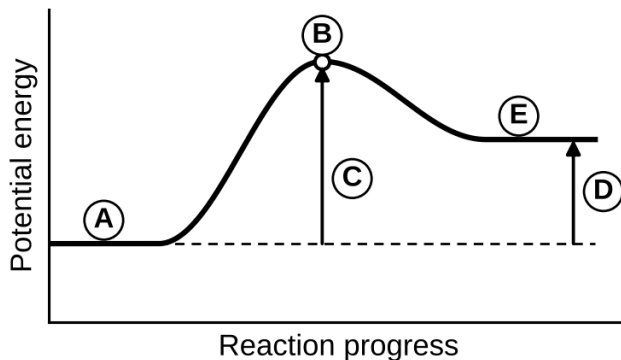


Show all work with units and correct significant figures.

Heat	$q = mc\Delta T$, $\Delta T = T_{\text{final}} - T_{\text{initial}}$	$q = m\Delta H_{\text{fus}}$ or $q = m\Delta H_{\text{vap}}$	$q_{\text{rxn}} = -q_{\text{soln}}$; $\Delta H = q_{\text{rxn}} \div \text{mol}$
Energy	$\Delta G = \Delta H - T\Delta S$	$K = ^\circ\text{C} + 273$	1 kJ = 1000 J
Formation	$\Delta H^\circ_{\text{rxn}} = \sum n\Delta H^\circ_f(\text{products}) - \sum n\Delta H^\circ_f(\text{reactants})$		
Water	$c_{\text{water}} = 4.18 \text{ J/g}\cdot^\circ\text{C}$	$c_{\text{ice}} = 2.06 \text{ J/g}\cdot^\circ\text{C}$	$c_{\text{steam}} = 1.99 \text{ J/g}\cdot^\circ\text{C}$
Water (phase)	$\Delta H_{\text{fus}} = 334 \text{ J/g}$	$\Delta H_{\text{vap}} = 2260 \text{ J/g}$	density = 1.00 g/mL
Metals (c)	aluminum 0.897 J/g $\cdot^\circ\text{C}$	iron 0.449 J/g $\cdot^\circ\text{C}$	copper 0.385 J/g $\cdot^\circ\text{C}$

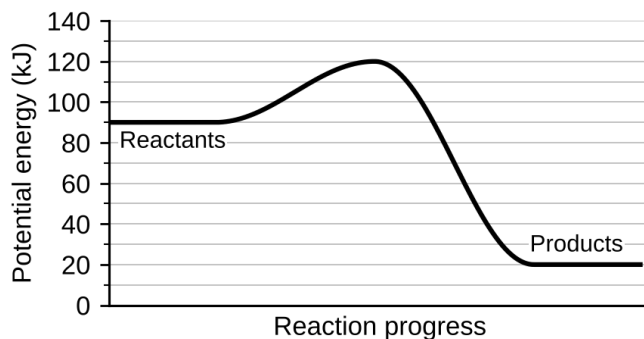
Part 1. PE Diagrams

1. Identify what each letter on the PE diagram represents. Then decide if the reaction is exothermic or endothermic.



Letter	What it represents	Letter	What it represents
A		B	
C		D	
E		Exo or endo?	

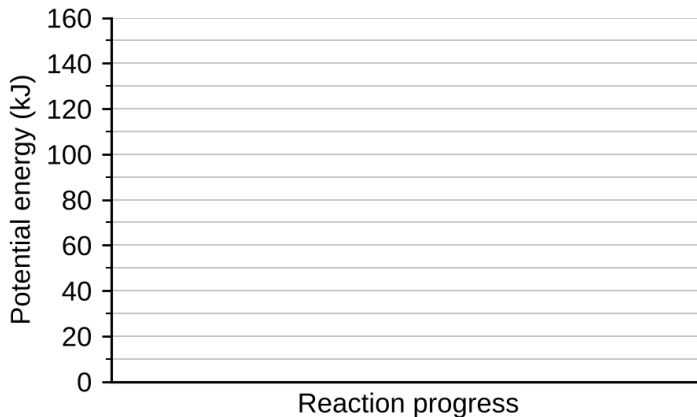
2. Use the PE diagram below.


