Introduction to redox reactions

1 What is a redox reaction?

- oxidation and reduction occuring simultaneously

Reduction (oxidating agents)	Oxidation (reducing agents)
oxidation no# of an atom ↓	oxidation no# of an atom ↑
−O / +H	+O / −H
accept e^- (e^- in half equ. RHS)	loses e^- (e^- in half equ. LHS)

→ 其中一个条件符合就行

→ R.A. $\xrightarrow{e^-}$ O.A.

2 Oxidation number

- (of an element in a compound) imaginery charge / charge an atom would have if it existed as an ion.
- Rules
  - > 自己一个 element : 0 Na = 0, Cl = 0
    自己一个 ion : charge of ion $Na^+ = +1$, $Cl^- = -1$
    sum of all atoms in element : 0 $H_2O = 0$
    sum of all atoms in polyatomic ion : charge of ion $MnO_4^- = -1$ (eg. find Mn oxidation no#. $x + 4(-2) = -1$, $x = +7$)
  - > Oxygen
    → in compound : 通常 −2 H_2O, ClO_2
    → exceptions ⇒ Na_2O_2, K_2O_2, H_2O_2 : −1
  - > Hydrogen
    → w/ non-metal : +1 H_2O, HCl
    → w/ metal : −1 NaH
  - > Main grp metal
    → in compound : +X (X = group no#) $AlCl_3$
  - > Nitrogen
    → max : +5 (∵ Grp V), min : −3 } 相差 = 8
    → NO_3^- : +5
    NO_2^- : +3
    NO_2 : +4
    N : 0
    NH_3, NH_4^+ : −3
  - > Sulphur
    → max : +6 (∵ Grp VI), min : −2 } 相差 = 8
    → SO_4^{2-}, SO_3 : +6
    SO_3^{2-}, SO_2 : +4
    SO : +2
    S : 0
    H_2S : −2
- Minimum and maximum O.N.
  - > main group metals ⟶ min = max = +X (X = Grp no#)
    main group non-metals ⟶ max = +X (X = Grp no#), min = −(8−X)
    transitional metals ⟶ max = +7, min = 0
  - > original O.N. = min O.N. → can only ↑ after rx → R.A.
    original O.N. = max O.N. → can only ↓ after rx → O.A.
    original O.N. in (min O.N., max O.N.) (exclusive range) → can ↑ / ↓ after rx → O.A. / R.A. (→ if in middle of range → weak → requires strong R.A. / O.A. for rx)

3 Common O.A.s and R.A.s

Strength ↑ (不在表上 = 較弱)

Common O.A. (after rx 变 R.A.)

- $MnO_4^- \rightarrow Mn^{2+}$
- $Cl_2 \rightarrow 2Cl^-$ (pale yellowish green)
- $Br_2 \rightarrow 2Br^-$ (brown)
- $I_2 \rightarrow 2I^-$ ((aq) brown, (s) black, (g) purple, (org. solvent) purple)
- $Cr_2O_7^{2-} \rightarrow Cr^{3+}$
- conc. $H_2SO_{4(l)} \rightarrow SO_2$ (choking smell)
- conc. $NO_3^- \rightarrow NO_2$ (brown + choking smell)
- dilute $NO_3^- \rightarrow NO$ (附帶: $2NO + O_2 \rightarrow NO_2$ - NO 不溶水 → colourless gas bubbles - 出水外与 O_2 react 成 NO_2 → brown gas evolve)
- $Ag^+ \rightarrow Ag$
- $Cu^{2+} \rightarrow Cu$
- $Ni^{2+} \rightarrow Ni$
- $2H^+ \rightarrow H_2$

Common R.A. (after rx 变 O.A.)

- metal (看 metal reactivity series 方向下) { $M \rightarrow M^{n+}$
- $Fe^{2+} \rightarrow Fe^{3+}$
- $SO_2 / SO_3^{2-} \rightarrow SO_4^{2-}$
- conc. { $2I^- \rightarrow I_2$, $2Br^- \rightarrow Br_2$, $2Cl^- \rightarrow Cl_2$
- $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$

4 Identify if reaction is redox

SKILLS (MC)

1. 有必背 common O.A. / R.A. ⟶ ✓
2. 有 metal element / non-metal element ⟶ ✓
3. Element ⇌ compound ⟶ ✓
4. 1 变 2 / 2 变 1 ⟶ ✓
5. 排除法 (rx 为 A-B / ppt) ⟶ ✗
6. 算 O.N. ⟶ ?

ANSWERING STRUCTURE (LQ)

✓ redox - oxidation number of X in X_nY (reactant) = …
oxidation number of X in X (product) = …
∵ there is change in oxidation number of X after reaction
∴ It is redox reaction.

✗ redox - There is no change in oxidation number of all atoms before & after reaction.
Not redox reaction.

EXAMPLES

1. $2MnO_4^- + 5SO_3^{2-} + 6H^+ \longrightarrow 2Mn^{2+} + 5SO_4^{2-} + 3H_2O$
   判断 → Rule 1 : MnO_4^-, SO_3^{2-}
   → ✓ redox
   作答 → oxidation number of Mn in MnO_4^- = +7
   oxidation number of Mn in Mn^{2+} = +2
   ∵ there is change in oxidation number of Mn
   ∴ It is redox reaction.

2. $Cl_2 + NaOH \rightarrow NaCl + NaOCl + H_2O$
   判断 → Rule 2/3 : ✓ non-metal element
   Rule 4 : Cl_2 ⇒ NaCl, NaOCl
   → ✓ redox
   作答 → oxidation number of Cl in Cl_2 = 0
   oxidation number of Cl in NaCl = −1
   oxidation number of Cl in NaOCl = +1 (reason not yet taught)
   ∵ there is change in oxidation number of Cl
   ∴ It is redox reaction.
   Cl_2 (O.N. = 0) → NaCl (O.N. = −1) → Cl_2 is O.A.; → NaOCl (O.N. = +1) → Cl_2 is R.A. → 一样物质同时是 O.A., R.A. ⇓ disproportionation rx

3. $Cr_2O_7^{2-} + H_2O \rightleftharpoons 2CrO_4^{2-} + 2H^+$
   判断 → (其他 rule 不合用, 一定得算) Rule 6
   $Cr_2O_7^{2-} + H_2O \rightleftharpoons 2CrO_4^{2-} + 2H^+$ (O: −2, H: +1)
   O 与 H 的 O.N. 没变, Cr 不可能自己变 (除非一变二 / 二变一)
   作答 → There is no change in oxidation number of all atoms before & after reaction
   ∴ Not redox reaction

4. $Na_2CO_3 + 2HCl \rightarrow 2NaCl + CO_2 + H_2O$
   判断 → Rule 5 : Acid-base rx
   → ✗ redox
   作答 → There is no change in oxidation number of all atoms before & after reaction
   ∴ Not redox reaction

5. $Pb(NO_3)_2 + 2NaCl \rightarrow 2NaNO_3 + PbCl_2$
   判断 → Rule 5 : precipitation rx
   → ✗ redox
   作答 → There is no change in oxidation number of all atoms before & after reaction
   ∴ Not redox reaction