

Hydrogen Safety



Introduction

- Millions of workers are exposed to hydrogen hazards daily
- Hydrogen is very safe under controlled conditions
- Each year, numerous accidents with hydrogen result in death
- Workers must know the hazards associated with hydrogen
- Safety can be greatly enhanced if training is provided
- Standards require:
 - ✓ Hazards be assessed
 - ✓ Training be conducted
 - ✓ Hazards and precautions be explained
 - ✓ Emergency response capability be established

Objectives

- Provide an Introduction to the Toxicology of Hydrogen
- Discuss Hydrogen's Usage in Today's Industry
- Discuss General Terms Used in Hydrogen Safety
- Discuss Methods of Compliance with Hydrogen Safety
- Discuss the Routes of Entry Into the Human Body
- Discuss the Hazards of Hydrogen in the Human Body
- Discuss Any Medical Surveillance Requirements
- Discuss Personal Protective Equipment Requirements
- Discuss Hazard Recognition and Control Skills

Learning Outcome

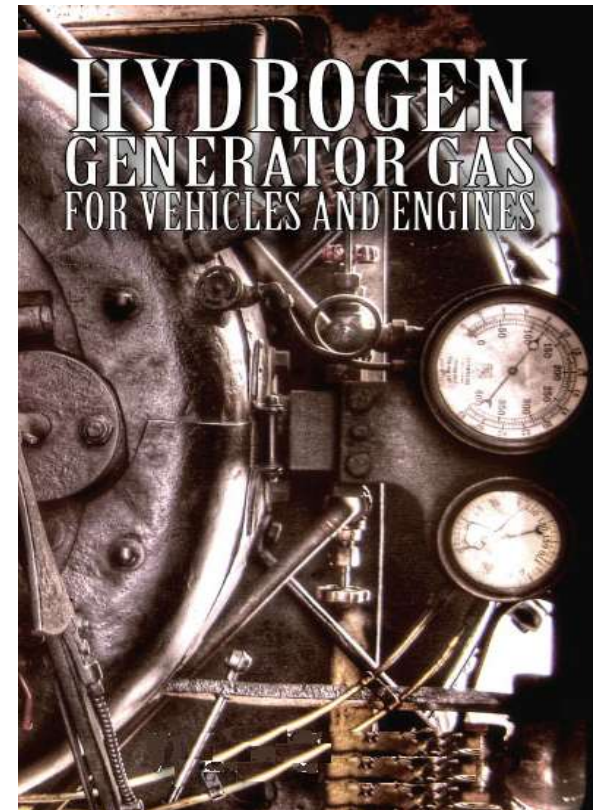
UNDERSTAND THE FOLLOWING:

- Why Hydrogen Safety Is Important
- The Basics of Toxicology as it Relates to Hydrogen
- Basic Safety Precautions Related to Hydrogen Safety
- Specific Hazards Associated with Hydrogen Exposure
- The Training Requirements Associated with Hydrogen
- Housekeeping Requirements Where Hydrogen is Present
- The Use of Personal Protective Equipment to Prevent Exposure

Use of Hydrogen in Industry

USES OF HYDROGEN IN INDUSTRY:

- Dental industry
- Glass manufacturing
- Tool making industry
- Proprietary processes
- Production of methanol
- Low-temperature research
- Hydrogenation of fats and oils
- Embrittlement of stainless steel
- Fixation of atmospheric nitrogen



Hydrogen Hazards

- Hydrogen usage is very common and extremely hazardous
- Deaths from hydrogen include both responders and on-site workers
- Injuries and deaths from hydrogen accidents are 100% preventable
- Hydrogen inhalation exposure can result in asphyxiation
- Inhalation is the primary route of entry for hydrogen into the body
- Skin exposure can cause frostbite and loss of limbs
- Work area releases of hydrogen can displace oxygen
- Hydrogen may ignite when mixed with ambient air
- Hydrogen fires are nearly impossible to extinguish
- Hydrogen emergencies can happen instantaneously

