Equilibrium

Please write what is in the box

Molarity review

- Molarity is a way to express concentration (in mol/L)
- To calculate dilutions we use

  $M_1V_1 = M_2V_2$ (same as $C_1V_1 = C_2V_2$)
- What happens when you dissolve a substance?
  - Ionic bonds dissociate $NaCl_{(s)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$
  - Covalent bonds do not! $ClO_{2\,(g)} \rightarrow ClO_{2\,(aq)}$

Use $M_1V_1 = M_2V_2$ to solve the following dilution problems

1. An experiment requires 200 mL of a 0.2 M solution of KCl. A 0.43 M solution is available. How much should you use?

$$M_1V_1 = M_2V_2$$

(0.2M)(200ml)=0.43M)V_2

V_2 =93 mL of the solution then add water to make 200 mL

2. 72 mL of a 0.02 M solution is mixed with 33 mL of water. What is the concentration of the resulting solution?

$$M_1V_1 = M_2V_2$$

(0.02M)(72ml)=M_2(105) ***105 is from (72+33 because this is the new total)*

M_2 =0.014 M

Use $M_1V_1 = M_2V_2$ to solve the following dilution problems

3. Find the molarity of a solution made using 15g NaI and 125 mL water.

$$\frac{1\ mol\ NaI}{x} = \frac{149.89\ g}{15\ g}$$ x = 0.10 mol NaI

$$\frac{0.10}{0.125L} = \frac{x}{1L}$$ x = 0.80 M

*this proportion is done so that we see what the concentration would be for 1L.

