Q1.

Calcium oxide is manufactured by heating limestone at 1000 °C for 30 minutes.

The equation for the reaction is:

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g) \qquad \Delta_r H = +178\,kJ\,mol^{-1}$$

(a) The numerical value of the equilibrium constant for this reaction is increased by:

(1)

☐ **A** allowing the carbon dioxide to escape

☐ **B** increasing the heating time

☐ **C** increasing the temperature

☐ **D** reducing the pressure

(b) Which is the correct expression for the equilibrium constant, K_c, for this reaction?

(1)

☐ **A** $K_c = [CO_2]$

☐ **B** $K_c = \frac{1}{[CO_2]}$

☐ **C** $K_c = \frac{[CaCO_3]}{[CaO][CO_2]}$

☐ **D** $K_c = \frac{[CaO][CO_2]}{[CaCO_3]}$

(Total for question = 2 marks)

Q2.

Iodine was dissolved in an organic solvent, trichloromethane, and the resulting solution added to an equal volume of deionised water. The mixture was then shaken, producing two immiscible solutions: iodine in water and iodine in trichloromethane.

At equilibrium, the equation for the reaction can be written as:

$$I_2(\text{trichloromethane}) \rightleftharpoons I_2(aq)$$

(a) What is the expression for this equilibrium constant, K_c?

(1)

☐ **A** $K_c = \dfrac{[I_2(\text{trichloromethane})]}{[I_2(aq)]}$

☐ **B** $K_c = \dfrac{(I_2(aq))}{(I_2(\text{trichloromethane}))}$

☐ **C** $K_c = \dfrac{I_2(aq)}{I_2(\text{trichloromethane})}$

☐ **D** $K_c = \dfrac{[I_2(aq)]}{[I_2(\text{trichloromethane})]}$

(b) Which statement describes what is happening at equilibrium?

(1)

☐ **A** iodine molecules move from the water to the trichloromethane layer only

☐ **B** iodine molecules move from the trichloromethane to the water layer only

☐ **C** iodine molecules move from the water to the trichloromethane and from the trichloromethane to the water layer.

☐ **D** there is no movement of individual iodine molecules

(Total for question = 2 marks)

Q3.

This question is about the thermodynamics of the reaction:

$$N_2O_4(g) \rightarrow 2NO_2(g) \qquad \Delta H = +57.2\,kJ\,mol^{-1}.$$

Compound	Standard molar entropy at 298 K, $S^{\ominus}$ / J K^{-1} mol^{-1}	Standard molar enthalpy of formation at 298 K, $\Delta_f H^{\ominus}$ / kJ mol^{-1}	Colour
NO_2	+240.0	+33.2	brown
N_2O_4	+304.2		colourless

(a) Calculate the entropy change for the reaction, using the information in the table.

Include a sign and units in your answer.

(2)

(b) Calculate the enthalpy change of formation, $\Delta_f H$, of N_2O_4 (g) at 298 K, using the information in the table and the enthalpy change of the reaction.

Include a sign and units in your answer.

(2)

(c) Calculate the entropy change of the surroundings, $\Delta S_{surroundings}$, at 298 K.

Give your answer to an appropriate number of significant figures.
Include a sign and units in your answer.

(3)

(d) (i) Use your answers to parts (a) and (c) to calculate the total entropy change, ΔS_{total}, for this reaction at 298 K.

(1)

(ii) This reaction can also be written as an equilibrium:

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

Calculate the temperature at which ΔS_{total} is zero for this equilibrium.

(2)

(e) (i) Write the expression for the equilibrium constant, K_p, for this reaction, including the units, if any.

(2)

(ii) In an experiment, 10 mol of $N_2O_4(g)$ was placed in a closed container at 50 °C. At equilibrium, 27% of the $N_2O_4(g)$ had dissociated, and the pressure in the container was 4.0 atm.

Calculate the value of K_p at 50 °C.

(4)

(iii) The total pressure is doubled to 8.0 atm.

State the effect on K_p.

(1)

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(iv) The total pressure is doubled to 8.0 atm at constant temperature.

Explain the change in the percentage dissociation of $N_2O_4(g)$ by considering the effect on the partial pressures of $NO_2(g)$ and $N_2O_4(g)$.

(3)

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(Total for question = 20 marks)