CH3041 Tutorial 7 Answers

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

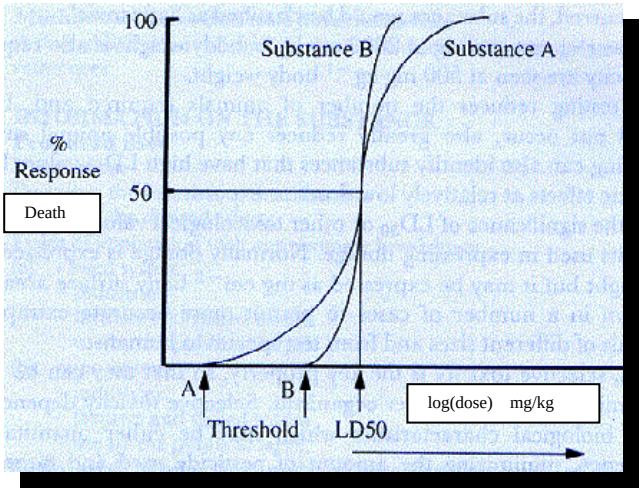
acute local poison
A substance which has a harmful effect on an organism, an acute poison acts quickly and a local effect is one which occurs near the point of exposure. This will be a single exposure (1s - 24h) which typically effects the skin, eyes, mucous membranes.
eg. NO_2 pulmonary edema , conc-HCl skin

systemic nerve poison
A systemic poison acts on one of the body systems and in this case it is the central nervous system.
Typically enters the system by ingestion, contact or inhalation and gets into the blood-lymph system
where it migrates to the CNS.
eg. parathion 120mg adult 2 mg child, tetrodotoxin Pb (not HCN)

mutagenic substance
A substance which brings about alterations in cellular DNA to produce inheritable traits. The Ames Test is used to determine mutagenicity. Often a mutagenic substance is carcinogenic as the alteration results in cell replication occurring in an uncontrolled manner which forms a tumor.
eg. benzo[α]pyrene, aflatoxin

teratogenic substance
A substance which results in birth defects as a result of damaging of foetal cells, germ cells or embryos.
eg. thalidomide, MeHg

2. Draw a typical dose response curve for a highly toxic chemical showing the LD_{50} value and the threshold value. The chemical is toxic over a wide range of doses.



3. Radon is a naturally occurring gas, explain why it is a health hazard.

Radon is a daughter nuclide on the U238 radio-decay series. Rn222 is a dense, inert and non-polar gas which emitted from all uranium containing rocks. The mineral monazite contains thorium which is on the same decay series and so this mineral also releases Rn gas.

- $t_{½}$ = 3.8d $^{222}Rn \rightarrow {}^{218}Po$ + 5.6MeV α particle
- $t_{½}$ = 3.1m $^{218}Po \rightarrow {}^{214}Pb$ + 6.1MeV α particle

It is found in particular in the basements of houses which have been built over these granitic type minerals. Under conditions of poor ventilation quite high concentrations of the gas build up.
The decay of Rn222 to Po218 and Pb214 occurs with the loss of high energy alpha particles. The Po will quickly oxidise in the air to form solid oxide particles which will coat dust particles which lodge in the alveoli of the lungs, the same occurs with Pb.
These radioactive oxides cause significant damage to the lungs as the alpha particles released are a form of ionising radiation which is able to cause mutations in DNA. After smoking radon causes the next highest incidence of lung cancer and it is responsible for 1/2 the average human exposure to radiation. This is because uranium series elements are widely distributed in the crust and so humans can inhale considerable quantities of the radioactive oxides over long periods.

4. Explain why so much more energy can be liberated by the nuclear reaction of 1 mol of a fissionable element than can be liberated by a chemical reaction (eg. combustion) of 1 mol of a non-radioactive element. Illustrate your answer using equations.

Chemical combustion: no change in the nuclei essentially mass balance, a change in electronic energy.

$H_2 + 1/2O_2 \rightarrow H_2O$ ΔH = -285.8 kJ/mol

$\Delta E = \Delta mc^2 = 3.18 \times 10^{-9}$ g/mol

Nuclear fission: change in the nuclei the binding energy per nucleon is not the same in the daughter nuclei as the parent nuclei.

$^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{142}_{56}Ba + {}^{91}_{36}Kr + 3\,{}^{1}_{0}n$

Each daughter nucleus has more binding E per nucleon than U235.
When we think of an atomic nucleus it is made up of protons $^{1}_{1}p$, $^{1}_{0}n$, the difference in mass of the nucleus relative to the sum of the mass of the nucleons is called the mass deficit as the nucleus is lighter than the sum of the nucleons.

The difference in energy $\Delta E = \Delta mc^2$

for U235 $\Delta E = 3.5 \times 10^{-11}$ J per nuclear event.

(3.89×10^{-23} g per event, 0.23 g/mol)

$\Delta E = 2.1 \times 10^{10}$ kJ / mol.

5. A proposed method of storing the high level waste from nuclear power plants involves processing using the Synroc process into a stable mineral which is then buried in deep wells. Plutonium (^{239}Pu) is the highly toxic chemical which is most troublesome in this high level waste as it has a half life of 2.4×10^4 years. The plutonium activity is required to decrease to 0.1% of it's initial value at burial for the material to be 'safe' . Calculate how long this will take.

$\ln N_o - \ln N = kt$

$k = \ln 2 / t_{½}$

$N = 0.001 \times N_o$

$k = \ln 2 / 2.4 \times 10^4$ yr = 2.888e-5

$\ln N_o - \ln(0.001 \times N_o) / k = t \quad \Rightarrow \quad \ln (N_o / 0.001 N_o) / 2.888e\text{-}5 = t$

t = 239 188 y