ANSWERS TO REVIEW QUESTIONS

CHAPTER 1—INTRODUCTION TO INDUSTRIAL HYGIENE

1. Define the term *industrial hygiene*.

   Industrial hygiene is the science of anticipating, recognizing, evaluating, and controlling workplace hazards.

2. Explain what is meant by *anticipation* as it is used in industrial hygiene.

   The ability to predict emerging issues by means of the following:
   - maintaining lines of communication with workers & management
   - reviewing the literature
   - developing sufficient knowledge of the process

3. Explain what is meant by recognition as it is used in industrial hygiene.

   Anticipation is the ability to detect hazardous conditions by using the following:
   - industrial hygiene surveys
   - sampling/monitoring
   - incident reports, referrals, etc.

4. Explain what is meant by *evaluation* as it is used in industrial hygiene.

   Evaluation is the ability to assemble and interpret data through the following methods:
   - investigation—including routes of exposure
   - data tracking—is a trend developing?
   - trends analysis—compare to baseline or national standard (i.e., Does the result exceed the permissible exposure limit or TLV?)
   - using information to set priorities for control

5. Explain what is meant by *control* or *intervention* as it is used in industrial hygiene.

   Intervention is the ability to take appropriate action through the following:
   - leadership
   - effective communication
   - the hierarchy of controls

6. What is the hierarchy of controls?

   The hierarchy of controls in order of decreasing importance includes:
   - hazard elimination
   - hazard substitution
   - engineering controls
   - adminstrative controls
   - personal protective equipment

7. Give examples of four types of environmental factors or stresses.

   - chemical
   - physical
   - biological
   - psychological

8. Name four major professional organizations closely related to the practice of industrial hygiene.

   Any of the following:
   - American Conference of Governmental Industrial Hygienists (ACGIH)
   - American Industrial Hygiene Association (AIHA)
   - American Board of Industrial Hygiene (ABIH)
   - American Academy of Industrial Hygiene (AAIH)
   - American Society of Safety Engineers (ASSE)

9. Name two major governmental organizations closely associated with the practice of industrial hygiene and explain the role of each.

   - The Occupational Safety and Health Administration (OSHA) issues and enforces regulations.
   - The National Institute for Occupational Safety and Health (NIOSH) conducts research and provides guidance.

10. Describe the requirements for effective occupational safety and health (OSH) programs.

    - An effective OSH program requires a team approach. The members of the team include the industrial hygienist (IH), the safety professional, the occupational health nurse, the occupational physician, the employee, senior management, and line management.
    - A safety and health committee is also required. This committee offers a forum for information exchange, policy making, program planning, implementation, and evaluation.

11. Describe the role of the industrial hygienist on the OSH team.

    The role of the industrial hygienist on the OSH team is to:
    - protect the health of workers
    - maintain an objective view
    - counsel employees
    - respect confidences
    - advise honestly and report accurately
    - be responsible to employer/client

CHAPTER 2—THE OCCUPATIONAL SAFETY AND HEALTH ACT AND INDUSTRIAL HYGIENE

1. What does the Fourth Amendment protect? Does this same right apply to organizations and businesses?

   The Fourth Amendment protects citizens from unreasonable search and seizure. The government may not conduct any searches without a warrant, and such warrants must be issued by a judge and be based on probable cause. These rights extend to organizations and businesses.

2. If a neighborhood group sues a company for allowing lead paint chips to blow off its property and into the neighborhood, what constitutional amendment allows the company to have a jury in the civil suit?

   The Seventh Amendment guarantees a jury trial for civil cases in federal courts.

3. Under what branch of the U.S. government does the Department of Labor fall?

   Executive

4. At what phase of the preparation of a proposed bill is an industrial hygienist likely to be called to testify before Congress?

   An industrial hygienist would likely be called to testify when the bill is being reviewed by committees or subcommittees.

5. What is the *Federal Register*?

   It is where new laws and regulations are announced and eventually published.

6. What type of information is typically reviewed in appeals courts?

   The information about how the case was tried is reviewed to determine whether there were any errors that may have affected the outcome adversely.

7. What is the role of federal agencies and commissions? What are two agencies whose responsibilities involve industrial hygiene?

   These agencies and commissions are created in various capacities to develop laws or regulate various activities. The following are agencies with industrial hygiene responsibilities:
   - Federal Communications Commission
   - Nuclear Regulatory Commission
   - Environmental Protection Agency
   - Mine Safety and Health Administration

8. When was OSHA created?

   1970

9. To whom or what did the fellow servant rule apply, and how was it used?

   The fellow servant rule applied to workplaces and stated that employers were not liable for workplace injuries that resulted from the negligence of other employees. Many employers used this clause to relieve themselves from injuries to their employees.

