolve minerals and initiate fissure in rock
Ammonium bisulfite	Removes oxygen from water to protect pipes from corrosion
Borate salts	Maintain fluid viscosity as temperature increases
Citric acid	Prevents precipitation of metal oxides
N,N-Dimethyl formamide	Prevents pipe corrosion
Ethylene glycol	Prevents scale deposits in pipes
Glutaraldehyde	Eliminates bacteria in water
Guar gum	Thickens water to suspend sand
Isopropyl alcohol	Increases the viscosity of fracture fluids
Petroleum distillates	Slick water to minimize friction
Polyacrylamide	Minimizes friction between fluid and pipe
Potassium chloride	Creates a brine carrier fluid
Sodium chloride	Allows a delayed breakdown of gel polymer chains

NOTE: Companies use proprietary mixes of chemical additives that include a subset of those listed. **SOURCE:** Energy In Depth

http://cen.acs.org/articles/87/i33/Drilling-Chemicals.html
http://cen.acs.org/articles/88/i22/Geochemistry-Hydraulic-Fracturing-Fluid-Chemical.html

http://cen.acs.org/articles/90/i16/Methane-New-FrackingFiasco.html

4/16/12, CEN, p. 34 "Methane: A New 'Fracking' Fiasco"

The flood of natural gas production is hoped to slow climate change, but it might just make it worse

Oil and gas production is the largest source of man-made methane emissions.

1st 12 years in the atmosphere, methane is 72 times more potent a greenhouse gas than CO_2.

1st 100 years in the atmosphere, methane is 21 times more potent a greenhouse gas than CO_2. (Source: the Intergovernmental Panel on Climate Change)

But CO_2 makes up 82% of annual U.S. anthropogenic greenhouse gas emissions, and CH_4 makes up 9%. (Source: Energy Information Administration (EIA))

Natural Gas (fossil fuel) **is used for heating and cooking**

1 therm = 100,000 Btu = 105.4804 MJ

PG&E rate = $1.10/therm

Calculate the mass of methane burned to produce 1 therm. (Hint: $\Delta H_{combustion}$ of CH_4 = -802 kJ/mole)

1 g 1000 g 2000 g

Electricity is Used for heating and cooking, lights, etc.

1 kW hr = 3.6×10^6 J = 3.6 MJ = 0.034 therm

PG&E rate = $0.165/kW hr

Is Electricity cheaper than Natural Gas?

YES NO

Methane, CH_4, is the fuel in natural gas.
a. Calculate the heat of combustion of methane.
b. Is work produced in the methane combustion reaction?
c. 1 g of methane burns to heat up 1 cup of water at 25°C. Calculate the final temperature of the water.

http://www.diylife.com/2008/06/03/troubleshoot-your-stove/

T_f = 50°C 75°C 100°C

<u>Strategy</u>:
a. Write chemical equation. Apply Hess' law
b. Compare moles of gas reactants to gas products. Is $\Delta n > 0$, < 0, or $=0$?
If $\Delta n > 0$, then $\Delta V > 0$ ∴ w is < 0 (work is produced)
If $\Delta n < 0$, then ΔV is _____ ∴ w is ___ (work is ________)
c. Use heat equations

