

Given: Speed of light in a vacuum = 3.00×10^8 m/s
 Planck's constant = 6.626×10^{-34} J•s

$$\Delta E = (-2.18 \times 10^{-18} \text{ J}) \left(\frac{1}{n_{\text{final}}^2} - \frac{1}{n_{\text{initial}}^2} \right)$$

Part A. Multiple Choice – Circle the best answer, FILL IN THE BLANK or ANSWER.

- The first law of thermodynamics is: (1 pt.)
 - Mass is neither created nor destroyed.
 - *B) Energy is neither created nor destroyed.**
 - Pressure is constant.
 - Gases obey the gas laws.
- Standard Temperature and Pressure (STP) for gases is _____. (2 pts.)
 - 25°C, 1 atm
 - 0°C, 760 atm
 - *C) 0°C, 760 Torr**
 - 1°C, 0 atm
- If the temperature of a gas decreases, what will happen to the volume if all other variables are held constant? (2 pts.)
 - increase
 - *b) decrease**
 - stays the same
- Question #3 above illustrates: (2 pts.)
 - *a) Charles' Law**
 - Avogadro's Law
 - Boyle's Law
 - Graham's Law
 - Dalton's Law
- What are the possible values of n and m_l for an electron in a 3d orbital? (2 pts.)
 - $n = 3$ and $m_l = 2$
 - $n = 3$ and $m_l = -1, 0, \text{ or } +1$
 - $n = 2$ and $m_l = -2, -1, 0, +1, \text{ or } +2$
 - *d) $n = 3$ and $m_l = -2, -1, 0, +1, \text{ or } +2$**
 - $n = 3$ and $m_l = -3, -2, -1, 0, +1, +2, \text{ or } +3$
- Which of the following set of quantum numbers are not allowed? (2 pts.)
 - $n=2, l=1, m_l = -1, 0, +1$
 - $n=3, l=2, m_l = -2, -1, 0, +1, +2$
 - *c) $n=3, l=3, m_l = -3, -2, -1, 0, +1, +2, \text{ or } +3$**
 - $n=3, l=1, m_l = -1, 0, +1$

7. Kinetic Energy is defined as:
(2 pts.)

= the energy of a moving object

8. The change of state from a gas to a solid is called deposition. (1 pt.)

9. The name of the quantum number n is the principal quantum number. (1 pt.)

10. Give a general description in words of the van der Waals equation (don't need to give the actual equation) and list at least one "thing" that this equation corrects for. (3 pts.)

- Calculates P, V, n, or T of a real gas, includes constants a & b that must be measured in the lab for each gas.
- Corrects for the volume of a gas molecule
- Corrects for attractions between molecules

11. The temperature of a 5.00 L container of N₂ gas is increased from 20°C to 250°C. If the volume is held constant, predict qualitatively how this change affects the following: (a) the average kinetic of the molecules; (b) the average speed of the molecules; (c) the total number of collisions of molecules with the walls per second; (d) the pressure in the container. (8 pts.)

(a) The average kinetic energy increases since the temperature increases (energy is being added).

(b) The average velocity of the molecules increase because kinetic energy (K.E.) increased and

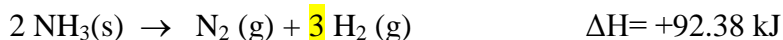
$K.E. = (1/2) mv^2$, (mass doesn't change so velocity must)

(c) the total number of collisions of molecules with the walls increase per second because they are moving faster, so they hit walls more frequently

(d) the pressure in the container increases because pressure is created by collisions of molecules with the walls, if there are more collisions per sec then the pressure increases.

Part B. Calculations. MUST SHOW ALL WORK. Give answer to correct significant figures and units.