 (a) Find ΔH for the reaction.

(b) Find the activation energy, E_a .

(c) Is the reaction exothermic or endothermic? Give two pieces of evidence.

3. A reaction has reactants at 40 kJ, $\Delta H = +60$ kJ, and $E_a = 100$ kJ.



(a) Find the potential energy of the products and of the activated complex.

(b) Draw the PE diagram on the grid. Label the reactants, products, activated complex, E_a , and ΔH .

(c) A catalyst lowers E_a to 70 kJ. Draw the catalyzed path as a dashed curve on the same grid. Does the catalyst change ΔH ? Explain.

Part 2. Heat Calculations

4. How much heat is needed to warm 350. g of water from 18.0 °C to 75.0 °C? Give your answer in J and kJ.

5. A 45.0 g sample of a metal absorbs 1.21 kJ of heat and warms from 22.0 °C to 52.0 °C. Find its specific heat and use the reference table to identify the metal.

6. 200. g of water at 85.0 °C releases 12.5 kJ of heat. What is its final temperature?

Part 3. Calorimetry

7. Solid ammonium nitrate, NH_4NO_3 , is dissolved in water in a coffee-cup calorimeter. The temperature of the water drops.

(a) What is the system? What are the surroundings?

(b) Give the sign of q_{soln} and q_{rxn} . Is dissolving exothermic or endothermic?

8. 10.0 g of CaCl_2 (molar mass 110.98 g/mol) is dissolved in 90.0 g of water in a calorimeter. The temperature rises from 21.0 °C to 38.5 °C.

(a) Find q_{soln} . (Use the total mass of the solution.)

(b) Find q_{rxn} . Is dissolving CaCl_2 exothermic or endothermic?

(c) Find ΔH in kJ/mol of CaCl_2 .

9. 150. g of water at 70.0 °C is mixed with 50.0 g of water at 10.0 °C in a calorimeter. Find the final temperature. (Heat lost = heat gained.)

10. A student runs the CaCl_2 experiment in a single foam cup with no lid. Some heat escapes into the air. Will the measured temperature rise be too high or too low? Will the calculated ΔH be too large or too small in size? Explain.

Part 4. Entropy, Enthalpy and Gibbs Energy

11. Predict the sign of ΔS (+ or -) for each change and give a reason.

Change	ΔS (+ or -)	Reason
$\text{CO}_2(\text{s}) \rightarrow \text{CO}_2(\text{g})$		
$2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{H}_2\text{O}(\text{l})$		
$\text{NaCl}(\text{s}) \rightarrow \text{Na}^+(\text{aq}) + \text{Cl}^-(\text{aq})$		
$2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{SO}_3(\text{g})$		
$\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s})$		

12. Calculate ΔS° for $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{SO}_3(\text{g})$. Does your answer match your prediction in the table above?

Substance	$\text{SO}_2(\text{g})$	$\text{O}_2(\text{g})$	$\text{SO}_3(\text{g})$
S° (J/mol·K)	248.2	205.0	256.8

13. For the same reaction, $\Delta H = -197.8$ kJ and $\Delta S = -187.8$ J/K.

(a) Calculate ΔG at 25 °C. Is the reaction spontaneous?

(b) Above what temperature does this reaction stop being spontaneous?

14. Complete the table for the four combinations of ΔH and ΔS .

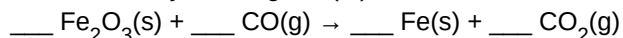
ΔH	ΔS	Is the reaction spontaneous?
-	+	
-	-	
+	+	
+	-	

Part 5. Heat of Formation Calculations

15. Circle every substance whose ΔH_f° is zero. Explain why the others are not zero.

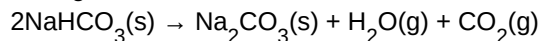
$\text{O}_2(\text{g})$ $\text{H}_2\text{O}(\text{l})$ $\text{Fe}(\text{s})$ $\text{O}_3(\text{g})$ $\text{N}_2(\text{g})$ $\text{Br}_2(\text{l})$ $\text{Br}_2(\text{g})$ $\text{NaCl}(\text{s})$ $\text{C}(\text{s, graphite})$

16. Iron is made by reacting iron(III) oxide with carbon monoxide. Balance the equation, then calculate $\Delta H^\circ_{\text{rxn}}$.



