

Thermodynamics — NEET Chemistry PYQ (2005-2021)

Class 11 Chemistry · 38 real NEET & AIPMT questions, year-tagged · answers checked by RankUp

NEET 2021

1. Which one among the following is the correct option for right relationship between C_p and C_v for one mole of ideal gas ?

- (A) $C_p + C_v = R$
- (B) $C_p - C_v = R$
- (C) $C_p = RC_v$
- (D) $C_v = RC_p$

NEET 2021

2. For irreversible expansion of an ideal gas under isothermal condition, the correct option is :

- (A) $\Delta U = 0$, $\Delta S(\text{total}) = 0$
- (B) $\Delta U \neq 0$, $\Delta S(\text{total}) \neq 0$
- (C) $\Delta U = 0$, $\Delta S(\text{total}) \neq 0$
- (D) $\Delta U \neq 0$, $\Delta S(\text{total}) = 0$

NEET 2020 · Q94

3. Hydrolysis of sucrose is given by the following reaction. $\text{Sucrose} + \text{H}_2\text{O} \rightleftharpoons \text{Glucose} + \text{Fructose}$. If the equilibrium constant (K) is 2×10^{13} at 300 K, the value of $\Delta_r G^\circ$ at the same temperature will be :

- (A) $-8.314 \text{ J mol}^{-1}\text{K}^{-1} \times 300 \text{ K} \times \ln(2 \times 10^{13})$
- (B) $8.314 \text{ J mol}^{-1}\text{K}^{-1} \times 300 \text{ K} \times \ln(2 \times 10^{13})$
- (C) $8.314 \text{ J mol}^{-1}\text{K}^{-1} \times 300 \text{ K} \times \ln(3 \times 10^{13})$
- (D) $-8.314 \text{ J mol}^{-1}\text{K}^{-1} \times 300 \text{ K} \times \ln(4 \times 10^{13})$

NEET 2020 · Q104

4. The correct option for free expansion of an ideal gas under adiabatic condition is :

- (A) $q = 0$, $\Delta T = 0$ and $w = 0$
- (B) $q = 0$, $\Delta T < 0$ and $w > 0$
- (C) $q < 0$, $\Delta T = 0$ and $w = 0$
- (D) $q > 0$, $\Delta T > 0$ and $w > 0$

NEET 2020 · Q127

5. For the reaction, $2\text{Cl}(\text{g}) \rightarrow \text{Cl}_2(\text{g})$, the correct option is :

- (A) $\Delta_r H > 0$ and $\Delta_r S > 0$
- (B) $\Delta_r H > 0$ and $\Delta_r S < 0$
- (C) $\Delta_r H < 0$ and $\Delta_r S > 0$
- (D) $\Delta_r H < 0$ and $\Delta_r S < 0$

NEET 2019 · Q86

6. In which case change in entropy is negative?

- (A) Evaporation of water
- (B) Expansion of a gas at constant temperature
- (C) Sublimation of solid to gas
- (D) $2\text{H}(\text{g}) \rightarrow \text{H}_2(\text{g})$

NEET 2018 · Q85

7. The bond dissociation energies of X_2 , Y_2 and XY are in the ratio of 1 : 0.5 : 1. ΔH for the formation of XY is -200 kJ mol^{-1} . The bond dissociation energy of X_2 will be

- (A) 800 kJ mol^{-1}
- (B) 100 kJ mol^{-1}
- (C) 200 kJ mol^{-1}
- (D) 400 kJ mol^{-1}

NEET 2017 · Q24

8. For a given reaction, $\Delta H = 35.5 \text{ kJ mol}^{-1}$ and $\Delta S = 83.6 \text{ J K}^{-1} \text{ mol}^{-1}$. The reaction is spontaneous at: (Assume that ΔH and ΔS do not vary with temperature)

- (A) $T < 425 \text{ K}$
- (B) $T > 425 \text{ K}$
- (C) all temperatures
- (D) $T > 298 \text{ K}$