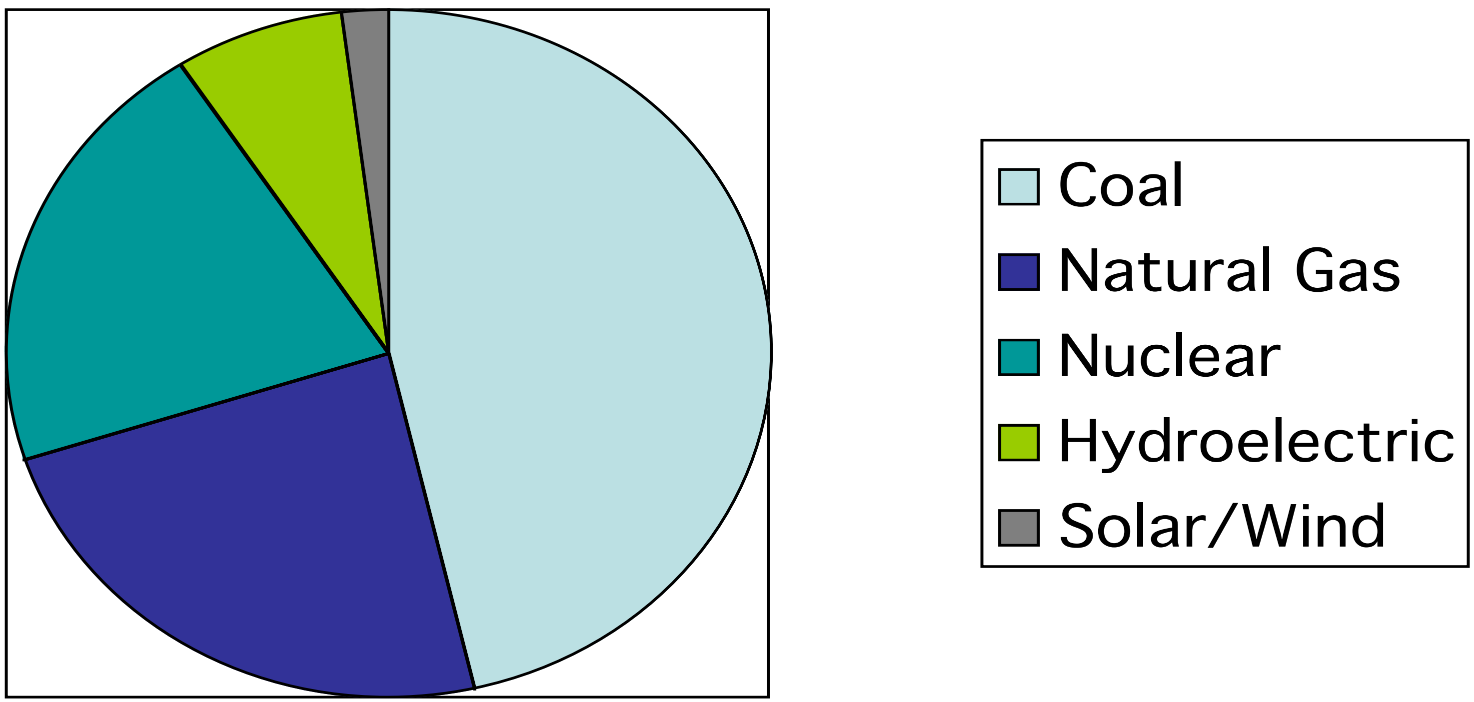
Where does electricity come from?

3.95×10^{12} kW hr   45% Coal   23% Natural gas

20% Nuclear   7% Hydroelectric   < 2% Solar/wind

Reference: http://www.eia.gov/totalenergy/data/annual/index.cfm -2009

Where does the electricity come from for an electric car?



Where does Electricity Come From?

UPSTART

China is ramping up alternative energy in addition to coal

ELECTRICITY GENERATION CAPACITY, GIGAWATTS	2007	2015	2020	2035
U.S.				
All types	**995**	**1,069**	**1,082**	**1,216**
Coal-fired	313	325	326	337
Wind	16	64	64	69
Solar	1	1	1	1
CHINA				
All types	**716**	**1,021**	**1,242**	**1,924**
Coal-fired	496	625	750	1,233
Wind	6	39	63	130
Solar	0	4	6	6
WORLD				
All types	**4,428**	**5,005**	**5,470**	**7,009**
Coal-fired	1,425	1,545	1,671	2,366
Wind	93	277	347	486
Solar	8	45	53	64

