# CANADIAN CHEMISTRY CONTEST

# CHEMISTRY

## TOPIC QUESTIONS

King

CANADIAN CHEMISTRY OLYMPIAD | OLYMPIADE DE CHIMIE DU CANADA

6A Thermochemistry

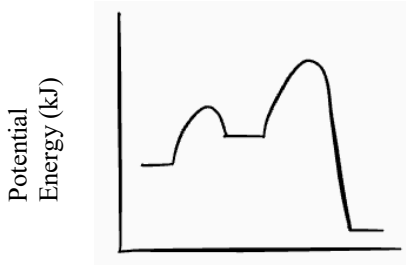
KingCh

4) Respiration is an example of a catabolic process in which energy is released. Which statement best explains why energy is released in this reaction?

$$C_6H_{12}O_6\ (s) + 6\ O_2\ (g) \rightarrow 6\ CO_2 + 6\ H_2O$$

A) Breaking the bonds in glucose releases energy
B) Burning calories converts molecules into energy
C) Bond formation in carbon dioxide and water is highly exothermic
D) The larger a molecule is, the more potential energy it contains.
E) Kinetic energy is converted into potential energy in this reaction.

5) The following reaction diagram represents a two step reaction. Which of the statements about this reaction are correct?




i) The rate determining step is endothermic.
ii) The overall reaction enthalpy is negative.
iii) Producing reaction intermediates releases energy.

A) i only B) ii only C) iii only D) i and iii E) i, ii and iii

19) The human body is approximately 60% water (specific heat capacity of water, c = 4.184 J $g^{-1}$ $K^{-1}$). When not dressed properly on a 5 °C day, body temperature drops at 2.0 °C $h^{-1}$. For a 60.0 kg person, what mass of glucose ($C_6H_{12}O_6$, $\Delta H_c$ = -2880 kJ $mol^{-1}$) must be burned per hour to maintain a constant body temperature?

A) 9.4 g B) 16 g C) 19 g D) 31 g E) 47 g

20) An ice calorimeter measures the heat released in a reaction using the mass of ice melted during a chemical process. The heat of fusion of ice ($\Delta H_{fus}$) is 333 J $g^{-1}$. Assuming there is some energy lost in the process, if 1.75 g of ice melt when 0.250 g of an unknown metal react with excess hydrochloric acid to produce the metal chloride $XCl_2$ and hydrogen gas. In a separate experiment, the volume of hydrogen gas evolved in the reaction of excess hydrochloric acid and 0.250 g of the metal was 0.0850 L at 0°C and 101.3 kPa. What is the approximate enthalpy of this reaction?

A) 154 kJ B) 198 kJ C) 258 kJ D) 396 kJ E) 761 kJ

11) Hydrogen peroxide decomposes to form oxygen gas and water via the following chemical equation:

$$2\ H_2O_2\ (aq) \rightarrow 2\ H_2O\ (l) + O_2\ (g) \qquad \Delta H = -392\ kJ$$

The density of 30% hydrogen peroxide is 1.11 g $mL^{-1}$. If 50.0 mL of a 30% by mass hydrogen peroxide solution decomposes, what is the accompanying change in energy?

A) 96 kJ released B) 117 kJ absorbed C) 173 kJ released

D) 192 kJ released E) 392 kJ absorbed

22) The crossover temperature for a reaction is the temperature at which a chemical reaction changes from occurring spontaneously to being non-spontaneous. For a particular chemical reaction, the entropy change is -157 J $mol^{-1} \cdot K^{-1}$ and the enthalpy change is -82 kJ $mol^{-1}$. What is the crossover temperature for the reaction?

A) 0 K B) 75K C) 239 K D) 522K E) There is no crossover temperature for this reaction

25) The enthalpy of formation ($\Delta H_f^\circ$) of liquid water is –285.8 kJ $mol^{-1}$. The enthalpy of combustion of 1 mol of acetic acid ($CH_3COOH$) is –874.1 kJ $mol^{-1}$. Given the reaction:

$$C\ (s, \text{graphite}) + O_2\ (g) \rightarrow CO_2\ (g)\ \Delta H^\circ = -393.5\ kJ\ mol^{-1},$$

what is the standard enthalpy of formation of acetic acid in kJ $mol^{-1}$?