NEET 2017 (Gujarati paper) · Q12

9. Of the following, the largest value of entropy at 25°C and 1 atm is that of:

- (A) H_2
- (B) C_2H_6
- (C) C_2H_2
- (D) CH_4

NEET 2017 (Gujarati paper) · Q31

10. Under isothermal and reversible conditions, the term "free energy" in thermodynamics signifies:

- (A) non-expansion work done by the system
- (B) expansion work done by the system
- (C) non-expansion work done on the system
- (D) expansion work done on the system

NEET 2016 Phase 2 · Q52

11. For a sample of perfect gas when its pressure is changed isothermally from p_i to p_f , the entropy change is given by

- (A) $\Delta S = nR \ln(p_f/p_i)$
- (B) $\Delta S = nR \ln(p_i/p_f)$
- (C) $\Delta S = nRT \ln(p_f/p_i)$
- (D) $\Delta S = RT \ln(p_i/p_f)$

NEET 2016 Phase 1 · Q64

12. The correct thermodynamic conditions for the spontaneous reaction at all temperatures is:

- (A) $\Delta H < 0$ and $\Delta S = 0$
- (B) $\Delta H > 0$ and $\Delta S < 0$
- (C) $\Delta H < 0$ and $\Delta S > 0$
- (D) $\Delta H < 0$ and $\Delta S < 0$

AIPMT 2014

13. For the reaction: $\text{X}_2\text{O}_4(\text{l}) \rightarrow 2\text{XO}_2(\text{g})$, $\Delta U = 2.1 \text{ kcal}$, $\Delta S = 20 \text{ cal K}^{-1}$ at 300 K . Hence, ΔG is:

- (A) -2.7 kcal
- (B) 9.3 kcal
- (C) -9.3 kcal
- (D) 2.7 kcal

AIPMT 2012 Mains

14. Equal volumes of two monoatomic gases, A and B, at same temperature and pressure are mixed. The ratio of specific heats (C_p/C_v) of the mixture will be

- (A) 0.83
- (B) 1.50
- (C) 3.3
- (D) 1.67

AIPMT 2012 Prelims

15. The enthalpy of fusion of water is 1.435 kcal/mol. The molar entropy change for the melting of ice at 0°C is

- (A) 0.526 cal/(mol K)
- (B) 10.52 cal/(mol K)
- (C) 21.04 cal/(mol K)
- (D) 5.260 cal/(mol K)

AIPMT 2012 Prelims

16. In which of the following reactions, standard reaction entropy change (ΔS°) is positive and standard Gibbs energy change (ΔG°) decreases sharply with increasing temperature?

- (A) $(1/2)\text{C}(\text{graphite}) + (1/2)\text{O}_2(\text{g}) \rightarrow (1/2)\text{CO}_2(\text{g})$
- (B) $\text{C}(\text{graphite}) + (1/2)\text{O}_2(\text{g}) \rightarrow \text{CO}(\text{g})$
- (C) $\text{CO}(\text{g}) + (1/2)\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g})$
- (D) $\text{Mg}(\text{s}) + (1/2)\text{O}_2(\text{g}) \rightarrow \text{MgO}(\text{s})$

AIPMT 2012 Prelims

17. Standard enthalpy of vapourisation $\Delta_{\text{vap}}H^\circ$ for water at 100°C is 40.66 kJ mol⁻¹. The internal energy of vapourisation of water at 100°C (in kJ mol⁻¹) is

- (A) +40.66
- (B) +37.56
- (C) -43.76
- (D) +43.76

AIPMT 2011 Mains

18. Consider the following processes:

$(1/2)\text{A} \rightarrow \text{B}; \Delta H = +150 \text{ kJ/mol}$

$3\text{B} \rightarrow 2\text{C} + \text{D}; \Delta H = -125 \text{ kJ/mol}$

$\text{E} + \text{A} \rightarrow 2\text{D}; \Delta H = +350 \text{ kJ/mol}$

For $\text{B} + \text{D} \rightarrow \text{E} + 2\text{C}$, ΔH will be

- (A) -325 kJ/mol
- (B) 325 kJ/mol
- (C) 525 kJ/mol
- (D) -175 kJ/mol

AIPMT 2011 Prelims

19. Which of the following is correct option for free expansion of an ideal gas under adiabatic condition?

- (A) $q = 0, \Delta T < 0, w \neq 0$
- (B) $q = 0, \Delta T \neq 0, w = 0$
- (C) $q \neq 0, \Delta T = 0, w = 0$
- (D) $q = 0, \Delta T = 0, w = 0$

