Chemistry 101

File: Chapter 6
Concept: the whole required material for the 2nd exam

*CH6: THERMOCHEMISTRY

Thermodynamics: is the science of the relationships between heat and other forms of energy.

Thermochemistry: is one area of thermodynamics. It concerns the study of the quantity of heat absorbed or evolved (given off) by chemical reactions.

6.1: Energy and its units:

Energy: is the potential or capacity to move matter.

- Energy can exist in different forms, including heat, light, and electrical energy, and these different forms can be interconverted. Energy is a property of matter not material.

- **Kinetic Energy:** is the energy associated with an object by virtue of its motion.

$$E_k = \frac{1}{2} m v^2$$

$kg.m^2/s^2$ = joule

Watt = joule/s

For example: A 100 watt bulb uses 100 joules of energy every second.

- **<u>Potentail Energy:</u>** the energy an object has by virtue of its position in a field of force.

  E_p= mgh , (m=mass, g=constant acceleration of gravity, h=height)

- **<u>Internal Energy(U):</u>** Is the sum of the kinetic and potential energies of the particles making up a substance.

  $U= E_k + E_p$

  $E_{tot}:= E_K+E_p+U$

- **<u>calorie (cal)</u>**: (non-SI unit) the amount of energy required to raise the temperature of one gram of water by one degree Celsius.

  1 cal =4.184 J

  <u>Ex.1:</u>

  An electron (mass = 9.11×10^{-31}kg) is accelerated by a positive charge to a speed of 5.0×10^{6} m/s.

  What is the kinetic energy of the electron in joules? in calories?

  $E_k = ½mv^2$

  $E_k =½ \times 9.11\times10^{-31}kg \times (5.0\times10^{6}\ m/s)^2 = 1.13\times10^{-17}\ kg.m^2/s^2$ or J

  $1.13\times10^{-17}\ J \times \frac{1\ Cal}{4.184\ J} = 2.7\times10^{-18}$ Cal.

- **Law of Conservation of Energy** (first law of thermodynamics):

  - Energy may be converted from one form to another, but the total quantity of energy remains constant.

الطاقة لا تفنى ولا تستحدث من العدم ولكن تتحول من شكل الى اخر.

6.2:First Law of Thermodynamics; Work and Heat

Definition of Work (w):

Work is an energy transfer (or energy flow) into or out of a thermodynamic system **whose effect** on the surroundings is equivalent to moving an object through a field of force.

Definition of Heat (q):

Heat is an energy transfer (energy flow) into or out of a thermodynamic system **that results** from a temperature difference between the system and its surroundings.

- Change of Internal Energy:

$$\Delta U = U_f - U_i$$

-Internal energy is an **extensive property**, that is, it depends on **the amount of substances in the system.**

Other examples of extensive properties are **mass and volume**.

-**Intensive property** does **not** depend on the amount of substance **(color, density).**

-Internal energy is also a **state function.**
-A **state function:** is a property of a system that depends only **on initial and final states,** Such as **temperature** and **pressure.**

-First Law of Thermodynamics:

$$\Delta U = q + w$$

Work done by the system on the surroundings.	**-W**
Work done on the system by the surroundings.	**+W**
Heat absorbed by the system from the surroundings. “endothermic reaction”	**+q**
Heat absorbed by the surroundings from the system. “exothermic reaction”	**-q**

6.3: Heat of Reaction; Enthalpy of Reaction

- exothermic process (q is negative):

is a chemical reaction or a physical change in which heat is **evolved or is released** from the system.

- endothermic process (q is positive):

is a chemical reaction or a physical change in which heat is **absorbed** by the system.

Type of Reaction	Experimental Effect noted	Result on System	Sign of q
Endothermic	Reaction vessel cools "heat is absorbed"	Energy added	+
Exothermic	Reaction vessel warms "heat is evolved"	Energy subtracted	-

Ex.1:

The work done when a gas is compressed in a cylinder is 462J. During this process, there is a heat transfer of 128 J from the gas to the surroundings. Calculate the energy change for this process.

$\Delta U = q + w$

$= -128\ \text{J} + 462\ \text{J} = 334\ \text{J}$

Compressed means that the work is done on the system so w must be +

Heat transfer **from** the gas **to the surroundings** means that the rxn is exothermic so q is -

لازم ننتبه للاشارات لانها اشي
بسيط بس بأثر بالإجابة**!!**

Ex.2:

A gas is cooled and loses 82 J of heat. The gas contracts as it cools, and work done on the system equal to 29 J is exchanged with the surroundings. Calculate ΔU ?

system loses heat so $q = -82$ J

system contracts so $w = +29$ J.

$\Delta U = q + w = -82\ \text{J} + 29\ \text{J} = -53\ \text{J}$

Ex.3:

Ammonia burns in the presence of a platinium catalyst to give nitric oxide, NO. In an experiment, 4 mol NH3 is burned and evolves +170 kJ of heat. Is the reaction endothermic or exothermic? What is the value of q?

$4NH_3\,(g) + 5O_2\,(g) \rightarrow 4NO(g) + 6H_2O(l)$

Heat is evolved then the reaction is exothermic, so the value of q is -170 Kj

Ex.4:

If 417 J of heat is added to a system, and the change in internal energy was 254 J. Calculate the work involved with the change.

A) -231 J
B) -163 J
C) 1067 J
D) -1067 J
E) 231 J

ANS:B

* heat is added to the system means → +q

$\Delta U = q + w$

$254 = +417 + w$

$w = -163\ J$

-Pressure-Volume Work:

$w=-P\Delta V$

Ex.1:

Consider the combustion of CH_4

$CH_{4\,(g)} + 2O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2H_2O_{(l)}$

The heat of reaction at 77°C and 1.00 atm is – 885.5 kJ. What is the change in volume when 1.00 mol CH4 reacts with 2.00 mol O2?(You can ignore the volume of liquid water). What is w for this change? Calculate ΔU for the change indicated by the chemical equation.

Remember : ch.5

$P\Delta V=\Delta nRT$

$\Delta V=\frac{\Delta nRT}{P}$

$$1\text{-}\ \Delta V = V_{final} - V_{initial} = \frac{n_f RT}{P} - \frac{n_i RT}{P} = \frac{(n_f - n_i)RT}{P}$$

$$\Delta V = \frac{(1mol - 3mol)\left(0.08206\,\frac{L.atm}{mol.K}\right)(350\ K)}{1.00\ atm} = -57.44\ L$$

Because the change is from 3 moles of gas to 1 mole of gas, this represents a compression being performed on the system->work is done on the system (+ve).

للتحويل !

1 atm.L = 101.3 J

$2\text{-}\ W= -P\,\Delta V$

$= -\,(1.00\ atm) \times (-57.44\ L) = 57.44\ atm.L$

$= 57.44\ atm.L \times 101.3 = +5818\ J = +5.8\ kJ$

$3\text{-}\ \Delta U= q+w = -885.5\ kJ + 5.8\ kJ = -879.7\ kJ$

- Enthalpy (H) and Enthalpy of Reaction

$H = U + PV$

- Because U, P, and V are state functions, H is also a state function.

So, $\Delta H = H_f - H_i$

$\Delta U = q + w = q - P\Delta V = q - RT\Delta n$

Δn= number of moles of product **gas** – number of moles of reactant **gases**

بس الغازات!!

$q = \Delta U + P\Delta V = (U_f - U_i) + P(V_f - V_i) = U_f - Ui + PV_f - PV_i q = (U_f + PV_f) - (U_i + PV_i) = H_f - H_i$

$q = \Delta H$ (at fixed pressure and given temperature)

-Enthalpy of reaction:

The change in enthalpy, ΔH, for a reaction at a given temperature and fixed pressure.

$\Delta H = H\ (\text{products}) - H\ (\text{reactants})$

Ex.1:

Calculate the change in internal energy when 2 moles of CO are converted to 2 moles of CO2 at 1 atm. and 25°C fixed pressure & temp.