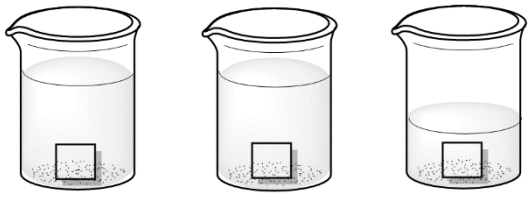
A) –2232.7 B) –1553.4 C) – 981.8 D) – 484.5 E) – 194.8

13) A student placed 3 identical metal cubes into an oven and heated them to the same final temperature. The student entirely submerged each of the 3 cubes in separate beakers as shown in the diagram below. All solutions had approximately the same density and all were at room temperature before adding the metal cubes. The maximum temperature compared as follows:

$$T_{max} \text{ beaker B} > T_{max} \text{ beaker A} > T_{max} \text{ beaker C.}$$

Which of the following is true about the relationship of the specific heat capacities of solutions A, B and C?

A) $c_A > c_C > c_B$
B) $c_C > c_B > c_A$
C) $c_C > c_A > c_B$
D) $c_B > c_A > c_C$
E) $c_B > c_C > c_A$



17) A student adds two moles of liquid water initially at 273 K to three moles of liquid water at 363 K in a perfectly insulated container. The total volume of water remains constant. Assume that the molar heat capacity of liquid water is constant and independent of temperature. What is the final equilibrium temperature of the water?

A) 298 K B) 309 K C) 318 K D) 327 K E) 358 K

CCC 2020

14) A system undergoes a reversible cyclic process and proceeds through a series of thermodynamic processes, exchanging heat and work with its surroundings and ultimately returning to its original state. Which one of the following statements is true? Assume that the surroundings are much larger than the system.

A) $\Delta S_{surroundings} > 0$ B) $q > 0$ C) $q < 0$ D) $q = w = 0$ E) $\Delta S > 0$

15) The thermite reaction is the reaction of aluminum metal and iron (III) oxide:

$$2\ Al\ (s) + Fe_2O_3\ (s) \rightarrow Al_2O_3\ (s) + 2\ Fe\ (s) \qquad \Delta H = -852\ kJ$$

A teacher does a demonstration with 1.00 mol of iron (III) oxide and 2.00 mol of aluminum metal both initially at 25.0 °C. If the combined specific heat of the products is 0.800 J $g^{-1}$ $°C^{-1}$ over a wide range of temperatures, what is the final temperature of the products?

A) 3550°C B) 4960 °C C) 5010 °C D) 6470 °C E) 6500°C

24) Calculate ΔG° at 25 °C for the reaction given the data below

$$4\ HCl\ (g) + O_2\ (g) \rightarrow 2\ Cl_2\ (g) + 2\ H_2O\ (g) \qquad \Delta H° = -114.4\ kJ$$

$S^o_{Cl_2}$ = 223.0 J $mol^{-1}$ $K^{-1}$ $S^o_{H_2O}$ = 188.7 J $mol^{-1}$ $K^{-1}$,
$S^o_{O_2}$ = 205.0 J $mol^{-1}$ $K^{-1}$ $S^o_{HCl}$ = 186.8 J $mol^{-1}$ $K^{-1}$

A) + 14.4 kJ B) –111.18 kJ C) + 3105.6 kJ
D) + 38 kJ E)– 76.0 kJ

CCC 2019

6) To increase strength and hardness when forging knives and blades, hot steel can be quenched by rapidly cooling in water. A 454 g steel blade is heated to a uniform temperature, and then quenched in 2000 mL of 25.0 °C water. If the steel blade loses 173.7 kJ of heat during the quenching process, what is the final temperature of the water? The specific heat capacity of water is 4.18 J $g^{-1}$ $°C^{-1}$. Assume no water evaporates during the quenching process.

A) 16.9 °C B) 20.7 °C C) 41.9 °C D) 45.8 °C E) 91.5 °C

17) Use the information provided below to calculate the enthalpy of reaction when one mole of chlorine trifluoride gas decomposes into one mole of chlorine monofluoride gas and one mole of gaseous fluorine.

