2011

Chemistry 30

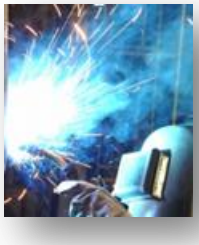
Unit 1 Thermochemical Change

Practice Exam

RTD
Diploma Preparation
1/1/2011

Acetylene is used for oxyacetylene gas welding. Oxyacetylene is the hottest burning common fuel gas. The combustion of acetylene with oxygen creates a flame of over 3300 °C.

1. **Which of the following equations represents the correct thermochemical reaction for the combustion of 1 mole of ethyne?**



A. $C_2H_2 + \frac{3}{2} O_2 \rightarrow 2CO_2 + H_2O + 1.3\ MJ$

B. $C_2H_2 + \frac{5}{2} O_2 \rightarrow 2CO_2 + H_2O + 802\ kJ$

C. $2\ C_2H_2 + 5\ O_2 + 2.6\ MJ \rightarrow 4\ CO_2 + 2\ H_2O$

D. $C_2H_2 + \frac{5}{2} O_2 + \rightarrow 2CO_2 + H_2O + 1.3\ MJ$

NR 1. Rank the following reactions from the most exothermic to the most endothermic:

1. $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)} + 393.5\ KJ$
2. $N_{2(g)} + O_{2(g)} + 91.3\ KJ \rightarrow 2\ NO_{(g)}$
3. $2C_{(S)} + 3H_{2(g)} \rightarrow C_2H_{6(g)}$ $\Delta H = -84.0\ kJ$
4. $C_{(g)} + CO_{2(g)} \rightarrow 2CO_{(g)}$ $\Delta H = 173.0\ kJ$

Most exothermic most endothermic

The first match sticks were invented in China AD 577. These were small sticks of pinewood impregnated with sulphur. Modern match stick heads contain the compound P_4S_3

$P_4S_3 + 8O_2 \rightarrow P_40_{10} + 3\ SO_2$ $\Delta_fH^\circ\ P_40_{10} = -2984.0\ kJ/mol$ $\Delta_fH^\circ\ P_4S_3 = -155.0\ kJ/mol$

2. **Calculate the enthalpy of combustion for the reaction above:**

A. -4.03×10^3 KJ

B. -3.72×10^3 KJ

C. -3.45×10^3 KJ

D. -3.12×10^3 KJ

NR 2. If a match contained 0.276 g of P_4S_3, what would be the energy released in_____kJ?

Zinc oxide is widely used in the manufacturing of concrete to improve the resistance of concrete against water. ZnO can be easily synthesized in a simple teacher demo. Zinc powder is mixed with sulphur power and the reaction is started with a glowing wire on a fire resistant pad. The reaction is so exothermic that the resulting zinc sulfide reacts further to zinc oxide. 88.2 kJ are released during the combustion of 19.5 g of zinc sulfide to zinc oxide and sulphur dioxide. $2\ ZnS + 3O_2 \rightarrow 2\ ZnO + 2\ SO_2$

3. **Calculate the molar enthalpy of combustion of zinc sulfide:**

A. -1764.0 kJ/mol

B. 441.0 kJ/mol

C. -441.0 kJ/mol

D. -882.0 kJ/mol

NR 3. Diborane is a highly reactive reagent. Diborane reacts with alkynes to form substituted alkene products and it reacts with water to form hydrogen and boric acid.

I. $H_2 + \frac{1}{2} O_2 \rightarrow H_2O$ ΔH°=-241.8 kJ

II. $2\ B + \frac{3}{2} O_2 \rightarrow B_2O_3$ ΔH°=1274.0 kJ

III. $B_2H_6 + 3O_2 \rightarrow B_2O_3 + 3H_2O$ ΔH°=-2037.0 kJ

The enthalpy change for the formation of diborane $2B + 3H_2 \rightarrow B_2H_6$ is +/- _____kJ

4. **When a piece of strontium is dropped into water, the temperature of the water increases. The statement that correctly interprets this information is?**

A. $Sr_{(s)} + 2H_2O_{(l)} + 434\ KJ \rightarrow Sr(OH)_2 + H_{2(g)}$
B. Heat is absorbed by the reaction
C. The reaction is endothermic
D. The reactants have more potential energy than the products

Butterfat is the fatty portion of milk.

