APPROVED SOLUTION

CADET ____________________ SECTION ______TIME OF DEPARTURE ________

DEPARTMENT OF CHEMISTRY & LIFE SCIENCE

CH365 2023-2024
WRITTEN PARTIAL REVIEW I
7 September 2023, A-Hour

TEXT: Smith, Van Ness, & Abbott
SCOPE: Lessons 1-8

References Permitted: Open note, book, and computer. You may not share files or communicate with other cadets in any way during the exam.

INSTRUCTIONS

1. You will have 55 minutes to complete the exam.
2. Do not mark the exam or open it until “begin work” is given.
3. There are 3 problems on 5 pages (not including the cover page). Write your name on the top of each sheet. Answer all questions.
4. Solve the problems in Mathematica or in the space provided. Show work to receive for partial credit.

(TOTAL WEIGHT: 200 POINTS)

DO NOT WRITE IN THIS SPACE

PROBLEM	VALUE	CUT
A	60	
B	70	
C	70	
TOTAL CUT		
TOTAL GRADE	200	

Problem: Weight:
A 60

A well-insulated container filled with 21.25 kg of mineral oil at 17.910 °C is fitted with a stirrer made to turn by gravity acting on a weight of mass 150.00 kg connected to the stirrer by a cable and a system of pulleys. Initially, the weight and the fluid are completely at rest. When the weight drops, energy is transferred through the pulley system into the mineral oil through the stirrer. After the weight stops falling, the mineral oil is allowed to come to rest so that any swirling motion ceases and the bulk velocity of the fluid is zero. At this point, the weight and the fluid are again completely at rest, but the temperature is observed to have increased slightly but reproducibly, leading to the hypothesis that the potential energy change of the weight is transferred to the mineral oil.

The first law for a steady-state, steady flow process is given by equation 2.31. Note carefully that this equation also applies to non-flowing systems because the flow rate was subsumed into the different terms. The local acceleration of gravity is 9.807 (m)(s^{-2}), and that the specific heat of mineral oil is 1.67 (kJ)(kg^{-1})(°C^{-1}).

(a) Define the thermodynamic system and then write and simplify equation 2.31 for the Joule experiment as described above.

Solution:

The system is defined as the fluid in the vessel.

$$\Delta H + \cancelto{0}{\frac{\Delta\left(u^2\right)}{2}} + \cancelto{0}{g\Delta z} = \cancelto{0}{Q} + W_{shaft} \qquad \text{(Equation 2.31)}$$

The system (fluid) is at rest before and after the weight drop.

The fluid does not change elevation.

There is no heat transfer to or from the surroundings.

$$\underline{\underline{\Delta H = W_{shaft}}}$$

ANS

(b) Use the definition of enthalpy to explain how ΔH in equation 2.31 leads to ΔU and explain any simplifying assumptions.

Solution:

- Since the experiment is open to the atmosphere, pressure is assumed constant.
- Molar volume of the oil is also essentially constant for small temperature changes.

$$\Delta H = \Delta U + \cancelto{0}{\Delta\left(PV\right)} = \Delta U$$

$$\therefore \underline{\underline{\Delta H = \Delta U}}$$

ANS

(c) Determine the internal energy change of the oil if the final temperature is 18.51$\underline{2}$ °C.

Solution:

- ΔH is given by equation 2.21 with constant C_p, which leads to $\Delta H^t = mC_P\Delta T$:

$$\therefore \Delta H^t = m \cdot C_P \cdot \Delta T = 21.2\underline{5}\,\text{kg} \cdot \frac{1.6\underline{7}\,\text{kJ}}{\text{kg deg C}} \cdot \left(18.51\underline{2}\,\text{deg C} - 17.91\underline{0}\,\text{deg C}\right) = \underset{\text{ANS}}{\underline{\underline{21.\underline{3}63\ \text{kJ}}}} = \Delta U^t$$

(d) How far did the weight drop?