AIPMT 2011 Prelims

20. If the enthalpy change for the transition of liquid water to steam is 30 kJ mol⁻¹ at 27°C, the entropy change for the process would be

- (A) 100 J mol⁻¹ K⁻¹
- (B) 10 J mol⁻¹ K⁻¹
- (C) 1.0 J mol⁻¹ K⁻¹
- (D) 0.1 J mol⁻¹ K⁻¹

21. Enthalpy change for the reaction, $4\text{H(g)} \rightarrow 2\text{H}_2\text{(g)}$ is -869.6 kJ. The dissociation energy of H-H bond is

- (A) $+217.4$ kJ
- (B) -434.8 kJ
- (C) -869.6 kJ
- (D) $+434.8$ kJ

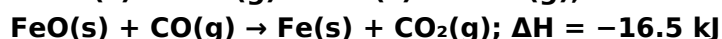
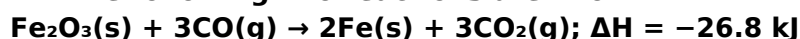
22. Three moles of an ideal gas expanded spontaneously into vacuum. The work done will be

- (A) Infinite
- (B) 3 Joules
- (C) 9 Joules
- (D) Zero

23. For vaporization of water at 1 atmospheric pressure, the values of ΔH and ΔS are 40.63 kJ mol $^{-1}$ and 108.8 J K $^{-1}$ mol $^{-1}$, respectively. The temperature when Gibbs energy change (ΔG) for this transformation will be zero, is

- (A) 273.4 K
- (B) 393.4 K
- (C) 373.4 K
- (D) 293.4 K

24. The following two reactions are known:



The value of ΔH for the following reaction $\text{Fe}_2\text{O}_3(\text{s}) + \text{CO}(\text{g}) \rightarrow 2\text{FeO}(\text{s}) + \text{CO}_2(\text{g})$ is

- (A) $+10.3$ kJ
- (B) -43.3 kJ
- (C) -10.3 kJ
- (D) $+6.2$ kJ

25. Standard entropies of X_2 , Y_2 and XY_3 are 60, 40 and 50 J K $^{-1}$ mol $^{-1}$ respectively. For the reaction $(1/2)\text{X}_2 + (3/2)\text{Y}_2 \rightleftharpoons \text{XY}_3$, $\Delta H = -30$ kJ to be at equilibrium, the temperature should be

- (A) 500 K
- (B) 750 K
- (C) 1000 K
- (D) 1250 K

26. The values of ΔH and ΔS for the reaction, $\text{C}(\text{graphite}) + \text{CO}_2(\text{g}) \rightarrow 2\text{CO}(\text{g})$ are 170 kJ and 170 J K $^{-1}$, respectively. This reaction will be spontaneous at:

- (A) 910 K
- (B) 1110 K
- (C) 510 K
- (D) 710 K

27. From the following bond energies:

H-H bond energy: 431.37 kJ mol⁻¹

C=C bond energy: 606.10 kJ mol⁻¹

C-C bond energy: 336.49 kJ mol⁻¹

C-H bond energy: 410.50 kJ mol⁻¹

Enthalpy for the reaction $\text{H}_2\text{C}=\text{CH}_2 + \text{H}-\text{H} \rightarrow \text{H}_3\text{C}-\text{CH}_3$ will be:

- (A) -243.6 kJ mol⁻¹
- (B) -120.0 kJ mol⁻¹
- (C) 553.0 kJ mol⁻¹
- (D) 1523.6 kJ mol⁻¹