10. Name two instances where OSHA regulations do not apply.

    OSHA regulations do not apply to sole proprietors where the owner is the only worker, and they do not apply to farms with fewer than 10 workers or family members.

11. What is the General Duty Clause?

    Section 5(a)(1) of the OSH Act, which states that each employer shall "furnish to each of his employees employment and a place of employment which are free from recognized hazards that are likely to cause death or serious physical harm to his employees."

12. What is NIOSH's role?

    NIOSH is responsible for setting national strategic goals for workplace health and safety. They are charged with conducting a focused program of research to reduce injuries and illnesses among workers in high-priority areas and high-risk sectors. NIOSH is also responsible for implementing and maintaining a system of surveillance for major workplace illnesses, injuries, exposures, and health and safety hazards.

13. Explain the difference between a performance standard and a specification Standard.

    Specification Standards are clear rules that say exactly what engineering or design criteria must be met to protect workers from a particular hazard. Performance standards, on the other hand, only state the levels of the toxic chemical in the air that are acceptable.

14. Explain the difference between a horizontal standard and a vertical standard?

    Vertical standards are rules that typically apply to only one industry where a particular hazard exists. Horizontal standards are rules that can apply to nearly any workplace or industry across the board.

15. Explain the difference between an OSHA special emphasis program and a regional emphasis program.

    The special emphasis program is more national in nature and could apply anywhere. The regional emphasis program focuses on different parts of the country or works in relation to the types of jobs or industries that exist there.

CHAPTER 3—MANAGEMENT SYSTEMS

1. What is a "culture of safety," and how is it created and developed within an organization?

   A culture of safety involves setting the values and attitudes regarding safety issues to be shared by all work groups and individuals within the organization. Safety culture means encouraging workers to report unsafe or potentially illegal conditions, accidents, injuries, illnesses, and near misses, without reprimand.

2. Why is the management of industrial hygiene and safety a good business practice even when there are no regulations covering a certain area or work hazard?

   There is an ethical element that requires employers to provide a safe and healthful workplace. Plus, the efficient and productive operation of the organization is closely linked to the level of safety in the organization.

3. Create a short policy describing a beauty salon's safe operations and commitment to safety.

   Answers may vary.

4. Why are established procedures necessary, and how do they relate to worker safety?

   Procedures provide explicit instructions for how to perform a task or operate equipment. Sometimes they provide important safety information regarding how to do the job without being injured.

5. How does quality assurance apply to safety?

   Quality assurance provides a means to ensure that jobs and workplaces are as safe as possible in accordance with programs and procedures. Quality assurance represents an organizational way to ensure that work is being done correctly and safely.

6. How does a program review differ from an audit?

   Audits are typically conducted as a snapshot to evaluate a specific aspect of a program over a specific timeframe. Program reviews tend to be comprehensive analyses of the regulations and written documents within the organization.

7. What are three of the basic business principles associated with TQM methods?

   TQM is geared toward customer satisfaction, requires employee involvement, relies on effective communications, is focused on processes and efficiency, and all the various business parts are fully integrated. Quality control is an integral part of the business process, and it uses strategic long-term planning for setting and achieving goals, and it is continually trying to improve.

8. What are the four parts of the Deming wheel used to describe the TQM process?

   Plan, Do, Study, Act

9. What type of safety management system is designed around the collection and statistical analysis of data?

   Six sigma

10. What does the International Standards Organization (ISO) do?

    The ISO is a nonprofit network of international standards-development bodies that create consensus standards on all aspects of technology and manufacturing. There are several ISO standards related to business operations, quality assurance, the environment, and safety.

11. What is the highest level a company can attain in OSHA's Voluntary Protection Programs sequence, and what does a company need to do to be accepted into the program?

    The Star Program is the highest level, which is for exemplary worksites with comprehensive and successful safety and health management systems.

12. What is the most important step when selecting an alternative, safer process or chemical? Why?

    All of the steps in the alternative chemical process are important, however, a key feature of the system is tied to the concept of continuous improvement. Therefore, the last step of continually reviewing changes and conditions, and making improvements is probably the most important step in the process.

CHAPTER 4—BASIC CONCEPTS IN INDUSTRIAL TOXICOLOGY

1. What is the difference between mechanism of action and mode of action?

    Mechanism of action is a detailed description of the events that cause an effect. Mode of action describes only the key events of the mechanism of action.

2. What are biomarkers, and why are they important?

    Biomarkers are measurable signs of toxic effects of chemicals. They allow for observing and measuring the progress of toxic effects to chemicals.