NR 4. The following is data collected from an experiment to determine the molar heat of combustion of butter fat $C_{15}H_{26}O_6$.

m_{water}= 350 g
$T_{initial(water)}$ = 17.8 °C
$T_{final\ (water)}$ = 49.5 °C
$M_{butter\ fat\ burned}$ = 2.15 g

The heat of combustion of butter fat calculated from this data is_____ kJ/mol.

5. **Use the following information to answer the next question**

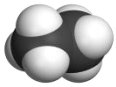
Molar Enthalpy of Combustion for different hydrocarbon fuels

Methane	−802.4 kJ/mol	Butane	−2 657.2 kJ/mol
Propane	−2040.3 kJ/mol	Octane	−5 074.3 kJ/mol

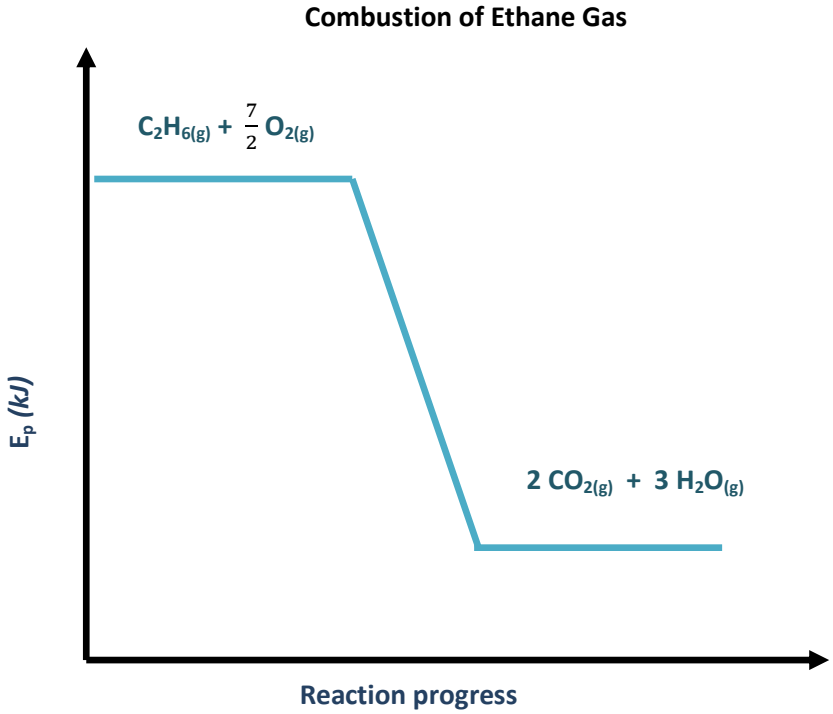
The greater the number of carbon atoms in a fossil fuel molecule, the

A. greater the energy released during reduction.
B. greater the strength of each ionic bond.
C. greater the energy released during combustion.
D. lower the mass of oxygen required for complete combustion.

Ethane was first synthetically created in 1834 by Michael Faraday by the electrolysis of a potassium acetate solution. The complete combustion of ethane releases 1560 kJ/mol of heat, and produces carbon dioxide and water.

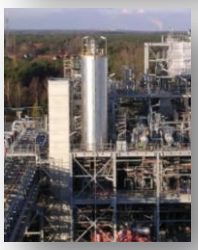


6. Use the following information to answer the following question



The enthalpy change for the combustion of 1.00 mol of ethane gas is

A. exothermic and represented by a negative ΔH *value*
B. endothermic and represented by a negative ΔH value
C. endothermic and represented by a positive ΔH value
D. exothermic and represented by a positive ΔH value



Copper (II) chloride has a major application as a co-catalyst with palladium (II) chloride in the Wacker process. In the Wacker process, ethene is converted to ethanal using water and air. During the reaction, Pd^{2+} is reduced to Pd, and copper (II) chloride re-oxidizes this back to Pd^{2+}. Air oxidizes the resultant Cu^{+} back to Cu^{2+} thus completing the cycle.

