

## CHEM 3530 - Exam 1 – February 9, 2018

### Constants and Conversion Factors

$$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$$

$$R = 8.31 \text{ J/mol-K} = 8.31 \text{ kPa-L/mol-K}$$

$$1 \text{ bar} = 100 \text{ kPa}$$

$$1 \text{ kPa} = 7.50 \text{ torr}$$

$$1 \text{ J} = 1 \text{ kPa-L}$$

### Molar Masses

$C_{10}H_{22}$  - 142.

$CH_4$  - 16.

He - 4.

$CO_2$  - 44.

$H_2$  - 2.0

$F_2$  - 38.

$C_2H_6$  - 30.

$C_7H_8$  - 92.

$C_2H_2$  - 26.

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Name

Solutions

## (88) PART I. MULTIPLE CHOICE (Circle the ONE correct answer)

- A sample of decane,  $C_{10}H_{22}$ , contains  $5.0 \times 10^{24}$  atoms of Hydrogen. What is the mass of the sample?  
(A) 28.4 g      (B) 53.6 g      (C) 1180 g      (D)  $2.6 \times 10^4$  g
- The volume of a sample of  $N_2(g)$  at 600 torr and  $200^\circ C$  is 400 mL. What is the volume of the  $N_2$  at 350 torr and  $100^\circ C$ ?  
(A) 184 torr      (B) 340 torr      (C) 540 torr      (D) 870 torr
- At sea level, where the pressure is 100 kPa and the temperature is  $20^\circ C$ , a sample of gas in a balloon occupies a volume of  $350 \text{ cm}^3$ . The balloon is raised to an altitude where the pressure is 35 kPa, and its volume expands to  $600 \text{ cm}^3$ . What is the temperature (in  $^\circ C$ ) of the gas in the balloon?  
(A)  $-97^\circ C$       (B)  $+176^\circ C$       (C)  $-63^\circ C$       (D)  $+12^\circ C$
- A 20. L container contains  $1.2 \times 10^{24}$  molecules of  $CO_2$  at a temperature of  $150^\circ C$ . What is the pressure of the gas, in bar.  
(A) 1.2 bar      (B) 350 bar      (C) 28.4 bar      (D) 3.5 bar
- What is the approximate density, in g/L, of a sample of  $CH_4(g)$  at  $100^\circ C$  and 8. bar pressure?  
(A) 0.15 g/L      (B) 4.1 g/L      (C) 0.041 g/L      (D) 15.4 g/L
- A container has a gaseous mixture of 8.0 grams of  $He(g)$  and 96. grams of  $CH_4(g)$ . The partial pressure of  $He(g)$  in the mixture is 0.3 bar. What is the total pressure of both gases?  
(A) 3.9 bar      (B) 2.4 bar      (C) 1.2 bar      (D) 0.9 bar
- The RMS average speed of  $C_2H_6(g)$  molecules at  $800^\circ C$  is 940 m/s. What is the RMS average speed of  $C_2H_6(g)$  molecules at  $200^\circ C$ ?  
(A) 620 m/s      (B) 410 m/s      (C) 940 m/s      (D) 1420 m/s
- Consider the three gases (all at 1 bar pressure):  $CO_2$  at  $80^\circ C$ ,  $He$  at  $80^\circ C$ ,  $CH_4$  at  $20^\circ C$ . Of these three gases, He has the **highest** rms average speed and  $CO_2$  has the **lowest** molar kinetic energy.  
(A)  $CO_2$ ,  $CH_4$       (B)  $CH_4$ ,  $He$       (C)  $He$ ,  $CO_2$       (D)  $He$ ,  $CH_4$

9. One mole of  $\text{H}_2(\text{g})$  effuses through a pinhole in 300 s. How long will it take for one mole of  $\text{F}_2(\text{g})$  to effuse through the pinhole under the same conditions?

- (A) 16 s                      (B) 70 s                      (C) 5700 s                      (D) 1310 s

10. The rate of effusion of  $\text{CO}_2(\text{g})$  through a pinhole is 8.0 mol/hr. Under the same conditions, the rate of effusion of an unknown gas through the pinhole is 6.5 mol/hr. The Molar Mass of the unknown gas is approximately:

- (A) 36 g/mol                      (B) 67 g/mol                      (C) 29 g/mol                      (D) 54 g/mol

11. The van der Waals equation for a non-ideal gas is given by:

$$\left[ P + a \left( \frac{n}{V} \right)^2 \right] [V - nb] = nRT$$

The pressure of a gas obeying the van der Waals equation is \_\_\_\_\_ than that of a Perfect Gas because of \_\_\_\_\_ forces between molecules.

- (A) higher, attractive                      (B) higher, repulsive  
(C) lower, attractive                      (D) lower, repulsive

12. The **constant volume** Molar heat capacity of ethane,  $\text{C}_2\text{H}_6(\text{g})$  is 44.3 J/mol-K. When 9.0 kJ of heat is removed at **constant volume** from 90 grams of ethane, the final temperature is 53 °C. What was the approximate initial temperature of the  $\text{C}_2\text{H}_6$  before the heat is removed

- (A) +120 °C                      (B) +15 °C                      (C) -68 °C                      (D) -68 °C

13. The **constant pressure** molar heat capacity of  $\text{Ar}(\text{g})$  is 20.8 J/mol-K. What is the heat involved, in kJ, when 2.5 moles of  $\text{Ar}(\text{g})$  is cooled from 200 °C to 50 °C at **constant volume**?

- (A) -10.9 kJ                      (B) -4.7 kJ                      (C) -7.8 kJ                      (D) +10.9 kJ

14. For a process in which the internal energy change of a gas is 0 (zero), which of the following processes is/are possible?