Solution:

$$\Delta H = W_{shaft} = mg\Delta z$$

$$21.\underline{3}63\,\text{kJ} \cdot \frac{1000\,\text{J}}{1\,\text{kJ}} = 150.0\underline{0}\ \text{kg} \cdot 9.807\frac{\text{m}}{\text{s}^2} \cdot \Delta z \cdot \frac{1\ \text{J}}{\frac{1\,\text{kg} \cdot \text{m}^2}{\text{s}^2}}$$

$$\underset{\text{ANS}}{\underline{\underline{\Delta z = 14.\underline{5}2\,\text{m}}}}$$

Cadet: APPROVED SOLUTION

Problem: B

Weight: 70

1. A mercury manometer is attached at one end to a pressure vessel containing a gas and is open to the atmosphere at the other end. The reading on the manometer is 22.23 inches of mercury (in Hg) and the absolute pressure in the vessel is 51.54 in Hg. What is the atmospheric pressure in psia?

Additional information: The temperature of the vessel and the surroundings are both 70 °F, the density of mercury at 70 °F is 13.543 g/cm^3, the local acceleration of gravity is 32.243 ft/s^2 (9.828 m/s^2), and 1 torr = 1 mm Hg.

Solution:

The absolute pressure in the vessel is the sum of the manometer pressure and the atmospheric pressure, so the atmospheric pressure is obtained by subtracting the manometer (gauge) pressure from the total:

$$P_{total} = P_{gauge} + P_{atm},\ \therefore\ P_{atm} = P_{total} - P_{gauge} = 51.54 - 22.23 = 29.31\text{ in Hg}$$

$$29.3\underline{1}\text{ inches Hg} \cdot \frac{1000\text{ mm Hg}}{39.3701\text{ inches Hg}} \cdot \frac{14.5038\text{ psi}}{750.063\text{ torr}} \cdot \frac{1\text{ torr}}{1\text{ mm Hg}} = \underline{\underline{14.3\underline{9}6\text{ psi}}}_{\text{ANS}}$$

2. A mass of 10$\underline{0}$ kg is placed on a dead-weight gauge with a piston diameter of 5.0$\underline{0}$ mm. What is the pressure produced in bar?

Additional information: The local acceleration of gravity is 9.828 m/s^2.

Solution:

Pressures is force per area, so calculate the force, calculate the area, then divide and apply the appropriate conversion factor:

$$\text{force} = 10\underline{0}\text{ kg} \cdot \frac{9.828\text{ m}}{s^2} \cdot \frac{1\text{ N}}{1\text{ kg}\cdot\text{m}/s^2} = 98\underline{2}.8\text{ N}$$

$$\text{area} = \frac{\pi}{4}\left(5.0\underline{0}\text{ mm} \cdot \frac{1\text{ m}}{1000\text{ mm}}\right)^2 = 1.9\underline{6}35\times10^{-5}\text{ m}^2$$

$$\text{pressure} = \frac{\text{force}}{\text{area}} = \frac{98\underline{2}.8\text{ N}}{1.9\underline{6}35\times10^{-5}\text{ m}^2} \cdot \frac{1\text{ bar}}{10^5\text{ N/m}^2} = \underline{\underline{50\underline{0}.5\text{ bar}}}_{\text{ANS}}$$

Problem: Weight:
C 70

One kilogram of hydrogen is cooled reversibly at constant pressure from an initial state of 20.0 L/mol (State 1) until its molar volume is reduced to 5.00 L/mol and its temperature reduced to 75.0 K (State 2).

The table summarizes the conditions at states 1 and 2, where the question marks (??) designate unknowns. Complete the table below and then calculate W, Q, ΔH, and ΔU for the process, in units of kJ mol^{-1}.

Assume that PV/T = 0.08314 bar L mol^{-1} K^{-1} and that C_P = 30.74 J mol^{-1} K^{-1} for hydrogen.

