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CIVE 3331 - ENVIRONMENTAL ENGINEERING
Spring 2003

Document Name: CIVE3331_Exercises_002.doc

Purpose: Exercises related to Lecture # 2. These exercises develop unit conversion skills and an understanding of the concept of concentrations in different environmental media (air and water). The last exercise requires the student to exercise critical thinking and make an assessment of the relative risk of two exposure pathways. Direct relationships to various accreditation objectives are highlighted in **Bold** type in the following sections. The exercises start on the next page.

Relevant ABET EC 2000 Criteria: Criterion 3 Program Outcomes and Assessment

(3-a) an ability to **apply knowledge of mathematics, science, and engineering.**
(3-e) an ability to identify, **formulate, and solve engineering problems.**
(3-b) an ability to design and conduct experiments, as well as **to analyze and interpret** data.
(3-k) **an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.**

Relevant CEE Educational Objectives:

(3) Emphasize problem-identification, **problem-formulation** and communication skills, **problem-solving techniques and the many facets of engineering design** throughout the curriculum.

(5) **Prepare every student to develop the skills for critical thinking and lifelong learning.**

Relevant CEE Program Outcomes:

ii. **Students should acquire the ability to solve** practical civil engineering **problems by applying the knowledge of mathematics, science**, engineering, modern techniques, skills and practical tools they gained in their courses.

Exercise_002-1

The proposed air quality standard for ozone (O_3) is 0.08 ppm. Express this standard in $\mu g/m^3$ at 1 atm of pressure and 25°C.

Gas problem: ppm is vol/vol unit

~~.068~~ $0.08 \cdot 10^{-6}\, m^3/m^3 \times \frac{10^3 L}{m^3} \times \frac{1 mol}{24.46 L} \times \frac{48 g\, O_3}{1 mol} = 1.569 \cdot 10^{-4}\, g/m^3$

$1.569 \cdot 10^{-4}\, g/m^3 \times \frac{10^6 \mu g}{1 g} = 156.9\, \mu g/m^3$

Report as $157\, \mu g/m^3$

Exercise_002-2

The proposed air quality standard for ozone (O_3) is 0.08 ppm. At the elevation of Denver (about 1700 meters), the pressure is about 0.82 atm. Express the ozone standard at this pressure and at a temperature of 15°C.

Ideal gas

$pV = nRT$ $T = 273.15$, $P = 1\ atm$, $n = 1\ mol$, $V = 22.414$

Boyle's Law

$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$$

$$\frac{(1\ atm)(22.414L)}{273.15K} = \frac{(0.82\ atm)(??\ L)}{(273.15+15\ K)}$$ solve for ??

$V_{@\ denver\ is} = 28.835 L/mol$

Now repeat 002-1 using this volume

$$0.08 \cdot 10^{-6}\ m^3/m^3 \times \frac{10^3 L}{m^3} \times \frac{1 mol}{28.835 L} \times \frac{48 g\ O_3}{mol} = 1.3317 \cdot 10^{-4}\ g/m^3$$

$$1.3317 \cdot 10^{-4}\ g/m^3 \times \frac{10^6 \mu g}{g} = 133.1\ \mu g/m^3$$

report as $133\ \mu g/m^3$

Exercise_002-3

Suppose the exhaust gas from an automobile contains 1.0 % by volume of carbon monoxide (CO). Express this concentration in mg/m^3 at 25°C and 1 atm.

$$[CO] = 0.01 \, m^3/m^3 \times \frac{10^3 L}{m^3} \times \frac{1 mol}{24.46 L} \times \frac{28 g\ CO}{mol} = 11.447 g_{CO}/m^3$$

$$11.447 g_{CO}/m^3 \times \frac{10^3 mg}{g} = 11,447 mg/m^3\ CO$$

report as $11,450\ mg/m^3\ CO$

Exercise_002-4

Suppose the average concentration of SO_2 is measured to be 400 $\mu g/m^3$ at 25°C and 1 atm. Does this exceed the (24-hr) air quality standard of 0.14 ppm? (Table 2.1 of textbook, or a periodic table of elements contains the required atomic weights for this exercise)