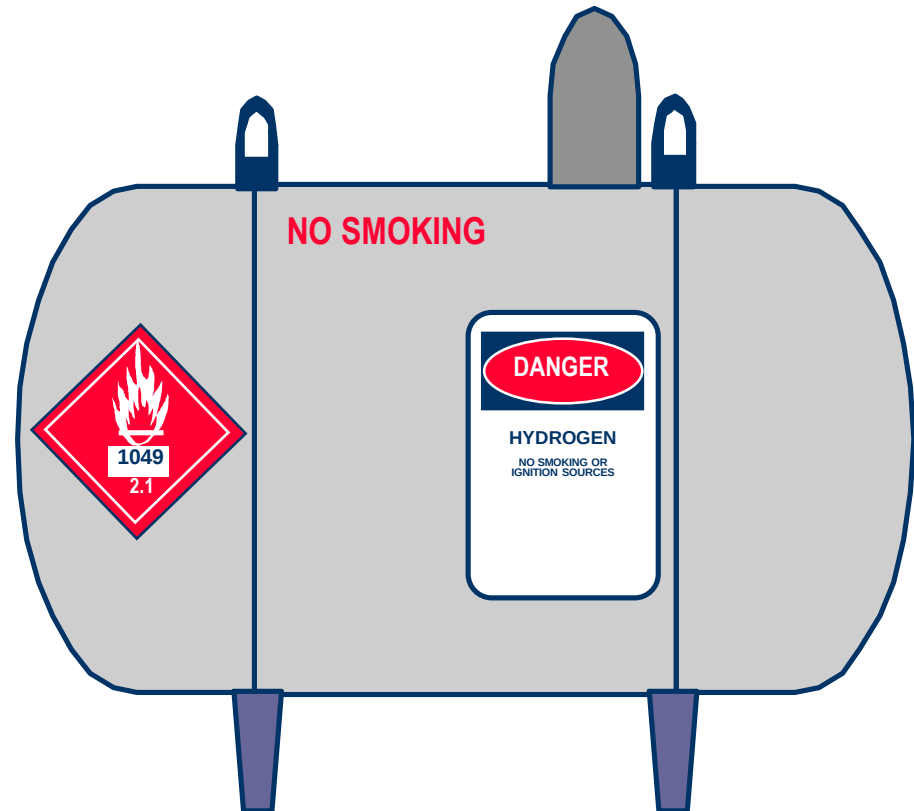
Physical Properties

SYNONYMS AND TRADE NAMES:

- ✓ Hydrogen
- ✓ Liquefied hydrogen
- ✓ Protium

PHYSICAL DESCRIPTION:

- ✓ Colorless, odorless gas when pure



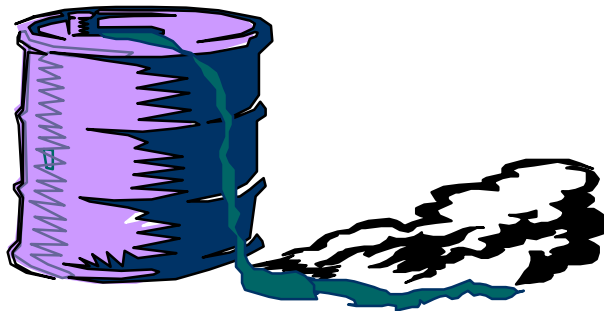
Physical Properties

VAPOR DENSITY:

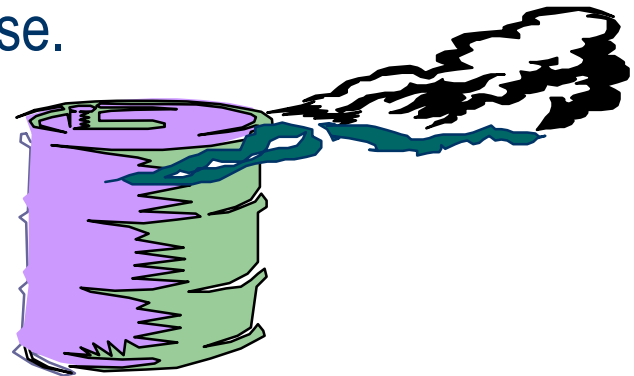
Vapor Density is the mass of gases and vapors as it is compared to the mass of an equal volume of air or other reference gas.

VAPOR DENSITY OF HYDROGEN IS: 0.07

VD greater than 1.0: the vapors are heavier than air and lay in low areas.



VD less than 1.0: the vapors are lighter than air and will rise.

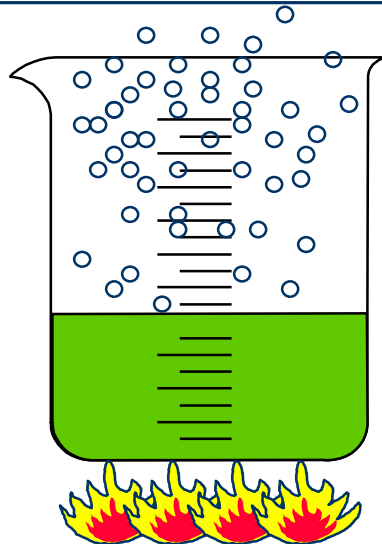


Physical Properties

BOILING POINT:

Liquid boils at the point when vapor pressure equals atmospheric pressure. The corresponding temperature is called the boiling point of liquid.

BOILING POINT OF HYDROGEN IS: - 423 Degrees F



Physical Properties

FLAMMABLE RANGE:

The numerical difference between the upper and lower explosive limits. In other words, the range that the vapors of a flammable liquid (when ignited) will burn when mixed with ambient air.

HIGHER EXPLOSIVITY LIMIT (HEL)