3. What are some examples of biomarkers?

    Clinical measures like body weight, urinalysis measurements, and hematological markers; pathological measurements like changes in gross physiology or histopathology changes; neuronal markers of toxicity like gait and behavior changes; teratogenicity

4. List and describe Hill's criteria of causation.

    - First Criterion: Strength. Strength of the effect describes the strength or magnitude of the relationship between events. A strong association between the exposure and the specific effect means it is more likely that the exposure is causal to the effect. In toxicology, this would be seen as a high incidence of effect at a given dose or the appearance of severe effects as opposed to mild effects.
    - Second Criterion: Consistency. Different studies with potentially different populations seeing a correlation between a specific exposure and a specific effect greatly increase the chances of a causal relationship between the exposure and the effect. This is also true for laboratory and epidemiological data. This criterion also incorporates information consistency in the range of biological responses within a study. For example, in a toxicology study where an increase in blood markers of liver damage was observed, did the histopathology observe any evidence of damage?
    - Third Criterion: Specificity. The third criteria of consideration are specificity. If a rare disease or effect is associated with a group of people who all had a specific exposure and the incidence of the effect in the population is not otherwise explainable, the specificity of the association between the exposure and the effect greatly strengthens the case for causality of the exposure.
    - Fourth Criterion: Temporality of Events. A fourth criterion of interest is the temporality of the events. For determining that an exposure causes an effect and perturbs a particular mechanism of action, the exposure must occur before the effect occurs.
    - Fifth Criterion: Coherence and Plausibility. The fifth criterion to examine is the coherence and plausibility of the relationship between the exposure and the potential effect. Does the laboratory biological evidence for an exposure to a chemical show that a chemical is usually not absorbed into the body at all? Then it is not plausible that a systemic effect is likely for that chemical. The question for

this criterion is, "Is the effect reasonable given all the other known data on this chemical?"

- Sixth Criterion: Dose-Response Relationship. It is important to establish a dose-response relationship between the exposure and the effect. Exposure to a large amount of the agent of interest should cause a greater response than exposure to a lesser amount. If the agent of interest accumulates in the body, then chronic exposure should cause an increase in effect. In addition, the dose for early (less severe) key events should be lower than the later (more severe) effects.

5. What is ADME?

   Absorption, distribution, metabolism, elimination

6. What is the blood-gas partition coefficient?

   The constant that describes the ratio of a gas in the alveolar air compared with the blood.

7. What is biotransformation?

   It is the transformation of a chemical to a different metabolite by metabolism.

8. Define V_{max} and Km. If a chemical has a V_{max} of 150 mg/min and a Km of 3 mg/L, what is that chemical's intrinsic clearance rate?

   V_{max} is the measure of how fast an enzyme can clear a chemical. Km is the affinity of an enzyme for a chemical.

   $$\text{Clearance} = \frac{150 \text{ mg/min}}{3 \text{ mg/L}} = 50$$

9. What is the half-life of a chemical that has a volume of distribution of 2 L and that can be cleared from 1,500 mL of blood per hour?

   K_{el} = Vd / Cl
   = 2 L / (1.5 L/hour) = 1.33 $hour^{-1}$
   $T_{1/2}$ = 0.693 / K_{el}
   = 0.693 / 1.33 $hour^{-1}$
   = 0.52 hours = 31 minutes

10. What is the difference between an acute and chronic exposure, and which is more dangerous?

    Acute exposure is a short-term exposure; chronic exposure is a long-term or repeated exposure. Which is more dangerous depends on the dose and the chemical. An acute exposure to a low dose may be safe when a chronic exposure may be dangerous.

CHAPTER 5—OCCUPATIONAL EXPOSURE LIMITS AND ASSESSMENT OF WORKPLACE CHEMICAL RISKS

1. What are the components of the risk assessment and risk management framework of NAS?

   Problem formulation, risk assessment, risk management, and risk communication.

2. What is the general purpose of an OEL?

   The OEL is intended to provide a quantitative estimate of the maximum air concentration that is believed to be safe for an occupational population that may be exposed daily for a working lifetime.

3. The risk assessment phase includes several distinct activities pertinent to the development and application of the OEL. What do they include?

   Hazard characterization, dose-response assessment, exposure assessment, and risk characterization

4. In addition to its actual value, what are the other elements of an OEL?

   Concentration units presented, the time-weighted averaging recommended, and the provision of additional notations for hazards not addressed quantitatively in the OEL.

5. Identify and describe the three types of OELs.

   - The full-shift TWA is usually presented as an 8-hour or 10-hour time-weighted average limit.
   - STEL is also a time-weighted average exposure limit, but the averaging time is short.
   - Ceiling limit is a maximum exposure concentration that should not be exceeded at any time during the workday.

6. Identify the key steps to OEL derivation.

   - Define the scenario and develop the problem formulation.
   - Gather and summarize the scientific data.
   - Select a point of departure if necessary; perform extrapolations to increase the relevance of the point of departure.
   - Adjust for route of exposure and exposure duration/patterns.
   - Perform animal-to-human extrapolations and human variability extrapolations.
   - Apply any additionally required uncertainty factors.
   - Submit value for external review.

