South Pasadena • AP Chemistry

Name ________________________________

Period ___ Date ___/___/___

6 • Energy and Chemical Reactions

PRACTICE TEST

1. A system has an increase in internal energy, ΔE, of 40 kJ. If 20 kJ of work, w, is done on the system, what is the heat change, q?
   a) +60 kJ d) -20 kJ
   b) +40 kJ e) -60 kJ
   c) +20 kJ

2. A gas at 20 atm pressure with a volume of 2.0 Liters expands against a 5 atm pressure to a volume of 8.0 Liters. How much work is done by the gas?
   a) 30 L·atm c) 8 L·atm
   b) 18 L·atm d) 5 L·atm

3. Which equation represents the heat of formation, ΔH_f, for $MgCl_2$?
   a) $Mg^{2+}(aq) + 2\ Cl^- \rightarrow MgCl_2(s)$
   b) $Mg(s) + 2\ Cl(g) \rightarrow MgCl_2(s)$
   c) $MgCl_2(s) \rightarrow Mg^{2+}(aq) + 2\ Cl^-(aq)$
   d) $Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$

4. Take a toy balloon. Quickly stretch the balloon and press it against your lower lip. What is the **ΔH** for the reaction:

   unstretched → stretched

   a) + c) –
   b) 0 d) impossible to tell

5. Which of the following is NOT a state function?
   a) pressure c) temperature
   b) volume d) none of these

6. The correct units for specific heat capacity:
   a) J/°C c) J/g °C
   b) J/g d) °C/g

7. How much heat is required to convert solid sulfur to gaseous sulfur at 298 K and 1 atm pressure?

	$\Delta H°$ (kJ/mol)
$S(s) + O_2(g) \rightarrow SO_2(g)$	–395
$S(g) + O_2(g) \rightarrow SO_2(g)$	–618

   a) –1013 kJ/mol c) +223 kJ/mol
   b) –223 kJ/mol d) +618 kJ/mol

8. Using the $\Delta H_f°$ given below, calculate the $\Delta H_{combustion}$ for propane, C_3H_8.

	$\Delta H_f°$ (kJ/mol)
$H_2O(l)$	-286
$CO_2(g)$	-394
$C_3H_8(g)$	-104

   a) 576 kJ c) -2222 kJ
   b) -576 kJ d) -2330 kJ

9. The heat of vaporization of methane, CH_4, at its boiling point is 9.20 kJ/mol. How much heat energy is required to vaporize 100. g of methane at its boiling point?
   a) 1380 kJ c) 21.6 kJ
   b) 86.3 kJ d) 57.4 kJ

10. How much energy is required to melt 10.0 g benzene, C_6H_6? The heat of fusion of benzene is 2.37 kJ/mol.
   a) 3.30 kJ c) 1850 kJ
   b) 23.7 kJ d) 0.303 kJ

11. If ΔH for a reaction is positive, …
    a) the reaction rate is generally very fast.
    b) the enthalpy change of the reverse reaction is positive.
    c) the enthalpy of the products is greater than the enthalpy of the reactants.
    d) the energy released during bond formation is greater than the energy absorbed during bonding breaking for the reaction.

12. Given the two equations:

$2\ S(s) + 3\ O_2(g) \rightarrow 2\ SO_3(g)$ $\Delta H° = –790.4$ kJ

$SO_2(g) + {}^1/_2\ O_2(g) \rightarrow SO_3(g)$ $\Delta H° = –99.1$ kJ

What is the standard enthalpy of formation for sulfur dioxide, $SO_2(g)$?

a) +99.1 kJ c) –592.2 kJ
b) –296.1 kJ d) –839.5 kJ

13. When 0.100 g benzoic acid ($HC_6H_4CO_2$) and excess oxygen is ignited in a bomb calorimeter, the temperature of the water changes from 25.000°C to 25.225°C. The heat capacity of the calorimeter is 603 J/°C. What is the ΔE for this reaction?

a) -597 J c) -136 J
b) -1660 J d) -149 J

14. Under conditions of constant volume, the heat change that occurs during a chemical reaction is equal to

a) ΔH c) ΔT
b) ΔE d) ΔP

15. Systems tend toward:
    a) maximum entropy and minimum enthalpy
    b) maximum entropy and maximum enthalpy
    c) minimum entropy and minimum enthalpy
    d) minimum entropy and maximum enthalpy

Answers:

1.	C	6.	C	11.	C
2.	A	7.	C	12.	B
3.	D	8.	C	13.	C
4.	C	9.	D	14.	B
5.	D	10.	D	15.	A

Notes:

1. an increase in internal energy means an increase in P.E. of system by 40 kJ
   work done ON system increases P.E., +20 kJ, so q = +20 kJ, too.
2. work = $P\Delta V$ = 5 atm x (8-2 L)… the 20 atm is not used for anything.
4. balloon gets warm, $\Delta H < 0$
5. each of these only depends on the STATE of the substance, not on its HISTORY.
7. reverse second reaction
8. recall: $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ and use Hess's Law
9. Given: 100g CH_4, use molar mass & H_{vap} as conversion factors.
10. Given: 10.0g C_6H_6, use molar mass & Hfus as conversion factors.
11. this is an "uphill" reaction.
12. take half of first equation, reverse second equation. if you reverse and double second equation, you get TWICE the answer.
13. answer = heat capacity x ΔT… you don't use 0.100 g anywhere. You would IF the question asked for MOLAR heat of combustion.
14. if volume is constant, $P\Delta V$ work = 0 so $\Delta E=q + w$ becomes $\Delta E = q$.
15. from lecture… THIS chapter, however, concentrates on enthalpy, ΔH.

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6 • Energy and Chemical Reactions

PRACTICE TEST

1. How many joules are equivalent to 37.7 cal?
   a) 9.01 J
   b) 4.184 J
   c) 1.51 J
   d) 158 J

2. The quantity of heat that is needed to raise the temperature of a sample of a substance 1.00 degree is called its
   a) heat capacity
   b) specific heat
   c) enthalpy
   d) kinetic energy

3. Equal masses of two substances, A & B, each absorb 25 Joules of energy. If the temperature of A increases by 4 degrees and the temperature of B increases by 8 degrees, one can say that
   a) the specific heat of A is double that of B.
   b) the specific heat of B is double that of A.
   c) the specific heat of B is negative.
   d) the specific heat of B is triple that of A.

4. If 25 J are required to change the temperature of 5.0 g of substance A by 2.0°C, what is the specific heat of substance A?
   a) 250 J/g°C
   b) 63 J/g°C
   c) 10. J/g°C
   d) 2.5 J/g°C

5. How much energy is required to change the temperature of 2.00 g aluminum from 20.0°C to 25.0°C? The specific heat of aluminum is 0.902 J/g°C.
   a) 2.3 J
   b) 9.0 J
   c) 0.36 J
   d) 0.090 J

6. Consider the thermal energy transfer during a chemical process. When heat is transferred to the system, the process is said to be _______ and the sign of ΔH is ________.
   a) exothermic, positive
   b) endothermic, negative
   c) exothermic, negative
   d) endothermic, positive

7. What is the ΔE for a system which has the following two steps:
   Step 1: The system absorbs 60 J of heat while 40 J of work are performed on it.
   Step 2: The system releases 30 J of heat while doing 70 J of work.
   a) 100 J
   b) 90 J
   c) 30 J
   d) zero

8. When two solutions react the container “feels hot.” Thus,
   a) the reaction is endothermic.
   b) the reaction is exothermic.
   c) the energy of the universe is increased.
   d) the energy of both the system and the surroundings is decreased.

9. The equation for the standard enthalpy of formation of N_2O_3 is
   a) $N_2O(g) + O_2(g) \rightarrow N_2O_3(g)$
   b) $N_2O_5(g) \rightarrow N_2O_3(g) + O_2(g)$
   c) $NO(g) + NO_2(g) \rightarrow N_2O_3(g)$
   d) $N_2(g) + {}^3/_2\ O_2(g) \rightarrow N_2O_3(g)$

10. For the general reaction
    $2\ A + B_2 \rightarrow 2\ AB$, ΔH is +50.0 kJ.
    We can conclude that
    a) the reaction is endothermic.
    b) the surroundings absorb energy.
    c) the standard enthalpy of formation of AB is -50.0 kJ.
    d) the molecule AB contains less energy than A or B_2.