	State 1	State 2
P, bar	____ ??	____ ??
T, K	____ ??	75.0
V, L/mol	20.0	5.00

Solution:

Solve for P_2:

$$\frac{P_2V_2}{T_2} = 0.08314 \Rightarrow P_2 = \frac{0.08314T_2}{V_2} = \frac{0.08314\ \dfrac{\text{bar}\cdot\text{L}}{\text{mol}\cdot\text{K}}\cdot 75.\underline{0}\,\text{K}}{5.0\underline{0}\ \dfrac{\text{L}}{\text{mol}}} = 1.2\underline{4}7\ \text{bar} = P_1$$

The system is at constant pressure, so $P_1 = P_2$ = $\underline{\underline{1.2\underline{4}7\ \text{bar}}}$.
ANS

Now solve for T_1:

$$\frac{P_1V_1}{T_1} = 0.08314 \Rightarrow T_1 = \frac{P_1V_1}{0.08314} = \frac{1.2\underline{4}7\ \text{bar}\cdot 20.\underline{0}\ \dfrac{\text{L}}{\text{mol}}}{0.08314\ \dfrac{\text{bar}\cdot\text{L}}{\text{mol}\cdot\text{K}}} = \underline{\underline{30\underline{0}.\ \text{K}}}_{\text{ANS}}$$

Work done on the system:

$$W = -1.2\underline{4}7\,\text{bar}\cdot\left(\frac{5.00\ \text{L}}{\text{mol}} - \frac{20.0\,\text{L}}{\text{mol}}\right) = 18.\underline{7}05\ \frac{\text{bar}\cdot\text{L}}{\text{mol}}$$

Note: work done on the system is positive for a compression.

Convert this to kJ/mol:

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$$\frac{18.\underline{7}05\,\text{bar}\cdot\text{L}}{\text{mol}}\cdot\frac{10^5\ \text{Pa}}{\text{bar}}\cdot\frac{\frac{1\text{N}}{\text{m}^2}}{\text{Pa}}\cdot\frac{1\ \text{m}^3}{1000\ \text{L}}\cdot\frac{1\text{J}}{1\,\text{Nm}}\cdot\frac{1\ \text{kJ}}{1000\ \text{J}}=\underline{\underline{1.8\underline{7}05\frac{\text{kJ}}{\text{mol}}}}_{\text{ANS}}$$

Heat:

$$Q=C_p\cdot\Delta T=\frac{30.74\,\text{J}}{\text{mol}\cdot\text{K}}\cdot(75.\underline{0}\,\text{K}-30\underline{0}.\,\text{K})\cdot\frac{1\text{kJ}}{1000\,\text{J}}=\underline{\underline{-6.9\underline{1}65\ \frac{\text{kJ}}{\text{mol}}}}_{\text{ANS}}$$

Note: heat is negative.

Enthalpy change:

$$\Delta H=Q=\underline{\underline{-6.9\underline{1}65\ \frac{\text{kJ}}{\text{mol}}}}_{\text{ANS}}$$

Internal energy change:

$$\Delta U=Q+W=-6.9\underline{1}65\frac{\text{kJ}}{\text{mol}}+1.8\underline{7}05\frac{\text{kJ}}{\text{mol}}=\underline{\underline{-5.0\underline{4}6\frac{\text{kJ}}{\text{mol}}}}_{\text{ANS}}$$

APPROVED SOLUTION

CADET ____________________ SECTION ______TIME OF DEPARTURE ________

DEPARTMENT OF CHEMISTRY & LIFE SCIENCE

CH365 2023-2024
WRITTEN PARTIAL REVIEW I
7 September 2023, B-Hour

TEXT: Smith, Van Ness, & Abbott
SCOPE: Lessons 1-8

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PROBLEM	VALUE	CUT
A	60	
B	70	
C	70	
TOTAL CUT		
TOTAL GRADE	200	

Problem:	Weight:
A	60

A well-insulated container filled with $80.0\underline{0}$ kg of liquid bromine at $19.00\underline{0}$ °C is fitted with a stirrer made to turn by gravity acting on a weight of mass $100.\underline{0}$ kg connected to the stirrer by a cable and a system of pulleys. Initially, the weight and the fluid are completely at rest. When the weight drops, energy is transferred through the pulley system into the mineral oil through the stirrer. After the weight stops falling, the mineral oil is allowed to come to rest so that any swirling motion ceases and the bulk velocity of the fluid is zero. At this point, the weight and the fluid are again completely at rest, but the temperature is observed to have increased slightly but reproducibly, leading to the hypothesis that the potential energy change of the weight is transferred to the mineral oil.

