1. *Radiant energy* is
   A) the energy stored within the structural units of chemical substances.
   B) the energy associated with the random motion of atoms and molecules.
   C) solar energy, i.e. energy that comes from the sun.
   D) energy available by virtue of an object's position.

2. *Thermal energy* is
   A) the energy stored within the structural units of chemical substances.
   B) the energy associated with the random motion of atoms and molecules.
   C) solar energy, i.e. energy that comes from the sun.
   D) energy available by virtue of an object's position.

3. *Chemical energy* is
   A) the energy stored within the structural units of chemical substances.
   B) the energy associated with the random motion of atoms and molecules.
   C) solar energy, i.e. energy that comes from the sun.
   D) energy available by virtue of an object's position.

4. *Potential energy* is
   A) the energy stored within the structural units of chemical substances.
   B) the energy associated with the random motion of atoms and molecules.
   C) solar energy, i.e. energy that comes from the sun.
   D) energy available by virtue of an object's position.

5. *Heat* is
   A) a measure of temperature.
   B) a measure of the change in temperature.
   C) a measure of thermal energy.
   D) a measure of thermal energy transferred between two bodies at different temperature.

6. An endothermic reaction causes the surroundings to
   A) warm up.
   B) become acidic.
   C) condense.
   D) decrease in temperature.
   E) release CO_2.

7. An exothermic reaction causes the surroundings to
   A) warm up.
   B) become acidic.
   C) expand.
   D) decrease its temperature.
   E) release CO_2.

8. A sample of nitrogen gas expands in volume from 1.6 L to 5.4 L at constant temperature. Calculate the work done in joules if the gas expands (a) against a vacuum, (b) against a constant pressure of 0.80 atm, and (c) against a constant pressure of 3.7 atm. $W = -P\Delta V$

Answer

a) $P = 0$ $\quad W = -P\Delta V = -0(\Delta V) = 0$

$\Delta V = 5.4 - 1.6 = 3.8 \times 10^{-3}\ m^3$

b) $P = 0.8\ atm$ $\quad W = -P\Delta V$

$P = 0.8 \times 1.013 \times 10^5$

$W = -0.8 \times 1.013 \times 10^5 \times 3.8 \times 10^{-3}$

$W = -307\ J = -3 \times 10^2\ J$

$P = 3.7 \times 1.013 \times 10^5$

c) $P = 3.7$ $\quad W = -P\Delta V = -3.7 \times 1.013 \times 10^5 \times 3.8 \times 10^{-3} = -1.4 \times 10^3\ J$

9. The work done to compress a gas is 74 J. As a result, 26 J of heat is given off to the surroundings. Calculate the change in energy of the gas.

$W = 74 \qquad q = -26$

$\Delta E = q + W = -26 + 74 = 48\ J$

10. Determine the amount of heat (in kJ) given off when 1.26×10^4 g of NO_2 are produced according to the equation: $2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$ $\Delta H = -114.6$ kJ/mol

$NO + \frac{1}{2}O_2 \rightarrow NO_2 \quad \Delta H = -57.3\ kJ$

① قسمة المعادلة على 2

② حساب عدد المولات

$n = \frac{m}{M_w} = \frac{1.26 \times 10^4}{46} = 273.9$

$(M_w = 14 + 2 \times 16 = 46)$

③ حساب كمية الطاقة نضرب عدد المولات بـ كمية الطاقة الناتجة للمول الواحد

$57.3 \times 273.9 = 1.57 \times 10^4\ kJ$

11. Consider the reaction:

$H_2(g) + Cl_2(g) \longrightarrow 2HCl(g) \qquad \Delta H = -184.6$ kJ/mol $\times 3$

If 3 moles of H_2 react with 3 moles of Cl_2 to form HCl, calculate the work done against a pressure of 1.0 atm at 25°C. What is ΔE for this reaction? Assume the reaction goes to completion.