$2\ ClF(g) + O_2(g) \rightarrow Cl_2O(g) + F_2O(g)$ $\Delta H = +167.4$ kJ

$2\ ClF_3(g) + 2\ O_2(g) \rightarrow Cl_2O(g) + 3\ F_2O(g)$ $\Delta H = +341.4$ kJ

$3\ F_2O\ (g) \rightarrow 3\ F_2(g) + \frac{3}{2} O_2(g)$ $\Delta H = +65.1$ kJ

A) -217.4 kJ B) +25.0 kJ C) +68.4 kJ D) +108.7 kJ E) 573.9 kJ

23) Another way to make diamonds in the lab is by converting graphite to diamond. At 2000 K and 200 000 atm:

C (graphite) ⇌ C (diamond); $\Delta G = -10$ kJ $mol^{-1}$, $\Delta S = -10$ J $K^{-1}$ $mol^{-1}$

Which of the following is a good approximation of the equilibrium temperature for the reaction at 200 000 atm if enthalpy and entropy are assumed to be temperature independent?

A) $T_{eq} = 2000$ K B) $T_{eq} = 3000$ K C) $T_{eq} = 1000$ K
D) $T_{eq} = 4000$ K E) $T_{eq} = 100$ K

22) The market for lab-made diamonds is growing. Chemists can create diamonds identical to mined diamonds by using chemical vapour deposition in which methane decomposes in the presence of a hydrogen catalyst and plasma. If this methane decomposition reaction were possible at 298 K, what would be the Gibbs Free Energy ($\Delta G°$) of the lab-made diamond synthesis process indicated below (in kJ $mol^{-1}$)?

$$CH_{4\ (g)} \rightleftharpoons C_{(diamond)} + 2H_{2\ (g)}$$

| Compound | $CH_{4\ (g)}$ | $C_{(diamond)}$ | $H_{2\ (g)}$ |
|---|---|---|---|
| $\Delta H°_f$ (kJ $mol^{-1}$) | -74.87 | 1.897 | 0 |
| $S°$ (J $K^{-1}$ $mol^{-1}$) | 186.1 | 2.377 | 130.6 |

A) -23.0 B) 23.0 C) 53.7 D) -53.7 E) 92.6

6) Given the following heats of formation, what is the enthalpy of combustion for toluene shown in the following equation?

$$C_7H_8\ (l) + 9\ O_2\ (g) \rightarrow 7\ CO_2\ (g) + 4\ H_2O\ (l)$$

| **Substance** | **$\Delta H_f$** (kJ mol$^{-1}$) |
|---|---|
| $C_7H_8$ (l) | +12.0 |
| $CO_2$ (g) | -394 |

| **Substance** | **$\Delta H_f$** (kJ mol$^{-1}$) |
|---|---|
| $H_2O$ (l) | -286 |
| $O_2$ (g) | 0 |

A) 680 kJ mol$^{-1}$ B) 692 kJ mol$^{-1}$ C) –692 kJ mol$^{-1}$
D) –3890 kJ mol$^{-1}$ E) –3914 kJ mol$^{-1}$

CCC 2017

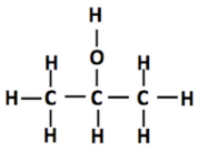
14) A student places 0.750 g of solid sodium hydroxide (NaOH) into 20.00 mL of water at 25.0 °C inside a coffee cup calorimeter. The final temperature of the calorimeter contents is 34.6 °C. The density of water is 1.0 g mL$^{-1}$. Assume the specific heat capacity of the solution approximates that of water at 4.184 J g$^{-1}$ °C$^{-1}$ and the calorimeter has 100% efficiency. What is the $\Delta H_{rxn}$ for the dissolution reaction below?

$$NaOH\ (s) \rightarrow NaOH\ (aq)$$

A) –42.8 kJ mol$^{-1}$ B) – 44.4 kJ mol$^{-1}$ C) – 803 J mol$^{-1}$
D) –833 J mol$^{-1}$ E) – 1070 J mol$^{-1}$

12) For a spontaneous reaction, which relationship below is always true?