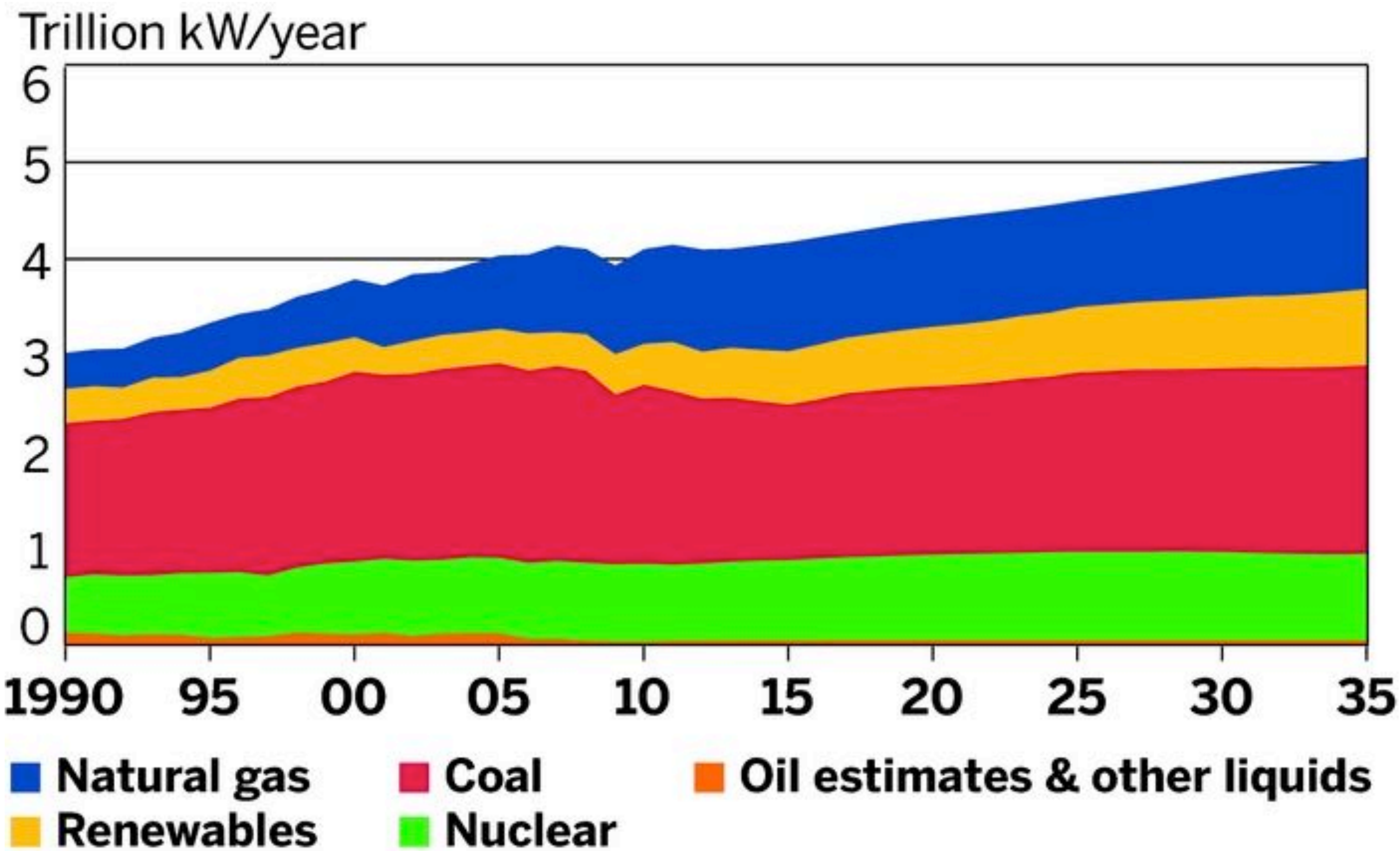
SOURCE: DOE, International Energy Outlook 2010

http://cen.acs.org/articles/88/i40/Chemistry-Energizes-China.html

Electricity generated with natural gas (from fracking) is expected to grow at coal's expense.

NOTE: Actual data for 1990–2010, estimates for 2011–35.

SOURCE: EIA, "AEO2012 Early Release Overview"



http://cen.acs.org/articles/90/i16/Methane-New-FrackingFiasco.html

Confirm or Refute:

“Natural gas emits about half the amount of CO_2 than coal for the same amount of energy produced.”

