SI Chemistry - Full Discipline Demo

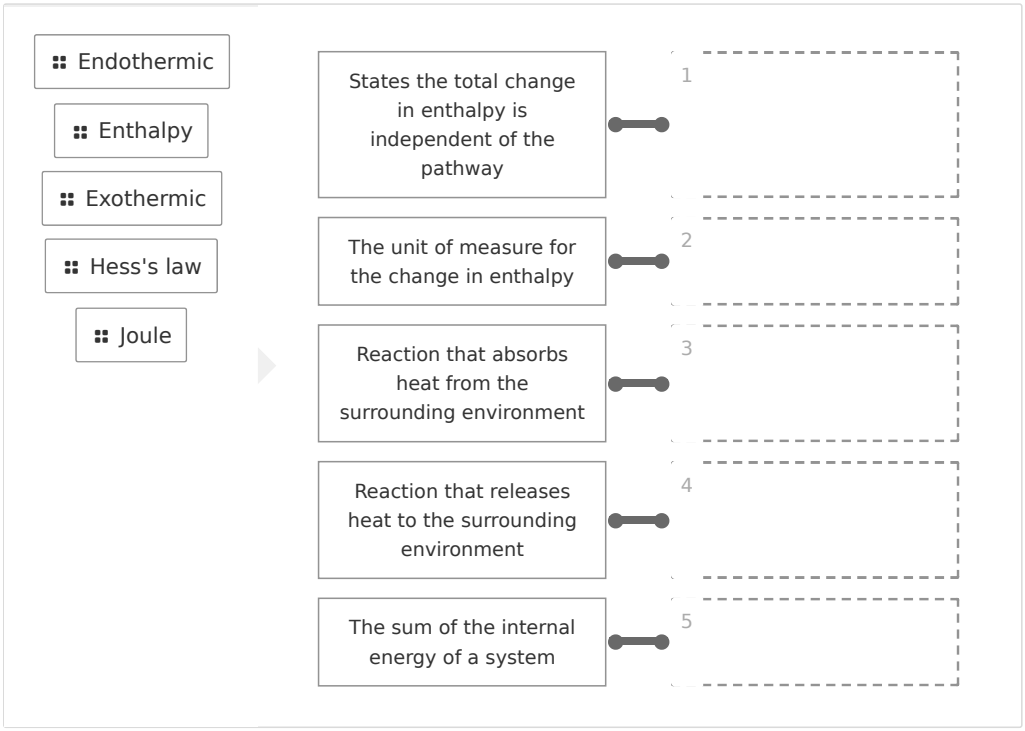
Digital Thermodynamics and Hess' Law - Beyond Labz

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Chemistry - Full Discipline Demo
Course	SI Chemistry - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

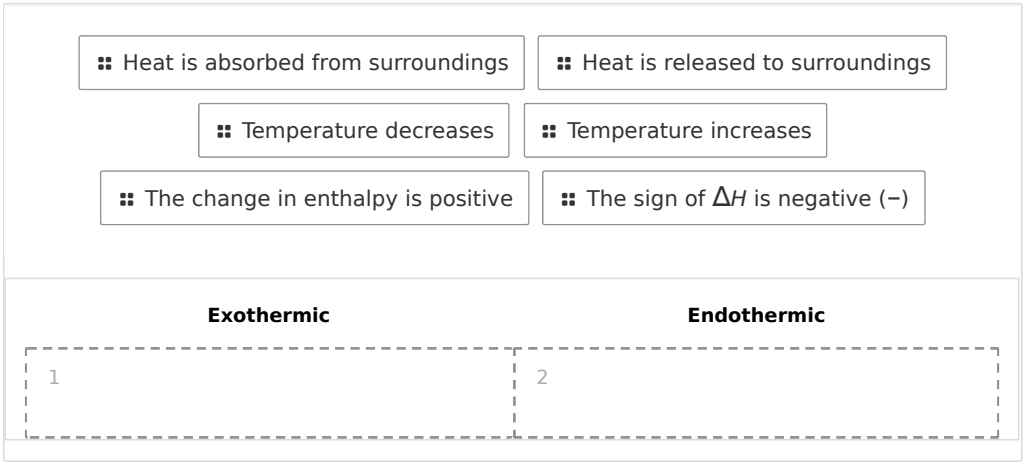
Match each term with the best description.



Correct answers:

1 Hess's law 2 Joule 3 Endothermic 4 Exothermic 5 Enthalpy

Categorize each statement as representing an exothermic or endothermic reaction.



Correct answers:

1 Heat is released to surroundings Temperature increases

The sign of ΔH is negative (−)

2 Heat is absorbed from surroundings Temperature decreases

The change in enthalpy is positive

Fill in the blank with the multiplier for ΔH based on the transformation performed on the associated equation.