A) $\Delta G^0_{rxn} > 0$ B) $\Delta S_{universe} > 0$ C) $\Delta S_{universe} < 0$
D) $\Delta H^0_{rxn} > 0$ E) $\Delta H^0_{rxn} < 0$

21) 2- propanol  reacts with oxygen as follows:

$$2\ C_3H_7OH\ (l) + 9\ O_2\ (g) \rightarrow 6\ CO_2\ (g) + 8\ H_2O\ (g)$$

If 0.500 moles of 2-propanol react in the presence of 4.00 moles of oxygen, how many kilojoules of heat would be absorbed or released? A table of average bond energies is given below.

| Bond Type | Bond Energy (kJ mol$^{-1}$) | Bond Type | Bond Energy (kJ mol$^{-1}$) |
|---|---|---|---|
| C-H | 413 | O=O | 495 |
| O-H | 467 | C=O | 799 |
| C-O | 358 | C-C | 347 |

A) – 1890 kJ B) + 1890 kJ C) – 1680 kJ
D) – 946 kJ E) + 473 kJ

CCC 2016

13. The combustion of acetylene, $C_2H_2$, provides the hottest flame temperature of all commercially available fuels. The average bond energy ($\Delta H$) data table and the balanced chemical equation are below.

$$2\ C_2H_2\ (g) + 5\ O_2\ (g) \rightarrow 4\ CO_2\ (g) + 2\ H_2O\ (g)$$

| Bond type | $\Delta H$ (kJ mol$^{-1}$) | Bond type | $\Delta H$ (kJ mol$^{-1}$) |
|---|---|---|---|
| C–H | +411 | C=O | +799 |
| C–C | +346 | O=O | +494 |
| C≡C | +835 | O–H | +459 |

What is the enthalpy of combustion for **1 mole** of acetylene?

A) + 3422 kJ mol$^{-1}$ B) + 2444 kJ mol$^{-1}$ C) – 611 kJ mol$^{-1}$
D) – 1222 kJ mol$^{-1}$ E) – 3422 kJ mol$^{-1}$

20. Joseph Priestley discovered sweet-smelling, colourless laughing gas, nitrous oxide ($N_2O$), in 1763. $N_2O$ has been widely used as an anesthetic for medical and dental applications. Nitrogen dioxide ($NO_2$) is a toxic reddish brown gas that is the major component of smog. Nitrogen oxide (NO) is a colourless, non-toxic gas that readily oxidizes to nitrogen dioxide in the presence of oxygen. Using the reactions:

$4\ NO\ (g) \rightarrow 2\ N_2O\ (g) + O_2\ (g)$ $\quad \Delta G° = -139.56$ kJ
$2\ NO\ (g) + O_2\ (g) \rightarrow 2\ NO_2\ (g)$ $\quad \Delta G° = -\ 69.70$ kJ

calculate the Gibbs Free Energy released or required when 2 moles of nitrous oxide combine with three moles of oxygen to produce four moles of nitrogen dioxide.

A) – 209.26 kJ B) – 139.86 kJ C) – 69.86 kJ
D) + 0.16 kJ E) +139.72 kJ

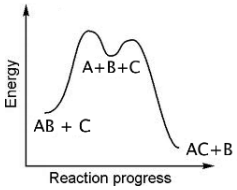
CCC 2015

11. What is the final temperature of a mixture of 50.0 g of Cu (specific heat capacity = 0.3845 J g$^{-1}$ $^{o}$C$^{-1}$) initially at 135.0$^{o}$C and 150.0 mL of water (specific heat capacity = 4.184 J g$^{-1}$ $^{o}$C$^{-1}$) initially at 21.0 $^{o}$C? Assume that there is no loss of heat and the container has a negligible heat capacity.

A) 17.4°C B) 22.5°C C) 24.4°C D) 35.2°C E) 78.0°C

12. Consider the following potential energy diagram for the reaction

$$AB + C \rightarrow AC + B.$$




What is/are the reaction intermediate(s) in this reaction?

