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CHEMISTRY WORKSHEET

# PHASE CHANGES

Course: Grade 12 Chemistry

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## 50 Practice Problems with Answers and Detailed Solutions

**Full version** of this worksheet contains 4 selected representative problems on:

- ✓ Heating and cooling within one phase, ✓ Melting and freezing, ✓ Vaporization and condensation,
- ✓ Multi-step heating and cooling curves, ✓ Ice-water heat exchange, ✓ Steam-water heat exchange,
- ✓ Heater power and efficiency problems.

All problems are designed to reflect style and difficulty commonly seen on quizzes, tests, and final exams. Detailed solutions are included to help students understand the reasoning behind every step.

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### PART A - FUNDAMENTAL PROBLEMS

Selected Problem 8

### PART B - INTERMEDIATE PROBLEMS

Selected Problem 16

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### PART C - ADVANCED PROBLEMS

Selected Problem 32

### PART D - CHALLENGE PROBLEMS

Selected Problem 45

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SUITABLE FOR:

quizzes, unit tests and final exam preparation

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## Section 1 - Essential Information – included in full version

This page includes only the formulas and habits needed to solve calorimetry problems efficiently

| Formula                                    | Use                                                 |
|--------------------------------------------|-----------------------------------------------------|
| $q = m \cdot \Delta T$                     | Heat gained or lost by a substance                  |
| $\Delta T = T_f - T_i$                     | Temperature change with sign                        |
| $q_{\text{cal}} = C_{\text{cal}} \Delta T$ | Heat absorbed by a calorimeter                      |
| $q_{\text{sys}} = -q_{\text{surrounds}}$   | Sign convention for coffee-cup and bomb calorimetry |
| $q_{\text{ex}} = q_{\text{sys}} = 0$       | Heat exchange between substances                    |
| $\Delta H = q_{\text{surrounds}}/n$        | Molar enthalpy at constant pressure                 |

**Important definitions:** coffee-cup calorimetry is usually constant pressure, so  $q_p$  can be used for  $\Delta H$ . Bomb calorimetry is constant volume, so the result is commonly treated as  $\Delta U$  for ICMI-style calculations.

**Fast method:** identify what gains heat, identify what loses heat, convert volumes to masses when density is given, calculate  $\Delta T$  carefully, include  $C_{\text{cal}}$  when provided, then apply the sign convention at the end.

**Important notes:** for dilute aqueous solutions, use density = 1.00 g/mL and  $c = 4.184 \text{ J/g } ^\circ\text{C}$  only when stated or clearly assumed. For reactions, the solution and calorimeter are surroundings, while the chemical reaction is the system.

**Common mistakes:** using only one solution volume after mixing, forgetting that  $q_{\text{surrounds}}$  has the opposite sign of  $q_{\text{system}}$ , ignoring the limiting reagent, mixing  $J$  and  $kJ$ , and using the sample mass instead of moles when a molar amount is requested.

## Section 2 - Practice Problems

### Part A - Fundamental Problems (Problems 1-15)

#### Problem 8

How much heat is required to change 30.0 g of ice at  $-10.0\text{ }^{\circ}\text{C}$  into liquid water at  $25.0\text{ }^{\circ}\text{C}$ ? Use  $c_{\text{ice}} = 2.09\text{ J/(g}\cdot^{\circ}\text{C)}$ ,  $\Delta H_{\text{fus}} = 334\text{ J/(g)}$ , and  $c_{\text{water}} = 4.184\text{ J/(g}\cdot^{\circ}\text{C)}$

### Part B - Intermediate Problems (Problems 16-30)

#### Problem 16

Calculate the heat needed to convert 80.0 g of ice at  $-20.0\text{ }^{\circ}\text{C}$  into liquid water at  $35.0\text{ }^{\circ}\text{C}$

### Part C - Advanced Problems (Problems 31-40)

#### Problem 32

80.0 g of steam at  $100.0\text{ }^{\circ}\text{C}$  is bubbled into 500.0 g of water at  $25.0\text{ }^{\circ}\text{C}$ . Determine the final temperature and whether all the steam condenses