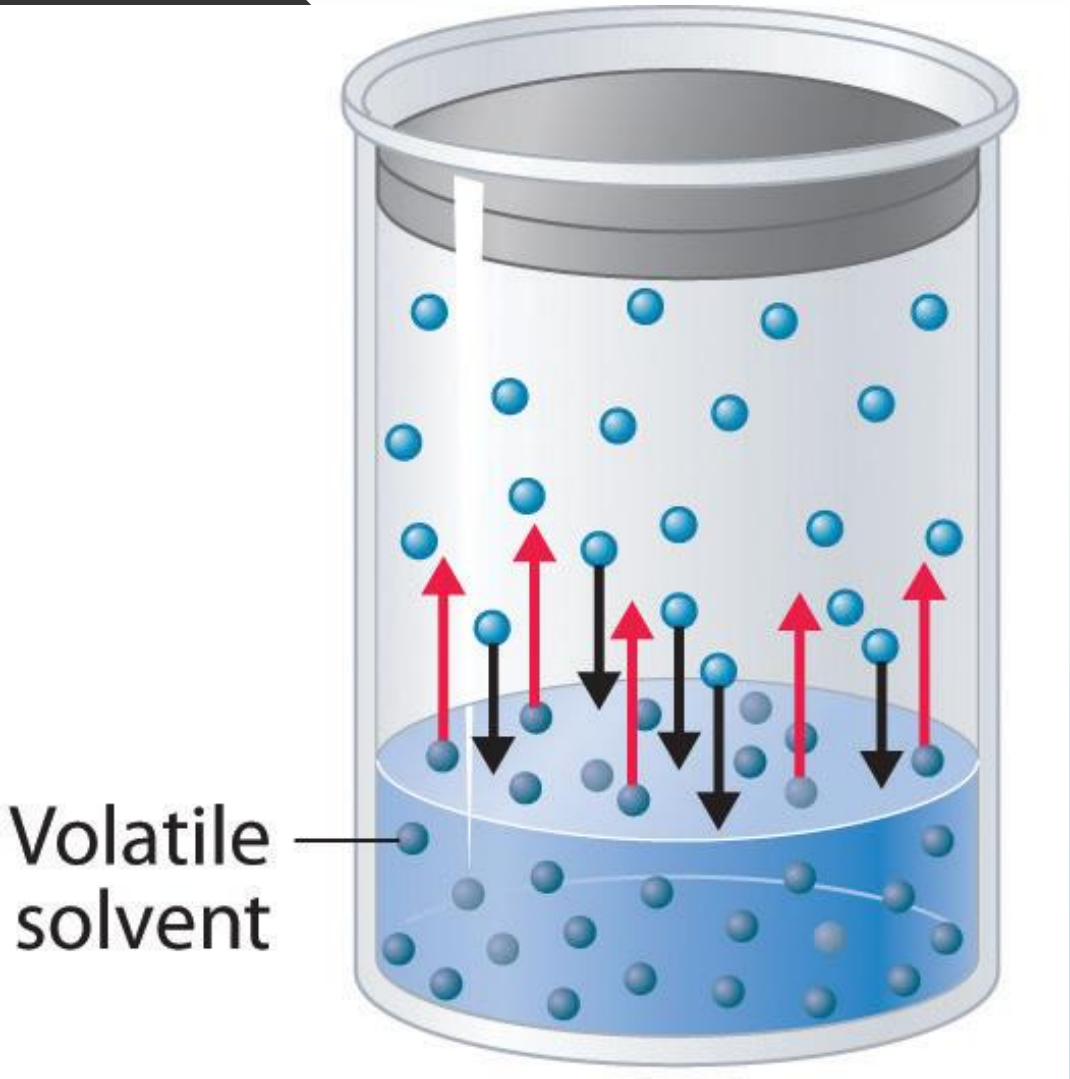
Static vs Dynamic Equilibrium

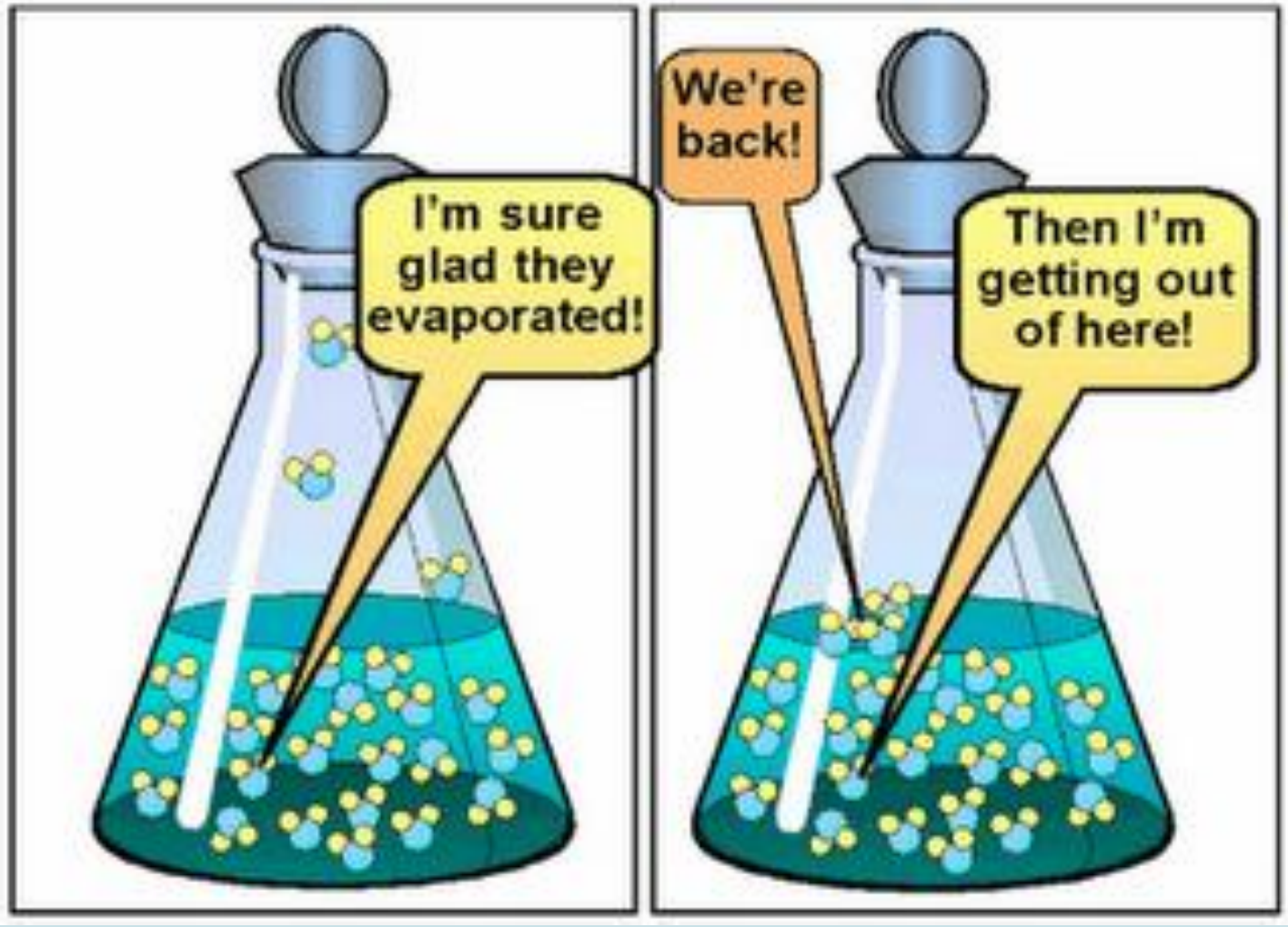
Dynamic Equilibrium

Static Equilibrium

Dynamic involves movement, but not net change in position or quantity.