7. Identify and describe the basis of each of the six common uncertainty factors.

   - Animal to Human. Adjusts for differences in sensitivity between animals and the average human, when the POD is based on animal studies
   - Average Human to Sensitive Human. Adjusts the POD for the difference between the average human and the most sensitive applicable worker subpopulation
   - LOAEL to NOAEL. Adjusts for uncertainty in the value of the POD as an estimate of the threshold for the onset of effects, if based on a LOAEL rather than a NOAEL
   - Short-term to Long-term Exposure. Adjusts for the possibility of identifying a lower POD for chronic toxicity when extrapolating from a study of shorter duration
   - Database Insufficiency. Adjusts for the possibility of identifying a lower POD (or more sensitive effect) if additional studies were available
   - Modifying Factor. Adjusts for additional considerations, including difference in exposure routes or other toxicokinetic considerations

8. How does the industrial hygienist calculate the HQ?

   HQ = Exposure / OEL

9. True or False: The HQ concept is the most common risk characterization method employed in occupational risk assessments.

   True

10. What concept can be used to provide a quantitative exposure benchmark when an OEL is not available?

    The Hierarchy of OELs

CHAPTER 6—GASES AND VAPORS

1. If acetone has an SG of 0.79, how many mL are in 2.0 g of acetone?

   a. 2.53 (mL)

2. What is the term for the temperature at which a fire can be maintained?

   Fire point

3. Fill in the blanks in the table below for ppm to mg/m^3 conversions (assume NTP):

Chemical	Molecular Weight	ppm	mg/m^3
a. methanol	32	1,000	1,309
b. naphthalene	128	1.9	10.0
c. phenol	94	10	38
d. perchloroethylene	166	14.7	100

4. What is the name of the direct-reading meter that uses an ultraviolet lamp to ionize organic compounds to detect and quantify them?

   b. Photoionization detector

5. If you sampled for 4 hours and obtained a sample volume of 960 L, what was the flow rate?

   c. 4.0 L per min

6. A tank car with a tight-fitting lid is reported to contain pure acrylonitrile monomer. You have been asked to verify the tank car's contents. Estimate the concentration of ethyl alcohol in ppm in the air space above the liquid. Acrylonitrile monomer has a vapor pressure of 83 mmHg.

   ppm = Pv/Patm × 106
   = 83/760 × 106
   = 109,210 ppm

7. According to a NIOSH analytical method, the minimum level of detection (LOD) for a chemical is 50 µg, the recommended exposure limit for this chemical is 1.0 mg/m^3, and the fraction is set at 0.1. How many liters of air must be collected to obtain the minimum sample volume?

   d. 500 (L)

8. What are five useful features of direct-reading industrial hygiene air monitoring instruments?

   Any of the following:
   - Real-time information
   - Lightweight, portable
   - Rugged
   - Simple to operate
   - Quickly indicate presence of potentially dangerous levels of gases and vapors
   - Complex system that can differentiate and quantify numerous unknown chemicals in the air at the same time
   - Look at short exposures, ceiling limits, short-term exposure limits, work practices, motivational tools to detect leaks in systems and ventilation allowing for timely repairs

9. What is the principle of operation of electrochemical sensing portable instruments?

   Chemical oxidation of the test gas

10. What is the principle of operation of a flame ionization detector?

    Creates organic ions by passing a hydrogen gas through a flame and then measures the conductivity change in the flame as a concentration of the gas

11. What environmental conditions can affect the accuracy and usefulness of direct-reading instruments?

    Temperature, humidity, particulates, other aerosols, oxygen concentration, pressure

12. What type of direct-reading instrument would likely be used to monitor for carbon monoxide or oxygen?

    Electrochemical

13. If you have a 1-L balloon of nitrogen gas at an initial pressure of 760 mmHg and you take that balloon to the top of a mountain where the pressure is only 610 mmHg, what is the new volume of nitrogen in the balloon?

    1.25 L

14. What is the main purpose of collecting a grab sample when analyzing air contaminants?

    a. Collect a relatively instantaneous sample to be compared with (ceiling limits)

15. What is the main advantage of passive dosimeters?

    b. They are lightweight and don't interfere with the workers during their activities.

16. Which of the following is NOT a principle of operating a direct-reading instrument?

    b. Gravimetric

17. What is the basic principle of operating a passive air-sampling device?

    c. Diffusion

CHAPTER 7—AEROSOLS

1. In what ways are mists different from fogs?

   Fogs tend to be smaller than mists (1 µm to 10 µm, rather than 10 µm to 100 µm in the case of mists). Mists tend to be created by physical processes such as splashing, agitating, electroplating, bubbling, painting, and other spraying applications. Because the chemical composition of a mist doesn't change from that of its parent solution, the mist retains the hazardous properties of its parent solution. Because fogs are smaller than mists, they tend to remain in the air longer than mists and can also penetrate more deeply into the lungs.