- ✓ (i) the gas is expanded and heated  
✗ (ii) the gas is expanded and cooled  
✓ (iii) the gas is compressed and cooled

- (A) i only                      (B) ii only                      (C) i and ii                      (D) i and iii

15. The deposition of gold vapor [ $\text{Au}(\text{g})$ ] onto the surface of a silicon wafer is

- (A) Endothermic and  $w > 0$                       (B) Endothermic and  $w < 0$   
(C) Exothermic and  $w > 0$                       (D) Exothermic and  $w < 0$

16. When a gas is compressed reversibly and adiabatically,  
 (A)  $q > 0$  &  $w > 0$  (B)  $q = 0$  &  $w > 0$  (C)  $q = 0$  &  $w < 0$  (D)  $q < 0$  &  $w > 0$
17. What are  $q$  and  $\Delta H$  when 2 moles of a gas is expanded reversibly and isothermally from 5 L to 40 L at 25 °C?  
 (A)  $q = -10.3$  kJ,  $\Delta H = 0$  (B)  $q = +10.3$  kJ,  $\Delta H = 0$   
 (C)  $q = 0$ ,  $\Delta H = 0$  (D)  $q = 0$ ,  $\Delta H = +10.3$  kJ
18. When a gas is cooled at constant volume,  
 (A)  $\Delta U < 0$  &  $w < 0$  (B)  $\Delta U < 0$  &  $w > 0$  (C)  $\Delta U > 0$  &  $w = 0$  (D)  $\Delta U < 0$  &  $w = 0$
19. For the combustion reaction,  $C_4H_8(\text{gas}) + 6 O_2(\text{gas}) \rightarrow 4 CO_2(\text{gas}) + 4 H_2O(\text{liq})$ , at 25 °C, the enthalpy change is  $\Delta H = -2630$  kJ. What is  $\Delta U$  for this reaction?  
 (A)  $-2622.6$  kJ (B)  $-2637.4$  kJ (C)  $-2627.6$  kJ (D)  $-2632.5$  kJ

**For #20-#22:** The normal boiling point of toluene,  $C_7H_8$  is 111 °C. The enthalpy of vaporization of toluene,  $C_7H_8$ , is 32.6 kJ/mol.

20. What is the heat involved when 184 grams of toluene are vaporized to the gas phase at 1 bar pressure and 111 °C?  
 (A)  $+65.2$  kJ (B)  $+71.6$  kJ (C)  $+58.8$  kJ  
 (D) Cannot be determined without the constant pressure molar heat capacity.
21. What is the work involved when 184 grams of toluene are vaporized to the gas phase at 1 bar pressure and 111 °C?  
 (A)  $-3.8$  kJ (B)  $-6.4$  kJ (C)  $+3.8$  kJ (D)  $+6.4$  kJ
22. What is  $\Delta U$  when 184 grams of toluene are vaporized to the gas phase at 1 bar pressure and 111 °C?  
 (A)  $+65.2$  kJ (B)  $+71.6$  kJ (C)  $+58.8$  kJ  
 (D) Cannot be determined without the constant volume molar heat capacity.

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**PART II. ONE (1) PROBLEM FOLLOWS**  
**You MUST show your work for credit.**

$$n = 65 \text{ g} \times \frac{1 \text{ mol}}{26 \text{ g}} = 2.5 \text{ mol}$$

- (12) 1. The **constant pressure** molar heat capacity of acetylene,  $\text{C}_2\text{H}_2(\text{g})$ , is  $43.9 \text{ J/mol}\cdot\text{K}$ . A sample of  $65 \text{ g}$  of  $\text{C}_2\text{H}_2(\text{g})$ , is initially at a volume of  $40 \text{ L}$  and pressure of  $2.0 \text{ bar}$ .

Calculate  $q$ ,  $w$ ,  $\Delta U$  and  $\Delta H$  (all in  $\text{kJ}$ ) when the gas is heated reversibly at **constant pressure** until the volume has increased to  $90 \text{ L}$ .

$$= 200 \text{ kPa}$$

$$T_1 = \frac{P_1 V_1}{nR} = \frac{200 \text{ kPa} \cdot 40 \text{ L}}{2.5 \text{ mol} \cdot (8.315 \text{ J/mol}\cdot\text{K})} = 385 \text{ K}$$

$$C_{p,m} - C_{v,m} = R$$

$$C_{v,m} = C_{p,m} - R$$

$$= 43.9 - 8.31$$

$$= 35.6 \text{ J/mol}\cdot\text{K}$$

$$T_2 = \frac{P_2 V_2}{nR} = \frac{200 \times 90}{2.5 \cdot (8.31)} = 866 \text{ K}$$

$$\Delta H = n C_{p,m} \Delta T = (2.5 \text{ mol}) / (43.9 \text{ J/mol}\cdot\text{K}) / (866 \text{ K} - 385 \text{ K})$$

$$= 52800 \text{ J} \times \frac{1}{10^3} = \boxed{52.8 \text{ kJ}}$$

$P = \text{const.} \rightarrow q = \Delta H = \boxed{52.8 \text{ kJ}}$

$$\Delta U = n C_{v,m} \Delta T = 2.5 (35.6) (866 - 385)$$

$$= 42800 \text{ J} \times \frac{1}{10^3} = \boxed{42.8 \text{ kJ}}$$

$$\Delta U = q + w \rightarrow w = \Delta U - q = 42.8 - 52.8 = \boxed{-10.0 \text{ kJ}}$$

Alternative  
ans A

$$w = -P \Delta V = -200 \text{ kPa} (90 \text{ L} - 40 \text{ L})$$

$$= -10,000 \text{ kPa}\cdot\text{L} = -10,000 \text{ J}$$

$$= \underline{\underline{-10.0 \text{ kJ}}}$$