Chemical Equilibrium





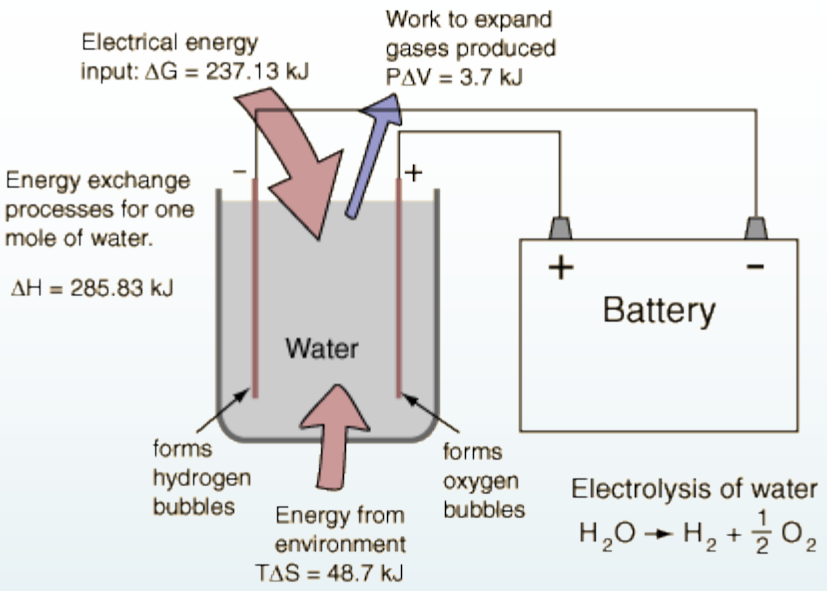
An example of eversible Chemical Reactions used in the car industry.

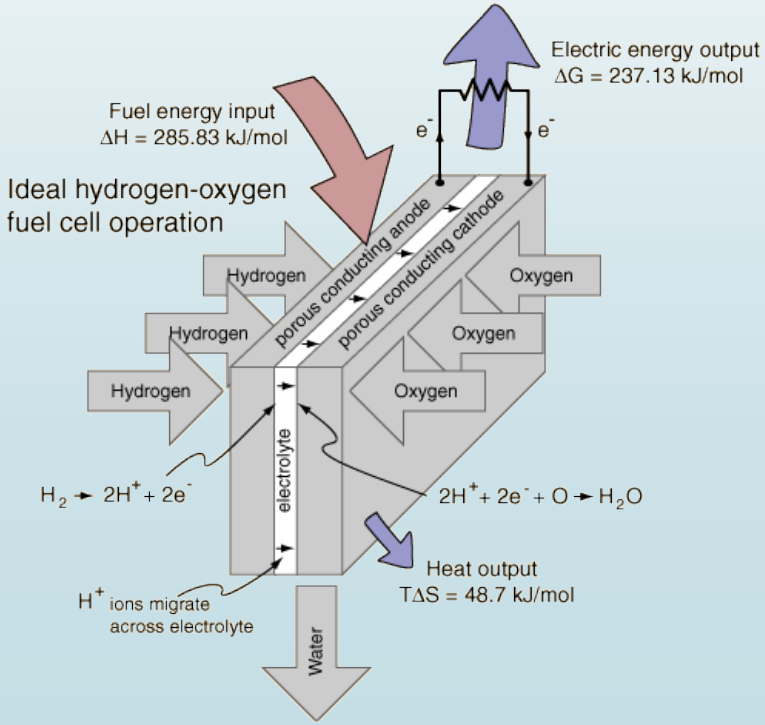
Some reactions are easily reversed using common laboratory procedures.

