1. Explain what is meant by dynamic equilibrium
   - rate(s) of forward and reverse / backward reactions are equal / are the same
   - no change in measurable properties OR concentration of reactants and products remain constant

2. $2HI(g) \rightleftharpoons H_2(g) + I_2(g)$

   Describe one difference in the initial appearance of the reaction mixture compared to the mixture at equilibrium.
   - (colourless gas) becomes purple (gas)

3.

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

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.

	2HI	H_2	I_2
initial	0.025	0	0
at eq.	$0.025 - x$	$\frac{x}{2}$	$\frac{x}{2}$
change	x	$\frac{x}{2}$	$\frac{x}{2}$

$$\frac{0.025 - x}{0.025 - x + \frac{x}{2} + \frac{x}{2}} \times 100 = 86.4$$

$$\Rightarrow \frac{(0.025 - x)}{0.025} \times 100 = 86.4$$

$$\Rightarrow 0.025 - x = 0.0216 = \text{amount of HI at eq.}$$

4.

When **G**, $C_4H_{10}O$, is heated in a sealed container, an equilibrium mixture is produced.

$$C_4H_{10}O(g) \rightleftharpoons C_2H_6(g) + CO(g) + CH_4(g)$$

(iv) Thermal decomposition of **G** in the presence of I_2 affects the activation energy, E_a, for the reaction. Table 3.2 shows E_a for the thermal decomposition of **G** with and without I_2.

Table 3.2

reaction	E_a (with I_2) / kJ mol^{-1}	E_a / kJ mol^{-1}
$C_4H_{10}O(g) \rightarrow C_2H_6(g) + CO(g) + CH_4(g)$	143	224

State what effect adding I_2 to the reaction mixture has on the value of K_c.
Explain your answer.

- no change / none
- I_2 is a catalyst AND does not affect position of equilibrium; it reduces time taken to reach (same) equilibrium

5.

reaction **2** $S_2Cl_2(l) + Cl_2(g) \rightleftharpoons 2SCl_2(l)$ $\Delta H_r = -40.6\,kJ\,mol^{-1}$

State the effect of a decrease in pressure on the position of equilibrium in reaction 2. Explain your answer.

- equilibrium moves to left AND more moles / molecules of gas on LHS

CAREFUL: pressure only depends on number of gaseous particles. In this case, only Cl2 is gaseous.

6.

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.

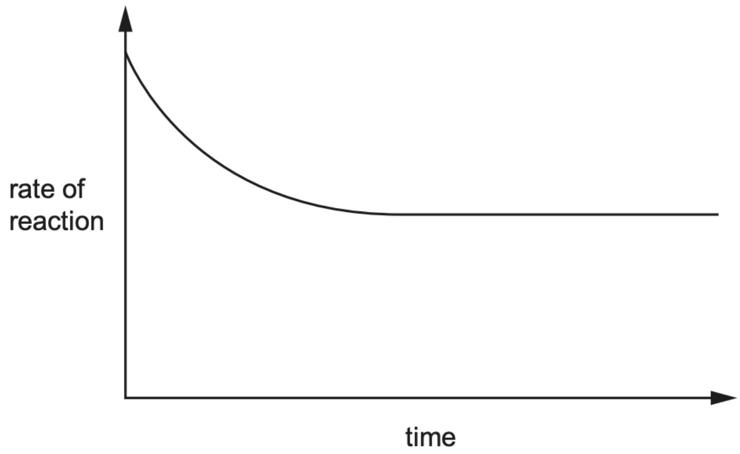

Fig. 2.1

- curved line from (0,0) to reach same horizontal line

7.

In industry, ethanol is made by reacting ethene with steam in the presence of H_3PO_4.

$$\text{reaction 1} \quad C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$$

Reaction 1 reaches equilibrium at constant temperature and pressure.
Deduce what effect increasing the pressure will have on the amount of ethanol in the new equilibrium mixture. Use Le Chatelier's principle to explain your answer.

- effect of increasing pressure: amount ethanol increases
- Explanation: equilibrium shifts right AND to produce fewer moles of gas to reduce the pressure

8.

A sample of HI(g) is added to a 2.00 dm^3 sealed vessel at 764 K and allowed to reach equilibrium.

$$\text{reaction 1} \qquad 2HI(g) \rightleftharpoons H_2(g) + I_2(g) \qquad K_c = 0.0217 \text{ at } 764\,K$$

At equilibrium the mixture contains 1.70 mol of HI(g).

The experiment is repeated at 500K. The value of Kc under these conditions is 0.00625.

a. Describe the difference in the composition of the equilibrium mixture at 500K compared to 764K.
- new mixture will have a lower / smaller conc / amount of H2 and I2

b. Use Le Chatelier's principle to deduce whether the decomposition of HI(g) is endothermic or exothermic. Explain your answer.
- endothermic AND decrease in temperature causes position of equilibrium to shift in exothermic direction

9. Define Le Chatelier's principle
   - if a change in conditions occurs the equilibrium shifts
   - to minimise the change in conditions

10.

In another experiment, equimolar amounts of $Fe^{3+}(aq)$ and $SCN^{-}(aq)$ are mixed together and allowed to reach equilibrium. The total volume of the mixture is 25.0 cm^3.

reaction 1 $$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons FeSCN^{2+}(aq)$$

At equilibrium the mixture contains:

- $[SCN^{-}] = 1.30 \times 10^{-3}$ mol dm^{-3}
- $[FeSCN^{2+}] = 0.300 \times 10^{-3}$ mol dm^{-3}.

(i) Calculate the initial amount, in mol, of $Fe^{3+}(aq)$ added to $SCN^{-}(aq)$ to produce this mixture.

M1 *deduce the concentration of SCN^{-} present in initial mixture*
$[SCN^{-}$ eq'm$]$ = $[Fe^{3+}$ eq'm$]$ = [original SCN^{-}] – [$FeSCN^{2+}$ produced]
$1.30 \times 10^{-3} + 0.300 \times 10^{-3} = 1.60 \times 10^{-3}$ mol dm^{-3}

M2 *find initial amount of Fe^{3+} initially*
M1 $\times$ 25 / 1000 = amount of Fe^{3+} added initially = 4.00×10^{-5} (mol)

11.

N_2(g) reacts with H_2(g) in the Haber process, as shown in reaction 1.

reaction 1 $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H = -x\ kJ\ mol^{-1}$

Table 2.1 shows the different conditions used to produce three equilibrium mixtures, **A**, **B** and **C**.

Table 2.1

	A	**B**	**C**
initial molar ratio of $N_2 : H_2$ added	1 : 3	1 : 3	1 : 3
temperature / °C	500	500	1000
pressure / atm	1000	1000	1000
iron present in mixture	no	yes	no
percentage yield of NH_3(g) at equilibrium	58	x	y

Write an expression for the equilibrium constant, Kp, for reaction 1. State the units.

M1 $K_p = (pNH_3)^2 / (pN_2)(pH_2)^3$
M2 atm^{-2}

REMEMBER to check whether pressure is given in Pa or atm

12. Hydrogen sulfide gas, H2S(g), is slightly soluble in water. It acts as a weak acid in aqueous solution. Give the formula of the conjugate base of H2S.

- HS^-