2. Why is aerosol size important when determining where aerosols will interact in the lungs?

   Larger particles tend to be trapped in the upper parts of the respiratory tract such as the nose and throat. Smaller particles can make it all the way down into the alveoli without colliding with the trachea or bronchioles.

3. In the field, you set the air-sampling pump's flow rate to 1.7 L/min using a precision rotameter and sample the air for 350 min. You note and record the field temperature as 80°F (26.6°C) and the barometric pressure as 650 mmHg. Calculate the corrected volume of air in liters for normal temperature and pressure (25°C and 760 mmHg). Show all work.

   $Q_{actual} = Q_{cal} \times (T_{actual}\ [°K])/(T_{cal}\ [°K]) \times (P_{cal}\ [mmHg])/P_{actual}$
   $Q_{actual} = 2.0\ L/min \times (298\ [°K])/(299.6\ [°K]) \times (650\ [mmHg])/(760\ [mmHg])$
   $Q_{actual} = 1.7\ L/min$
   $R = Q/T$
   $1.7\ L/min = Q/350\ min$
   $Q = 595\ L$

CHAPTER 10—DERMAL HAZARDS

1. Why is the study of dermal exposure to hazardous agents important today?

   There are approximately 13 million workers in the United States with the potential for skin exposure to hazardous chemicals. Workplace skin diseases account for 15–20% of all reported occupational diseases. The economic burden in total annual costs associated with occupational skin disease is estimated at several billion dollars.

2. Why have dermal routes of occupational exposure become more prevalent in the past several years?

   Partly because they have been identified as significant routes and partly because less volatile chemicals are replacing those that evaporate easily

3. How many square centimeters of skin do average hands and forearms have in total?

   2,030 cm^2

4. What are three of the primary functions of the skin?

   Any of the following:
   - Provide a barrier to the environment
   - Protect muscles and tissues
   - Keep harmful materials out
   - Let necessary materials in
   - Temperature control
   - Neurosensory reception

5. What are the three main means of permeation of agents through the skin?

   Travel on the intracellular lipid pathway, transcellular permeation, and through appendages in the skin

6. List at least three skin factors that may increase chemical absorption and permeation through the skin.

   Any of the following:
   - Younger skin
   - Wet skin
   - Broken skin
   - Anatomical location
   - Skin thickness
   - Individual difference
   - Metabolic rates

7. What are three exposure factors that may increase chemical absorption and permeation through the skin?

   Any of the following:
   - Chemical type
   - Chemical concentration
   - Duration of exposure
   - Surface area exposed
   - Ambient temperatures
   - Use of protective clothing

8. What are three chemical factors that may increase chemical absorption and permeation through the skin?

   Any of the following:
   - Chemical volatility and vapor pressure
   - Molecular weight
   - Hydrophilic or lipophilic properties
   - Specific chemical structure

9. What are the two primary differences between irritant contact dermatitis and allergic contact dermatitis?

   Allergic contact dermatitis is an inflammation of the skin caused by an immunologic reaction triggered by dermal contact with a skin allergen. Allergic contact dermatitis reactions are not confined to the area of exposure.

10. The best ways to minimize or control exposures through the dermal route are through (1) _____, (2) _____, and (3) _____.

    elimination, substitution, process changes

11. Splash guards, lids, and glove boxes are examples of _____ controls for dermal exposures.

    engineering

12. Why does chemical PPE need to be changed periodically?

    Because the equipment can become saturated with the chemical or physically degraded

13. What are some of the drawbacks of using PPE as a worker protection strategy?

    PPE is thin and a last line of defense to protect the worker. It has limited durations of use. Workers need to be trained on its proper use, maintenance, and limitations. It can be more expensive to implement than other controls.

CHAPTER 11—NOISE

1. Find the wavelength in meters of a pure sound at the following frequencies:

    a. $\lambda = 0.172$ m
    b. $\lambda = 0.404$ m
    c. $\lambda = 0.013$ m

2. How loud in decibels is an audio system with a sound power rating of 280 W per channel?

    $L_w = 144$ dB

3. How loud in dB is a drill press with a sound power rating of 0.003 W?

    $L_w = 94.7$ dB

4. What is the SPL in decibels coming from a source generating 2.3 Pa?

    $L_p = 101.2$ dB

5. You conducted a survey and obtained the following results (see table). Was the OSHA permissible exposure limit exceeded? Was the HCA exceeded?