7. A student determined experimentally that 2.06 KJ of heat energy were released when 0.635 g of copper reacted with excess chlorine. The enthalpy of formation of copper (II) chloride from this data would be?

A. -206 kJ/mol
B. -1.09 kJ/mol
C. 2.71 kJ/ mol
D. -436 kJ/mol

Catalysts work by increasing the frequency of collisions between reactants, altering the orientation of reactants so that more effective collisions occur or reducing intramolecular bonding within reactant molecules. The presence of a catalyst helps a reaction to reach equilibrium more quickly.

8. If a catalyst is added to a reaction mixture

1. Rate of the reaction increases
2. ΔH value for the reaction increases
3. ΔH for the reaction stays the same
4. The potential energy of the product increases

A. 1 only
B. 1 & 3
C. 1,2 & 4
D. 2 & 4 only

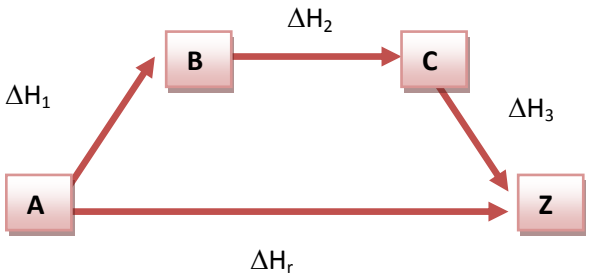
Corn syrup has a high concentration of fructose, $C_6H_{12}O_{6(s)}$. Fructose has the same number of carbon atoms, oxygen atoms, and hydrogen atoms as glucose, yet it has a different structural formula.

9. If 1.80 mmol of fructose is burned in a calorimeter that contains 250.0 g of water and the temperature increases by 3.85 °C, then the molar enthalpy of combustion of fructose is

A. -6.08×10^{-3} kJ/mol
B. -9.68×10^{-2} kJ/mol
C. –4.03 kJ/mol
D. -2.24×10^{3} kJ/mol

10. Use the following information to answer the next question.

The reaction A → Z can proceed directly or through a series of steps, as shown.

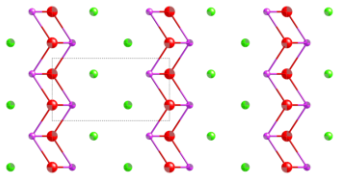


This diagram illustrates

A. the Law of Conservation of Mass
B. Hess' Law
C. an exothermic reaction
D. an endothermic reaction

Bismuth oxychloride is a chemical compound of bismuth, oxygen, and chlorine with the formula BiOCl and exists in nature as the mineral bismoclite. The heat of formation for bismuth oxychloride is

$\Delta H_f^\circ{}_{BiOCl} = -366.9$ kJ



11. Use the following information to answer the next question

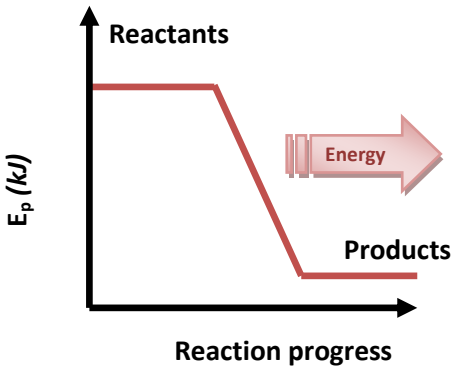
$$2Bi_{(s)} + \frac{3}{2}O_{2(g)} \rightarrow Bi_2O_{3(s)} + 573.9 \text{ kJ}$$

$$Bi_{(s)} + \frac{3}{2}Cl_{2(g)} \rightarrow BiCl_{3(s)} + 379.1 \text{ kJ}$$

The enthalpy change for $BiCl_{3(s)} + Bi_2O_{3(s)} \rightarrow 3BiOCl_{(s)}$, is

A. +1319.9 kJ
B. +586.1 kJ
C. –147.7 kJ
D. –2053.7 kJ

12. Use the following information to answer the next question



The graph could represent the formation of the following organic compounds from their elements **except** for

