**SCH 4UI Exam Review Unit #2 - Energy and Rates of Reactions**

**Thermochemistry**

1. **Define specific heat capacity**

The quantity of heat required to raise the temp of a mass unit (ie. One gram) of a substance by 1°C

1. **How much heat is required to raise the temperature of 0.5kg of aluminum by 10°C**

Specific heat of aluminum is 0.900J/g °C (page 799 in your textbook)

q = m c Δt

q = ( 500 g ) (0.900 J/g °C ) ( 10 °C )

q = 4500J

q = 4.5 kJ

1. **Define enthalpy**

The total (kinetic and potential) energy in a substance. (Note: we cannot measure the enthalpy only the change in enthalpy ΔH)

1. **Identify the following as either an exothermic or endothermic reaction**
   1. H2(g) + ½O2(g) → H2O(g) ΔH = -243 kJ/mol exothermic
   2. ½N2(g) + ½ O2(g) + 90.7kJ → NO(g) endothermic
   3. ½ H2(g) + ½ I2(g) → HI(g) ΔH = +26 kJ/mol endothermic
2. **Write thermochemical equations for the following**
   1. **7.0kJ of energy is required to vaporize 3.0g of water**

3.0g / (18g/mol H2O) = 0.167mol H2O

7.0 kJ/0.167mol H2O = 42kJ/mol H2O

H2O (l) + 42kJ → H2O (g)

* 1. **5.0 g of NH4Cl(s) is dissolved in 100mL of water. The temperature of the water drops 7.5°**

5.0g / (53.45g/mol NH4Cl) = 0.0935 mol NH4Cl

ΔH(system) = - ΔH(surroundings)

nΔH = - m c Δt

(0.0935 mol NH4Cl ) ΔH = - ( 100 g ) (4.18 J/g °C ) ( -7.5 °C )

(0.0935 mol NH4Cl) ΔH = 3135 J

ΔH = 33513.15 J/ mol NH4Cl

ΔH = 33.51 kJ/ mol NH4Cl

NH4Cl(s) + 33.51kJ → NH4+(aq) + Cl- (aq)

1. **One of the methods that the steel industry uses to obtain metallic iron is to react iron(III) oxide with carbon monoxide**

**Fe2O3(s) + 3CO(g) → 3CO2(g) + 2Fe(s)**

**Determine the enthalpy change of this reaction given the following**

**Eq #1 CO(g) + ½ O2(g) → CO2(g) ΔH = -283.0 kJ**

**Eq #2 2Fe(s) + 3/2O2(g) → Fe2O3(s) ΔH = -824.2 kJ**

Eq #1 x 3 3CO(g) + 3/2 O2(g) → 3CO2(g) ΔH = -849.0 kJ

Eq #2 x -1 Fe2O3(s) → 2Fe(s) + 3/2O2(g) ΔH = 824.2 kJ

3CO(g) + ~~3~~~~/~~~~2~~ ~~O~~~~2(g)~~ Fe2O3(s) → 3CO2(g) 2Fe(s) + ~~3~~~~/~~~~2~~~~O~~~~2(g)~~ ΔH = - 24.8 kJ

1. **Write formation equations for the following**
   1. **Propane**

3 C(s) + 4 H2(g) → C3H8(g) ΔH = -103.8 kJ

* 1. **calcium hydroxide**

Ca(s) + O2(g) + H2(g)  → Ca(OH)2(s) ΔH = -985.2 kJ

* 1. **ammonium chloride (solid)**

N2(g) + 2H2(g) + Cl2(g) → 2NH4Cl(s)

½ N2(g) + H2(g) + ½ Cl2(g) → NH4Cl(s) ΔH = -314.4 kJ

* 1. **oxygen gas**

(O2(g) → O2(g) ΔH = 0.0 kJ)

The enthalpy of formation of an element in its standard state is defined as zero

\* ΔH values found on page 743 of textbook

1. **Using enthalpies of formation and Hess’s Law to determine the enthalpy of combustion of one mole of benzene**

Combustions of benzene

C6H6(l) + 15/2 O2(g)  → 6CO2(g) + 3H2O(g)

Elementary Reactions

6C(s) + 3H2(g) → C6H6(l) ΔH = + 49.0 kJ

C(s) + O2(g) → CO2(g) ΔH = -393.5 kJ

H2(g) + ½ O2(g) → H2O(g) ΔH = -241.8 kJ

C6H6(l) → ~~6C~~~~(s)~~ + ~~3H~~~~2(g)~~ ΔH = - 49.0 kJ

~~6C~~~~(s)~~ + 6O2(g) → 6CO2(g) ΔH = -2361.0 kJ

~~3H~~~~2(g)~~ + 3/2 O2(g) → 3H2O(g) ΔH = - 725.4 kJ

C6H6(l) + 15/2 O2(g)  → 6CO2(g) + 3H2O(g) ΔH = -3135.4 kJ

OR

ΔH = Σn∆H(products) - Σn∆H(reactants)

ΔH = [(6 x -393.5 kJ) + (3 x -241.8 kJ)] - [(1 x 49.0 kJ) + (15/2 x 0 kJ)]

ΔH = -3135.4 kJ

**Rates of Reaction**

1. **Describe four ways you can measure the rate of a reaction**
   * Volume of gas
   * Conductivity of solution
   * pH of solution
   * colour of solution
2. **Explain the difference between instantaneous rate and average rate**