12. (a) Is the following reaction exothermic or **endothermic**? Circle one. (2 pts.)
 (b) How much heat is absorbed or released when 7.55g of hydrogen are produced? (4 pts.)



$$\Delta\text{H} = \frac{+92.38 \text{ kJ}}{3 \text{ moles H}_2} = \frac{+30.79 \text{ kJ}}{1 \text{ mole H}_2}$$

$$7.55 \text{ g} \left(\frac{1 \text{ mole H}_2}{2.01588 \text{ g}} \right) = 3.745 \text{ moles H}_2$$

$$3.745 \text{ moles H}_2 \left(\frac{+30.79 \text{ kJ}}{1 \text{ mole H}_2} \right) = +115 \text{ kJ}$$

OR:

$$7.55 \text{ g} \left(\frac{1 \text{ mole H}_2}{2.01588 \text{ g}} \right) \left(\frac{92.38 \text{ kJ}}{3 \text{ mole H}_2} \right) = +115 \text{ kJ}$$

13. We obtain uranium-235 and U-238 by fluorinating the uranium to form UF_6 (which is a gas) and then taking advantage of the different rates of effusion and diffusion for compounds containing the two isotopes. Calculate the ratio of effusion rates for $^{238}\text{UF}_6$ and $^{235}\text{UF}_6$. The atomic mass of U-235 is 235.054 amu and that of U-238 is 238.051 amu (6 pts.)

$$\frac{r_{238}}{r_{235}} = \sqrt{\frac{\text{mass of } ^{235}\text{UF}_6}{\text{mass of } ^{238}\text{UF}_6}} = \sqrt{\frac{349.0444 \text{ g/mole}}{352.0414 \text{ g/mole}}} = 0.995737$$

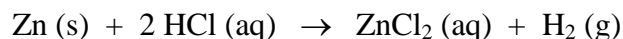
14. (a) Convert 738 mmHg into Torr.
 (b) Convert 738 mmHg into atm.
 (c) Convert 738 mmHg into in.Hg. Show work. (8 pts. total)

$$(a) \quad 738 \text{ mmHg} \left(\frac{1 \text{ Torr}}{1 \text{ mmHg}} \right) = 738 \text{ Torr}$$

$$(b) \quad 738 \text{ mmHg} \left(\frac{1 \text{ atm}}{760 \text{ mmHg}} \right) = 0.971 \text{ atm}$$

$$(c) \quad 738 \text{ mmHg} \left(\frac{1 \text{ m}}{1000 \text{ mm}} \right) \left(\frac{100 \text{ cm}}{1 \text{ m}} \right) \left(\frac{1 \text{ in.}}{2.54 \text{ cm}} \right) = 29.1 \text{ in. Hg}$$

15. Zinc metal reacts with hydrochloric acid according to the balanced equation:



When 0.103 g of Zn (s) is combined with enough HCl to make 50.0 mL of solution in a coffee-cup calorimeter, all of the zinc reacts, raising the temperature of the solution from 22.5°C to 23.7°C. Find ΔH for this reaction as written. (Use 50.0 g as the mass of the solution and 4.18 J/g·°C as the specific heat.) (7 pts.)

$$q_{\text{surr}} = \left(\frac{4.18 \text{ J}}{\text{g} \cdot ^\circ\text{C}} \right) (50.0 \text{ g}) (23.7^\circ\text{C} - 22.5^\circ\text{C}) = 250.8 \text{ J} \quad , \quad q_{\text{rxn}} = -250.8 \text{ J}$$

$$0.103 \text{ g Zn} \left(\frac{1 \text{ mole Zn}}{65.39 \text{ g}} \right) = 0.001575 \text{ mole}$$

$$\Delta H = \frac{q_{\text{rxn}}}{\# \text{ of moles}} = \frac{-250.8 \text{ J}}{0.001575 \text{ mole}} \left(\frac{1 \text{ kJ}}{1000 \text{ J}} \right) = -159.22 = \frac{-160 \text{ kJ}}{1 \text{ mole Zn}}$$

16. A 248 mL gas sample has a mass of 0.433 g at a pressure of 745 Torr and a temperature of 28°C. What is the molar mass of the gas? (6 pts.)

$$P = 745 \text{ Torr} \left(\frac{1 \text{ atm}}{760 \text{ Torr}} \right) = 0.9802631579 \text{ atm} \quad , \quad T = 28 \text{ }^\circ\text{C} = 301.15 \text{ K} \quad , \quad V = 248 \text{ mL} = 0.248 \text{ L}$$

$$PV = nRT$$

$$n = \frac{PV}{RT} = \frac{(0.9802631579 \text{ atm})(0.248 \text{ L})}{\left(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mole} \cdot \text{K}}\right)(301.15 \text{ K})} = 0.0098373921 \text{ mole}$$

$$\text{Molar mass} = \frac{\text{grams}}{\text{moles}} = \frac{0.433 \text{ g}}{0.0098373921 \text{ mole}} = 44.0 \frac{\text{g}}{\text{mole}}$$

