

The Science of Chemical Safety
Essential Toxicology

Short Essay

Self Assessment Questions

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Natural and Synthetic Chemicals

- List natural and synthetic chemicals that you know to be harmful to living organisms and indicate what harm they cause and under what circumstances; compare this harm with any benefits of which you are aware

Natural Chemicals

Answer

- Natural chemicals - some examples
 - common salt (sodium chloride), vitamin A, *Clostridium botulinum* toxin, saxitoxin, sodium arsenite, asbestos
- Synthetic chemicals - some examples
 - aspirin, antibiotics, organochlorine pesticides, organophosphate pesticides

Natural Chemicals

Answer

- common salt (sodium chloride) - regular high intake associated with high blood pressure; necessary for life
- vitamin A - teratogenic in rodents (possibly all mammals), necessary for health in small quantities
- *Clostridium botulinum* toxin - lethal at very small doses

Natural Chemicals

Answer

- saxitoxin - found in shellfish contaminated by protozoa in “red tides”; lethal at small doses
- sodium arsenite - causes cancer, particularly skin cancer; acutely lethal in large doses
- asbestos - causes mesothelioma and lung cancer; fire resistance has saved many lives

Synthetic Chemicals

Answer

- aspirin - causes peptic ulcers after repeated dosing; relieves pain; may help to prevent heart disease
- antibiotics - various harmful side effects, e.g. penicillin may kill from anaphylactic shock in hypersensitive individuals; excess and incorrect use, e.g. against viral diseases, selects out resistant infectious bacteria

Synthetic Chemicals

Answer

- organochlorine pesticides - bio-accumulation, endocrine disruption, immune system inhibition; persistence and cheapness make them cost-effective in eliminating mosquitoes carrying malaria
- organophosphate pesticides - acutely lethal by blocking nerve impulses; effective insecticides which do not persist in the environment and do not bio-accumulate

Toxicity and Dose

- List some chemicals with different levels and types of toxicity; relate their toxicity to dose, at least in qualitative terms

Toxicity and Dose

Answer

- Lethality and LD50 (mg/kg body weight)
 - ethanol - 10 000
 - sodium chloride - 4 000
 - DDT - 100
 - nicotine - 1
 - botulinum toxin - 0.00001

Toxicity and Dose

Answer

- Sublethal effects
 - Lead
 - low dose - possible effects on baby in the womb
 - medium dose - anaemia; brain and kidney damage
 - Benzene
 - low dose (chronic) - leukaemia
 - medium dose - headache, inhibition of immune system

Human Exposure

- 1. Name the more likely routes by which direct human exposure to toxic materials may occur
- 2. Generally absorption from the lungs is greater than from the mouth, why?

Human Exposure

Answer

- 1. The most likely routes of exposure are:
 - Through the mouth to gut and lungs
 - Remember risk to a baby from maternal milk
 - Through the eyes
 - By skin absorption
 - For a fetus, through the placenta from the maternal blood supply

Human Exposure

Answer

- 2. Because of the structure of the lung alveoli.
 - The innermost part of the lungs consists of small “balloons” of lung tissue (the alveoli) which expand and contract as the lungs inhale and exhale air. This is where the very efficient exchange of gases (and other materials) with the blood system occurs.
 - The alveoli give a very large area in contact with the air and with the blood supply, which is why the uptake of gases and toxic contaminants is so efficient.

Environmental Exposure

- Substances move through the environment. List the different phases they might move through before and after entering a living organism
 - Substances may be chemically modified during this movement, list some examples

Environmental Exposure

Answer

- Substances may move through the air, soil, water and sediments, before or after entering living organisms.
 - Substances that may be chemically modified during this movement include:
 - Proteins which are broken down by bacteria yielding ammonia which is converted into nitrates by other bacteria
 - Nitrates which may be converted into amino compounds by plants or into nitrogen gas by bacteria

Environmental Exposure

Answer

- Substances that may be chemically modified during this movement also include:
- Nitrogen which may be fixed by plants and converted to amino compounds which may be returned to the soil through plant death and decay or, indirectly, following animal ingestion; animals may convert amino compounds directly to ammonia which is excreted; these reactions are part of the nitrogen cycle in the environment.
- Paraquat and diquat which are detoxified on reaction with divalent ions in the soil.

Hazard and Risk

- What is the difference between hazard and risk?
 - List some examples of high hazard and high risk; high hazard and low risk; low hazard and high risk.

Hazard and Risk

Answer

- Hazard is the potential of a substance to cause damage.
- Risk is a measure of the probability of that happening in defined circumstances.
- An example of high hazard and high risk:
 - Taking illegal drugs; drugs such as “crack” are very hazardous and taking them illegally is likely to involve high dose and impurities making it extremely risky.

Hazard and Risk

Answer

- An example of high hazard and low risk:
 - Paracetamol - very toxic to the liver (high hazard) but low risk if taken in low prescribed dose
- An example of low hazard and high risk:
 - Exposure to sunlight (uv light) is a low hazard and is important for the formation of vitamin D, essential for healthy bone development and growth; overexposure to sunlight is a high risk cause of skin cancers.

Risk Management

- What would be the likely “cradle to grave” process for the production and use of unleaded petrol?
- What are the hazards and risks involved?

Risk Management

Answer

- The cradle to grave process for the production and use of unleaded petrol includes:
 - Drilling for crude oil
 - Transport of crude oil to the refinery
 - The refining process
 - Transport of refined petrol to the storage depot and then to the retail outlet
 - Combustion of petrol in the internal combustion engine with the production of carbon monoxide and dioxide and oxides of nitrogen and sulfur.