### Part D - Challenge Problems (Problems 41-50)

#### Problem 45

A 30.0 g sample is heated with a 180 W heater. On its heating curve, the solid warms from  $-30.0\text{ }^{\circ}\text{C}$  to  $0.0\text{ }^{\circ}\text{C}$  in 42.0 s, melts in 210 s, the liquid warms from  $0.0\text{ }^{\circ}\text{C}$  to  $75.0\text{ }^{\circ}\text{C}$  in 280 s, and boils in 960 s. Calculate  $c_{\text{solid}}$ ,  $\Delta H_{\text{fus}}$ ,  $c_{\text{liquid}}$ , and  $\Delta H_{\text{vap}}$

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## Section 3 - Solutions

### Problem 8 Solution

**Given:** The starting sample is 30.0 g of ice at -10.0 °C and the final sample is liquid water at 25.0 °C

**Find:** The total heat absorbed across the complete path from cold ice to warmer liquid water

**Method:** The path has three parts: warm ice to 0.0 °C, melt the ice, then warm the liquid water to 25.0 °C

**Formula:**  $q_{\text{total}} = m \cdot c_{\text{ice}} \cdot \Delta T_{\text{ice}} + m \cdot \Delta H_{\text{fus}} + m \cdot c_{\text{water}} \cdot \Delta T_{\text{water}}$

$$q_{\text{ice}} = (30.0 \text{ g})(2.09 \text{ J/(g} \cdot ^\circ\text{C)})(10.0 ^\circ\text{C}) = 627 \text{ J}$$

$$q_{\text{melt}} = (30.0 \text{ g})(334 \text{ J/(g)}) = 10020 \text{ J}$$

$$q_{\text{water}} = (30.0 \text{ g})(4.184 \text{ J/(g} \cdot ^\circ\text{C)})(25.0 ^\circ\text{C}) = 3138 \text{ J}$$

$$q_{\text{total}} = 627 \text{ J} + 10020 \text{ J} + 3138 \text{ J} = 13785 \text{ J} = 13.785 \text{ kJ}$$

**Final answer:** +13.8 kJ absorbed

The final answer is rounded to three significant figures because the measured values in the problem are mostly given to three significant figures

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### Problem 16 Solution

**Given:** The sample is 80.0 g of ice at -20.0 °C and the final state is liquid water at 35.0 °C

**Find:** The total heat absorbed from the initial solid state to the final liquid state

**Method:** The heating curve has three required sections: warming ice, melting ice, and warming liquid water

**Formula:**  $q_{\text{total}} = m \cdot c_{\text{ice}} \cdot \Delta T_{\text{ice}} + m \cdot \Delta H_{\text{fus}} + m \cdot c_{\text{water}} \cdot \Delta T_{\text{water}}$

$$q_{\text{ice}} = (80.0 \text{ g})(2.09 \text{ J/(g} \cdot \text{°C)})(20.0 \text{ °C}) = 3344 \text{ J}$$

$$q_{\text{melt}} = (80.0 \text{ g})(334 \text{ J/(g)}) = 26720 \text{ J}$$

$$q_{\text{water}} = (80.0 \text{ g})(4.184 \text{ J/(g} \cdot \text{°C)})(35.0 \text{ °C}) = 11715.2 \text{ J}$$

$$q_{\text{total}} = 3344 \text{ J} + 26720 \text{ J} + 11715.2 \text{ J} = 41779.2 \text{ J} = 41.7792 \text{ kJ}$$

**Final answer:** +41.8 kJ absorbed

The final answer is rounded to three significant figures because the measured values in the problem are mostly given to three significant figures

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### Problem 32 Solution

**Given:** There are 80.0 g of steam at 100.0 °C and 500.0 g of liquid water at 25.0 °C

**Find:** The final state of the system and the mass of steam that remains uncondensed

**Method:** First compare the heat needed to warm the water to 100.0 °C with the heat released if all the steam condensed