17. A local radio station broadcasts and an energy of 7.82×10^{-26} J. What is this frequency in MHz? Show work. (4 pts.)

$$E = h\nu, \quad \nu = \frac{E}{h} = \left(\frac{7.82 \times 10^{-26} \text{ J}}{6.626 \times 10^{-34} \text{ J} \cdot \text{s}} \right) \left(\frac{1 \text{ Hz}}{1 \text{ s}^{-1}} \right) \left(\frac{1 \text{ MHz}}{1 \times 10^6 \text{ Hz}} \right) = 118 \text{ MHz}$$

18. Green light has a wavelength of about 0.550 μm . What is the frequency in Hertz? (3 pts.)

$$\lambda = 0.550 \mu\text{m} \left(\frac{1 \times 10^{-6} \text{ m}}{1 \mu\text{m}} \right) = 5.50 \times 10^{-7} \text{ m}$$

$$\lambda\nu = c, \quad \nu = \frac{c}{\lambda} = \left(\frac{3.00 \times 10^8 \text{ m/s}}{5.50 \times 10^{-7} \text{ m}} \right) = 5.45 \times 10^{14} \text{ s}^{-1} = 5.45 \times 10^{14} \text{ Hz}$$

19. A gas mixture contains 1.45 g N₂ and 0.65 g O₂ in a 1.75 L container at 19°C. Calculate the partial pressure of each component in the gas mixture and calculate the total pressure. (7 pts.)

There are several ways to do this problem, all are shown below. T 19°C = 292.15 K , V = 1.75 L

$$1.45 \text{ g N}_2 \left(\frac{1 \text{ mole N}_2}{28.0134 \text{ g}} \right) = 0.051760943 \text{ mole}$$

$$0.65 \text{ g O}_2 \left(\frac{1 \text{ mole O}_2}{31.9988 \text{ g}} \right) = 0.0203132617 \text{ mole}$$

$$n_{\text{total}} = 0.0720742047 \text{ mole}$$

$$P_{\text{total}} = \frac{n_{\text{total}} RT}{V} = \frac{(0.0720742047 \text{ mole}) \left(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mole} \cdot \text{K}} \right) (292.15 \text{ K})}{1.75 \text{ L}} = 0.9873683771 = 0.99 \text{ atm}$$

$$P_{\text{N}_2} = \frac{n_{\text{N}_2} RT}{V} = \frac{(0.051760943 \text{ mole}) \left(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mole} \cdot \text{K}} \right) (292.15 \text{ K})}{1.75 \text{ L}} = 0.7090902836 = 0.709 \text{ atm}$$

$$P_{\text{O}_2} = \frac{n_{\text{O}_2} RT}{V} = \frac{(0.0203132617 \text{ mole}) \left(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mole} \cdot \text{K}} \right) (292.15 \text{ K})}{1.75 \text{ L}} = 0.2782780928 = 0.28 \text{ atm}$$

$$P_{\text{O}_2} = P_{\text{total}} - P_{\text{N}_2} = 0.278278 \text{ atm} = 0.28 \text{ atm}$$

$$P_{\text{O}_2} = \left(\frac{n_{\text{O}_2}}{n_{\text{total}}} \right) P_{\text{total}} = \left(\frac{0.020313 \text{ mole}}{0.07207 \text{ mole}} \right) (0.987 \text{ atm}) = 0.278278 \text{ atm} = 0.28 \text{ atm}$$

$$P_{\text{N}_2} = \left(\frac{n_{\text{N}_2}}{n_{\text{total}}} \right) P_{\text{total}} = \left(\frac{0.05176 \text{ mole}}{0.07207 \text{ mole}} \right) (0.987 \text{ atm}) = 0.70909 \text{ atm} = 0.709 \text{ atm}$$