A) AB and C B) B C) AC and B
D) A, B and C E) A

14. The reaction to convert iron (II) oxide to iron (III) oxide is as follows:

$$4\ FeO_{(s)} + O_{2\,(g)} \rightarrow 2\ Fe_2O_{3\,(s)}\ \ \Delta H_{rxn} = -564\ kJ\ mol^{-1}$$

If the enthalpy of formation ($\Delta H^\circ_f$) of rust ($Fe_2O_{3(s)}$) is – 826 kJ mol$^{-1}$, what is the enthalpy of formation of FeO in kJ mol$^{-1}$?

A) – 554 B) – 272 C) + 272 D) – 262 E) +262

22. Given the following standard reference values at 25°C and 100 kPa, which of the following combination of thermodynamic values describes a reaction that is endothermic and spontaneous at 2000 °C? Assume enthalpy and entropy values are not temperature dependent.

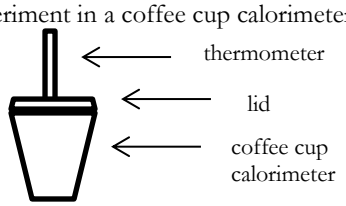
| | $\Delta H^\circ$(kJ mol$^{-1}$) | $\Delta S^\circ$ (J mol$^{-1}$ K$^{-1}$) | $\Delta G^\circ$(kJ mol$^{-1}$) |
|---|---|---|---|
| A) | 217.0 | 115.0 | 182.7 |
| B) | – 230.0 | – 11.0 | – 226.7 |
| C) | 52.0 | 10.0 | 49.0 |
| D) | – 363.0 | 249.0 | – 437.2 |
| E) | 268.6 | – 88.0 | 294.8 |

CCC 2014

10. The hydrocarbon propyne has the following structure: $H_3C–C{\equiv}CH$. The standard enthalpy for the complete combustion of 1 mole of propyne is –1938 kJ mol$^{-1}$. If the standard enthalpies for the complete combustion of 1 mole of propane and 1 mole of hydrogen are –2220 kJ mol$^{-1}$ and –286 kJ mol$^{-1}$ respectively, the standard enthalpy for the complete hydrogenation of 1 mole of propyne to propane is equal to:

A) – 4730 kJ mol$^{-1}$ B) + 3586 kJ mol$^{-1}$ C) + 4.00 x 10$^2$ J mol$^{-1}$
D) + 290 kJ mol$^{-1}$ E) – 290 kJ mol$^{-1}$

19. You perform an experiment in a coffee cup calorimeter depicted below




You place 0.500 g of lithium metal in the calorimeter that already contains 75.0 mL of water. The specific heat capacity of water is 4.184 J g$^{-1}$ K$^{-1}$. You can assume that all of the solutions in the reaction are dilute enough that they have the same density and specific heat capacity as water. Assume that the heat absorbed by the calorimeter is negligible.
You collect the following data:

| | |
|---|---|
| Mass of lithium (g) | 0.500 |
| Mass of water in calorimeter (g) | 75.0 |
| Initial temperature of water (°C) | 22.0 |
| Final temperature of water (°C) | 73.0 |

The reaction occurring in the calorimeter is

$$2\ Li\ (s) + 2\ H_2O\ (l) \rightarrow 2\ LiOH\ (aq) + H_2\ (g)$$

What is the enthalpy in kJ mol$^{-1}$ for this reaction?

A) – 11.2 B) – 16.1 C) – 112 D) – 222 E) – 16100

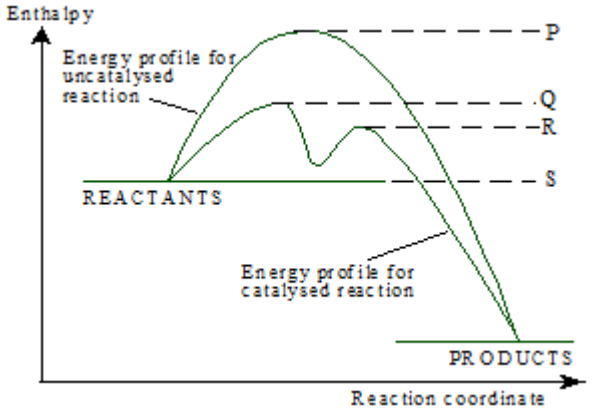
CCC 2013

5. A teenager requires about 8 200 kJ of body energy from food per day. Calculate the mass of glucose, $C_6H_{12}O_6(s)$, required to provide this energy if it is generated by the metabolism of glucose with oxygen to produce water and carbon dioxide.