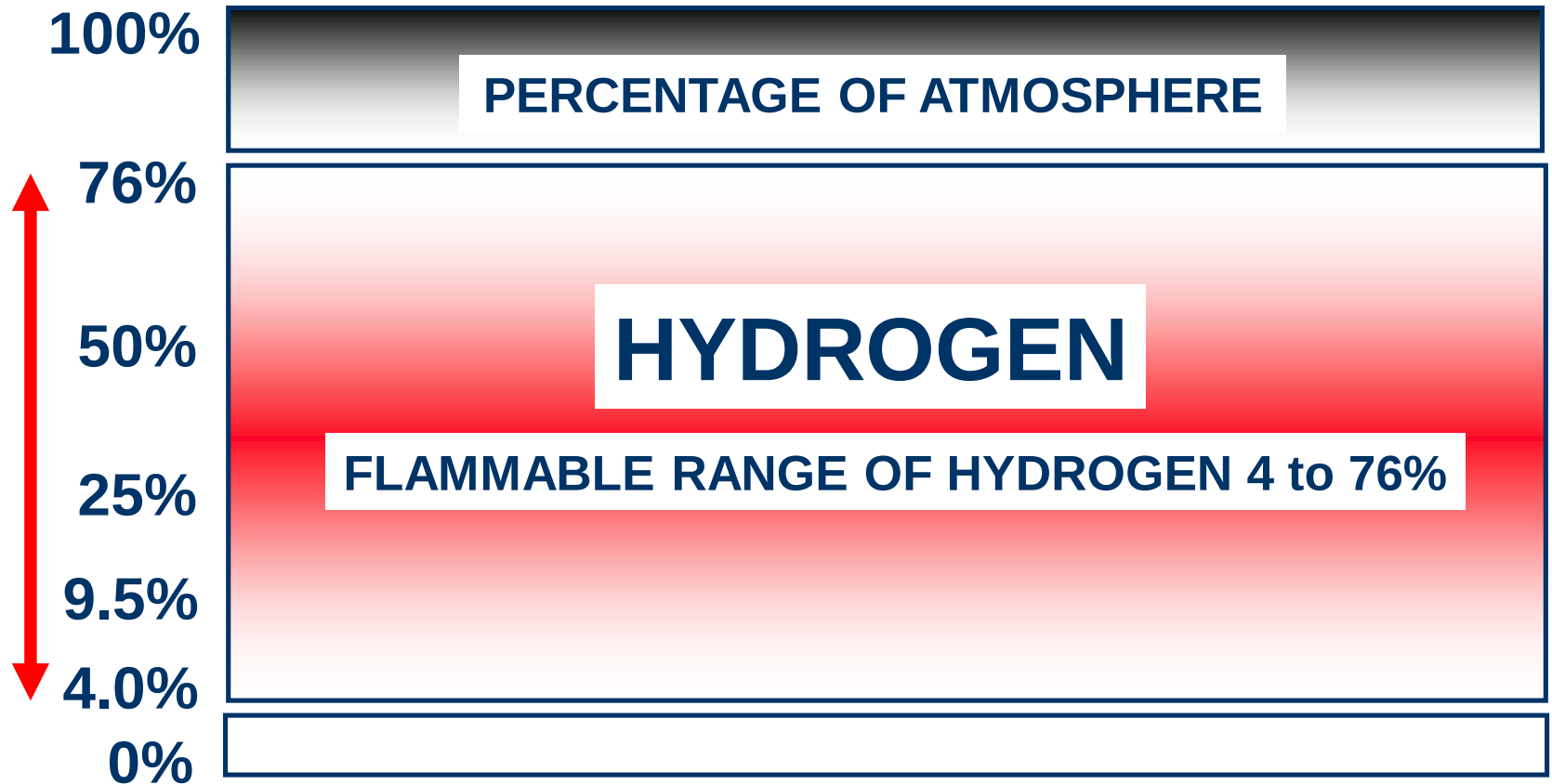
The highest point at which a mixture of flammable vapor and air will no longer support combustion

LOWER EXPLOSIVITY LIMIT (LEL)

The lowest point at which a mixture of flammable vapor and air will no longer support combustion

Physical Properties

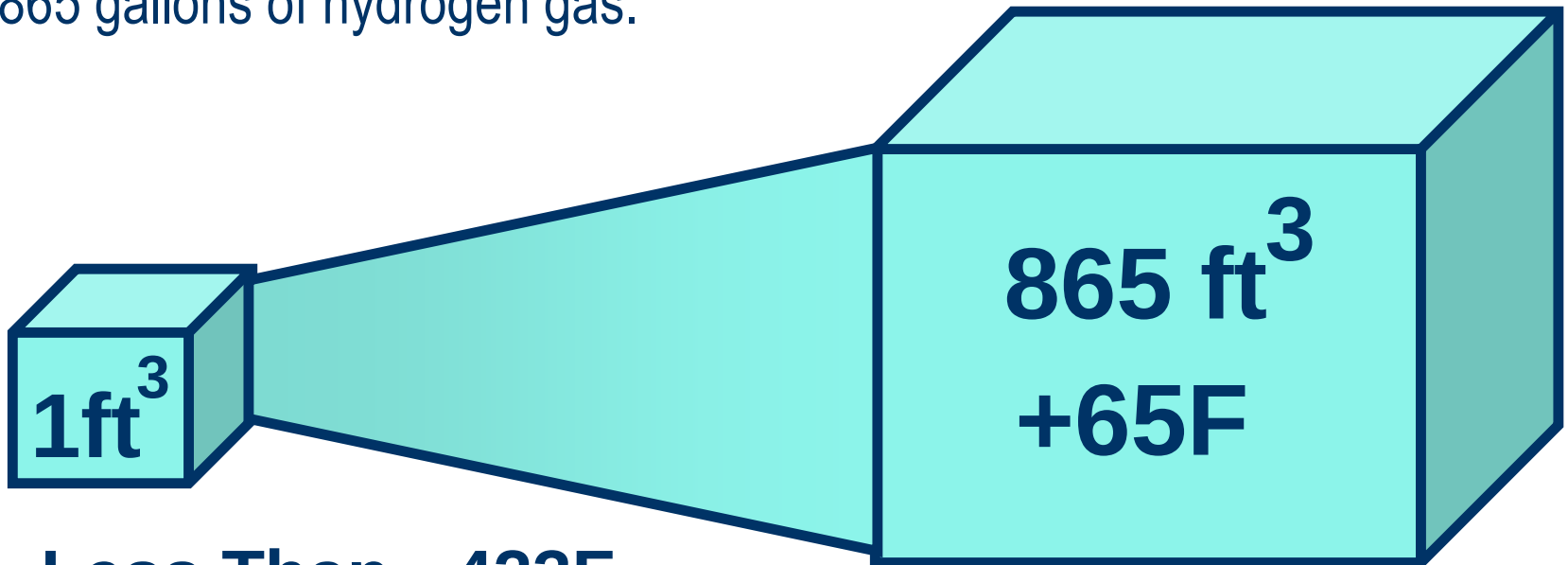
FLAMMABLE RANGE OF HYDROGEN IS: 4% TO 76 %