The first law for a steady-state, steady flow process is given by equation 2.31. Note carefully that this equation also applies to non-flowing systems because the flow rate was subsumed into the different terms. The local acceleration of gravity is $9.80\underline{7}$ $(m)(s^{-2})$, and that the specific heat of bromine is $0.473\underline{6}$ $(kJ)(kg^{-1})(°C^{-1})$.

(a) Define the thermodynamic system and then write and simplify equation 2.31 for the Joule experiment as described above.

Solution:

The system is defined as the fluid in the vessel.

$$\Delta H + \cancelto{0}{\frac{\Delta\left(u^2\right)}{2}} + \cancelto{0}{g\Delta z} = \cancelto{0}{Q} + W_{shaft} \qquad \text{(Equation 2.31)}$$

The system (fluid) is at rest before and after the weight drop.

The fluid does not change elevation.

There is no heat transfer to or from the surroundings.

$$\underline{\underline{\Delta H = W_{shaft}}}$$

ANS

(b) Use the definition of enthalpy to explain how ΔH in equation 2.31 leads to ΔU and explain any simplifying assumptions.

Solution:

- Since the experiment is open to the atmosphere, pressure is assumed constant.
- Molar volume of the oil is also essentially constant for small temperature changes.

$$\Delta H = \Delta U + \Delta\cancelto{0}{\left(PV\right)} = \Delta U$$

$$\therefore \underline{\underline{\Delta H = \Delta U}}$$

ANS

(c) Determine the internal energy change of the liquid bromine if the final temperature is 19.16$\underline{2}$ °C.

Solution:

- ΔH is given by equation 2.21 with constant C_p, which leads to $\Delta H^t = mC_P\Delta T$:

$$\Delta H^t = m \cdot C_P \cdot \Delta T = 80.0\underline{0}\,\text{kg} \cdot \frac{0.473\underline{6}\,\text{kJ}}{\text{kg deg C}} \cdot \left(19.16\underline{2}\,\text{deg C} - 19.00\underline{0}\,\text{deg C}\right) = \underline{\underline{6.1\underline{3}79\ \text{kJ}}} = \Delta U^t$$

ANS

(d) How far did the weight drop?

Solution:

$$\Delta H = W_{shaft} = mg\Delta z$$

$$6.1\underline{3}79\,\text{kJ} \cdot \frac{1000\ \text{J}}{1\,\text{kJ}} = 100.0\underline{0}\ \text{kg} \cdot 9.807\,\frac{\text{m}}{\text{s}^2} \cdot \Delta z \cdot \frac{1\ \text{J}}{\frac{1\,\text{kg} \cdot \text{m}^2}{\text{s}^2}}$$

$$\underline{\underline{\Delta z = 6.2\underline{5}9\,\text{m}}}$$

ANS

Cadet: **APPROVED SOLUTION**

Problem:	Weight:
B	70

1. A mercury manometer is attached at one end to a pressure vessel containing a gas and is open to the atmosphere at the other end. The reading on the manometer is 33.79 inches of mercury (in Hg) and the atmospheric pressure is 28.78 in Hg. What is the absolute pressure in the vessel in psia?

Additional information: The temperature of the vessel and the surroundings are both 70 °F, the density of mercury at 70 °F is 13.543 g/cm^3, the local acceleration of gravity is 32.243 ft/s^2 (9.828 m/s^2), and 1 torr = 1 mm Hg.

Solution:

The absolute pressure in the vessel is the sum of the manometer pressure and the atmospheric pressure, so the vessel pressure is obtained by adding the manometer (gauge) and atmosphere pressures:

$$P_{vessel} = P_{gauge} + P_{atm} = 33.79 + 28.78 = 62.5\underline{7}\ \text{in Hg}$$

$$62.5\underline{7}\ \text{inches Hg} \cdot \frac{1000\ \text{mm Hg}}{39.3701\ \text{inches Hg}} \cdot \frac{14.5038\ \text{psi}}{750.063\ \text{torr}} \cdot \frac{1\ \text{torr}}{1\ \text{mm Hg}} = \underset{\text{ANS}}{\underline{\underline{30.7\underline{3}\ \text{psi}}}}$$

2. A mass of 200 kg is placed on a dead-weight gauge with a piston diameter of 6.00 mm. What is the pressure produced by the gauge in bar?