$2CO_{(g)} + O_{2\,(g)} \rightarrow 2CO_{2\,(g)}$ $\Delta H = -566.0$ kJ /mol

$\Delta U = q - RT\Delta n$

Δn= number of moles of product gas – number of moles of reactant gases

$= 2 - 3 = -1$

R = 8.314 J/K.mol , T= 298 K

$\Delta U = \Delta H - RT\Delta n$

$$= -566\,\frac{kJ}{mol} - \left(8.314\,\frac{J}{\cancel{K}.mol}\right)\left(\frac{1\,kJ}{1000J}\right)(298\,\cancel{K})\,(-1)$$

$= -\ 563.5$ kJ /mol

Remember :

q=ΔH

- لازم نوحد الوحدات قبل الجمع والطرح،ما بفرق من J او العكس kJ

EX.2:

Consider the reaction:

$C2H5OH(l) + 3O2(g) \rightarrow 3H2O(g) + 2CO2(g)$,

$\Delta H = -1236$ kJ.If the reaction mixture expands under constant pressure and does work on the surroundings equal to 5.0 kJ, then ΔU (internal energy change) for the reaction (in kJ/mol) is:

a) - 1231

b) - 1237

c) -1251

d) -1241

e) -1246

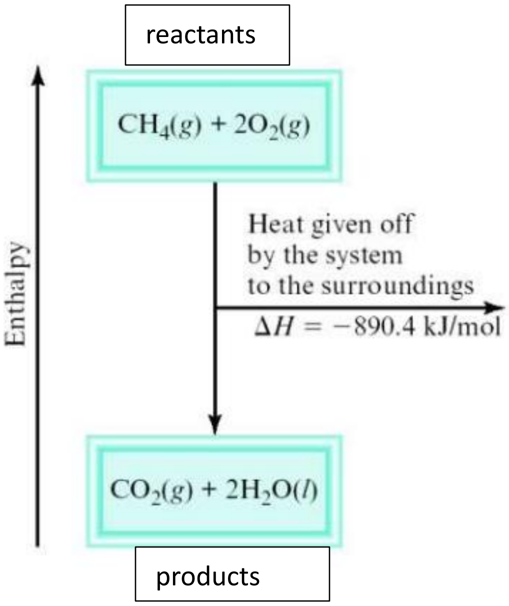
ANS:D

Constant pressure means $\Delta H = q$

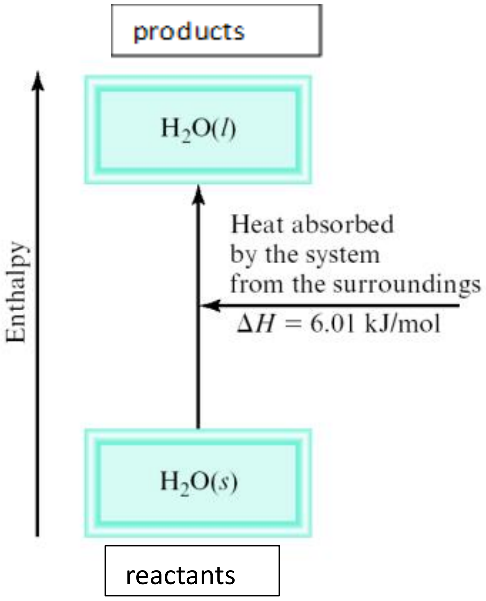
$\Delta U = q + w$ work done on the surrounding

$= -1236 - 5 = -1241$ kJ/mol

6.4: Thermochemical Equations:



$$H_{products} < H_{reactants}$$
$$\Delta H < 0$$



$$H_{products} > H_{reactants}$$
$$\Delta H > 0$$

$\Delta H = H_p - H_R$ = negative

So , it is exothermic reaction

System gives off heat

890.4 kJ are released for every 1 mole of methane

that is combusted at 25C and 1 atm.

التفاعل بطلع طاقة مقدارها 890.4

$\Delta H = H_p - H_R$ = positive

So, it is endothermic reaction

System absorbs heat

6.01 kJ are absorbed for every 1 mole of ice that melts at 0 C and 1 atm

يعني انا بحاجة لطاقة مقدارها 6.01 عشان احول مول واحد من الثلج الى سائل

-The stoichiometric coefficients always refer to the number of moles of a substance.

$H_2O_{(S)} \rightarrow H_2O_{(l)}$ $\Delta H = 6.01$ kJ/mol

-If you reverse a reaction, the **sign** of ΔH changes

$H_2O_{(l)} \rightarrow H_2O_{(s)}$ $\Delta H = -6.01$ kJ/mol

-If you multiply both sides of the equation by a factor n, then ΔH must change by the same factor n.

$2H_2O_{(s)} \rightarrow 2H_2O_{(l)}$ $\Delta H = 2 \times 6.01 = 12.0$ kJ

- The physical states of all reactants and products must be specified in thermochemical equations.

$H_2O_{(s)} \rightarrow H_2O_{(l)}$ $\Delta H = 6.01$ kJ/mol

$H_2O_{(l)} \rightarrow H_2O_{(g)}$ $\Delta H = 44.0$ kJ/mol

ΔH

بتختلف لما احول نفس المركب من صلب لسائل او من سائل لغاز

6.5: Applying Stoichiometry to Heats of Reaction

Ex.1:

مدخولها لمولات

How much heat is evolved when 9.07 x 10^5 g of ammonia_is produced according to the following equation? $(M_m\ NH_3 = 17)$

$N_{2\,(g)} + 3H_{2\,(g)} \rightarrow 2NH_{3(g)}$ $\Delta H = -91.8$ kJ

$$n = \frac{m}{M_m} = \frac{9.07 \times 10^5}{17} = 5.33 \times 10^4 \text{ mol}$$

$$2 \text{ mol } NH_3 = -91.8 \text{ kJ}$$

$$5.3 \times 10^4 \text{ mol } NH_3 = x$$

$$\frac{(-91.8)(5.3 \times 10^4)}{2} = x \Rightarrow x = -2.45 \times 10^6 \text{ kJ}$$

Ex.2:

Given the thermochemical equation

$2SO_{2(g)} + O_{2(g)} \longrightarrow 2SO_{3(g)}$ $\Delta H = -198.2$ kJ/mol

calculate the heat evolved when 87.9 g of SO2

(molar mass =64.07 g/mol) is converted to SO3

$$n = \frac{m}{M_m} = \frac{87.9}{64.07} = 1.37 \text{ mol}$$

$$2 \text{ mol } SO_2 = -198.2 \text{ kJ/mol}$$

$$1.37 \text{ mol } SO_2 = x \Rightarrow x = -136 \text{ kJ}$$

Ex.3:

How much heat (in KJ) is produced when 85.0 g of $NH_3(g)$,(Molar mass= 17.0 g/mol), are oxidized according to:
$4NH_3(g) + 7O_2(g) \rightarrow 4NO_2(g) + 6H_2O(g)$; ΔH= -1396 KJ

a. 698

b. 1745

c. 1047

d. 1396

e. 2094

$n = \frac{85}{17} = 5\ \text{mol}$

$4\ \text{mol}\ NH_3 = -1396\ \text{kJ}$

$\times$

$5\ \text{mol}\ NH_3 = x$

$x = -1745\ \text{kJ}$

heat produced = 1745 kJ, ANS: B

Ex.4:

In the following reacton: $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$, the enthalpy change of the reacton is found to be ΔH°=-1250 kJ. How many grams of oxygen molecules must (32 g/mol) be reacted by this reacton to release 10^4kJ of heat?

A- 914 g

B- 835 g

C- 768 g

D- 711 g

E- 662 g

$3\ \text{mol}\ O_2 = -1250\ \text{kJ}$

$\times$

$x = 10^4\ \text{kJ}$

$x = 24\ \text{mol}\ O_2$

$24 = \frac{m}{32} \Rightarrow m = 768\ \text{g}$

ANS:C

6.6: Measuring Heats of Reaction

- Heat Capacity and Specific Heat

- **The heat capacity (C)** of a sample of substance: is the quantity of heat needed to raise the temperature of the sample of substance one degree Celsius (or one kelvin).

$q= C\Delta t$

هي الطاقة اللازمة لرفع درجة حرارة العينة درجة سيليسيوسية واحدة " او درجة كلفن واحدة"

-**The specific heat capacity (S)** (or simply specific heat): is the quantity of heat required to raise the temperature of one gram of a substance by one degree Celsius (or one kelvin) at constant pressure.

$q= S \times m \times \Delta t$

$C = m \times s$

كمية الحرارة اللازمة لرفع درجة حرارة 1 غرام من المادة درجة سيليسيوسية واحدة "او درجة كلفن واحدة"

Ex.1:

*بنختار أي معادلة
بناءً على المعطيات
بالسؤال

Calculate the heat absorbed by 15.0 g of water to raise its temperature from 20.0°C to 50.0°C (at constant pressure).

The specific heat of water is 4.18 J/(g ·°C).

$q = s \times m \times \Delta t$ $\Delta t = t_f - t_i = 50.0\ C - 20.0\ C = +30.0\ C$

$= 4.18\ J/(g.C) \times 15.0\ g \times (+30.0\ C) = 1.88 \times 10^3\ J$.

- Measurement of Heat of Reaction

-Heat of a reaction is measured in a **calorimeter**, a device used to measure the heat absorbed or evolved during a physical or chemical change.