Solution:

$\Delta H = -184.6 \times 3 = -553.8\ kJ/mol$

$\Delta E = \Delta H + P\Delta V$

$P\Delta V$ → zero

تغير في الحجم

لان عدد المولات ثابت

اذاً الحجم ايضا ثابت

$\Delta V = 0$

$\Delta E = \Delta H$

$= -553.8\ kJ$

12. Consider two metals A and B, each having a mass of 100 g and an initial temperature of 20°C. The specific heat of A is larger than that of B. Under the same heating conditions, which metal would take longer to reach a temperature of 21°C?

Solution:

A takes longer time to reach 21 because it has highes (C)

13. A piece of silver of mass 362 g has a heat capacity of 85.7 J/°C. What is the specific heat of silver?

Solution:

$$s = \frac{C}{m} = \frac{85.7}{362} = 0.237 \text{ J/C.g}$$

14. A 0.1375-g sample of solid magnesium is burned in a constant-volume bomb calorimeter that has a heat capacity of 3024 J/°C. The temperature increases by 1.126°C. Calculate the heat given off by the burning Mg, in kJ/g and in kJ/mol.

Solution:

1mol (Mg) = 24.3 g

$m = 0.1375\ g \qquad \Delta t = 1.126\ C^{\circ}$

$C = 3024\ J/C^{\circ}$

$$q = C\Delta t = 3024 \times 1.126 = 3405\ J = 3.405\ KJ$$

$$q\ (KJ/g) = \frac{3.405}{0.1375} = 24.76\ KJ/g$$

$$g\ (KJ/mol) = 24.76 \times 24.3 = 601\ KJ/mol$$

15. Which is the more negative quantity at 25°C: ΔH°_f for $H_2O(l)$ or ΔH°_f for $H_2O(g)$?

Solution:

$H_2O_{(l)}$ is more stable

$\Delta Hf^{\circ}(H_2O_l)$ more negative

16. Suggest ways (with appropriate equations) that would enable you to measure the ΔH°_f values of $Ag_2O(s)$ and $CaCl_2(s)$ from their elements. No calculations are necessary.

$$2Ag + \frac{1}{2}O_2 \longrightarrow Ag_2O$$

$$\Delta H_{rxn} = \Delta H^\circ_f (Ag_2O)$$

$$Ca + Cl_2 \longrightarrow CaCl_2$$

$$\Delta H_{rxn} = \Delta H^\circ_f (CaCl_2)$$

17. Calculate the heat of decomposition for this process at constant pressure and 25°C:

$$CaCO_3(s) + CaO(s) \rightarrow CO_2(g)$$

(Look up the standard enthalpy of formation of the reactant and products in Table)

Solution:

$$\Delta H_{rxn} = \left[\Delta H_f (CaO) + \Delta H_f (CO_2)\right] - \Delta H_f (CaCO_3)$$

$$= [-635.1 - 393.5] - -1206.9$$

$$= 178 \text{ kJ/mol}$$

Table 3.10.1: Some Standard Enthalpies of Formation at 25°C.

