610-280 Environmental Chemistry

Rachel Caruso

Lectures 1-10

Tutorials

- NO TUTORIALS this week

References

- No set reference, recommendations to texts will be made during the course.

Environmental Chemistry

- is an interdisciplinary science that includes atmospheric, aquatic and soil chemistry as well as heavily relying on analytical chemistry.
- the study of the sources, reactions, transport, effects, and fates of chemical species in the air, soil, and water environments; and the effect of human activity on these.

Course Outline

- Dr Rachel Caruso (Energy/Soil)
- Assoc. Prof. Trevor Smith (Atmosphere/Water)
- SBL Introductory lecture – Scenario and group allocation

  Given lecture time for group work, report writing and presentations.
- Assoc. Prof. Spas Kolev (Contamination/Monitoring)
- Information and resources: LMS or www.chemistry.unimelb.edu.au/courses/200/610280.php

Handbook Entry for 610-280 Environmental Chemistry

On completion of 610-280, students should comprehend the relationship between chemistry and the environment: namely the sources, reactions, transport, effects and fates of chemical species in the water, soil and atmospheric environments; the consequences of changes in the chemical composition of the environment for humankind and other species; and the consequences of energy utilisation. Students should appreciate the need for the integration of a chemically centred study of the environment with other approaches to the treatment of environmental data, and have developed an appreciation of the role of environmental chemistry in a wider social context.

Students should have developed skills in recognising chemically based environmental problems, an awareness of the possible effects of chemicals on the environment and a capacity to interpret environmental data and to apply diverse chemical principles in the explanation of environmental phenomena. Students should appreciate the need for high quality environmental analysis, the links between the misuse of chemicals and pollution events, and the importance of selecting and utilising appropriate analytical methods and techniques for their monitoring. Students should understand the principles of the key analytical methods used in environmental chemistry.

Students will also develop skills in investigating contemporary environmental chemistry issues, a consideration of the wider context of these issues, generic skills in operating in small teams and an awareness of professional practice as a scientist.

The subject matter in 610-280 covers some or all of the following topics: emissions to the troposphere; behaviour of pollutants in the troposphere and stratosphere; ozone and SMOG chemistry; air pollution potential (chemistry and meteorology); airborne particulates; acid rain and the greenhouse effect; the ozone layer; the structure and chemistry of freshwater bodies; the chemistry of nutrients; dissolved oxygen, Henry's Law and oxygen demand; the environmental impact of selected examples of metals, organic priority pollutants, pesticides and herbicides; water quality and health; the chemistry of soils (formation, constituents and properties); sources and characteristics of soil contaminants; absorption and persistence of contaminants in soils; soil degradation, salinity and acid-sulphate soils; chemical assessment of contaminated soils; introduction to soil and water remediation, energy utilisation and conservation; and the most frequently used environmental monitoring instrumental analytical techniques. A key aspect will be the comprehensive investigation of a current environmental chemistry issue, which will be taught in a small-group, scenario-based learning mode.

610-280 Environmental Chemistry

Energy

Fossil Fuels: Coal, Petroleum, Natural Gas
Nuclear Fuel: Radiation, Fuel cycle, Waste
Solar Cells: Types, Working mechanism

Soil

Components, Composition, Charge
Contamination

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610-280 Environmental Chemistry

Energy – Fossil Fuels

• Energy sources, requirements
• Chemical Energy, exothermic/endothermic reactions
• Coal – types, combustion
• Petroleum, natural gas
• Environmental impact and related chemistry

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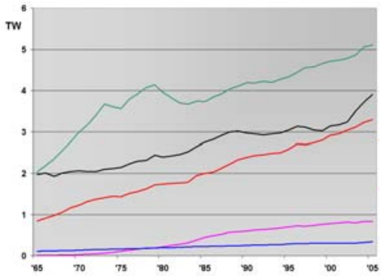
References

- www.worldcoal.org
- P. T. McTigue, Chemistry – Key to the Earth

We need Energy

Energy has become an essential part of our lives!