- H_2O can decompose into H_2 & O_2 in a <u>electrolytic cell</u>, and
- One can synthesize H_2O from H_2 & O_2 in a <u>fuel cell</u>:

$$2H_2O + \text{electrical energy} \rightarrow 2\,H_2 + O_2$$

$$2H_2 + O_2 \rightarrow 2H_2O + \text{electrical energy}$$



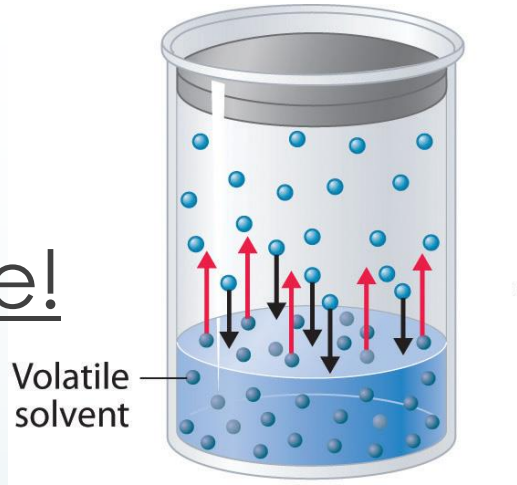


Irreversible Chemical Reactions

Burning a log …

Please write

Chemical Equilibrium:



- In a closed system, some reactions are reversible!

$$A + B \rightleftharpoons AB$$

- The conversion of reactants to products (***forward rxn***) & the conversion of products to reactants (***reverse rxn***) occur simultaneously.
- **Chemical equilibrium** exists when:
  1. There is no observable change in [products] & [reactants].
  2. The rate of forward rxn = rate of the reverse rxn
  3. Only REVERSIBLE reactions can achieve equilibrium.

Work on Molarity review sheet

Please write

Ex. $E + N_2O_{4\,(g)} \rightleftarrows 2\,NO_{2\,(g)}$

At equilibrium **Rate F**
Rate R

equal

Inc. temp. **Rate F**
Rate R

Forward rxn is favoured.
For a time $[N_2O_4]$ will dec. & $[NO_2]$ will inc.

Later **Rate F**
Rate R

As $[NO_2]$ inc. the reverse rate inc. & as $[N_2O_4]$ dec. the forward rate dec.