Confirm or Refute:

"Natural gas emits about half the amount of CO_2 than coal for the same amount of energy produced."

CH_4 (g) + 2 O_2 (g) → CO_2 (g) + 2 H_2O (g) + 802 kJ/mole

C (s) + 2 O_2 (g) → CO_2 (g) + 393 kJ/mole

Currently, on a global scale, **energy usage is on the order of 13 terawatts** (13 trillion W or 13 trillion joules per second), of which roughly **85% is generated by burning fossil fuels**. (CEN, 8/27/07, p. 16)

"MORE ENERGY—in the form of sunlight—strikes Earth in one hour than all of the energy consumed by humans in an entire year." -- Nathan Lewis, Cal Tech Chemistry Professor

Sun showers Earth with an energy flow of some 120,000 TW.

We need to Figure out a way to ***inexpensively convert sunlight to electricity***.

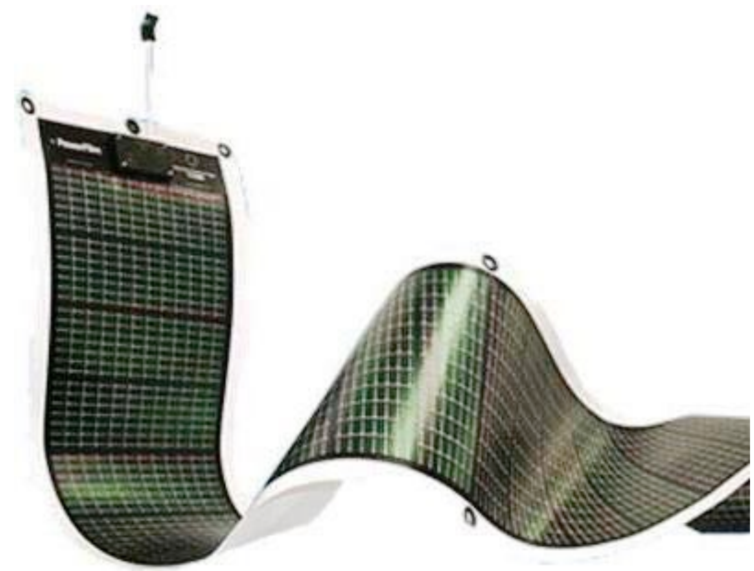
Solar Energy ≈ 0.125% of U.S. electricity (2008)