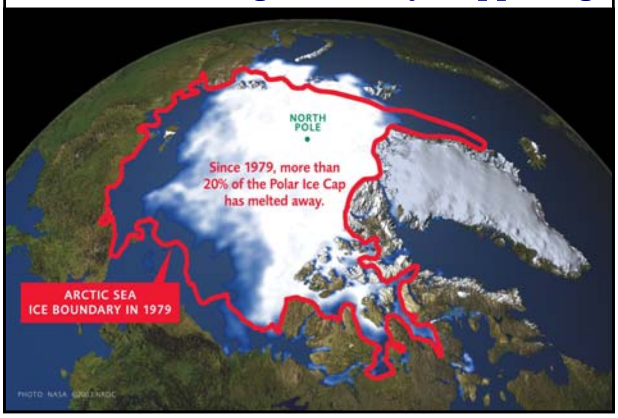


Victoria’s electricity sources:

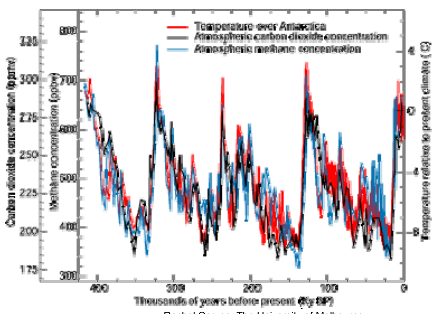
What energy source are we currently using the most to obtain electricity?

A. Coal
B. Hydro
C. Natural gas
D. Nuclear
E. Oil

Global Warming is Already Happening



CO_2 concentration



Global Carbon Budget

- Must reduce global CO_2 emissions by about 60% by 2050 and 80% by 2100
- 1990 global CO_2 emissions – 22,388 Mt p.a.
- By 2050 global CO_2 emissions must be reduced to 8,955 Mt p.a.

Photo: www.healthandenergy.com

Per person carbon budget

By 2050:

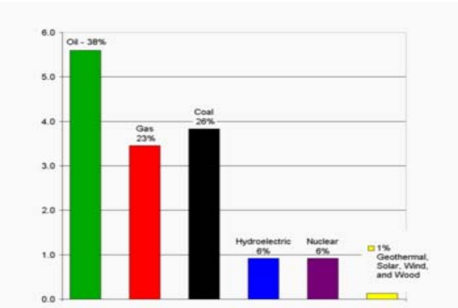
- projected world population is 8,938 million
- global CO_2 emissions must be reduced to 8,955 Mt p.a.
- Per person emissions should be reduced to 1.00 tonne per person

For Victorians

What is the solution?

- Conserve energy
- Capture pollution
- Cleaner energy sources

Energy Sources



World wide energy supply TW

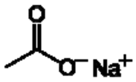
Chemical Energy

When chemical reactions occur heat can be released or absorbed.

- Exothermic reactions – release of energy
  Reactants → Products + heat
- Endothermic reactions – absorb energy from surroundings
  Reactants + heat → Products

An Exothermic Reaction

- Saturated sodium acetate solution

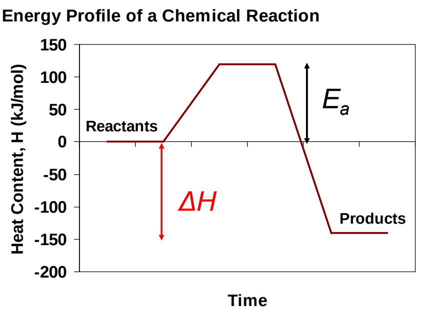


Sodium acetate

Movie: Amazing Rust Website

$Na^+(aq) + CH_3CO_2^-(aq) \rightarrow NaCH_3CO_2(s)$ + heat

Energy Profile



Magnesium

$2Mg + O_2 \rightarrow 2MgO \quad \Delta H = -1203.40\ kJmol^{-1}$

Pyrophoric Iron

The reaction of fine iron pieces with oxygen is also exothermic.