Additional information: The local acceleration of gravity is 9.828 m/s^2.

Solution:

Pressures is force per area, so calculate the force, calculate the area, then divide and apply the appropriate conversion factor:

$$\text{force} = 20\underline{0}\ \text{kg} \cdot \frac{9.828\ \text{m}}{\text{s}^2} \cdot \frac{1\ \text{N}}{1\ \text{kg} \cdot \text{m}/\text{s}^2} = 19\underline{6}5.5\ \text{N}$$

$$\text{area} = \frac{\pi}{4}\left(6.0\underline{0}\ \text{mm} \cdot \frac{1\ \text{m}}{1000\ \text{mm}}\right)^2 = 2.8\underline{2}743 \times 10^{-5}\ \text{m}^2$$

$$\text{pressure} = \frac{\text{force}}{\text{area}} = \frac{196\underline{5}.5\ \text{N}}{2.87243 \times 10^{-5}\ \text{m}^2} \cdot \frac{1\ \text{bar}}{10^5\ \text{N}/\text{m}^2} = \underset{\text{ANS}}{\underline{\underline{69\underline{5}.2\ \text{bar}}}}$$

Cadet: **APPROVED SOLUTION**

<u>Problem:</u> C   <u>Weight:</u> 70

One kilogram of oxygen is heated reversibly at constant pressure from an initial state of 5.00 L/mol and 20$\underline{0}$ K bar (State 1) until its molar volume increases to 30.0 L/mol (State 2).

The table summarizes the conditions at states 1 and 2, where the question marks (??) designate unknowns. Complete the table below and then calculate W, Q, ΔH, and ΔU for the process, in units of kJ mol^{-1}.

Assume that PV/T = 0.08314 bar L mol^{-1} K^{-1} and that C_p = 32.41 J mol^{-1} K^{-1} for oxygen.

	State 1	State 2
P, bar	____ ??	____ ??
T, K	20$\underline{0}$	____ ??
V, L/mol	5.00	30.0

Solution:

Solve for P_1:

$$\frac{P_1V_1}{T_1} = 0.08314 \Rightarrow P_1 = \frac{0.08314T_1}{V_1} = \frac{0.08314\,\dfrac{\text{bar}\cdot\text{L}}{\text{mol}\cdot\text{K}}\cdot 20\underline{0}.\text{K}}{5.0\underline{0}\,\dfrac{\text{L}}{\text{mol}}} = 3.3\underline{2}56\text{ bar}$$

The system is at constant pressure, so $P_2 = P_1 = \underline{\underline{3.3\underline{2}56\text{ bar}}}$. ANS

Now solve for T_2:

$$\frac{P_2V_2}{T_2} = 0.08314 \Rightarrow T_2 = \frac{P_2V_2}{0.08314} = \frac{3.3\underline{2}56\text{ bar}\cdot 30.\underline{0}\,\dfrac{\text{L}}{\text{mol}}}{0.08314\,\dfrac{\text{bar}\cdot\text{L}}{\text{mol}\cdot\text{K}}} = 12\underline{0}0\text{ K}$$

Work done by the system.

$$W = -3.3\underline{2}56\,\text{bar}\cdot\left(\frac{30.\underline{0}\text{ L}}{\text{mol}} - \frac{5.0\underline{0}\,\text{L}}{\text{mol}}\right) = -83.\underline{1}4\,\frac{\text{bar}\cdot\text{L}}{\text{mol}}$$

Note: work done by the system is negative for an expansion.

Convert this to kJ/mol:

Cadet: **APPROVED SOLUTION**

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$$\frac{-83.\underline{1}4\,\text{bar}\cdot\text{L}}{\text{mol}}\cdot\frac{10^5\ \text{Pa}}{\text{bar}}\cdot\frac{\frac{1\text{N}}{\text{m}^2}}{\text{Pa}}\cdot\frac{1\ \text{m}^3}{1000\ \text{L}}\cdot\frac{1\text{J}}{1\,\text{Nm}}\cdot\frac{1\ \text{kJ}}{1000\ \text{J}}=\underline{\underline{-8.3\underline{1}4\frac{\text{kJ}}{\text{mol}}}}_{\text{ANS}}$$

Heat:

$$Q=C_p\cdot\Delta T=\frac{32.41\text{J}}{\text{mol}\cdot\text{K}}\cdot(12\underline{0}0\,\text{K}-20\underline{0}\,\text{K})\cdot\frac{1\text{kJ}}{1000\,\text{J}}=\underline{\underline{32.\underline{4}1\ \frac{\text{kJ}}{\text{mol}}}}_{\text{ANS}}$$

Note: heat is positive.

