1. **In a bomb calorimeter that has a heat capacity of 1340 J/°C and contains 500.0 g of water, 0.1946 g of magnesium "Mg" metal is burned. The temperature rise is 1.40°C. Given the specific heat of water as 4.184 J/g °C, the molar heat of combustion of magnesium in kJ/mol is:**

   A) 620   B)   610   C)   600   D)   580

SOLUTION
$q_{calorimeter} = C_{cal.} \times \Delta T = 1340 \times 1.4 = 1867\ J = 1.876\ kJ$
$q_{H_2O} = (m \times C_s \times \Delta T)_{H_2O} = 500 \times 4.184 \times 1.4 = 2928.8 = 2.929\ kJ$
$Q_{total} = 1.876 + 2.929 = 4.805\ kJ$
0.1946 g release 4.805 kJ
1 mol ≡ 24.3 g release molar heat of combustion
molar heat of combustion $= -\dfrac{24.3 \times 4.805}{0.1946} = -600\ kJ$

2. **A glass containing 500.0 g of water at 23°C was placed into a refrigerator. As the water cools to a constant temperature it looses 31.38 kJ of heat. Given the specific heat of water as 4.184 J/g °C, the new temperature of water in °C is:**

   A) 10   B)   5   C)   6   D)   8

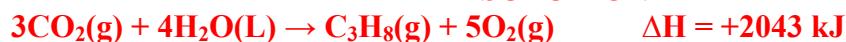 | SOLUTION |
   |---|
   | $q = C_s \times m \times \Delta T$, $-51380 = 4.185 \times 500 \times (T_2 - 23)$, $T_2 = 8\ °C$ |

3. **Given the following thermochemical equations:**

   $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$ $\Delta H = -2043\ kJ$
   $C(gr) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = -394\ kJ$
   $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g)$ $\Delta H = -242\ kJ$
   Find H_{rxn} (in kJ) for:

   $$3C(gr) + 4H_2(g) \rightarrow C_3H_8(g)$$

   A) −132   B)   −118   C)   −107   D)   −99

SOLUTION
$3CO_2(g) + 4H_2O(L) \rightarrow C_3H_8(g) + 5O_2(g)$ $\Delta H = +2043\ kJ$
$2C(gr) + 3O_2(g) \rightarrow 3CO_2(g)$ $\Delta H = -1182\ kJ$
$4H_2(g) + 2O_2(g) \rightarrow 4H_2O(L)$ $\Delta H = -968\ kJ$
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$4H_2(g) + 3C(gr) \rightarrow C_3H_8(g)$ $\Delta H = -107\ kJ$

4. **Given the following thermochemical reaction:**

   $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$ $\Delta H^o_{rxn} = -902\ kJ$
   and knowing that ΔH^o_f for: $NO(g) = 91\ kJ.mol^{-1}$ and for $H_2O(g) = -242\ kJ.mol^{-1}$
   Therefore, ΔH^o_f $NH_3(g)$ in $kJ.mol^{-1}$ is:

   A) −120.5   B)   −90.8   C)   −65.4   D)   −46.5

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SOLUTION

$\Delta H^o_{rxn} = \sum \Delta H^o_f(p) - \sum \Delta H^o_f(r)$

$-902 = (4 \times 91 + 6 \times -242) - (4 \times \Delta H^o_f, NH_3(g) + 3 \times 0)$

$\Delta H^o_f, NH_3(g) = -46.5 \text{ kJ/mol}$

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5. **The combustion of natural gas (methane gas "CH_4") produces heat energy according to:**

   $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ $\Delta H^o_{rxn} = -890 \text{ kJ}$

   the mass of methane gas (in g) needed to be burned in order to supply 62692 kJ of heat energy is:
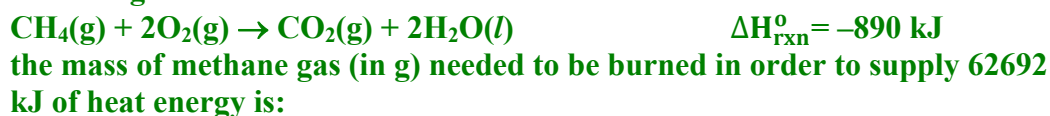
   A) 1150   **B)   1130**   **C)   1120**   **D)   1100**