CEN, 10/20/08, p. 40

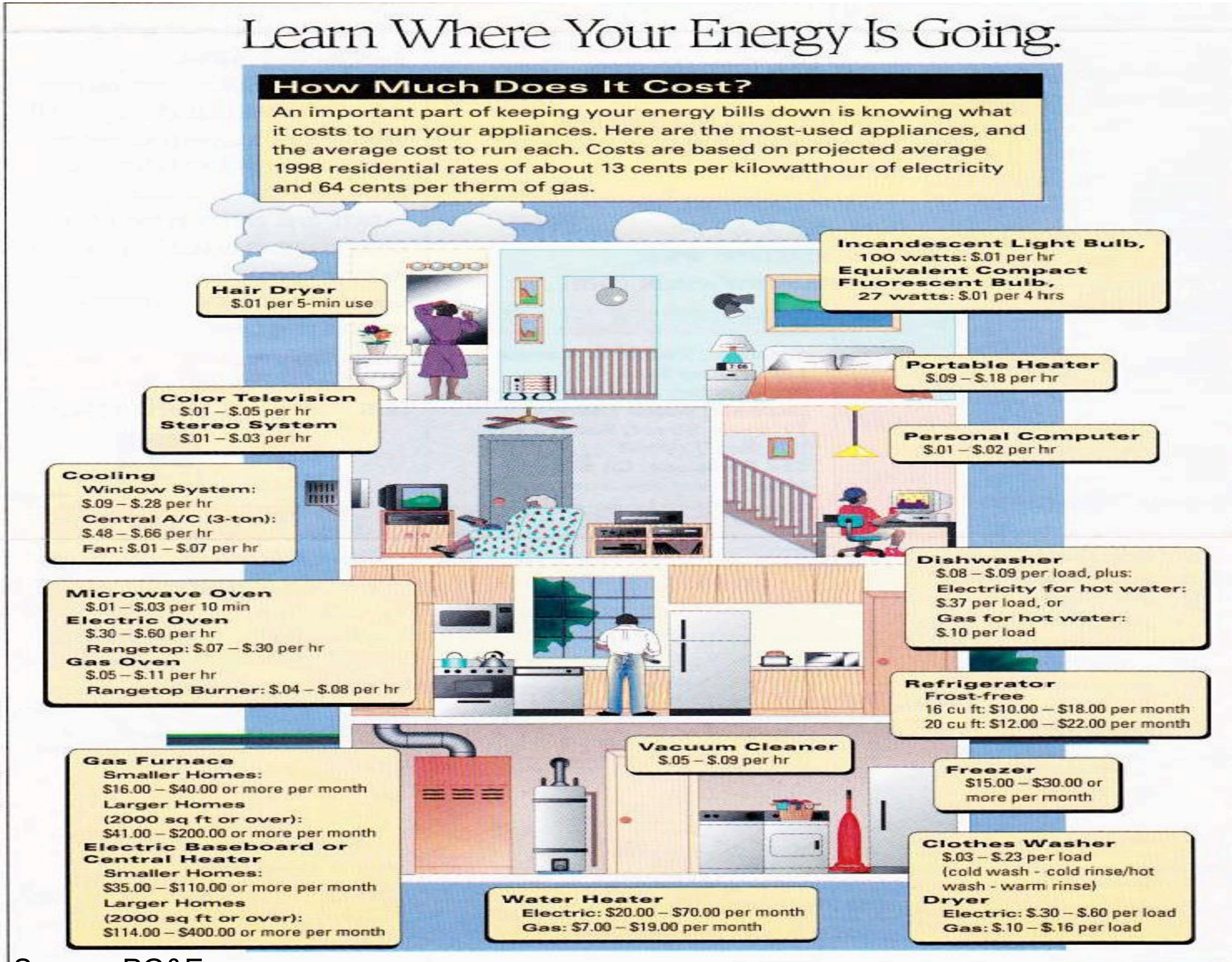
920 MW on Electric Grid = 500 MW photovoltaics + 420 MW concentrating solar power

2260 MW captured solar from solar calculators, road signs, pools,

Polysilicon solar cells
14% efficiency
http://www.topsky-tech.com/poly-silicon-solar-cell-tianwei-supplier.html