Enthalpy change:

$$\Delta H=Q=\underline{\underline{32.\underline{4}1\ \frac{\text{kJ}}{\text{mol}}}}_{\text{ANS}}$$

Internal energy change:

$$\Delta U=Q+W=32.\underline{4}1\frac{\text{kJ}}{\text{mol}}-8.3\underline{1}4\frac{\text{kJ}}{\text{mol}}=\underline{\underline{24.\underline{0}96\ \frac{\text{kJ}}{\text{mol}}}}_{\text{ANS}}$$

APPROVED SOLUTION

CADET ____________________ SECTION ______TIME OF DEPARTURE ________

DEPARTMENT OF CHEMISTRY & LIFE SCIENCE

CH365 2023-2024
WRITTEN PARTIAL REVIEW I
8 September 2022, Makeup

TEXT: Smith, Van Ness, & Abbott
SCOPE: Lessons 1-8

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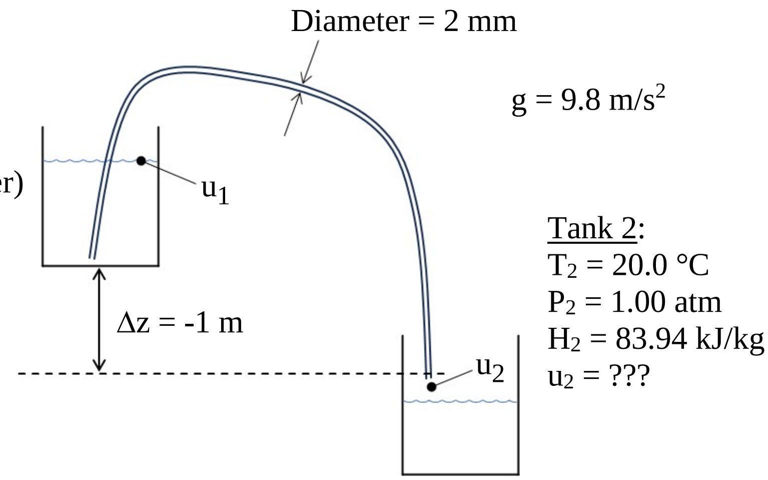
B	70	
C	70	
TOTAL CUT		
TOTAL GRADE	200	

Cadet: **APPROVED SOLUTION**

Problem: A   Weight: 60

Siphons have been used since ancient times to move water in pipes over hills and through valleys. The diagram below illustrates transferring water between two tanks in a laboratory using a siphon tube. In this apparatus, tank 1 is initially filled with 1 L of water and tank 2 is 1 m below tank 1. A 2-mm tube is placed so that the left-hand end of the tube is below the liquid level in tank 1, and the right-hand end of the tube is placed into tank 2. Tank 2 is also large enough to contain all of the water initially in tank 1. Additional property information is also provided in the figure.



Tank 1 is initially filled with 1 L of water and heat transfer to and from the system is negligible and we can ignore frictional losses in the tube.

The first law for a steady-state, steady flow process is given by equation 2.31. Note carefully that this equation also applies to flowing systems because the flow rate was subsumed into the different terms. (a) Write this equation in this exam and simplify it for the siphon experiment as described above. (b) Use the simplified equation derived in (a) to solve for the exit velocity of the siphon tube (u_2). (c) Determine the time required to drain tank 1. (d) Determine the time to drain the tank if a 5-mm tube is used.

Solution:

(a) Equation 2.31 is written and simplified below:

Define the system: fluid in the tube.

$$\cancelto{0}{\Delta H} + \frac{\Delta(u^2)}{2} + g\Delta z = \cancelto{0}{Q} + \cancelto{0}{W_{shaft}} \qquad \text{(Equation 2.31)}$$

Initial and final enthalpies are the same ($H_1 = H_2$).

