



Attempt all questions before checking the answer key.
Chemistry convention: $\Delta U = q + w$; expansion work $w = -P_{\text{ext}}\Delta V$. Use $R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$; $1 \text{ L bar} = 100 \text{ J}$.

A. Very short answers - 1 mark each

1. Define a state function and give one example.
2. Distinguish an open system from a closed system.
3. Is heat a state function? Explain briefly.
4. State the sign of enthalpy change in an exothermic reaction.
5. Define standard enthalpy of formation.
6. What is the entropy criterion for spontaneous change in an isolated system?

B. Short answers / practice - 2 marks each

7. A system absorbs 500 J heat while doing 200 J work. Find ΔU .
8. A gas expands by 2 L against constant external pressure 1 bar. Find work.
9. Explain the difference between intensive and extensive properties using two examples each.
10. State Hess's law and explain why it is valid.
11. Why can a spontaneous process be slow?
12. For $\Delta H = -40 \text{ kJ/mol}$ and $\Delta S = -100 \text{ J mol}^{-1} \text{ K}^{-1}$, calculate ΔG at 300 K.
13. A system loses 100 J heat and receives 40 J work. Find ΔU .
14. Does an isolated system exchange heat or matter with surroundings?
15. Find work for expansion by 3 L against 2 bar.
16. For $\Delta H = 20 \text{ kJ/mol}$, $\Delta S = 50 \text{ J mol}^{-1} \text{ K}^{-1}$, find crossover temperature.
17. Is enthalpy an extensive property?
18. Explain why entropy usually increases on melting a crystalline solid.

C. Short answers - 3 marks each

19. Derive $\Delta H = \Delta U + \Delta n(g)RT$ for a reaction involving ideal gases, stating assumptions.
20. For $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$ at 300 K, $\Delta U = -90.0 \text{ kJ/mol}$ of reaction. Find ΔH .
21. Use $\Delta_f H^\circ$ values $\text{CO}_2(g) = -393.5$, $\text{H}_2\text{O}(l) = -285.8$ and $\text{CH}_4(g) = -74.8 \text{ kJ/mol}$ to find methane's standard combustion enthalpy.

22. A reaction heats 200 g water by 5 K in a negligible-heat-capacity calorimeter. Find heat absorbed by water and released by the reaction; $c = 4.18 \text{ J g}^{-1} \text{ K}^{-1}$.

23. Estimate ΔH for $\text{H}_2 + \text{Cl}_2 \rightarrow 2\text{HCl}$ using bond enthalpies $\text{H-H } 436$, $\text{Cl-Cl } 243$ and $\text{H-Cl } 431 \text{ kJ/mol}$.

24. For $\Delta H = +30 \text{ kJ/mol}$ and $\Delta S = +100 \text{ J mol}^{-1} \text{ K}^{-1}$, find the temperature range for spontaneity, assuming both are temperature-independent.

D. Long answers - 5 marks each

25. State the first law and explain q , w , ΔU and ΔH . Compare constant-volume and constant-pressure heating and state when measured heat equals ΔU or ΔH .
26. Given $\Delta_c H^\circ(\text{C}) = -393.5$ and $\Delta_c H^\circ(\text{CO}) = -283.0 \text{ kJ/mol}$, use Hess's law to find $\Delta_f H^\circ(\text{CO})$. Draw an energy cycle and explain the signs.
27. Classify spontaneity for all four sign combinations of ΔH and ΔS using $\Delta G = \Delta H - T\Delta S$. Explain why exothermicity alone is insufficient.
28. A system expands from 2 L to 8 L against 1 bar and absorbs 1.2 kJ heat. Find w and ΔU . Compare with free expansion between the same volumes in an insulated container for an ideal gas.
29. Explain the relation $\Delta G^\circ = -RT \ln K$. Calculate ΔG° at 300 K for $K = 100$ using $\ln 10 = 2.303$, and interpret the equilibrium position without claiming the reaction goes fully to completion.
30. Define enthalpies of atomisation, bond dissociation, combustion, solution and neutralisation with one balanced thermochemical example each, stating physical states.

ANSWER KEY - Numerical / short answers

3) No; heat is path dependent. 7) $\Delta U = +300 \text{ J}$. 8) -200 J . 12) -10 kJ/mol . 13) -60 J . 14) No. 15) -600 J . 16) 400 K. 17) Yes. 20) -94.99 kJ/mol of reaction. 21) -890.3 kJ/mol . 22) Water $+4.18 \text{ kJ}$; reaction -4.18 kJ . 23) -183 kJ/mol . 24) $T > 300 \text{ K}$; $\Delta G = 0$ at 300 K. 26) -110.5 kJ/mol . 28) $w = -600 \text{ J}$; $\Delta U = +600 \text{ J}$; insulated ideal-gas free expansion: $w = q = \Delta U = 0$. 29) -11.49 kJ/mol ; K favours products.