Substance	$\text{Fe}_2\text{O}_3(\text{s})$	$\text{CO}(\text{g})$	$\text{Fe}(\text{s})$	$\text{CO}_2(\text{g})$
ΔH°_f (kJ/mol)	-824.2	-110.5	0	-393.5

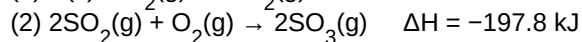
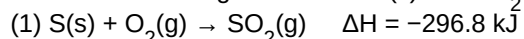
17. Baking soda breaks down when heated in an oven. Calculate $\Delta H^\circ_{\text{rxn}}$ and explain why the oven must keep supplying heat.



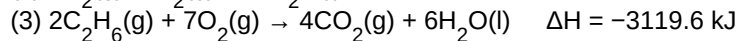
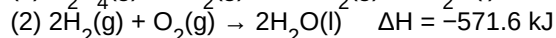
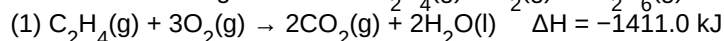
Substance	$\text{NaHCO}_3(\text{s})$	$\text{Na}_2\text{CO}_3(\text{s})$	$\text{H}_2\text{O}(\text{g})$	$\text{CO}_2(\text{g})$
ΔH°_f (kJ/mol)	-950.8	-1130.7	-241.8	-393.5

Part 6. Hess's Law

18. Find ΔH for the target reaction: $\text{S}(\text{s}) + 3/2 \text{O}_2(\text{g}) \rightarrow \text{SO}_3(\text{g})$

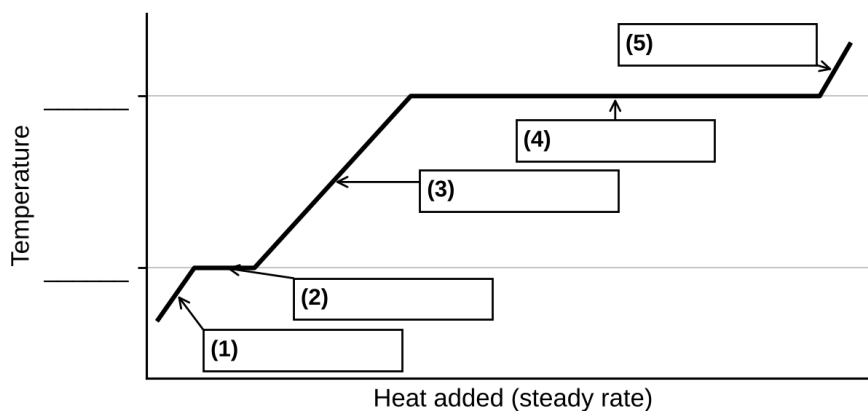


19. Find ΔH for the target reaction: $\text{C}_2\text{H}_4(\text{g}) + \text{H}_2(\text{g}) \rightarrow \text{C}_2\text{H}_6(\text{g})$



Part 7. Heating and Cooling Curves

20. Ice is heated at a steady rate. In each box, write the phase or phases present. Write the melting and boiling temperatures on the blanks.



Segment	Does KE or PE increase?	Equation for q
(1), (3), (5)		
(2)		
(4)		

(a) On segment (4), heat is still being added, but the temperature does not change. Where does the energy go?

(b) Why is plateau (4) much longer than plateau (2)?

21. How much heat is needed to change 20.0 g of water at 25.0 °C into steam at 110.0 °C? Show one q for each segment.