

Problem Set #7

CHEM101A: General College Chemistry

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8 Topic D Problem 8

Consider the following two facts about the reaction of HCl with NaOH

Fact #1: ΔE is a negative number for this reaction, which means that the energy of the chemicals decreases.

Fact #2: When HCl and NaOH are mixed, the mixture becomes hotter, which means that the energy of the chemicals increases.

Explain how both of these statements can be true at the same time.

8.1 Solution

The energy in ΔE refers to the potential energy, not the kinetic energy. What likely happened is that the potential energy decreased, so the kinetic energy increased by the potential energy being converted to kinetic energy.

9 Topic D Problem 9

When aqueous HCl reacts with solid NaHCO₃, the mixture becomes colder.

- a) Does the kinetic energy of the chemicals increase, decrease, or remain the same during the reaction?
- b) Does the potential energy of the chemical increase, decrease, or remain the same during the reaction?
- c) What is the sign of ΔE for this reaction?

9.1 Solution (a)

The mixture becoming colder implies the temperature decreased, implying the kinetic energy decreased.

9.2 Solution (b)

The total energy of the system would have to remain the same. Since the kinetic energy decreases, the potential energy must increase.

9.3 Solution (c)

Since ΔE refers to the change in potential energy, the sign of ΔE is positive.

10 Topic D Problem 10

For the reaction $2 \text{Al(s)} + 6 \text{H}^+(\text{aq}) \longrightarrow 2 \text{Al}^{3+}(\text{aq}) + 3 \text{H}_2(\text{g})$, $\Delta E = -1057 \text{ kJ}$.

- How much energy is given off when 2.822 g of Al reacts with hydrogen ions, assuming the hydrogen ions are in excess?
- How much energy is given off when 1.413 g of Al is added to 23.0 mL of a solution that contains 5.89 M H^+ ?
- If you want to obtain 50.0 kJ of energy from this reaction, how many grams of aluminum and how many mL of 3.00 M HCl must you use?
- If this reaction produces 13.3 L of $\text{H}_2(\text{g})$ at 25.0°C and 1.014 atm, how much energy does it give off?

10.1 Solution (a)

First convert grams to moles.

$$MM(\text{Al}) = 26.98 \text{ g/mol} \quad (1)$$

$$n(\text{Al}) = \frac{m}{MM} = \frac{2.822 \text{ g}}{26.98 \text{ g/mol}} = 0.104595997 \text{ mol} \quad (2)$$

Next, we use our favorite ratio for energy.

$$\frac{\Delta E_{\text{sp}}}{n_{\text{sp}}(\text{Al})} = \frac{\Delta E}{n(\text{Al})} \quad (3)$$

$$\frac{\Delta E_{\text{sp}}}{0.10459 \text{ mol}} = \frac{-1057 \text{ kJ}}{2 \text{ mol}} = -528.5 \text{ kJ/mol} \quad (4)$$

$$\Delta E = -55.27898 \text{ kJ} \quad (5)$$

This means that it releases $\boxed{55.28 \text{ kJ}}$.

10.2 Solution (b)

First, find the limiting reactant.

$$n(\text{Al}) = \frac{m}{MM} = \frac{1.413 \text{ g}}{26.98 \text{ g/mol}} = 0.052317 \text{ mol Al} \quad (6)$$

$$n(\text{H}^+) = cV = (5.89 \text{ mol/L})(23.0 \text{ mmol}) = 0.13547 \text{ mol H}^+ \quad (7)$$

Dividing the number of moles of H^+ by 6 and the number of moles of Al by 2 makes clear that the H^+ is the limiting reactant. From here, just use our favorite ratio again.

$$\frac{\Delta E_{\text{sp}}}{0.13547 \text{ mol}} = \frac{-1057 \text{ kJ}}{6 \text{ mol}} = 176.167 \text{ kJ/mol} \quad (8)$$

$$\Delta E_{\text{sp}} = 23.8653 \text{ kJ} \quad (9)$$

That means it releases $\boxed{23.9 \text{ kJ}}$.

10.3 Solution (c)

In this instance, it would have to be that $\Delta E_{sp} = -50.0\text{kJ}$. We can put this into our favorite ratio to find the number of necessary moles of each.

$$\frac{-50.0\text{ kJ}}{n(\text{Al})} = \frac{-1057\text{ kJ}}{2\text{ mol}} \quad (10)$$

$$n(\text{Al}) = \frac{50.0\text{ kJ}}{528.5\text{ kJ/mol}} = 0.09460738\text{ mol} \quad (11)$$

$$\frac{-50.0\text{ kJ}}{n(\text{H}^+)} = \frac{-1057\text{ kJ}}{6\text{ mol}} \quad (12)$$

$$n(\text{H}^+) = \frac{50.0\text{ kJ}}{176.1667\text{ kJ/mol}} = 0.2838221\text{ mol} = n(\text{HCl}) \quad (13)$$

Now we can convert both to their requested units.