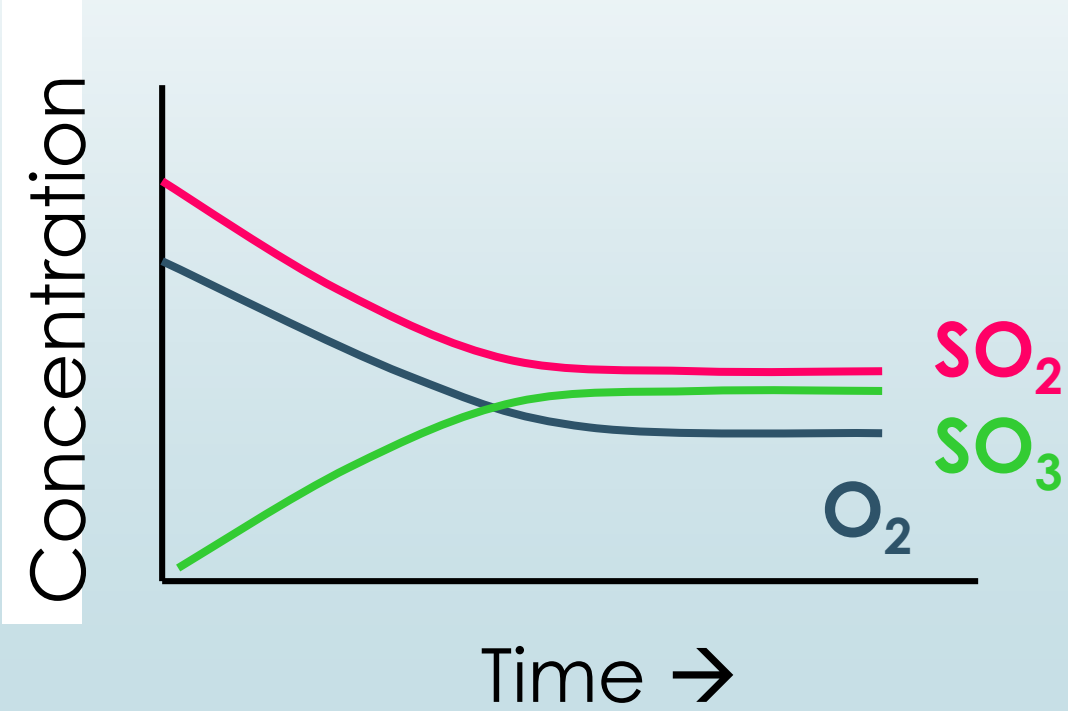
Much later! **Rate F**
Rate R

Eventually a new equilibrium is established

Ex. $2SO_2 + O_2 \leftrightarrow 2SO_3 \quad \Delta H = -197kJ$

Initially: only SO_2 & O_2

At equilibrium: synthesis rate of SO_3 = synthesis rate of SO_2 & O_2