Physical Properties

EXPANSION RATIO:

Expansion Ratio compares the amount of gas produced when a certain volume of liquid is vaporized. The expansion ratio of hydrogen is 865 to 1. In open air, one gallon of hydrogen becomes 865 gallons of hydrogen gas.



Less Than - 423F

Physical Properties

HYDROGEN ARE INCOMPATIBLES AND REACTIVES:

- When mixed with oxygen across a wide range of proportions, hydrogen explodes upon ignition
- Reacts directly with other oxidizing elements
- Hydrogen burns violently in air
- Hydrogen gas is highly flammable and will burn at concentrations of 4% to 76% in air
- Hydrogen mixed with Halogens can produce acids



Physical Properties

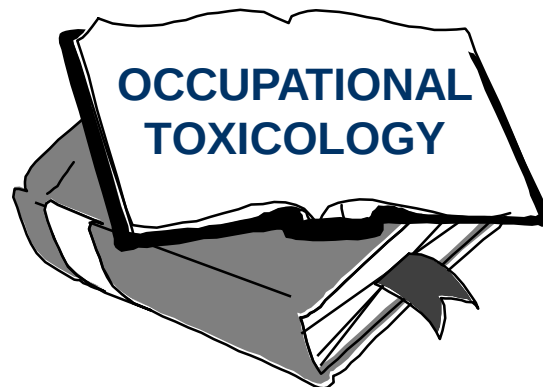
SPECIFIC PROPERTIES:

- Toxicity: Non-toxic
- Color: Colorless
- Odor: Odorless
- Vapor density: 0.082
- Range of Flammability: 4 to 76%
- Expansion Factor: 865 Cu. Ft. To 1
- Boiling point: - 423 deg. F



Hydrogen Toxicology

LETS DISCUSS SOME OF THE TERMS THAT WILL BE HELPFUL IN UNDERSTANDING THE AFFECTS OF HYDROGEN ON YOUR BODY.



Hydrogen Toxicology

ALL THINGS ARE POISONS, OR THERE IS NOTHING WITHOUT POISONOUS QUALITIES. IT IS ONLY THE DOSE WHICH MAKES A THING POISON.

PARACELSUS

(1493 - 1541)

Hydrogen Toxicology

EXPOSURE TERMINOLOGY

Hazardous Material. A Material That Falls Into One or More Of the Following Categories. Hazardous Materials Can Have One or Many Characteristics That Can Add to the Intensity of the Toxic Action of a Particular Solid, Liquid, or Gas.

- **Ignitability:** Is Flammable or Combustible
- **Reactivity:** Can React With Itself or Other Materials
- **Corrosivity:** Can Deteriorate Another Substance
- **Toxicity:** In Its Normal State Is Harmful to Living Things

Hydrogen Toxicology

**EVERYTHING IS TOXIC;
IT ALL DEPENDS ON THE DOSE.**

How Well the Body Accepts a Substance Depends on:

- The Type of Substance
- The Amount (Dose) Absorbed
- The Period of Time Over Which It Is Absorbed
- The Susceptibility/Sensitivity of the Person Exposed