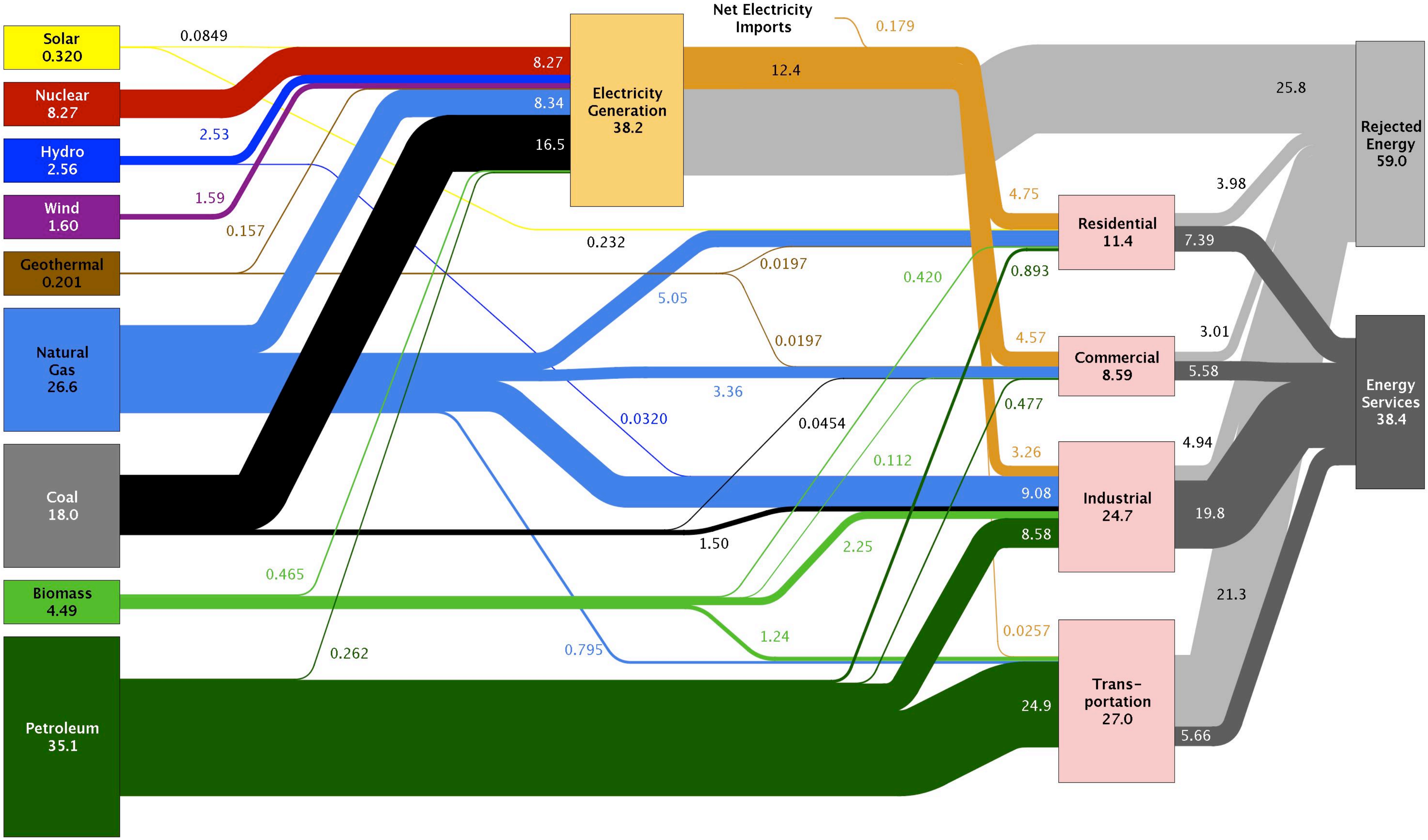


Thin Films
8% efficiency
http://www.circuitstoday.com/thin-film-solar-cell


Learn Where Your Energy Is Going.
How Much Does It Cost?
An important part of keeping your energy bills down is knowing what it costs to run your appliances. Here are the most-used appliances, and the average cost to run each. Costs are based on projected average 1998 residential rates of about 13 cents per kilowatthour of electricity and 64 cents per therm of gas.
Hair Dryer
$.01 per 5-min use
Incandescent Light Bulb, 100 watts: $.01 per hr
Equivalent Compact Fluorescent Bulb, 27 watts: $.01 per 4 hrs
Portable Heater
$.09 – $.18 per hr
Color Television
$.01 – $.05 per hr
Stereo System
$.01 – $.03 per hr
Personal Computer
$.01 – $.02 per hr
Cooling
Window System:
$.09 – $.28 per hr
Central A/C (3-ton):
$.48 – $.66 per hr
Fan: $.01 – $.07 per hr
Dishwasher
$.08 – $.09 per load, plus:
Electricity for hot water:
$.37 per load, or
Gas for hot water:
$.10 per load
Microwave Oven
$.01 – $.03 per 10 min
Electric Oven
$.30 – $.60 per hr
Rangetop: $.07 – $.30 per hr
Gas Oven
$.05 – $.11 per hr
Rangetop Burner: $.04 – $.08 per hr
Refrigerator
Frost-free
16 cu ft: $10.00 – $18.00 per month
20 cu ft: $12.00 – $22.00 per month
Vacuum Cleaner
$.05 – $.09 per hr
Freezer
$15.00 – $30.00 or more per month
Gas Furnace
Smaller Homes:
$16.00 – $40.00 or more per month
Larger Homes
(2000 sq ft or over):
$41.00 – $200.00 or more per month
Electric Baseboard or Central Heater
Smaller Homes:
$35.00 – $110.00 or more per month
Larger Homes
(2000 sq ft or over):
$114.00 – $400.00 or more per month
Clothes Washer
$.03 – $.23 per load
(cold wash - cold rinse/hot wash - warm rinse)
Dryer
Electric: $.30 – $.60 per load
Gas: $.10 – $.16 per load
Water Heater
Electric: $20.00 – $70.00 per month
Gas: $7.00 – $19.00 per month