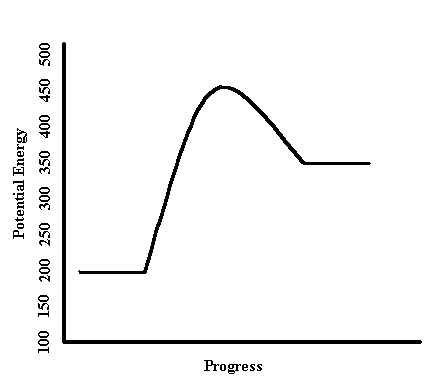
Instantaneous rate – measures the rate at a particular instant

Average rate measure the rate over a time interval

1. **List four factors that affect the rate of reaction and explain how each one affects the rate**

* Temperature – increases the number of collisions (reactants are moving faster) and increases percentage of effective collisions (more particles have enough energy to overcome the activation energy)
* Concentration – increases the number of collisions
* Catalyst – lowers the activation energy which increases the percentage of effective collisions (more particles have enough energy to overcome the activation energy)
* Surface Area – increases the number of collisions

1. **Label the following graph**



1. Ammonia reacts with oxygen according to the following reaction: 4NH3(g) + 5O2(g) → 4NO(g) + 6H2O(g)

The following graph shows the rate of production of H2O(g).



* + Determine the average rate of production of H2O between 20 min and 60 min

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| RateH2O = | ∆ moles H2O | = | 0.0068 – 0.0036 | = | 0.0032 mol H2O | = 0.000080 mol H2O/min |
| ∆ time | 60 min – 20 min | 40 min |

* + Determine the instantaneous rate of production of H2O at 40 min

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| RateH2O = | ∆ moles H2O | = | 0.0078 – 0.0044 | = | 0.0034 mol H2O | = 0.000085 mol H2O/min |
| ∆ time | 60 min – 20 min | 40 min |

\*Note – numbers may be slightly different depending on your tangent line

* + Determine the instantaneous rate of production of NO(g) at 40 min

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| RateNO = | 0.000085 mol H2O/min | = | 4 mol NO/min | = 0.000057 mol NO/min |
|  | 6 mol H2O/min |

* + Determine the instantaneous rate of consumption of oxygen gas at 40 min

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| RateNO = | 0.000085 mol H2O/min | = | 5 mol O2/min | = 0.000071 mol O2/min |
|  | 6 mol H2O/min |

1. Determine the rate law for the following equilibrium

H2O2(aq) + 3I-(aq) 2H+(aq) = I3-(aq) + 2H2O(l)

Given the following experimental data

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Trial | [H2O2] | [ I-] | [H+] | Rate of I3- production |
| 1 | 0.010 | 0.010 | 0.00050 | 1.15 x 10-6 |
| 2 | 0.020 | 0.010 | 0.00050 | 2.30 x 10-6 |
| 3 | 0.010 | 0.020 | 0.00050 | 2.30 x 10-6 |
| 4 | 0.010 | 0.010 | 0.00100 | 1.15 x 10-6 |

General Rate Law: rate = k[H2O2]m [ I-]n [H+]p

**Solve for m (use trials 1 and 2)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| rate | = | k[H2O2]m [ I-]n [H+]p |  | |
| rate | k[H2O2]m [ I-]n [H+]p |  | |
|  |  |  | |  |
| 2.30 x 10-6 | = | ~~k~~[0.020]m ~~[0.010]~~~~n~~ ~~[0.00050]~~~~p~~ | |  |
| 1.15 x 10-6 | ~~k~~[0.010]m ~~[0.010]~~~~n~~ ~~[0.00050]~~~~p~~ | |  |
|  |  |  | |  |
| 2 | = | (2)m | |  |
| m | = | 1 | |  |

**Solve for n (use trials 1 and 3)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| rate | = | k[H2O2]m [ I-]n [H+]p |  | |
| rate | k[H2O2]m [ I-]n [H+]p |  | |
|  |  |  | |  |
| 2.30 x 10-6 | = | ~~k[0.010]~~~~m~~ [0.020]n ~~[0.00050]~~~~p~~ | |  |
| 1.15 x 10-6 | ~~k[0.010]~~~~m~~ [0.010]n ~~[0.00050]~~~~p~~ | |  |
|  |  |  | |  |
| 2 | = | (2)n | |  |
| n | = | 1 | |  |

**Solve for p (use trials 1 and 4)**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| rate | = | k[H2O2]m [ I-]n [H+]p |  | |
| rate | k[H2O2]m [ I-]n [H+]p |  | |
|  |  |  | |  |
| 1.15 x 10-6 | = | ~~k[0.010]~~~~m~~ ~~[0.010]~~~~n~~ [0.00100]p | |  |
| 1.15 x 10-6 | ~~k[0.010]~~~~m~~ ~~[0.010]~~~~n~~[0.00050]p | |  |
|  |  |  | |  |
| 1 | = | (2)p | |  |
| p | = | 0 | |  |

**Solve for k**

rate = k[H2O2]1 [ I-]1 [H+]0

2.30 x 10-6 = k[0.020]1 [0.010]1 [0.00050]0

k = 0.0115 L/mol•s

1. What is an elementary step?

An elementary step is a simple step that typically involves 1-3 particles

1. What is a rate determining step?

The rate determining step is the slowest elementary step in a reaction mechanism