-Calorimeters are considered **isolated systems** → $q_{system} = 0$

$q_{sys} = q_{water} + q_{cal} + q_{rxn} = 0$

$q_{sys} = 0$

$q_{rxn} = -(q_{water} + q_{cal})$

$q_{water} = m \times s \times \Delta t$

$q_{cal} = C_{cal} \times \Delta t$

-Constant-pressure calorimeter

coffee-cup calorimeter

$\Delta H = q_{rxn}$

Ex.1:

Suppose 33 mL of 1.20 M HCl is added to 42 mL of a solution containing excess sodium hydroxide, NaOH, in a coffee-cup calorimeter. The solution temperature, originally 25.0°C, rises to 31.8°C. Give the enthalpy change, ΔH, for the reaction: assume that the specific heat and the density of the final solution in the cup are those of water (s_{water}=4.184 J/(g.C))

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

$q_{sys} = q_{water} + q_{cal} + q_{rxn}$

$q_{solution} = s \times m \times \Delta t = 4.184\ J/(g.°C) \times 75\ g \times (31.8°C - 25.0°C) = 2133.8\ J$

كيف طلعنا كتلة المحلول؟

حكالنا بالسؤال انه كثافة المحلول زي كثافة الماء وكثافة الماء =1 ف

$d = \frac{m}{V}$

$1 = \frac{m}{75} \Rightarrow m = 75g$

$q_{sys} = q_{solution} + q_{rxn} = 0$

$q_{rxn} = -q_{solution}$

$q_{rxn} = -2133.8\ J$ →

هاي للتفاعل كامل بدي اعرف لكل مول فمنقسم على عدد مولات المحدد للتفاعل

mol HCl = 1.20 mol/L x 0.033 L = 0.0396 mol

$$\Delta H = \frac{-2133.8\ J}{0.0396\ mol} = -53884\ J/mol = -54\ kJ/mol$$

$-\Delta H = q_{rxn}$

لانه الضغط ثابت

-بما انه ما في معلومات بالسؤال لحساب qcal بعتبرها مش موجودة

Ex2.:

When 15.3 g of NaNO3 (85.0 g/mol) was dissolved in water in a constant-pressure calorimeter, the temperature fell from 25.00°C to 21.56°C. If the heat capacity of the solution and the calorimeter is 1071 J/°C, what is the enthalpy change when 1 mol. of NaNO3 dissolves in water? The solution process is

$q_{sys} = q_{water} + q_{cal} + q_{rxn}$

$$NaNO_3(s) \longrightarrow Na^+(aq) + NO_3^-(aq);\ \Delta H = ?$$

$q_{calorimeter} = C_{cal} \times \Delta T = (1071\,J/°C)(21.56°C - 25.00°C) = -3684.2\,J$

$q_{calorimeter} = -\,q_{rxn} \rightarrow\ q_{rxn} = 3684.2\,J$

The amount of heat absorbed by 15.3 g of NaNO3 = 3684.2 J

The amount of heat absorbed by 1mol of NaNO3 is ?

$15.3\,g\ NaNO_3 = 3684.2\,J$

$85\,g\ NaNO_3 = x$

$x = 20467.8\,J$

$1\ mol\ NaNO_3 = \frac{m}{85}$

$m_{NaNO_3} = 85\,g$

Ex.3:

When 0.0500 mol of HCl (aq) reacted with 0.0500 mol of NaOH(aq) in a coffue cup calorimeter, the temperature of the solution increases by 5.99°C. What is the enthalpy change for the following reaction (in kJ)

HCl(aq) + NaOH(aq) → NaCl(aq) + H2O(I)

Assume that the heat capacity of the calorimeter and its contents is 465.4 J/°C.

increases by $= +\Delta t$

decreases by $= -\Delta t$

a) -55.8

b) - 38.6

c) 38.6

d) -0.139

e) 55.8

ANS:A

$q_{sol.} = c\Delta t$

$= 465.4 \times 5.99 = 2787 \text{ J}$

$q_{rxn} = -q_{sol.} \Rightarrow q_{rxn} = -2787 \text{ J} = -2.787 \text{ kJ}$

- The limiting reactant is either HCl or NaOH since both are 0.05 mol

$$\Delta H = \frac{-2.787}{0.05} = -55.8 \text{ kJ}$$

-Constant-volume calorimeter

Bomb calorimeter

$\Delta H \sim q_{rxn}$

Ex.1:

Suppose 0.562 g of graphite is placed in a bomb calorimeter with an excess of oxygen at 25.0°C and 1 atm. pressure. The graphite is ignited, and it burns according to the equation:

$C\ (graphite) + O_{2\ (g)} \rightarrow CO_{2\ (g)}$

On reaction, the calorimeter temperature rises from 25.0°C to 25.89°C. The heat capacity of the calorimeter and its contents was determined in a separate experiment to be 20.7 kJ/°C. What is the heat of reaction? Express the answer as a thermochemical equation.

$q_{sys} = q_{water} + q_{cal} + q_{rxn}$

$q_{\ rxn} = -q_{cal}$

$q_{\ rxn} = -C_{\ cal}\ \Delta t = -20.7\ kJ/C \times (25.89\ C - 25.00\ C) = -18.4\ kJ$

$$\text{mol C} = \frac{0.562}{12} = 0.047\ \text{mol}$$

$$\Delta H = \frac{-18.4\ kJ}{0.047\ mol} = -\ 3.9 \times 10^{2}\ kJ$$

$C\ (graphite) + O_{2\ (g)} \rightarrow CO_{2(g)}\ \ ;\Delta H = -3.9 \times 10^{2}\ kJ$

Ex2.:

200 ml of 0.631 M HCl were mixed with 200 ml of 0.631 M NaOH and the enthalpy of the reaction was -55.8 kJ/mol. Given that the density of solution is 1.00 g/ml and its specific heat is 4.07 J/g.C . Calculate the increase temperature of the reaction solution. (ignore the heat absorbed by the calorimeter).

$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$

A)1.58 C

B) 2.27 C

C)2.95 C

D)3.64 C

E)4.33 C

- There is no limiting reactant, since NaOH & HCl have the same volume and molarity so the same moles.
- moles of HCl & NaOH = 200 mL * 0.631M = 0.126 mol
- heat of reaction = $-55.8 \frac{kJ}{mol} * 0.126\ mol = -7.042\ kJ$

$q_{rxn} = -q_{cal.}$

$-7.042 = -mass * s * \Delta t$ → density $= 1 = \frac{m}{200+200} \Rightarrow m = 400g$

$-7.042 = -400 * 4.07 * \Delta t$

$\Delta t = 4.33\ °C \Rightarrow$ ANS: C

Ex.3:

A bomb calorimeter has a heat capacity of 2.47 kJ/°C.

When a 3.74×10^{-3} mol sample of ethylene was burned in this calorimeter, the temperature increased by 2.14 °C. Calculate the energy of combustion for one mole of ethylene.

A. –5.29 kJ/mol

B. 5.29 kJ/mol

C. –148 kJ/mol

D. –1410 kJ/mol

E. 1410 kJ/mol

$$q_{cal} = C \Delta t$$

$$= 2.47 * 2.14 = 5.286$$

$$q_{rxn} = -q_{cal}$$

$$= -5.286$$

$$\Delta H_{rxn} = \frac{-5.286}{3.74 \times 10^{-3}} = -1410 \text{ kJ/mol}$$

ANS: D

Ex.4:

A lead (Pb) pellet having a mass of 26.47 g at 89.98°C was placed in a constant-pressure calorimeter of negligible heat capacity containing 100.0 mL of water. The water temperature rose from 22.50°C to 23.17°C. What is the specific heat of the lead pellet?

$\Rightarrow q_{cal} = 0$

$$q_{Pb} = -q_{H_2O}$$

from the density

$$q_{H_2O} = (100\,g)(4.184\,J/g\cdot{}^\circ C)(23.17\,{}^\circ C - 22.50\,{}^\circ C)$$

$$= 280.3\,J \Longrightarrow q_{Pb} = -280.3\,J$$

$$-280.3 = (26.47\,g)(S)(23.17\,{}^\circ C - 89.98\,{}^\circ C)$$

the same as water

$$\boxed{S = 0.158\,J/g\cdot{}^\circ C}$$

-A 4.50 g sample of sugar C5H10O5 (molar mass= 150.0 g/mol) was burned in excess oxygen in a bomb calorimeter according to: $C_5H_{10}O_5(s) + 5O_2(g) \longrightarrow 5CO_2(g) + 5H_2O(l)$ If the heat capacity of the calorimeter and its contents was 16.0 KJ/ ° C, and the temperature rose from 25.0 °C to 26.5 °C, calculate ΔH in K/mol for the combustion reaction.

a. -1600

b. -960

c. -800

d. -2400

e. -1200

$q_{rxn} = -q_{cal}$

$q_{cal} = C\Delta t = (16)(26.5-25)$

$= 24\ \text{kJ} \Rightarrow \boxed{q_{rxn} = -24\ \text{kJ}}$

$n_{C_5H_{10}O_5} = \frac{4.5}{150} = 0.03\ \text{mol}$

$\Delta H = \frac{-24}{0.03} = -800\ \text{kJ/mol}$

ANS:C

-A bomb calorimeter has a heat capacity of 2.47 kJ/°C. When a 0.106 g sample of a compound was burned in this calorimeter, the temperature increased by 2.44 °C. Calculate the energy of combuston for 1 g of the hydrocarbon.