Hydrogen Toxicology

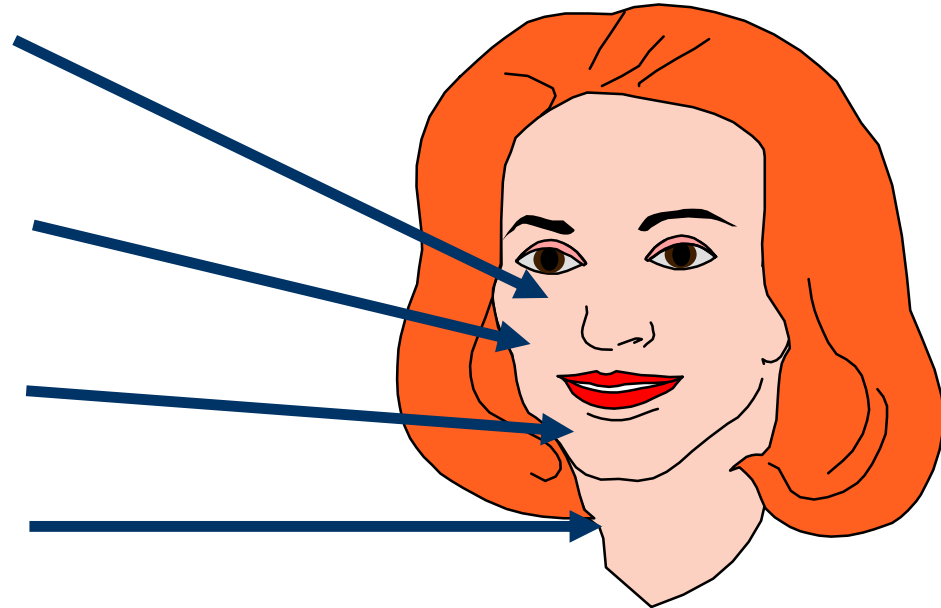
THE PRIMARY ROUTE FOR HYDROGEN

INHALATION

INGESTION

ABSORPTION

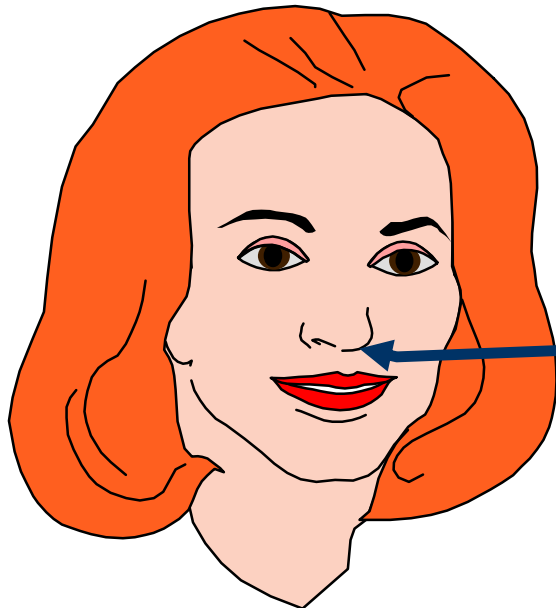
INJECTION



Hydrogen Toxicology

INHALATION

Breathing and smoking causes us to inhale substances which enter the lungs. Substances inhaled into the lungs cause scarring of the lungs or are readily absorbed into the blood stream.

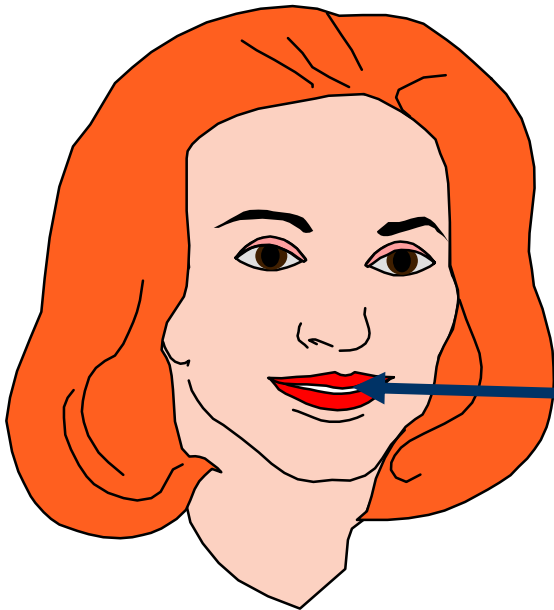


- ☒ INHALATION
- ☒ INGESTION
- ☒ ABSORPTION
- ☒ INJECTION

Hydrogen Toxicology

INGESTION

Swallowing a substance causes penetration into the blood stream via the stomach and small intestine.

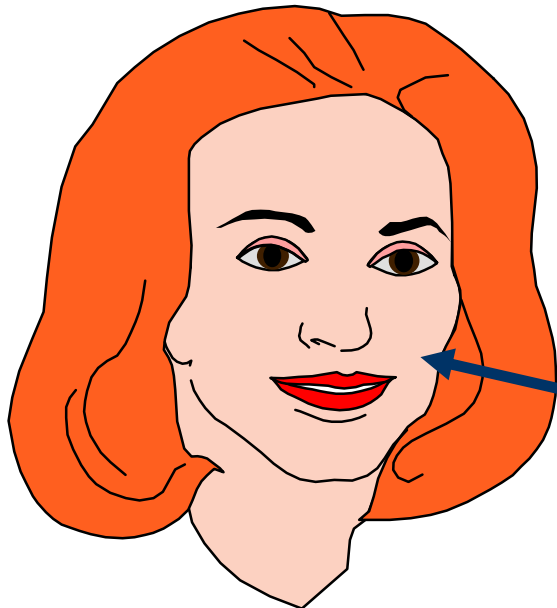


- ☑ INHALATION
- ☑ INGESTION
- ☑ ABSORPTION
- ☑ INJECTION

Hydrogen Toxicology

ABSORPTION

Entering the body through the skin causes substances to enter the blood stream at a slower rate than by inhalation or absorption. However, the resulting entry and distribution within the body is the same.