Risk Management

Answer

- Hazards and risks associated with use of unleaded petrol include:
 - Risk to the workers in the drilling process
 - Crude oil is highly toxic and thus high hazard
 - Transport of large amounts of crude oil presents a high spillage hazard; risk of accident and environmental damage may be very high at sea in huge tankers under storm conditions
 - Refined petrol is highly flammable and thus high hazard; risk depends inversely on care in handling and may be very high

Risk Management

Answer

- Hazards and risks associated with use of unleaded petrol include:
 - Transport and storage of refined petrol involves high risk because of the possibility of accident and fire
 - The use of refined petrol in a modern engine presents little danger and thus low hazard and risk (apart from accidents)
 - The products of burning petrol, the carbon, nitrogen and sulfur oxides are either toxic (especially CO) or harmful to the environment or both and thus hazardous; risk is high if large amounts are produced

Toxic Waste

- How are the problems of disposal of industrial and domestic waste different?

Toxic Waste

Answer

- Industrial waste may be highly toxic but it is concentrated where factories are and can be controlled to reduce the risk of harm to people and the environment
- Domestic waste is usually not highly toxic (batteries may be an exception) but its production is widespread; resources and organization are required to collect it and concentrate it for treatment

Toxic Waste

Answer

- Domestic waste may require a considerable land area for landfill disposal; incineration is expensive and may produce toxic gases and vapours
- Both industrial and domestic wastes may give rise to large amounts of contaminated water effluent which must be treated to remove hazardous components and, if possible, to recycle the water

Risk Perception

- List some common perceptions of risk which may not be correct
 - For example - air travel is safer than car travel but many people think the opposite

Risk Perception

Answer

- Production of electricity by nuclear reactions is widely regarded as highly hazardous and risky; although the hazard is high, in general the risk is low because of careful management
- Producing electricity from fossil fuels has caused many more deaths and chronic illness, for example from smog, and environmental damage as a result of acid rain and the “greenhouse effect”

Risk Perception

Answer

- It is widely believed that herbal remedies are safer (less risky) than synthetic drugs; all marketed synthetic drugs have been tested and thus can be prescribed in safe doses (minimal risk); few, if any, herbal remedies have been tested and therefore safe doses can only be guessed and the risk of excess causing harm is high.

Risk Perception

Answer

- Many people think that antibiotic treatment is risk free
- People have died following antibiotic treatment by mouth which killed “friendly” bacteria in the gut permitting bacteria producing toxins to flourish
- Excessive use of antibiotics has caused the selection of antibiotic resistant bacteria which can cause serious disease and death

Organic Solvents

- List the hazards and risks that may be associated with some named organic solvents
 - Include halogenated solvents in your consideration
 - Pay special attention to ethanol!

Organic Solvents

Answer

- Chloroform
 - Effective fat solvent, easily ingested, attacks the liver and the brain and nervous system, causing loss of control and anaesthesia
 - Removes natural oils from skin, causing blistering
 - Dissolves sealants in plumbing systems
 - Vapour is poisonous, affecting the nervous system: not flammable

Organic Solvents

Answer

- Carbon tetrachloride
 - Similar properties to chloroform but much more toxic
 - Liver damage may lead to liver cancer
 - Not flammable

Organic Solvents

Answer

- Ethanol
 - Effective fat solvent, after ingestion attacks the liver and the brain and nervous system, causing loss of control and anaesthesia
 - Dissolves natural oils from the skin
 - Vapour is poisonous, affecting the nervous system
 - Flammable
- Note: All organic solvents attack the brain and nervous system

Global Warming

- List possible ways global warming could change the climate and ecology of our planet and alter toxic effects of chemicals

Global Warming

Answer

- Global warming melts the polar ice caps and reduces the size of icefields; this increases sea levels, affecting the world's coastline

Global Warming

Answer

- Local changes
 - Marshlands will become flooded; lakes and rivers increase in size; human settlements become flooded
 - Increased evaporation in dry areas increases desert

Metals

- List some of those metals used in industrial processes which can give rise to toxicity and indicate what chemical species are involved and what kind of toxicity is produced
 - NOTE: Many texts wrongly refer to potentially toxic metals as “heavy metals”; there is no relationship between “heaviness” and toxicity

Metals - Answer

- Lead
 - lead(II) ions
 - possible reduced fertility
 - possible effects on baby in the womb
 - anaemia; brain and kidney damage
 - death

Metals - Answer

- Mercury
 - elemental mercury
 - vapour well absorbed from the lungs; may be absorbed through the skin; inhibits nerve function and kidneys
 - mercuric ions
 - poorly absorbed; inhibits enzymes dependent on SH groups; affects nervous system and kidneys

Metals - Answer

- Mercury (continued)
 - alkoxymercury
 - broken down to inorganic mercuric ions (see earlier)
 - alkylmercury
 - readily absorbed through skin, gut or lungs; accumulates in fatty tissue and the nervous system; causes paralysis and death; developing baby in the womb is especially sensitive and may die though mother is unaffected

Chemical Safety Information

- What information should appear on a chemical safety card for (a) ethanol and (b) ethanoic acid (acetic acid)?

Chemical Safety Information

Answer

- Ethanol
 - Highly flammable
 - Intoxication if inhaled or ingested
 - Causes drying of the skin or mucous tissues
 - Causes damage to the eyes
 - Is miscible with water

Chemical Safety Information

Answer

- Ethanoic Acid
 - Flammable
 - Causes severe burns
 - Causes severe irritation if ingested
 - Irritating odour
 - Miscible with water