Heat transfer is negligible.

No shaft work is done on the system.

$$\frac{\Delta(u^2)}{2} + g\Delta z = 0 \qquad \text{(Equation 1a)}$$

ANS

(b) Solve equation 1a for u_2:

$$\frac{\Delta\left(u^2\right)}{2}+g\Delta z=0$$

$$\frac{u_2^2}{2}-\frac{u_1^2}{2}=-g\Delta z$$

$$u_2=\pm\sqrt{u_1^2-2g\Delta z}$$

$$\therefore u_2=\underline{\underline{4.43\,\text{m/s}}}_{\text{ANS}}$$

(c) Use the velocity from (b) and the cross-sectional area of the tune to calculate volumetric flow rate, then divide liquid volume (V1) by the volumetric flow rate to obtain the time:

$$\text{area}=\frac{\pi}{4}d^2=\frac{\pi}{4}(0.002\,\text{m})^2=3.14\times10^{-6}\,\text{m}^2$$

$$v_0=\text{area}\times u_2=\left(3.14\times10^{-6}\,\text{m}^2\right)\times\left(4.43\frac{\text{m}}{\text{s}}\right)\times\frac{1000\,\text{L}}{\text{m}^3}=0.0139\frac{\text{L}}{\text{s}}$$

$$\underline{\underline{\frac{1\,\text{L}}{.0139\frac{\text{L}}{\text{s}}}=71.9\,\text{s}}}_{\text{ANS}}$$

(d) Repeat the calculation in part (c) with the larger diameter (5 mm):

$$\text{area}=\frac{\pi}{4}d^2=\frac{\pi}{4}(0.005\,\text{m})^2=1.96\times10^{-5}\,\text{m}^2$$

$$v_0=\text{area}\times u_2=\left(1.96\times10^{-5}\,\text{m}^2\right)\times\left(4.43\frac{\text{m}}{\text{s}}\right)\times\frac{1000\,\text{L}}{\text{m}^3}=0.0869\frac{\text{L}}{\text{s}}$$

$$\underline{\underline{\frac{1\,\text{L}}{.0869\frac{\text{L}}{\text{s}}}=11.5\,\text{s}}}_{\text{ANS}}$$

Problem:	Weight:
B	70

1. A mercury manometer is attached at one end to a pressure vessel containing a gas and is open to the atmosphere at the other end. The reading on the manometer is 23.32 inches of mercury (in Hg) and the absolute pressure in the vessel is 52.45 in Hg. What is the atmospheric pressure in psia?

Additional information: The temperature of the vessel and the surroundings are both 70 °F, the density of mercury at 70 °F is 13.543 g/cm^3, the local acceleration of gravity is 32.243 ft/s^2, and 1 torr = 1 mm Hg.

Solution:

The absolute pressure in the vessel is the sum of the manometer pressure and the atmospheric pressure, so the atmospheric pressure is obtained by subtracting the manometer (gauge) pressure from the total:

$$P_{total} = P_{gauge} + P_{atm},\ \therefore\ P_{atm} = P_{total} - P_{gauge} = 52.45 - 23.32 = 29.13 \text{ in Hg}$$

$$29.1\underline{3}\text{ inches Hg}\cdot\frac{1000\text{ mm Hg}}{39.3701\text{ inches Hg}}\cdot\frac{14.5038\text{ psi}}{750.063\text{ torr}}\cdot\frac{1\text{ torr}}{1\text{ mm Hg}} = \underline{\underline{14.3\underline{0}7\text{ psi}}}_{\text{ANS}}$$

2. A mass of 14$\underline{4}$ kg is placed on a dead-weight gauge with a piston diameter is 3.0$\underline{0}$ mm. What is the pressure produced by the gauge in bar?

Additional information: The local acceleration of gravity is 9.80665 m/s^2.