A) -49.9 kJ

B)-52.2 kJ

C)-54.5 kJ

D)-56.9 Kj

E)-59.2 kJ

$q_{rxn} = -q_{cal}$

$q_{cal} = C\Delta t = (2.47)(2.44)$

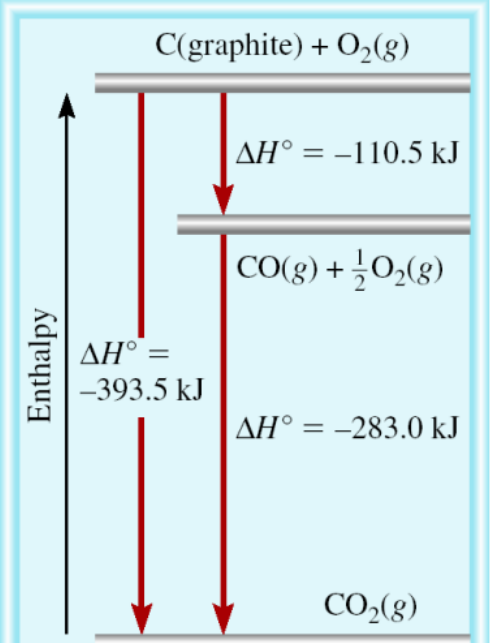
$= 6.03\ \text{kJ} \Rightarrow q_{rxn} = -6.03$

$\Delta H = -\frac{6.03\ \text{kJ}}{0.106\ \text{g}} = -56.9\ \text{kJ/g}$

ANS:D

6.7: Hess's Law

"for a chemical equation that can be written as the sum of two or more steps, the enthalpy change for the overall equation equals the sum of the enthalpy changes for the individual steps"



$$\text{C (graphite)} + 1/2O_2\ (g) \longrightarrow CO\ (g) \quad \Delta H_1$$

$$CO\ (g) + 1/2O_2\ (g) \longrightarrow CO_2\ (g) \quad \Delta H_2$$

$$\text{C (graphite)} + O_2\ (g) \longrightarrow CO_2\ (g) \quad \Delta H_3$$

$$\Delta H_3 = \Delta H_1 + \Delta H_2$$

Ex.1:

What is the enthalpy of reaction, ΔH, for the formation of tungsten carbide, WC, from the elements?

$W_{(s)} + C\ (graphite) \rightarrow WC_{(s)}$

(1) $2W_{(s)} + 3O_{2\,(g)} \rightarrow 2WO_{3\,(s)}$; $\Delta H = -1685.8$ kJ

(2) $C\ (graphite) + O_{2(g)} \rightarrow CO_{2(g)}$; $\Delta H = -393.5$ kJ

(3) $2WC_{(s)} + 5O_{2(g)} \rightarrow 2WO_{3(s)} + 2CO_{2(g)}$; $\Delta H = -2391.8$ kJ

بهاد النوع من الأسئلة ممكن انه نعكس المعادلة ونضرب ΔH ب -1 او نضربها بأي معامل عشان نخلي عدد المولات زي بعض

بهاد السؤال عنا ال WC بالمعادلة الي بدنا نوصلها بالنواتج وبالمعادلة الثالثة موجودة بالمتفاعلات فمنستنتج انه لازم نعكسها

(3) $2WO_{3(s)} + 2CO_{2(g)} \rightarrow 2WC_{(s)} + 5O_{2(g)}$; $\Delta H = 2391.8$ kJ

بالمعادلة الي بدنا نوصلها ما في CO_2 فمنستنتج انه لازم نشطبها وبنشطبها عن طريق معادلة 2 و 3 بس لازم لما نشطبهم يكون الهم نفس المعامل فمنضرب معادلة 2 ب 2

وننتبه لما نضرب انه نضرب كل المعادلة بكل ما فيها وما ننسى نضرب ΔH

(2) $2C + 2O_{2(g)} \rightarrow 2CO_{2(g)}$; $\Delta H = -787$ kJ

$2W_{(s)} + \cancel{3O_2}_{(g)} \rightarrow 2\cancel{WO_3}_{(s)}$ $\Delta H = -1685.8$ kJ

$2C + \cancel{2O_2}_{(g)} \rightarrow \cancel{2CO_2}_{(g)}$ $\Delta H = -787$ kJ

$2\cancel{WO_3}_{(s)} + \cancel{2CO_2}_{(g)} \rightarrow 2WC_{(s)} + \cancel{5O_2}_{(g)}$ $\Delta H = +2391.8$ kJ

2÷ $2W_{(s)} + 2C \rightarrow 2WC$ $\Delta H = -81$ kJ

$W_{(s)} + C \rightarrow WC$ $\Delta H = -40.5$ kJ #

Ex.2:

Manganese metal can be obtained by reaction of manganese dioxide with aluminum.

$4Al_{(s)} + 3MnO_{2(s)} \rightarrow 2Al_2O_{3(s)} + 3Mn_{(s)}$

What is ΔH for this reaction? Use the following data:

$2Al_{(s)} + \frac{3}{2}O_{2(g)} \rightarrow 2Al_2O_{3(s)}$; ΔH= -1676 kJ

$Mn_{(s)} + O_{2(g)} \rightarrow MnO_{2(s)}$; ΔH= -520 Kj

2X $2Al_{(s)} + \frac{3}{2}O_{2(g)} \rightarrow 2Al_2O_{3(s)}$; $\Delta H = -1676$ KJ

$4Al_{(s)} + 3O_{2(g)} \rightarrow 4Al_2O_{3(s)}$; $\Delta H = -3352$ KJ

3x $\rightleftarrows$ $Mn_{(s)} + O_{2(g)} \rightarrow MnO_{2(s)}$; $\Delta H = -520$ KJ

$3MnO_{2(s)} \rightarrow 3Mn_{(s)} + 3O_{2(g)}$; $\Delta H = 1560$ KJ

$4Al_{(s)} + \cancel{3O_{2(g)}} \rightarrow 4Al_2O_{3(s)}$; $\Delta H = -3352$ KJ

$3MnO_{2(s)} \rightarrow 3Mn_{(s)} + \cancel{3O_{2}}_{(g)}$; $\Delta H = 1560$ KJ

$4Al_{(s)} + 3MnO_{2(s)} \rightarrow 4Al_2O_{3(s)} + 3Mn_{(s)}$

$\Delta H = -1792$ KJ

Ex.3:

Using two or more of the following,

$N_{2(g)}+3/2O_{2(g)}\rightarrow N_2O_{3(g)}$; ΔH°=83.7KJ

$N_{2(g)}+O_{2(g)}\rightarrow 2NO_{(g)}$; ΔH°=180.4KJ

$1/2N_{2(g)}+O_{2(g)}\rightarrow NO_{2(g)}$;ΔH°=33.2KJ

$1/2N_{2(g)}+3/2H_{2(g)}\rightarrow NH_{3(g)}$;ΔH°=45.9KJ

Determine ΔH° for the following reaction.

$NO_{(g)}+NO_{2(g)}\rightarrow N_2O_{3(g)}$

a. -207.1kj

b. 207.1kj

c. 39.7kj

d. 24.3kj

e. -39.7kj

$\Delta H = 167.4$ $\quad 2\cancel{N_{2(g)}} + 3\cancel{O_{2(g)}} \rightarrow 2N_2O_3$

$\Delta H = -180.4$ $\quad 2NO_{(g)} \longrightarrow \cancel{N_{2(g)}} + \cancel{O_{2(g)}}$

$\Delta H = -66.4$ $\quad 2NO_2 \longrightarrow \cancel{N_{2(g)}} + \cancel{2O_2}$

$2\div$ $\Delta H = -79.4$ $\quad 2NO_{(g)} + 2NO_{2(g)} \rightarrow 2N_2O_3$

$\Delta H = -39.7$ KJ

ANSWER:E

Ex.4:

Given the following thermochemical equations:

C2H6O(l)+3O2(g)→2CO2(g)+ 3H2O(l); ΔH=-710.5 kJ

C2H4O(l)+$\frac{5}{2}$O2(g) →2CO2(g)+2H2O(l); ΔH=-583.5 Kj

Calculate ΔH for the following reaction (kJ/mol)

2C2H4O(l)+2H2O(l)→ 2C2H6O(l)+O2(g)

A)204

B)114

C)404

D)407

E)254

$\Delta H = -1167$ $\quad 2C_2H_4O_{(l)} + \cancel{5O_{2(g)}} \rightarrow \cancel{4CO_2} + \cancel{4H_2O}$

$\Delta H = 1421$ $\quad \cancel{4CO_{2(g)}} + 6H_2O_{(l)} \rightarrow 2C_2H_6O + 6O_2$

$\Delta H = 254J$ $\quad 2C_2H_4O_{(l)} + 2H_2O_{(l)} \rightarrow 2C_2H_6O_{(l)} + O_2$

ANS:E

6.8: Standard Enthalpies of Formation

-The term standard state refers to the standard thermodynamic conditions chosen for substances when listing or comparing thermodynamic data: 1 atm pressure and the specified temperature (usually 25°C).