11. Calculate the enthalpy of combustion of C_3H_6:
    $C_3H_6(g) + {}^9/_2O_2(g) \rightarrow 3CO_2 + 3H_2O$
    using the following data:
    $3C(s) + 3H_2(g) \rightarrow C_3H_6(g)$ $\Delta H° = 53.3$ kJ
    $C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H° = -394$ kJ
    $H_2(g) + {}^1/_2O_2(g) \rightarrow H_2O(l)$ $\Delta H° = -286$ kJ
    a) -1517 kJ c) -626 kJ
    b) 1304 kJ d) -2093 kJ

12. Which one of the following would have an enthalpy of formation value (ΔH_f) of zero?
    a) $H_2O(g)$ c) $H_2O(l)$
    b) $O(g)$ d) $O_2(g)$

13. Calculate the heat of vaporization of titanium (IV) chloride: $TiCl_4(l) \rightarrow TiCl_4(g)$
    using the following enthalpies of reaction:
    $Ti(s) + 2Cl_2(g) \rightarrow TiCl_4(l)$ $\Delta H° = -804.2$ kJ
    $TiCl_4(g) \rightarrow 2Cl_2(g) + Ti(s)$ $\Delta H° = 763.2$ kJ
    a) -1567 kJ c) 1165 kJ
    b) -783.7 kJ d) 41 kJ

14. Calculate the enthalpy of reaction for:
    $D + F \rightarrow G + M$
    using the following equations and data:
    $G + C \rightarrow A + B$ $\Delta H° = +277$ kJ
    $C + F \rightarrow A$ $\Delta H° = +303$ kJ
    $D \rightarrow B + M$ $\Delta H° = -158$ kJ
    a) -132 kJ c) +422 kJ
    b) -422 kJ d) +132 kJ

15. Calculate the standard enthalpy of the reaction for the process
    $3NO(g) \rightarrow N_2O(g) + NO_2(g)$
    using the standard enthalpies of formation (in kJ/mol): NO = 90; N_2O = 82.1; NO_2 = 34.0
    a) -153.9 kJ c) -26.1 kJ
    b) 206 kJ d) 386 kJ

16. The standard molar enthalpy of combustion is -1277.3 kJ for the combustion of ethanol.
    $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$
    Calculate the standard molar enthalpy of formation for ethanol based on the following standard enthalpies of formation:
    $\Delta H°_f\ CO_2 = -393.5$ kJ/mol
    $\Delta H°_f\ H_2O = -241.8$ kJ/mol
    a) -642.7 kJ/mol c) 235.1 kJ/mol
    b) -235.1 kJ/mol d) 642.7 kJ/mol

17. Calculate the amount of heat needed to change 25.0 g ice at 0°C to water at 0°C. The heat of fusion of H_2O = 333 J/g;

a) 56.5 kJ c) 7.06 kJ
b) 8.33 kJ d) 463 kJ

Questions 18-20: (1/2 point each)

The following data was collected in an experiment similar to the Specific Heat experiment performed in class. Fill in the missing values. (Assume the calorimeter has a calorimeter constant of 0 J/°C)

Data & Calculations		Glass Beads
	mass of glass beads	4.88 g
	mass of water	10.14 g
	initial temperature of water	19.2 °C
	initial temperature of beads	89.2 °C
	final temperature of mixture	24.8 °C
18.	temp change of water (°C)	
18.	temp change of hot beads (°C)	
19.	change in energy of water, q_{water} (J)	
	change in energy of calorimeter (J)	0 J
19.	change in energy of beads, q_{beads} (J)	
20.	specific heat of beads ($J \cdot g^{-1} \cdot {}^{\circ}C^{-1}$)	
	accepted value of specific heat	.833
20.	% error	

Answers: (Please use CAPITAL letters) **- V1**

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South Pasadena • AP Chemistry

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6 • Energy & Chemical Thermodynamics

PRACTICE TEST

$$C_2H_2(g) + 2\ H_2(g) \rightarrow C_2H_6(g)$$

Information about the substances involved in the reaction represented above is summarized in the following tables.

Substance	$\Delta H°f$ (kJ/mol)
$C_2H_2(g)$	226.7
$C_2H_6(g)$	-84.7

(a) Write the equation for the heat of formation of C_2H_6(g)

(b) Use the above information to determine the enthalpy of reaction for the equation given.

$$C_6H_5OH(s) + 7\ O_2(g) \rightarrow 6\ CO_2(g) + 3\ H_2O(l)$$

When a 2.000-gram sample of pure phenol, $C_6H_5OH(s)$, is completely burned according to the equation above, 64.98 kilojoules of heat is released. Use the information in the table below to answer the questions that follow.

Substance	Standard Heat of Formation, ΔH°_f; at 25°C (kJ/mol)
$CO_2(g)$	-393.5
$H_2O(l)$	-285.85
$C_6H_5OH(s)$	?