Solution:

Pressures is force per area, so calculate the force, calculate the area, then divide and apply the appropriate conversion factor:

$$\text{force} = 14\underline{4}\text{ kg}\cdot\frac{9.80665\text{ m}}{\text{s}^2}\cdot\frac{1\text{ N}}{1\text{ kg}\cdot\text{m}/\text{s}^2} = 14\underline{1}2.16\text{ N}$$

$$\text{area} = \frac{\pi}{4}\left(3.0\underline{0}\text{ mm}\cdot\frac{1\text{ m}}{1000\text{ mm}}\right)^2 = 7.0\underline{6}86\times10^{-6}\text{ m}^2$$

$$\text{pressure} = \frac{\text{force}}{\text{area}} = \frac{1412.16\text{ N}}{7.0686\times10^{-6}\text{ m}^2}\cdot\frac{1\text{ bar}}{10^5\text{ N}/\text{m}^2} = 19\underline{9}7.8\text{ bar} = \underline{\underline{20\underline{0}0\text{ bar}}}_{\text{ANS}}$$

Problem: C   Weight: 70

One kilogram of air is heated reversibly at constant pressure from an initial state of 25.0 L/mol and 300 K (State 1) until its molar volume is increased by a factor of 4 (State 2).

The table summarizes the conditions at states 1 and 2, where the question marks (??) designate unknowns. Complete the table below and then calculate W, Q, ΔH, and ΔU for the process, in units of kJ mol^{-1}.

Assume that PV/T = 0.08314 bar L mol^{-1} K^{-1} and that C_p = 31.44 J mol^{-1} K^{-1} for air.

	State 1	State 2
P, bar	____ ??	____ ??
T, K	300	____ ??
V, L/mol	25.0	100.0

Solution:

Solve for P_1 (= P_2 = P):

$$\frac{P_1V_1}{T_1} = 0.08314 \Rightarrow P_1 = \frac{0.08314T_1}{V_1} = \frac{0.08314\,\frac{\text{bar}\cdot\text{L}}{\text{mol}\cdot\text{K}}\cdot 300\,\text{K}}{25.0\,\frac{\text{L}}{\text{mol}}} = \underline{\underline{0.998\ \text{bar} = P_2}}\ \text{ANS}$$

Solve for T_2:

$$\frac{P_2V_2}{T_2} = 0.08314 \Rightarrow T_2 = \frac{P_2V_2}{0.08314} = \frac{0.99768\ \text{bar}\cdot 100\,\frac{\text{L}}{\text{mol}}}{0.08314\,\frac{\text{bar}\cdot\text{L}}{\text{mol}\cdot\text{K}}} = \underline{\underline{1200.\ \text{K}}}\ \text{ANS}$$

Work done on the system:

$$W = -0.99768\,\text{bar}\cdot\left(\frac{100\ \text{L}}{\text{mol}} - \frac{25.0\,\text{L}}{\text{mol}}\right) = -74.826\,\frac{\text{bar}\cdot\text{L}}{\text{mol}}$$

Note: work done on the system is negative for an expansion.

Convert this to kJ/mol:

$$-\frac{74.826\,\text{bar}\cdot\text{L}}{\text{mol}}\cdot\frac{10^5\ \text{Pa}}{\text{bar}}\cdot\frac{\frac{1\text{N}}{\text{m}^2}}{\text{Pa}}\cdot\frac{1\ \text{m}^3}{1000\ \text{L}}\cdot\frac{1\text{J}}{1\text{Nm}}\cdot\frac{1\ \text{kJ}}{1000\ \text{J}} = \underline{\underline{-7.48\,\frac{\text{kJ}}{\text{mol}}}}\ \text{ANS}$$

Enthalpy change:

$$\Delta H = C_p \cdot \Delta T = \frac{31.44\,J}{mol \cdot K} \cdot (120\underline{0}\,K - 30\underline{0}.\,K) \cdot \frac{1\,kJ}{1000\,J} = \underset{ANS}{\underline{\underline{2\underline{8}.296\ \frac{kJ}{mol}}}}$$

Heat:

$$Q = \Delta H = \underset{ANS}{\underline{\underline{2\underline{8}.296\ \frac{kJ}{mol}}}}$$

Note: heat is positive.

Internal energy change:

$$\Delta U = Q + W = 2\underline{8}.296\frac{kJ}{mol} - 7.4\underline{8}26\frac{kJ}{mol} = \underset{ANS}{\underline{\underline{2\underline{0}.8134\frac{kJ}{mol}}}}$$