    No; yes

6. If you measured the 3,000-Hz noise coming from a compressor outdoors to be 110 dBA at a distance of 10 ft, what would you estimate the noise level to be at a distance of 200 ft?

    83.9 dBA

7. Referring to Question 6, what would the noise level be at 200 ft from the source if you placed a wall 20 ft high, 15 ft away from the source?

    58.1 dBA

8. At which frequency would a noise-induced hearing loss notch most likely occur?

    d. 4,000 Hz

9. What is the maximum noise level in decibels of a receiver that is rated at 200 W per channel?

    $L_W = 133$ dB

10. The root-mean-square sound pressure level (SPL) of the receiver is rated at 80 N/m^2. What is the maximum noise level in decibels from this system?

    $L_p = 132$ dB

11. The NRR for a pair of earplugs is 24 dBA, and the 8-h time-weighted average in a work area is 100 dBA. At how many decibels will the earplugs reduce the noise level using ACGIH's safety factor of 2?

    8.5 dB

12. If you want to install five machines with the individual noise levels listed below, what would the total noise level be?

    $SPL_{total} = 93.3$ dBA

13. What is the frequency of the sound emitted from a fan with 35 blades operating at 4,000 rpm?

    2,333 Hz

14. What percent of the OSHA criterion allowable dose does a worker receive if she works in an area with 100 dB for 0.5 hours, 70 dB for 4 hours, 90 dB for 3.0 hours, and 105 dB for 0.5 hours?

    113%

15. What is sensorineural hearing loss, and why is it typically irreversible?

    Permanent degeneration of auditory nerve, damage to hair cells and nerve fibers

16. The audible range of an average young person with unimpaired hearing is _____.

    c. 16,000–20,000 Hz

17. OSHA requires audiograms for all employees exposed to an 8-hour time-weighted average of _____ dBA.

    85

CHAPTER 12—RADIATION

1. What types of human cells tend to be the most sensitive to biological damage from ionizing radiation?

    d. Those that divide and replicate often and rapidly

2. If a patient is to be treated with 2.3 mBq of radioactive iodine-131, how much will be in his or her system 80 hours later if the physical half-life is 8.0197 days and the biological half-life is 120 days?

    1.7 mBq

3. If the dose rate from a stationary source is 2.0 Sv at 45 cm, what is the dose rate at 10 cm?

    40.5 Sv

4. Why are children more sensitive to the harmful effects of ionizing radiation?

    Rapidly dividing cells during growth

5. Why is an alpha-particle capable of doing such a large amount of biological damage to living tissue?

    2 protons + 2 neutrons, large mass, high energy, high LET

6. What part of the body is commonly exposed to and especially sensitive to alpha-particles?

    Lungs

7. In radiation protection, what is the becquerel (Bq) used to quantify?

    d. Radioactivity

8. Explain the concept of ionization and describe why it is biologically significant.

    Ionization occurs when an outer orbital electron is ejected, which generally requires about 13 eV of energy. This is biologically significant because when it occurs in living tissue, it can lead to cellular or molecular damage. If it occurs in genetic material, it can cause mutations in cellular progeny.

9. What does the physical half-life of a radioactive material refer to?

    The physical half-life is the amount of time it takes for a given quantity of radioactive material to decay to one-half of its original quantity.

10. If you went into a radioactive materials laboratory with your Geiger counter and noticed high readings all over a benchtop near where the scientists had previously been pouring a liquid containing radioactive phosphorous, this would be an example of _____.

    a. radioactive material contamination

11. What is the effective half-life of a radionuclide with a physical half-life of 28 hours and a biological half-life of 50 days?

    27.36 hours

12. If you start with 300 μCi of iodine-131, how much will you have after 25 days? (I-131 has a half-life of 8.04 days.)

    34.9 μCi

13. Radioactivity may be defined as what?

    Radioactivity is the property of certain radionuclides with an imbalance of neutrons and protons that spontaneously emit particles or photons in a nuclear transformation to try to return to a stable state.

14. On the basis of material-penetrating ability, indicate in the spaces provided the type of ionizing radiation (beta, gamma, alpha, or neutron) that would be stopped by the materials shown.

    a. Alpha
    b. Beta
    c. Gamma

15. Who is affected by a teratogenic health effect?

    An embryo or fetus

16. What is biological half-life?

    Biological half-life is the time it takes for one-half of the material present in the body to be biologically removed.

17. What is the lethal dose of whole-body exposure to ionizing radiation?

    a. 5 Gy

18. What does the acronym ALARA stand for?

    As low as is reasonably achievable

19. What part of the body is most sensitive to the effects of ionizing radiation?

    b. Blood

20. What is the photon energy level of ionizing radiation?

    d. > 13.0 eV

21. What distinguishes broadband optical sources from lasers?

    c. All broadband sources emit noncoherent light.