Source: PG&E

Estimated U.S. Energy Use in 2013: ~97.4 Quads



Source: LLNL 2014. Data is based on DOE/EIA-0035(2014-03), March, 2014. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential and commercial sectors 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

https://flowcharts.llnl.gov/content/energy/energy_archive/energy_flow_2013/2013USEnergy.png

Washing Clothes in Cold Water vs. Using *Clothes Dryer*

Which uses less energy?

http://cen.acs.org/articles/89/i44/Cold-Facts.html

2011: 40% of U.S. laundry is washed in cold water.
4% of the energy consumed in the U.S. would be saved if all laundering were done in cold water (P&G calculation).
If everybody in the U.S. turned their washing machine dials from hot to warm and from warm to cold, reduce CO_2 by 16 million and 20 million tons per year.

81% of the electricity used to do laundry is consumed by the dryer

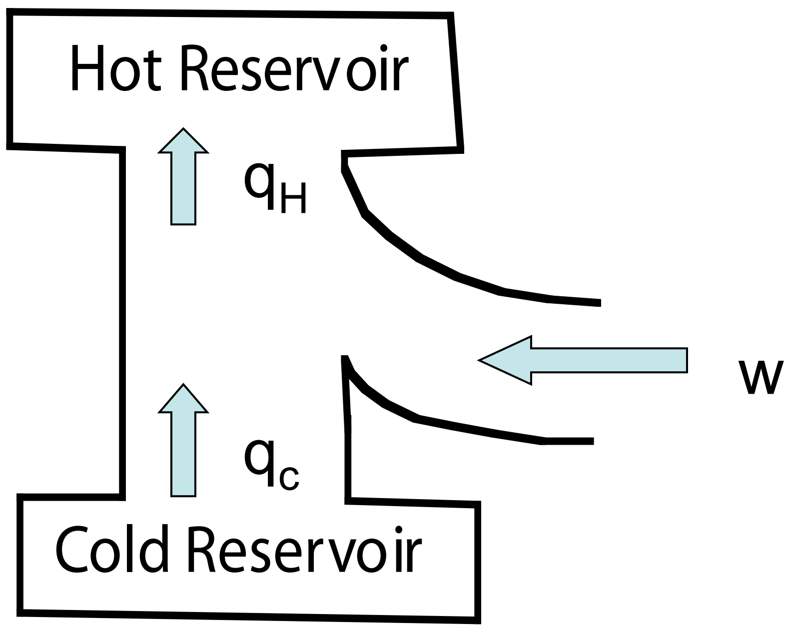
How to use the dryer less?

http://www.clotheslineshop.com/Merchant2/merchant.mvc?Screen=PROD&Store_Code=C&Product_Code=1600&Category_Code=OCI

Maximize water removal during the washing machine's spin cycle to reduce the amount of time clothes must spend in the dryer.