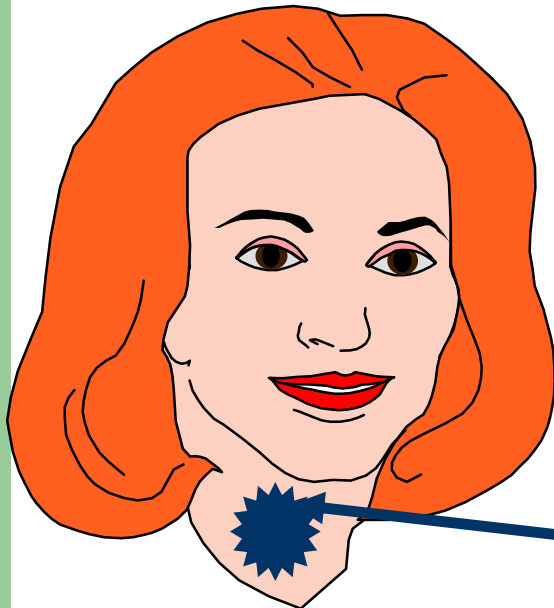


- ✓ INHALATION
- ✓ INGESTION
- ✓ ABSORPTION
- ✓ INJECTION

Hydrogen Toxicology

INJECTION

Injection occurs when substances are forced through the skin. This can occur as a result of such means as compressed air, or by having the skin abraded by a penetrating object.



- ☒ INHALATION
- ☒ INGESTION
- ☒ ABSORPTION
- ☒ INJECTION

Hydrogen Toxicology

TLV - Threshold Limit Value: One of three categories of chemical exposure levels - TLV-TWA, TLV-STEL or TLV-C.

TLV-TWA - Threshold Limit Value Time-Weighted Average: The-time weighted average concentration for a normal 8-hour workday and a 40-hour work week to which nearly all workers may be repeatedly exposed without adverse effect.

NOTE: Should be used as an exposure guide rather than an absolute. A physician has the final word.

Hydrogen Toxicology

TLV-STEL - Threshold Limit Value - Short Term Exposure Limit: A 15-minute time-weighted average exposure that should not be exceeded at any time during the work day.

TLV-C - Threshold Limit Value - Ceiling: The concentration that should not ever be exceeded, even instantaneously.

Factors Influencing Toxic Action

- **RATE OF ENTRY**
- **STATE OF HEALTH**
- **AGE OF INDIVIDUAL**
- **ROUTE OF EXPOSURE**
- **PREVIOUS EXPOSURE LEVELS**
- **WORKPLACE ENVIRONMENTAL FACTORS**
- **INDIVIDUAL SUSCEPTIBILITY AND HEREDITY**



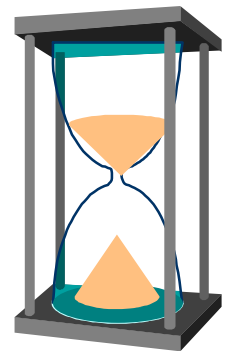
Exposure Terminology

✓ Acute Exposure:

Usually Minutes, Hours, or Several Days

✓ Chronic Exposure:

Regular Exposure Over Months, Years, or a Lifetime



The Toxicity of the Chemical or Material Combined With the Susceptibility of the Individual, Determines Whether the Exposure Is Acute or Chronic.

Exposure Terminology

- ☑ Latent Exposure: An injury or disease that remains undeveloped until an incubation period has elapsed. The period of time could be hours, days, months, or years.



The Toxicity of the Chemical or Material Combined With the Susceptibility of the Individual Is a Key Factor.

Factors Affecting Exposure

The Amount Entering the Body
The Length of Time of Exposure
The Rate of Absorption Into the Blood
The Physical Nature of the Chemical
The Chemical Nature of the Chemical
The Age of the Individual
The Health of the Individual

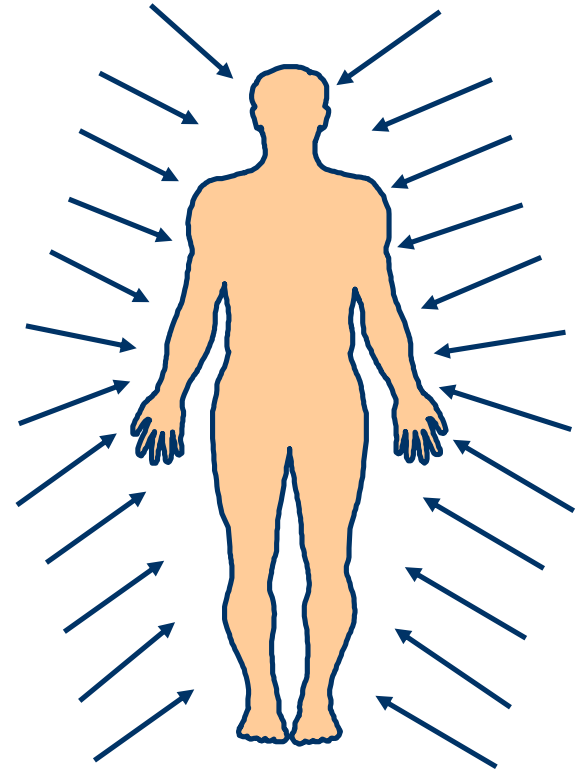
Health Effect of Hydrogen Exposure

COMMON SYMPTOMS OF HYDROGEN EXPOSURE:

- Simple asphyxiation

TARGET ORGANS:

- None



Health Effect of Hydrogen Exposure

HEALTH AFFECTS OF HYDROGEN EXPOSURE:

- Severe Frostbite and loss of limbs or extremities
- Asphyxiation
- Respiratory Failure
- Death

Methods of Compliance

GENERAL TYPES OF CONTROLS:

Methods of Compliance Include:

- Implementation of a Written Program
- Establishment of Safe Work Practices
- Establishment of Engineering Controls
- Establishment of Administrative Controls
- Regular Evaluation of Mechanical Safety Systems
- Evaluation of Each Facility Where Hydrogen is Used
- Use of Personal Protective Equipment As a Last Resort
- On-Going Review of the Program's Effectiveness

Methods of Compliance

ENGINEERING CONTROLS:

CONSISTS OF:

- Local exhaust is required
- Automatic alerting is appropriate in most cases
- Purge all systems before introducing hydrogen
- Design and install automatic safety control systems
- Detailed preventative maintenance programs
- On-going on site maintenance activities
- Proper placement of storage systems
- Detailed coordination with emergency responders

Methods of Compliance

ADMINISTRATIVE CONTROLS:

CONSISTS OF:

- Assignment of Responsibility
- Support From Upper Management
- On-Site Safety Inspections and Audits
- Written Policies - Establishment of Site Safety Protocols
- Training - Job Specific Training Programs
- Checklists - Job Specific Safety Checklists
- Placement of Warning Signs and Employee Information

Methods of Compliance

PROTECTIVE EQUIPMENT AND CLOTHING:

- GENERAL REQUIREMENTS:
 - Full body skin protection for potentially exposed workers
 - Proper gloves to prevent hand exposure
 - Adequate Eye and Face Protection
 - Availability of respiratory equipment is mandatory
 - Air supplied breathing apparatus is mandatory

Methods of Compliance

HOUSEKEEPING IN PROCESS/STORAGE AREAS:

Vehicle Safety:

- ✓ Adequate Protection Against Accidental Vehicle Collisions
- ✓ Pre-Planned Traffic Routing for Forklifts and Other Vehicles

Control of Flammable/Combustible Material in Storage Areas:

- ✓ Periodic Inspection of Process and Storage Areas
- ✓ Adherence to Safe Distance Requirements for Combustible Materials

Waste and Empty Container Management:

- ✓ Collection and Disposal of Empty Containers
- ✓ Storage and handling of dike Containers for Disposal

Exposure Control

EMERGENCY ACTIONS IF LEAK IS DETECTED:

- Stay out of leak area and avoid downwind areas
- High concentrations in the air can cause a displacement of oxygen with the risk of unconsciousness or death
- Responder: Check oxygen content before entering leak area
- Wear Self Contained Breathing Apparatus
- Allow fires to burn out (generally)
- Follow local emergency procedures

Exposure Control

EXPOSURE INFORMATION:

Supervisors will maintain the following for each job:

- A description of each job
- A list of tools or machinery used in the job
- Types of materials processed
- Exposure controls that are in place
- Crew size (if applicable)
- Employee job responsibilities
- Safety controls specific to the job
- Operating procedures specific to the job
- Maintenance practices specific to the job

Exposure Control

EXPOSURE INFORMATION:

Means to Achieve Safety Compliance:

- Each job where hydrogen is used will have a written description of the specific means that will be employed to achieve compliance, including engineering plans and studies used to determine methods selected for controlling safety of hydrogen.
- Ensuring employees are familiar with written safety policies.

Warning Signs

WARNING SIGNS:

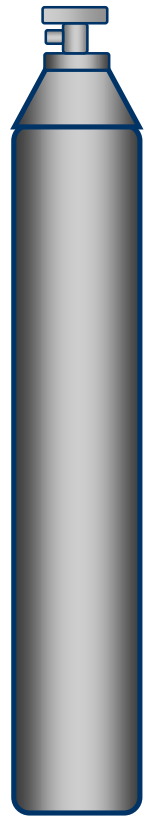
Warning signs shall be install in the area where hydrogen are stored.



Basic Safety Rules

CONTENT IDENTIFICATION:

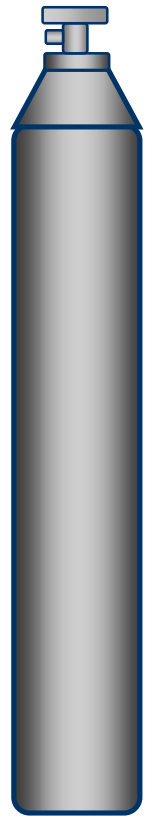
- Never assume you know what it is!
- Assuming (with gases) can kill you!
- Labels must be legible at all times
- Labels may not be altered or removed
- Labels may not be bypassed, ignored, or otherwise defeated
- Labels must be understood by all
- Illegible/missing labels must be reported



Basic Safety Rules

CONTENT IDENTIFICATION:

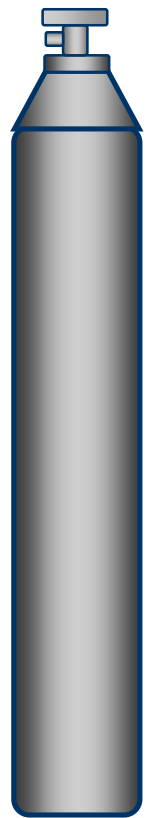
- Labels and their means of attachment must withstand their normal operating environment
- Labels may evoke a false sense of security, and their meaning needs to be understood
- Labels must be securely attached to cylinders so that they cannot be inadvertently or accidentally detached during use
- Each container must bear the proper label for the gas contained



Basic Safety Rules

PAINTING CYLINDERS/CONTAINERS:

- Containers may not be painted
- Painting may cover cylinder defects
- Containers showing signs of corrosion must be removed from service and returned to the supplier
- Never rely solely on the cylinder color for identification



Basic Safety Rules

LEAKING AND DEFECTIVE CYLINDERS:

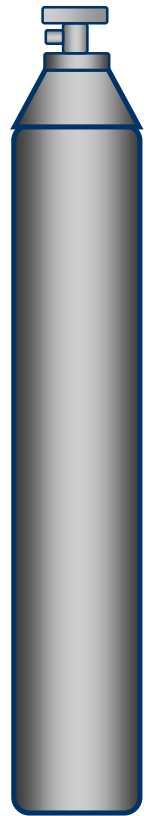
- Never underestimate the hazard!
- Notify co-workers of the hazard
- Consider evacuation of the area
- Evacuate to open air, upwind or side wind
- Report the contents, location, situation
- Begin role call to account for co-workers
- Do not return to work until all-clear is given
- Bulk Containers - follow established procedures



Basic Safety Rules

CYLINDER USAGE REQUIREMENTS:

- Verify contents before transporting or using
- Keep cylinder caps on until ready to connect
- Keep valve caps on until ready to use
- Never use as a door stop
- Never underestimate the hazard



Basic Safety Rules

MOVEMENT OF COMPRESSED GAS CYLINDERS:

- Never handle roughly
- Never use magnetic lifting devices
- Never lift by valves or cylinder caps
- Never roll, drag, or slide the cylinder
- Always use a hand-truck, fork truck, etc
- Cradles, ropes, chains, or slings are prohibited from use unless lugs or lifting attachments are provided by the manufacturer as with bulk containers

Gas Storage

STORAGE REQUIREMENTS (GENERAL):

- No Smoking signs must be posted
- The name of the gas must be posted
- Specific hazards must be posted
- Containers must be stored upright
- Gases must be stored with like gases
- Do not intermingle full and empty containers
- The oldest material must be used first
- Store only on stable surfaces
- Some gases must always be shaded from sun
- Bulk Containers - follow established procedures



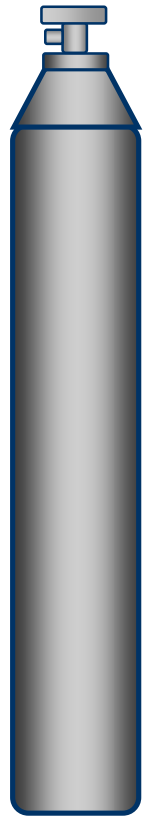
Gas Storage



Gas Storage

STORAGE ROOMS (GENERAL):

- Must be dry
- Must not exceed 130 F
- Must be well-ventilated
- Should be protected from tampering
- Local fire inspectors should evaluate
- Compressed Gas Handling Procedure should be reviewed
- Subsurface storage should be avoided
- Should be of fire-resistive construction



Gas Storage

STORAGE ROOMS (GENERAL):

- Cylinders
 - Must not impede emergency egress
 - Cannot be located near exits
 - Cannot be located near stairs
- Must be secured to prevent toppling
- Bulk Containers - follow established procedures



Gas Storage

OUTDOOR STORAGE (GENERAL):

- Bottoms must be protected from corrosion
- Must be secured to prevent toppling.
- Must be shaded in extreme temperatures
- Some gases must always be shaded from sun
- Should be of fire-resistive construction
- Should be protected from tampering
- Local fire inspectors should evaluate
- Warning signs should be provided

Cylinder Inspection

GENERAL INSPECTION CRITERIA:

INSPECT FOR:

Dents
Crevice Corrosion
Bulges
ARC/ Torch Burns
Cuts, Gouges, or Digs
Corrosion
Pitting
Neck Defects
Valve Ease-Of-Movement
Valve Thread Serviceability

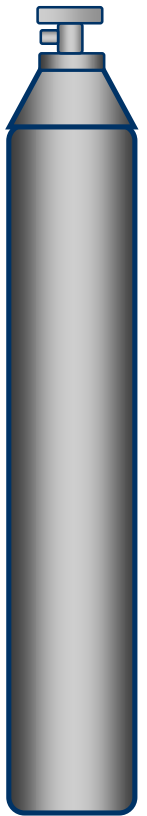
POSSIBLE RESULT:

Weakening of cylinder wall
Weakening of cylinder wall
Weakening of cylinder wall
Weakening of cylinder wall
Decrease in wall thickness
Decrease in wall thickness
Decrease in wall thickness
Leak or cylinder explosion
Corrosion leading to leak
Leak during operation

Summary

PRE-OPERATION SAFETY RULES:

- If you're not trained; do not touch it
- Read the Material Safety Data Sheet before use
- Ensure tag is present
- Ensure all labels/warnings are readable
- Place upright on stable dry surface
- Ensure cylinder is restrained above midpoint
- Keep heat, flame, and electrical sources from gas
- Use in accordance with established procedures
- Bulk Containers - follow established procedures



Summary

POST-OPERATION SAFETY RULES:

- If you're not trained; do not touch it!
- Read the Material Safety Data Sheet before use.
- Ensure an empty label is present
- Close valve completely and cap cylinder
- Remove from operation (established procedures)
- Transport cylinder using established procedures
- Place in empty Container storage area
- Ensure empty label is readable
- Bulk Containers - follow established procedures