A. $C_2H_5OH_{(l)}$
B. $CH_3COOH_{(l)}$
C. $C_2H_{6\,(g)}$
D. $C_2H_{4\,(g)}$

13. Nitrogen is a colourless gas. The molar enthalpy of formation for nitrogen is:

A. 0 kJ/mol
B. –21.1 kJ/mol
C. –39.5 kJ/mol
D. –180.4 kJ/mol

14. Use the following information to answer the next two questions.

Nitric acid is a highly corrosive and toxic strong acid. Ammonia is used for the production of nitric acid. An intermediate step in the production of nitric acid is the following:

$4NH_{3\,(g)} + 5O_{2(g)} \rightarrow 4NO_{(g)} + 6H_2O_{(g)}$

The change in the enthalpy for the reaction is

A. 902.0 kJ
B. -902.0 kJ
C. -20.7 kJ
D. -1274.4 kJ

Sodium hydroxide is industrially produced as a 50 % solution by an electrolytic chloralkali process. Chlorine gas is also a product of this process. Solid sodium hydroxide is obtained from this solution by the evaporation of water. Solid sodium hydroxide is most commonly sold as flakes or tablets.

15. The molar enthalpy of solution for $NaOH_{(s)}$ is – 44.6 kJ/mol. If 30.0g of $NaOH_{(s)}$ is dissolved in water in a calorimeter, the energy released inside the calorimeter is

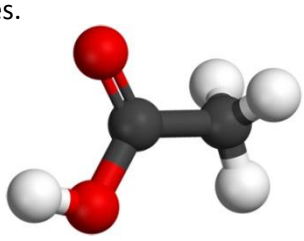
A. 71.4 kJ
B. 33.5 kJ
C. 7.78 MJ
D. 1.12 MJ

Enzymes are proteins that catalyze chemical reactions. Almost all processes in living systems require enzymes for chemical reactions to occur at significantly viable rates.

16. Like all catalysts, enzymes speed up the rate of a chemical reaction by

A. increasing ΔH
B. increasing E_a
C. decreasing E_a
D. decreasing ΔH

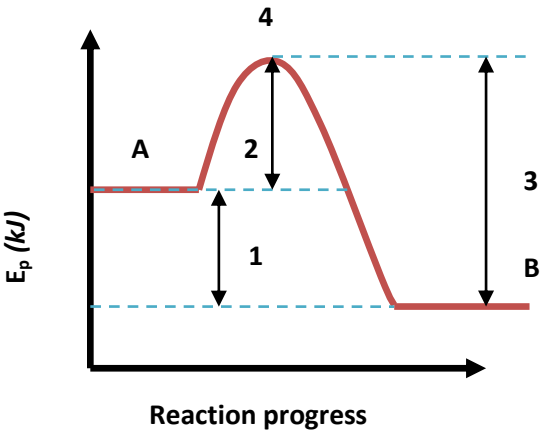
In the 1920s, the German chemists Alwin Mittasch and Mathias Pier developed a process to convert synthesis gas (a mixture of carbon monoxide, carbon dioxide, and hydrogen) into methanol. Chromium and manganese oxide catalysts, and extremely vigorous conditions with pressures of 200 atm, and temperatures ranging up to 450 °C, were required for this process. Modern methanol production has been made more efficient through the use of catalysts capable of working at lower pressures and temperatures.



17. Why can methanol be stored safely in a closed container without worry of combustion?

A. The statement is incorrect
B. The reaction is endothermic
C. The ethanol is sealed in an airtight container
D. There is insufficient energy to supply the E_a

18. Use this information to answer the question below



On the diagram provided above, which number represents the enthalpy of reaction?

a) 3
b) 4
c) 2
d) 1

19. The activation energy (E_a) of the reverse reaction can be expressed by the value of

A. 2 - 1
B. 3 - 1
C. 2 + 3
D. 1 + 2

20. Use the following information to answer the next question

Cold packs are used to ease sprains and bruises. Ammonium nitrate, $NH_4NO_{3(s)}$, is commonly used in such cold packs.