$\Delta H = -824.2\ kJmol^{-1}$ for the formation of $Fe_2O_3(s)$ or

$\Delta H = -1118.4\ kJmol^{-1}$ for the formation of $Fe_3O_4(s)$

Movie: Amazing Rust Website

Endothermic reaction

- Reactants + heat → Products

- Ammonium nitrate and water

$NH_4NO_3(s) + H_2O(l) + heat$
$\rightarrow NH_4^+(aq) + NO_3^-(aq)$

- Where does the heat come from?

Fossil Fuels

- Coal
- Oil
- Natural Gas

  - Cheap, readily available

Coal Output

Wikipedia

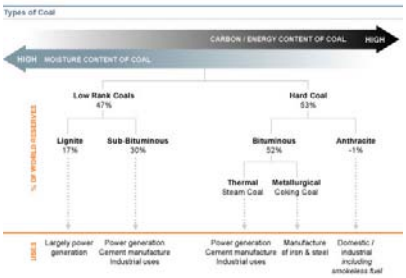
Coal Types

- Coal doesn't have a simple "molecular" composition, composition varies with type of coal:

By mass	% C	% O	% H
Wood	53	42	5
Peat	60	34	6
Lignite (brown coal)	67	28	5
Bituminous (black coal)	88	6	6

Key to the Earth

Coal Type - Energy

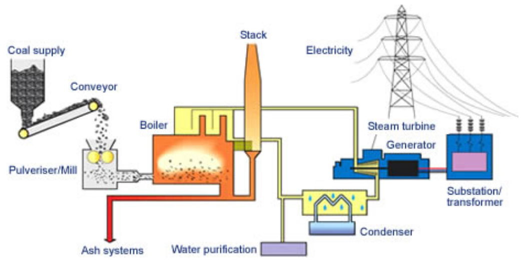


Worldcoal

Coal Type - Energy

	Water content (by weight %)	Heat of combustion (kJ g^{-1})
Wood	-	~ 18
Peat	80	~ 20
Lignite (brown coal)	33	~ 30
Bituminous (black coal)	10	~ 33

Electrical energy from coal



www.worldcoal.org

610-280 Environmental Chemistry Lectures, 2008
Rachel Caruso, The University of Melbourne

Coal Combustion

- Coal combustion: ~35 % thermodynamic efficiency

$$Coal + O_2 \rightarrow Tar + light\ HC + H_2O$$
$$Tar \rightarrow light\ HC + soot$$
$$Light\ HC + O_2 \rightarrow CO_2 + H_2O$$
$$C(s) + O_2\,(g) \rightarrow CO_2\,(g)$$
$$\Delta H = -393\ kJ\ mol^{-1}$$

- Coal also contains some N and S, so other by products of combustion are NO_x and SO_x.

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Post Combustion Capture

- http://www.australiancoal.com.au/cleantechAus.htm
- http://www.csiro.au/multimedia/pfug.html

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Fischer-Tropsch synthesis

Coal to "liquid fuel" (hydrocarbons)

- Coke – Carbon (coal with volatile organics removed by heating without air)

  $C\ (s) + H_2O\ (g) \rightarrow CO\ (g) + H_2\ (g)$
- Add more H_2 and metal/metal oxide catalysts:

  $5CO\ (g) + 11H_2\ (g) \rightarrow 5H_2O\ (g) + C_5H_{12}\ (g)$

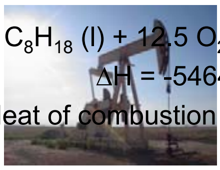
  $2CO\ (g) + 5H_2\ (g) \rightarrow 2H_2O\ (g) + C_2H_6\ (g)$

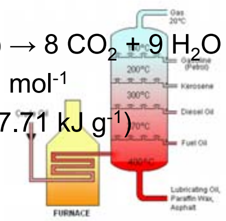
Note - source of hydrogen:

$C\ (s) + 2H_2O\ (g) \rightarrow 2H_2\ (g) + CO_2\ (g)$

Oil

- Crude oil – complex mix of hydrocarbons, generally use C_5H_{12} – $C_{16}H_{34}$ as fuels





- $C_8H_{18}\ (l) + 12.5\ O_2\ (g) \rightarrow 8\ CO_2 + 9\ H_2O$

  $\Delta H = -5464\ kJ\ mol^{-1}$

(Heat of combustion = $47.71\ kJ\ g^{-1}$)

Natural Gas

- Gaseous fossil fuel, primarily methane also containing ethane, propane, butane CO_2, nitrogen, helium, and hydrogen sulfide.