ΔH° is called the standard enthalpy of reaction

- An **allotrope** is one of two or more distinct forms of an element in the same physical state. ($O2$ and $O3$), (C: graphite and diamond)

-The **reference form** of an element for the purpose of specifying the formation reaction is usually the most stable form of the element under standard thermodynamic conditions.

-The reference form of oxygen at 25°C is $O_{2(g);}$ the reference form of carbon at 25°C is graphite ($C_{graphite}$)

The **standard enthalpy of formation** (also called the **standard heat of formation**) of a substance, denoted $\Delta H^o{}_f$, is the enthalpy change for the formation of one mole of the substance in its standard state from its elements in their reference form and in their standard states.

هي الطاقة المصاحبة لتكوين 1 مول من المادة من عناصرها الاساسية

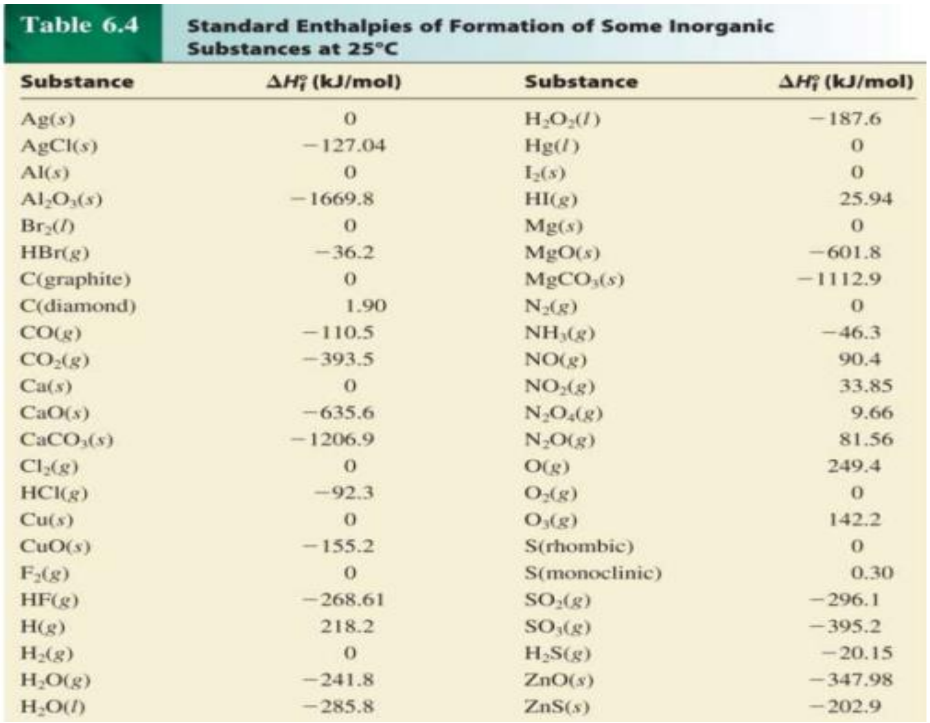


Table 6.4 **Standard Enthalpies of Formation of Some Inorganic Substances at 25°C**

Substance	ΔH_f° (kJ/mol)	Substance	ΔH_f° (kJ/mol)
$Ag(s)$	0	$H_2O_2(l)$	−187.6
$AgCl(s)$	−127.04	$Hg(l)$	0
$Al(s)$	0	$I_2(s)$	0
$Al_2O_3(s)$	−1669.8	$HI(g)$	25.94
$Br_2(l)$	0	$Mg(s)$	0
$HBr(g)$	−36.2	$MgO(s)$	−601.8
C(graphite)	0	$MgCO_3(s)$	−1112.9
C(diamond)	1.90	$N_2(g)$	0
$CO(g)$	−110.5	$NH_3(g)$	−46.3
$CO_2(g)$	−393.5	$NO(g)$	90.4
$Ca(s)$	0	$NO_2(g)$	33.85
$CaO(s)$	−635.6	$N_2O_4(g)$	9.66
$CaCO_3(s)$	−1206.9	$N_2O(g)$	81.56
$Cl_2(g)$	0	$O(g)$	249.4
$HCl(g)$	−92.3	$O_2(g)$	0
$Cu(s)$	0	$O_3(g)$	142.2
$CuO(s)$	−155.2	S(rhombic)	0
$F_2(g)$	0	S(monoclinic)	0.30
$HF(g)$	−268.61	$SO_2(g)$	−296.1
$H(g)$	218.2	$SO_3(g)$	−395.2
$H_2(g)$	0	$H_2S(g)$	−20.15
$H_2O(g)$	−241.8	$ZnO(s)$	−347.98
$H_2O(l)$	−285.8	$ZnS(s)$	−202.9