The thermochemical change which occurs in cold packs is an ___*i*___ change, which results in a*(n)* ___*ii*___ in the ___*iii*___ energy of the system.

ROW	*i*	*ii*	*iii*
A.	**Endothermic**	**Increase**	**potential**
B.	**Exothermic**	**Increase**	**potential**
C.	**Endothermic**	**Decrease**	**kinetic**
D.	**Exothermic**	**Decrease**	**kinetic**

Solutions

1.

D. $C_2H_2 + \frac{5}{2} O_2 \rightarrow 2CO_2 + H_2O$ + **1.3 MJ (correctly balanced!)**

The reaction is extremely exothermic

$$\Delta H°_{reaction} = \sum \Delta H_f°_{products} - \sum \Delta H_f°_{reactants}$$

$$\Delta H°_{reaction} = 2mol \times \left(-393.5 \frac{kJ}{mol}\right) + 1mol \times \left(-241.8 \frac{kJ}{mol}\right) - 1mol \times \left(227.4 \frac{kJ}{mol}\right)$$

$$= \mathbf{-1256.2 \frac{kJ}{mol}}$$

NR 1

1. $C + O_2 \rightarrow CO_2 + 393.5$ kJ **the most exothermic**
2. $N_2 + O_2 + 91.3$ KJ $\rightarrow 2$ NO
3. $2C + 3H_2 \rightarrow C_2H_6$ ΔH = -84.0 kJ
4. $C + CO_2 \rightarrow 2CO$ ΔH = 173.0 kJ **the most endothermic**

1324

Most exothermic most endothermic

2. B. -3.72 x 10^3 KJ

$P_4S_3 + 8O_2 \rightarrow P_4O_{10} + 3\ SO_2$ $\Delta H_f°\ P_4O_{10}$ = -2984.0 kJ/mol $\Delta H_f°\ P_4S_3$ = -155.0 kJ/mol

$$\Delta H°_{reaction} = \sum \Delta H_f°_{products} - \sum \Delta H_f°_{reactants}$$

$$\Delta H°_{reaction} = 3mol \times \left(-296.8 \frac{kJ}{mol}\right) + 1mol \times \left(-2984.0 \frac{kJ}{mol}\right) - 1mol \times \left(-155.0 \frac{kJ}{mol}\right)$$

$$= \mathbf{-3719.4 \frac{kJ}{mol}}$$

NR 2

$$\frac{\Delta H_r}{\Delta_m H_r} = \frac{\Delta H_r}{-37194\ kJ} = \frac{n_{P_4S_3}}{1mol}$$

$$n = \frac{m}{M}$$

$$\frac{\Delta H_r}{-37194\ kJ} = \frac{m_{P_4S_3}}{1mol \times M_{P_4S_3}}$$

$$\frac{\Delta H_r}{-3719.4\ kJ} = \frac{0.276\ g\ mol}{1mol \times 220.09\ g}$$

$$\Delta H_r = 4.66\ KJ$$

3.

$$\frac{\Delta H_f}{-88.3\ kJ} = \frac{1\ mol \times 97.48\ g}{19.5\ g\ mol}$$

$$\Delta H_r = -441\ kJ/mol$$

NR 3

I. $(H_2 + \frac{1}{2}O_2 \rightarrow H_2O)$ x 3 — ΔH°=-241.8 kJ x 3

II. $2\ B + \frac{3}{2}O_2 \rightarrow B_2O_3$ — ΔH°=1274.0 kJ

III. $B_2O_3 + 3\ H_2O \rightarrow B_2H_6 + 3O_2$ — **ΔH°=+2037.0 kJ (reverse reaction !)**

I.+ II.+III.

$3H_2 + 2B \rightarrow B_2H_6$ **1376.6 kJ**

3.

D. The reactants have more potential energy than the products

NR 4 $n \times \Delta_m H_r = (m \times c \times \Delta T)_{H_2O} = \frac{m}{M} \times \Delta_m H_r$

$$\Delta_m H_r = \frac{(m \times c \times \Delta T)_{H_2O} \times M}{m} = \frac{350\ g \times 4.19\ J \times 31.7\ ℃ \times 302.26\ g}{2.15\ g\ mol\ J℃} = 6535571.2\ J$$

$$\Delta_m H_r = 6536\ kJ$$

4.