28. Which of the following are not state functions?

(I) q + w

(II) q

(III) w

(IV) H - TS

- (A) (II) and (III)
- (B) (I) and (IV)
- (C) (II), (III) and (IV)
- (D) (I), (II) and (III)

29. Bond dissociation enthalpy of H_2 , Cl_2 and HCl are 434, 242 and 431 kJ mol⁻¹ respectively. Enthalpy of formation of HCl is

- (A) 245 kJ mol⁻¹
- (B) 93 kJ mol⁻¹
- (C) -245 kJ mol⁻¹
- (D) -93 kJ mol⁻¹

30. For the gas phase reaction, $\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$, which of the following conditions is correct?

- (A) $\Delta H > 0$ and $\Delta S < 0$
- (B) $\Delta H = 0$ and $\Delta S < 0$
- (C) $\Delta H > 0$ and $\Delta S > 0$
- (D) $\Delta H < 0$ and $\Delta S < 0$

31. Consider the following reactions:

(i) $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) = \text{H}_2\text{O}(\text{l})$, $\Delta H = -X_1$ kJ mol⁻¹

(ii) $\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) = \text{H}_2\text{O}(\text{l})$, $\Delta H = -X_2$ kJ mol⁻¹

(iii) $\text{CO}_2(\text{g}) + \text{H}_2(\text{g}) = \text{CO}(\text{g}) + \text{H}_2\text{O}$, $\Delta H = -X_3$ kJ mol⁻¹

(iv) $\text{C}_2\text{H}_2(\text{g}) + (5/2)\text{O}_2(\text{g}) = 2\text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$, $\Delta H = -X_4$ kJ mol⁻¹

Enthalpy of formation of $\text{H}_2\text{O}(\text{l})$ is

- (A) $+X_3$ kJ mol⁻¹
- (B) $-X_4$ kJ mol⁻¹
- (C) $+X_1$ kJ mol⁻¹
- (D) $-X_2$ kJ mol⁻¹

32. Given that bond energies of H-H and Cl-Cl are 430 kJ mol^{-1} and 240 kJ mol^{-1} respectively and ΔH_f for HCl is -90 kJ mol^{-1} , bond enthalpy of HCl is

- (A) 380 kJ mol^{-1}
- (B) 425 kJ mol^{-1}
- (C) 245 kJ mol^{-1}
- (D) 290 kJ mol^{-1}

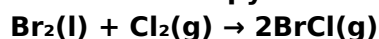
33. Identify the correct statement for change of Gibbs energy for a system (ΔG_{system}) at constant temperature and pressure :

- (A) If $\Delta G_{\text{system}} > 0$, the process is spontaneous
- (B) If $\Delta G_{\text{system}} = 0$, the system has attained equilibrium
- (C) If $\Delta G_{\text{system}} = 0$, the system is still moving in a particular direction
- (D) If $\Delta G_{\text{system}} < 0$, the process is not spontaneous

34. Assume each reaction is carried out in an open container. For which reaction will $\Delta H = \Delta E$?

- (A) $\text{H}_2(\text{g}) + \text{Br}_2(\text{g}) \rightarrow 2\text{HBr}(\text{g})$
- (B) $\text{C}(\text{s}) + 2\text{H}_2\text{O}(\text{g}) \rightarrow 2\text{H}_2(\text{g}) + \text{CO}_2(\text{g})$
- (C) $\text{PCl}_5(\text{g}) \rightarrow \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$
- (D) $2\text{CO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g})$

35. The enthalpy and entropy change for the reaction :



are 30 kJ mol^{-1} and $105 \text{ J K}^{-1} \text{ mol}^{-1}$ respectively. The temperature at which the reaction will be in equilibrium is :

- (A) 285.7 K
- (B) 373 K
- (C) 250 K
- (D) 400 K

36. The enthalpy of combustion of H_2 , cyclohexene (C_6H_{10}) and cyclohexane (C_6H_{12}) are -241 , -3800 and -3920 kJ per mol respectively. Heat of hydrogenation of cyclohexene is :