**Formula:**  $q_{\text{water to 100}} = m \cdot c_{\text{water}} \cdot \Delta T$  and  $m_{\text{condensed}} = q / \Delta H_{\text{vap}}$

$$q_{\text{water to 100}} = (500.0 \text{ g})(4.184 \text{ J/(g} \cdot \text{°C)})(75.0 \text{ °C}) = 156900 \text{ J}$$

If all 80.0 g of steam condensed, it would release  $(80.0 \text{ g})(2260 \text{ J/(g)}) = 180800 \text{ J}$ , which is more than needed to bring the water to 100.0 °C

The system reaches 100.0 °C before all steam condenses

$$m_{\text{condensed}} = 156900 \text{ J} / 2260 \text{ J/(g)} = 69.4248 \text{ g}$$

$$m_{\text{steam remaining}} = 80.0 \text{ g} - 69.4248 \text{ g} = 10.5752 \text{ g}$$

**Final answer:**  $T_f = 100.0 \text{ °C}$ ; 10.6 g of steam remains

The final answer is rounded to three significant figures because the measured values in the problem are mostly given to three significant figures

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### Problem 45 Solution

**Given:** The sample mass is 30.0 g and the heater power is 180 W. The heating curve gives times for solid warming, melting, liquid warming, and boiling

**Find:** The specific heat capacities and latent heats represented by the curve

**Method:** For each curve section,  $q = P \cdot t$ . Sloped sections use  $q = m \cdot c \cdot \Delta T$ , while plateaus use  $q = m \cdot L$

**Formula:**  $c = (P \cdot t) / (m \cdot \Delta T)$  and  $L = (P \cdot t) / m$

$$c_{\text{solid}} = (180 \text{ J/s})(42.0 \text{ s}) / [(30.0 \text{ g})(30.0 \text{ }^\circ\text{C})] = 8.40 \text{ J/(g}\cdot^\circ\text{C)}$$

$$\Delta H_{\text{fus}} = (180 \text{ J/s})(210 \text{ s}) / 30.0 \text{ g} = 1260 \text{ J/(g)}$$

$$c_{\text{liquid}} = (180 \text{ J/s})(280 \text{ s}) / [(30.0 \text{ g})(75.0 \text{ }^\circ\text{C})] = 22.4 \text{ J/(g}\cdot^\circ\text{C)}$$

$$\Delta H_{\text{vap}} = (180 \text{ J/s})(960 \text{ s}) / 30.0 \text{ g} = 5760 \text{ J/(g)}$$

**Final answer:**  $c_{\text{solid}} = 8.40 \text{ J/(g}\cdot^\circ\text{C)}$ ;  $\Delta H_{\text{fus}} = 1.26 \times 10^3 \text{ J/(g)}$ ;  $c_{\text{liquid}} = 22.4 \text{ J/(g}\cdot^\circ\text{C)}$ ;

$$\Delta H_{\text{vap}} = 5.76 \times 10^3 \text{ J/(g)}$$

The final answer is rounded to three significant figures because the measured values in the problem are mostly given to three significant figures

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## Section 4 - Answer Key

| Problem | Answer                                                                                                                                                                                                                                            |
|---------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 8       | +13.8 kJ absorbed                                                                                                                                                                                                                                 |
| 16      | +41.8 kJ absorbed                                                                                                                                                                                                                                 |
| 32      | $T_f = 100.0\text{ }^{\circ}\text{C}$ ; 10.6 g of steam remains                                                                                                                                                                                   |
| 45      | $c_{\text{solid}} = 8.40\text{ J/(g}\cdot^{\circ}\text{C)}$ ; $\Delta H_{\text{fus}} = 1.26 \times 10^3\text{ J/(g)}$ ; $c_{\text{liquid}} = 22.4\text{ J/(g}\cdot^{\circ}\text{C)}$ ;<br>$\Delta H_{\text{vap}} = 5.76 \times 10^3\text{ J/(g)}$ |

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