22. Which of the following is *not* a way to control the blue-light hazard?

    b. Use white light instead of blue light.

23. The daily dose limit for germicidal UV radiation at 254 nm is 6.0 mJ/cm^2. Suppose a worker is exposed to an (unweighted) irradiance of 0.01 mW/cm^2 at this wavelength. How long can the worker be exposed without exceeding the dose limit?

    10 min

24. What is the maximum irradiance at 254 nm that a worker can be exposed to for 8 hours without exceeding the dose limit (6.0 mJ/cm^2)?

    0.001667 mW/cm^2

25. A worker is exposed to an irradiance of 0.01 mW/cm^2 at a distance of 6 ft from a source. What will the irradiance be if the worker moves another 3 ft away?

    0.0044 mW/cm^2

26. A 100-MHz RF electric field is measured as 40 V/m. What is the equivalent plane wave power density in watts per square meter?

    4.2 W/m^2

27. What is the frequency and band designation of RF radiation with a 2-m wavelength?

    150 MHz; VHF band

28. What is the wavelength of 1 terahertz (THz) of radiation? (Tera = 10^{12})

    0.3 mm

29. Estimate the distance to the far field for a laptop WiFi antenna that is 10 cm long and radiates at a frequency of 2.4 GHz.

    16 cm

CHAPTER 13—THERMAL STRESSORS

1. A worker's metabolic heat (M) is 61 kcal/h. He gains 135 kcal/h by radiation (R) and 47 kcal/h by convection (C). He loses 229 kcal/h by sweating (E). How much is his body heat storage rate (dH)?

   + 14 kcal/h (heat gain)

2. In a workplace, ambient temperature (ta) is measured at 39°C and wind speed is measured at 2.3 m/s. Calculate heat exchange by convection. (Assume skin temperature is 35°C.)

   46.2 kcal/h

3. If mean radiant temperature (tr) in a glass-manufacturing shop is 54°C, what is the radiant heat exchange (R)? (Assume skin temperature is 35°C.)

   125.4 kcal/h

4. Water vapor of ambient air is 19 mmHg, and wind speed is 1.7 m/s. Calculate the maximum evaporative heat loss (Emax). (Assume skin temperature is 35°C; vapor pressure at 35°C is 42 mmHg.)

   443 kcal/h

5. In a shop, a globe thermometer reads 34.0°C, air velocity is 1.3 m/s, and ambient temperature is 30.5°C. Determine the mean radiant temperature (1°C = 5/9[°F – 32]).

   41.2°C

6. Using a sling psychrometer, ta and tw are determined to be 33.9°C (93°F) and 25.6°C (78°F), respectively. Using Figure 13–6, find relative humidity, dew point temperature, and water vapor pressure.

   Relative humidity is 52%, dew point temperature is 22.5°C, and water vapor pressure is 0.0173 lbs of moisture per lbs of air.

7. Inside a smelting shop, the tg is measured at 33.0°C and the tnw is measured at 28.0°C. Calculate the WBGT in degrees Fahrenheit.

   WBGT = 0.7tnw + 0.3tg
   WBGT = 0.7(28.0) + 0.3(33.0) = 19.6 + 9.9
   WBGT = 29.5°C
   F = 9/5C + 32 = 85.1
   WBGT = 85.1°F

8. The heat stress exposure profile of a glass factory worker, in terms of WBGT, was as follows: 2.7 h at 97°F, 3.2 h at 101°F, and 2.1 h at 76°F. What was this worker's time-weighted average exposure?

   93.1°F

9. Consider a tw of 65°F (18.3°C) and a tg of 90°F (32.2°C) in a work environment in which the air is moving at 100 ft/min (0.51 m/s). What is the workers' feeling of warmth in this workplace in terms of *corrected effective temperature* (CET)?

   CET = 77°F

CHAPTER 14—ERGONOMICS

1. What is ergonomics?

   Ergonomics is the study of the relationship between the human body, the human mind, and the physical environment. Ergonomists evaluate a person's size, shape, and neural/cognitive abilities in order to match them to the appropriate materials, equipment, structures, tools, and systems.

2. Why is ergonomics important to the successful operations of, say, an airline company?

   By implementing ergonomics principles and controls, the company can reduce injuries and their associated costs. Ergonomics can also improve employee efficiency, morale, and comfort on the job.

3. If an ergonomist walked into a factory, what worker activities would he or she scrutinize to identify musculoskeletal hazards?

   Repetition, awkward postures, force being used, working environment

4. What is carpal tunnel syndrome, and why are women more likely to experience it?

   Carpal tunnel syndrome occurs when the median nerve, which runs from the forearm into the palm of the hand, becomes pressed or squeezed at the wrist. The carpal tunnel is smaller in some people than in others; therefore, women are more likely to suffer carpal tunnel syndrome.

