CH3041 Tutorial 7 Answers

1. Describe the toxicity characteristics and give an example of each of the following toxicants:

chronic systemic poison

A substance which has a harmful effect on an organism, a chronic poison acts slowly 1d- 10y in this case on one of the body systems where the point of entry may be remote from the point of action the
eg. Hg(II), inorganic ingestion which builds up and destroys the kidneys.

acute local poison

A substance which has a harmful effect on an organism, an acute poison acts quickly and a local effect is one which occurs near the point of exposure.
eg. Mustard gas, $Cl\text{-}CH_2CH_2SCH_2CH_2Cl$, reddening and blistering of skin, and, if inhaled, will also cause blistering to the lining of the lungs, causing chronic impairment, or at worst, death. Exposure to high concentrations will attack the corneas of the eyes, eventually rendering the victim blind.
The impure compound smells a bit like mustard!

xenobiotic substance

A chemical that is foreign to natural biology eg. PCBs

carcinogenic substance

A chemical that induces cancerous tumours. eg. TCDD

2. Explain the following toxicological terms LD_{50}, EC_{50} and banded toxicity data. How are these different methods used to assess the risk of chemicals to exposed individuals.

LD_{50} : The LD_{50} is the dose (mg toxicant / kg body weight) that results in mortality of 50% of the population.

EC_{50} : The EC_{50} is the concentration of toxicant (for instance in mg /L water) that results in an observable non-lethal effect on 50% of the population eg. tumour formation.

Banded toxicity data : The bands use a set dose an look for an observable non-lethal effect. A set dose is used for each band and 14 days are normally taken for the tests.

Band range	Test value	Label
< 25 mg/kg	5 mg/kg	Very toxic
25 - 200 mg/kg	50 mg/kg	toxic
200 - 2000 mg/kg	500 mg/kg	harmful
> 2000 mg/kg	2000mg/kg	“safe”

The LD_{50} data is for a given dose of chemical and is a lethal test, it does not indicate the on-set of non-lethal side effects. It just indicates if the individual will die.

The EC_{50} is the concentration that the organism is presented with. A dose must be calculated from this. A non-lethal test looking for the severity of side effects. Indicates to the individual if they are likely to suffer side effects it they can calculate the dose.

The banded toxicity data is the most modern approach. It reflects the fact that there will be similar response for a range of doses around a particular dose level, it is also looking for side effects. More useful to the consumer as they are given simple labels and do not have to worry about the size of the test value numbers. The individual only needs to worry about the size of the dose they have been exposed to.

3. Not all nuclides are kinetically stable. Give 2 examples of radionuclides that are produced in the nuclear industry and 1 example of a stable nuclide that is normally found in the environment. For the radionuclides you have chosen show the method of decay, the half-life and explain why the nuclide is not stable.

α decay: $^{4}_{2}He$ alpha α particle ($^{4}_{2}He^{2+}$)

eg. $^{239}_{94}Pu \rightarrow {}^{235}_{92}U + {}^{4}_{2}He$ $t_{½}$ = 24 000y

β decay: $^{0}_{-1}e$ beta particle; high E

eg. $^{90}_{38}Sr \rightarrow {}^{90}_{39}Y + {}^{0}_{-1}e$ $t_{½}$ = 28.8y

The plutonium and strontium nuclides are radioactive because they lie outside the zone of stability where the strong force (attr.p^+/p^+, p^+/n^o) ≈ electrostatic force (rep.p^+/p^+) and also all nuclei with Z > 83 are radioactive.

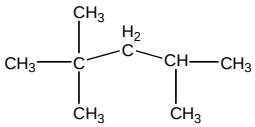
$^{12}_{6}C$ this is a kinetically stable nuclide and it has a 1:1 neutron : proton ratio.

4. **Ethanol** and **Biodiesel** are alternative fuels that may be used in the automobile industry.
   - Provide an illustrative molecular formulae for each of these fuels and the fossil fuels petrol and diesel.
   - Explain the advantages/disadvantages of using ethanol and biodiesel when compared with fossil fuels.

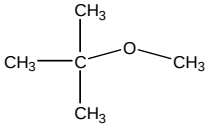
CH_3CH_2OH = ethanol (ethanol)

$CH_3(CH_2)_{16}COOCH_3$ = biodiesel (FAME here made from frying oil, methyl stearate)
(or methyl octadecanoate)

$(CH_3)_3CCH_2CH(CH_3)_2$ = petrol (*iso*-octane (petrol is the hydrocarbon distillation fraction $C_7 – C_8$).



2,2,4-trimethylpentane = isooctane



methyl *t*-butyl ether = MTBE

$CH_3(CH_2)_8CH_3$ = diesel (diesel is the hydrocarbon distillation fraction $C_9 – C_{11}$).

Ethanol is normally produced from either corn or sugar by fermentation followed by distillation. As long as the distillation process is carried out using co-generation with a non-fossil fuel and the fertilisers used in crop production are not produced in an energy intensive manner then the fuel has a reasonable calorific value. The fuel does not contain sulphur compounds and does not require the addition of oxygenates such as MTBE or aromatics such as BTX (benzene, toluene, xylene) to increase the octane rating.
When used as a straight fuel automobile engines must be modified to use ethanol, otherwise it may be blended with petrol (again reducing the requirement for MTBE type additives). In energy terms ethanol produces less energy per mole than either petrol or diesel.

Biodiesel is produced by methylating vegetable oils (produced from crops such as canola,) or animal fats (fast foods waste). These long chain fatty acids are converted into fatty acid methyl esters by methylation with methanol using an acid catalyst. Further distillation is needed to obtain the purified product. The fuel has good characteristics as a diesel substitute in terms of volatility and again has no sulphur content in contrast to diesel which has a higher sulphur content than petrol. In a similar vein to ethanol if the fatty acids are grown then the energy concerns to do with fertiliser production, refining of the fatty acids need to be considered when evaluating the CO_2 production per kJ of energy used in powering the vehicle. In absolute energy terms biodiesel produces essentially the same amount of energy as diesel itself.

If the production processes associated with the manufacture of ethanol and biodiesl are carried out in an energy efficient fashion then these fuels in principle can fix (through photosynthesis in production) the CO_2 that is generated when the fuel is burnt – renewable fuels. In contrast the fossil fuels are burning a limited resource that is releasing new C to the atmosphere.