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SOLUTION

$1\text{mol} \equiv 16 \text{ g } CH_4(g)$ release 890 kJ

       m g $CH_4(g)$ release 62692 kJ

$m = -\dfrac{16 \times 62692}{890} = 1127 \text{ g}$

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6. **7.0 L of a gas is supplied by 476 J of heat and is allowed to expand to 15.0 L volume against an external pressure of 0.76 atm. The change in the internal energy E (U) for this gas system (in J) is:**

   A) −180   **B)   +180**   **C)   −140**   **D)   −160**

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SOLUTION

$\Delta E = q + w = (+476) + (-076 \times 101325 \dfrac{15 - 7}{1000}) = -140 \text{ kJ}$

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7. **The mass (in g) of nitrogen gas "N_2" that dissolves in 80.0 L of water at 25^oC and under nitrogen gas partial pressure of 0.79 atm is:**
   (The value of Henery's law constant for nitrogen gas in water at 25^oC = 6.8×10^{-4} mol/L.atm)

   A) 1.8   **B)   1.6**   **C)   1.4**   **D)   1.2**

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SOLUTION

$S_g = KP_g = 6.8 \times 10^{-4} \times 0.79 = 5.372 \times 10^{-4} \text{ mol/L}$

5.372×10^{-4} mol is in 1 L

     n mol   is in 80 L

$n = \dfrac{80 \times 5.372 \times 10^{-4}}{1} = 0.043 \text{ mol/L}$

$m = n \times M = 0.034 \times 28 = 1.2 \text{ g}$

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8 **Three separate aqueous solutions. Each is prepared by dissolving 200.0 g of a nonvolatile and nonelectrolyte solute in 750.0 g of water. These solutes are either sucrose "$C_{12}H_{22}O_{11}$", glucose "$C_6H_{12}O_6$" or urea "H_2NCONH_2". At the same temperature, which of the following statements is true:**

   A) The sucrose solution will have the highest vapor pressure.
   B) The glucose solution will have the highest vapor pressure.

C) The urea solution will have the highest vapor pressure.
D) The three solutions will have the same vapor pressure.

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SOLUTION

Because $P_{H_2O} = X_{H_2O} \times P^o_{H_2O}$, P_{H_2O} will be higher when X_{H_2O} is higher, when X_{solute} is lower, when M_{solute} is higher. Therefore, sucrose solution has the highest P_{H_2O}.

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9 The freezing point of an aqueous 0.05 m $CaCl_2$ solution is -0.27^oC. The Vant's Hoff factor (i) for this $CaCl_2$ solution is: (K_f water = 1.86 ^oC/m)

A) 2.6   B)   2.7   C)   2.8   D)   2.9

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SOLUTION

$$i = \frac{(\Delta T_f)_{measured}}{(\Delta T_f)_{calculated}} = \frac{0.27}{K_f m} = \frac{0.27}{1.86 \times 0.05} = 2.9$$

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10 The osmotic pressure (in atm) of a solution containing 24.5 g of glycerin "$C_3H_8O_3$" (a nonvolatile and nonelectrolyte) in 250 mL of aqueous solution at 25^oC is:

A) 15   B)   21   C)   26   D)   28

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SOLUTION

$$\Pi = \frac{mRT}{MV} = \frac{24.5 \times 0.0821 \times 298}{92 \times 0.05} = 26 \text{ atm}$$

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11 A solution containing 50.0 g of heptane "C_7H_{16}" and 50.0 g of octane "C_8H_{18}" at 25^oC. Knowing that at 25^oC the vapor pressure of pure heptane is 45.8 torr and that of pure octane is 10.9 torr, and assuming ideal behavior, the total vapor pressure (in torr) above the solution is:

A) 32.7   B)   29.5   C)   27.7   D)   25.3

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SOLUTION

$n = \frac{m}{M}$, $n_1 = \frac{50}{100} = 0.5$ mol , $n_2 = \frac{50}{114} = 0.44$ mol , $n_T = 0.94$ mol

$X = \frac{n_i}{n_T}$, $X_1 = \frac{0.5}{0.94} = 0.53$, $X_2 = 1 - X_1 = 1 - 0.53 = 0.47$

$P_T = X_1 P_1 + X_1 P_1 = 0.53 \times 54.8 + 0.47 \times 10.9 = 29.4$ atm

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12 A hypothetical reaction: A → B follows a first order kinetics. Which of the following statements is true regarding the half life period "t½" for such reaction?

A) t½ increases as the magnitude of [A]$_o$ increases.
B) t½ increases as the temperature increases.
C) t½ increases as the temperature decreases.
D) t½ is always constant for the first order reaction and never changes with either the temperature or the magnitude of [A]$_o$.
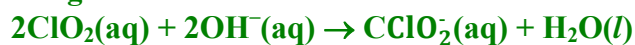
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SOLUTION

According to Arrhenius equatin: $lnk = lnA - \frac{E_a}{RT}$

as T decreases, k decreases. And because:

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13 Given the following reaction:

$$2ClO_2(aq) + 2OH^-(aq) \rightarrow CClO_2^-(aq) + H_2O(l)$$

and the following initial rates of the reaction have been measured for the given reagent concentrations:

Exp.	$[ClO_2]$ (M)	$[OH^-]$ (M)	Initial rate (M/s)
1	0.060	0.03	0.0243
2	0.020	0.03	0.0027
3	0.020	0.09	0.0081

The rate law for this reaction is

A) rate = k $[ClO_2]^2$ $[OH^-]$ B)   rate = k $[ClO_2]^2$ $[OH^-]^2$
C) rate = k $[ClO_2]^3$ $[OH^-]$ D)   rate = k $[ClO_2]^3$ $[OH^-]^2$

SOLUTION

rate = k $[ClO_2]^x[OH^-]^y$

$\frac{(\text{rate})_1}{(\text{rate})_2} = \frac{0.0243}{0.0027} = \frac{k\,(0.06)^x\,(0.03)^y}{k\,(0.02)^x\,(0.03)^y}$, $9 = 3^x$, x = 2

$\frac{(\text{rate})_3}{(\text{rate})_2} = \frac{0.0081}{0.0027} = \frac{k\,(0.02)^x\,(0.09)^y}{k\,(0.02)^x\,(0.03)^y}$, $3 = 3^y$, y = 1

rate = k $[ClO_2]^2[OH^-]$

14 A first order reaction has a rate constant of 7.5×10^{-3} s^{-1}. The time (in seconds) required for the reaction to be 60% complete is:

A) 116   B)   118   C)   122   D)   112

SOLUTION

$\ln \frac{[A]_o}{[A]_t} = kt,$

$t = \frac{\ln \frac{[A]_o}{[A]_t}}{k} = \frac{\ln \frac{100}{40}}{7.5 \times 10^{-3}} = 122$ s

15 The isomerization of cyclopropane follows first order kinetics. The rate constant at 700 K is 6.2×10^{-4} and at 760 K is 2.4×10^{-2}. The activation energy (in kJ) for this reaction is:

A) 465.8   B)   325.6   C)   312.7   D)   269.5

SOLUTION

$\frac{\ln k_2}{\ln k_1} = \frac{E_a}{R} = (\frac{T_2 - T_1}{T_1 T_2})$

$\frac{2.4 \times 10^2}{6.2 \times 10^4} = \frac{E_a}{8.414 \times 10^3} = (\frac{760 - 700}{700 \times 760})$

$E_a = 269.5$ k