(a) Calculate the **molar** heat of combustion of phenol in kilojoules per mole at 25°C.

(b) Calculate the standard heat of formation, ΔH°_f, of phenol in kilojoules per mole at 25°C.

6 • Energy and Chemical Reactions

PRACTICE TEST ANSWERS

D 1) $37.7\,cal \times \frac{4.184\,J}{\cancel{4.184}\ cal} = 157.7 \approx \boxed{158\,J}$

A 2) $\frac{J}{°C}$ = heat capacity

assume any mass ... 1g

A 3) A $\frac{25\,J}{1g \cdot 4°C} = 6.25\ \frac{J}{g°C}$ | B $\frac{25\,J}{1g \cdot 8°C}$ $3.13\ \frac{J}{g°C}$

A is twice as difficult to heat up as B

D 4) $\frac{25\,J}{5.0g \cdot 2°C} = \boxed{2.5\ \frac{J}{g°C}}$

B 5) $q = mC\Delta T = (2.00g)(.902\ \frac{J}{g°C})(5.0°C) = \boxed{9.02\ J}$

D 6) Heat is ABSORBED = ENDOTHERMIC ΔH ⊕

D 7) Step 1 ↑40 ↑40 Step 2 ↓30 ↓70 $\boxed{\Delta E = \text{ZERO}}$

B 8) Hot = exothermic (Energy of universe is constant)

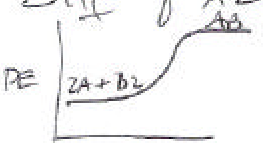
D 9) FORM FROM ITS ELEMENTS $N_2 + \frac{3}{2}O_2 \rightarrow N_2O_3$

A 10) ΔH ⊕ ∴ ENDOTHERMIC

~~b)~~ surrounding LOSE energy

~~c)~~ ΔH_f of AB is +50.0 kJ

~~d)~~



AB has MORE energy (PE) than A & B_2

D 11) $\underbrace{C_3H_6 + \frac{9}{2}O_2 \rightarrow 3CO_2 + 3H_2O}$

$3C + 3H_2 \rightarrow C_3H_6$ $\qquad - (+53.3\text{ kJ})$

$\hookrightarrow$

$(C_{(s)} + O_2 \rightarrow CO_2)\times 3$ $\qquad 3\times(-394\text{ kJ})$

$(H_2 + \frac{1}{2}O_2 \rightarrow H_2O)\times 3$ $\qquad 3\times(-286)$

or SHORTLY

$$\Delta H_{RXN} = 3(\Delta H_f CO_2) + 3(\Delta H_f H_2O) - \Delta H_f C_3H_6$$
$$= 3(-394) + 3(-286) - 53.3$$
$$= -2093.3 \approx \boxed{-2090\text{ kJ}}$$

D 12) $\underbrace{O_{2(g)} \rightarrow O_{2(g)}}_{\text{same}}$ $\qquad \Delta H = 0$

D 13) $\underbrace{TiCl_{4(l)} \rightarrow TiCl_{4(g)}}$

~~$Ti + 2Cl_2 \rightarrow TiCl_{4(l)}$ $\qquad -804.2\text{ kJ}$~~

$\hookrightarrow$ $TiCl_{4(l)} \rightarrow \cancel{Ti} + \cancel{2Cl_2}$ $\qquad +804.2\text{ kJ}$

~~$TiCl_{4(g)} \rightarrow 2Cl_{2(g)} + Ti_{(s)}$ $\qquad 763.2\text{ kJ}$~~

$\hookrightarrow$ $\cancel{2Cl_2} + \cancel{Ti} \rightarrow TiCl_{4(g)}$ $\qquad -763.2\text{ kJ}$

TURN BOTH EQUATION AROUND $\qquad \Delta H = \begin{array}{r} 804.2 \\ -\ 763.2 \\ \hline \boxed{41.0\text{ kJ}} \end{array}$

$D + F \rightarrow G + M$

A 14) ~~$G + C \rightarrow A + B$ +277~~ Reverse this

$\cancel{C} + F \rightarrow \cancel{A}$ +303

$D \rightarrow \cancel{B} + M$ −158

$\cancel{A} + B \rightarrow \cancel{C} + G$ −277

$\Delta H = -132$ kJ

A 15) SHORTCUT: $\Delta H_{rxn} = \Delta H_f\, N_2O + \Delta H_f\, NO_2 - 3(\Delta H_f\, NO)$