$$m(\text{Al}) = n * MM = 0.09460738\text{ mol} * 26.98\text{ g/mol} \quad (14)$$

$$= \boxed{2.55\text{ g}} \quad (15)$$

$$V(\text{H}^+) = \frac{n}{M} = \frac{0.2838221\text{ mol}}{3.00\text{ M HCl}} = \boxed{0.0946\text{ L}} \quad (16)$$

10.4 Solution (d)

Use the ideal gas law to find the number of moles.

$$PV = nRT \quad (17)$$

$$n = \frac{PV}{RT} = \frac{(1.014\text{ atm})(13.3\text{ L})}{(0.08206\text{ atm} \cdot \text{L/mol} \cdot \text{K})(298.15\text{ K})} \quad (18)$$

$$= 0.5512178\text{ mol} \quad (19)$$

This can be used with our favorite ratio.

$$\frac{\Delta E_{sp}}{n_{sp}(\text{H}_2)} = \frac{\Delta E}{n(\text{H}_2)} \quad (20)$$

$$\frac{\Delta E_{sp}}{0.5512178\text{ mol}} = \frac{-1057\text{ kJ}}{3\text{ mol}} = -352.333\text{ kJ/mol} \quad (21)$$

$$\Delta E_{sp} = (0.5512178\text{ mol})(-352.333\text{ kJ/mol}) = 194.21\text{ kJ} = \boxed{194.2\text{ kJ}} \quad (22)$$

11 Topic D Problem 11

When 4.00 g of Br_2 reacts with excess Al to form AlBr_3 , 8.80 kJ of energy is given off. Calculate ΔE for the reaction $2 \text{Al}(\text{s}) + 3 \text{Br}_2(\text{s}) \longrightarrow 2 \text{AlBr}_3(\text{s})$.

11.1 Solution

First convert the number of grams of Br_2 to moles.

$$n(\text{Br}_2) = \frac{4.00 \text{ g}}{159.8 \text{ g/mol}} = 0.0250313 \text{ mol} \quad (23)$$

Next, use our favorite fraction.

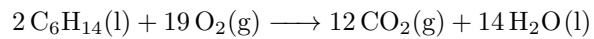
$$\frac{\Delta E}{n(\text{Br}_2)} = \frac{\Delta E_{sp}}{n_{sp}(\text{Br}_2)} \quad (24)$$

$$\frac{\Delta E}{3 \text{ mol}} = \frac{-8.80 \text{ kJ}}{0.0250313 \text{ mol}} = -351.56 \text{ kJ/mol} \quad (25)$$

$$\Delta E = (3 \text{ mol})(351.56 \text{ kJ/mol}) = -1054.68 \text{ kJ} = \boxed{-1.054 \text{ MJ}} \quad (26)$$

12 Topic D Problem 12

A chemist burns 0.5177 g of liquid hexane (C_6H_{14}) in a bomb calorimeter that has a heat capacity of 4287 J/ $^\circ\text{C}$. The temperature of the calorimeter rises from 21.382 $^\circ\text{C}$ to 27.170 $^\circ\text{C}$ during the reaction. Calculate ΔE for the following reaction:



12.1 Solution

13 Topic D Problem 13

Explain why some reactions give off different amounts of heat when they are carried out at constant pressure versus constant volume.

13.1 Solution

I just did Thermodynamics in Physics, so that's the perspective I'm approaching this from.

$$W = P\Delta V \quad (27)$$

When you carry out a reaction at constant pressure, the volume can still change. This volume change allows work to be done because the work depends on the change in volume but only the raw value of the pressure. Meanwhile, when you carry out a reaction at constant volume, no work can be done because the work is dependant on the change in volume, not the raw value.

14 Topic D Problem 14

A reaction has $\Delta E = -50$ kJ.

- a) If this reaction occurs, will the reaction mixture become hotter, or colder?
- b) Is this an exothermic reaction, or is it an endothermic reaction?
- c) After this reaction has occurred, will the potential energy of the chemical mixture be higher than, lower than, or the same as it was before the reaction?
- d) After this reaction has occurred, will the kinetic energy of the universe be higher than, lower than, or the same as it was before the reaction (assuming no other reaction has occurred)?

14.1 Solution

- a) Immediately, the mixture will become hotter, but the temperature will even out to equilibrium over time.
- b) Since the energy causes the mixture to warm up and exert energy from within, the process would be exothermic.
- c) It would be lower.
- d) The kinetic energy of the universe will increase.

15 Topic D Problem 15

A reaction has $\Delta E = 10$ kJ, and it converts a solid into a gas.

- a) If this reaction occurs in a closed, rigid container, will the amount of heat that is absorbed be larger than 10 kJ, smaller than 10 kJ, or exactly 10 kJ? Justify your answer.
- b) If this reaction occurs in an open container, will the amount of heat that is absorbed be larger than 10 kJ, smaller than 10 kJ, or exactly 10 kJ? Justify your answer.
- c) Will PV work be done in either part a or part b? If so, which part(s)?
- d) What is the sign of the PV work when PV work occurs?