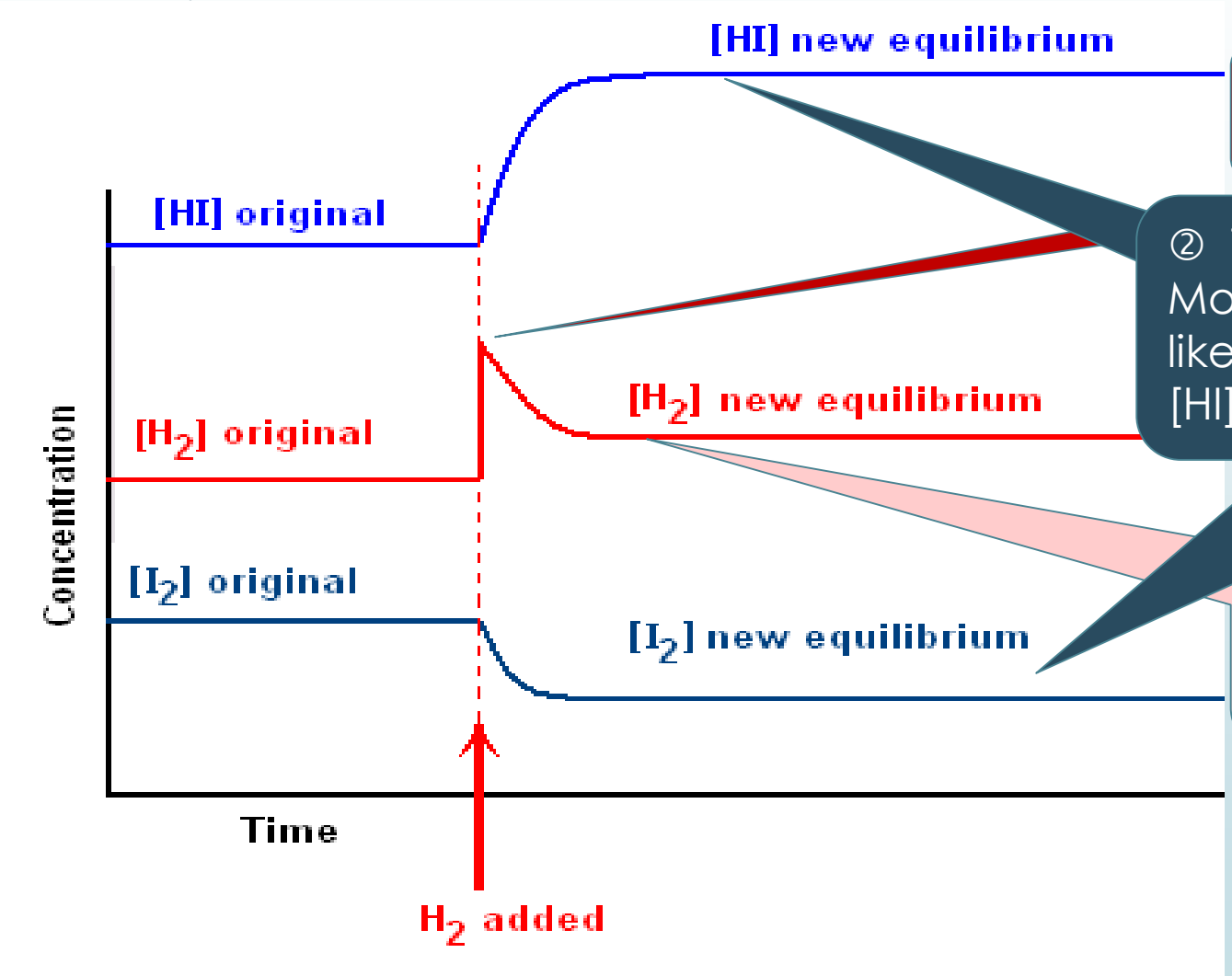


SO_2 & SO_3 are meant to overlap.

They are at equal concentration

$H_2 + I_2 \leftrightarrow 2HI$

This example starts at equilibrium. Then the chemist decides to add H_2!



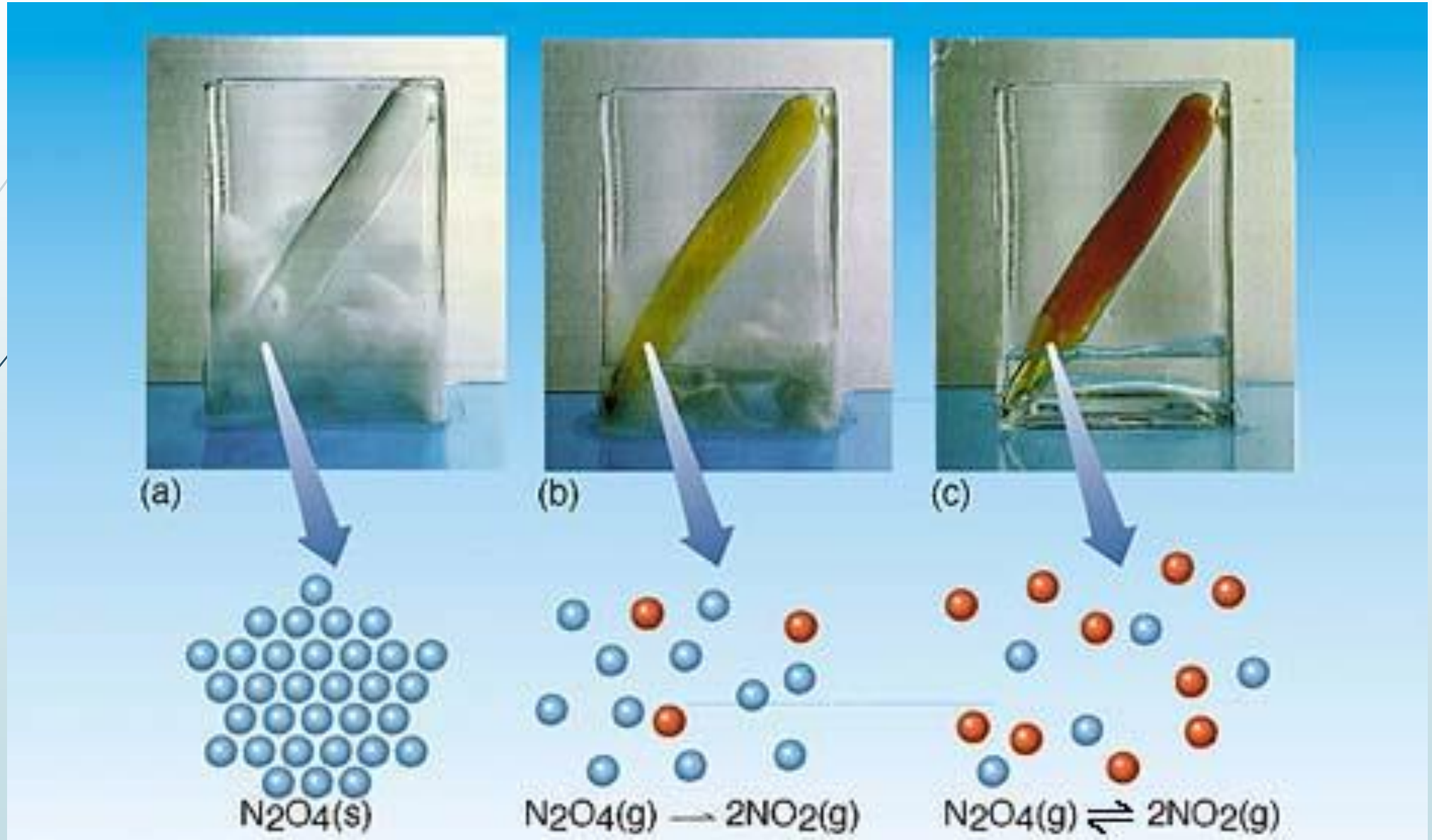
① Sudden increase in$[H_2]$.