- $CH_4\ (g) + 2O_2\ (g) \rightarrow CO_2\ (g) + 2H_2O\ (l)$

  $\Delta H = -889\ kJ\ mol^{-1}$

(Heat of combustion = $55.64\ kJ\ g^{-1}$)

Environmental impact

- Acid mine drainage - Neutralization
- Air borne particulates from flue, Black lung (pneumoconiosis), - Electrostatic precipitators
- SO_x and NO_x – Desulfurizing and de-NO_x flue gas
- Oil spillage

Tinto River

Acid Mine Drainage

- Pyrite oxidation:

$2FeS_2$ (s) + $7O_2$ (g) + $2H_2O$ (l) → $2FeSO_4$ (aq) + $2H_2SO_4$ (aq)

$4FeSO_4$ (aq) + 10 H_2O (l) + O_2 (g) → $4Fe(OH)_3$ (s) + 4 H_2SO_4 (aq)

- Acid leaches into streams - plants & fish

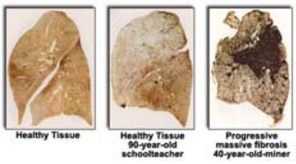
Neutralise by adding lime $Ca(OH)_2$ or limestone $CaCO_3$

eg. $CaCO_3$ (s) + H_2SO_4 (aq) → H_2CO_3 (aq) + $CaSO_4$ (aq)

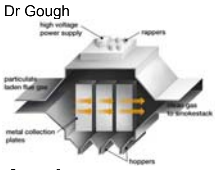
H_2CO_3 → H_2O + CO_2

Missouri Stream

Air borne particulates



Dr Gough



Powerspan Corp.

- Particulates – fine particles (s or l) suspended in gas
- Size range: 10 nm to > 100 µm
- Ventilation
- Filtration, electrostatic precipitators

SO_x

SO_2 is an acid gas

- Wet scrubbing using a $CaCO_3$ (limestone) slurry

  $CaCO_3$ (s) + SO_2 (g) → $CaSO_3$ (s) + CO_2 (g)
- Further oxidize the $CaSO_3$ to produce $CaSO_4.2H_2O$:

  $CaSO_3$ (s) + ½O_2 (g) + $2H_2O$ (l) → $CaSO_4.2H_2O$ (s)

De-NO_x

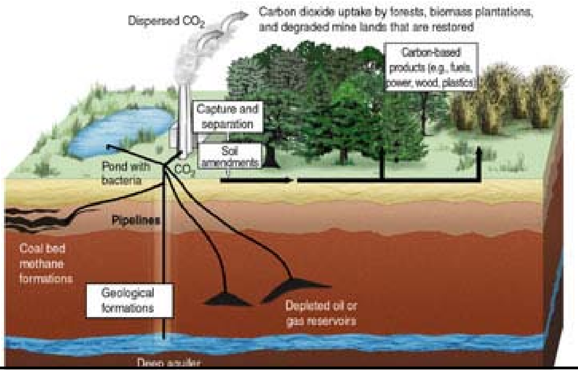
- React ammonia with NO_x
- Safer source: urea
- $NH_2CONH_2 + 2H_2O$ (steam) → $2\ NH_3 + CO_2 + H_2O$
- $4NH_3 + 3NO_2 \rightarrow 3.5\ N_2 + 6H_2O$

Oil Spill

- Leave, but monitor
- Disperse - surfactants
- Contain and recover (sorbents)
- Biodegradation/bioremediation
- Burn

www.earthsci.org

CO_2!



In summary

<u>Energy – Fossil Fuels</u>

- Chemical Energy – exothermic & endothermic reactions
- Coal – different types, heats of combustion, Fischer Tropsch synthesis
- Oil – C_5 to C_{18} HCs, fractional distillation, heat of combustion
- Gas – methane, heat of combustion
- Chemistry involved in clean-up of AMD, de-SO_x and de-NO_x reactions, oil spills