Compound	ΔH_f/kJ mol^{-1}	ΔH_f/kcal mol^{-1}	Compound	ΔH_f/kJ mol^{-1}	ΔH_f/kcal mol^{-1}
$AgCl(s)$	−127.068	−30.35	$H_2O(g)$	−241.818	−57.79
$AgN_3(s)$	+620.6	+148.3	$H_2O(l)$	−285.8	−68.3
$Ag_2O(s)$	−31.0	−7.41	$H_2O_2(l)$	−187.78	−44.86
$Al_2O_3(s)$	−1675.7	−400.40	$H_2S(g)$	−20.63	−4.93
$Br_2(l)$	0.0	0.00	$HgO(s)$	−90.83	−21.70
$Br_2(g)$	+30.907	+7.385	$I_2(s)$	0.0	0.0
$C(s)$, graphite	0.0	0.00	$I_2(g)$	+62.438	+14.92
$C(s)$, diamond	+1.895	+0.453	$KCl(s)$	−436.747	−104.36
$CH_4(g)$	−74.81	−17.88	$KBr(s)$	−393.798	−94.097
$CO(g)$	−110.525	−26.41	$MgO(s)$	−601.7	−143.77
$CO_2(g)$	−393.509	−94.05	$NH_3(g)$	−46.11	−11.02
$C_2H_2(g)$	+226.73	+54.18	$NO(g)$	+90.25	+21.57
$C_2H_4(g)$	+52.26	+12.49	$NO_2(g)$	+33.18	+7.93
$C_2H_6(g)$	−84.68	−20.23	$N_2O_4(g)$	+9.16	+2.19
$C_6H_6(l)$	+49.03	+11.72	$NF_3(g)$	−124.7	−29.80
$CaO(s)$	−635.09	−151.75	$NaBr(s)$	−361.062	−86.28
$CaCO_3(s)$	−1206.92	−288.39	$NaCl(s)$	−411.153	−98.24
$CuO(s)$	−157.3	−37.59	$O_3(g)$	+142.7	+34.11
$Fe_2O_3(s)$	−824.2	−196.9	$SO_2(g)$	−296.83	−70.93
$HBr(g)$	−36.4	−8.70	$SO_3(g)$	−395.72	−94.56
$HCl(g)$	−92.307	−22.06	$ZnO(s)$	−348.28	−83.22
$HI(g)$	+26.48	+6.33			

18. The standard enthalpies of formation of ions in aqueous solutions are obtained by arbitrarily assigning a value of zero to H^+ ions; that is, $\Delta H^\circ_f [H^+(aq)] = 0$.

(a) For the following reaction:

$$HCl(g) \xrightarrow{H2O} H^+(aq) + Cl^-(aq) \quad \Delta H^\circ = -74.9 \text{ kJ/mol}$$

calculate ΔH°_f for the Cl^- ions.

(b) Given that ΔH°_f for OH^- ions is - 229.6 kJ/mol, calculate the enthalpy of neutralization when 1 mole of a strong monoprotic acid (such as HCl) is titrated by 1 mole of a strong base (such as KOH) at 25°C.

a)

$$\Delta H_{rxn} = \Delta H_f(H^+) + \Delta H_f(Cl^-) - \Delta H_f(HCl)$$

$$-74.9 = 0 + \Delta H_f(Cl^-) - -92.3$$

$$\Delta H_f(Cl^-) = -74.9 - 92.3$$

$$= -167.2 \text{ kJ/mol}$$

---

b)

$$H^+ + OH^- \longrightarrow H_2O$$

-285.8 -229.6 zero

$$\Delta H_{rxn} = \Delta H_f(H_2O) - [\Delta H_f(OH^-) + \Delta H_f(H^+)]$$

$$\Delta H_{rxn} = -285.8 - [-229.6] = -56.2 \text{ kJ/mol}$$

19. The standard enthalpy change for the following reaction is 436.4 kJ/mol:

$H_2(g) \rightarrow H(g) + H(g)$

Calculate the standard enthalpy of formation of atomic hydrogen (H). $\Delta H_f(H)$

Solution:

$$\Delta H_{rxn} = 2\Delta H_f(H) - \Delta H_f(H_2)$$ zero

$$436.4 = 2\,\Delta H_f(H)$$

$$\Delta H_f(H) = \frac{436.4}{2} = 218.2 \text{ kJ/mol}$$

20. From these data,

$$S(rhombic) + O_2(g) \longrightarrow SO_2(g) \qquad \Delta H^\circ_{rxn} = -296.06 \text{ kJ/mol}$$
$$S(monoclinic) + O_2(g) \longrightarrow SO_2(g) \qquad \Delta H^\circ_{rxn} = -296.36 \text{ kJ/mol}$$

calculate the enthalpy change for the transformation

$$S(rhombic) \longrightarrow S(monoclinic)$$

(Monoclinic and rhombic are different allotropic forms of elemental sulfur.)