- (A) -121 kJ per mol
- (B) $+121 \text{ kJ per mol}$
- (C) $+484 \text{ kJ per mol}$
- (D) -484 kJ per mol

37. A reaction occurs spontaneously if :

- (A) $T\Delta S < \Delta H$ and both ΔH and ΔS are +ve
- (B) $T\Delta S > \Delta H$ and both ΔH and ΔS are +ve
- (C) $T\Delta S = \Delta H$ and both ΔH and ΔS are +ve
- (D) $T\Delta S > \Delta H$ and ΔH is +ve and ΔS is -ve

38. Which of the following pairs of a chemical reaction is certain to result in a spontaneous reaction ?

- (A) Exothermic and decreasing disorder
- (B) Endothermic and increasing disorder
- (C) Exothermic and increasing disorder
- (D) Endothermic and decreasing disorder

Answer key and explanations

1. Answer: (B) $C_p - C_v = R$

For one mole of an ideal gas, C_p exceeds C_v by the work done in expansion at constant pressure, which is R per kelvin. So Mayer's relation is $C_p - C_v = R$; a product relation like $C_p = RC_v$ is dimensionally inconsistent.

2. Answer: (C) $\Delta U = 0$, $\Delta S(\text{total}) \neq 0$

For an ideal gas, internal energy depends only on temperature, so $\Delta U = 0$ in any isothermal process. An irreversible process always increases the total entropy of system + surroundings, so $\Delta S(\text{total}) > 0$. $\Delta S(\text{total}) = 0$ holds only for a reversible process.

3. Answer: (A) $-8.314 \text{ J mol}^{-1}\text{K}^{-1} \times 300 \text{ K} \times \ln(2 \times 10^{13})$

$\Delta_r G^\circ = -RT \ln K$, so with $K = 2 \times 10^{13}$ at 300 K, $\Delta_r G^\circ = -8.314 \times 300 \times \ln(2 \times 10^{13}) \text{ J mol}^{-1}$, a large negative value as expected for $K \gg 1$. The same expression without the minus sign would make a reaction with a huge K non-spontaneous, which is wrong.

4. Answer: (A) $q = 0$, $\Delta T = 0$ and $w = 0$

In free expansion the gas expands into vacuum, so no work is done ($w = 0$), and the adiabatic condition gives $q = 0$. Then $\Delta U = 0$, and since the internal energy of an ideal gas depends only on temperature, $\Delta T = 0$. A temperature drop would need work done by the gas against an external pressure, which is absent here.

5. Answer: (D) $\Delta_r H < 0$ and $\Delta_r S < 0$

Forming a Cl-Cl bond releases energy, so $\Delta_r H < 0$, and two gaseous particles become one, so disorder falls and $\Delta_r S < 0$. A positive enthalpy change would correspond to bond breaking, the reverse process.

6. Answer: (D) $2\text{H(g)} \rightarrow \text{H}_2\text{(g)}$

Combining two gaseous atoms into one molecule reduces the number of particles and hence disorder, so $\Delta S < 0$. Evaporation, sublimation and isothermal expansion all increase entropy.

7. Answer: (A) 800 kJ mol^{-1}

Let $\text{BE}(\text{X}_2) = a$, $\text{BE}(\text{Y}_2) = 0.5a$, $\text{BE}(\text{XY}) = a$. For $\frac{1}{2}\text{X}_2 + \frac{1}{2}\text{Y}_2 \rightarrow \text{XY}$: $\Delta H = \frac{1}{2}a + \frac{1}{2}a - a = -a/4 = -200$, so $a = 800 \text{ kJ mol}^{-1}$. Forgetting the $\frac{1}{2}$ coefficients (forming 2XY) gives 400 kJ mol^{-1} .

8. Answer: (B) $T > 425 \text{ K}$

$\Delta G = \Delta H - T\Delta S$ is negative when $T > \Delta H/\Delta S = 35500 / 83.6 \approx 425 \text{ K}$. Both ΔH and ΔS are positive, so the reaction is non-spontaneous at low temperature and becomes spontaneous only above 425 K; it is not spontaneous at all temperatures.