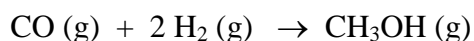
20. How much energy is needed to heat 45.0 g of H₂O (s) from -25.0°C to 0.0°C? (4 pts.)

$$q = \left(\frac{2.092 \text{ J}}{\text{g} \cdot \text{K}} \right) (45.0 \text{ g}) (0.0^\circ \text{C} - (-25.0^\circ \text{C})) \left(\frac{1 \text{ kJ}}{1000 \text{ J}} \right) = 2.35 \text{ kJ}$$

21. How much energy in kJ is needed to convert 115.0 g of H₂O from a liquid at 100°C to a gas at 100°C? (4 pts.) (see Given information on page 1)

$$115.0 \text{ g H}_2\text{O} \left(\frac{1 \text{ mole H}_2\text{O}}{18.01528 \text{ g}} \right) \left(\frac{40.67 \text{ kJ}}{1 \text{ mole H}_2\text{O}} \right) = 259.6 \text{ kJ}$$

22. CH₃OH can be synthesized by the reaction:



What volume of H₂ gas (in liters), at 85°C and 746 mmHg partial pressure of hydrogen gas, is required to synthesize 27.7 g of CH₃OH? MUST SHOW WORK. (7 pts.)

$$T = 85^\circ \text{C} = 358.15 \text{ K} \quad , \quad P = 746 \text{ mmHg} \left(\frac{1 \text{ atm}}{760 \text{ mmHg}} \right) = 0.9815789474 \text{ atm}$$

$$27.7 \text{ g CH}_3\text{OH} \left(\frac{1 \text{ mole CH}_3\text{OH}}{32.04216 \text{ g}} \right) \left(\frac{2 \text{ mole H}_2}{1 \text{ mole CH}_3\text{OH}} \right) = 1.728972079 \text{ mole H}_2$$

$$P_{\text{H}_2} V = n_{\text{H}_2} RT$$

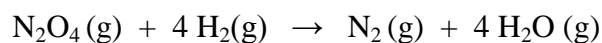
$$V = \frac{n_{\text{H}_2} RT}{P_{\text{H}_2}} = \frac{(1.72897 \text{ mol}) \left(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mole} \cdot \text{K}} \right) (358.15 \text{ K})}{0.9815789 \text{ atm}} = 51.7677 = 51.8 \text{ L}$$

23. The volume of helium gas in a balloon is 5.0 L at 788 Torr. What is the volume of the balloon at 465 Torr if the temperature is constant? (6 pts.)

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}, \quad T_1 = T_2, \quad \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}, \quad P_1 V_1 = P_2 V_2$$

$$V_2 = \frac{P_1 V_1}{P_2} = \frac{(788 \text{ Torr})(5.0 \text{ L})}{465 \text{ Torr}} = 8.473 = 8.5 \text{ L}$$

24. Use the change in enthalpy of formations to calculate ΔH of the following reaction. (7 pts.)



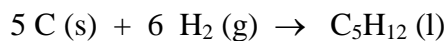
The enthalpy of formations of $\text{H}_2\text{O}(\text{g})$ and $\text{N}_2\text{O}_4(\text{g})$ are given on an attached table.

$$\Delta H_{\text{rxn}} = [(1 \text{ mole})\Delta H_f(\text{N}_2(\text{g})) + (4 \text{ mole})\Delta H_f(\text{H}_2\text{O}(\text{g}))] - [(1 \text{ mole})\Delta H_f(\text{N}_2\text{O}_4(\text{g})) + (4 \text{ mole})\Delta H_f(\text{H}_2(\text{g}))]$$

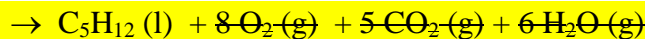
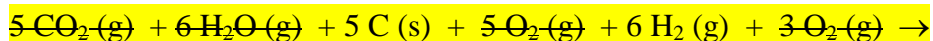
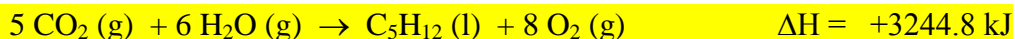
$$= [0 + (4 \text{ mole})(-241.82 \text{ kJ})] - [+9.66 \text{ kJ} + 0]$$

$$= [-967.28 \text{ kJ}] - [+9.66 \text{ kJ}] = -976.94 \text{ kJ}$$

25. Calculate ΔH for the following reaction: (8 pts) **MUST SHOW ALL WORK!**



Using the enthalpies of reactions:



$$\Delta H = (+3244.8 \text{ kJ}) + (-1967.5 \text{ kJ}) + (-1450.5 \text{ kJ}) = -173.2 \text{ kJ}$$