Solution:

نبدأ بالمعادلة الأولى كما هي ونقلب المعادلة الثانية

$S(rhombic) + O_2 \longrightarrow SO_2 \qquad \Delta H = -296.06$

$SO_2 \longrightarrow O_2 + S(monoclinic) \qquad \Delta H = +296.36$

$S\ rhombic \longrightarrow S\ monoclinic = 0.3$ kJ/mol

21. From the following data,

$$C(graphite) + O_2(g) \longrightarrow CO_2(g) \qquad \Delta H^\circ_{rxn} = -393.5 \text{ kJ/mol}$$
$$H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(l) \qquad \Delta H^\circ_{rxn} = -285.8 \text{ kJ/mol}$$
$$2C_2H_6(g) + 7O_2(g) \longrightarrow 4CO_2(g) + 6H_2O(l) \qquad \Delta H^\circ_{rxn} = -3119.6 \text{ kJ/mol}$$

calculate the enthalpy change for the reaction

$$2C(graphite) + 3H_2(g) \longrightarrow C_2H_6(g)$$

Solution:

نضرب المعادلة ① بـ ②

$2C(gra) + 2O_2 \longrightarrow 2CO_2 \qquad \Delta H = 787$

نقلب معادلة 3 ونقسم على ②

$2CO_2 + 3H_2O \longrightarrow C_2H_6 + \frac{7}{2}O_2 \qquad \Delta H = 1559.8$

نضرب معادلة 2 في ③

$3H_2 + \frac{3}{2}O_2 \longrightarrow 3H_2O \qquad \Delta H = -857.4$

$2C + 3H_2 \longrightarrow C_2H_6$

$\Delta H = -787 + -857.4 + 1559.8$

$= -84.6$ kJ/mol

22. Calculate the standard enthalpy change for the reaction $2Al(s) + Fe_2O_3(s) \longrightarrow 2Fe(s) + Al_2O_3(s)$ given that

$2Al(s) + 3/2O_2(g) \longrightarrow Al_2O_3(s)$ $\Delta H°_{rxn} = -1669.8$ kJ/mol

$2Fe(s) + 3/2O_2(g) \longrightarrow Fe_2O_3(s)$ $\Delta H°_{rxn} = -822.2$ kJ/mol

Solution:

$2AL + \frac{3}{2}O_2 \longrightarrow AL_2O_3$ $\Delta H = -1669$

$Fe_2O_3 \longrightarrow 2Fe + \frac{3}{2}O_2$ $\Delta H = 822.2$

$2AL + Fe_2O_3 \longrightarrow 2Fe + AL_2O_3$

$\Delta H = -1669 + 822.2 = -847.6$ kJ/mol

23. Define *specific heat*.

Ans: The amount of heat required to raise the temperature of one gram of a substance by one degree Celsius.

$q = m\,s\,\Delta T$ $\Delta T = \frac{q}{m\,s}$

24. Mark the Answer with True or False

a) The specific heats of water and iron are 4.184 and 0.444 J/g°C, respectively. When equal masses of water and iron both absorb the same amount of heat, the temperature increase of the water will be 5.42 times greater than that of the iron.

$\Delta T_w = \frac{q}{m\,s_w}$ $\Delta T_i = \frac{q}{m\,s_i}$

Ans: ~~True~~ False

b) Chemical reactions in a bomb calorimeter occur at constant pressure.

$\frac{\Delta T_w}{\Delta T_i} = \frac{s_i}{s_w} = \frac{0.444}{4.184} = 0.106$

Ans: True.

c) If $2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$, $\Delta H° = -1203.6$ kJ/mol.
For $Mg(s) + (1/2)O_2(g) \longrightarrow MgO(s)$, the enthalpy change is $\Delta H = -601.8$ kJ/mol.

Ans: True

d) The heat capacity of 20.0 g of water is 83.7 J/°C.

$C = m\,s = 20 \times 4.184$

Ans: True

e) The work done on the surroundings by the expansion of a gas is $w = -P\Delta V$.

Ans: True

f) The heat absorbed by a system at constant pressure is equal to $\Delta E + P\Delta V$.

Ans: True

g) In an endothermic process, heat is absorbed by the system.

Ans: True

h) A home aquarium is an example of an open system.

Ans: True

i) The heat of hydration (ΔH_{hydr}) of ions is always endothermic.

Ans: False