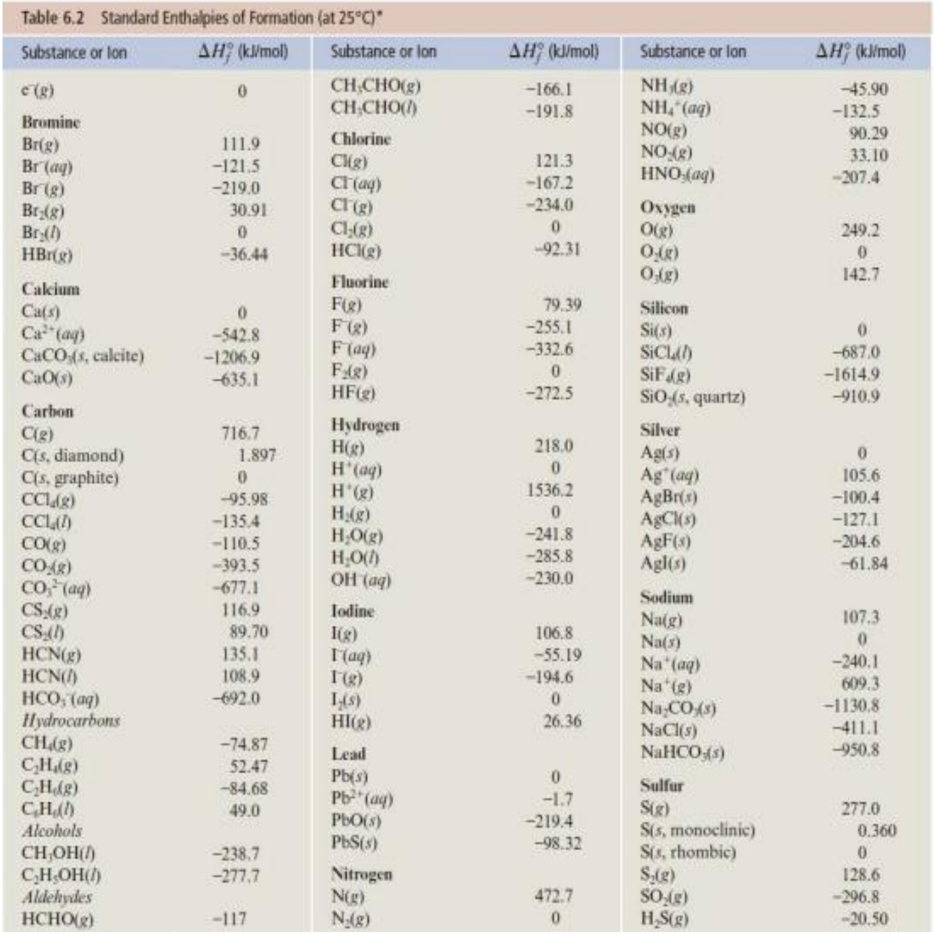


Table 6.2 Standard Enthalpies of Formation (at 25°C)*

Substance or Ion	ΔH_f° (kJ/mol)
$e^-(g)$	0
Bromine	
$Br(g)$	111.9
$Br^-(aq)$	−121.5
$Br^-(g)$	−219.0
$Br_2(g)$	30.91
$Br_2(l)$	0
$HBr(g)$	−36.44
Calcium	
$Ca(s)$	0
$Ca^{2+}(aq)$	−542.8
$CaCO_3(s, calcite)$	−1206.9
$CaO(s)$	−635.1
Carbon	
$C(g)$	716.7
$C(s, diamond)$	1.897
$C(s, graphite)$	0
$CCl_4(g)$	−95.98
$CCl_4(l)$	−135.4
$CO(g)$	−110.5
$CO_2(g)$	−393.5
$CO_3^{2-}(aq)$	−677.1
$CS_2(g)$	116.9
$CS_2(l)$	89.70
$HCN(g)$	135.1
$HCN(l)$	108.9
$HCO_3^-(aq)$	−692.0
Hydrocarbons	
$CH_4(g)$	−74.87
$C_2H_4(g)$	52.47
$C_2H_6(g)$	−84.68
$C_6H_6(l)$	49.0
Alcohols	
$CH_3OH(l)$	−238.7
$C_2H_5OH(l)$	−277.7
Aldehydes	
$HCHO(g)$	−117
$CH_3CHO(g)$	−166.1
$CH_3CHO(l)$	−191.8
Chlorine	
$Cl(g)$	121.3
$Cl^-(aq)$	−167.2
$Cl^-(g)$	−234.0
$Cl_2(g)$	0
$HCl(g)$	−92.31
Fluorine	
$F(g)$	79.39
$F^-(g)$	−255.1
$F^-(aq)$	−332.6
$F_2(g)$	0
$HF(g)$	−272.5
Hydrogen	
$H(g)$	218.0
$H^+(aq)$	0
$H^+(g)$	1536.2
$H_2(g)$	0
$H_2O(g)$	−241.8
$H_2O(l)$	−285.8
$OH^-(aq)$	−230.0
Iodine	
$I(g)$	106.8
$I^-(aq)$	−55.19
$I^-(g)$	−194.6
$I_2(s)$	0
$HI(g)$	26.36
Lead	
$Pb(s)$	0
$Pb^{2+}(aq)$	−1.7
$PbO(s)$	−219.4
$PbS(s)$	−98.32
Nitrogen	
$N(g)$	472.7
$N_2(g)$	0
$NH_3(g)$	−45.90
$NH_4^+(aq)$	−132.5
$NO(g)$	90.29
$NO_2(g)$	33.10
$HNO_3(aq)$	−207.4
Oxygen	
$O(g)$	249.2
$O_2(g)$	0
$O_3(g)$	142.7
Silicon	
$Si(s)$	0
$SiCl_4(l)$	−687.0
$SiF_4(g)$	−1614.9
$SiO_2(s, quartz)$	−910.9
Silver	
$Ag(s)$	0
$Ag^+(aq)$	105.6
$AgBr(s)$	−100.4
$AgCl(s)$	−127.1
$AgF(s)$	−204.6
$AgI(s)$	−61.84
Sodium	
$Na(g)$	107.3
$Na(s)$	0
$Na^+(aq)$	−240.1
$Na^+(g)$	609.3
$Na_2CO_3(s)$	−1130.8
$NaCl(s)$	−411.1
$NaHCO_3(s)$	−950.8
Sulfur	
$S(g)$	277.0
$S(s, monoclinic)$	0.360
$S(s, rhombic)$	0
$S_2(g)$	128.6
$SO_2(g)$	−296.8
$H_2S(g)$	−20.50

Reference state means $\Delta H^o_f = 0$

يعنى انه مش بحاجة لطاقة عشان نكونهم و يفترض حفظهم

Ex.1:

Which reaction corresponds to the standard_enthalpy of formation of $NaHCO_{3(s)}$,$\Delta H^{o}_{f} = -947.7$ kJ/mol?

A. $Na(s) + \frac{1}{2}H_2(g) + {}^{3}/{}_{2}O_2(g) + C(s, gr) \rightarrow NaHCO_3(s)$
B. $Na^{+}(g) + H^{+}(g) + 3O^{2-}(g) + C^{4+}(g) \rightarrow NaHCO_3(s)$
C. $Na^{+}(aq) + H^{+}(aq) + 3O^{2-}(aq) + C^{4+}(aq) \rightarrow NaHCO_3(s)$
D. $NaHCO_3(s) \rightarrow Na(s) + \frac{1}{2}H_2(g) + {}^{3}/{}_{2}O_2(g) + C(s, gr)$
E. $Na^{+}(aq) + HCO_3^{-}(aq) \rightarrow NaHCO_3(s)$

-بهاد النوع من الأسئلة بدنا نفصل المركب الي معطيني إياه لل Reference state فمثلًا ال Na
بتكون بحالتها الأساسية لما تكون (s) وال H لما تكون H_2 بس هون بما انها بالمركب H وحدة لازم
اضرب ب $\frac{1}{2}$ وال C لما تكون graphite وال O لما تكون O_2 وبما انها بالمركب 3O منضرب
ب $\frac{3}{2}$
فالجواب هو A

Ex.2:

Which reaction corresponds to the standard enthalpy of formation of C4H3Br2NO2(l)?

A. $4C(s, gr) + 3H(g) + 2Br(s) + N(g) + 2O(g) \rightarrow C_4H_3Br_2NO_2(l)$
B. $8C(s, gr) + 3H_2(g) + 2Br_2(g) + N_2(g) + 2O_2(g) \rightarrow 2C_4H_3Br_2NO_2(l)$
C. $4C(s, gr) + {}^{3}/{}_{2}H_2(g) + Br_2(l) + \frac{1}{2}N_2(g) + O_2(g) \rightarrow C_4H_3Br_2NO_2(l)$
D. $4C(s, gr) + {}^{3}/{}_{2}H_2(g) + Br_2(s) + \frac{1}{2}N_2(g) + \frac{1}{2}O_2(g) \rightarrow C_4H_3Br_2NO_2(l)$

ANS: C

Ex.3:

The standard enthalpy of formation of sulfur dioxide (SO2) is-296.9 kJ. What is ΔH for the formation of 16.03g of sulfur dioxide in its standard state from its elements in their standard states?

(SO2 = 64.07 g/mol)

A. 74.28 kJ

B. - 296.9 kJ

C. - 4,759 kJ

D. -74.28 kJ

E. 593.6 Kj

$$n_{SO_2} = \frac{16.03}{64.07} = 0.25 \text{ mol}$$

$1 \text{ mol } SO_2 = -296.9 \text{ KJ}$

$0.25 \text{ mol } SO_2 = x$

$x = -74.28 \text{ KJ}$

$\boxed{\text{ANS: D}}$

Ex.4:

- The value of ΔH^O for the reaction below is -72 kJ.

$H_2 (g) + Br_2 (g) \rightarrow 2HBr (g)$

how many kJ of heat are released when 80.9 grams of HBr is formed in this reaction

A)-72

B) 0.44

C)72

D) 36

E) 144

$$n_{HBr} = \frac{80.9}{80.9} = 1$$

$2 \text{ mol } HBr = -72 \text{ KJ}$

$1 \text{ mol } HBr = x$

$x = \underset{\text{released}}{-}36$

ANS:D

-Way to apply Hess's Law without needing to manipulate thermochemical equations:

ΔH° reaction = { Sum of all ΔH°_f of all of the products} – {sum of all ΔH°_f of all of the reactants}

-Consider the reaction:

$aA + bB \rightarrow cC + dD$

ΔH° reaction = (c x ΔH°_f (C)+ d x ΔH°_f (D))-(a x ΔH°_f (A)+ b x ΔH°_f (B))

ΔH° reaction has units of kJ because

Coefficients x heats of formation have units of mol x kJ/mol

$$\Delta H^\circ_{rxn} = \sum\left[\Delta H^\circ_f(\text{products}) \times (\text{moles of product})\right] - \sum\left[\Delta H^\circ_f(\text{reactants}) \times (\text{moles of reactant})\right]$$

ΔH° rxn has units of kJ

ΔH°_f has units of kJ/mol

Ex.1:

Calculate ΔH° rxn using ΔH°_f data for the reaction

$SO_{3(g)} \rightarrow SO_{2(g)} + \frac{1}{2} O_{2\,(g)}$

substance	ΔH°_f
SO3 (g)	-396 KJ/mol
SO2 (g)	-297 kJ/ mol

$$\Delta H^\circ_{rxn} = \sum\left[\Delta H^\circ_f(\text{products}) \times (\text{moles of product})\right] - \sum\left[\Delta H^\circ_f(\text{reactants}) \times (\text{moles of reactant})\right]$$

$$\Delta H^\circ_{rxn} = (\Delta H^\circ_f (SO_2) + \tfrac{1}{2} \Delta H^\circ_f O_2) - \Delta H^\circ_f SO_3$$

$$= (-297 + \tfrac{1}{2}(0)) - (-396)$$

$$\Delta H^\circ_{rxn} = 99 \text{ kJ}$$

Ex.2:

Calculate ΔH° rxn using ΔH°_f data for the reaction

$4NH_{3\,(g)} + 7O_{2\,(g)} \rightarrow 4NO_{2(g)} + 6\,H_2O_{\,(l)}$

substance	ΔH°_f
NH3 (g)	-46 kJ/mol
NO2 (g)	34 kJ/mol
H2O (l)	-285.9 kJ/mol

$$\Delta H^\circ_{rxn} = (4\,\Delta H(NO_2) + 6\,\Delta H^\circ_f(H_2O) - (4\,\Delta H^\circ_f(NH_3) + 7\,\Delta H^\circ_f(O_2))$$

$$= (4 * 34 + 6 * -285.9) - (4 * -46 + 7 * 0)$$

$$= -1395\ kJ$$

Ex.3:

- $2Fe_{(s)} + 6H_2O_{(l)} \rightarrow 2Fe(OH)_{3\,(s)} + 3H_{2\,(g)}$

substance	ΔH°_f
H2O (l)	-285.8 KJ/mol
Fe(OH)3 (s)	-696.5 kJ/ mol

$$\Delta H^\circ_{rxn} = (2\,\Delta H(Fe(OH)_3) + 3\Delta H(H_2)) - (2\Delta H(Fe) + 6\Delta H(H_2O))$$

$$= (2 * -696.5 + 3 * 0) - (2 * 0 + 6 * -285.8)$$

$$\boxed{\Delta H^\circ_{rxn} = 321.8\ kJ}$$

- $CO_{2\,(g)} + 2H_2O_{(l)} \rightarrow 2O_{2\,(g)} + CH_{4\,(g)}$

substance	ΔH°_f
CO2 (g)	-393.5 kJ/mol
CH4(g)	-74.8 kJ/mol
H2O (l)	-285.8 kJ/mol

$$\Delta H^\circ_{rxn} = (2\,\Delta H(O_2) + \Delta H(CH_4)) - (\Delta H(CO_2) + 2\,\Delta H(H_2O))$$

$$= (2 * 0 + -74.8) - (-393.5 + 2 * -285.8)$$

$$\boxed{\Delta H^\circ_{rxn} = 890.3\ kJ}$$

-We don't always want to know ΔH°rxn, so we can use Hess's Law and ΔH°rxn to calculate ΔH°_f for compound where not known

Ex.1:

Given the following data, what is the value of

$\Delta H^\circ_f (C_2H_3O_2^-, aq)$?

$$Na^+_{(aq)} + C_2H_3O_2^-{}_{(aq)} + 3H_2O_{(l)} \rightarrow NaC_2H_3O_2{\cdot}3H_2O_{(s)}$$

ΔH°rxn = -19.7 kJ/mol

substance	ΔH°_f
Na^+ (aq)	-239.7 kJ/mol
$NaC_2H_3O_2{\cdot}3H_2O$ (s)	710.4 kJ/mol
H_2O (l)	285.9 kJ/mol

$$\Delta H^\circ_{rxn} = \Delta H^\circ_f \; NaC_2H_3O_2 \cdot 3H_2O - (H^\circ_f \; Na^+ + H^\circ_f \; C_2H_3O_2^- + 3 H^\circ_f \; H_2O)$$

$$-19.7 = 710.4 - (-239.7 + 3(285.9) + \Delta H^\circ_f \; C_2H_3O_2^-)$$

$$-19.7 = 710.4 - (-239.7 + 857.7 + \Delta H^\circ_f \; C_2H_3O_2^-)$$

$$-19.7 = 710.4 - 618 - \Delta H^\circ_f \; C_2H_3O_2^-$$

$$-19.7 = 92.4 - \Delta H^\circ_f \; C_2H_3O_2^-$$

$$\Delta H^\circ_f \; C_2H_3O_2^- = 112.1 \text{ kJ/mol}$$

Ex.2:

Calculate ΔH°_f for FeO(s) using the informationbelow.

$Fe_3O_{4(s)} + CO_{(g)} \rightarrow 3FeO_{(s)} + CO_{2(g)}$; ΔH° rxn= 21.9 kJ

substance	ΔH°_f
$Fe_3O_{4(s)}$	-1120.9 kJ/mol
$CO_{(g)}$	-110.5 kJ/mol
$CO_{2(g)}$	-393.5 kJ/mol

A. 272.0 kJ

B. -816.0 kJ

C. -272.0 kJ

D. 26.00 J

E. -38.60 kJ

$$21.9 = (3\,\Delta H FeO + -393.5) - (-1120.9 - 110.5)$$

$$21.9 = 3\,\Delta H FeO + 837.9$$

$$\Delta H^\circ_f = -272 \text{ kJ}$$

ANS: C

Ex.3:

What is the standard enthalpy of formation of liquid methylamine (CH3NH2)?

4CH3NH2(1)+ 13O2(g)→ 4CO2(g)+ 4NO2(g) + 10H2O(l)

ΔH°= -4110.4 KJ

C(s) + O2(g) ⟶ CO2(g) ΔH°= -393.5 KJ

2H2O(1) ⟶ 2H2(g) + O2(g) ΔH°= 571.6 KJ

½ N2(g) + O2(g)⟶NO2(g) ΔH°= 33.10 KJ

A) +3899.2 KJ/mol

B) -3899.2 KJ/mol

C) -47.3 KJ/mol

D) +3178.4 KJ/mol

E) +47.3 KJ/mol

ANS:C

(a) $C_{(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)}$ $\Delta H^{\circ} = -393.5$ KJ

$\Delta H^{\circ}_{rxn} = \Delta H^{\circ}_{f}\, CO_2 - (\Delta H^{\circ}_{f}\, C + \Delta H^{\circ}_{f}\, O_2)$

$-393.5 = \Delta H^{\circ}_{f}\, CO_2 - (0 + 0)$

$\boxed{\Delta H^{\circ}_{f}\, CO_2 = -393.5}$

(b) $2H_2O_{(l)} \rightarrow 2H_{2\,(g)} + O_{2\,(g)}$ $\Delta H^{\circ} = -571.6$ KJ

$571.6 = (2*0 + 0) - (2*\Delta H^{\circ}_{f}\, H_2O)$

$\boxed{\Delta H^{\circ}_{f}\, H_2O = -285.8}$

(c) $\frac{1}{2} N_{2\,(g)} + O_{2\,(g)} \rightarrow NO_{2\,(g)}$ $\Delta H^{\circ} = 33.10$ KJ

$33.10 = \Delta H^{\circ}_{f}\, NO_2 - (\frac{1}{2}*0 + 0)$

$\boxed{\Delta H^{\circ}_{f}\, NO_2 = 33.1}$

$4CH_3NH_{2(l)} + 13O_{2(g)} \rightarrow 4CO_{2(g)} + 4NO_{2(g)} + 10H_2O_{(l)}$

$\Delta H^\circ_{rxn} = -4110.4$ KJ

$-4110.4 = (4 * -393.5 + 4 * 33.1 + 10 * -285.8) -$

$(4 * \Delta H^\circ_f \, CH_3NH_2 + 13 * 0)$

$-4110.4 = (-1574 + 132.4 - 2858) - 4\Delta H^\circ_f \, CH_3NH_2$

$-4110.4 = -4299.6 - 4\Delta H^\circ_f \, CH_3NH_2$

$189.2 = -4\Delta H^\circ_f \, CH_3NH_3$

$$\boxed{\Delta H^\circ_f \, CH_3NH_3 = -47.3 \text{ KJ/mol}}$$

QUESTIONS:

-An endothermic reaction causes the surroundings to:

A- Warm up.
B- Become acidic.
C- Condense.
D- Decrease in temperature.
E- Expand.

ANS:C

-An endothermic reaction causes the system to:

A- Become acidic.
B- Warm up.
C- Condense.
D- Decrease in temperature.
E- Expand.

ANS:B

-Use Hess's law to determine the standard enthalpy of formation for the following reaction

3 C(s) + 4 H2 (g) → C3H8 (g)

Use the following information:

(a) $C_3H_{8(g)} + 5O_{2\,(g)} \rightarrow 3CO_{2(g)} + 4\,H_2O_{(l)}$;ΔH° = - 2219.9 Kj

(b) $C_{(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)}$; ΔH° = - 393.5 kJ

(c) $H_{2\,(g)} + 1/2\,O_{2\,(g)} \rightarrow H_2O_{(l)}$; ΔH° = - 285.8 kJ

(a) $\cancel{3CO_2} + 4\cancel{H_2O} \rightarrow C_3H_8 + \cancel{5O_2}$ $\Delta H = 2219.9$

(b) $3C + 3\cancel{O_2} \rightarrow \cancel{3CO_2}$ $\Delta H = -1180.5$

(c) $4H_2 + \cancel{2O_2} \rightarrow 4\cancel{H_2O}$ $\Delta H = -1143.2$

$3C + 4H_2 \rightarrow C_3H_8$ $\Delta H = -103.8$ kJ

-Calculate the standard enthalpy change for the reaction:

$2C_8H_{18(l)} + 17O_{2\,(g)} \rightarrow 16CO_{(g)} + 18H_2O_{(l)}$. Given:

(a) $2C_8H_{18(l)} + 25O_{2\,(g)} \rightarrow 16CO_{2(g)} + 18H_2O_{(l)}$

$\Delta H° = -11020$ kJ

(b) $2CO_{(g)} + O_{2\,(g)} \rightarrow 2CO_{2\,(g)}$; $\Delta H° = -566.0$ kJ

$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$ $\Delta H = -11020$

$16CO_2 \rightarrow 16CO + 8O_2$ $\Delta H = 4528$

$2C_8H_{18} + 17O_2 \rightarrow 16CO + 18H_2O$ $\boxed{\Delta H = -6492 \text{ kJ}}$

- To which one of the following reactions occurring at 25°C does the symbol $\Delta H°_f$ [H_2SO_4 (l)] refer?