9. Answer: (B) C_2H_6

Standard molar entropy rises with molar mass and the number of atoms (more vibrational and rotational freedom). C_2H_6 (about $229 \text{ J K}^{-1} \text{ mol}^{-1}$) exceeds C_2H_2 (about 201), CH_4 (about 186) and H_2 (about 131).

10. Answer: (A) non-expansion work done by the system

At constant temperature and pressure for a reversible change, $-\Delta G$ equals the maximum useful (non-expansion) work the system can do, such as electrical work in a cell. Expansion (PV) work is already accounted for in the enthalpy term and is not what ΔG measures.

11. Answer: (B) $\Delta S = nR \ln(p_i/p_f)$

For an isothermal reversible change $\Delta S = q_{\text{rev}}/T = nR \ln(V_f/V_i)$, and at constant T , $V_f/V_i = p_i/p_f$, so $\Delta S = nR \ln(p_i/p_f)$. Expressions containing T have units of energy, not entropy, and the ratio p_f/p_i has the wrong sign.

12. Answer: (C) $\Delta H < 0$ and $\Delta S > 0$

$\Delta G = \Delta H - T\Delta S$. With $\Delta H < 0$ and $\Delta S > 0$, both terms make ΔG negative at every temperature. If $\Delta S < 0$, the $-T\Delta S$ term becomes positive and the reaction stops being spontaneous at high temperature.

13. Answer: (A) -2.7 kcal

$\Delta n(g) = 2$, so $\Delta H = \Delta U + \Delta nRT = 2.1 + 2 \times 1.987 \times 10^{-3} \times 300 \approx 3.3 \text{ kcal}$. $\Delta G = \Delta H - T\Delta S = 3.3 - 300 \times 0.020 = -2.7 \text{ kcal}$; using ΔU directly would give -3.9 kcal .

14. Answer: (D) 1.67

For any monoatomic ideal gas $C_v = (3/2)R$ and $C_p = (5/2)R$, so a mixture of two monoatomic gases still has $C_p/C_v = 5/3 \approx 1.67$. 1.50 is not the value for any simple ideal gas, and values below 1 are impossible.

15. Answer: (D) $5.260 \text{ cal/(mol K)}$

$\Delta S_{\text{fus}} = \Delta H_{\text{fus}}/T = 1435 \text{ cal mol}^{-1}/273 \text{ K} = 5.26 \text{ cal mol}^{-1} \text{ K}^{-1}$. 0.526 results from a misplaced decimal and 10.52 from doubling.

16. Answer: (B) $\text{C}(\text{graphite}) + (1/2)\text{O}_2(\text{g}) \rightarrow \text{CO}(\text{g})$

In $\text{C}(\text{graphite}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{CO}(\text{g})$, gaseous moles increase from $\frac{1}{2}$ to 1, so ΔS° is clearly positive and $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ falls steeply as T rises. Forming CO_2 from C keeps gas moles unchanged ($\Delta S^\circ \approx 0$), while $\text{CO} \rightarrow \text{CO}_2$ and $\text{Mg} \rightarrow \text{MgO}$ decrease gas moles ($\Delta S^\circ < 0$).

17. Answer: (B) +37.56

For $\text{H}_2\text{O}(\text{l}) \rightarrow \text{H}_2\text{O}(\text{g})$, $\Delta n_g = 1$. $\Delta U = \Delta H - \Delta n_g RT = 40.66 - (8.314 \times 10^{-3} \times 373) = 40.66 - 3.10 = 37.56 \text{ kJ mol}^{-1}$. 43.76 comes from adding RT instead of subtracting it.

18. Answer: (D) -175 kJ/mol

Double the first equation ($\text{A} \rightarrow 2\text{B}$, +300), add the second ($3\text{B} \rightarrow 2\text{C} + \text{D}$, -125) and reverse the third ($2\text{D} \rightarrow \text{E} + \text{A}$, -350). Adding gives $\text{B} + \text{D} \rightarrow \text{E} + 2\text{C}$ with $\Delta H = 300 - 125 - 350 = -175 \text{ kJ/mol}$.