$$\frac{400 \cdot 10^{-6}\, g\, SO_2}{m^3} \times \frac{1\, m^3}{1000\, L} \times \frac{24.46\, L}{1\, mol} \times \frac{1\, mol}{64\, g\, SO_2} = 1.53 \cdot 10^{-7} \frac{m^3}{m^3}$$

$$1.53 \cdot 10^{-7} \frac{m^3}{m^3} \times 10^6 = 0.152\, ppm$$

report as 0.15 ppm which does exceede 0.14 ppm

Exercise_002-5

A typical motorcycle emits about 20 g of CO per mile. What volume of CO would a 5-mile trip produce after the gas cools to 25°C at 1 atm?

$$V = \frac{20\,g\,CO}{mile} \times 5\,mile \times \frac{1\,mol\,CO}{28\,g\,CO} \times \frac{24.465\,L}{mol} \times \frac{1\,m^3}{10^3\,L} = 0.087\,m^3$$

report as $0.09\,m^3$

Exercise_002-6

A typical motorcycle emits about 20 g of CO per mile. What volume of air per meter of distance traveled could be polluted to the air quality standard of 9 ppm (after the gas has cooled to 25°C at 1 atm)?

9 ppm CO : $\frac{9 m^3\ CO}{10^6 m^3\ air}$

20g CO * 5mi = $0.087 m^3$ CO

∴ at 9ppm the following must hold:

$$\frac{9 m^3\ CO}{10^6 m^3\ air} = \frac{0.087 m^3\ CO}{V\ m^3\ air}$$ solve for V

$V = 9666 m^3$

5miles pollutes $9666 m^3$ air

so one meter pollutes

$$\frac{9666 m^3}{5 miles} \cdot \frac{1 miles}{1609 meters} = \frac{1.2 m^3}{m}$$

Exercise_002-7

a) In Harris County, TX the median indoor airborne concentration of chloroform ($CHCL_3$) was 0.4 µg/m3. Convert this concentration to a mole fraction in parts per billion assuming T=293K and P=1 atm.

b) The mean concentration of chloroform in drinking water in Harris County is 42 µg/L. Convert this to a mass fraction in parts per billion (ppb).

c) A typical adult inhales about 20 m^3 of air and ingests about 2 L of water per day. Assuming that the concentrations determined above are appropriate, compare the exposure to chloroform via inhalation (µg per day) and ingestion (µg per day).

d) Assume tetrachloroethylene (C_2CL_4) has median concentrations of 0.10 µg/L in water and 2.1 µg/m^3 in air. Repeat the exposure pathway analysis for this chemical.

e) Comment on the relative significance of breathing and drinking exposure to these two chemicals.

a) $V_{293K} = V_{273K}\left(\frac{293K}{273K}\right) = 24.04\ L/mol$ (Version of Boyle's law)

$0.4\cdot10^{-6}\frac{g\ CHCl_3}{m^3}\cdot\frac{1\ mol\ CHCl_3}{118\ g\ CHCl_3}\cdot\frac{24.04\ L\ air}{mol\ air}\cdot\frac{1\ m^3}{1000\ L\ air} = 8.149\cdot10^{-10}\frac{mol\ CHCl_3}{mol\ air}$

$8.149\cdot10^{-10}\times10^{9} = 0.082$ ppb $CHCl_3$

$42\cdot10^{-6}\frac{g\ CHCL_3}{L\ H_2O}\cdot\frac{1\ L\ H_2O}{1000\ g} = 42\cdot10^{-9}\frac{g\ CHCl_3}{g\ H_2O}\times10^{9} = 42$ ppb $CHCl_3$

20 m^3 air × 0.4 µg/m^3 = 8.0 µg/day inhalation $CHCl_3$

2 L H_2O × 42 µg/L = 84 µg/day ingest $CHCL_3$

20 m^3 air × 2.1 µg/m^3 = 40.2 µg/day inhale TCE

2L H_2O × 0.1 µg/L = 0.2 µg/day ingest TCE

relative exposure $CHCl_3$ is 10x greater via ingestion

relative exposure TCE is 400x greater via inhalation

if health effects (per chemical) are same by either route then greater risk by ingestion for $CHCl_3$, and greater risk by inhalation for TCE