C. greater the energy released during combustion.

5.

A. exothermic and represented by a negative ΔH value

6.

$$\frac{\Delta H_f}{2.06\ kJ} = \frac{1\ mol \times 63.55\ g}{0.635\ g\ mol}$$

$$\Delta H_f = 206\ kJ$$

7. B. 1 & 3
8.

$$n \times \Delta_m H_r = m \times c \times \Delta T$$

$$\Delta_m H_r = \frac{m \times c \times \Delta T}{n} = \frac{250.0g \times 4.19\ J \times 3.85℃}{0.0018\ mol\ g\ ℃} = 2.24 \times 10^6 J/mol = 2.24 \times 10^3 kJ/mol$$

9. B. Hess' Law

Hess's Law: The energy change for any chemical process does not depend on the pathway or number of steps required to complete the process provided that the final and initial reaction conditions are the same.

10.

$Bi_{(s)} + 3/2\ Cl_{2(g)} \rightarrow BiCl_{3(s)}$ $\Delta H^\circ = -379.1$ kJ

$2Bi_{(s)} + 3/2\ O_{2(g)} \rightarrow Bi_2O_{3(s)}$ $\Delta H^\circ = -573.9$ kJ

$Bi_{(s)} + ½O_{2(g)} + ½Cl_{2(g)} \rightarrow BiOCl_{(s)}$ $\Delta H^\circ = -366.9$ kJ

(formation reaction for bismuth oxychloride!)

I. $BiCl_{3(s)} \rightarrow Bi_{(s)} + 3/2\ Cl_{2(g)}$ **ΔH°= +379.1 kJ (reverse reaction !)**

II. $Bi_2O_{3(s)} \rightarrow 2Bi_{(s)} + 3/2\ O_{2(g)}$ **ΔH°= +573.9 kJ (reverse reaction !)**

III. $(Bi_{(s)} + \frac{1}{2}O_{2(g)} + \frac{1}{2}Cl_{2(g)} \rightarrow BiOCl_{(s)})$x3 ΔH°= -366.9 kJ x 3

I.+ II.+III.

$BiCl_{3(s)} + Bi_2O_{3(s)} \rightarrow 3BiOCl_{(s)}$, **$\Delta H^\circ$= -147.7 kJ**

or

$$\Delta H^\circ_{reaction} = \sum \Delta H_f{}^\circ_{products} - \sum \Delta H_f{}^\circ_{reactants}$$

$$\Delta H^\circ_{reaction} = 3mol \times \left(-366.9\frac{kJ}{mol}\right) + 1mol \times \left(-573.9\frac{kJ}{mol}\right) - 1mol \times \left(-379.1\frac{kJ}{mol}\right)$$

$$= \mathbf{-147.7\frac{kJ}{mol}}$$

11. D. C_2H_4 is the only compound which has an endothermic heat of formation
12. A. Nitrogen is an element, therefore the heat of formation equals zero
13. B.

$$\Delta H^\circ_{reaction} = \sum \Delta H_f{}^\circ_{products} - \sum \Delta H_f{}^\circ_{reactants}$$

$$\Delta H^\circ_{reaction} = 6mol \times \left(-241.8\frac{kJ}{mol}\right) + 4mol \times \left(-91.3\frac{kJ}{mol}\right) - 4mol \times \left(-45.9\frac{kJ}{mol}\right) = \mathbf{-902\frac{kJ}{mol}}$$

14. B.

$$\frac{\Delta H_r}{-44.6\ kJ} = \frac{30.0\ g\ mol}{1\ mol\ 40\ g}$$

$$\Delta H_r = -33.45\ kJ$$

15. C.

Like all catalysts, enzymes speed up the rate of a chemical reaction by decreasing E_a

16. D. There is insufficient energy to supply the E_a

17. D (enthalpy : potential energy difference between products and reactions)
18. 1 + 2 (activation energy of reverse reaction = activation energy of forward reaction + enthalpy)
19. A (endothermic reaction: products have more potential energy than reactants)