−2 | −1 | 2

Original: $Mg(s) + 2\ H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$

Transformed: $2\ Mg(s) + 4\ H^+(aq) \rightarrow 2\ Mg^{2+}(aq) + 2\ H_2(g)$

1 ΔH

Original: $2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(g)$

Transformed: $2\ H_2O(g) \rightarrow 2\ H_2(g) + O_2(g)$

2 ΔH

Original: $MgO(s) + 2\ H^+(aq) \rightarrow Mg^{2+}(aq) + H_2O(l)$

Transformed: $2\ Mg^{2+}(aq) + 2\ H_2O(l) \rightarrow 2\ MgO(s) + 4\ H^+(aq)$

3 ΔH

Correct answers:

1 2 2 −1 3 −2

Exploration

Enthalpy is the internal energy of the system, including heat energy.

- True ✔
- False

The change in enthalpy of a reaction is equal to the enthalpy of the reactants minus the enthalpy of the products.

- True
- False ✔

When a reaction is exothermic, the enthalpy of the products is _____ the reactants.

- greater than
- less than ✔
- equal to
- of no relationship to

Hess's law states that the total change in enthalpy is independent of the pathway.

- True ✔
- False

After cross-cancelling compounds that appear on both sides of the reaction arrows, the remaining terms should _____.

- add up to 1
- be multiplied or reversed to reflect the manipulations performed on the equations
- also cancel out
- add up to the final equation ✔

Exercise 1

Reaction 1 and Reaction 2 can be described by the following equations:

$$\text{Reaction 1: } \mathrm{NaOH(s)} \rightarrow \mathrm{Na^+(aq)} + \mathrm{OH^-(aq)}$$

$$\text{Reaction 2: } \mathrm{NaOH(s)} + \mathrm{H^+(aq)} + \mathrm{Cl^-(aq)} \rightarrow \mathrm{Na^+(aq)} + \mathrm{Cl^-(aq)} + \mathrm{H_2O(l)}$$

Multiply, divide, or reverse these equations until they can cancel out and add together to produce the following, which describes Reaction 3:

$$\text{Reaction 3: } \mathrm{Na^+(aq)} + \mathrm{OH^-(aq)} + \mathrm{H^+(aq)} + \mathrm{Cl^-(aq)} \rightarrow \mathrm{Na^+(aq)} + \mathrm{Cl^-(aq)} + \mathrm{H_2O(l)}$$

Write out on a piece of paper how the first two reactions add up to equal the third, making sure to cross out the cancelled terms. Note that spectator ions (species that do not participate in the reaction) are present; your final answer may be written with or without them. Upload an image showing how the equations are added to equal Reaction 3 into Image 1. Based on how you manipulated Reactions 1 and 2, write out in this answer field a statement that describes how their corresponding ΔH values add to equal ΔH_3. Use the following format:

$$\pm n\,\Delta H_1 \pm n\,\Delta H_2 = \Delta H_3$$

where *n* is any integer or fraction the equations were multiplied by, and (+/–) is chosen based on whether the reaction is as written above (ΔH would be positive) or is reversed (ΔH would be negative).

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Using your values for ΔH_1 and ΔH_2, plug them into the ΔH equation you determined in the previous question to calculate ΔH_3.

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Compare your calculated value of ΔH_3 from the previous question to your experimentally measured value of ΔH_3 from step 75 using the percent difference equation:

$$\text{percent difference} = \frac{|measured - calculated|}{\left(\frac{measured + calculated}{2}\right)} \times 100\%$$

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Which of the reactions performed in this exercise were endothermic and which were exothermic? Reference the results of Data Table 1 in your explanation.

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Do your results support Hess' law? Explain why or why not.

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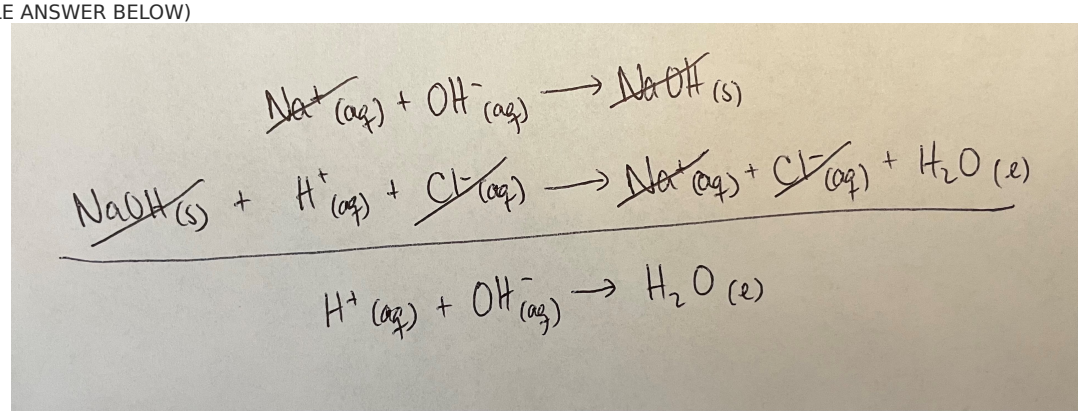
Data Table 1: Reaction Data
(SAMPLE ANSWER BELOW)

Trial	**Reaction 1**	**Reaction 2**	**Reaction 3**
Mass H_2O (g)	99.7851	99.6744	50.0390
Mass NaOH (g)	3.0161	2.9146	52.3981
Initial temperature (°C)	25.00	25.00	25.00
Max/min temperature (°C)	32.45	41.25	30.71
ΔT (°C)	7.45	16.25	5.71
m (g)	102.8012	102.5890	102.4371
q (kJ)	-3.20	-6.975	-2.45
n (mol)	0.07541	0.07287	0.04954
ΔH (kJ/mol)	-42.4	-95.72	-49.5

Image 1: Reactions 1 and 2 Added to Equal Reaction 3
(SAMPLE ANSWER BELOW)



Competency Review

In an endothermic reaction, heat is _____ and temperature _____.