| Compound | Standard enthalpy of formation $\Delta H_f^\circ$ (kJ mol$^{-1}$) |
|---|---|
| $C_6H_{12}O_6(s)$ | –1273 |
| $CO_2(g)$ | –394 |
| $H_2O(l)$ | –286 |

A. 2.92 g B. 276 g C. 526 g D. 757 g E. 2.49 kg

6. For the potential energy (or enthalpy) diagram below, what is the minimum activation energy required for the CATALYSED reaction to occur?




A. (P – Q) B. (P – S) C. (Q – S) D. (R – S) E. (Q – R)

8. Calculate the bond energy of $I_2(g)$ given the following standard enthalpy of reaction:

$$\tfrac{1}{2}\ H_2(g) + \tfrac{1}{2}\ I_2(g) \rightarrow HI(g); \qquad \Delta H^\circ = -4.7\ \text{kJ mol}^{-1}$$

| Compound | Bond Energy (kJ mol$^{-1}$) |
|---|---|
| $H_2$ (g) | 436 |
| HI (g) | 298 |

A. –138 kJ mol$^{-1}$ B. –80 kJ mol$^{-1}$ C. +80 kJ mol$^{-1}$

D. –151 kJ mol$^{-1}$ E. +151 kJ mol$^{-1}$

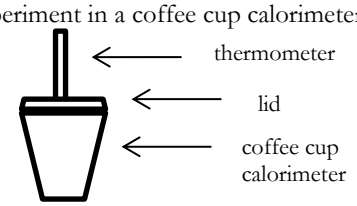
16. At a temperature of 25.0°C, a reaction has an enthalpy change of – 26.9 kJ mol$^{-1}$and an entropy change of –11.3 J mol$^{-1}$ K$^{-1}$. Which of the following statements is true if the temperature is lowered to –25.0°C?

A. The reaction is spontaneous at both temperatures
B. The reaction is non-spontaneous at both temperatures
C. The reaction is spontaneous at + 25.0°C and non-spontaneous at – 25.0 °C
D. The reaction is non-spontaneous at + 25.0°C and spontaneous at – 25.0 °C
E. The reaction is non-spontaneous at + 25.0°C and at equilibrium at – 25.0 °C

10. The hydrocarbon propyne has the following structure: $H_3C–C{\equiv}CH$. The standard enthalpy for the complete combustion of 1 mole of propyne is –1938 kJ $mol^{-1}$. If the standard enthalpies for the complete combustion of 1 mole of propane and 1 mole of hydrogen are –2220 kJ $mol^{-1}$ and –286 kJ $mol^{-1}$ respectively, the standard enthalpy for the complete hydrogenation of 1 mole of propyne to propane is equal to:

A) – 4730 kJ $mol^{-1}$ B) + 3586 kJ $mol^{-1}$ C) + 4.00 x $10^2$ J $mol^{-1}$
D) + 290 kJ $mol^{-1}$ E) – 290 kJ $mol^{-1}$

19. You perform an experiment in a coffee cup calorimeter depicted below




You place 0.500 g of lithium metal in the calorimeter that already contains 75.0 mL of water. The specific heat capacity of water is 4.184 J $g^{-1}$ $K^{-1}$. You can assume that all of the solutions in the reaction are dilute enough that they have the same density and specific heat capacity as water. Assume that the heat absorbed by the calorimeter is negligible.
You collect the following data:

| | |
|---|---|
| Mass of lithium (g) | 0.500 |
| Mass of water in calorimeter (g) | 75.0 |
| Initial temperature of water (°C) | 22.0 |
| Final temperature of water (°C) | 73.0 |

The reaction occurring in the calorimeter is

$$2\ Li\ (s) + 2\ H_2O\ (l) \rightarrow 2\ LiOH\ (aq) + H_2\ (g)$$

What is the enthalpy in kJ $mol^{-1}$ for this reaction?