② The equilibrium changes:
More H_2 means that they are more likely to collide with I_2 so…
[HI] goes way up, $[I_2]$ goes down.

③ This causes $[H_2]$ to adjust towards its original level.
It is a little higher because some HI will revert to H_2!

This is a classic reversible reaction, it allows a visual indication of the concentration of N_2O_4 vs NO_2.

The next example refers to this reaction.



Please write

Ex. 1 $E + N_2O_{4\,(g)} \rightleftarrows 2\,NO_{2\,(g)}$

clear red/brown

1. Inc. in temp.

   Favours the endothermic rxn.

2. [inc.] favour the higher order rxn at first.

   $Rate_F = k\,[N_2O_4]$ vs $Rate_R = k\,[NO_2]^2$ if you [x3] …

   $Rate_F = x3$ vs $Rate_R = x9$

this math proves that reverse rxn is faster when the concentration goes up!

Please write

Ex. 2

$$2\,SO_{2(g)} + O_{2(g)} \rightleftarrows 2\,SO_{3(g)}$$

What happens to the rates if Px2?

An inc. in pressure on gases = inc. in [ ]

$Rate_F = k\,[SO_2]^2[O_2]$ $\quad$ $Rate_R = k\,[SO_3]^2$

x 8 $\quad$ x 4

∴ both rates inc.

But the forward rate will inc. most initially!

Eventually the system returns to equilibrium.

Don't write

$H_{2(g)} + Br_{2(g)} \rightleftarrows 2\ HBr_{(g)}$
What happens to the rates if Px2?

An inc. in pressure on gases = inc. in [ ]

$Rate_F = k\ [H_2][Br_2]$ $\qquad$ $Rate_R = k\ [HBr]^2$

x 4 $\qquad$ x 4

∴ both rates inc. but equally.

Pressure will not have an effect on this rxn!

You could predict this because both the forward reaction is 2nd order and the reverse reaction is 2nd order.

Ex. 3 $BiCl_{3(aq)} + H_2O_{(l)} \rightleftarrows 2\ HCl_{(aq)} + BiOCl_{(s)}$

What happens to the rates if HCL is added such that the [HCl] is doubled?

The reverse rate would increase initially.

The amount of $BiCl_3$ & H_2O will go up, but then the forward reaction will inc.

The final concentrations depend on the amount of HCl added, the amount BiOCl present etc… *calculations needed (next lesson).*

Textbook page 298

1 to 6

Le Châtelier's Principle

Henri Louis Le Châtelier (1850-1937) was a French chemist who is most famous for his studies of chemical equilibrium.

He also studied metal alloys and, with his father, was involved in the development of methods of purifying aluminum.

"If the conditions of a system in equilibrium change, the system will react to partially oppose this change until it attains a new state of equilibrium."

Please write

Le Châtelier's Principle:

If a change is made to a rxn at equilibrium, the rxn will shift to counteract the change.

$$E + N_2O_{4\,(g)} \rightleftarrows 2\,NO_{2\,(g)}$$

Please write

1. Temperature increase

- The rxn will shift to decrease the temperature.
- By shifting to the right (using up the energy making the temperature decrease!)
- Favours the endo rxn.

$$E + N_2O_{4\,(g)} \rightleftarrows 2\,NO_{2\,(g)}$$

Please write

2. Pressure increase (or volume dec. for gases)

- The rxn will shift to decrease the pressure.
- More molecules = more pressure, so … the rxn will shift to the left! (less molecules)
- For gases ONLY!