A) $2H(g) + S(g) + 4O(g) \rightarrow H_2SO_4$ (l)

B) H_2 (g) + S(g) + $2O_2$ (g) $\rightarrow H_2SO_4$ (l)

C) H_2SO_4 (l) $\rightarrow H_2$ (g) + S(s) + $2O_2$ (g)

D) H_2SO_4 (l) $\rightarrow$ 2H(g) + S(s) + 4O(g)

E) H_2 (g) + S(s) + $2O_2$ (g) $\rightarrow H_2SO_4$ (l)

ANS:E

- $\Delta H°_f$ [HNO_3 (l)] : $\frac{1}{2}H_{2(g)} + \frac{1}{2}N_{2(g)} + \frac{3}{2}O_{2(g)} \rightarrow HNO_{3(l)}$

- $\Delta H°_f$ [CO(g)] : $C_{(s)} + \frac{1}{2}O_{2(g)} \rightarrow CO_{(g)}$

-$\Delta H°_f$ [CO_2 (g)]: $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$

لازم تكونوا حافظين العناصر الرئيسية لتعرفوا تجاوبوا هاد النوع من الاسئلة

- 86.9-g sample of chromium (s=0.447J/(g. °C)), initially at 338.33°C, is added to an insulated vessel containing 189.9g of water (s=4.18J/(g.°C)) initially at 16.17°C.At equilibrium, the final temperature of the metal-water mixture is 28.06°C. how much heat was absorbed by the water? The heat capacity of the vessel is 0.220KJ/°C.

  A) 9.43KJ
  B) 15.2KJ
  C) 12KJ
  D) 6.82KJ
  E) 112KJ

ANS: C

- . a bomb calorimeter has a heat capacity of 2.47KJ/K. When a 0.106-g sample of certain hydrocarbon was burned in this calorimeter, the temperature increased by 2.14K. calculate the energy of combustion for 1g of the hydrocarbon?

  A) -2.33x10^3 J/g
  B) -0.560 J/g
  C) -4.99x10^5 J/g
  D) -5.29 J/g
  E) -0.120 J/g

ANS:C

- Given the following thermochemical data at 25°C and 1 atm pressure, $3/2O_2(g)+2B(s) \rightarrow B_2O_3(s)$; $\Delta H° =-1264KJ$

$O_3(g)+2B(s) \rightarrow B_2O_3(s)$; $\Delta H°=-1406KJ$

Determine H° for the following reaction at 25°C and 1 atm pressure. $3O_2(g) \rightarrow 2O_3(g)$

A) +980KJ/mol

B) +284KJ/mol

C) -284KJ/mol

D)-980KJ/mol

E) -2670KJ/mol

ANS:B

-Given the data in the table below calculate $H°_f$ (KJ) for the reaction: $2CH_3OH(I) + 3O_2(g) \rightarrow 2CO_2(g) + 4H_2O(I)$

A) -1432

B) -1412

C) -1452

D) -1392

E)-1372

Substance	$\Delta H°_f$
CH_3OH (l)	-249 kJ
CO_2 (g)	-393 KJ
H_2O (l)	-286 kJ

ANS:A

-Given the following thermochemical equation:

$2S(s) + 3O_2(g) \rightarrow 2SO_3(g)$; ΔH= -792 KJ

$S(s) + O_2(g) \rightarrow SO_2(g)$; ΔH= -297 KJ

Calculate ΔH(in KJ) for the reaction:

$SO_2(g) + \frac{1}{2} O_2(g) \rightarrow SO_3(g)$

A) -139

B) -99

C) -119

D) -109

E) -129

ANS:B

-In a process 455 KJ of heat were evolved and 656 KJ of work were done on the system. Calculated ΔU (KJ) for the system is

A) 201

B) 601

C) 401

D) 501

E) 301

ANS:A

-When 3.50 g of sucrose undergoes combustion in a constant volume calorimeter, the temperature rises from 25.00oC to 29.00oC. Calculate ΔH for the combustion of sucrose in (KJ/mol) sucrose. The heat capacity of the calorimeter is 3.7 kJ/^{O}C. (The molar mass of sucrose is 342.3 g/mol)

C12H22O11 (s) + 12O2 (g) →12CO2 (g) + 11H2O (I)

A) -5.07 * 10^3

B) -1.45 * 10^3

C) +1.45 * 10^3

D) -1.48 * 10^3

E) +1.48 * 10^1

ANS:B

-A system that does not work but which transfers heat to the system has:

A) $q < 0$ and $\Delta U > 0$

B) $q > 0$ and $\Delta U < 0$

C) $q > 0$ and $\Delta U > 0$

D) $q < 0$ and $\Delta U < 0$

E) $q < 0$ and $\Delta U = 0$

ANS:C

-A system absorbs 25.8 kJ of heat while performing 10.9 kJ of work on the surroundings. If the final internal energy U is 70.8 Kj What is the initial value of U?

A) 65.9 kJ
B) 45.9 kJ
C) 75.9 kJ
D) 55.9 kJ
E) 89.7 KJ

ANS:D

-10.0 g of NaCI (58.44 g/mol) at 20.00 °C was added to a calorimeter containing 200 g of water at 20.00 °C. The temperature of the solution decreased to 17.30 °C. If the specific heat of the mixture is 4.184 J.g^{1}°C^{1}, the density of water is 1 g/mL, and the heat capacity of the calorimeter is ignored, what is the heat absorbed per mole of NaCI?

A) 10.8 kJ
B) 11.8 kJ
C) 12.8 kJ
D) 13.9 kJ
E) 14.9 Kj

ANS:D

-Consider the reaction:

$C_2H_4O_2(l) + 2O_2(g) \rightarrow 2H_2O(l) + CO_2(g)$; $\Delta H^\circ = -875$ Kj

Calculate ΔH°_f for $CO_2(g)$, in kJ/mol

Substance	ΔH°_f
H_2O (l)	-286 kJ/mol
$C_2H_4O_2$ (l)	-485 kJ/mol

A)-394

B)-344

C)-244

D)-244

E)-444

ANS:A

- A sample of 1.43g of naphthalene ($C_{10}H_8$, molar mass= 128g/mol) was burned in excess oxygen in a bomb calorimeter. The temperature of the calorimeter increased from 20.28 °C to 25.95 °C. If the heat evolved from the reaction was 5632 kJ/mol. Calculate the heat capacity of the calorimeter.

  $C_{10}H_8$ (l) + $12O_2$ (g) $\rightarrow$ $4H_2O$ (l) + $10CO_2$ (g)

  A) 11.1 KJ/K

  B) 20.9 KJ/K

  C) 4.4 KJ/K

  D) 18.4 KJ/K

  E) 9.54 KJ/K

ANS:A

الإجابات مكتوبة بوحدة الكلفن,لكن هاد لا يعني انه نحول السيلسيوس لكلفن لانهم نفس الاشي وهاد تريك لتضييع الوقت

-How much heat is liberated at constant pressure when 97.7 g of calcium oxide reacts with 29.0 L of carbon dioxide gas, measured at 1.00 atm pressure and 25.0 °C ?(R= 0.0821 L.atm(K.mol))

$CaO(s) + CO2(g) \longrightarrow CaCO3(s)$; ΔH°= -178.3

A) -1.74*10^4 KJ

B) -2.11*10^2 KJ

C) -5.22*10^2 KJ

D) -5.17*10^3 KJ

E) -3.11*10^2 KJ

ANS:B

-When 500 ml of 0.4 M $Ca(NO_3)_2$ is added to 500ml of 0.8 M NaF,CaF_2 precipitates , as shown in the net ionic equation below, the initial temperature of both solutions is 20 C, assuming that the resulting solution has a mass of 1000 g and a specific heat of 4.18 J/(g.C).Calculate the final temperature of the solution.

$Ca_2(aq)+2F^-(aq) \rightarrow CaF_2(s)$;ΔH= -11.5 Kj

A)18.9 C

B)20 C

C) 19.45 C

D) 20.55 C

E) 21.1 C

ANS:C

A 0.156 mol of methanol, CH3OH, was combusted in the presence of excess oxygen in a bomb calorimeter. If the temperature of the calorimeter increased from 24.00 °C to 29.77°C and the heat capacity of the calorimeter and its contents was 19400. J/°C, calculate ΔU for the reaction in KJ/mol.

A) -314 KJ/mol
B) - 789 KJ/mol
C) -718 KJ/mol
D) -121 KJ/mol
E) -69.5 KJ/ mol

ANS:C