

COURSE “INTRODUCTION TO GREEN AND SUSTAINABLE CHEMISTRY”

Written exam - July 21, 2017 (part I)

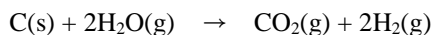
PLAGIARISM. The Course takes plagiarism very seriously. Cutting and pasting from an article or any another person's work is plagiarism, even if you cite them (the exception to this is quotations).

1) Analyze the material exchanges at Kalundborg Park as reported in the following table:

Material	From	To	Sold/free	Began	Quantity [T/yr]
Fuel gas (x-flare gas)	Statoil	Gyproc	sold	1972	8,000
Sludge	Novo Nordisk	1,000 farmers	free	1976	1,100,000
Fly-ash & clinker	Asnæs	Aalborg Portland	sold	1979	200,000
Steam	Asnæs	Kalundborg	sold	1981	225,000
Steam	Asnæs	Novo Nordisk	sold	1982	215,000
Steam	Asnæs	Statoil	sold	1982	140,000
Water (x-cooling)	Statoil	Asnæs	sold	1987	700,000
Hot sea water	Asnæs	Fish Farm	free	1989	?
Sulfur (liquid)	Statoil	Kemira	sold	1990	2,800
Water, biotreated	Statoil	Asnæs	free	1991	200,000
Fuel gas (x-flue gas)	Statoil	Asnæs	sold	1992	60,000
Gypsum	Asnæs	Gyproc	sold	1993	85,000
Total annual quantity:					2.9 million

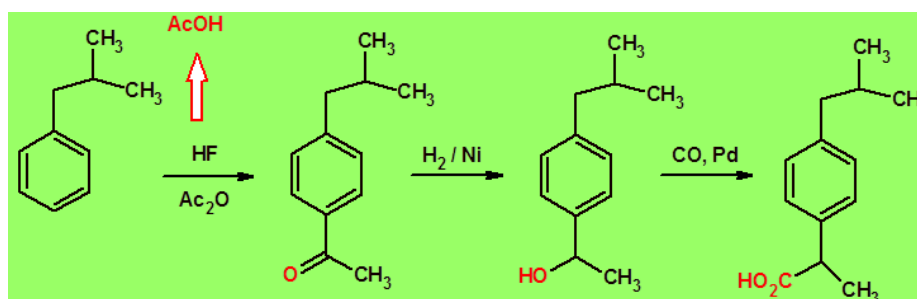
The quantities involved in these exchanges are about the same as the amount of coal which Asnæs buys (2+ million tons/year) or the tonnage of North Sea crude oil refined by Statoil (3.2 million tons). Can these data justify the following sentence from a partner of this park: “Without a conscious intent at the beginning to develop an industrial ecosystem, a very effective, and environmentally beneficial symbiosis among half a dozen companies has evolved, albeit slowly”.

2) Outlines the importance of the Water Gas Shift Reaction (for making hydrogen by reacting coal with steam):



What is the atom economy of the reaction? Can you compare this number with the AE of the reaction to produce hydrogen by electrolysis of water? Which are the main impacts involved in the two alternative processes?

- Define sustainability and provide examples of three ways that Triple Bottom Line companies promote sustainability.
- Name four functional groups in organic chemistry and what important natural molecules are they used to build. Heavy metals react with what functional groups inside biological important molecules or metabolites?
- In green chemistry and in the green engineering principles there are several statements on the attention to be paid to renewable sources in chemical processes. With examples evidence these principles and their practical applications.
- Hoechst route to Ibuprofen ($\text{C}_{13}\text{H}_{18}\text{O}_2$) consists of three-step sequence:



Knowing that the first step have an 80% yield, the second a 100% yield and the third a 50% yield, calculate the amounts of raw materials and intermediates necessary to produce 1 kg of Ibuprofen. Moreover, evaluate the atom economy (AE), the E factor, and EMY of the each reaction step and overall reaction. Provide reasons to justify if this can (or cannot) be considered a good example of process which follow the green chemistry principles.

- 7) Recently has been suggested to divide the LCA into two different broad areas: the attributional LCA (aLCA) and the consequential LCA (cLCA). The first correspond to the classical LCA which is applied retrospectively to relatively contained (in terms of system boundaries) products or systems, whereas the second deals with how environmental impacts might change in response to potential policy decisions with expansion of system boundary. Explain why the cLCA has increased in importance in the last years in connection with the debate on “fuel / food” use of biomasses?
- *8) Chemical engineers practice a profession and must obey rules governing their professional conduct. One important set of rules that all engineers should be aware of is environmental statutes, which are laws enacted by national states and European community. Engineers need to be aware of the potential legal liability resulting from violation of environmental laws and regulations to protect their company and themselves from legal and administrative actions. Which are the main environmental laws in the European context and where can be found the related texts?
- *9) What barriers stand in the way of making cellulosic biofuel more widely available to European consumers? Should cellulosic biofuels grow as a source of transportation energy and why or why not?
- 10) What is biomimicry and how does it relate to green chemistry. Name how two chemicals that are used in nature can have multiple uses for mankind.
- 11) What is the defining principle of toxicology and what environmental parameters affect it? What is the difference between acute and chronic toxicity and how do we express the potency of each one?
- **12) ECHA every six month publish a candidate list of Substances of Very High Concern (SVHCs) (<https://echa.europa.eu/it/candidate-list-table>) and provide examples of articles containing SVHCs available for consumer use on the EU market. Deliver examples of this type of substances and related articles and clarify in EU nations they are banned or restricted, and how they are identified and treated in the REACH regulation.
- **13) Which are the raw materials for the production of biodiesel? Indicate two main technologies to convert two appropriate biomass sources into a biodiesel to be used in very cold regions of the earth.

^Mandatory for both Eng. Chem. And Environmental students * Eng. Chem. Students ** Environmental students