Entropy and spontaneity [19 marks]

1. [Maximum mark: 1]

What are the signs of $\Delta H^{\ominus}$ and $\Delta S^{\ominus}$ for this reaction that is non-spontaneous at high temperatures and spontaneous at low temperatures?

$\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$

$SO_3(l) + CaO(s) \rightarrow CaSO_4(s)$

	$\Delta H^{\ominus}$	$\Delta S^{\ominus}$
A.	+	+
B.	−	−
C.	−	+
D.	+	−

[1]

2. [Maximum mark: 1]

Which of the following statements is correct for the position of equilibrium of a reaction?

$\Delta G^{\ominus} = -RT\ln K$

I. It will always shift to the right when temperature increases.

II. If $\Delta G^{\ominus} < 0$, then $K > 1$ and products are favoured over reactants.

III. If $\Delta G^{\ominus} = 0$, then $K = 1$ and [reactants] and [products] are approximately equal.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III [1]

3. [Maximum mark: 1]

Which change results in the greatest decrease in entropy?

A. $NaCl\,(s) \rightarrow NaCl\,(aq)$

B. $2NO_2\,(g) \rightarrow N_2O_4\,(g)$

C. $Mg\,(s) + 2HCl\,(aq) \rightarrow MgCl_2\,(aq) + H_2\,(g)$

D. $CH_4\,(g) + H_2O\,(g) \rightarrow CO\,(g) + 3H_2\,(g)$ [1]

4. [Maximum mark: 1]

Which combination is correct for a spontaneous reaction?

	$E^{\ominus}$	$\Delta G^{\ominus}$
A.	positive	positive
B.	positive	negative
C.	negative	positive
D.	negative	negative

[1]

5. [Maximum mark: 1]

Which combination of values of ΔH and ΔS belongs to a reaction which is spontaneous at low temperatures but not spontaneous at high temperatures?

	ΔH	ΔS
A.	Negative	Negative
B.	Negative	Positive
C.	Positive	Positive
D.	Positive	Negative

[1]

6. [Maximum mark: 13]

Carbon disulfide, CS_2, undergoes gas phase hydrolysis according to the overall equation

$$CS_2(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 2H_2S(g)$$

(a.i) Calculate the enthalpy change in this reaction from section 12 of the data booklet and the given values:

	$CS_2(g)$	$H_2S(g)$
$\Delta H_f^{\ominus}$	$+88.7\,kJ\,mol^{-1}$	$-20.6\,kJ\,mol^{-1}$

[2]

(a.ii) Outline why you would expect the entropy change for this reaction to be quite small. [1]

(a.iii) Neglecting any entropy change, use your answer to (a)(i), section 1 and section 2 of the data booklet to estimate the equilibrium constant, K_c, at 500 K.

(If you did not obtain an answer to (a)(i), use a value of $^{-}50.0$ kJ mol^{-1}, although this is not the correct answer.) [2]

(a.iv) The concentrations of the species involved at equilibrium are:

$CS_2(g)$	$H_2O(g)$	$CO_2(g)$	$H_2S(g)$
$0.0400\,mol\,dm^{-3}$	$0.100\,mol\,dm^{-3}$	$x\,mol\,dm^{-3}$	$2x\,mol\,dm^{-3}$

Calculate the numerical value of X, the concentration of carbon dioxide at equilibrium, using your answer from (a)(iii).

[2]

(If you did not obtain an answer to (a)(iii), then use a value of 1.68×10^5, although this is not the correct answer.)

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(b) Deduce the molecular geometries of CS_2 and H_2S, and the reason why they are different.

Molecular geometry CS_2: .....
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Molecular geometry H_2S: .....
.....

Reason for difference: .....
.....

.....
.....

[2]

(c) Sulfur has a number of natural isotopes and a sample of sulfur was enriched in $^{36}_{16}\mathrm{S}$, to produce a mixture with the following composition:

Isotope	Percent
$^{32}_{16}S$	90 %
$^{33}_{16}S$	1 %
$^{34}_{16}S$	4 %
$^{36}_{16}S$	5 %

(c.i) Calculate the relative atomic mass of this enriched sample, correct to two decimal places. [2]

(c.ii) In naturally occurring sulfur, the relative abundance of $^{36}_{16}S$ is only 0.0100 %. Calculate the number of atoms of this isotope that would be present in 1.00 g of natural sulfur. Use sections 2 and 7 of the data booklet. [2]

7. [Maximum mark: 1]

Which changes would increase the rate of an exothermic reaction?

	Temperature	Particle size
A.	Increase	Decrease
B.	Increase	Increase
C.	Decrease	Increase
D.	Decrease	Decrease

[1]