Given:

$$N_2O_{4\,(g)} + 59.0kJ \rightleftharpoons 2NO_{2\,(g)}$$

Concentration:

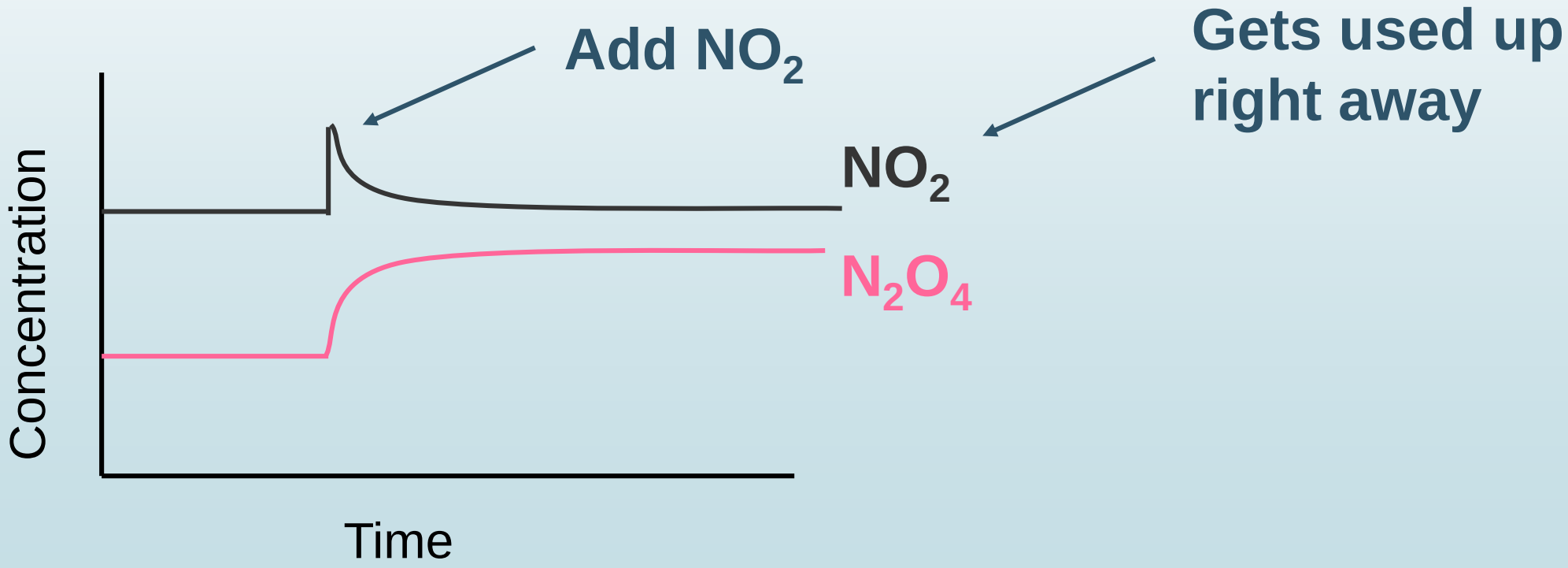
- Adding **more reactants** pushes the rxn toward the **products**
- **Removing reactants** pushes the rxn towards the **reactants**
- Adding **more products** pushes the rxn towards the **reactants**
- **Removing products** pushes the rxn towards the **products**

Given:

$$N_2O_{4\,(g)} + 59.0kJ \leftrightarrow 2NO_{2\,(g)}$$

Inc. $[NO_2]$ =

More products, so the rxn will shift to the left to produce more N_2O_4



$$E + N_2O_{4\,(g)} \rightleftarrows 2\,NO_{2\,(g)}$$

Please write

3. Concentration increase

- The rxn will shift to decrease the concentration.
- If you add N_2O_4 the system will shift to the right to use it up.

$$E + N_2O_{4\,(g)} \rightleftarrows 2\,NO_{2\,(g)}$$

4. Adding a catalyst?

Please write

- No effect!
- It lowers the E_a of both the forward and reverse rxns.
- Both rates go faster, no effect on concentration.

Important!

- Adding an **inert gas** will have no effect on the equilibrium.
- Adding an insoluble solid has no effect.
- Adding a **pure liquid** has no effect, because their concentration doesn't change.

Please write

Will the amount of product always equal the amount of reactant at equilibrium?

- **<u>NO</u>!** they are not always equal.
- At equilibrium the [reactant] & [product]vary depending on:
  - Initial concentration.
  - Change imposed

Do equilibrium I and then check your answers using the answer key