5. Which plane divides the body into front and back halves?

   The coronal or frontal plane

6. If workers turn a dial clockwise with their right hand, what type of motion are they performing? If they perform the same activity with their left hand, what type of action are they performing?

   Supination and pronation

7. What is anthropometry, and why is it important in ergonomics?

   Anthropometry is "the science that defines physical measures of a person's size, form, and functional capacities." It is important because it accounts for physical differences in individuals' capabilities to do work. Not everyone can do the same tasks safely and efficiently.

8. How many kilocalories per hour does a person's body use while driving an automobile?

   170

9. What are three main working conditions or activities associated with musculoskeletal injuries?

   - Repetitive activities
   - Awkward postures
   - Excessive force

10. How can the force needed to perform a task be measured?

    By using a dynamometer

11. What does an accelerometer measure?

    Vibration

12. How does a goniometer work, and what does it measure?

    A goniometer is lined up with body parts to measure the angles and ranges of motion associated with different job activities.

13. What is a key aspect of workplace design in terms of ergonomic performance?

    The workplace should be designed to fit the worker, rather than the other way around.

14. What are some ways that facility design can reduce musculoskeletal hazards?

    - Reducing walking distances
    - Minimizing changes in elevation
    - Improving lighting
    - Reducing stress and noise
    - Reducing chemical or biological hazards

15. Why should workers be involved in developing ergonomic programs or improvements?

    Frontline workers are often the most knowledgeable about the musculoskeletal hazards at their workstations.

16. What are some organizational stressors that can increase the risk of musculoskeletal injuries?

    Fast pace, lack of control over the job, long hours, working off shift, short staffing

CHAPTER 15—BIOLOGICAL HAZARDS

1. What are some factors that affect the viability of infectious agents in the environment?

    Air temperature, humidity, and UV light can affect the viability of a range of infectious agents. Moisture on surfaces can also affect the survivability of infectious agents.

2. Describe one of the body's natural defenses that keeps infectious agents out or eliminates them once they get into the body.

    The innate immune system is the first line of defense. Anatomical barriers and the skin are another defense. In the intestine, gastric acids and digestive enzymes kill pathogens. In the respiratory tract, the mucociliary escalator can actively remove biological particles. The nasopharynx secretes lysozymes, and the eyes produce tears.

3. What are some of the factors that affect the likelihood of becoming infected?

    Environmental viability, infectiveness, virulence

4. What is the difference between infectiveness and virulence?

    Infectiveness is a measure of an agent's ability to colonize and cause infection. Virulence is a measure of how aggressive an infectious agent is.

5. How is a pandemic different from an epidemic?

    An epidemic is the widespread occurrence of a disease affecting an unusually large number of population members and is beyond what is normally expected or encountered (as in endemic disease). Pandemics are epidemics that spread out into geographic areas where the disease is not typically expected to occur.

6. UV germicidal radiation can be a useful tool to control infectious agents in health care settings. What challenges does the use of UV radiation present to the industrial hygienist?

    UV radiation can cause sunburn and eye irritation and is indicated as a probable carcinogen by the International Agency for Research on Cancer. The industrial hygienist needs to ensure that workers and the public are not overexposed to this potentially dangerous type of radiation.

7. What does a biological safety officer do?

    This individual ensures that facility activities are conducted with appropriate controls to minimize worker exposure to hazardous agents and to prevent the agents' release into the environment or surrounding community. He or she works with others on the laboratory team to ensure that appropriate precautions are taken.

8. According to the World Health Organization, what types of agents fall into Risk Group 3?

    (High individual risk; low community risk) A pathogen that usually causes serious human or animal disease but does not ordinarily spread from one infected individual to another. Effective treatment and preventive measures are available.

ANSWERS TO REVIEW QUESTIONS

9. What types of agents can be handled in a BSL-2 laboratory?

   Agents of moderate potential risk to personnel and the environment. These agents can cause disease in healthy individuals and pose a moderate risk to the environment.

10. What are four examples of secondary barriers in biological safety facilities?

    Any of the following:
    - access control
    - self-closing doors
    - decontamination devices (autoclaves)
    - designated hand-washing facilities
    - specially designed and filtered ventilation systems
    - airlocks or antechambers at laboratory entrances
    - various levels of laboratory isolation

11. What type of Class 2 hood offers the best protection to both workers and the product?

    Class 2 Type B2

12. What is the main difference between disinfection and sterilization?

    Sterilization completely eliminates all living microorganisms, bacterial endospores, and viruses from tools, equipment, and solutions. Disinfection involves reducing the amount of pathogenic microorganisms on surfaces, but it does not eliminate all microbiological agents, such as bacterial spores.