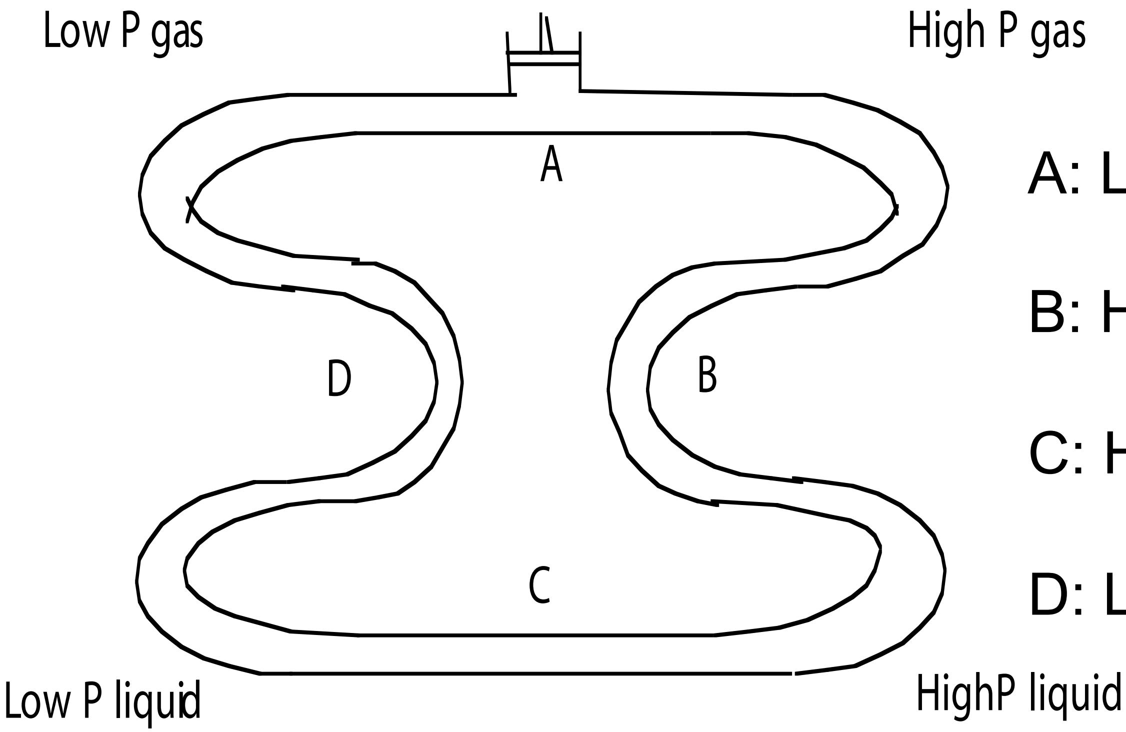
Objective: know how a refrigerator works

A Refrigerator is a Heat Engine in Reverse



Is work produced or supplied?
What part of the refrigerator is the cold reservoir?
How is work converted into heat ?

How Does a Refrigerator Work? http://home.howstuffworks.com/refrigerator3.htm



A: Low P gas --> High P gas

B: High P gas --> High P liq

C: High P liq --> Low P liq

D: Low P liq --> Low P gas

a. Determine q and w for each step.
b. Which step cools air inside the refrigerator?
c. Would you want the refrigerant to have a high boiling point or low boiling point? Give reasons.
d. Would you want the refrigerant to be compressible or incompressible? Give reasons.

1st Law of Thermodynamics states:

"Energy is converted from one form to another"
"Energy can't be created or destroyed"
"Energy is conserved"

$$\Delta E = q + w$$

Internal energy (E) can be converted into heat (q) or work (w) or both.

Internal energy (E) is a <u>state</u> (thermodynamic) function - property of a substance - contained in substances.

Heat and work are <u>path</u> (non-thermodynamic) functions - <u>not</u> a property of a substance - <u>not</u> contained in substances.

$q = m\ s\ \Delta T$ $\qquad\qquad$ $w = -\ p\ \Delta V$

When air is pumped into a bicycle tire, a *warming* effect at the valve stem occurs. The action of the pump compresses the air inside the pump and the tire. The process is rapid enough to be treated as an adiabatic process.

Apply the first law of thermodynamics to account for the warming effect. (Chang, “General Chemistry: The Essential Concepts”, 5th ed., 2008, p. 208, Problem 6.104 a and b.)

http://bikeacrossamerica.net/tour/11/safford-to-lordsburg.htm

Apply the first law of thermodynamics to explain how a snow making machine works. (Chang, "General Chemistry: The Essential Concepts", 6th ed., 2011, Problem 6.104 a.)