Forgetting to double the first equation leads to -325 kJ/mol.

19. Answer: (D) $q = 0$, $\Delta T = 0$, $w = 0$

In free expansion into vacuum, no work is done ($w = 0$) and in adiabatic conditions $q = 0$. Thus $\Delta U = 0$, and for an ideal gas U depends only on T, so $\Delta T = 0$ as well. A temperature drop would occur only for a real gas or reversible adiabatic expansion.

20. Answer: (A) $100 \text{ J mol}^{-1} \text{ K}^{-1}$

At the transition temperature $\Delta S = \Delta H/T = 30000 \text{ J mol}^{-1}/300 \text{ K} = 100 \text{ J mol}^{-1} \text{ K}^{-1}$. Forgetting to convert kJ to J gives 0.1, the trap.

21. Answer: (D) +434.8 kJ

$4\text{H}(\text{g}) \rightarrow 2\text{H}_2(\text{g})$ forms two H-H bonds and releases 869.6 kJ. Breaking one mole of H-H bonds therefore needs $869.6/2 = +434.8 \text{ kJ}$. Dissociation energy is always positive, so the negative values are wrong.

22. Answer: (D) Zero

Work in expansion is $w = -p(\text{ext})\Delta V$, and for free expansion into vacuum $p(\text{ext}) = 0$, so no work is done whatever the number of moles. Values like 3 J or 9 J wrongly link the work to the amount of gas.

23. Answer: (C) 373.4 K

$\Delta G = \Delta H - T\Delta S = 0$ gives $T = \Delta H/\Delta S = 40630/108.8 = 373.4 \text{ K}$. Forgetting to convert kJ to J (or mixing units) gives nonsensical values; 373 K is also the normal boiling point of water, as expected.

24. Answer: (D) +6.2 kJ

Target = (first equation) - 2 × (second equation): $\text{Fe}_2\text{O}_3 + 3\text{CO} - 2\text{FeO} - 2\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2 - 2\text{Fe} - 2\text{CO}_2$, i.e. $\text{Fe}_2\text{O}_3 + \text{CO} \rightarrow 2\text{FeO} + \text{CO}_2$. $\Delta H = -26.8 - 2(-16.5) = -26.8 + 33.0 = +6.2 \text{ kJ}$. -10.3 kJ comes from subtracting the second equation only once.

25. Answer: (B) 750 K

$\Delta S^\circ = 50 - (\frac{1}{2} \times 60 + \frac{3}{2} \times 40) = 50 - 90 = -40 \text{ J K}^{-1} \text{ mol}^{-1}$. At equilibrium $\Delta G = 0$, so $T = \Delta H/\Delta S = (-30000)/(-40) = 750 \text{ K}$. Forgetting the stoichiometric halves gives a different ΔS and a wrong T.

26. Answer: (B) 1110 K

$\Delta G = \Delta H - T\Delta S$ becomes negative when $T > \Delta H/\Delta S = 170000 \text{ J}/170 \text{ J K}^{-1} = 1000 \text{ K}$. Only 1110 K is above 1000 K. Remember to convert kJ to J before dividing.

27. Answer: (B) -120.0 kJ mol⁻¹

$\Delta H = \text{bonds broken} - \text{bonds formed} = [\text{BE}(\text{C}=\text{C}) + \text{BE}(\text{H}-\text{H})] - [\text{BE}(\text{C}-\text{C}) + 2\text{BE}(\text{C}-\text{H})] = (606.10 + 431.37) - (336.49 + 821.00) = -120.0 \text{ kJ mol}^{-1}$. The four C-H bonds common to both sides cancel out.

28. Answer: (A) (II) and (III)

Heat q and work w depend on the path, so they are not state functions. Their sum q + w equals ΔU , and $H - TS$ is the Gibbs energy G; both depend only on the state. So only q and w are not state functions.