- released; increases
- released; decreases
- absorbed; decreases ✔
- absorbed; increases

A chemical reaction that releases heat to the surrounding environment is considered _____.

- enthalpy
- entropy
- endothermic
- exothermic ✔

The amount of heat given off or absorbed by a chemical reaction is called _____.

- an exothermic reaction
- the change in enthalpy ✔
- a Joule
- the product of pressure and volume

Using Hess' law, the following equation is reversed as part of adding several processes up to equal a final equation.

$2\ Mg^{2+}(aq) + 2\ H_2O(l) \rightarrow 2\ MgO(s) + 4\ H^+(aq)$

The associated ΔH value should be _____.

- divided by 1
- multiplied by the other values of ΔH
- multiplied by –1 ✔
- multiplied by –2

The change in enthalpy of a reaction is equal to the enthalpy of the _____ minus the enthalpy of the _____.

- products; reactants ✔
- reactants; products
- total; calorimeter
- calorimeter; total

When an exothermic reaction occurs, the products have a greater enthalpy than the reactants, whereas during an endothermic reaction the enthalpy of the products is less than the enthalpy of the reactants.

- True
- False ✔

Hess's law indicates that if a reaction takes place in one or multiple steps, the change in enthalpy for the overall process must be the sum of the change in enthalpy of the constituent reactions.

- True ✔
- False

The percent difference in the results of an experiment with a calculated enthalpy change of -45.68 kJ/mol and a measured enthalpy change of -54.78 kJ/mol is _____.

$$\text{percent difference} = \frac{|measured - calculated|}{\left(\frac{measured + calculated}{2}\right)} \times 100\%$$

- 20.10%
- 16.61%
- 18.12% ✔
- 21.37%

The ΔT of a reaction where the starting temperature was 28.2°C, the mass of the solution was 18.7 g, the specific heat was 5.008 J/g°C, and the final temperature was 35.4°C is _____.

- 7.2°C ✔
- –7.2°C
- -67.42 J
- -674.27 J

If an experiment has a q_{rxn} of 518.07 J, the change in enthalpy of the reaction if there was 0.04 moles of limiting reagent in the solution is _____.

$$\Delta \mathrm{H} = \frac{q}{n}$$

- 12951.75 kJ/mol ✔
- -12951.75 kJ/mol
- -12.95 kJ/mol
- 7.72 kJ/mol

The first two of the following equations will be measured to add up to the third equation:

$$\mathrm{NaOH(s)} \longrightarrow \mathrm{Na^+(aq)} + \mathrm{OH^-(aq)}$$

$$+ \quad \mathrm{NaOH(s)} + \mathrm{H^+(aq)} \longrightarrow \mathrm{Na^+(aq)} + \mathrm{H_2O(l)}$$

$$\mathrm{OH^-(aq)} + \mathrm{H^+(aq)} \longrightarrow \mathrm{H_2O(l)}$$

The manipulation(s) that need(s) to be performed on the first equation _____.

- is multiplying all of the coefficients by 2
- are multiplying all of the coefficients by 2 and reversing the equation
- is reversing the equation ✔
- No manipulations need to be performed.

Extension Questions

Worldwide, scientists are working on different options for clean energy to replace the burning of fossil fuels. One option that could potentially be successful is the use of

hydrogen gas. This gas can be generated through a reaction between carbon and water. The following two reactions have the listed ΔH values. They can add up to the reaction discussed above, which is listed as the third equation.

$CO_2(g) \rightarrow C(s) + O_2(g)$ $\Delta H_1 = 393.5$ kJ
$2\ H_2O(g) \rightarrow 2\ H_2(g) + O_2(g)$ $\Delta H_2 = 483.6$ kJ

$C(s) + 2\ H_2O(g) \rightarrow CO_2(g) + 2\ H_2(g)$ $\Delta H_3 = ?$

Apply the equations above and your knowledge of Hess' law to determine the ΔH_3 for the reaction between carbon and water. Note whether this reaction is exothermic or endothermic.

(SAMPLE ANSWER BELOW)

Equation 1 must be reversed to properly cancel terms and add up to Equation 3.

H_1 will therefore have its sign reversed to be negative.

–393.5 kJ + 483.6 kJ = 90.1 kJ

A positive heat of reaction means that the reaction is endothermic.