$= 82.1 + 34.0 - 3(90)$

$= -153.9$ kJ

B 16) SHORTCUT

$\Delta H_{combustion} = 2(\Delta H_f\, CO_2) + 3(\Delta H_f\, H_2O) - \Delta H_f\, C_2H_5OH$

$-1277.3 = 2(-393.5) + 3(-241.8) - x$

$x = 2(-393.5) + 3(-241.8) + 1277.3$

$= -787.0 - 725.4 + 1277.3$

$= -235.1$ kJ

B 17) $25.0\text{ g ice} \times \frac{333\text{ J}}{1\text{ g ice}} \times \frac{1\text{ kJ}}{1000\text{ J}} = 8.325\text{ kJ}$

$= \boxed{8.33\text{ kJ}}$

18) $\Delta T_{H_2O} = 24.8 - 19.2°C = \boxed{5.6°C}$

$\Delta T_{beads} = 24.8 - 89.2°C = \boxed{-64.4°C}$

2 sig. figs.

19) $q = mc\Delta T = (10.14\text{g})(4.184\frac{J}{g°C})(5.6°C) = 237.58 = \boxed{240\text{ J}}$

$q_{beads} = -q_{water} = \boxed{-240\text{ J}}$

20) $q_{beads} = m\ c\ \Delta T \therefore -240\text{ J} = (4.88\text{g})(x)(-64.4°C)$

$x = .76366 = \boxed{.76 \frac{J}{g°C}}$

$\%\text{ error} = \frac{.833 - .76}{.833} \times 100 = \boxed{8.8\%}$

South Pasadena • AP Chemistry

Name Glover (KEY)
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6 • Energy & Chemical Thermodynamics

PRACTICE TEST

$$C_2H_{2(g)} + 2\ H_{2(g)} \rightarrow C_2H_{6(g)}$$

Information about the substances involved in the reaction represented above is summarized in the following tables.

Substance	$\Delta H°_f$ (kJ/mol)
$C_2H_{2(g)}$	226.7
$C_2H_{6(g)}$	-84.7

(a) Write the equation for the heat of formation of $C_2H_6(g)$

$2C_{(s)} + 3H_{2(g)} \longrightarrow C_2H_{6(g)}$ $\quad \Delta H_f = -84.7$ kJ/mol

(b) Use the above information to determine the enthalpy of reaction for the equation given.

$$\Delta H_{rxn} = \Delta H_f\ C_2H_6 - \Delta H_f\ C_2H_2$$
$$= -84.7\text{ kJ} - (226.7)\text{kJ}$$
$$= \boxed{-311.4\text{ kJ/mol}}$$

$$C_6H_5OH_{(s)} + 7\ O_{2(g)} \rightarrow 6\ CO_{2(g)} + 3\ H_2O_{(l)}$$

When a 2.000-gram sample of pure phenol, $C_6H_5OH_{(s)}$, is completely burned according to the equation above, 64.98 kilojoules of heat is released. Use the information in the table below to answer the questions that follow.

– sign for ΔH

Substance	Standard Heat of Formation, $\Delta H°_f$, at 25°C (kJ/mol)
$CO_{2(g)}$	-393.5
$H_2O_{(l)}$	-285.85
$C_6H_5OH_{(s)}$	?

$C_6 = 72.066$ g
$H_6 = 6.0474$ g
$O = 16.00$ g
94.113 g/mol

(a) Calculate the **molar** heat of combustion of phenol in kilojoules per mole at 25°C.

$$\Delta H_{combustion} = \frac{-64.98\text{ kJ}}{2.000\text{ g } C_6H_5OH} \times \frac{94.113\text{ g } C_6H_5OH}{1\text{ mol } C_6H_5OH} = \boxed{-3058\ \frac{\text{kJ}}{\text{mol}}}$$

(b) Calculate the standard heat of formation, $\Delta H°_f$, of phenol in kilojoules per mole at 25°C.

$$\Delta H_{combustion} = 6(\Delta H_f\ CO_2) + 3(\Delta H_f\ H_2O) - \Delta H_f\ C_6H_5OH$$
$$-3058\ \frac{\text{kJ}}{\text{mol}} = 6(-393.5) + 3(-285.85) - x$$
$$x = 6(-393.5) + 3(-285.85) + 3058\text{ kJ/mol}$$
$$= -2361 - 857.55 + 3058\text{ kJ/mol}$$

$C_6H_5OH \quad \Delta H_f = \boxed{-160.6\text{ kJ/mol}}$