29. Answer: (D) -93 kJ mol⁻¹

For $\frac{1}{2}\text{H}_2 + \frac{1}{2}\text{Cl}_2 \rightarrow \text{HCl}$, $\Delta H_f = \frac{1}{2}(434) + \frac{1}{2}(242) - 431 = 338 - 431 = -93 \text{ kJ mol}^{-1}$. The ± 245 values come from using the full bond enthalpies of H_2 and Cl_2 with only one H-Cl bond ($434 + 242 - 431 = 245$); that equation actually forms 2 mol HCl.

30. Answer: (C) $\Delta H > 0$ and $\Delta S > 0$

Dissociation of PCl_5 breaks P-Cl bonds, so it absorbs heat ($\Delta H > 0$). One mole of gas gives two moles of gas, so disorder increases ($\Delta S > 0$). A negative ΔS would require fewer gas molecules on the product side.

31. Answer: (D) $-X_2 \text{ kJ mol}^{-1}$

Enthalpy of formation is for forming 1 mol of the compound from elements in their standard states: $\text{H}_2(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$, $\Delta H = -X_2$. The neutralisation enthalpy $-X_1$ does not start from elements.

32. Answer: (B) 425 kJ mol⁻¹

$\frac{1}{2}\text{H}_2 + \frac{1}{2}\text{Cl}_2 \rightarrow \text{HCl}$: $\Delta H_f = \frac{1}{2}(430) + \frac{1}{2}(240) - x = -90$, so $x = 335 + 90 = 425 \text{ kJ mol}^{-1}$. 245 kJ mol⁻¹ subtracts the 90 instead of adding it.

33. Answer: (B) If $\Delta G_{\text{system}} = 0$, the system has attained equilibrium

At constant temperature and pressure $\Delta G < 0$ means spontaneous, $\Delta G > 0$ means non-spontaneous, and $\Delta G = 0$ means the system is at equilibrium. So $\Delta G = 0$ marks equilibrium, with no net change in any direction. The other statements reverse these signs.

34. Answer: (A) $\text{H}_2(\text{g}) + \text{Br}_2(\text{g}) \rightarrow 2\text{HBr}(\text{g})$

$\Delta H = \Delta E + \Delta n_g RT$, so $\Delta H = \Delta E$ only when the number of moles of gas is unchanged. For $\text{H}_2 + \text{Br}_2 \rightarrow 2\text{HBr}$, $\Delta n_g = 2 - 2 = 0$. The water-gas reaction and the PCl_5 decomposition have $\Delta n_g = +1$, and the CO combustion has $\Delta n_g = -1$.

35. Answer: (A) 285.7 K

At equilibrium $\Delta G = \Delta H - T\Delta S = 0$, so $T = \Delta H/\Delta S = 30\,000 \text{ J mol}^{-1}/105 \text{ J K}^{-1} \text{ mol}^{-1} = 285.7 \text{ K}$. Forgetting to convert kJ to J gives a meaningless 0.29 K.

36. Answer: (A) -121 kJ per mol

For $\text{C}_6\text{H}_{10} + \text{H}_2 \rightarrow \text{C}_6\text{H}_{12}$, $\Delta H = \sum \Delta_c H(\text{reactants}) - \sum \Delta_c H(\text{products}) = (-3800 - 241) - (-3920) = -121 \text{ kJ mol}^{-1}$. Reversing the subtraction gives +121 kJ mol⁻¹, but hydrogenation of an alkene is exothermic.

37. Answer: (B) $T\Delta S > \Delta H$ and both ΔH and ΔS are +ve

$\Delta G = \Delta H - T\Delta S$. When ΔH and ΔS are both positive, $\Delta G < 0$ only when $T\Delta S > \Delta H$. With ΔH positive and ΔS negative, ΔG is always positive.

38. Answer: (C) Exothermic and increasing disorder

With $\Delta H < 0$ (exothermic) and $\Delta S > 0$ (increasing disorder), $\Delta G = \Delta H - T\Delta S$ is negative at every temperature. The other combinations are spontaneous only in some temperature range or never.

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