A) – 11.2 B) – 16.1 C) – 112 D) – 222 E) – 16100

CCC 2012

11. Acetylene (ethyne), which is used in welding, produces a very hot flame when burned in oxygen according to the following equation:

$$H–C{\equiv}C–H\ (g) + 2½\ O_2\ (g) \rightarrow 2CO_2\ (g) + H_2O\ (g)$$

Propyne, $H–C{\equiv}C–CH_3$ (g), can be more easily stored and is used in preference to acetylene as a rocket fuel. The average molar bond energies (BE) are given in the table below:

| Bond | C–C | C–H | O=O | C=O | O–H | C≡C |
|---|---|---|---|---|---|---|
| BE (kJ $mol^{-1}$) | 346 | 411 | 494 | 745 | 459 | 835 |

How much more energy is released when one mole of propyne is completely burned in oxygen compared with one mole of ethyne (under standard conditions)?

**A. 499 kJ $mol^{-1}$** B. 845 kJ $mol^{-1}$ C. 1006 kJ $mol^{-1}$

D. 1505 kJ $mol^{-1}$ E. 2408 kJ $mol^{-1}$

7. A cold pack used for first aid contains solid ammonium nitrate that dissolves in water when the pack is activated. This entropy-driven reaction rapidly cools the pack. Given the data in the table below, what is the standard molar Gibbs free energy change, $\Delta G^{\circ}$, for the reaction taking place in the cold pack? ($\Delta G = \Delta H - T\Delta S$)

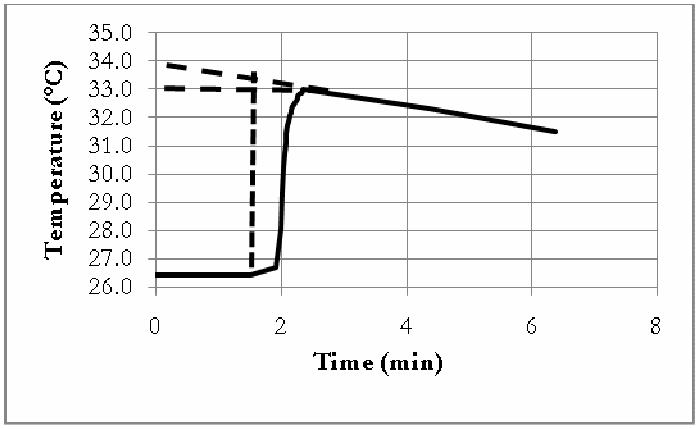
| Ammonium nitrate | Standard molar values at 25°C | |
|---|---|---|
| | Enthalpy change of formation ($\Delta H_f^{\circ}$) kJ mol$^{-1}$ | Entropy, ($S^{\circ}$) J mol$^{-1}$ K$^{-1}$ |
| Crystalline solid | –365.6 | 151.1 |
| Aqueous solution | –339.9 | 259.8 |

A. – 32.4 kJ mol$^{-1}$ B. – 25.7 kJ mol$^{-1}$ **C. – 6.7 kJ mol$^{-1}$**

D. + 25.7 kJ mol$^{-1}$ E. + 108.7 kJ mol$^{-1}$

CCC 2011

11. The solid line on the following graph represents data collected from a reaction in a constant-pressure coffee cup calorimeter:




Which **one** of the following statements is TRUE?

A. The temperature change for this experiment cannot be measured because of the loss of heat from the calorimeter
B. The maximum temperature used for the $\Delta T$ calculation is 33.0°C
C. The faster the reaction, the more precise the data
D. The point at which the reaction begins must be taken into account to correctly measure the change in temperature
E. The rate of heat loss can be measured by extrapolation of the final slope to the y–axis

13. Fluorine reacts explosively with hydrogen to form hydrogen fluoride, even in the dark. If a 1.00 g sample of fluorine gas reacts completely with excess hydrogen gas and releases 14.27 kJ of heat, the heat of formation of 1 mol of HF(g) is:

A. 813 kJ B. –542 kJ C. 136 kJ D. –1084 kJ E. –271 kJ

CCC 2010

22. The standard enthalpy change of formation of nitric oxide, $\Delta H^{\ominus}_{f}(NO)$, cannot be determined directly from the elements but it can be calculated using the following thermodynamic equations:

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(l);\ \Delta H^{\ominus} = -1170\,kJ$$
$$4NH_3(g) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(l);\ \Delta H^{\ominus} = -1530\,kJ$$

What is the value of $\Delta H^{\ominus}_{f}(NO)$ as found from these equations?