26. The oxygen gas formed in a chemical reaction is collected over water at 30.0°C at a total pressure of 732 mmHg. What is the partial pressure of the oxygen gas collected in this way? If the total volume of gas collected is 722 mL, what mass of oxygen gas is collected? (8 pts.)

$$T = 30.0^{\circ}\text{C} = 303.15 \text{ K}$$

$$P_{\text{total}} = 732 \text{ mmHg}$$

$$P_{\text{H}_2\text{O}} = 31.82 \text{ Torr}$$

$$P_{\text{O}_2} = P_{\text{total}} - P_{\text{H}_2\text{O}} = 732 \text{ Torr} - 31.82 \text{ Torr} = 700.18 \text{ Torr} \left(\frac{1 \text{ atm}}{760 \text{ Torr}} \right) = 0.9212897737 \text{ atm}$$

$$P_{\text{O}_2} V = n_{\text{O}_2} RT$$

$$n_{\text{O}_2} = \frac{P_{\text{O}_2} V}{RT} = \frac{(0.921289 \text{ atm})(0.722 \text{ L})}{\left(0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mole} \cdot \text{K}}\right)(303.15 \text{ K})} = 0.0267389421 \text{ mole O}_2 \left(\frac{31.9988 \text{ g}}{1 \text{ mole O}_2} \right) = 0.856 \text{ g O}_2$$

Given for Test 3

Gas constant = $0.08206 \text{ L}\cdot\text{atm}/\text{mole}\cdot\text{K} = 8.314 \text{ J}/\text{mole}\cdot\text{K}$

1 cal = 4.184 J

Properties of Water

Density = 0.99987 g/mL at 0°C
 1.00000 g/mL at 4°C
 0.99707 g/mL at 25°C
 0.95838 g/mL at 100°C

Specific heat = ice, 2.092 J/gK
 water, 4.184 J/gK
 steam, 1.841 J/gK

Heat of fusion = 6.008 kJ/mol

Heat of vaporization = 40.67 kJ/mol

Properties of Ethanol (C₂H₅OH)

Melting point = -117.3°C

Boiling point = 78.5°C

Heat of fusion = 26.05 cal/g

Heat of vaporization = 9,673.9 cal/mol

Specific heat = liquid, 27.0 cal/mol
 gas, 15.7 cal/mol

<u>compound</u>	ΔH_f (kJ/mole)	<u>compound</u>	ΔH_f (kJ/mole)
CH ₄ (g)	-74.8	C ₃ H ₈ (g)	-103.85
CO (g)	-110.5	C ₄ H ₁₀ (g)	-124.73
CO ₂ (g)	-393.5	C ₄ H ₁₀ (l)	-147.6
H ₂ O (g)	-241.82		
H ₂ O (l)	-285.83		
NO(g)	+90.37		
NO ₂ (g)	+33.84		
N ₂ O(g)	+81.6		
N ₂ O ₄ (g)	+9.66		
C ₂ H ₄ (g)	+52.30		
C ₂ H ₆ (g)	-84.68		

Vapor pressure of water (Torr):

Vapor Pressure (torr)							
T (°C)	P	T (°C)	P	T (°C)	P	T (°C)	P
0	4.58	21	18.65	35	42.2	92	567.0
5	6.54	22	19.83	40	55.3	94	610.9
10	9.21	23	21.07	45	71.9	96	657.6
12	10.52	24	22.38	50	92.5	98	707.3
14	11.99	25	23.76	55	118.0	100	760.0
16	13.63	26	25.21	60	149.4	102	815.9
17	14.53	27	26.74	65	187.5	104	875.1
18	15.48	28	28.35	70	233.7	106	937.9
19	16.48	29	30.04	80	355.1	108	1004.4
20	17.54	30	31.82	90	525.8	110	1074.6