(f) In the laboratory, HI(aq) can be formed in a two-step process.

step 1 $3I_2(s) + 2P(s) \rightarrow 2PI_3(s)$

step 2 $PI_3(s) + 3H_2O(l) \rightarrow H_3PO_3(aq) + 3HI(aq)$

(i) Draw a 'dot-and-cross' diagram of a PI_3 molecule.

[2]

(ii) Name the type of reaction in **step 2**.

.... [1]

(iii) H_3PO_3(aq) and HI(aq) are both strong Brønsted–Lowry acids.

Give the meaning of the term *strong Brønsted–Lowry acid*.

....

....

.... [2]

(iv) Give the formula of the conjugate base of H_3PO_3.

.... [1]

2 NO and NO_2 react at 25 °C to give N_2O_3 as shown in the equation.

$$NO(g) + NO_2(g) \rightleftharpoons N_2O_3(g) \qquad \Delta H = -7.2\,kJ\,mol^{-1}$$

The reaction is reversible and reaches equilibrium in a closed system.

(a) Fig. 2.1 shows how the rate of the forward reaction changes with time.

Initially, the rate of the reverse reaction is zero.

Complete Fig. 2.1 to sketch how the rate of the **reverse** reaction changes with time.

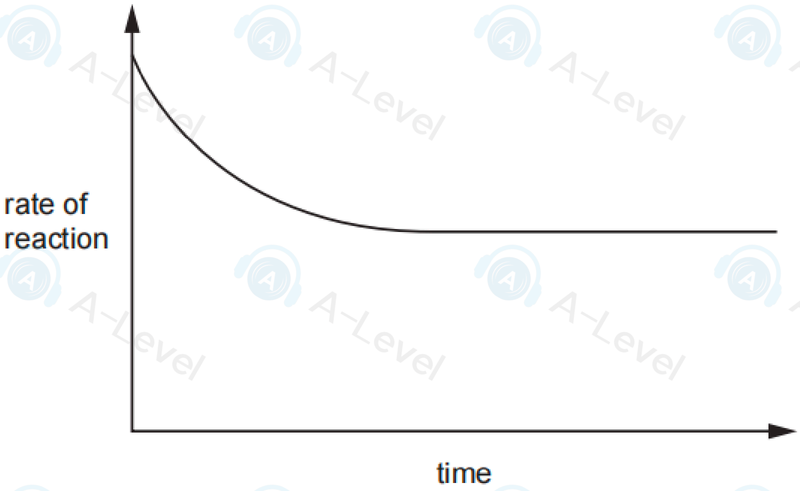

Fig. 2.1

[1]

(b) State how the position of equilibrium changes, if at all, when the reaction takes place at 100 °C.

Explain your answer.

Assume the pressure remains constant.

....

....

....

.... [2]

(c) Table 2.1 shows the composition of an equilibrium mixture of NO(g), NO_2(g) and N_2O_3(g) at 101 kPa.

Table 2.1

gas	number of moles at equilibrium / mol
NO	0.605
NO_2	0.605
N_2O_3	0.390

Calculate K_p, the equilibrium constant with respect to partial pressures.

Deduce the units of K_p.

K_p = ... units ....
[3]

(d) Identify one natural process and one man-made process that cause the formation of atmospheric NO and NO_2.

natural process ....

man-made process ....
[2]

3 (a) Describe what is meant by dynamic equilibrium.

....

....

.... [2]

(b) Reaction 4 describes the reversible reaction between yellow $Fe^{3+}(aq)$ and colourless $SCN^{-}(aq)$ to produce red $FeSCN^{2+}(aq)$.

reaction 4 $\quad Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq)$

yellow colourless red

An equilibrium mixture contains $Fe^{3+}(aq)$, $SCN^{-}(aq)$ and $FeSCN^{2+}(aq)$. A few colourless crystals of soluble KSCN(s) are added. The mixture is then left until it reaches equilibrium again. The temperature of both equilibrium mixtures is the same.

(i) Deduce the changes that occur, if any, in the equilibrium mixture after KSCN(s) is added compared to the original equilibrium mixture.

- change in appearance

 ....

- change in relative concentration of $Fe^{3+}(aq)$

 ....

- change in value of the equilibrium constant, K_c

 ....

[3]

(ii) The expression for the equilibrium constant, K_c, for reaction 4 is shown.

$$K_c = \frac{[FeSCN^{2+}(aq)]}{[Fe^{3+}(aq)] \times [SCN^{-}(aq)]}$$

5.00×10^{-5} mol of $Fe^{3+}(aq)$ and 5.00×10^{-5} mol of $SCN^{-}(aq)$ are added together and allowed to reach equilibrium. The total volume of the mixture is $25.0\,cm^3$.

At equilibrium the concentration of $FeSCN^{2+}(aq)$ is $4.23 \times 10^{-4}\,mol\,dm^{-3}$.

Calculate the equilibrium constant, K_c, for reaction 4.

Include the units in your answer.

K_c = ...

units ....

[4]

(b) Complete Table 1.1 to show the total numbers of protons and electrons in the molecular ions NH_4^+, CO_3^{2-} and PO_4^{3-}.

Table 1.1

molecular ion	total number of protons	total number of electrons
NH_4^+		
CO_3^{2-}		
PO_4^{3-}		

[3]

(c) NH_4^+ is a Brønsted–Lowry acid.

(i) Define Brønsted–Lowry acid.

....

.... [1]

(ii) When $NH_4^+(aq)$ is heated with NaOH(aq), a pungent gas is produced.

Write an ionic equation for this reaction.

.... [1]

3 **(a)** 0.025 mol of HI(g) is added to a closed vessel and left to reach dynamic equilibrium. The total pressure of the vessel is 100 kPa.

equation **1** $2HI(g) \rightleftharpoons H_2(g) + I_2(g)$

(i) Explain what is meant by dynamic equilibrium.

....

....

.... [2]

(ii) Describe **one** difference in the initial appearance of the reaction mixture compared to the mixture at equilibrium.

.... [1]

(iii) Write an expression for K_p for the reaction described in equation **1**.

K_p =

[1]

(iv) At equilibrium the partial pressure of HI(g) is 86.4 kPa.

Calculate the amount of HI(g) present in the mixture at equilibrium. Show your working.

amount of HI(g) = ... mol [2]

(b) Use equation **1** and the bond energy values in Table 3.1 to calculate the change in enthalpy, ΔH, for the thermal decomposition of 1 mole of HI(g). Show your working.

Table 3.1

bond	bond energy / $kJ\,mol^{-1}$
H–H	436
I–I	151
H–I	299

ΔH = ... $kJ\,mol^{-1}$ [2]

(c) Describe the effect of increasing pressure on the value of K_p for the decomposition of HI(g).

.... [1]

(d) HC*l*(g) is prepared by adding NaC*l*(s) to concentrated H_2SO_4.

HI(g) is **not** prepared by adding NaI(s) to concentrated H_2SO_4 because the HI(g) produced also reacts with concentrated H_2SO_4.

(i) Identify the type of reaction that occurs when NaI(s) reacts with concentrated H_2SO_4 to form HI(g).

.... [1]

(ii) Write an equation for the reaction of HI(g) and concentrated H_2SO_4.

.... [1]

(iii) Explain why HI(g) reacts with concentrated H_2SO_4 whereas HC*l* does not.

.... [1]

[Total: 12]