15.1 Solution

16 Topic D Problem 16

A reaction has $\Delta E = -10$ kJ, and it converts a gas into a liquid. a) If this reaction occurs in a closed, rigid container, will the amount of heat that is given off be larger than 10 kJ, smaller than 10 kJ, or exactly 10 kJ? Justify your answer. b) If this reaction occurs in an open container, will the amount of heat that is given off be larger than 10 kJ, smaller than 10 kJ, or exactly 10 kJ? Justify your answer. c) Will PV work be done in either part a or part b? If so, which part(s)? d) What is the sign of the PV work when PV work occurs?

16.1 Solution

17 Topic D Problem 17

A reaction has $\Delta E = -10$ kJ, and it converts a liquid into a gas. a) If this reaction occurs in a closed, rigid container, will the amount of heat that is given off be larger than 10 kJ, smaller than 10 kJ, or exactly 10 kJ? Justify your answer. b) If this reaction occurs in an open container, will the amount of heat that is given off be larger than 10 kJ, smaller than 10 kJ, or exactly 10 kJ? Justify your answer. c) Will PV work be done in either part a or part b? If so, which part(s)? d) What is the sign of the PV work when PV work occurs?

17.1 Solution

18 Topic D Problem 18

a) What is the PV work when 3.00 moles of liquid water boils at 100°C at constant pressure? Give your answer in kJ, and include the correct sign. b) What is the PV work when 3.00 moles of steam condenses at 100°C at constant pressure? Give your answer in kJ, and include the correct sign.

18.1 Solution

19 Topic D Problem 19

Consider the following reaction: $4 \text{ C}_3\text{H}_9\text{N}(\text{l}) + 21 \text{ O}_2(\text{g}) \rightarrow 12 \text{ CO}_2(\text{g}) + 18 \text{ H}_2\text{O}(\text{l}) + 2 \text{ N}_2(\text{g})$ $\Delta E = -9667 \text{ kJ}$ The following questions (parts a through j) refer to this reaction. a) Calculate ΔH for this reaction at 25°C . b) How much heat will be given off if 8.250 g of $\text{C}_3\text{H}_9\text{N}$ reacts with excess O_2 in a closed, rigid container at 25°C ? c) How much heat will be given off if 8.250g of $\text{C}_3\text{H}_9\text{N}$ reacts with excess O_2 in an open container at 25°C ? d) Calculate the PV work in part b. Include the correct sign. e) Calculate the PV work in part c. Include the correct sign. f) If you want to obtain 200.0 kJ of heat by reacting $\text{C}_3\text{H}_9\text{N}$ with O_2 in an open container, what mass of $\text{C}_3\text{H}_9\text{N}$ must you use? g) How much heat is produced when 2.199 g of liquid $\text{C}_3\text{H}_9\text{N}$ reacts with 5.738 g of gaseous O_2 in an open container? h) If you burn enough liquid $\text{C}_3\text{H}_9\text{N}$ to produce 841.2 kJ of heat in an open container, what volume of gaseous N_2 will you form at 25.0°C and 752 torr? i) If this reaction is carried out in a closed, rigid container and produces 31.74 g of liquid H_2O , how much heat does it produce?

19.1 Solution

20 Topic D Problem 20

When 2.810 g of solid Al reacts with excess gaseous F₂ in an open container at 25°C, 157.3 kJ of heat is produced. a) Calculate ΔH and ΔE for the following reaction at 25°C: $2 \text{ Al(s)} + 3 \text{ F}_2\text{(g)} \rightarrow 2 \text{ AlF}_3\text{(s)}$ b) How much heat will be produced if 8.493 g of solid Al reacts with 16.610 g of gaseous F₂ in a closed, rigid container at 25°C? Use your answer from part a to solve this problem.

20.1 Solution

21 Topic D Problem 21

A chemist burns 1.628 g of liquid isopropyl alcohol ($\text{C}_3\text{H}_8\text{O}$) in a bomb calorimeter that has a heat capacity of $3927 \text{ J}/^\circ\text{C}$. The temperature of the calorimeter rises from 19.085°C to 31.683°C during the reaction. Calculate ΔH and ΔE for the following reaction at 25°C : $2 \text{ C}_3\text{H}_8\text{O}(\text{l}) + 9 \text{ O}_2(\text{g}) \rightarrow 6 \text{ CO}_2(\text{g}) + 8 \text{ H}_2\text{O}(\text{l})$

21.1 Solution

22 Topic D Problem 22

For the reaction $2 \text{C(s)} + \text{O}_2\text{(g)} \rightarrow 2 \text{CO(g)}$, $\Delta E = -219 \text{ kJ}$. When will ΔH also be -219 kJ ? a) When the reaction is carried out in an open container. b) When the reaction is carried out in a closed, rigid container. c) ΔH will always equal ΔE . d) ΔH will never equal ΔE .

22.1 Solution