A. $+90\ kJ\,mol^{-1}$ B. $-90\ kJ\,mol^{-1}$ C. $+360\ kJ\,mol^{-1}$
D. $-360\ kJ\,mol^{-1}$ E. $+2700\ kJ\,mol^{-1}$

CCC 2010

16. Propenenitrile (acrylonitrile) is used in the manufacture of synthetic fibres and nitrile rubber. It can be made from propene using the following gas phase reaction:

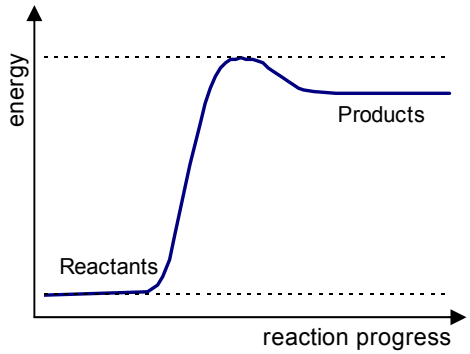
$$CH_2{=}CH{-}CH_3 + NH_3 + 3/2\,O_2 \rightarrow CH_2{=}CH{-}CN + 3\,H_2O$$

Which one of the following values corresponds to the correct standard enthalpy change for this reaction? Assume that the combustion of both reactants and products yields $CO_2$, $H_2O$ and $N_2$, and that the enthalpy changes of combustion are $\Delta H_c^{\ominus}[CH_2{=}CH{-}CH_3] = -2058.0\ kJ\ mol^{-1}$, $\Delta H_c^{\ominus}[NH_3] = -382.8\ kJ\ mol^{-1}$, $\Delta H_c^{\ominus}[CH_2{=}CH{-}CN] = -1756.4\ kJ\ mol^{-1}$.

A. $-4197.2\ kJ\ mol^{-1}$ B. $-684.4\ kJ\ mol^{-1}$ C. $-41.0\ kJ\ mol^{-1}$
D. $+41.0\ kJ\ mol^{-1}$ E. $+684.4\ kJ\ mol^{-1}$

CCC 2008

17. The following diagram shows the energy profile of a reaction:




Which one of the following correctly identifies the type of reaction shown in the diagram, together with the correct reason for this choice?

| | **Type of reaction** | **Reason** |
|---|---|---|
| **A.** | Exothermic | Energy is supplied to the reactants |
| **B.** | Exothermic | Energy is given out by the reaction |
| **C.** | Exothermic | The products have a higher potential energy than the reactants |
| **D.** | Endothermic | Energy is given out by the reaction |
| **E.** | Endothermic | The products have a higher potential energy than the reactants |

18. Acetylene (ethyne) is burned in oxy-acetylene blowtorches, which are used for cutting and welding metals. The combustion reaction is represented by the following equation:

$$2\,C_2H_2(g) + 5\,O_2(g) \rightarrow 4\,CO_2(g) + 2\,H_2O(g)$$

Given the following enthalpies of formation:

$\Delta H_f^{\ominus}\{C_2H_2(g)\} = +226.7$ kJ mol$^{-1}$, $\Delta H_f^{\ominus}\{CO_2(g)\} = -393.5$ kJ mol$^{-1}$ and $\Delta H_f^{\ominus}\{H_2O(g)\} = -241.8$ kJ mol$^{-1}$

what is the enthalpy of combustion ($\Delta H_c^{\ominus}$) **per mole of ethyne**?

A. –1256 kJ mol$^{-1}$ B. –2511 kJ mol$^{-1}$ C. –1604 kJ mol$^{-1}$
D. +1256 kJ mol$^{-1}$ E. +2511 kJ mol$^{-1}$