07 Chemical Energetics II

Set B Exam practice

Name	Time 1 hour	Total 26 marks	Score ____ / 26

A Data Booklet may be used.

Marks by notes section For the marker: total each row. A score below the target means that section of the notes needs revising.

Notes section	Questions	Marks	Target	Score
6 Hydration and Solution	6(a), 6(b)	3	2	
8 Factors Affecting Entropy	1, 4, 5(a), 6(c), 7	6	4	
9 Gibbs Free Energy	3, 5(b), 9(a), 10	10	6	
10 Effect of Temperature on Spontaneity	2, 8, 9(b)	7	5	

A Multiple choice

4 MARKS

1 COMMON Which of the following reactions has a negative ΔS?

A Heating solid calcium carbonate.

B Sublimation of solid carbon dioxide.

C Rusting of an iron bar to form iron(III) oxide.

D Reaction between aqueous sodium hydroxide and aqueous ammonium chloride.

Answer ☐ [1]

/1

Source: HCI 2018 Promo, via EJC 2022 Chemical Energetics Topical Revision, Q16

2 Which of the following processes is spontaneous under all conditions?

A $N_2O(g) \rightarrow N_2(g) + \frac{1}{2}O_2(g)$ $\Delta H = -82$ kJ mol^{-1}

B $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ $\Delta H = -890$ kJ mol^{-1}

C $2CO(g) + 2NH_3(g) \rightarrow C_2H_6(g) + 2NO(g)$ $\Delta H = +409$ kJ mol^{-1}

D $SO_3(g) \rightarrow SO_2(g) + \frac{1}{2}O_2(g)$ $\Delta H = +99.0$ kJ mol^{-1}

Answer ☐ [1]

/1

Source: CJC 2018 Promo, via EJC 2022 Chemical Energetics Topical Revision, Q18

3 Instant cold packs are composed of powdered ammonium nitrate and water separated by a thin plastic membrane. When the pack is squeezed, the membrane breaks and the ammonium nitrate dissolves in the water. $NH_4NO_3(s) + nH_2O(l) \rightarrow NH_4NO_3(aq)$

Which line in the table gives the signs of ΔH, ΔS and ΔG for the overall process?

	ΔH	ΔS	ΔG
A	–	–	+
B	–	+	–
C	+	+	–
D	+	+	+

Answer ☐ [1]

/1

Source: A Level 2008 P1 Q10, via EJC 2022 JC1 Chemical Energetics Tutorial, A7

4 COMMON When water freezes, 6.0 kJ mol^{-1} of heat is evolved. What is the entropy change when 54 g of water freezes at 0 °C?

A $-66\ J\ K^{-1}\ mol^{-1}$ **B** $-22\ J\ K^{-1}\ mol^{-1}$ **C** $22\ J\ K^{-1}\ mol^{-1}$ **D** $66\ J\ K^{-1}\ mol^{-1}$

Answer ☐ [1]

/1

Source: A Level 2009 P1 Q10, via EJC 2022 JC1 Chemical Energetics Tutorial, A8

B Structured questions

22 MARKS

5 The reaction of 2,2-dimethylhydrazine, $(CH_3)_2N_2H_2$, with dinitrogen tetroxide, N_2O_4, is an energy source for rockets.

$$(CH_3)_2N_2H_2(l) + 2N_2O_4(l) \rightarrow 2CO_2(g) + 3N_2(g) + 4H_2O(g) \quad \Delta S^{\ominus} = +1141.2\ J\ K^{-1}\ mol^{-1}$$

(a) Dinitrogen tetroxide, N_2O_4, may be obtained from the more commonly available NO_2. State and explain the effect on the entropy, S, of the chemical system during the conversion of $NO_2(g)$ to $N_2O_4(g)$.

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..... **[1]**

(b) By using the standard enthalpy change of formation values given below, calculate the standard Gibbs free energy change, $\Delta G^{\ominus}$, in kJ mol^{-1}, for the reaction of $(CH_3)_2N_2H_2$ with N_2O_4 at 298 K.

substance	$(CH_3)_2N_2H_2(l)$	$N_2O_4(l)$	$CO_2(g)$	$H_2O(g)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	+48.9	−19.6	−393.5	−241.8

[3]

/4

Source: 2025 CJC J2 Prelim P2 Q1(b)

6 Calcium hydroxide is produced commercially by treating lime (calcium oxide) with water. The following are some thermochemistry data.

	ΔH / kJ mol^{-1}
enthalpy change of atomisation of calcium	+178
enthalpy change of $Ca(s) \rightarrow Ca^{2+}(aq) + 2e^-$	+268
enthalpy change of hydration of Ca^{2+} ion	x
enthalpy change of hydration of OH^- ion	−550

(a) Define standard enthalpy change of hydration of calcium ion.

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[1]

(b) Using the data above, and relevant data from the Data Booklet, construct an energy cycle to determine x.

[2]

(c) The entropy change of hydration of the calcium ion is −208 J mol^{-1} K^{-1}. Explain why the sign is negative.

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[1]

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Source: TJC 2017 Promo, via EJC 2022 Chemical Energetics Topical Revision, Q42(i) to (iii)

7 Mercury melts at 234 K with an enthalpy change of melting of +2.3 kJ mol^{-1}. It boils at 630 K with an enthalpy change of vaporisation of +59 kJ mol^{-1}. Calculate the entropy change of the system (per mole of mercury) on

(a) melting

[1]

(b) boiling

[1]

/2

Source: EJC 2022 JC1 Chemical Energetics Tutorial, B11(b)

8 COMMON Give explanations as to whether the following reactions are feasible.

(a) $X(s) \rightarrow Y(s) + Z(g) \quad \Delta H^{\ominus} = +250$ kJ mol^{-1}

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[1]

(b) $2X(g) + Y(g) \rightarrow 2Z(g) \quad \Delta H^{\ominus} = -100$ kJ mol^{-1}

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[1]

(c) $X(l) \rightarrow Y(l) + Z(g) \quad \Delta H^{\ominus} = -200$ kJ mol^{-1}

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[1]

(d) $2X(s) + 2Y(g) \rightarrow Z(g) \quad \Delta H^{\ominus} = +50$ kJ mol^{-1}

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[1]

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Source: RJC H2 Chemistry Tutorial 5b (Chemical Energetics II), Q9

9 The table gives standard free energy changes of formation.

substance	$MgCO_3(s)$	$MgO(s)$	$CO_2(g)$
$\Delta G_f^{\ominus}$ / kJ mol^{-1}	−1012	−569	−394

(a) Use the data to calculate the free energy change, $\Delta G^{\ominus}$, for the reaction $MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$. Will the reaction take place spontaneously?

[2]

(b) Given that $\Delta H^{\ominus}$ of the reaction is +101 kJ mol^{-1} and $\Delta S^{\ominus}$ is +159 J mol^{-1} K^{-1}, estimate the temperature at which the reaction will take place spontaneously.

[2]

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Source: RJC H2 Chemistry Tutorial 5b (Chemical Energetics II), Q6

10 CHALLENGE For each reaction described below, write an equation and explain, by considering the changes in enthalpy (ΔH) and entropy (ΔS_{sys}), why the reaction is spontaneous under standard conditions.

(a) The decomposition of solid nitrogen triiodide, NI_3, to produce $N_2(g)$ and purple vapour is highly exothermic and explosive.

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[2]

(b) The solution cools down when ammonium nitrate crystals are dissolved in water.

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[2]

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Source: RJC H2 Chemistry Tutorial 5b (Chemical Energetics II), Q10(a) and (b)